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RESEARCH MEMORANDUM

ALTITUDE-WIND-TUNNEL INVESTIGATION OF COMPRESSOR PERFORMANCE ON J47 TURBOJET ENGINE

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NATIONAL ADVISORY COMMITTEE
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RESEARCH MEMORANDUM

ALTITUDE-WIND-TUNNEL INVESTIGATION OF COMPRESSOR PERFORMANCE ON J47 TURBOJET ENGINE

By William R. Prince and Emmert T. Jansen

SUMMARY

An investigation has been conducted in the NACA Lewis altitude wind tunnel to determine the performance of a 12-stage axial-flow compressor operating as an integral part of the turbojet engine. Compressor-performance data were obtained while the turbojet engine was run over its full operable range of engine speeds at various simulated altitudes and flight Mach numbers. The use of three different exhaust-nozzle-outlet areas extended the range of compressor operation.

Increases in altitude from 5000 to 50,000 feet resulted in a decrease in compressor efficiency at all corrected air flows. The loss of compressor efficiency with increasing altitude is largely attributed to the effect of Reynolds number on compressor performance. The compressor operating lines shifted toward the high air-flow side of the region of peak efficiency as the altitude was increased. The maximum compressor efficiency obtained was approximately 87 percent and occurred at an altitude of 5000 feet and a corrected air flow of 80 pounds per second, which corresponds to a corrected engine speed of about 6300 rpm and a compressor pressure ratio of 3.5.

The velocity profile at the compressor outlet was symmetrical and was unaffected in general by variations in altitude, flight Mach number, exhaust-nozzle-outlet area, or engine speed.

INTRODUCTION

An investigation of a turbojet engine having a thrust rating of 5000 pounds at static sea-level conditions has been conducted in the NACA Lewis altitude wind tunnel. The over-all engine performance is summarized in reference 1.

The performance of a 12-stage axial-flow compressor operating as an integral part of the turbojet engine is reported herein. The range of operation of a compressor functioning as a component of a turbojet engine is restricted by the characteristics of the other components. Three exhaust-nozzle-outlet areas were therefore used in this investigation in order to extend the range of operation of the compressor. The engine was operated with each exhaust nozzle over a range of simulated flight conditions covering altitudes from 5000 to 50,000 feet and flight Mach numbers from 0.20 to 0.97. At each simulated flight condition, the engine was run over the full operable range of speed.

The effects of variations in altitude, flight Mach number, and exhaust-nozzle-outlet area on the compressor performance characteristics are graphically presented. A complete tabulation of the compressor performance data is also presented.

APPARATUS AND INSTRUMENTATION

Engine

The J47 turbojet engine used in this investigation (fig. 1) has a sea-level static rating of 5000 pounds thrust at an engine speed of 7900 rpm and a turbine-outlet temperature of 1735° R (1275° F). The main components of the standard engine include a 12-stage axial-flow compressor, eight cylindrical direct-flow combustors, a single-stage impulse turbine, a tail pipe, and a fixed-area exhaust nozzle. The standard exhaust nozzle used in this investigation has an outlet area of 280 square inches.

Compressor

The compressor has approximately a flow capacity of 94 pounds of air per second and a compressor pressure ratio of 5.1 when the engine is operating at rated sea-level conditions.

Air enters the engine through an annular inlet duct around the accessory housing and passes into the compressor through a single row of inlet guide vanes. The air is discharged from the compressor through two rows of guide vanes into the combustion chambers. Small amounts of air are extracted from the eighth and twelfth stages of the compressor to cool the turbine rotor and to balance the axial thrust of the compressor rotor.

A seal is provided on the rotor at the twelfth rotor stage of the compressor and restricts the leakage flow to about $1\frac{1}{2}$ pounds of air per second at rated sea-level conditions.

The length of the 12-stage compressor rotor (fig. 2) from the front face of the first-stage rotor disk to the rear face of the twelfth-stage rotor disk is approximately 27.7 inches and the blading has a constant outside diameter of 28.9 inches. The compressor stator is the split-casing type (fig. 3).

Installation

The engine was mounted on a wing section that spanned the 20-foot-diameter test section of the altitude wind tunnel (fig. 1). Compressor-inlet total pressures consistent with flight at high speeds were obtained by introducing dry refrigerated air from the tunnel make-up air system through a duct to the engine inlet. This air was throttled from approximately sea-level pressure to the desired pressure at the engine inlet while the static pressure in the tunnel test section was reduced to simulate the desired altitude. Inlet-air temperatures below -20° F, corresponding to high altitude and low flight Mach number, were not obtained. The inlet-air duct was connected to the engine by means of a frictionless slip joint, which permitted installation drag and engine thrust to be measured by the tunnel balance scales.

Three exhaust nozzles were used with the engine installation. The range of nozzle areas was limited from a minimum area fixed by maximum allowable turbine-outlet temperature at rated engine speed to a maximum area limited by the tail-pipe outlet area. The largest exhaust nozzle (342 sq in.) consisted of a straight pipe section 4-inches long clamped to the outlet of the standard tail pipe. The other two exhaust nozzles were uniformly tapered sections having lengths of 18 inches for the standard 280-square-inch nozzle and 12 inches for the 302-square-inch nozzle. These two nozzles were attached directly to the 4-inch straight-pipe section.

Instrumentation

Pressures and temperatures were measured by instrumentation installed at several stations throughout the engine (fig. 4). Compressor-rotor-stage static pressures were measured by wall orifices located midway between the rows of stator blades. The location of instrumentation for stations 1, 2, and 3 is shown in figures 5, 6, and 7, respectively.

