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RESEARCH MEMORANDUM

ALTITUDE PERFORMANCE OF COMPRESSOR, TURBINE, AND COMBUSTOR COMPONENTS OF 600-B9 TURBOJET ENGINE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The altitude performance of the 600-B9 compressor, turbine, and combustor components operating as integral parts of the engine was determined in the NACA Lewis altitude wind tunnel. The investigation was conducted over a range of simulated flight conditions corresponding to altitudes from 6000 to 45,000 feet and flight Mach numbers from 0.160 to 0.997 (corresponding to a Reynolds number index range from 0.795 to 0.164).

The compressor and turbine were matched in such a manner that at a Reynolds number index of 0.795 and the sea-level static military thrust condition the compressor operated at the design pressure ratio of 9.0 with a compressor efficiency of 0.845 and a corrected air flow of 167 pounds per second. The maximum compressor efficiency of 0.87 occurred at a corrected engine speed corresponding to approximately 92 percent of rated engine speed. Compressor operation at lower Reynolds number index resulted in decreased compressor efficiency and corrected air flow. Turbine operation at the military thrust condition for 0.795 compressor-inlet Reynolds number index resulted in a turbine efficiency of 0.82 and a turbine pressure ratio of 3.6. Operation at minimum Reynolds number index resulted in decreased turbine efficiency and corrected gas flow. The combustion efficiency correlated with the combustion parameter PT/V (total pressure times total temperature/velocity, (lb/sq ft abs)(^{O}R)/(ft/sec)). Combustion efficiency was not affected by changes in corrected engine speed, and variations in flight conditions corresponding to a reduction in Reynolds number index from 0.795 to 0.164 lowered combustion efficiency from about 0.99 to 0.94.

The total variation in component efficiency with change in altitude at a constant flight Mach number resulted from both a change in corrected engine speed and in Reynolds number index. For the military thrust condition, an increase in altitude from sea level to 45,000 feet at a constant flight Mach number of 0.8 resulted in a decrease in compressor efficiency from 0.86 to 0.78; of this decrease, about two-thirds was due

to the increase in corrected engine speed. For the same operating conditions, the turbine efficiency decreased approximately 2 percent, primarily as a result of the reduction in Reynolds number.

INTRODUCTION

An investigation to determine the altitude performance of the 600-B9 components operating as integral parts of the engine was conducted in the NACA Lewis altitude wind tunnel. This investigation was made in conjunction with the altitude-wind-tunnel investigation to determine over-all performance characteristics of this turbojet engine.

Sea-level performance investigations of the compressor and turbine have been conducted and are reported in references 1 and 2, respectively. Because of the nature of the rig tests, altitude effects on the compressor and turbine performance could not be determined; and, since the components were separately tested, the effect of flight condition on the operating points of the components could not be determined.

The purpose of this report is (1) to describe the performance of each component over a range of altitudes, (2) to show the effect of flight conditions on operating point of each component, and (3) to summarize briefly the effects of changes in component performance with flight condition on the over-all engine performance.

The data were obtained at five fixed settings of the variable-area exhaust nozzle over an engine-speed range restricted to that obtainable with the acceleration air-bleed ports closed. Simulated flight conditions were for a range of altitudes from 6000 to 45,000 feet and flight Mach numbers from 0.160 to 0.997 (corresponding to Reynolds number index range from 0.795 to 0.164). A tabulation of component performance data is presented in table I.

INSTALLATION AND INSTRUMENTATION

Installation

The installation of the engine in the altitude wind tunnel is shown in figure 1. Dry refrigerated air was supplied to the engine inlet through a duct from the tunnel make-up air system. In this system, air is throttled from approximately sea-level pressure to an engine-inlet stagnation pressure corresponding to the desired flight condition.

Instrumentation

Location of the instrumentation used to determine the component performance is shown in figure 2. The engine air flow was measured both at the engine-inlet annulus (station 1) and at a station in the inlet-air duct (not shown in fig. 2).

The temperatures measured at the exhaust-nozzle inlet (station 6) were used as the turbine-outlet temperatures, because the downstream station was less affected by turbine radiation and also provided a greater mixing length for the gas.

The pressures at stations 1, 5, and 6 were measured with alkazene-filled manometers; whereas those at stations 2, 3, and 4 were measured with mercury-filled manometers. All pressures were photographically recorded. The temperatures at station 1 were measured with iron-constantan thermocouples, and those at stations 2, 4, and 6 with chromel-alumel thermocouples; all temperatures were recorded by self-balancing potentiometers.

APPARATUS

Engine

The 600-B9 turbojet engine with provision for afterburning has static sea-level ratings for the nonafterburning case as follows:

	Military	Normal
Engine speed, rpm	6100	6000
Turbine-outlet temperature, $^{\circ}F$	1210(1670° R)	
Thrust, lb	9515	8208
Specific fuel consumption, lb/(hr)(lb thrust)	0.989	0.927

Compressor

Compressor description and significant design parameters. - The 16-stage single-entry axial-flow compressor has a constant tip diameter of 33.5 inches. The rotor hub-tip radius ratios for the first and sixteenth stages are 0.550 and 0.891, respectively; rotor blade chords for these two stages are 2.25 and 0.75. Design air flow is 155 pounds per second, and specific air flow based on design flow is 25.4 pounds per second per square foot of frontal area (based on compressor tip diam.). The design tip Mach number is 0.72. The design compressor pressure ratio is is 9.0, and the average pressure ratio per stage is 1.147.

Acceleration air bleed. - The use of bleed ports permits engine acceleration in the intermediate speed range (65 to 85 percent of rated) where, as a consequence of the compressor surge characteristics, the compressor operating line approaches the surge line (ref. 1). Air is bled from eight ports in the combustor-inlet section. The ports operate automatically and are normally scheduled to be open between 55 and 92 percent of rated engine speed.

Combustor

The combustor is of the annular type with ten through-flow inner liners. Each of the ten liners was supplied fuel through 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 33.5-inch constant tip diameter; the annular area increases through the turbine, 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. Design weight flow based on design air flow (corrected to rated turbine-inlet pressure and temperature) is 38.8 pounds per second.

PROCEDURE

Component performance data were obtained, in conjunction with engine operation (afterburner inoperative), over a range of simulated flight conditions for altitudes from 6000 to 45,000 feet, flight Mach numbers from 0.160 to 0.997, and engine speeds from 86 to 102 percent of rated speed. For all the data presented herein, the acceleration air-bleed ports were set to remain in the closed position. Compressor surge characteristics did not allow steady-state operation at engine speeds below 86 percent of rated with the bleed ports closed. The data were obtained with five fixed positions of the variable-area exhaust nozzle having projected areas of 2.54, 2.685, 2.86, 3.18, and 4.13 square feet.

Test-section static pressures were set to the desired altitude pressure. Engine-inlet stagnation pressures were set to correspond to the desired flight conditions with 100-percent ram-pressure recovery assumed. Engine-inlet stagnation temperatures were set at NACA standard values for each flight condition, except that the minimum temperature obtained was about -20° F.

Fuel conforming to the specification 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 was used throughout the investigation.

The symbols and the methods used in the calculation of the component performance are presented in appendixes A and B, respectively.

RESULTS AND DISCUSSION

The altitude performance of the compressor, the turbine, and the combustor of the 600-B9 engine, operating as isolated components, will be discussed first; and, second, the effect of flight condition on operating point and the trends of the performance of each component with variations in engine and flight conditions will be shown. The effects of changes in component performance with flight condition on the over-all engine performance will also be discussed.

Since the exhaust nozzle was choked for most of the data, the performance maps are presented in terms of conventional Reynolds number index (see appendix B). The variation of Reynolds number index with altitude and flight Mach number is shown in figure 3 for the values of Reynolds number index corresponding to the simulated flight conditions of this investigation. Actual altitude performance variations shown later were obtained by interpolating maps at various Reynolds number indices.

All data presented have been generalized to standard sea-level conditions. A tabulation of component performance data is presented in table I.

Compressor Performance

The over-all performance of the compressor as an isolated component is presented in terms of compressor pressure ratio and corrected air flow for lines of constant corrected engine speed and compressor efficiency.

Performance maps. - The compressor performance map for a Reynolds number index of 0.795 is shown in figure 4(a). At design compressor pressure ratio (9.0) and rated corrected engine speed (6100 rpm), the corrected air flow was approximately 167 pounds per second, and the compressor efficiency was 0.845. Compressor efficiency reached a maximum of 0.87 at a corrected engine speed of approximately 5600 rpm. At a given corrected engine speed, variation in compressor pressure ratio as limited by operation of the compressor and turbine as engine components caused variations in compressor efficiency on the order of 1 percent. The corrected air flow for the high corrected engine speeds was affected only slightly by variation in compressor pressure ratio.

The compressor performance map at a Reynolds number index of 0.164 is shown in figure 4(b). At the design compressor pressure ratio and rated corrected engine speed, corrected air flow and compressor efficiency had decreased approximately 1 percent as compared with the higher Reynolds number condition. The decrease in compressor performance results from change in Reynolds number, as will be discussed in the next section. Although the map is not complete, the data indicate that the maximum compressor efficiency was 2 percent lower than for the high Reynolds number and occurred at approximately the same corrected engine speed. Variations in compressor pressure ratio at a given corrected engine speed had a greater effect on efficiency at the low Reynolds number condition.

Effect of Reynolds number index. - Compressor efficiency and corrected air flow are shown in figure 5 as functions of Reynolds number index for given corrected engine speeds and compressor pressure ratios. Effect of Reynolds number index on efficiency was greater at the higher corrected engine speeds. Variation in Reynolds number had no significant effect on corrected air flow or efficiency for values of Reynolds number index greater than about 0.5.

Performance maps for compressor and turbine as engine components. - The following analysis is presented to establish the interaction between the compressor and turbine when operating as engine components. When critical flow exists in the turbine, the corrected mass flow through the turbine remains constant and proportional to the effective flow area of the turbine; hence

$$\frac{W_{g,t}\sqrt{T_3}}{P_3} = K_1 A_t \tag{1}$$

(Symbols are defined in appendix A.)

If these quantities are generalized to engine-inlet conditions by the use of δ_1 and θ_1, then (assuming that the ratio of air flow to gas flow is constant) the following equation is obtained:

$$\frac{\frac{W_{a,1}\sqrt{\theta_1}}{\delta_1}\sqrt{\frac{T_3}{T_1}}}{\frac{P_3}{P_1}} = K_2A_t \qquad (2)$$

If it is assumed that the pressure drop across the combustor is a constant percentage of the compressor-outlet pressure, equation (2) may be rewritten as follows:

$$\frac{\frac{W_{a,1}\sqrt{\theta_1}}{\delta_1}\sqrt{\frac{T_3}{T_1}}}{\frac{P_2}{P_1}} = K_3A_t \qquad (3)$$

Thus, the operating point of a compressor functioning as an integral component of an engine is determined by the corrected engine speed (primary factor determining corrected air flow) and the turbine-inlet to engine-inlet temperature ratio, which, with effective area of the turbine, determines the compressor pressure ratio.

In order to show the performance of the compressor as an engine component, operating lines of constant turbine-inlet to engine-inlet temperature ratio are superimposed on the performance map of figure 4(a), and the resultant map is shown for the high Reynolds number condition in figure 6(a). At the military thrust condition where the turbine-inlet to engine-inlet temperature ratio was 4.16 (NACA standard static sea-level temperature) and the corrected engine speed was 6100 rpm, the compressor operated at the design compressor pressure ratio of 9.0 at which the corrected air flow was 167 pounds per second and the compressor efficiency was 0.845. Operation of the compressor at the design pressure ratio for the military thrust and high Reynolds number condition indicates that the compressor was properly matched with the turbine at design operating conditions.

For the military thrust conditions (corrected engine speed 6100 rpm and turbine-inlet to engine-inlet temperature ratio 4.16), the compressor operating point for the low Reynolds number condition (fig. 6(b)) occurred at a compressor pressure ratio of 9.2 with a corrected air flow of 163 pounds per second and a compressor efficiency of 0.83. The shift to lower corrected air flow and compressor efficiency was similar to that noted for the case of the compressor operating as an isolated component and has been accounted for primarily from the effect of Reynolds number on the compressor. The higher compressor pressure ratio also tends to reduce the corrected air flow. The shift in compressor operating point to increased compressor pressure ratio with the decrease in Reynolds number index is associated with a change in the matched operation of the compressor and turbine, which primarily results from a decrease in turbine critical flow area, as will be shown in conjunction with the turbine performance.

By use of figure 7, which presents the effect of exhaust-nozzle area on compressor pressure ratio and turbine-inlet to engine-inlet temperature ratio for the high Reynolds number condition, and of the compressor map (fig. 6(a)), compressor performance (for this specific Reynolds number index) can be determined for any combination of exhaust-nozzle area and corrected engine speed. Similar curves for other Reynolds number indices can be constructed from the data presented in table I.

Turbine Performance

Performance maps. - The over-all performance of the turbine is presented in terms of corrected turbine enthalpy drop and turbine weight-flow parameter for lines of constant corrected turbine speed, pressure ratio, and efficiency. The performance maps for compressor-inlet Reynolds number indices of 0.795 and 0.164 are shown in figure 8. The limited range of turbine operation is characteristic of that obtainable from investigation of a turbine as an integral part of an engine.

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. For the high Reynolds number condition the design operating point was at a turbine pressure ratio of 3.6, a turbine efficiency of 0.82, and a corrected turbine gas flow of approximately 40.8 pounds per second. Corrected turbine gas flow is obtained by dividing out the corrected turbine speed and the factor 60 from the weight-flow parameter. A decrease in Reynolds number caused the region of turbine operation to shift to lower values of weight-flow parameter. The design operating point for the low Reynolds number condition was at a turbine pressure ratio of 3.8, a turbine efficiency of approximately 0.79, and a corrected turbine gas flow of approximately 38.7 pounds per second.

The increase in turbine pressure ratio as Reynolds number decreased resulted from the reductions in both compressor and turbine efficiencies, which required greater expansion through the turbine to provide the component work. The decrease in turbine efficiency and corrected turbine gas flow is attributed primarily to the reduction in turbine Reynolds number, which will be discussed in the following section.

Turbine efficiency for both flight conditions increased slightly, either at a constant turbine pressure ratio with increase in corrected turbine speed, or at a constant corrected turbine speed with decrease in turbine pressure ratio. The maximum turbine efficiency for the high Reynolds number condition was 0.83 compared with 0.79 for the low Reynolds number. Corrected turbine enthalpy drop decreased with reduction in Reynolds number index (at a constant corrected turbine speed and pressure ratio) as a result of the decrease in turbine efficiency.

Effect of Reynolds number index. - The effect of Reynolds number on turbine performance is shown in the plot (fig. 9) of turbine efficiency and corrected turbine gas flow as functions of turbine-inlet Reynolds number index for several constant values of corrected turbine speed and pressure ratio. Turbine efficiency and corrected turbine gas flow for conditions shown remained essentially unchanged for values of Reynolds number index of 1.0 and greater.

In general, a decrease in turbine efficiency and corrected gas flow accompanied a decrease in Reynolds number index below 1.0. Turbine efficiency for a corrected turbine speed of 3200 rpm and turbine pressure ratio of 4.3 decreased approximately 4 percent for a decrease in Reynolds number index from 1.4 to 0.25. The effect of Reynolds number on turbine efficiency was less at the lower corrected turbine speeds. For a Reynolds number index of 0.3, an increase in corrected turbine speed from 3000 to 3200 rpm resulted in a 2-percent decrease in turbine efficiency.

The corrected turbine gas flow for a corrected turbine speed of 3200 rpm and a pressure ratio of 4.3 decreased approximately 5 percent over the range of Reynolds number index shown. This reduction in corrected turbine gas flow (as mentioned under compressor performance) follows from the apparent decrease in turbine effective flow area, which, for the range of flight conditions investigated, amounted to approximately 5 percent. As would be expected from the earlier discussion of compressor and turbine matching, the observed reduction in corrected turbine gas flow was accompanied by a proportional increase in compressor pressure ratio. An increase in corrected turbine speed for a given low value of Reynolds number index resulted in slightly lower corrected turbine gas flows. The change in corrected turbine gas flow for different corrected turbine speeds is indicative of a choking condition downstream of the first stator. This condition was also indicated in the turbine rig investigation reported in reference 2.

Combustor Performance

The efficiency of a fixed combustor design is primarily a function of such variables as fuel-air ratio, fuel atomization, and combustor-inlet pressure, temperature, and velocity. In evaluating the performance of a combustor as an integral part of an engine, it is impossible to control these variables independently; variations in engine speed, flight condition, and exhaust-nozzle area change in varying degrees these variables affecting combustion efficiency.

Variation of combustion efficiency with combustion parameters PT/V and W_aT_6. - The interaction of the primary combustion variables (pressure, temperature, and velocity) are combined into a parameter PT/V that has been found useful (ref. 3) in correlating combustion-efficiency data (fig. 10). By use of the parameter W_aT_6 (fig. 10), which is proportional to PT/V, it is possible to determine combustion efficiency when the engine operating and flight conditions are known.

The high pressures and temperatures inherent in the 600-B9 engine design result in PT/V values for the most part above 25,000, and combustion efficiencies below 0.90 were not encountered at any condition investigated. Combustion efficiency increased from approximately 0.93 at PT/V value of 25,000 to about 0.99 for PT/V values of 100,000 and above.

Effect of Reynolds number index on combustor total-pressure loss. - The total-pressure-loss ratio as a function of the square root of the combustor-outlet to combustor-inlet temperature ratio (fig. 11) decreased from 0.065 for a combustor temperature-ratio parameter of 1.26 to 0.055 at a temperature-ratio parameter of 1.52.

Performance of combustor as part of engine. - Primary combustion variables were not changed enough to affect efficiency appreciably through variations in exhaust-nozzle area. Consequently, the variation of combustion efficiency with corrected engine speed for each of the Reynolds number indices (fig. 12) is based on the average of data obtained over the range of exhaust-nozzle areas investigated. Combustion efficiency was not affected by changes in corrected engine speed, and variations in flight conditions corresponding to a reduction in Reynolds number index from 0.795 to 0.164 lowered combustion efficiency from about 0.99 to 0.94.

Engine Performance

Effect of flight condition on over-all component performance. - The effects of altitude on component performance for two engine thrust conditions (military and normal) are shown in figure 13(a) for a flight Mach number of 0.8. The variation in component performance is shown as a function of altitude, inasmuch as component efficiencies are directly a function of their environment pressure, which is changed to a greater extent by variation in altitude at a constant flight Mach number than by a Mach number variation at constant altitude.

An increase in altitude from sea level to 45,000 feet for the military thrust condition results in an increase in corrected engine speed from approximately 5750 to 6600 rpm and a decrease in Reynolds number index from 1.12 to 0.27. Both of the above variables affect compressor efficiency. For an increase in altitude from sea level to 45,000 feet, compressor efficiency (fig. 13(a)) decreased from approximately 0.86 to 0.78. Of this decrease in efficiency, approximately two-thirds was due to the increase in corrected engine speed accompanying the increase in altitude, and the remaining portion resulted from the effect of Reynolds number. The curves level off at an altitude of 35,000 feet (approximately the tropopause), since corrected engine speed remained constant for a further increase in altitude. Compressor efficiency for the normal power setting showed a trend similar to the higher thrust condition for a variation in altitude.

Combustion efficiency decreased from approximately 0.99 at sea level to 0.95 at 45,000 feet. This reduction in efficiency was due to the reduction in pressure accompanying the increase in altitude; variation in corrected engine speed or thrust condition had no discernible effect on efficiency.

Turbine efficiency for both thrust conditions decreased approximately 2 percent as altitude was increased over the range shown. Inasmuch as turbine-inlet temperature was constant for a constant thrust condition, corrected turbine speed was fixed; therefore, the decrease in turbine efficiency results from a change in Reynolds number or turbine pressure ratio. The change in turbine pressure ratio was very small; consequently, the decrease in turbine efficiency resulted primarily from the reduction in Reynolds number.

For an increase in altitude from sea level to 45,000 feet, it would be predicted that the corrected air flow (excluding Reynolds number effects) for the military thrust condition would increase about 17 pounds per second as a result of the increase in corrected engine speed. However, actual corrected air flow (including the effect of Reynolds number) increased only approximately 15.5 pounds per second.

Effect of changes in component performance on engine performance. - The effects of altitude on corrected net thrust and corrected specific fuel consumption at the military thrust condition for actual altitude performance (including Reynolds number effect on component performance) and for predicted performance where Reynolds number effects have been excluded are shown in figure 13(b). For the actual condition, corrected net thrust increased approximately linearly as altitude was increased to 35,000 feet due to the increase in corrected air flow. An increase in altitude beyond 35,000 feet resulted in slightly lower corrected air flows with concomitant lower corrected net thrust. The corrected net thrust remained equal for altitudes up to approximately 25,000 feet for both performance conditions considered, which indicates no discernible Reynolds number effect on engine performance. Further increase in altitude to 35,000 feet resulted in slightly higher corrected net thrust for the condition excluding Reynolds number effect; theoretical corrected net thrust remained constant for increase in altitude beyond 35,000 feet, because corrected engine speed and corrected air flow remained fixed. At an altitude of 45,000 feet, an improvement in corrected net thrust of approximately 3 percent would be attained if there were no Reynolds number effect on the components.

An increase in the actual corrected specific fuel consumption (fig. 13(b)) of approximately 7 percent (compared with predicted) at an altitude of 45,000 feet followed from the decrease in component efficiencies.

The aforementioned apparent decrease in turbine effective flow area of approximately 5 percent accompanying a change in Reynolds number index from 0.795 to 0.164 has also been analytically determined to have a rather insignificant effect on engine thrust, which indicates that the component matching was not affected significantly by the change in turbine flow area.

CONCLUDING REMARKS

The results of the investigation show that the compressor and turbine were matched in such a manner that at a Reynolds number index of 0.795 and the sea-level static military thrust condition the compressor operated at the design pressure ratio of 9.0 with a compressor efficiency of 0.845 and a corrected air flow of 167 pounds per second. Maximum compressor efficiency of 0.87 occurred at a corrected engine speed corresponding to approximately 92 percent of rated engine speed. Operation at a lower Reynolds number index resulted in decreased compressor efficiency and corrected air flow. Turbine operation at the military thrust condition for 0.795 compressor-inlet Reynolds number index resulted in a turbine efficiency of 0.82 and a turbine pressure ratio of 3.6. Operation at minimum Reynolds number index resulted in decreased turbine efficiency and corrected gas flow. Combustion efficiency correlated with combustion parameter PT/V (total pressure times total temperature/velocity, (lb/sq ft abs)($^{\circ}$R)/(ft/sec)). Combustion efficiency was not affected by changes in corrected engine speed, and variations in flight conditions corresponding to a reduction in Reynolds number index from 0.795 to 0.164 lowered combustion efficiency from about 0.99 to 0.94.

The total variation in component efficiency with change in altitude at a constant flight Mach number results from both a change in corrected engine speed and in Reynolds number index. For the military thrust condition, an increase in altitude from sea level to 45,000 feet at a constant flight Mach number of 0.8 resulted in a decrease in compressor efficiency from 0.86 to 0.78; of this decrease, about two-thirds was due to the increase in corrected engine speed. For the same operating conditions, turbine efficiency decreased approximately 2 percent, primarily as a result of the reduction in Reynolds number index.

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APPENDIX A

SYMBOLS

The following symbols are used in this report:

A	cross-sectional area, sq ft
c_p	specific heat at constant pressure, Btu/(lb)(°F)
g	acceleration due to gravity, 32.2 ft/sec^2
H	total enthalpy, Btu/lb
$K_1, K_2, K_3 \ldots$	constants
M	Mach number
N	engine speed, rpm
P	total pressure, lb/sq ft abs
p	static pressure, lb/sq ft abs
R	gas constant, 53.4 ft-lb/(lb)(°R)
T	total temperature, °R
t	static temperature, °R
V	velocity, ft/sec
V_{cr}	critical velocity, $\sqrt{\frac{2\gamma}{\gamma+1} gRT}$, ft/sec
W_a	air flow, lb/sec
W_f	fuel flow, lb/hr
W_g	gas flow, lb/sec
$\frac{W_{g,t}\sqrt{\theta_3}}{\delta_3}\beta$	corrected turbine gas flow, lb/sec
$\frac{W_{g,t}\sqrt{\theta_3}}{\delta_3}\frac{N}{60\sqrt{\theta_3}}\beta$	turbine weight-flow parameter, $\frac{(lb)(rpm)}{sec^2}$

β function of γ, $\dfrac{\gamma_0}{\gamma_3} \dfrac{\left(\dfrac{\gamma_3 + 1}{2}\right)^{\frac{\gamma_3}{\gamma_3 - 1}}}{\left(\dfrac{\gamma_0 + 1}{2}\right)^{\frac{\gamma_0}{\gamma_0 - 1}}}$

γ ratio of specific heats

δ pressure correction factor, P/2116 (total pressure divided by NACA standard sea-level pressure)

η efficiency

θ temperature-correction factor, squared ratio of critical velocity to critical velocity at NACA standard sea-level temperature (519° F), $\left(\dfrac{V_{cr}}{V_{cr,0}}\right)^2$

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

Subscripts:

a air

b combustor

c compressor

e engine

f fuel

g gas

i indicated

m manifold

t turbine

0	NACA standard sea-level conditions
1	engine inlet
2	compressor outlet
3	turbine inlet
4	turbine outlet
5	diffuser outlet
6	exhaust-nozzle inlet

APPENDIX B

METHODS OF CALCULATION

Temperatures

Total temperatures were determined from indicated temperatures by the following equation:

$$T = \frac{T_i\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}}}{1 + 0.85\left[\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]} \tag{B1}$$

where 0.85 is the impact recovery factor for the NACA thermocouple used.

Air Flow

Air flow was determined from pressure and temperature measurements at the engine inlet (station 1) and at a station in the inlet-air duct (not shown in fig. 2). Values for air flow obtained at these two stations showed good agreement and were obtained by the equation

$$W_a = pA\sqrt{\frac{2\gamma g}{(\gamma-1)RT}\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}}\left[\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]} \tag{B2}$$

Gas Flow

The gas flow downstream of the combustor adjusted for engine leakage is

$$W_g = W_a + \frac{W_f}{3600} \tag{B3}$$

Reynolds Number Index

For a given compressor Mach number (corrected engine speed), Reynolds number index varies linearly with Reynolds number and is defined as the ratio of Reynolds number at altitude to Reynolds number at standard sea-level conditions:

$$\text{Reynolds number index} = \frac{\delta}{\varphi\sqrt{\theta}} \tag{B4}$$

Combustor-Inlet Velocity

With the use of combustor Mach number M_b, combustor-inlet velocity was determined from the following equation:

$$V_b = M_b\sqrt{\gamma_2 gRt_2} \tag{B5}$$

where

$$t_2 = \frac{T_2}{1 + \frac{\gamma_2 - 1}{2} M_b^2}$$

Turbine-Inlet Total Temperature

Turbine-inlet total temperature was calculated on the assumption that the enthalpy drop across the turbine is equal to the enthalpy rise across the compressor. From this assumption, the temperature drop across the turbine, ΔT_t, may be computed from

$$\Delta T_t = \frac{W_{a,1} c_{p,a} \Delta T_c}{W_{g,3} c_{p,g}} \tag{B6}$$

where ΔT_c is the temperature rise across the compressor.

Since the turbine-outlet temperature T_4 is known,

$$T_3 = \Delta T_t + T_4 \tag{B7}$$

Compressor Efficiency

Compressor efficiency was calculated from the tables presented in reference 4 with water-vapor corrections neglected. With the known values of compressor pressure ratio and T_1, π_1 and H_1 can be obtained from the tables (where π is the relative pressure function). From the relation

$$\pi_2 = \frac{P_2}{P_1} \pi_1$$

π_2 and H_2 (isentropic) were found. From the measured value of T_2, H_2 (actual) was obtained from the tables. Compressor efficiency was then calculated by

$$\eta_c = \frac{\Delta H_{isentropic}}{\Delta H_{actual}}$$

$$= \frac{H_{2,isentropic} - H_1}{H_{2,actual} - H_1} \tag{B8}$$

Combustion Efficiency

Combustion efficiency is defined as the ratio of the actual enthalpy rise of the gas while passing through the engine to the theoretical increase in enthalpy that would result from complete combustion of the fuel:

$$\eta_b = \frac{\text{actual enthalpy rise of gas across engine}}{\text{heat input}}$$

$$= \frac{3600\left[W_{a,1}H_a\right]_{T_1}^{T_6} + \left[W_f H_f\right]_{T_m}^{T_6}}{18{,}700 W_f} \tag{B9}$$

where 18,700 Btu per pound is the lower heating value of the fuel.

Turbine Efficiency

Turbine efficiency was obtained from the relation

$$\eta_t = \frac{\text{work done by turbine}}{\text{adiabatic ideal work of expansion}}$$

$$= \frac{1 - \frac{T_4}{T_3}}{1 - \left(\frac{P_4}{P_3}\right)^{\frac{\gamma_t - 1}{\gamma_t}}} \qquad \text{(B10)}$$

where γ_t is based on $\frac{T_3 + T_4}{2}$ and fuel-air ratio.

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

TABLE I. - COMPONENT PERFORMANCE

Run	Tunnel static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Reynolds number index, $\delta_1\sqrt{\theta_1}/\varphi_1$	Engine speed, N, rpm	Engine fuel flow, $W_{f,e}$, lb/hr	Exhaust-nozzle-outlet area, sq ft	Engine inlet		Compressor outlet		Turbine inlet		Turbine outlet		Exhaust-nozzle-inlet total temperature, T_6, °R
							Total temperature, T_1, °R	Total pressure, P_1, lb/sq ft abs	Total temperature, T_2, °R	Total pressure, P_2, lb/sq ft abs	Total temperature, T_3, °R	Total pressure, P_3, lb/sq ft abs	Total temperature, T_4, °R	Total pressure, P_4, lb/sq ft abs	
(a) Altitude,															
1	1687	0.184	0.789	5240	4450	2.54	525	1727	932	10,587	1788	9,968	1427	3104	1413
2	1689	.176	.790	5362	4920		525	1727	948	11,190	1838	10,635	1466	3268	1452
3	1692	.164	.790	5484	5400		525	1724	966	12,028	1892	11,333	1507	3445	1492
4	1689	.169	.795	5606	6070		526	1722	986	12,656	1969	11,935	1587	3601	1558
5	1687	.155	.795	5727	6625		526	1716	1002	13,315	2021	12,555	1628	3778	1598
6	1687	.164	.797	5849	7290		525	1719	1019	14,168	2078	13,361	1684	4005	1652
7	1688	.141	.797	5971	7811		525	1711	1035	14,849	2144	14,007	1727	4187	1701
8	1688	.169	.789	5240	4120	2.69	525	1722	929	10,410	1723	9,781	1361	2930	1353
9	1690	.173	.789	5362	4520		525	1725	946	11,126	1771	10,458	1398	3077	1387
10	1687	.173	.789	5484	4950		525	1722	961	11,778	1818	11,080	1432	3222	1425
11	1687	.173	.791	5606	5540		525	1722	979	12,567	1879	11,822	1484	3400	1469
12	1690	.152	.792	5727	6050		526	1717	998	13,219	1940	12,437	1533	3568	1518
13	1687	.155	.795	5849	6535		526	1715	1014	13,829	1997	13,025	1573	3724	1561
14	1684	.152	.795	5971	7070		525	1711	1030	14,462	2058	13,623	1624	3867	1604
15	1687	.125	.796	6093	7528		525	1706	1045	14,980	2098	14,106	1660	4003	1645
16	1684	.125	.795	6215	7867		525	1703	1056	15,392	2131	14,498	1681	4081	1674
17	1686	.192	.789	5240	3750	2.86	525	1729	924	10,322	1647	9,680	1281	2760	1280
18	1684	.180	.790	5362	4105		525	1722	941	10,940	1699	10,263	1320	2879	1318
19	1691	.173	.790	5483	4490		525	1727	956	11,591	1739	10,882	1350	3014	1346
20	1688	.155	.788	5606	5030		525	1716	975	12,346	1805	11,599	1400	3170	1395
21	1687	-----	-----	5727	5400		527	----	992	12,903	----	12,119	1433	----	1427
22	1687	.152	.790	5849	5890		527	1714	1010	13,622	1903	12,806	1476	3447	1468
23	1687	.141	.797	5971	6375		526	1711	1025	14,130	1967	13,292	1526	3568	1515
24	1686	.141	.795	6093	6770		526	1710	1039	14,694	2013	13,821	1559	3690	1551
25	1683	.141	.798	6215	7220		523	1707	1051	15,104	2060	14,204	1602	3780	1589
26	1683	.184	.803	5240	3280	3.18	524	1723	918	10,080	1547	9,425	1181	2529	1186
27	1685	.176	.789	5484	3960		524	1722	951	11,391	1637	10,667	1244	2748	1248
28	1687	.160	.790	5606	4340		524	1718	968	12,077	1680	11,317	1277	2875	1277
29	1690	.155	.790	5727	4815		527	1718	988	12,647	1747	11,859	1334	2999	1328
30	1685	.147	.791	5849	5195		526	1711	1003	13,254	1785	12,438	1365	3106	1346
31	1686	.147	.803	5971	5585		526	1712	1018	13,787	1808	12,943	1403	3217	1361
32	1687	.147	.812	6093	5975		527	1712	1033	14,328	1890	13,447	1441	3313	1430
33	1690	.118	.812	6215	6250		524	1707	1043	14,692	1920	13,789	1463	3390	1453
34	1690	.192	.801	5240	2820	4.13	523	1734	910	9,870	1443	9,205	1078	2268	1087
35	1690	.164	.789	5484	3510		523	1722	945	11,137	1540	10,401	1141	2456	1149
36	1686	.184	.790	5606	3795		523	1727	960	11,805	1580	11,034	1186	2570	1179
37	1686	.160	.789	5727	4115		527	1717	981	12,241	1633	11,456	1230	2641	1219
38	1687	.160	.790	5727	4130		527	1717	982	12,328	1643	11,542	1226	2667	1223
39	1690	.152	.790	5849	4480		528	1717	998	12,974	1680	12,156	1259	2764	1256
40	1690	.152	.818	5971	4850		527	1717	1012	13,563	1730	12,705	1296	2858	1280
41	1685	.155	.816	6093	5235		527	1714	1027	14,012	1760	13,125	1335	2937	1307
42	1680	.147	.821	6215	5570		522	1705	1034	14,354	1817	13,446	1370	2999	1348
(b) Altitude,															
1	1186	0.192	0.611	5606	4800	2.54	495	1217	959	9,825	1970	9,297	1580	2810	1563
2	1185	.188	.608	5727	5210		497	1215	979	10,227	2033	9,727	1636	2928	1617
3	1186	.180	.608	5849	5690		493	1213	990	10,786	2097	10,236	1685	3088	1663
4	1187	.173	.600	5971	6090		493	1212	1003	11,165	2150	10,603	1725	3172	1709
5	1188	.173	.605	6093	6450		491	1213	1016	11,443	2200	10,885	1785	3251	1756
6	1185	.180	.595	5606	4340	2.69	496	1212	955	9,597	1887	9,057	1475	2598	1472
7	1184	.173	.600	5727	4720		496	1213	971	10,099	1943	9,550	1521	2735	1517
8	1188	.176	.600	5849	5070		496	1214	986	10,483	1993	9,927	1562	2823	1559
9	1184	.188	.599	5971	5390		496	1214	1001	10,802	2037	10,241	1607	2907	1601
10	1186	.169	.598	6093	5705		499	1210	1018	11,081	2097	10,513	1660	2976	1647
11	1187	.164	.598	5606	3900	2.86	495	1210	947	9,412	1793	8,862	1380	2405	1379
12	1185	.173	.601	5727	4215		495	1210	963	9,852	1840	9,291	1420	2501	1418
13	1185	.169	.600	5849	4530		495	1209	978	10,239	1887	9,673	1457	2593	1457
14	1185	.155	.600	5971	4825		495	1205	992	10,571	1933	10,001	1497	2667	1492
15	1185	.164	.601	6093	5125		495	1204	1007	10,847	1990	10,267	1546	2733	1536
16	1184	.152	.601	6093	5150		495	1207	1008	10,873	2000	10,294	1551	2733	1546
17	1181	.155	.601	6215	5390		495	1201	1022	11,009	2047	10,423	1598	2769	1584
18	1188	.180	.600	5606	3445	3.18	495	1215	942	9,461	1687	8,906	1282	2168	1276
19	1186	.176	.600	5727	3715		495	1212	957	9,623	1725	9,052	1320	2261	1308
20	1186	.164	-----	5849	4520		494	1208	971	9,982	1769	9,404	1353	2330	1342
21	1185	-----	.600	5971	4220		493	----	985	10,300	----	9,778	1393	----	1384
22	1186	.155	.601	6093	4530		494	1206	999	10,574	1867	9,989	1429	2451	1416
23	1183	.155	.603	6215	4770		494	1203	1015	10,844	1930	10,252	1479	2488	1462
24	1186	.184	.604	5606	3055	4.13	488	1215	927	9,165	1570	8,590	1173	1957	1171
25	1189	.176	.618	5727	3330		489	1215	944	------	----	------	1209	2028	1214
26	1188	.180	.617	5848	3525		495	1215	966	9,842	1677	9,244	1249	2068	1248
27	1185	.184	.608	5971	3735		493	1213	976	10,123	1717	9,519	1281	2117	1276
28	1186	.176	.603	5971	3785		488	1212	969	10,189	1710	9,574	1283	2135	1274
29	1188	.184	.612	6093	4030		488	1216	987	10,506	1763	9,890	1327	2193	1315
30	1190	.180	.611	6215	4275		496	1217	1009	10,656	1840	10,031	1376	2231	1369