SYMBOLS

The following symbols are used in the calculations:

A	area, square feet
a	stagnation speed of sound in air, feet per second
c_p	specific heat at constant pressure, Btu per pound per $^{\circ}R$
D	compressor rotor-blade-tip diameter, feet
g	acceleration due to gravity, 32.2 feet per second per second
H	total enthalpy, Btu per second
M	Mach number
N	engine speed, rpm
P	total pressure, pounds per square foot absolute
p	static pressure, pounds per square foot absolute
R	gas constant for air, 53.4 foot-pounds per pound per $^{\circ}F$
T	total temperature, $^{\circ}R$
T_i	indicated temperature, $^{\circ}R$
t	static temperature, $^{\circ}R$
U	rotor-tip speed, feet per second
V	velocity, feet per second
W_a	air flow, pounds per second
γ	ratio of specific heat at constant pressure to specific heat at constant volume
δ_1	ratio of absolute total pressure at engine inlet to absolute static pressure at NACA standard atmospheric sea-level conditions
θ_1	ratio of absolute total temperature at engine inlet to absolute static temperature at NACA standard atmospheric sea-level conditions

η_c	compressor efficiency, percent

Subscripts:

c	compressor
0	free-stream conditions
1	engine inlet
2	compressor inlet
2a	compressor stages
3	compressor outlet

The stations to which the numerical subscripts refer are shown in figure 4.

Generalizing parameters:

$N/\sqrt{\theta_1}$	corrected engine speed, rpm
$W_a(\sqrt{\theta_1}/\delta_1)$	corrected air flow, pounds per second

METHODS OF CALCULATION

In the calculation of desired parameters, arithmetic average values of temperature and pressure were used.

Flight Mach number. - Flight Mach number was calculated from the measured ram pressure ratio by the following relation, in which complete ram-pressure recovery at the engine inlet was assumed:

$$M_0 = \sqrt{\frac{2}{\gamma-1}\left[\left(\frac{P_1}{p_0}\right)^{\frac{\gamma-1}{\gamma}} -1\right]} \qquad (1)$$

Temperatures. - Static temperatures were determined from indicated temperatures with the following relation:

$$t = \frac{T_1}{1 + 0.85\left[\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}} -1\right]} \qquad (2)$$

Air flow. - Air flow through the compressor was calculated from pressures and temperatures measured at the engine inlet, station 1, by the equation

$$W_{a,1} = p_1 A_1 \sqrt{\frac{2\gamma g}{(\gamma-1)Rt_1}\left[\left(\frac{P_1}{p_1}\right)^{\frac{\gamma-1}{\gamma}} -1\right]} \qquad (3)$$

Air-flow values obtained from measurements at the engine-inlet station agreed within approximately 1 percent with those obtained from measurements at the exhaust nozzle.

Compressor efficiency. - Compressor efficiency was calculated in the following manner: The ideal total temperature T_3', which is the temperature the air would attain by an isentropic compression, is

$$T_3' = T_1 \left(\frac{P_3}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

The actual total temperature of the air T_3 is higher than T_3' because of losses in the compressor. These temperatures are related by the adiabatic efficiency, which is defined as

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

$$= \frac{W_a c_p \,(T_3'-T_1)}{W_a c_p \,(T_3-T_1)}$$

or substituting to eliminate T_3' gives

$$\eta_c = \frac{\left(\frac{P_3}{P_1}\right)^{\frac{\gamma-1}{\gamma}} -1}{\frac{T_3}{T_1} -1} \tag{4}$$

Compressor Mach number. - Compressor Mach number is defined as the ratio of the tip speed of the compressor rotor blade to the velocity of sound in air at the total temperature of the engine-inlet air. The equation used is

$$M_c = \frac{U}{a_1} = \frac{\pi DN}{60\sqrt{\gamma gRT_1}} \tag{5}$$

Compressor-outlet velocity. - Compressor-outlet velocity was determined by the equation

$$V_3 = \sqrt{\frac{2\gamma}{\gamma-1} gRt_3 \left[\left(\frac{P_3}{p_3}\right)^{\frac{\gamma-1}{\gamma}} -1\right]} \tag{6}$$

where P_3 is the average of the total pressures measured at each radial station. Average static pressures and static temperatures were used in equation (6).

RESULTS AND DISCUSSION

Method of Presentation

Compressor-performance data have been generalized to standard sea-level conditions by the use of correction factors δ_1 and θ_1.

A compressor operating line was obtained for each combination of altitude, flight Mach number, and exhaust-nozzle-outlet area. Three forms of the operating line are presented: (1) relation of compressor pressure ratio to corrected engine speed, (2) relation of corrected air flow to corrected engine speed, and (3) relation of compressor pressure ratio to corrected air flow. The characteristics of the compressor are shown by contours of constant efficiency and lines of constant corrected engine speed presented on plots of compressor pressure ratio as a function of corrected air flow. Data are presented to show the effect of altitude, flight Mach number, exhaust-nozzle-outlet area, and corrected engine speed on the velocity profiles at the compressor outlet and rotor-stage static-pressure ratios. A complete tabulation of compressor-performance data is presented in table I.

Compressor Operating Lines

Effect of altitude. - The effect of altitude on the compressor operating lines is shown in figure 8. At corrected engine speeds below 6000 rpm, the operating lines showing the relation of compressor pressure ratio to corrected engine speed generalized to a single curve (fig. 8(a)). Above 6000 rpm, an increase in altitude caused a shift in the operating line to higher pressure ratios such that at 7900 rpm an increase in altitude from 5000 to 50,000 feet resulted in a 3-percent increase in pressure ratio. This increase in pressure ratio at a constant corrected engine speed is a result of the decrease in compressor efficiency with increasing altitude largely due to the effect of Reynolds number on compressor performance. The operating lines showing the relation of corrected air flow to corrected engine speed shifted toward lower air flows with increasing altitude over the entire range of engine speeds (fig. 8(b)). The decrease in corrected air flow amounts to 3.5 percent at a corrected engine speed of 7900 rpm for an increase in altitude from 5000 to 50,000 feet; this loss in weight flow is likewise attributed to the Reynolds number effect on the compressor with increase in altitude. The characteristic shape of the air-flow curve (fig. 8(b)) as the engine approaches rated speed is a result of the air flow at the compressor inlet reaching a choked condition and thereby limiting the flow through the engine. The effect of altitude on the relation of compressor pressure ratio to corrected air flow is shown in figure 8(c).

Effect of flight Mach number. - The compressor pressure ratio decreased with an increase in flight Mach number (fig. 9(a)), the greatest shift taking place at corrected engine speeds below 6500 rpm. In general, increases in flight Mach number slightly increased the corrected air flow at all corrected engine speeds (fig. 9(b)). A change in flight Mach number from 0.20 to 0.97 at a corrected engine speed of 7900 rpm raised the corrected air flow approximately $1\frac{1}{2}$ pounds. A trend similar to that in figure 9(a) can be observed for the operating line based on corrected air flow (fig. 9(c)).