OF 600-B9 TURBOJET ENGINE

Compressor pressure ratio, P_2/P_1	Air flow, $W_{a,1}$, lb/sec	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Corrected air flow, $\frac{W_a\sqrt{\theta_1}}{\delta_1}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_2 - P_3}{P_2}$	Combustor efficiency, η_b	Turbine pressure ratio, P_3/P_4	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_3}$, rpm	Corrected turbine gas flow, $\frac{W_g\sqrt{\theta_3}}{\delta_3}\beta$, lb/sec	Turbine enthalpy drop, $\Delta H/\theta_3$, Btu/lb	Combustion parameter, $\frac{P_2T_2}{V_b}$, $\frac{(lb)(^{\circ}R)(sec)}{cu\ ft}$	Combustion parameter, $W_{a,1}T_6$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
6000 feet														
6.130	102.7	5210	126.5	0.8644	0.0585	1.000	3.211	0.8256	2855	40.89	30.00	107,000	145.1×10^3	1
6.479	107.8	5331	132.7	.8637	.0496	.9956	3.254	.8242	2886	40.82	30.38	114,100	156.5	2
6.977	112.9	5453	139.3	.8703	.0578	.9960	3.290	.8297	2909	40.78	30.65	123,800	168.4	3
7.350	117.1	5568	144.7	.8649	.0570	.9818	3.314	.8194	2915	40.97	30.84	133,800	182.4	4
7.759	121.5	5689	150.6	.8653	.0571	.9757	3.323	.8256	2942	41.01	31.12	141,800	194.2	5
8.242	127.0	5816	157.3	.8637	.0570	.9802	3.336	.8093	2964	40.95	30.82	154,700	209.8	6
8.679	130.8	5937	162.7	.8633	.0567	.9842	3.345	.8189	2979	40.91	31.41	166,200	222.5	7
6.045	103.1	5210	127.4	.8622	.0604	1.005	3.338	.8182	2906	41.00	30.80	103,400	139.5	8
6.450	108.2	5331	133.5	.8659	.0600	1.000	3.399	.8181	2937	40.85	31.19	113,300	150.1	9
6.840	112.9	5453	139.6	.8697	.0593	.9957	3.439	.8128	2965	40.84	31.28	120,900	160.9	10
7.298	118.4	5574	146.4	.8705	.0593	.9879	3.477	.8197	2981	40.85	31.69	130,200	173.9	11
7.699	122.9	5689	152.3	.8685	.0592	.9962	3.486	.8201	3002	41.03	31.83	138,258	186.6	12
8.064	126.8	5810	157.4	.8645	.0581	1.000	3.498	.8275	3021	41.09	32.30	145,826	197.9	13
8.452	130.5	5937	162.3	.8578	.5080	.9895	3.523	.8350	3040	41.08	32.39	156,239	209.3	14
8.781	134.5	6058	167.8	.8519	.0584	1.000	3.524	.8225	3073	41.35	32.55	162,900	221.3	15
9.038	135.0	6180	168 8	.8488	.0581	.9870	3.553	.8140	3110	40.76	32.55	171,100	226.0	16
5.970	103.9	5210	127.9	.8657	.0622	1.005	3.507	.8120	2971	40.75	31.86	100,600	133.0	17
6.353	108.2	5331	133.8	.8663	.0619	1.010	3.565	.8133	2996	40.73	32.17	107,700	142.6	18
6.712	116.4	5453	143.4	.8682	.0612	1.025	3.610	.8162	3030	-----	32.33	113,200	156.7	19
7.195	118.6	5574	147.1	.8702	.0605	.9955	3.659	.8175	3041	40.81	32.66	125,600	165.4	20
-----	-----	5683	-----	------	.0608	------	-----	------	----	-----	-----	-------	---------	21
7.947	126.8	5805	157.8	.8665	.0599	.9959	3.715	.8217	3092	40.71	33.55	143,345	186.1	22
8.258	130.7	5931	162.6	.8569	.0593	1.008	3.725	.8302	3105	-----	33.59	149,744	198.0	23
8.593	133.6	6052	166.2	.8537	.0594	1.004	3.746	.8300	3136	40.94	33.63	156,843	207.2	24
8.848	135.7	6191	169.0	.8394	.0596	.9893	3.758	.8421	3155	41.07	33.77	162,100	215.6	25
5.850	104.0	5215	128.3	.8618	.0650	1.000	3.727	.8085	3062	40.51	33.15	95,000	123.2	26
6.615	114.4	5458	141.3	.8660	.0636	1.017	3.882	.8057	3120	40.63	33.99	111,000	142.8	27
7.030	119.4	5579	147.8	.8665	.0629	1.000	3.936	.8152	3147	40.53	34.40	118,700	152.5	28
7.361	123.1	5683	152.8	.8653	.0623	.9951	3.954	.8165	3151	40.60	34.58	127,528	163.5	29
7.746	127.0	5810	158.0	.8613	.0616	.9767	4.005	.8313	3192	40.57	35.05	134,620	170.9	30
8.053	130.8	5931	162.6	.8556	.0612	.9598	4.023	.8377	3236	40.38	35.54	143,362	178.0	31
8.369	133.8	6047	166.5	.8533	.0615	.9915	4.059	.8273	3233	40.71	35.47	150,018	191.3	32
8.607	135.5	6185	168.9	.8412	.0615	.9918	4.068	.8266	3273	40.59	35.47	157,100	196.9	33
5.692	104.9	5220	128.5	.8593	.0674	..9859	4.059	.8015	3170	40.33	34.74	89,900	114.0	34
6.467	114.9	5463	141.8	.8615	.0661	..9752	4.235	.8120	3213	40.48	35.69	104,900	132.0	35
6.836	120.0	5585	147.6	.8635	.0653	.9940	4.293	.8078	3244	40.41	35.81	112,100	141.5	36
7.129	122.7	5683	152.2	.8605	.0641	.9888	4.338	.8049	3262	40.41	36.35	119,249	149.6	37
7.180	123.1	5683	152.8	.8618	.0638	1.006	4.328	.8151	3252	40.44	36.42	120,100	150.6	38
7.556	127.4	5799	158.2	.8645	.0631	1.000	4.398	.8020	3284	40.23	36.30	129,481	160.0	39
7.899	131.0	5926	162.6	.8594	.0633	.9897	4.445	.8236	3306	40.22	37.09	136,303	167.7	40
8.175	133.9	6047	166.6	.8515	.0633	.9709	4.469	.8158	3348	40.16	37.40	144,047	175.0	41
8.419	135.8	6197	169.0	.8389	.0633	.9814	4.483	.8209	3361	40.45	37.14	157,700	183.1	42
15,000 feet														
8.073	90.4	5741	153.5	0.8597	0.0538	0.9893	3.309	0.8121	2916	40.75	30.50	104,100	141.3×10^3	1
8.417	93.1	5853	158.7	.8514	.0489	.9932	3.322	.8068	2934	40.81	30.95	109,500	150.5	2
8.892	96.5	6001	164.1	.8477	.0510	.9935	3.315	.8244	3025	39.95	32.53	118,100	160.5	3
9.212	98.4	6126	167.5	.8429	.0503	.9938	3.343	.8155	2975	40.84	31.09	125,100	168.2	4
9.434	99.8	6264	169.3	.8271	.0488	.9882	3.348	.8046	3003	40.87	31.15	129,200	175.2	5
7.918	90.4	5735	154.3	.8598	.0563	1.000	3.486	.8267	2976	40.89	31.82	98,220	133.1	6
8.326	93.7	5859	159.8	.8569	.0544	.9962	3.492	.8269	2999	40.86	31.79	105,900	142.1	7
8.635	96.0	5984	163.7	.8496	.0530	1.004	3.516	.8225	3026	40.84	32.05	110,800	149.7	8
8.898	97.7	6108	166.5	.8388	.0519	.9966	3.523	.8107	3057	40.76	32.21	116,900	156.4	9
9.158	98.5	6215	168.9	.8345	.0513	.9902	3.533	.8160	3073	40.67	32.37	121,000	162.2	10
7.779	90.6	5741	154.7	.8614	.0584	1.004	3.685	.8258	3050	40.73	32.88	95,900	124.9	11
8.142	93.7	5864	160.0	.8565	.0570	1.004	3.715	.8208	3081	40.76	33.20	101,300	132.9	12
8.469	95.9	5986	164.0	.8492	.0553	.9960	3.730	.8180	3104	40.66	33.17	106,000	139.7	13
8.773	97.5	6114	167.3	.8435	.0539	.9923	3.750	.8212	3135	40.56	33.33	112,100	145.5	14
9.009	98.7	6239	169.4	.8315	.0535	.9927	3.757	.8232	3153	40.61	33.49	115,800	151.6	15
9.008	98.9	6239	169.3	.8301	.0533	.9964	3.767	.8192	3145	40.68	33.30	116,100	152.9	16
9.167	98.8	6364	170.1	.8161	.0532	.9965	3.764	.8199	3173	40.70	33.56	118,500	156.5	17
7.787	90.9	5741	154.6	.8727	.0587	.9900	4.108	.8053	3142	39.38	34.57	96,150	116.0	18
7.940	93.8	5864	159.9	.8546	.0593	.9952	4.004	.8166	3175	40.45	34.75	97,000	122.7	19
8.263	96.1	5995	164.2	.8454	.0579	.9745	4.036	.8142	3206	40.52	34.84	101,400	129.0	20
-----	-----	6126	-----	------	.0507	------	-----	------	----	-----	-----	-------	---------	21
8.768	98.8	6245	169.2	.8274	.0553	.9834	4.075	.8176	3251	40.35	35.03	110,600	139.9	22
9.014	99.1	6370	170.1	.8147	.0546	.9921	4.121	.8220	3265	40.18	35.02	114,400	144.9	23
7.543	93.0	5785	157.1	.8581	.0627	.9884	4.389	.7979	3254	40.13	35.96	88,130	108.9	24
-----	95.6	5899	161.6	------	------	------	-----	------	----	-----	-----	-------	---------	25
8.100	96.8	5989	164.7	.8479	.0608	.9948	4.470	.8049	3288	40.23	36.64	98,120	120.8	26
8.345	98.4	6126	167.3	.8382	.0597	.9950	4.496	.8102	3318	40.23	36.80	101,400	125.6	27
8.407	99.1	6162	167.7	.8382	.0604	.9900	4.484	.8039	3325	40.19	36.60	101,800	126.3	28
8.640	100.5	6288	169.5	.8211	.0586	.9953	4.510	.8028	3344	40.10	36.76	107,600	132.2	29
8.756	100.2	6358	170.3	.8173	.0587	1.000	4.492	.8148	3341	40.32	36.69	112,100	137.2	30

TABLE I. - Continued. COMPONENT

Run	Tunnel static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Reynolds number index, $\frac{\delta_1\sqrt{\theta_1}}{\varphi_1}$	Engine speed, N, rpm	Engine fuel flow, $W_{f,e}$, lb/hr	Exhaust-nozzle-outlet area, sq ft	Engine inlet: Total temperature, T_1, °R	Engine inlet: Total pressure, P_1, lb/sq ft abs	Compressor outlet: Total temperature, T_2, °R	Compressor outlet: Total pressure, P_2, lb/sq ft abs	Turbine inlet: Total temperature, T_3, °R	Turbine inlet: Total pressure, P_3, lb/sq ft abs	Turbine outlet: Total temperature, T_4, °R	Turbine outlet: Total pressure, P_4, lb/sq ft abs	Exhaust-nozzle-inlet total temperature, T_6, °R
(c) Altitude,															
1	767	0.188	0.425	5606	3560	2.54	462	786	929	6955	1997	6569	1634	1969	1577
2	767	.176	.424	5727	3805		463	784	945	7220	2047	6811	1685	2048	1626
3	766	.176	.424	5848	4055		463	783	961	7452	2100	7034	1734	2104	1673
4	767	.152	.431	5971	4280		462	779	976	7656	2153	7230	1784	2157	1717
5	765	.176	.424	5606	3235	2.69	464	782	---	6782	----	6394	----	1817	----
6	767	.176	.424	5727	3430		464	784	942	7064	1950	6660	1576	1890	1522
7	765	.160	.423	5849	3640		464	780	957	7298	2000	6880	1619	1945	1565
8	767	.173	.424	5971	3850		463	783	971	7489	2060	7064	1667	1996	1613
9	765	.173	.424	6093	4080		463	781	988	7636	2120	7202	1729	2031	1668
10	765	.160	.418	5606	2865	2.86	470	779	929	6572	1800	6181	1416	1660	1387
11	764	.152	.419	5727	3045		470	777	943	6809	1847	6407	1458	1711	1427
12	764	.152	.418	5849	3285		470	777	957	7070	1897	6632	1503	1759	1464
13	764	.160	.418	5971	3430		470	778	972	7259	1952	6829	1549	1810	1509
14	765	.141	.419	6093	3630		470	776	988	7419	2007	6975	1598	1847	1554
15	767	.176	.417	5606	2490	3.18	469	784	920	6449	1685	6055	1279	1494	1274
16	765	.173	.420	5727	2655		469	781	935	6661	1737	6255	1323	1536	1310
17	766	.160	.417	5848	2845		469	780	950	6904	1785	6483	1363	1581	1346
18	765	.130	.420	5971	3000		469	774	964	7082	1830	6655	1400	1625	1385
19	765	.160	.421	6093	3180		469	779	980	7220	1882	6781	1450	1651	1429
20	765	.118	.422	6215	3375		469	773	997	7396	1947	6942	1505	1681	1481
21	767	.180	.437	5727	2360	4.13	459	785	916	6569	1623	6162	1216	1366	1201
22	767	.173	.431	5971	2700		459	783	945	6943	1730	6517	1308	1435	1279
23	766	.173	.432	6093	2855		460	782	962	7085	1777	6650	1351	1456	1317
24	768	.160	.436	6215	3080		457	782	976	7266	1840	6822	1402	1499	1373
(d) Altitude,															
1	479	0.203	0.270	5240	1830	2.54	461	493	881	3757	1675	3549	1521	1075	1487
2	480	.210	.273	5484	2240		461	495	915	4243	1786	3996	1629	1207	1584
3	479	.203	.272	5606	2410		459	493	932	4263	2043	4015	1685	1265	1632
4	476	.188	.271	5727	2600		459	488	949	4633	2107	4379	1744	1321	1689
5	478	.173	.273	5240	1660	2.69	462	488	876	3681	1593	3477	1427	1004	1405
6	478	.188	.270	5484	2015		461	490	909	4136	1690	3893	1518	1113	1489
7	479	.155	.270	5606	2230		458	487	927	4380	1947	4130	1574	1173	1536
8	478	.147	.270	5727	2350		458	485	943	4553	2007	4292	1627	1218	1581
9	478	.147	.270	5849	2500		458	485	959	4709	2067	4438	1688	1263	1633
10	479	.155	.271	5971	2645		458	487	972	4808	2113	4531	1738	1293	1677
11	479	.203	.268	6093	2810		458	493	988	4927	2173	4649	1796	1315	1727
12	479	.180	.268	5240	1486	2.86	462	490	871	3622	1504	3411	1329	931	1317
13	479	.155	.268	5484	1803		460	487	903	4070	1790	3839	1412	1031	1393
14	477	.195	.269	5606	1960		457	490	918	4267	1847	4016	1462	1099	1432
15	479	.107	.270	5727	2110		459	483	937	4462	1910	4196	1511	1129	1483
16	479	.136	.269	5849	2275		458	485	952	4624	1957	4350	1565	1159	1525
17	479	.118	.272	5971	2390		459	484	968	4709	2020	4434	1621	1190	1578
18	478	.107	.269	6093	2545		458	482	984	4792	2083	4516	1678	1202	1629
19	477	.118	.270	6215	2655		458	482	1000	4878	2123	4595	1725	1224	1664
20	479	.203	.271	5240	1277	3.18	460	493	862	3519	1566	3301	1199	838	1200
21	479	.155	.271	5484	1574		461	487	898	3967	1690	3720	1293	924	1287
22	479	.147	.271	5606	1735		459	486	914	4192	1737	3939	1340	971	1325
23	479	.147	.271	5727	1840		458	486	929	4310	1780	4051	1375	1002	1355
24	479	.155	.271	5849	1970		458	487	942	4479	1820	4213	1420	1035	1391
25	479	.147	.271	5971	2090		458	486	959	4558	1887	4286	1472	1041	1439
26	478	.147	.268	6093	2210		458	485	974	4639	1947	4363	1526	1063	1480
27	479	.164	.272	6215	2350		458	488	993	4747	2013	4464	1583	1090	1542
28	477	.203	.271	5240	1103	4.13	460	491	858	3453	1477	3234	1102	746	1108
29	479	.180	.269	5484	1344		459	490	889	3869	1563	3617	1170	813	1172
30	477	.155	.270	5606	1475		458	485	907	4039	1615	3790	1209	848	1211
31	479	.118	.269	5727	1590		459	484	922	4213	1667	3954	1253	877	1247
32	477	.147	.269	5849	1700		459	484	937	4335	1723	4067	1293	900	1288
33	479	.164	.270	5971	1805		459	488	953	4459	1773	4163	1338	920	1326
34	477	.155	.270	6093	1935		459	485	970	4549	1847	4270	1392	941	1378
35	481	.155	.270	6215	2055		459	489	987	4656	1893	4368	1443	958	1420
1	480	.642	.342	5240	2250	2.54	455	633	871	4880	1807	4610	1451	1375	1432
2	480	.647	.342	5362	2520		455	636	888	5247	1875	4947	1511	1482	1489
3	481	.645	.347	5484	2770		453	636	902	5560	1933	5233	1566	1568	1538
4	479	.633	.360	5606	2900		466	627	934	5588	2013	5261	1630	1571	1604
5	477	.632	.360	5727	3125		465	624	950	5806	2077	5480	1687	1630	1653
6	477	.628	.358	5849	3350		465	622	966	6020	2130	5681	1741	1702	1702
7	481	.634	.342	5240	2010	2.69	454	630	864	4760	1700	4480	1350	1272	1330
8	480	.626	.341	5362	2240		454	625	881	5031	1763	4684	1408	1348	1380
9	478	.634	.341	5484	2490		454	626	898	5373	1833	4949	1467	1436	1436
10	479	.633	.341	5606	2620		463	627	926	5509	1903	5190	1512	1466	1494
11	479	.625	.343	5727	2800		464	623	942	5692	1970	5367	1565	1520	1546
12	479	.629	.357	5849	3025		463	625	958	5917	2020	5584	1620	1574	1591
13	480	.626	.357	5971	3215		464	625	974	6073	2090	5728	1681	1615	1646
14	478	.629	.358	6093	3400		465	624	990	6187	2143	5834	1735	1641	1695
15	478	.648	.342	5240	1810	2.86	455	634	862	4680	1615	4418	1253	1178	1244
16	480	.640	.342	5362	2010		455	632	877	4987	1667	4674	1307	1248	1288
17	481	.645	.341	5484	2260		455	636	893	5318	1737	4963	1367	1335	1338
18	478	.632	-----	5606	2350		463	625	920	5371	1803	5055	1402	1343	1393
19	478	.634	.342	5727	2525		463	626	933	5560	1850	5215	1444	1393	1430
20	478	-----	.342	5849	2700		463	---	949	5771	----	5432	----	----	----
21	478	.629	.357	5971	2875		463	624	965	5881	1970	5539	1552	1466	1526
22	479	.629	.357	6093	3045		463	625	980	6045	2023	5692	1609	1504	1578
23	481	.625	.357	6215	3170		463	626	994	6125	2083	5768	1658	1528	1622