Effect of exhaust-nozzle-outlet area. - An increase in exhaust-nozzle-outlet area caused a drop in the compressor pressure ratio at any constant corrected engine speed (fig. 10(a)); however, no significant change in corrected air flow occurred for any given corrected engine speed over the range of nozzles investigated (fig. 10(b)). Increasing the exhaust-nozzle-outlet area resulted in a decrease in compressor pressure ratio at any constant corrected air flow (fig. 10(c)).

Compressor Efficiency

Effect of altitude. - An increase in altitude caused a decrease in compressor efficiency at all corrected air flows (fig. 11(a)). At rated engine speed of 7900 rpm, an increase in altitude from 5000 to 50,000 feet decreased the compressor efficiency from 79 to 72 percent. This loss of efficiency with increasing altitude is largely attributed to the Reynolds number effect on compressor performance (reference 2).

Effect of flight Mach number. - At constant corrected air flows less than 70 pounds per second, an increase in flight Mach number resulted in a loss of compressor efficiency (fig. 11(b)). Above a corrected air flow of 90 pounds per second, an increase in flight Mach number at constant corrected air flow indicated an increase in compressor efficiency.

Effect of exhaust-nozzle-outlet area. - The effect of nozzle area on compressor efficiency is shown for altitudes of 5000, 25,000, and 45,000 feet at a flight Mach number of 0.20 in figures 11(c), 11(d), and 11(e), respectively. At an altitude of 5000 feet, the medium nozzle area of 302 square inches gave the highest compressor efficiencies below a corrected air flow of 90 pounds per second (fig. 11(c)). At corrected air flows greater than 90 pounds per second, an increase in nozzle area resulted in a drop in compressor efficiency. The general trend was the same at 25,000 feet except that the reversal of the order of the efficiency curves occurred at a corrected air flow of approximately 80 pounds per second (fig. 11(d)). At 45,000 feet, the standard 280-square-inch nozzle area gave the highest compressor efficiencies for all corrected air flows; and, at a constant corrected air flow, any increase in nozzle area caused a drop in compressor efficiency (fig. 11(e)).

In general, the change in efficiency between corrected air flows of 60 and 90 pounds per second was relatively small for all the conditions investigated, which gives the compressor a wide range of operation at close to maximum efficiency (fig. 11).

Characteristic Curves

Compressor-performance characteristics for three altitudes of 5000, 25,000, and 45,000 feet at a flight Mach number of 0.20 are presented in figures 12 and 13. These cross plots were constructed using figures 8 and 11 and comparable curves of the data for the other two nozzle configurations. Inasmuch as the range in compressor pressure ratio was small, because of the limited nozzle-area variation, only the operating line for the standard nozzle has been superimposed on figures 12 and 13. The length of the constant speed lines is indicative of the range of operation of the compressor with the nozzle-area variation used in this investigation. At a given compressor presssure ratio and a given corrected engine speed, an increase in altitude resulted in a decrease in corrected air flow (fig. 12). The operating lines and the lines indicating regions of maximum efficiency shift to higher compressor pressure ratios and lower corrected air flows with an increase in altitude. The shift of the region of maximum efficiency is greater, which results in the compressor operating lines shifting toward the high air-flow side of the region of maximum efficiency (fig. 12). The maximum compressor efficiency was approximately 87 percent and occurred at a corrected air flow of 80 pounds per second and an altitude of 5000 feet (fig. 13(a)). This maximum efficiency occurred at a compressor pressure ratio of approximately 3.5 and at a corrected engine speed of about 6300 rpm. A change in altitude from 5000 to 45,000 feet caused a decrease in maximum compressor efficiency for the range of nozzle areas investigated from 87 to about 80 percent (fig. 13).

The velocity profile at the compressor outlet (fig. 14) was symmetrical with no indication of reversal of flow at the blade roots. The data showed no general effect on the velocity profile or average velocities with variations in altitude (fig. 14(a)), flight Mach number (fig. 14(b)), exhaust-nozzle-outlet area (fig. 14(c)), or corrected engine speed (fig. 14(d)).

The compressor-rotor-stage static-pressure-ratio profiles for variations in altitude, flight Mach number, exhaust-nozzle-outlet area, and corrected engine speed are presented in figure 15.

SUMMARY OF RESULTS

From an investigation of a turbojet engine in the NACA Lewis altitude wind tunnel over a range of simulated altitudes and flight Mach numbers, the following results relating to the performance of the compressor were obtained:

1. Increases in altitude from 5000 to 50,000 feet resulted in a decrease in compressor efficiency at all corrected air flows. The loss of compressor efficiency with increasing altitude is largely attributed to the Reynolds number effect on compressor performance.

2. The change in efficiency between corrected air flows of 60 and 90 pounds per second is relatively small for all conditions investigated; as a result, the compressor may be operated over a wide range of engine speeds at close to maximum efficiency.

3. The compressor operating lines shifted toward the high air-flow side of the region of peak efficiency as the altitude was increased.

4. The maximum compressor efficiency obtained was approximately 87 percent and occurred at an altitude of 5000 feet and a corrected air flow of 80 pounds per second, which corresponds to a corrected engine speed of about 6300 rpm and a compressor pressure ratio of 3.5.

5. The velocity profile at the compressor outlet was symmetrical and was unaffected in general by variations in altitude, flight Mach number, exhaust-nozzle-outlet area, or engine speed.

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REFERENCES

1. Conrad, E. William, and Sobolewski, Adam E.: Altitude-Wind-Tunnel Investigation of J47 Turbojet-Engine Performance. NACA RM E9G09.

2. Wallner, Lewis E., and Fleming, William A.: Reynolds Number Effect on Axial-Flow Compressor Performance. NACA RM E9G11.