PERFORMANCE OF 600-B9 TURBOJET ENGINE

Compressor pressure ratio, P_2/P_1	Air flow, $W_{a,1}$, lb/sec	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Corrected air flow, $\frac{W_a\sqrt{\theta_1}}{\delta_1}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_2 - P_3}{P_2}$	Combustor efficiency, η_b	Turbine pressure ratio, P_3/P_4	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_3}$, rpm	Corrected turbine gas flow, $\frac{W_g\sqrt{\theta_3}}{\delta_3}\beta$, lb/sec	Turbine enthalpy drop, $\Delta H/\theta_3$, Btu/lb	Combustion parameter, $\frac{P_2T_2}{V_b}$, $\frac{(lb)(^oR)(sec)}{cu\ ft}$	Combustion parameter, $W_{a,1}T_6$, $\frac{(lb)(^oR)}{sec}$	Run
25,000 feet														
8.849	63.1	5942	160.2	0.8462	0.0555	0.9798	3.336	0.8254	2890	40.42	31.26	75,040	99.5×10^3	1
9.209	64.4	6065	164.1	.8400	.0567	.9776	3.326	.8140	2925	40.62	30.73	78,600	104.7	2
9.517	65.5	6194	167.2	.8295	.0561	.9755	3.343	.8045	2950	40.77	30.70	81,750	109.6	3
9.828	66.3	6329	170.0	.8165	.0557	.9735	3.352	.8065	2964	40.77	30.96	86,090	113.8	4
8.673	62.7	5931	160.5	------	.0572	------	3.519	------	----	-----	-----	-------	---------	5
9.010	64.5	6059	164.7	.8385	.0572	.9786	3.524	.8243	2992	39.66	32.27	75,450	98.2	6
9.356	65.7	6188	168.5	.8318	.0573	.9863	3.537	.8195	3021	39.84	32.21	79,910	102.8	7
9.564	66.2	6323	168.9	.8151	.0568	.9837	3.539	.8207	3037	39.96	32.37	82,630	106.8	8
9.777	66.4	6452	169.9	.7984	.0568	.9784	3.546	.8100	3059	40.40	32.24	84,960	110.8	9
8.436	62.1	5892	160.6	.8498	.0595	.9630	3.723	.8185	3045	40.38	33.08	67,400	86.1	10
8.763	63.4	6019	164.3	.8439	.0590	.9722	3.745	.8121	3072	40.41	33.10	71,540	90.5	11
9.099	64.4	6147	167.0	.8376	.0620	.9625	3.770	.8154	3098	40.33	33.08	76,100	94.3	12
9.330	65.4	6276	169.3	.8244	.0592	.9747	3.773	.8160	3118	40.48	33.29	78,730	98.7	13
9.561	65.8	6404	170.8	.8108	.0599	.9724	3.776	.8139	3140	40.46	33.45	81,140	102.3	14
8.226	62.5	5898	160.4	.8489	.0611	.9761	4.053	.8130	3144	39.49	34.92	64,800	79.6	15
8.529	64.0	6025	164.7	.8406	.0610	.9772	4.072	.8199	3166	39.79	35.14	67,410	83.8	16
8.851	65.0	6153	167.6	.8328	.0610	.9739	4.101	.8197	3189	39.67	35.11	71,630	87.5	17
9.150	65.5	6281	170.2	.8251	.0603	.9710	4.095	.8167	3221	39.58	35.17	74,030	90.7	18
9.268	65.9	6410	170.2	.8050	.0608	.9724	4.107	.8132	3239	39.85	35.06	77,330	94.2	19
9.568	65.7	6538	171.1	.7935	.0614	.9740	4.130	.8047	3251	39.76	35.00	81,270	97.3	20
8.368	66.2	6088	165.3	.8300	.0620	.9843	4.511	.8097	3270	39.83	37.16	64,770	79.5	21
8.867	66.5	6347	169.0	.8073	.0614	.9812	4.541	.8178	3306	40.58	37.09	70,700	85.1	22
9.060	66.7	6471	169.9	.7939	.0614	.9690	4.567	.8126	3330	40.31	37.40	72,740	87.8	23
9.292	67.2	6625	170.7	.7722	.0611	.9710	4.551	.8037	3343	42.02	36.69	76,420	92.3	24
35,000 feet														
7.621	35.0	5560	141.6	0.8553	0.0554	0.9567	3.301	0.7867	2737	41.00	28.10	39,460	52.0×10^3	1
8.572	38.2	5819	154.0	.8518	.0582	.9452	3.311	.8019	2849	40.14	30.21	45,440	60.5	2
8.647	39.5	5965	159.4	.8138	.0582	.9534	3.174	.8239	2866	42.07	30.04	45,288	64.5	3
9.494	40.3	6088	164.3	.8350	.0548	.9529	3.315	.7917	2883	40.35	30.16	51,388	68.1	4
7.543	34.7	5554	142.1	.8641	.0554	.9643	3.463	.7883	2863	39.60	30.46	38,550	48.8	5
8.441	38.0	5819	154.6	.8553	.0588	.9466	3.498	.7959	2911	39.96	30.96	44,130	56.6	6
8.994	39.5	5965	161.1	.8424	.0571	.9394	3.521	.7945	2932	39.25	31.19	47,206	60.7	7
9.388	40.4	6094	165.7	.8359	.0573	.9511	3.524	.8036	2952	39.63	31.60	49,481	63.9	8
9.709	41.1	6223	168.4	.8248	.0576	.9534	3.514	.7997	2971	39.81	31.23	52,505	67.1	9
9.873	41.5	6353	169.3	.8117	.0576	.9496	3.504	.7923	3000	40.20	31.36	53,978	69.6	10
9.994	42.1	6483	169.9	.7933	.0564	.9517	3.535	.7866	3022	41.27	31.49	55,779	72.7	11
7.392	35.0	5554	142.6	.8625	.0583	.9688	3.664	.7866	2935	39.51	31.68	36,590	46.1	12
8.357	38.4	5824	157.1	.8582	.0568	.9676	3.724	.7896	2989	39.79	32.07	41,840	53.5	13
8.708	39.8	5976	161.3	.8396	.0588	.9654	3.654	.8156	3007	40.14	32.52	44,983	57.0	14
9.238	40.3	6088	165.9	.8428	.0596	.9567	3.717	.8072	3025	38.92	32.62	48,345	59.8	15
9.534	41.2	6223	169.0	.8297	.0593	.9486	3.753	.7971	3053	39.32	32.69	50,500	62.8	16
9.729	41.3	6347	169.7	.8154	.0584	.9479	3.726	.7982	3070	39.39	32.74	51,876	65.2	17
9.942	41.4	6483	170.9	.7972	.0576	.9444	3.757	.7959	3084	39.83	32.53	54,137	67.4	18
10.120	41.5	6613	171.2	.7813	.0580	.9377	3.754	.7993	3115	40.01	32.98	55,571	69.1	19
7.138	35.3	5565	142.8	.8558	.0620	.9738	3.939	.7840	3046	39.59	33.40	34,210	42.4	20
8.146	38.4	5819	157.2	.8557	.0623	.9631	4.026	.7998	3072	39.77	33.88	40,000	49.4	21
8.626	39.8	5959	163.0	.8492	.0604	.9609	4.057	.7946	3099	39.17	33.92	43,352	52.7	22
8.868	40.5	6094	165.5	.8326	.0601	.9582	4.043	.8059	3128	39.68	34.32	44,938	54.9	23
9.197	41.2	6223	168.2	.8278	.0594	.9444	4.071	.7968	3164	39.91	34.48	47,832	57.3	24
9.379	41.4	6353	169.2	.8091	.0597	.9474	4.117	.8018	3172	40.21	34.39	49,097	59.6	25
9.565	41.5	6483	170.2	.7941	.0595	.9466	4.104	.7988	3186	40.34	34.47	50,383	61.4	26
9.727	41.9	6613	170.8	.7731	.0596	.9525	4.095	.8038	3199	40.10	34.69	52,946	64.6	27
7.033	35.6	5565	144.5	.8565	.0634	.9878	4.335	.7845	3134	39.47	35.06	32,960	39.4	28
7.896	38.6	5829	156.9	.8510	.0651	.9727	4.449	.7811	3192	39.45	35.83	38,180	45.2	29
8.328	39.5	5965	161.9	.8408	.0617	.9643	4.469	.7831	3211	38.24	35.74	40,279	47.8	30
8.705	40.4	6088	166.0	.8394	.0615	.9519	4.509	.7892	3228	38.24	35.95	43,055	50.4	31
8.957	41.0	6217	168.4	.8264	.0618	.9589	4.519	.7943	3246	38.47	36.01	44,661	52.8	32
9.137	41.5	6347	169.1	.8088	.0664	.9609	4.525	.7953	3267	38.50	36.24	47,090	55.0	33
9.379	41.5	6477	170.5	.7944	.0613	.9551	4.538	.8055	3270	38.27	35.98	48,479	57.2	34
9.521	41.8	6607	170.1	.7754	.0619	.9535	4.559	.7966	3296	37.97	36.24	50,908	59.4	35
7.709	46.5	5596	145.5	.8588	.0553	.9805	3.353	.7972	2844	40.28	29.91	50,140	66.6	1
8.250	48.9	5727	152.4	.8625	.0572	.9852	3.338	.7981	2856	40.03	30.05	55,320	72.8	2
8.742	51.0	5873	158.4	.8574	.0588	.9825	3.337	.7969	2877	40.37	30.05	59,110	78.4	3
8.912	50.1	5914	160.4	.8545	.0585	.9738	3.349	.7975	2886	39.88	30.47	60,435	80.4	4
9.304	51.2	6048	164.2	.8444	.0562	.9721	3.362	.8033	2903	40.41	30.35	64,466	84.6	5
9.678	52.0	6177	167.5	.8355	.0563	.9580	3.338	.7991	2927	40.51	30.61	67,385	88,5	6
7.556	46.3	5596	145.5	.8634	.0588	.9696	3.522	.7974	2927	39.95	31.26	47,870	61.6	7
8.050	48.1	5727	152.5	.8631	.0690	.9633	3.475	.8081	2948	40.51	31.30	51,090	66.4	8
8.583	50.2	5862	158.6	.8585	.0789	.9618	3.446	.8100	2953	40.84	31.33	56,010	72.1	9
8.786	50.7	5937	161.7	.8512	.0579	.9752	3.540	.8010	2967	39.59	31.59	58,341	75.7	10
9.136	51.6	6059	165.6	.8454	.0571	.9828	3.531	.8084	2978	39.69	31.66	61,837	79.8	11
9.467	52.4	6194	167.7	.8318	.0563	.9623	3.548	.8003	3007	39.74	31.92	64,812	83.4	12
9.717	52.8	6317	196.0	.8207	.0568	.9658	3.547	.8055	3018	40.04	31.67	68,272	86.9	13
9.915	53.0	6434	170.3	.8094	.0571	.9566	3.555	.7963	3041	40.47	31.92	70,146	89.8	14
7.382	46.8	5596	146.3	.8555	.0560	.9706	3.750	.7987	3001	39.85	32.78	45,500	58.2	15
7.891	48.7	5727	152.7	.8608	.0628	.9724	3.745	.7973	3024	39.86	32.72	49,720	62.7	16
8.362	50.9	5857	158.6	.8585	.0668	.9615	3.718	.8151	3031	40.17	32.98	54,400	68.1	17
8.594	50.7	5937	162.1	.8509	.0588	.9693	3.764	.8052	3043	39.62	33.04	55,759	70.6	18
8.882	51.7	6065	165.1	.8437	.0621	.9614	3.744	.8110	3074	40.24	33.07	58,103	73.9	19
-----	----	6194	-----	------	.0588	------	-----	------	----	-----	-----	-------	---------	20
9.425	52.7	6323	168.9	.8186	.0582	.9583	3.778	.8090	3105	40.47	33.21	64,674	80.4	21
9.672	53.2	6452	170.0	.8057	.0584	.9665	3.785	.7951	3129	40.39	32.98	66,977	83.9	22
9.784	53.3	6582	170.3	.7899	.0583	.9612	3.775	.8056	3145	40.55	33.04	68,338	86.5	23

TABLE I. - Concluded. COMPONENT

Run	Tunnel static pressure, P_0, lb/sq ft abs	Flight Mach number, M_0	Reynolds number index, $\delta_1\sqrt{\theta_1}/\varphi_1$	Engine speed, N, rpm	Engine fuel flow, $W_{f,e}$, lb/hr	Exhaust-nozzle-outlet area, sq ft	Engine inlet: Total temperature, T_1, °R	Engine inlet: Total pressure, P_1, lb/sq ft abs	Compressor outlet: Total temperature, T_2, °R	Compressor outlet: Total pressure, P_2, lb/sq ft abs	Turbine inlet: Total temperature, T_3, °R	Turbine inlet: Total pressure, P_3, lb/sq ft abs	Turbine outlet: Total temperature, T_4, °R	Turbine outlet: Total pressure, P_4, lb/sq ft abs	Exhaust-nozzle-inlet total temperature, T_6, °R
(d) Concluded. Altitude,															
24	481	0.645	0.342	5240	1575	3.18	455	857	636	4594	1507	4317	1144	1056	1144
25	480	.638	.341	5484	1925		456	889	631	5082	1620	4694	1234	1165	1225
26	479	.634	.341	5606	2055		462	628	911	5281	1685	4961	1279	1201	1276
27	482	.627	.345	5727	2195		462	628	926	5436	1737	5113	1322	1241	1315
28	479	.642	.344	5849	2330		462	632	940	5572	1793	5239	1367	1268	1355
29	478	.634	.344	5971	2515		462	626	957	5783	1847	5435	1403	1316	1404
30	478	.632	.357	6093	2665		462	625	974	5879	1917	5524	1469	1345	1455
31	479	.627	.357	6215	2845		463	624	991	6037	1967	5672	1520	1374	1500
32	479	.650	.340	5362	1505	4.13	457	868	636	4736	1467	4463	1092	977	1088
33	477	.645	.340	5484	1755		456	884	631	4975	1523	4647	1133	1025	1130
34	479	.647	.339	5606	1800		461	634	904	5143	1577	4825	1168	1057	1173
35	479	.631	.339	5727	1950		459	626	918	5345	1627	5009	1216	1099	1210
36	477	.630	.340	5849	2070		459	623	933	5441	1680	5114	1282	1119	1252
37	477	.630	.345	5971	2220		459	623	947	5609	1730	5261	1310	1152	1291
38	479	.631	.357	6093	2360		459	626	963	5734	1790	5379	1357	1179	1338
39	479	.631	.361	6215	2520		459	626	980	5883	1850	5511	1410	1210	1386
1	478	1.001	.481	5240	2820	2.54	474	907	884	6507	1747	6133	1405	1827	1373
2	477	1.007	.483	5484	3605		473	906	920	7485	1907	7061	1545	2111	1507
3	476	.995	.482	5606	3950		468	891	933	7802	1980	7360	1610	2193	1569
4	474	.996	.480	5727	4190		468	896	946	8101	2020	7639	1643	2276	1605
5	475	.996	.483	5849	4505		469	898	962	8447	2087	7971	1692	2372	1654
6	479	.992	.483	5971	4755		470	896	978	8634	2130	8145	1745	2420	1700
7	474	1.009	.487	5240	2570	2.69	472	906	878	6433	1663	6053	1301	1701	1290
8	476	1.010	.486	5484	3260		472	911	912	7315	1797	6884	1430	1945	1398
9	480	.997	.488	5606	3500		469	905	924	7672	1857	7229	1476	2027	1446
10	477	.997	.483	5727	3735		469	899	939	7906	1917	7450	1525	2091	1493
11	481	.994	.489	5849	4005		470	904	954	8285	1970	7806	1570	2188	1540
12	478	.996	.487	5971	4265		470	900	971	8435	2030	7946	1623	2228	1594
13	479	.995	.481	6093	4520		470	901	987	8674	2093	8182	1677	2289	1640
14	476	1.002	.482	5240	2285	2.86	471	903	872	6277	1577	5894	1209	1561	1210
15	477	1.001	.482	5484	2865		471	904	907	7139	1707	6706	1332	1771	1312
16	478	1.000	.490	5606	3140		468	904	919	7521	1763	7071	1369	1863	1352
17	477	.987	.480	5727	3360		468	889	934	7745	1810	7285	1418	1911	1395
18	477	.986	.480	5849	3580		468	888	948	7973	1867	7501	1469	1970	1440
19	479	.998	.490	5971	3865		468	904	964	8304	1925	7816	1514	2058	1485
20	479	.988	.481	6093	4030		469	894	981	----	----	----	1564	2070	1536
21	478	.991	.481	6215	4255		469	895	996	8585	2040	8082	1606	2114	1580
22	475	1.005	.483	5240	2010	3.18	469	904	866	6210	1480	5815	1106	1411	1115
23	475	1.005	.480	5484	2500		468	904	897	6959	1590	6523	1209	1582	1197
24	478	.999	.482	5606	2710		469	903	913	7295	1640	6848	1238	1654	1245
25	478	.991	.484	5727	2920		469	895	927	7576	1697	7116	1280	1706	1282
26	477	.997	.482	5849	3120		468	899	943	7788	1755	7312	1329	1755	1323
27	479	.987	.490	5971	3320		468	893	957	7995	1800	7510	1369	1800	1361
28	477	.988	.492	6093	3525		469	890	974	8156	1863	7659	1422	1834	1410
29	477	.996	.492	6215	3780		469	898	991	8416	1930	7901	1477	1895	1461
30	478	.991	.478	5240	1745	4.13	468	895	861	6026	1415	5627	1038	1240	1045
31	475	1.012	.479	5484	2230		468	911	892	6889	1515	6452	1126	1423	1123
32	479	.995	.478	5606	2435		467	901	907	7158	1557	6704	1159	1471	1152
33	479	.991	.483	5727	2600		468	896	920	7378	1597	6914	1194	1509	1186
34	477	1.000	.482	5849	2810		471	903	937	7683	1647	7199	1238	1573	1226
35	479	.992	.490	5971	2965		472	897	954	7797	1710	7318	1286	1593	1269
36	478	.995	.495	6093	3170		473	899	971	7994	1767	7503	1335	1636	1314
37	477	.995	.479	6215	3365		473	897	987	8136	1823	7634	1381	1667	1359
(e) Altitude,															
1	287	0.141	0.167	5240	1195	2.54	454	291	886	2326	1925	2234	1592	670	1543
2	288	.141	.167	5240	1070	2.69	456	292	880	2283	1803	2146	1467	621	1423
3	287	.173	.167	5362	1195		453	293	896	2424	1873	2260	1525	660	1480
4	284	.160	.167	5484	1320		454	289	913	2551	1947	2374	1580	691	1540
5	287	.118	.166	5606	1450		454	290	932	2692	2010	2497	1641	727	1598
6	289	.199	.167	5606	1465		459	297	942	2713	2030	2557	1646	728	1616
7	288	.155	.167	5727	1535		458	293	956	2822	2093	2661	1698	750	1666
8	289	.118	.169	5240	970	2.86	454	292	875	2253	1733	2132	1385	583	1351
9	287	.118	.169	5362	1060		454	290	892	2346	1798	2237	1431	608	1403
10	289	.173	.169	5484	1195		454	295	910	2554	1860	2424	1486	656	1453
11	289	.184	.169	5606	1310		453	296	927	2658	1928	2518	1537	683	1507
12	287	.199	.169	5727	1400		455	295	945	2753	1990	2622	1597	707	1565
13	290	.184	.167	5849	1535		454	297	959	2909	2047	2748	1648	744	1609
14	289	.210	.167	5971	1630		453	298	975	2961	2108	2815	1704	757	1661
15	287	.210	.167	6093	1725		454	296	991	3038	2150	2881	1748	775	1695
16	288	.173	.160	5362	941	3.18	458	294	888	2328	1700	2190	1316	549	1306
17	289	.173	.160	5484	1028		457	295	903	2465	1740	2317	1356	575	1339
18	291	.184	.160	5606	1134		457	298	920	2601	1800	2441	1404	606	1384
19	290	.174	.160	5727	1225		456	296	935	2718	1860	2553	1443	631	1429
20	288	.184	.160	5849	1316		457	295	953	2811	1925	2643	1502	648	1484
21	289	.155	.160	5971	1404		456	294	968	2887	1984	2712	1553	668	1531
22	288	.173	.161	6093	1502		456	294	985	2964	2044	2782	1598	684	1577
23	288	.141	.159	6215	1582		456	292	1000	3023	2094	2835	1655	692	1623
24	288	.252	.160	5484	894	4.13	460	301	899	2366	1630	2216	1245	500	1232
25	291	.173	.161	5606	984		458	297	913	2531	1680	2372	1283	526	1267
26	288	.173	.160	5727	1057		459	294	930	2598	1730	2436	1322	540	1304
27	288	.184	.159	5849	1147		---	295	----	2714	----	2542	----	559	----
28	289	.155	-----	5849	1144		458	294	946	2707	1790	2540	1370	559	1349
29	289	.173	.160	5971	1222		458	295	960	2805	1840	2627	1403	573	1387
30	289	.173	.168	6093	1292		457	295	976	2872	1894	2689	1454	587	1434
31	289	.155	.170	6215	1365		457	294	992	2933	1950	2748	1499	599	1476