TABLE I - COMPRESSOR PERFORMANCE

Run	Altitude (ft)	Exhaust-nozzle-outlet area, (sq in.)	Flight Mach number, M_0	Ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Tunnel static pressure, p_0 (lb/sq ft abs.)	Engine-inlet total temperature, T_1 (°R)	Engine-inlet total pressure, P_1 (lb/sq ft abs.)	Engine-inlet static pressure, p_1 (lb/sq ft abs.)	Compressor-inlet total pressure, P_2 (lb/sq ft abs.)	Compressor-inlet static pressure, p_2 (lb/sq ft abs.)	Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)					
												1	2	3	4	5	6
1	5,000	280	0.230	1.038	7895	1740	512	1806	1618	1790	1411	----	1254	1480	1733	2113	2507
2	5,000	280	.225	1.037	7692	1756	514	1821	1634	1803	1429	1094	1320	1552	1833	2200	2594
3	5,000	280	.230	1.039	7500	1740	512	1808	1624	1784	1425	1128	1346	1606	1895	2261	2648
4	5,000	280	.220	1.036	6993	1742	513	1805	1638	1788	1469	1291	1538	1812	2115	2488	2861
5	5,000	280	.215	1.034	6459	1742	512	1802	1666	----	1538	1446	1707	1981	2263	2615	2953
6	5,000	280	.210	1.033	5944	1744	511	1802	1692	1800	1605	1575	1807	2054	2314	2610	2920
7	5,000	280	.210	1.033	5024	1740	510	1797	1737	1800	1689	1705	1888	2064	2247	2444	2669
8	5,000	280	.215	1.034	4091	1749	509	1809	1779	1810	1755	1763	1890	1988	2101	2235	2361
9	5,000	280	.210	1.032	3147	1745	509	1800	1785	1806	1774	1780	1844	1907	1963	2041	2118
10	5,000	280	.210	1.032	2046	1738	509	1793	1786	1800	1782	1787	1815	1830	1858	1893	1921
11	5,000	302	.220	1.036	7895	1740	496	1802	1616	1783	1405	1085	1247	1444	1677	2008	2352
12	5,000	302	.215	1.033	7692	1745	497	1803	1617	1785	1410	----	1266	1492	1745	2083	2428
13	5,000	302	.220	1.036	7500	1753	498	1816	1632	1792	1428	----	1331	1563	1683	2189	2541
14	5,000	302	.215	1.033	6993	1747	499	1804	1634	1787	1456	1247	1487	1754	2050	2402	2768
15	5,000	302	.206	1.030	6459	1745	501	1798	1655	1789	1521	1407	1653	1928	2217	2562	2907
16	5,000	302	.206	1.030	5944	1745	501	1797	1687	1795	1588	1548	1787	2034	2294	2604	2914
17	5,000	302	.206	1.030	5024	1754	501	1806	1743	1814	1692	1712	1895	2078	2275	2479	2704
18	5,000	302	.198	1.029	4091	1748	499	1798	1764	1810	1740	1748	1875	1980	2100	2241	2375
19	5,000	302	.196	1.028	3147	1745	498	1793	1777	1812	1766	1773	1837	1900	1963	2048	2118
20	5,000	302	.198	1.029	2046	1748	497	1798	1792	1817	1786	1797	1818	1840	1868	1903	1931
21	5,000	342	.215	1.034	7895	1752	495	1812	1626	1768	1416	1069	1259	1456	1675	2005	2329
22	5,000	342	.210	1.032	7692	1745	496	1801	1618	1757	1406	1041	1259	1470	1717	2055	2379
23	5,000	342	.210	1.030	7500	1747	496	1800	1619	1759	1417	----	----	----	----	----	----
24	5,000	342	.210	1.030	6993	1753	498	1806	1638	1768	1460	1253	1485	1753	2035	2394	2739
25	5,000	342	.195	1.027	6459	1753	497	1801	1660	1768	1523	1401	1661	1922	2211	2541	2879
26	5,000	342	.210	1.030	5944	1741	497	1793	1682	1765	1581	1523	1769	2016	2269	2586	2881
27	5,000	342	.200	1.029	5024	1753	497	1803	1740	1785	1688	1704	1894	2070	2267	2478	2703
28	5,000	342	.200	1.029	4091	1744	498	1795	1762	1781	1737	1751	1878	1983	2103	2244	2378
29	5,000	342	.200	1.029	3147	1744	496	1795	1780	1785	1768	1765	1843	1892	1969	2047	2117
30	5,000	342	.200	1.029	2046	1742	495	1793	1787	1784	1783	1784	1812	1834	1862	1897	1918
38	15,000	302	.220	1.035	7895	1186	478	1228	1102	1218	955	686	848	982	1123	1341	1580
39	15,000	302	.215	1.034	7692	1186	478	1226	1101	1217	956	693	855	989	1151	1376	1608
40	15,000	302	.215	1.034	7500	1190	476	1230	1107	1201	964	718	873	1028	1190	1429	1662
41	15,000	302	.210	1.033	6993	1191	476	1230	1112	1223	981	804	966	1149	1339	1578	1818
42	15,000	302	.205	1.030	6459	1189	475	1225	1124	1224	1022	929	1097	1281	1478	1717	1956
43	15,000	302	.198	1.029	5944	1190	474	1225	1144	1229	1082	1028	1204	1373	1556	1774	1993
44	15,000	302	.197	1.028	5024	1188	475	1221	1176	1234	1138	1153	1287	1413	1547	1695	1850
45	15,000	302	.198	1.029	4091	1186	470	1220	1197	1238	1178	1193	1285	1355	1446	1545	1637
46	15,000	302	.205	1.030	3147	1183	472	1218	1206	1237	1198	1204	1253	1296	1338	1394	1451
47	15,000	342	.210	1.033	7895	1183	475	1222	1097	1190	951	669	838	965	1106	1310	1542
48	15,000	342	.210	1.033	7692	1187	477	1226	1103	1195	957	694	863	997	1152	1363	1595
49	15,000	342	.210	1.033	7500	1193	478	1232	1110	1202	966	721	883	1031	1200	1425	1658
50	15,000	342	.205	1.030	6993	1190	472	1226	1109	1198	979	810	972	1141	1331	1570	1802
51	15,000	342	.200	1.029	6459	1187	479	1221	1121	1197	1019	927	1103	1279	1469	1701	1933
52	15,000	342	.198	1.028	5944	1188	479	1221	1143	1203	1069	1026	1195	1371	1547	1758	1969
53	15,000	342	.198	1.028	5024	1188	481	1221	1176	1209	1137	1146	1272	1406	1533	1681	1836
54	15,000	342	.200	1.029	4091	1190	479	1224	1202	1217	1183	1190	1274	1359	1443	1542	1634
55	15,000	342	.200	1.029	3147	1190	478	1225	1213	1220	1205	1218	1267	1303	1352	1408	1465
56	15,000	342	.200	1.029	2046	1186	477	1220	1215	1217	1212	1214	1235	1256	1270	1292	1313
57	25,000	280	.225	1.037	7692	777	452	806	723	793	626	460	559	657	749	960	1115
58	25,000	280	.225	1.037	7500	774	455	803	721	791	626	471	570	661	760	943	1105
59	25,000	280	.220	1.036	6993	777	456	805	726	793	636	524	622	742	869	1030	1199
60	25,000	280	.210	1.033	6459	779	455	805	735	794	662	596	709	828	962	1124	1293
61	25,000	280	.210	1.033	5944	778	456	804	748	793	695	658	778	898	1024	1165	1320
62	25,000	280	.205	1.031	5024	778	455	802	770	795	744	750	841	933	1024	1123	1229
63	25,000	280	.205	1.030	4091	777	456	800	783	796	771	784	840	890	947	1016	1087
64	25,000	280	.205	1.030	3147	774	456	797	789	793	784	788	823	844	873	915	950

DATA FOR TURBOJET ENGINE

Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)						Straightening-vane static pressure, p_{2a} (lb/sq ft abs.)	Compressor-outlet total temperature, T_3 (°R)	Compressor-outlet total pressure, P_3 (lb/sq ft abs.)	Compressor-outlet static pressure, p_3 (lb/sq ft abs.)	Compressor pressure ratio, P_3/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$, (rpm)	Compressor Mach number, M_c	Air flow, $W_{a,1}$ (lb/sec)	Corrected air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$, (lb/sec)	Compressor efficiency, η_c, (percent)	Run
7	8	9	10	11	12											
3035	3859	4711	5950	6879	7872	8808	902	9339	9066	5.171	7950	0.896	81.08	94.37	78.8	1
3058	3847	4586	5755	6585	7677	8585	885	9095	8794	4.995	7730	.871	81.07	93.73	80.9	2
3092	3838	4542	5570	6400	7428	8308	873	8759	8458	4.845	7553	.851	80.28	93.27	80.9	3
3291	3938	4558	5382	6107	6888	7585	837	7980	7710	4.421	7035	.793	76.94	89.64	83.9	4
3333	3889	4389	5016	5551	6093	6593	798	6946	6703	3.855	6504	.733	70.23	81.88	84.3	5
3229	3673	4060	4525	4898	5236	5567	755	5874	5674	3.260	5992	.675	63.66	74.14	84.2	6
2866	3155	3373	3599	3760	3866	4007	684	4215	4082	2.346	5069	.571	48.05	56.10	80.9	7
2474	2629	2749	2847	2897	2875	2946	622	3066	2983	1.695	4132	.466	34.21	39.63	73.4	8
2174	2259	2308	2350	2350	2315	2350	574	2419	2372	1.344	3178	.358	23.73	27.63	69.1	9
1935	1970	1984	1998	1984	1949	1963	532	1993	1974	1.112	2066	.233	16.42	19.18	68.1	10
2754	3493	4225	5366	6288	7442	8414	869	8928	8634	4.954	8077	.910	81.86	93.94	77.2	11
2822	3519	4230	5251	6166	7229	8194	853	8637	8353	4.790	7861	.886	81.82	93.99	78.9	12
2943	3619	4301	5238	6132	7103	7997	841	8440	8149	4.648	7658	.863	81.83	93.37	80.1	13
3169	3796	4394	5183	5915	6668	7358	808	7770	7499	4.307	7133	.804	78.55	90.33	83.7	14
3273	3808	4315	4927	5469	5997	6497	770	6865	6621	3.818	6575	.741	72.30	83.60	87.0	15
3216	3667	4054	4512	4885	5202	5533	734	5867	5656	3.265	6051	.682	64.11	74.18	86.6	16
2909	3197	3422	3648	3817	3908	4049	668	4278	4130	2.369	5114	.576	49.38	56.85	83.9	17
2494	2663	2776	2881	2924	2896	2959	612	3093	3001	1.720	4173	.470	36.38	41.98	74.1	18
2189	2273	2322	2365	2365	2329	2350	562	2427	2379	1.354	3213	.362	25.40	29.35	70.4	19
1952	1987	2001	2023	2001	1973	1973	525	2012	1992	1.119	2091	.236	15.06	17.35	58.1	20
2688	3336	4026	5019	5969	7025	8011	855	8448	8178	4.662	8084	.911	82.17	93.73	76.1	21
2738	3378	4040	4976	5877	6857	7785	839	8237	7937	4.573	7869	.887	81.30	93.38	78.8	22
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3119	3710	4287	5027	5709	6406	7061	795	7481	7204	4.142	7140	.805	78.42	90.02	84.1	24
3231	3745	4231	4815	5329	5808	6266	764	6653	6406	3.693	6601	.744	72.30	83.12	84.3	25
3184	3628	4001	4444	4789	5092	5395	727	5738	5531	3.200	6075	.685	64.61	74.60	85.3	26
2901	3189	3414	3640	3788	3851	3992	664	4227	4078	2.343	5135	.579	49.49	56.85	82.1	27
2490	2659	2772	2863	2906	2863	2927	606	3060	2971	1.705	4177	.471	36.37	42.00	76.0	28
2180	2272	2321	2356	2349	2293	2321	561	2397	2342	1.335	3219	.363	23.97	27.63	65.7	29
1939	1981	1988	1988	1974	1946	1946	519	1982	1962	1.105	2095	.236	15.05	17.34	59.8	30
1890	2411	2981	3819	4495	5241	5882	857	6274	6086	5.109	8227	.927	56.71	93.77	74.9	38
1883	2376	2869	3615	4248	5023	5678	837	6018	5811	4.909	8015	.903	56.66	93.86	76.7	39
1929	2408	2880	3570	4196	4921	5583	821	5889	5687	4.788	7830	.882	56.30	92.76	78.0	40
2099	2543	2972	3535	4084	4662	5190	787	5465	5279	4.443	7301	.823	55.33	91.16	81.4	41
2217	2604	2970	3414	3836	4251	4632	751	4891	4718	3.993	6750	.761	51.61	85.29	83.6	42
2211	2542	2830	3168	3464	3724	3985	712	4217	4073	3.442	6217	.701	46.65	77.02	84.5	43
2005	2223	2385	2561	2695	2772	2878	646	3043	2938	2.492	5250	.592	35.04	58.11	82.9	44
1728	1848	1932	2017	2052	2038	2087	580	2188	2126	1.793	4300	.485	25.43	41.96	77.6	45
1493	1556	1598	1627	1627	1598	1619	535	1675	1641	1.375	3301	.372	18.37	30.42	71.5	46
1781	2225	2704	3415	4091	4872	5541	843	5893	5689	4.822	8250	.930	56.55	93.72	73.3	47
1835	2271	2729	3376	4024	4742	5397	828	5711	5503	4.658	8023	.904	56.24	93.07	75.1	48
1904	2333	2784	3397	4002	4664	5283	814	5589	5414	4.537	7815	.881	56.05	92.41	77.0	49
2063	2485	2894	3408	3914	4450	4935	776	5225	5034	4.262	7336	.827	55.37	91.11	79.8	50
2187	2553	2898	3306	3686	4052	4397	747	4657	4489	3.814	6724	.758	50.93	84.78	83.4	51
2181	2497	2765	3075	3328	3560	3793	712	4023	3879	3.295	6188	.697	45.43	75.63	83.6	52
1984	2188	2343	2504	2624	2695	2786	650	2952	2849	2.418	5220	.588	34.87	58.16	81.8	53
1711	1838	1915	1986	2014	2000	2042	590	2135	2075	1.744	4259	.480	24.56	40.79	74.4	54
1500	1570	1605	1626	1626	1598	1612	542	1667	1632	1.361	3279	.370	18.37	30.44	68.9	55
1327	1355	1362	1369	1362	1334	1334	502	1362	1352	1.116	2134	.241	11.56	19.22	60.9	56
1502	1820	2431	2840	3354	3741	4177	846	4451	4327	5.522	8238	.928	38.38	94.07	72.3	57
1358	1717	2140	2661	3125	3534	3942	819	4188	4064	5.215	8010	.903	38.02	93.80	75.6	58
1397	1720	2044	2467	2840	3297	3677	779	3873	3734	4.811	7462	.841	37.39	92.13	80.1	59
1483	1772	2039	2377	2680	3078	3320	742	3485	3368	4.329	6898	.777	35.39	87.12	82.5	60
1482	1721	1926	2172	2397	2622	2827	703	2976	2876	3.701	6342	.715	31.96	78.84	83.8	61
1334	1496	1609	1742	1834	1911	1996	633	2103	2040	2.622	5366	.605	24.64	60.86	81.1	62
1143	1228	1284	1347	1382	1397	1425	575	1498	1457	1.873	4365	.492	18.10	44.87	75.3	63
985	1020	1056	1077	1084	1077	1091	521	1127	1105	1.414	3358	.378	12.24	30.46	73.1	64