PERFORMANCE OF 600-B9 TURBOJET ENGINE

Compressor pressure ratio, P_2/P_1	Air flow, $W_{a,1}$, lb/sec	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Corrected air flow, $\frac{W_a\sqrt{\theta_1}}{\delta_1}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_2 - P_3}{P_2}$	Combustor efficiency, η_b	Turbine pressure ratio, P_3/P_4	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_3}$, rpm	Corrected turbine gas flow, $\frac{W_g\sqrt{\theta_3}}{\delta_3}\beta$, lb/sec	Turbine enthalpy drop, $\Delta H/\theta_3$, Btu/lb	Combustion parameter, $\frac{P_2 T_2}{V_b}$, $\frac{(lb)(^{\circ}R)(sec)}{cu\ ft}$	Combustion parameter, $W_{a,1}T_6$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
35,000 feet														
7.223	47.3	5596	147.5	0.8538	0.0603	0.9773	4.088	0.7847	3104	39.72	34.34	43,820	54.1×10^3	24
8.054	50.5	5851	158.7	.8502	.0764	.9700	4.029	.8113	3137	40.51	35.02	50,150	61.9	25
8:409	51.3	5942	163.2	.8528	.0606	.9785	4.131	.8002	3145	39.19	34.56	52,787	65.5	26
8.656	52.1	6071	165.5	.8399	.0594	.9764	4.120	.8068	3168	39.23	34.82	54,786	68.5	27
8.816	52.8	6200	166.9	.8238	.0598	.9868	4.132	.8122	3182	39.54	34.98	57,513	71.5	28
9.238	53.4	6329	170.2	.8183	.0602	.9718	4.130	.8045	3205	39.47	34.98	61,207	75.0	29
9.406	53.2	6459	170.1	.7989	.0604	.9730	4.107	.8169	3212	39.65	34.98	63,851	77.4	30
9.675	53.4	6582	171.0	.7888	.0605	.9573	4.128	.8110	3244	39.69	34.94	67,289	80.1	31
7.447	49.1	5716	153.2	.8550	.0577	.9814	4.568	.7885	3217	39.25	36.33	44,760	53.4	32
7.884	50.7	5851	159.4	.8493	.0659	.9282	4.534	.7961	3230	39.81	36.45	47,460	57.3	33
8.112	51.6	5948	162.3	.8434	.0618	.9735	4.565	.7903	3248	39.24	36.61	50,371	60.5	34
8.538	52.2	6088	166.1	.8362	.0629	.9623	4.558	.7952	3268	39.56	36.48	53,619	63.2	35
8.734	52.7	6217	168.5	.8214	.0601	.9695	4.570	.7925	3286	39.94	36.60	55,023	66.0	36
9.003	53.0	6347	169.3	.8123	.0621	.9515	4.567	.7941	3308	39.90	36.43	58,090	68.4	37
9.160	53.3	6477	169.6	.7946	.0619	.9571	4.562	.7955	3321	40.12	36.53	59,909	71.3	38
9.398	53.5	6607	170.2	.7794	.0632	.9509	4.555	.7957	3332	40.09	36.46	63,009	74.2	39
7.174	63.4	5481	141.5	.8668	.0575	.9829	3.357	.8166	2888	40.57	30.71	65,100	87.1	1
8.262	69.6	5742	155.2	.8670	.0567	.9817	3.345	.8135	2899	40.52	30.71	79,000	104.9	2
8.756	71.8	5903	161.9	.8545	.0567	.9897	3.356	.8109	2909	41.03	30.70	82,920	112.7	3
9.041	73.8	6031	165.5	.8481	.0570	.9933	3.356	.8040	2944	41.41	30.89	86,710	118.4	4
9.406	75.1	6153	168.2	.8428	.0564	.9842	3.360	.8176	2957	41.31	30.93	92,700	124.2	5
9.636	75.6	6276	169.9	.8306	.0566	.9760	3.366	.7964	2988	41.05	30.86	95,600	128.5	6
7.100	63.8	5497	142.1	.8646	.0591	.9765	3.558	.8385	2957	40.23	32.21	63,100	82.3	7
8.030	70.0	5753	155.1	.8638	.0589	.9755	3.539	.8171	2982	40.52	32.24	74,300	97.9	8
8.477	72.4	5898	160.9	.8575	.0578	.9921	3.566	.8151	2999	40.54	32.07	79,780	104.7	9
8.794	73.8	6025	165.1	.8490	.0577	.9925	3.563	.8208	3020	40.72	32.20	82,930	110.2	10
9.165	75.7	6147	168.7	.8467	.0578	.9964	3.568	.8146	3040	40.57	32.17	89,010	116.6	11
9.372	76.1	6276	170.2	.8289	.0580	.9932	3.567	.8075	3061	40.61	32.31	91,450	121.3	12
9.627	76.5	6404	171.1	.8153	.0567	.9840	3.574	.8166	3078	40.64	32.37	96,480	125.5	13
6.951	64.3	5502	143.5	.8619	.0610	1.0000	3.776	.8019	3038	40.47	33.23	60,400	77.8	14
7.897	69.7	5758	155.5	.8598	.0607	.9862	3.787	.8085	3058	40.26	33.25	71,200	90.5	15
8.320	72.8	5903	161.9	.8527	.0598	.9912	3.795	.8150	3074	40.43	33.41	75,480	98.4	16
8.712	73.5	6031	166.1	.8496	.0594	.9834	3.812	.8046	3102	40.64	33.43	79,640	102.5	17
8.979	74.6	6159	168.7	.8402	.0592	.9921	3.808	.8076	3119	40.63	33.32	82,610	107.4	18
9.186	76.5	6287	170.0	.8239	.0588	.9887	3.798	.8135	3142	40.99	33.46	88,240	113.6	19
-----	76.0	6410	171.1	------	------	------	-----	------	----	-----	-----	------	-----	20
9.592	76.5	6538	172.0	.7969	.0586	.9864	3.823	.8097	3177	40.65	33.72	94,290	120.9	21
6.869	65.0	5512	144.7	.8603	.0636	.9877	4.121	.7983	3130	40.13	34.99	57,700	72.5	22
7.698	70.5	5775	156.7	.8555	.0627	.9840	4.123	.8068	3166	40.27	35.29	66,800	84.4	23
8.079	72.7	5898	162.0	.8540	.0613	1.0000	4.140	.7898	3186	39.90	34.56	71,820	90.5	24
8.465	73.9	6025	166.0	.8521	.0607	.9904	4.171	.8007	3202	39.94	35.01	76,380	94.7	25
8.663	75.4	6159	168.6	.8307	.0611	1.000	4.166	.8139	3217	40.26	35.41	79,180	99.8	26
8.953	75.7	6287	170.4	.8238	.0607	.9847	4.172	.8079	3243	39.98	35.11	81,890	103.0	27
9.164	75.8	6410	171.3	.8091	.0609	.9878	4.176	.8112	3255	40.05	35.40	85,680	106.9	28
9.372	76.8	6538	171.9	.7926	.0612	.9846	4.169	.8168	3265	40.27	35.28	89,190	122.0	29
6.733	64.8	5518	145.4	.8558	.0662	110140	4.538	.7931	3200	40.30	36.15	54,200	67.7	30
7.562	71.5	5775	157.8	.8558	.0634	.9939	4.534	.7946	3241	40.23	36.63	65,000	80.3	31
7.945	73.3	5909	163.3	.8488	.0634	.9773	4.557	.8023	3267	40.20	36.71	68,080	84.4	32
8.234	74.0	6031	166.0	.8466	.0629	.9730	4.582	.7925	3297	39.99	36.83	71,810	87.8	33
8.508	75.7	6141	169.0	.8434	.0630	.9745	4.577	.7943	3319	39.45	37.00	76,640	92.8	34
8.692	75.6	6264	170.0	.8272	.0614	.9760	4.594	.8009	3325	39.99	36.92	78,450	95.9	35
8.892	76.1	6379	170.9	.8131	.0614	.9772	4.586	.8013	3340	40.01	36.68	82,470	100.0	36
9.070	76.2	6507	171.6	.7966	.0617	.9784	4.579	.8003	3355	40.27	36.74	84,650	103.6	37
45,000 feet														
7.993	20.8	5602	141.5	0.8448	0.0396	0.9340	3.334	0.7754	2755	38.51	29.37	25,380	32.1×10^3	1
7.818	20.8	5591	141.0	.8528	.0600	.9151	3.456	.7922	2847	38.68	30.69	24,380	29.6	2
8.273	21.8	5743	147.2	.8396	.0677	.9172	3.424	.8002	2859	39.41	30.73	26,140	32.3	3
8.827	22.6	5862	154.9	.8443	.0694	.9126	3.436	.7989	2868	39.70	30.70	28,270	34.8	4
9.283	23.5	5993	160.2	.8351	.0724	.9169	3.435	.7885	2888	39.85	30.47	30,120	37.6	5
9.135	23.4	5959	156.5	.8282	.0575	.9124	3.512	.7771	2873	38.32	30.73	30,520	37.8	6
9.631	23.9	6094	161.9	.8295	.0571	.9408	3.548	.7739	2894	39.09	30.87	32,570	39.8	7
7.716	20.9	5602	141.8	.8476	.0537	.9306	3.657	.7877	2901	38.32	31.52	23,580	28.2	8
8.090	21.7	5732	148.1	.8385	.0465	.9419	3.679	.7906	2915	38.67	31.66	24,790	30.4	9
8.658	23.0	5862	154.6	.8413	.0509	.9451	3.695	.7893	2934	38.56	31.72	27,250	33.4	10
8.980	23.7	6004	158.3	.8249	.0527	.9349	3.683	.7968	2945	38.97	32.08	29,160	35.7	11
9.332	24.2	6116	162.6	.8199	.0476	.9475	3.709	.7790	2964	38.89	31.85	30,500	37.9	12
9.795	24.9	6253	165.1	.8155	.0554	.9292	3.694	.7865	2986	38.71	31.79	33,010	40.1	13
9.936	25.3	6395	167.9	.7940	.0493	.9294	3.719	.7804	3007	39.08	32.15	33,880	42.0	14
10.26	25.3	6513	169.4	.7883	.0517	.9136	3.717	.8138	3037	38.64	32.31	35,710	42.9	15
7.918	21.9	5705	148.0	.8510	.0593	.9513	3.989	.7831	2995	38.65	33.11	24,130	28.6	16
8.356	22.8	5846	153.4	.8471	.0601	.9451	4.030	.7782	3029	38.56	32.98	26,210	30.5	17
8.728	24.0	5976	159.7	.8376	.0615	.9478	4.028	.7834	3045	39.17	33.33	27,460	33.2	18
9.182	24.5	6111	164.3	.8329	.0607	.9470	4.046	.7892	3061	39.00	33.75	29,410	35.0	19
9.529	25.0	6235	168.0	.8229	.0598	.9498	4.079	.7811	3077	39.09	33.43	30,720	37.1	20
9.820	25.1	6371	169.5	.8101	.0606	.9458	4.060	.7864	3093	38.95	33.88	32,360	38.4	21
10.08	25.3	6501	170.7	.7961	.0614	.9359	4.067	.7909	3113	38.90	33.91	33,500	39.9	22
10.35	25.3	6631	171.7	.7852	.0622	.9245	4.097	.7798	3139	38.62	33.88	35,070	41.1	23
7.860	23.1	5824	152.6	.8333	.0634	.9559	4.432	.7689	3128	39.33	35.08	23,500	28.5	24
8.522	23.8	5965	159.2	.8412	.0628	.9315	4.510	.7713	3149	38.52	35.05	26,170	30.2	25
8.837	24.1	6088	163.2	.8326	.0624	.9224	4.511	.7767	3170	38.61	35.30	27,560	31.4	26
9.200	----	----	-----	-----	.0634	------	4.547	------	----	-----	-----	------	-----	27
9.207	24.9	6223	168.6	.8216	.0617	.9419	4.544	.7783	3188	39.03	35.37	28,980	33.6	28
9.508	25.1	6353	169.4	.8136	.0635	.9258	4.585	.7781	3210	38.62	35.20	30,770	34.8	29
9.736	25.3	6495	170.6	.7960	.0637	.9331	4.581	.7851	3230	38.63	35.36	31,750	36.3	30
9.976	25.5	6625	171.6	.7837	.0631	.9326	4.588	.7769	3247	38.59	35.52	32,710	37.6	31

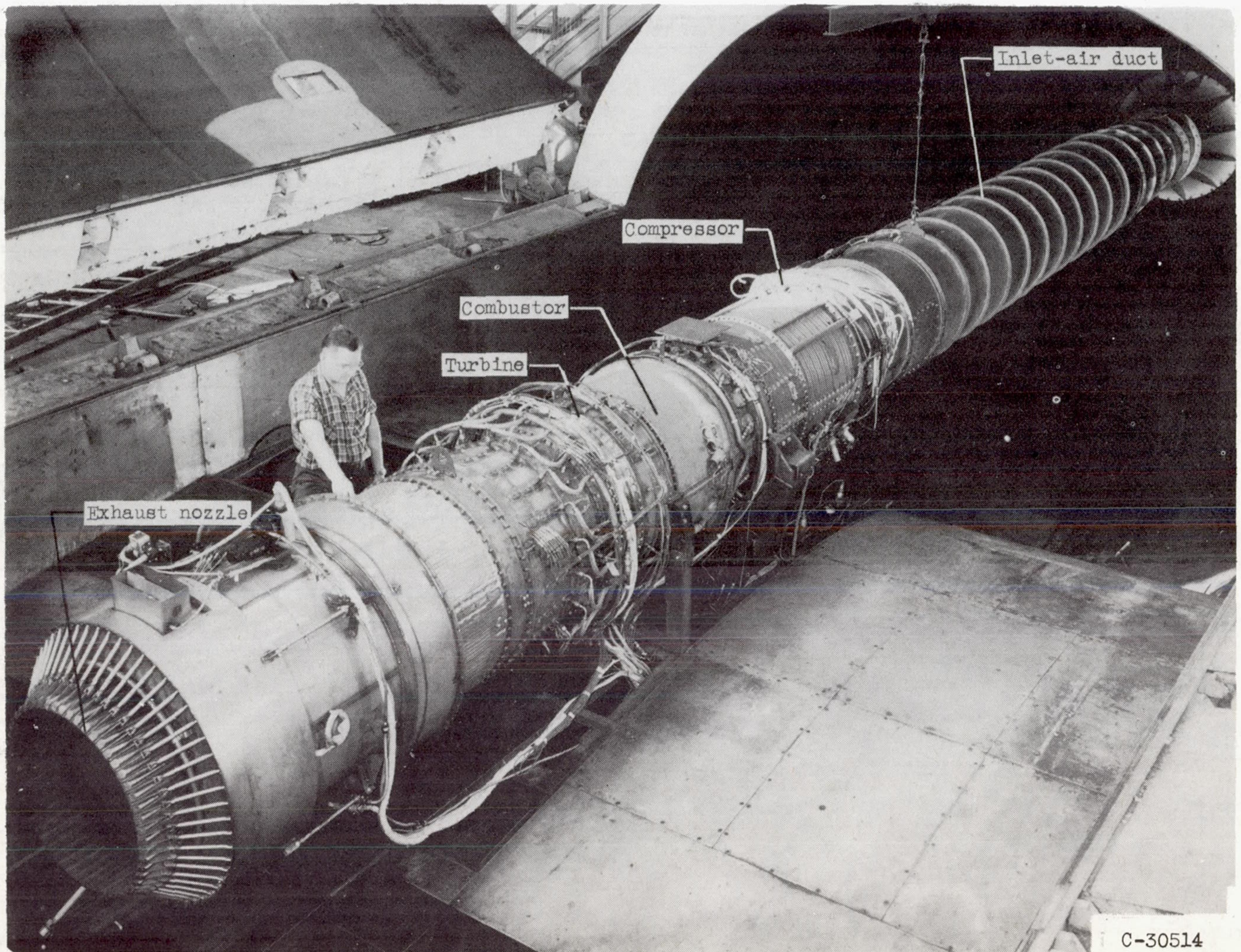
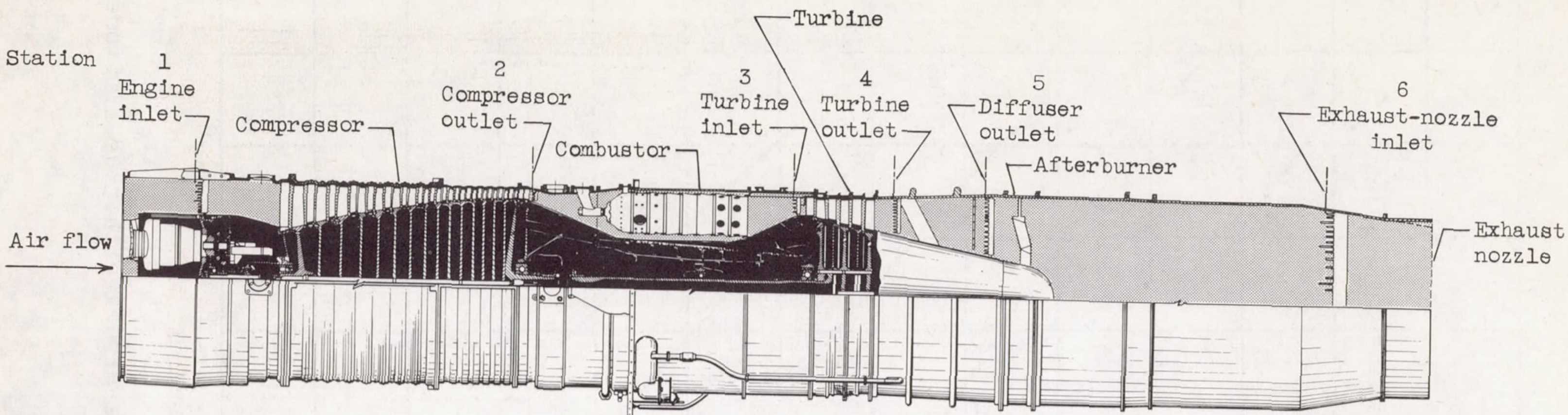