TABLE I - COMPRESSOR PERFORMANCE

Run	Altitude (ft)	Exhaust-nozzle-outlet area (sq in.)	Flight Mach number, M_0	Ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Tunnel static pressure, p_0 (lb/sq ft abs.)	Engine-inlet total temperature, T_1 (°R)	Engine-inlet total pressure, P_1 (lb/sq ft abs.)	Engine-inlet static pressure, p_1 (lb/sq ft abs.)	Compressor-inlet total pressure, P_2 (lb/sq ft abs.)	Compressor-inlet static pressure, p_2 (lb/sq ft abs.)	Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)					
												1	2	3	4	5	6
65	25,000	280	0.205	1.030	2046	774	455	797	793	793	791	795	809	823	830	837	858
66	25,000	280	.525	1.207	7895	781	468	943	845	927	732	535	647	753	858	1070	1260
67	25,000	280	.530	1.209	7692	774	466	936	838	920	726	535	647	753	866	1077	1260
68	25,000	280	.530	1.211	7500	781	456	946	847	928	735	542	661	774	894	1091	1281
69	25,000	280	.535	1.213	6993	774	456	939	844	923	740	598	718	851	999	1189	1394
70	25,000	280	.530	1.211	6459	778	458	942	858	927	774	701	834	975	1130	1320	1510
71	25,000	280	.530	1.208	5944	785	460	948	879	925	818	778	912	1053	1193	1369	1545
72	25,000	280	.520	1.203	5024	778	466	936	899	919	871	891	989	1088	1186	1299	1426
73	25,000	280	.520	1.202	4091	781	466	939	919	930	905	915	985	1041	1105	1175	1246
74	25,000	280	.525	1.204	3147	781	465	940	930	924	922	936	971	1006	1034	1084	1119
75	25,000	280	.515	1.199	2727	778	463	933	925	927	920	926	954	975	1003	1031	1060
76	25,000	280	.720	1.412	7895	774	469	1093	977	1061	848	626	753	880	1006	1246	1457
77	25,000	280	.715	1.403	7692	776	475	1089	976	1054	849	635	769	889	1029	1283	1501
78	25,000	280	.715	1.403	7500	781	478	1096	983	1057	858	661	767	929	1084	1316	1541
79	25,000	280	.720	1.413	6993	780	478	1102	992	1062	878	738	886	1048	1224	1449	1688
80	25,000	280	.720	1.410	6459	783	477	1104	1007	1072	916	839	994	1163	1339	1557	1776
81	25,000	280	.725	1.415	5944	781	480	1105	1026	1082	960	929	1077	1232	1386	1591	1774
82	25,000	280	.720	1.406	5024	781	477	1098	1054	1081	1020	1034	1147	1260	1379	1513	1647
83	25,000	280	.850	1.603	7895	793	491	1247	1114	1213	970	----	----	----	----	----	----
84	25,000	280	.830	1.567	7692	776	496	1236	1119	1191	976	755	889	1058	1227	1501	1762
85	25,000	280	.855	1.611	7500	774	498	1247	1118	1221	981	774	915	1098	1274	1541	1802
86	25,000	280	.855	1.611	6993	781	501	1258	1143	1231	1021	894	1056	1246	1457	1717	1978
87	25,000	280	.850	1.609	6459	781	501	1257	1155	1236	1061	1006	1175	1365	1562	1802	2041
88	25,000	280	.850	1.603	5944	781	498	1252	1173	1244	1104	1084	1246	1422	1591	1802	2013
89	25,000	280	.855	1.612	5024	781	502	1259	1212	1253	1176	1189	1302	1429	1555	1696	1837
90	25,000	280	.982	1.857	7895	746	502	1385	1238	1340	1083	816	971	1140	1316	1612	1894
91	25,000	280	.965	1.817	7692	778	511	1414	1265	1380	1111	862	1024	1214	1419	1728	2024
92	25,000	280	.975	1.839	7500	774	513	1423	1275	1391	1123	894	1063	1267	1485	1788	2098
93	25,000	280	.975	1.840	6993	774	514	1424	1290	1392	1160	1027	1210	1429	1661	1957	2252
94	25,000	280	.975	1.837	6459	773	---	1420	----	1396	1208	1153	1329	1554	1773	2047	2308
95	25,000	280	.965	1.820	5944	774	---	1409	----	1389	1252	1232	1408	1598	1788	2013	2238
96	25,000	302	.203	1.031	7895	785	458	809	728	814	629	454	560	637	736	869	1038
97	25,000	302	.203	1.032	7692	781	460	806	726	812	628	457	556	647	739	887	1049
98	25,000	302	.203	1.031	7500	781	458	805	726	813	629	471	577	668	774	922	1077
99	25,000	302	.200	1.029	6993	781	458	804	728	812	638	513	619	732	858	1013	1175
100	25,000	302	.200	1.029	6459	781	452	804	735	814	660	598	704	830	957	1112	1267
101	25,000	302	.198	1.028	5944	781	451	803	748	813	692	661	760	894	1013	1161	1309
102	25,000	302	.200	1.029	5024	781	451	804	772	817	744	746	844	929	1020	1119	1232
103	25,000	302	.198	1.028	4091	781	459	803	788	825	776	781	844	894	950	1020	1084
104	25,000	302	.203	1.032	3147	783	462	808	800	829	795	797	832	853	889	924	959
105	25,000	302	.203	1.031	2046	774	463	798	795	823	793	795	809	816	830	844	858
106	25,000	302	.712	1.402	7895	776	473	1088	974	1061	845	621	755	868	987	1191	1403
107	25,000	302	.710	1.398	7692	781	474	1092	980	----	852	640	767	894	1034	1232	1443
108	25,000	302	.720	1.405	7500	778	477	1093	980	1068	855	651	778	919	1067	1271	1475
109	25,000	302	.720	1.408	6993	781	478	1100	992	1075	878	732	873	1034	1201	1429	1647
110	25,000	302	.720	1.405	6459	780	479	1096	1004	----	913	836	984	1146	1322	1533	1744
111	25,000	302	.720	1.406	5944	781	480	1098	1023	1084	957	929	1070	1232	1386	1577	1760
112	25,000	302	.720	1.411	5024	776	479	1095	1052	1088	1017	1036	1142	1262	1374	1508	1642
113	25,000	302	.707	1.393	4091	778	480	1084	1062	1081	1045	1067	1151	1214	1285	1355	1440
114	25,000	302	.969	1.824	7895	774	491	1412	1262	1402	1103	816	985	1140	1309	1577	1837
115	25,000	302	.970	1.829	7692	767	492	1403	1256	1391	1097	823	999	1161	1351	1619	1886
116	25,000	302	.963	1.813	7500	781	492	1416	1268	1343	1112	858	1034	1217	1429	1703	1971
117	25,000	302	.969	1.827	6993	781	493	1427	1288	1416	1148	992	1175	1386	1612	1893	2175
118	25,000	302	.971	1.832	6459	779	495	1427	1309	1421	1204	1131	1321	1532	1751	2018	2286
119	25,000	302	.964	1.817	5944	781	494	1419	1327	1412	1247	1210	1393	1591	1788	2020	2252
120	25,000	342	.210	1.032	7895	781	463	806	725	785	627	457	563	647	732	865	1027
121	25,000	342	.210	1.032	7692	781	463	806	726	785	630	464	570	654	746	887	1041
122	25,000	342	.210	1.031	7500	778	463	802	723	781	629	468	574	665	764	912	1067
123	25,000	342	.200	1.029	6993	781	462	804	728	785	639	513	619	739	858	1013	1161
124	25,000	342	.200	1.028	6459	781	461	803	735	787	663	598	718	830	957	1112	1260
125	25,000	342	.195	1.027	5944	780	460	801	746	787	692	660	773	886	1012	1153	1294
126	25,000	342	.195	1.027	5024	780	459	801	770	794	744	752	843	928	1019	1111	1224
127	25,000	342	.200	1.028	4091	781	459	803	788	799	776	781	844	894	950	1020	1077