Figure 1. - Installation of 600-B9 engine in altitude wind tunnel.



Station	Total-pressure tubes	Static-pressure tubes	Wall static-pressure orifices	Thermo-couples
1	28	8	4	[a]6
2	16	1	0	8
3	8	0	0	4
4	21	0	6	18
5	12	0	2	0
6	20	4	2	12

[a]Approximately 43 inches upstream of station 1 in make-up air pipe.

CD-3030

Figure 2. - Cross section of 600-B9 turbojet-engine installation showing stations at which instrumentation was installed.

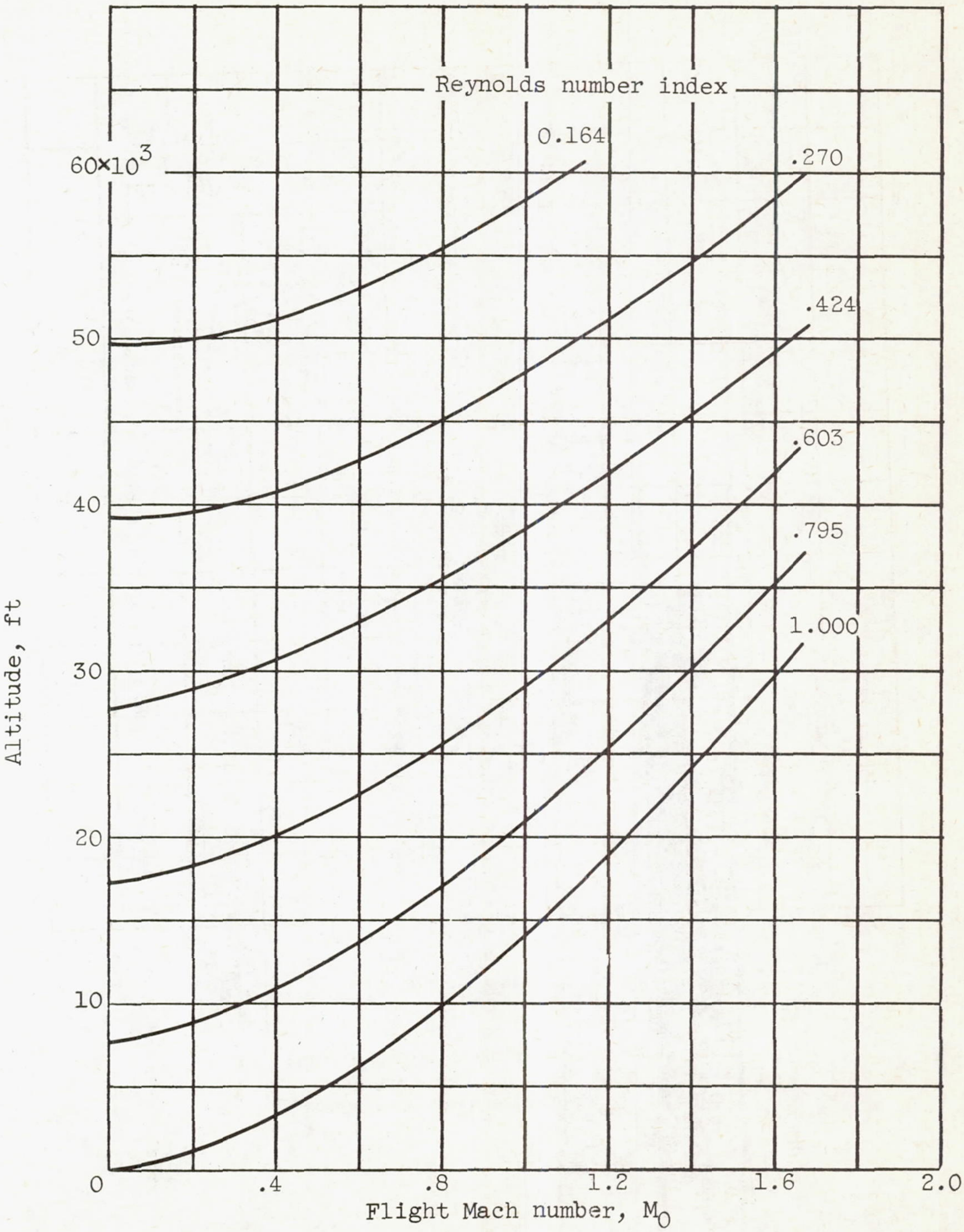
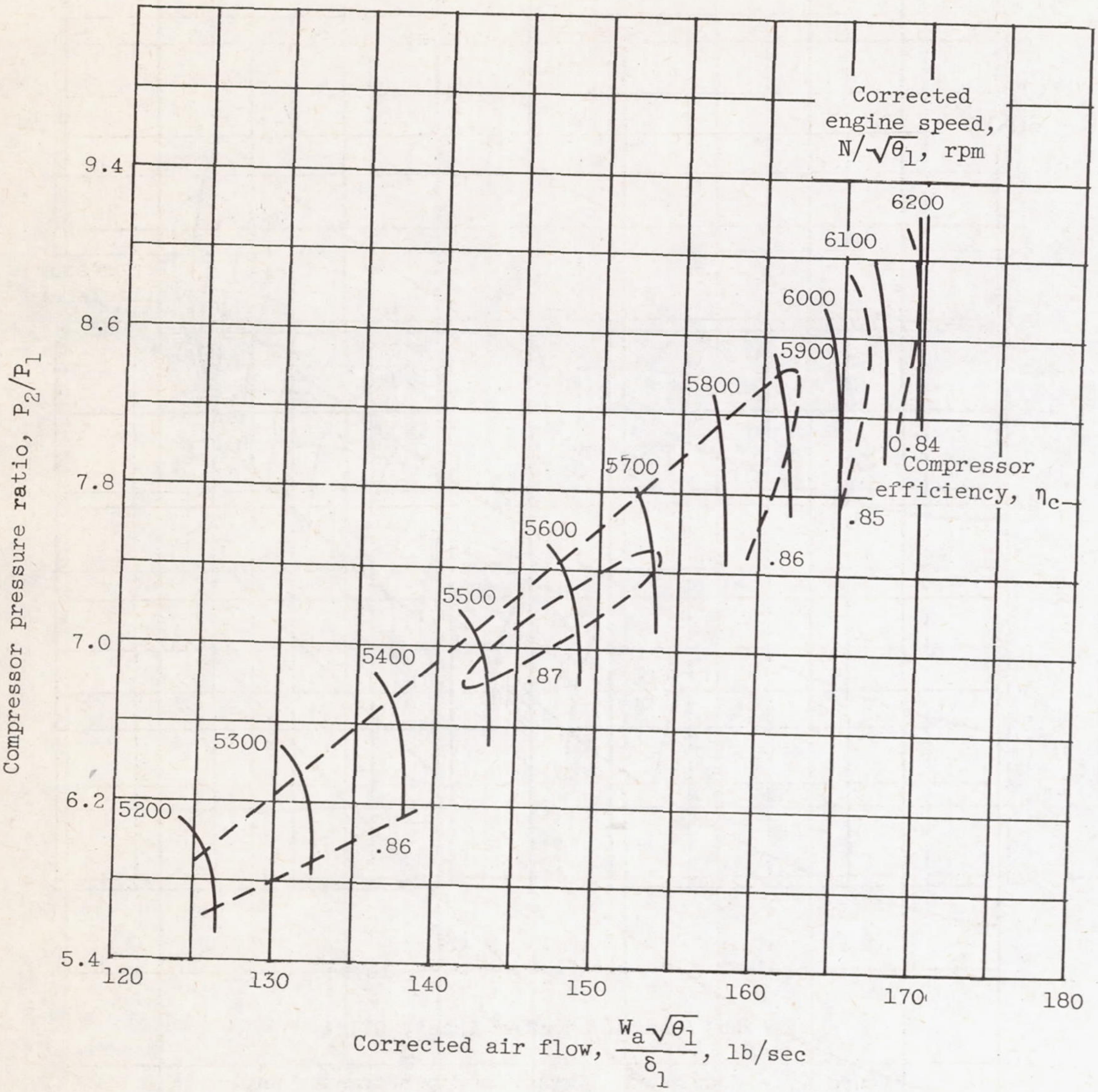
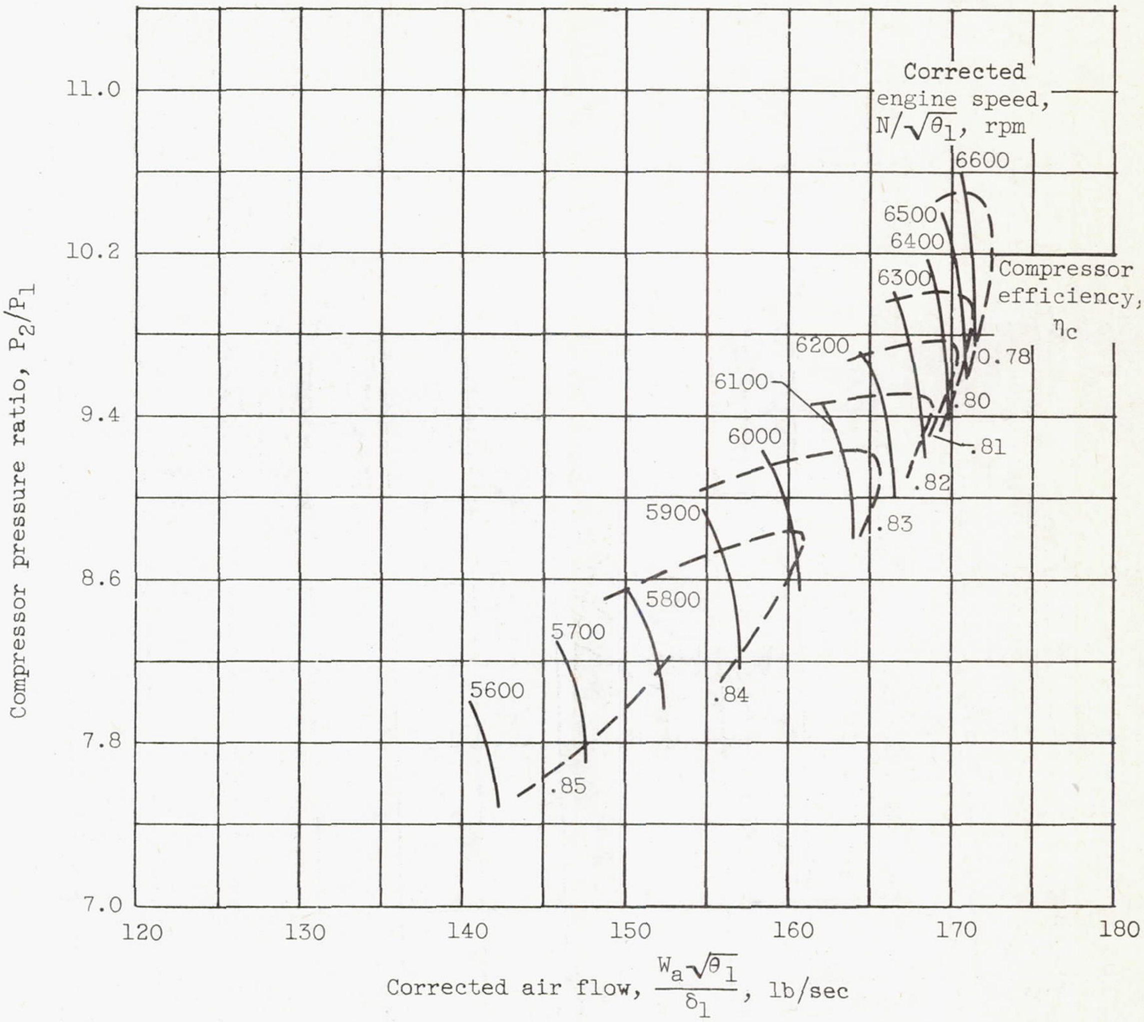


Figure 3. - Variation of Reynolds number index with true altitude and flight Mach number.



(a) Reynolds number index, 0.795.

Figure 4. - Compressor performance map.



(b) Reynolds number index, 0.164.

Figure 4. - Concluded. Compressor performance map.

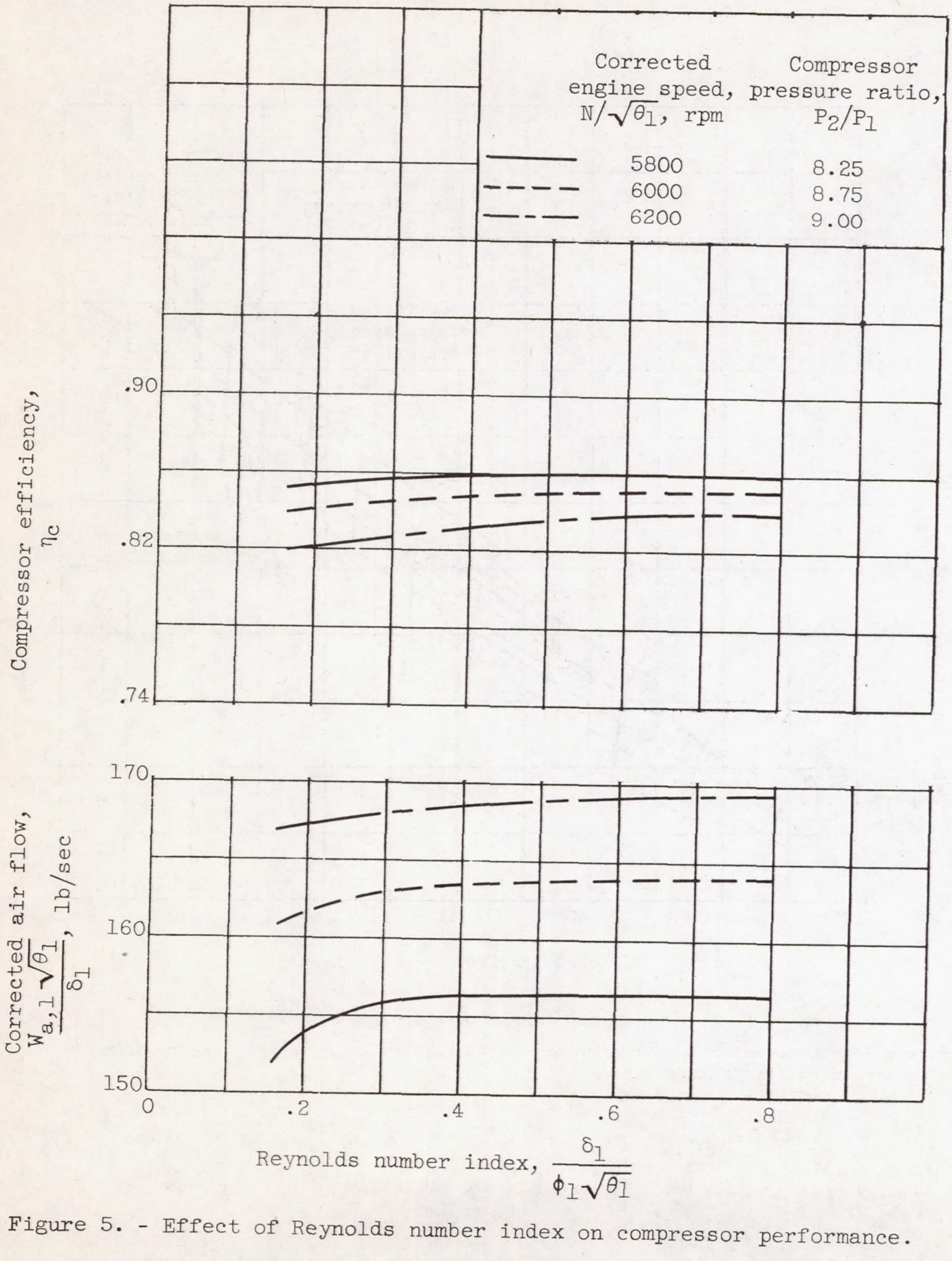
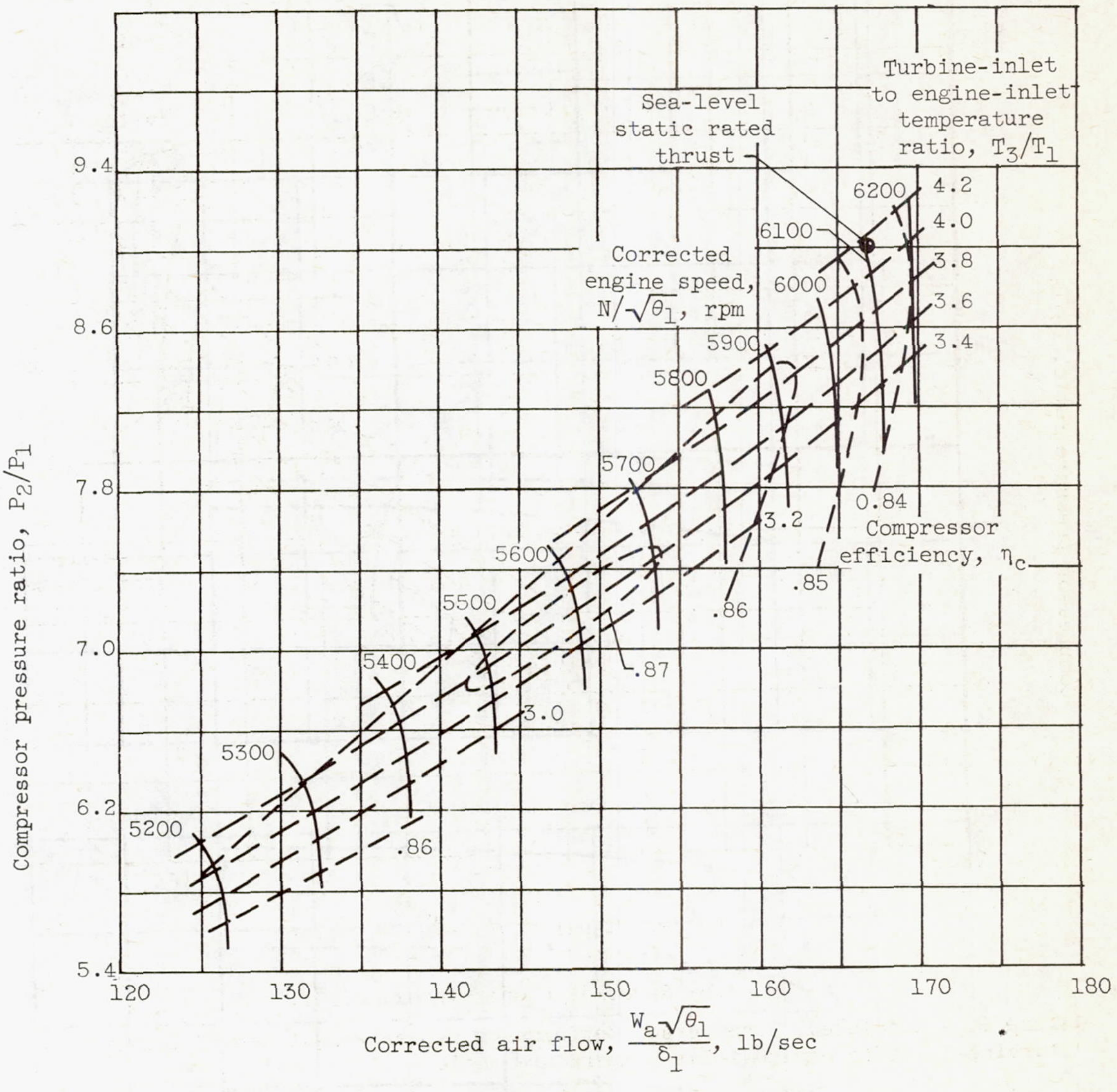
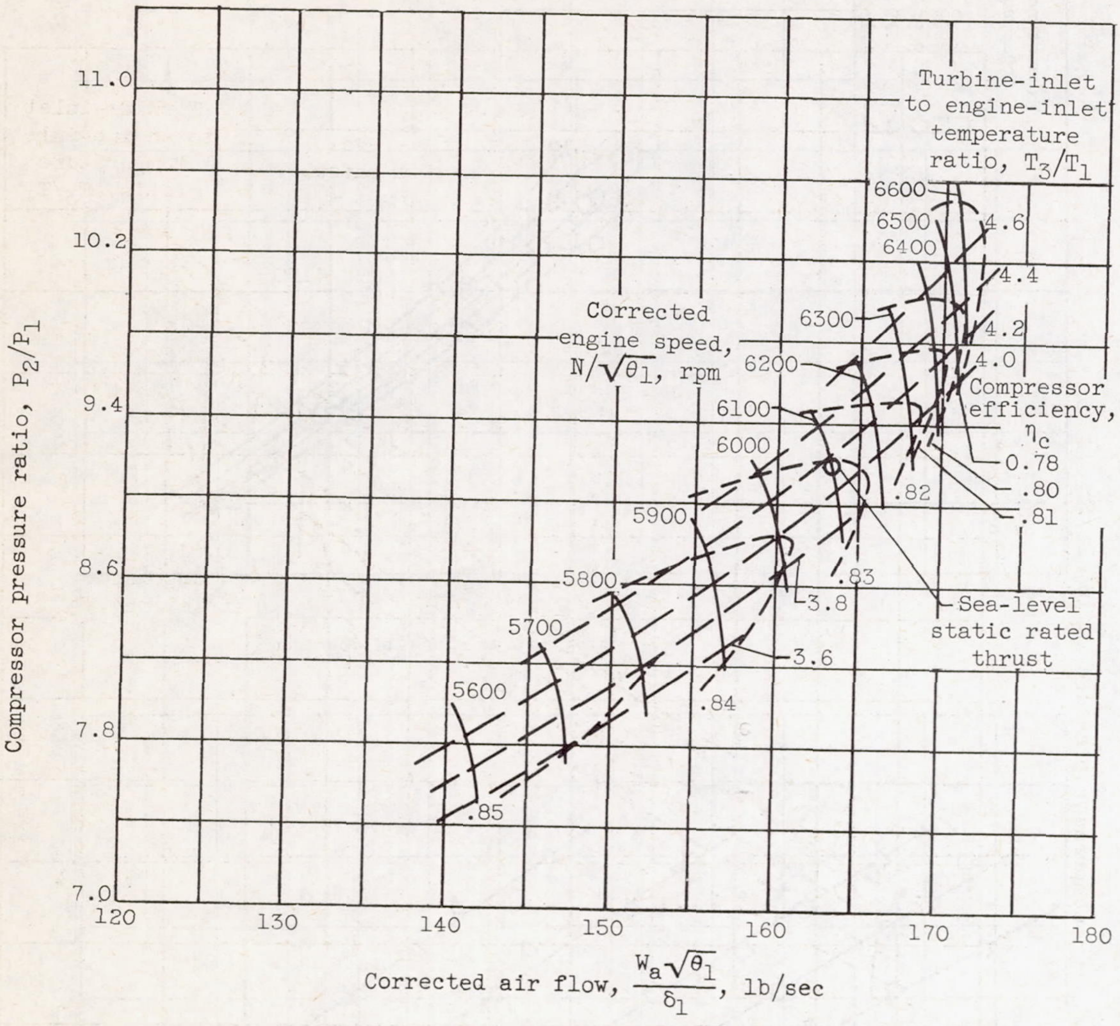


Figure 5. - Effect of Reynolds number index on compressor performance.



(a) Reynolds number index, 0.795.

Figure 6. - Compressor performance map showing lines of constant turbine-inlet to engine-inlet temperature ratio.



(b) Reynolds number index, 0.164.

Figure 6. - Concluded. Compressor performance map showing lines of constant turbine-inlet to engine-inlet temperature ratio.

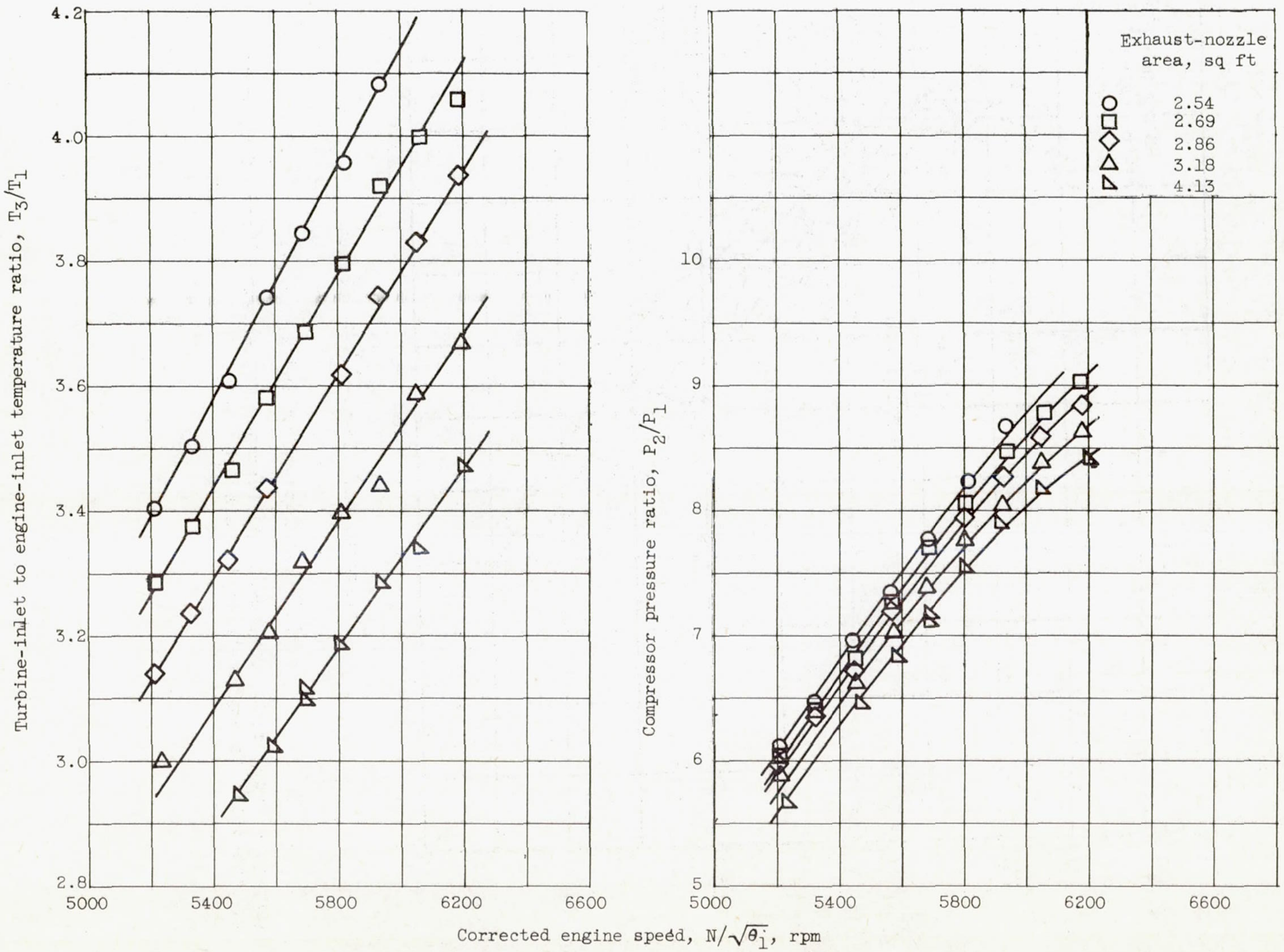


Figure 7. - Effect of exhaust-nozzle area and corrected engine speed on compressor ratio and turbine-inlet to engine-inlet temperature ratio. Reynolds number index, 0.795.

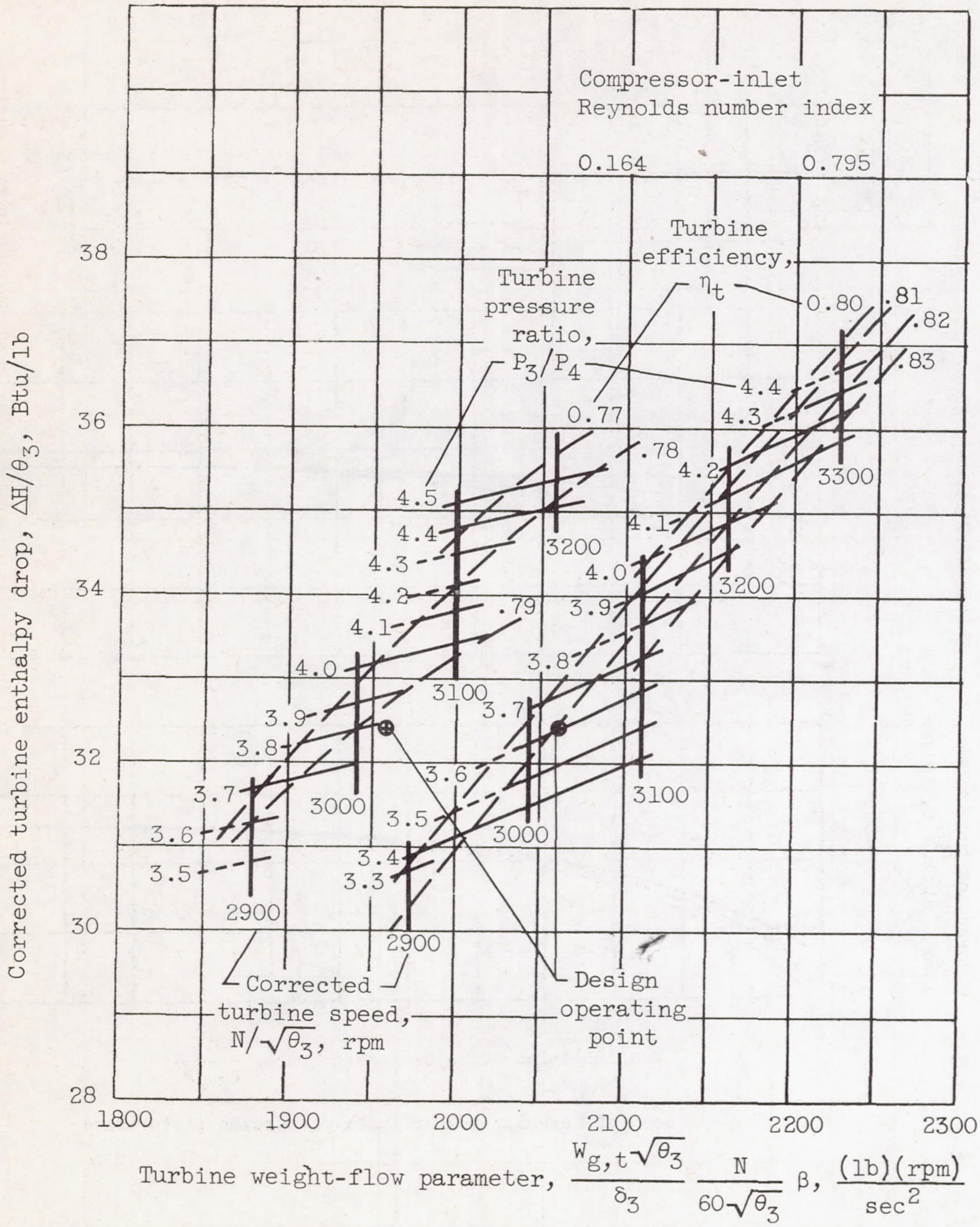


Figure 8. - Turbine performance maps.

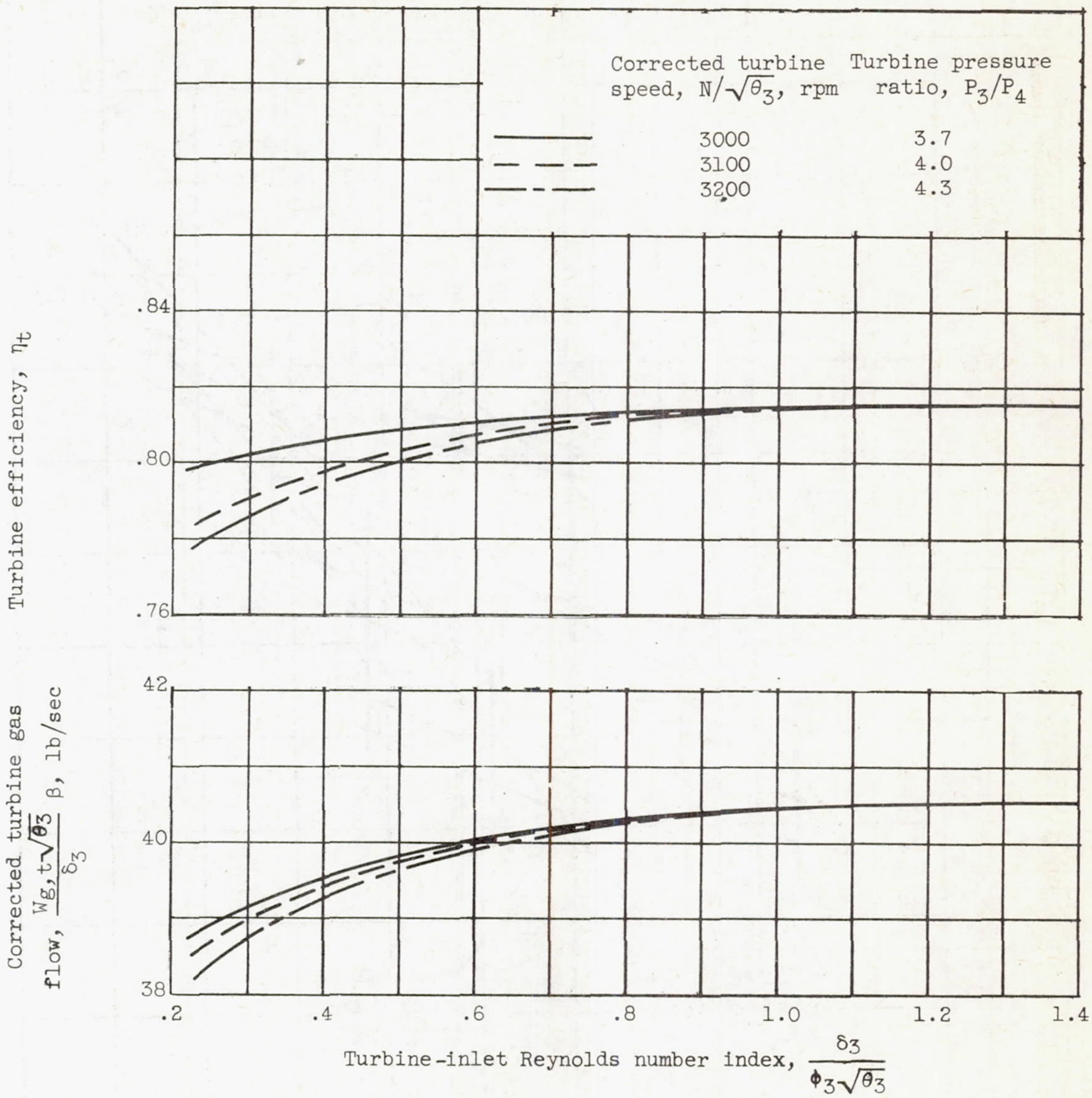


Figure 9. - Effect of Reynolds number index on turbine performance.

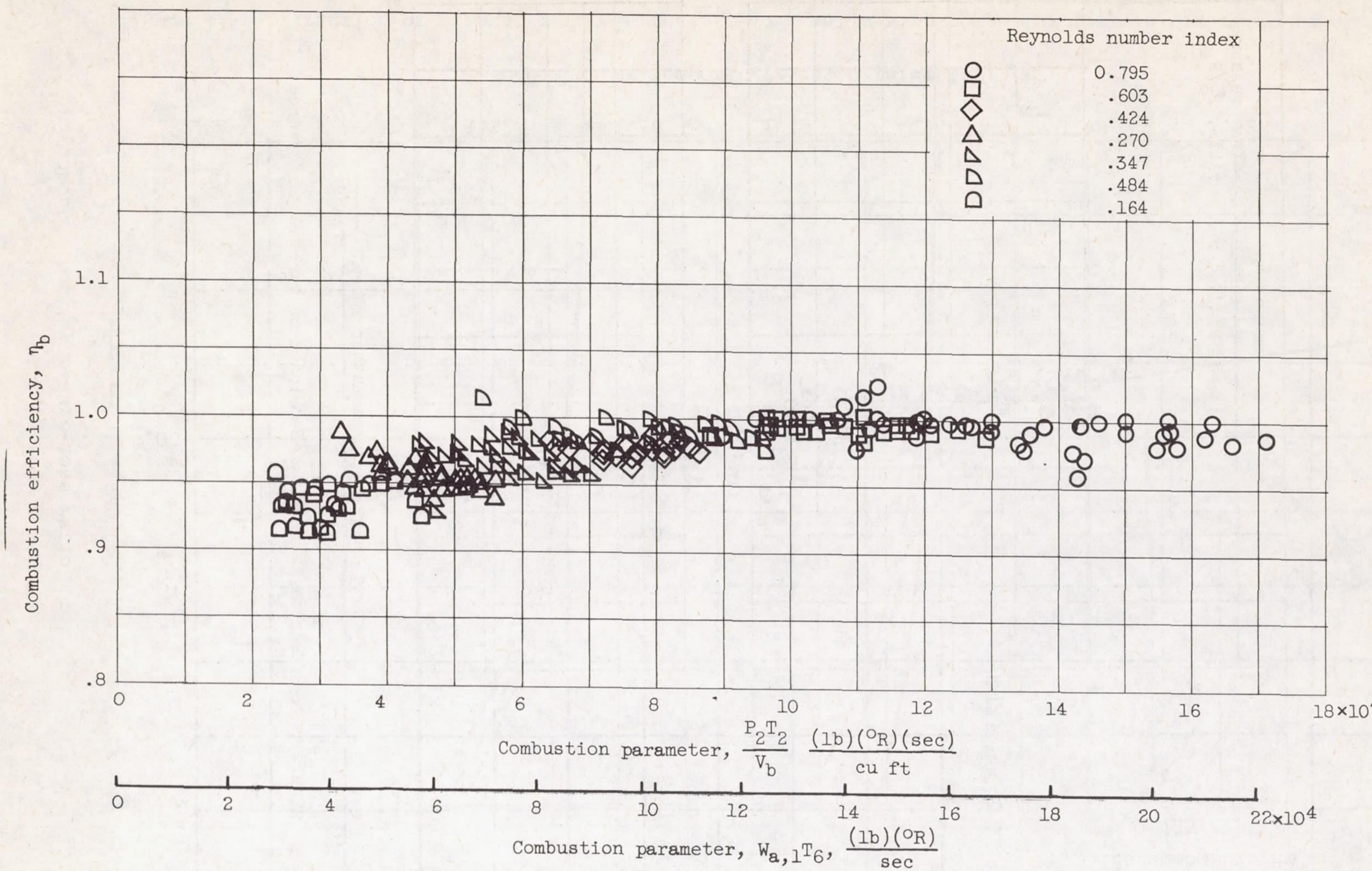


Figure 10. - Variation of combustion efficiency with combustion parameters.

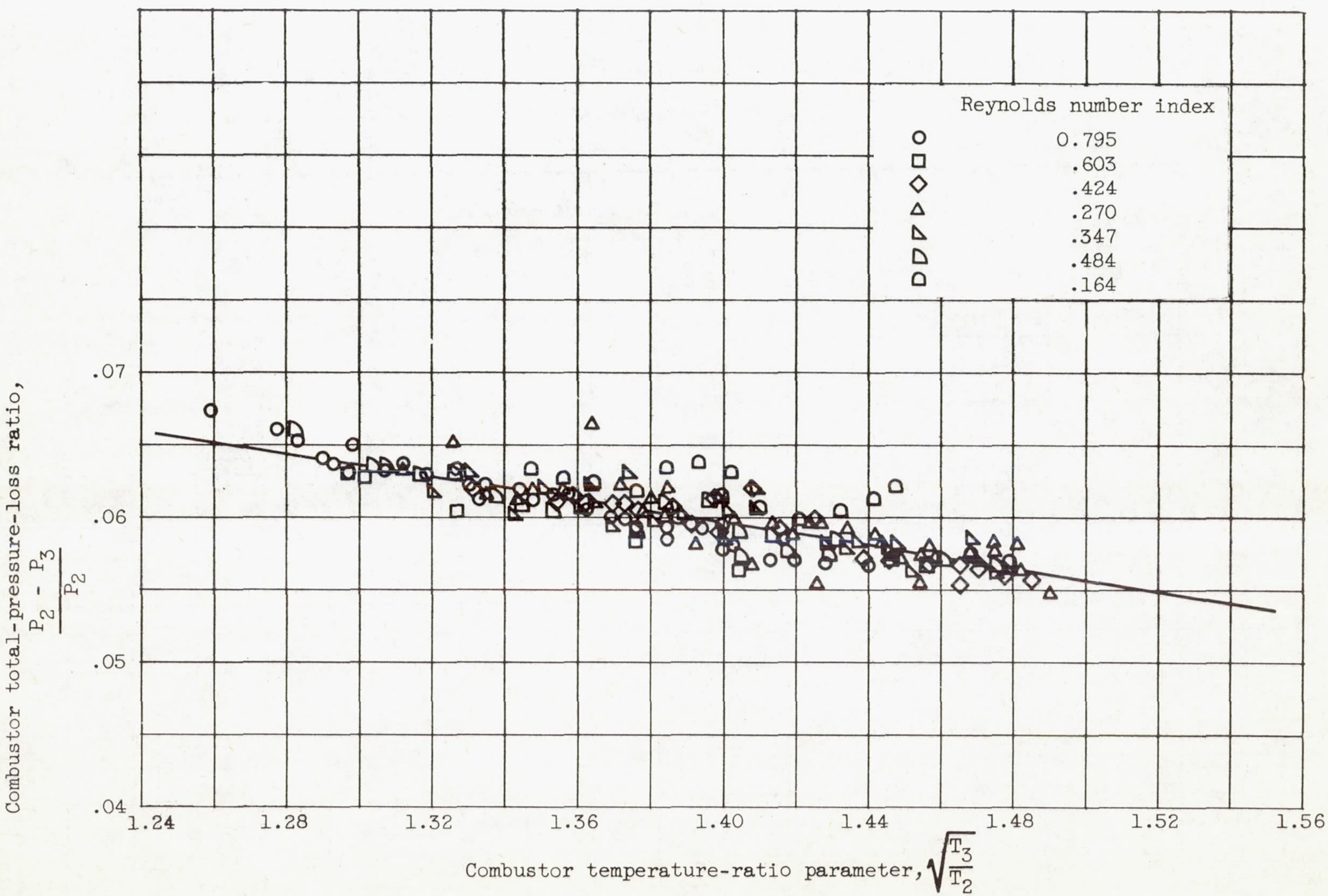


Figure 11. - Variation of combustor total-pressure-loss ratio with combustor temperature-ratio parameter.

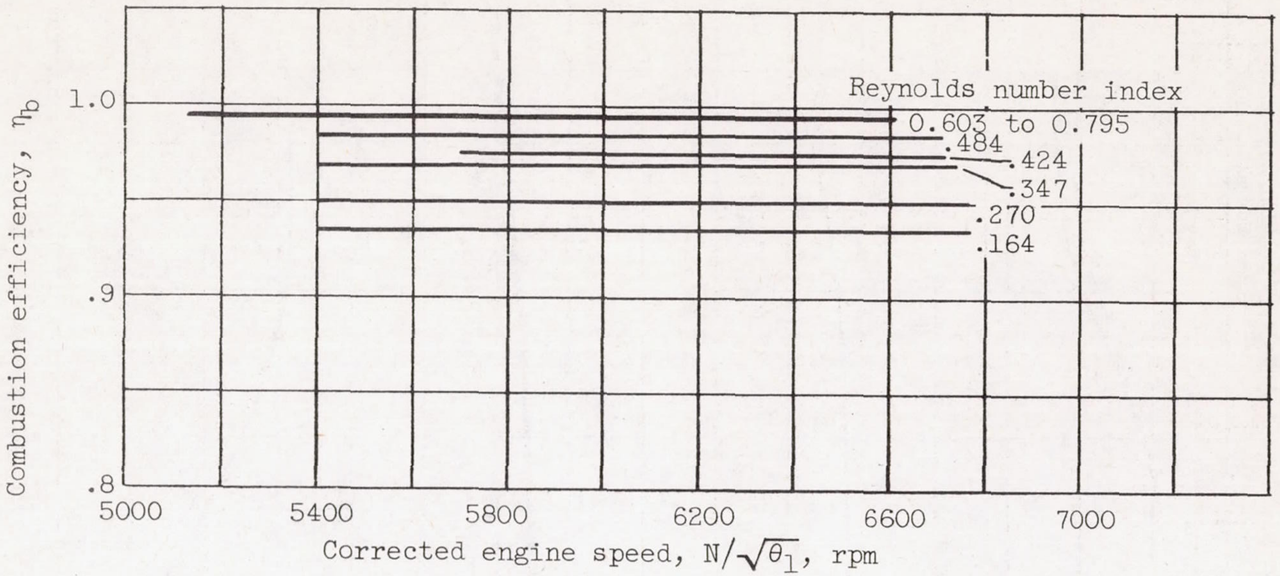
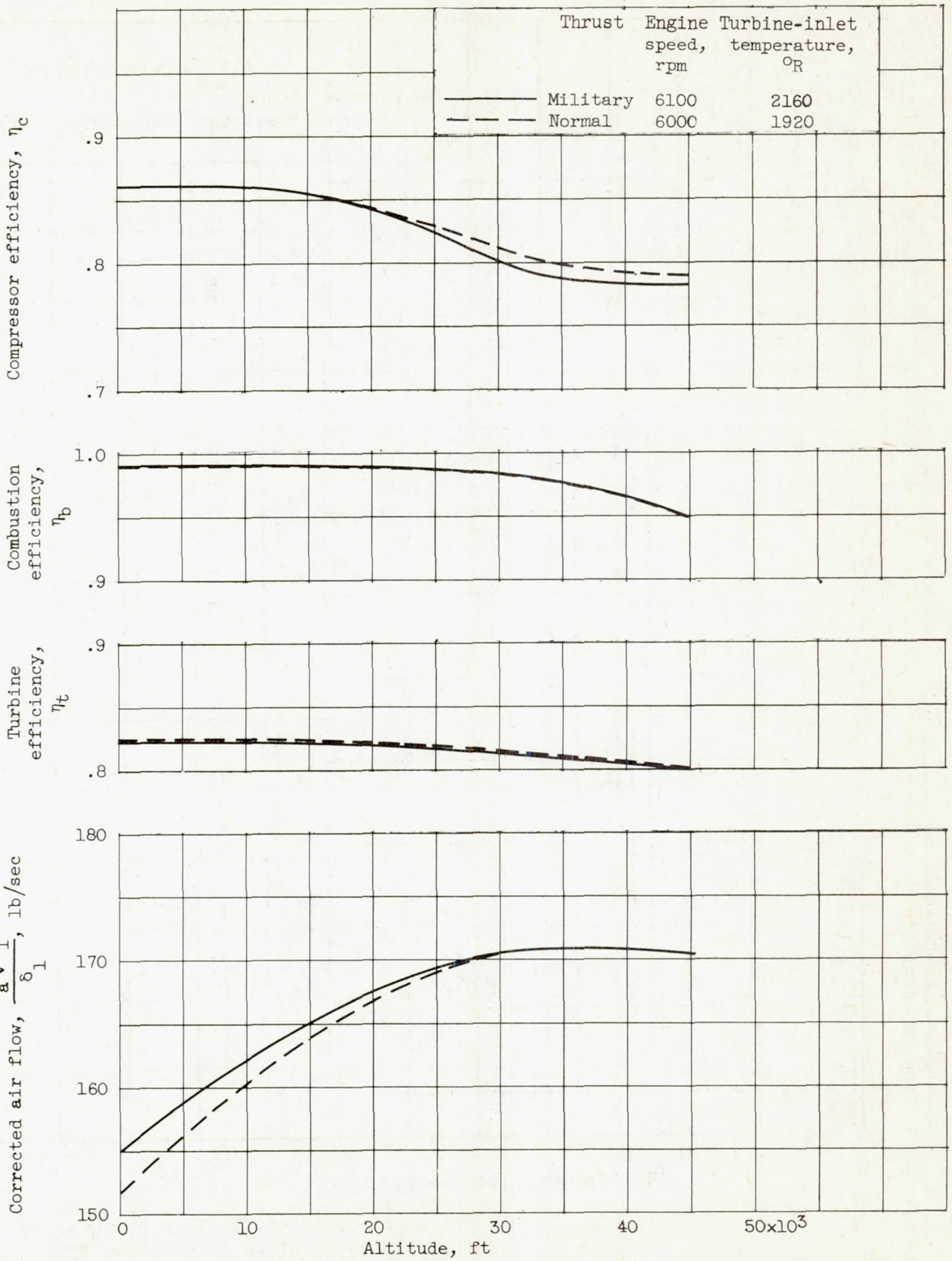
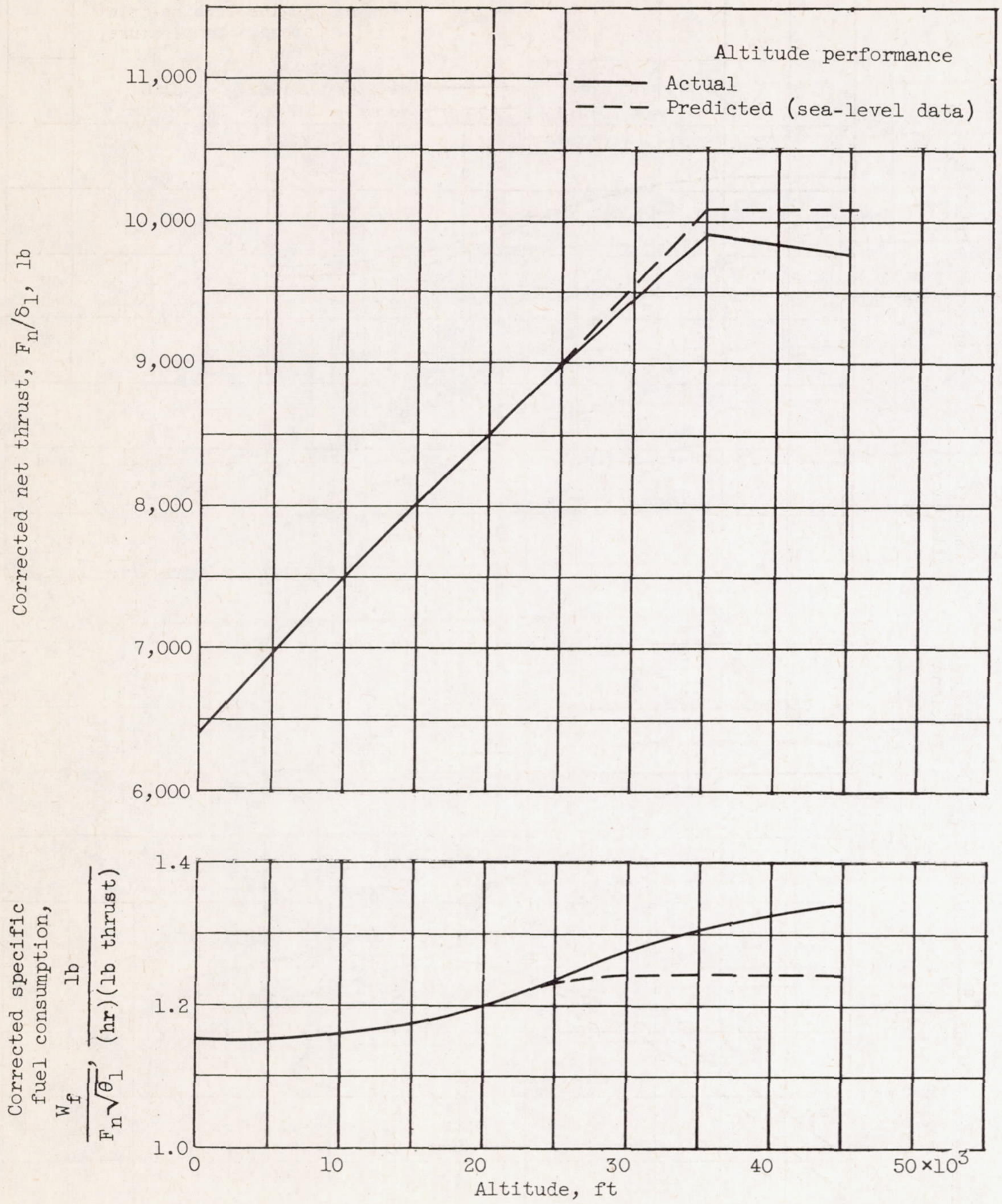


Figure 12. - Effect of Reynolds number index and corrected engine speed on combustion efficiency.



(a) Compressor, combustor, and turbine efficiencies and corrected air flow for two thrust conditions.

Figure 13. - Effects of altitude on engine performance. Flight Mach number, 0.80.



(b) Corrected net thrust and corrected specific fuel consumption at military thrust condition. Rated engine speed, 6100 rpm; rated turbine-inlet temperature, 2160° R.

Figure 13. - Concluded. Effects of altitude on engine performance. Flight Mach number, 0.80.