DATA FOR TURBOJET ENGINE - Continued

Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)						Straightening-vane static pressure, p_{2a} (lb/sq ft abs.)	Compressor-outlet total temperature, T_3 (°R)	Compressor-outlet total pressure, P_3 (lb/sq ft abs.)	Compressor-outlet static pressure, p_3 (lb/sq ft abs.)	Compressor pressure ratio, P_3/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$, (rpm)	Compressor Mach number, M_c	Air flow, $W_{a,1}$ (lb/sec)	Corrected air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$, (lb/sec)	Compressor efficiency, η_c, (percent)	Run
7	8	9	10	11	12											
866	887	894	901	901	894	894	485	909	898	1.141	2185	0.246	8.70	21.63	56.4	65
1647	2076	2717	3273	3872	4308	4822	879	5137	4979	5.448	8313	.937	44.26	94.32	71.1	66
1591	2013	2555	3161	3738	4188	4681	851	4985	4833	5.326	8115	.915	44.25	94.83	74.3	67
1569	1999	2464	3104	3632	4132	4618	817	4912	4764	5.192	8003	.902	45.17	94.70	76.0	68
1626	2006	2358	2865	3308	3843	4294	774	4525	4366	4.819	7462	.841	44.24	93.41	81.4	69
1728	2059	2362	2742	3094	3467	3805	737	4006	3874	4.253	6872	.774	41.79	88.21	84.2	70
1728	1996	2228	2503	2756	2996	3221	698	3405	3289	3.592	6313	.711	38.14	80.16	85.3	71
1545	1707	1834	1968	2066	2130	2214	628	2335	2251	2.495	5300	.597	28.06	60.14	86.0	72
1309	1401	1457	1506	1513	1471	1492	566	1575	1524	1.677	4316	.486	21.02	44.89	74.3	73
1154	1196	1217	1225	1196	1140	1126	520	1180	1151	1.255	3323	.375	15.02	32.02	56.7	74
1081	1109	1116	1116	1088	1024	1010	499	1060	1033	1.136	2888	.325	13.71	29.36	47.7	75
1879	2365	3090	3738	4456	4970	5561	869	5921	5755	5.417	8306	.936	51.82	95.36	72.9	76
1895	2374	3001	3676	4331	4852	5415	856	5759	5589	5.288	8038	.906	50.79	94.44	76.1	77
1830	2302	2773	3477	4012	4660	5209	835	5529	5348	5.045	7815	.881	50.75	94.05	78.8	78
1949	2371	2779	3314	3807	4363	4863	799	5115	4938	4.642	7287	.821	50.34	92.76	82.1	79
2022	2381	2712	3127	3507	3902	4254	758	4486	4328	4.063	6737	.759	47.59	87.47	83.7	80
1971	2259	2506	2787	3027	3231	3449	716	3657	3525	3.310	6182	.697	43.26	79.66	83.0	81
1767	1943	2069	2189	2266	2266	2337	635	2489	2390	2.267	5240	.591	32.96	60.90	79,6	82
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2142	2684	3296	4092	4747	5408	6035	875	6403	6208	5.180	7869	.887	53.5	91.0	78.7	84
2112	2633	3139	3872	4449	5188	5786	860	6123	5911	4.910	7658	.863	56.50	93.91	79.3	85
2273	2731	3175	3745	4266	4829	5343	823	5621	5425	4.468	7119	.802	54.06	89.32	83.1	86
2309	2682	3034	3463	3843	4217	4569	780	4829	4651	3.842	6575	.741	50.99	84.30	84.3	87
2217	2513	2766	3055	3280	3470	3660	727	3899	3759	3.114	6069	.684	45.33	75.03	83.5	88
1971	2147	2281	2393	2435	2365	2435	654	2599	2490	2.064	5109	.576	35.63	58.89	76.1	89
2330	2942	3639	4569	5336	6040	6751	887	7165	6964	5.173	8029	.905	63.45	95.33	78.2	90
2411	3017	3629	4516	5185	5995	6670	882	7088	6854	5.013	7754	.874	63.95	94.91	80.7	91
2450	3027	3583	4400	5047	5850	6540	874	6902	6663	4.850	7545	.850	63.83	94.35	81.1	92
2583	3090	3569	4195	4759	5371	5913	838	6230	6012	4.375	7028	.792	61.07	90.30	83.3	93
2589	3005	3392	3849	4251	4631	4997	794	5290	5096	3.725	----	-----	-----	-----	----	94
2457	2773	3027	3322	3548	3703	3893	740	4155	3993	2.949	----	-----	-----	-----	----	95
1250	1609	2031	2601	3087	3538	3967	848	4231	4103	5.230	8400	.947	37.77	92.87	71.0	96
1225	1562	1907	2428	2858	3372	3787	825	4032	3904	5.002	8169	.921	37.39	92.42	73.7	97
1253	1577	1893	2372	2773	3287	3703	806	3926	3791	4.877	7980	.899	37.31	92.19	75.5	98
1351	1647	1943	2323	2696	3090	3463	767	3651	3522	4.541	7441	.839	36.54	90.39	80.3	99
1450	1717	1971	2281	2576	2879	3161	727	3329	3214	4.141	6918	.780	35.26	86.65	82.4	100
1464	1696	1893	2133	2344	2548	2738	---	2894	2792	3.604	6378	.719	31.91	78.36	----	101
1337	1485	1605	1731	1823	1893	1971	621	2085	2017	2.593	5391	.608	24.49	60.07	83.1	102
1140	1225	1281	1337	1365	1365	1401	569	1466	1426	1.826	4349	.490	16.93	41.97	78.4	103
980	1029	1058	1079	1079	1065	1072	523	1114	1091	1.379	3336	.376	12.32	30.44	73.0	104
866	894	894	901	894	880	887	488	903	894	1.132	2167	.244	7.67	19.21	66.9	105
1663	2121	2620	3374	3972	4634	5204	852	5547	5375	5.098	8266	.932	51.04	94.81	74.1	106
1682	2119	2548	3203	3759	4442	5019	833	5320	5141	4.872	8046	.906	50.60	93.75	75.6	107
1721	2130	2545	3129	3686	4312	4882	821	5155	4971	4.716	7823	.882	50.64	94.00	77.4	108
1879	2266	2647	3118	3590	4076	4533	787	4788	4613	4.353	7287	.821	49.93	92.20	80.9	109
1963	2294	2603	2976	3314	3638	3948	749	4186	4029	3.819	6724	.758	46.36	85.99	82.8	110
1943	2217	2449	2710	2928	3104	3287	708	3504	3372	3.191	6182	.697	42.12	78.05	82.9	111
1762	1938	2064	2184	2247	2219	2290	636	2441	2341	2.229	5230	.589	32.38	60.10	78.7	112
1503	1595	1644	1679	1658	1538	1531	575	1631	1559	1.505	4255	.480	23.54	44.18	62.7	113
2154	2717	3294	4188	4914	5808	6554	863	6964	6739	4.932	8116	.915	65.43	95.41	76.3	114
2189	2717	3259	4041	4766	5589	6329	848	6696	6455	4.773	7900	.890	64.49	94.69	77.9	115
2281	2794	3322	4048	4752	5505	6202	835	6549	6318	4.625	7703	.868	65.10	94.70	78.8	116
2478	2970	3428	4033	4590	5174	5716	798	6040	5826	4.233	7175	.809	63.48	91.75	82.6	117
2560	2961	3335	3785	4179	4538	4890	758	5204	5000	3.647	6614	.745	58.85	85.22	84.3	118
2478	2801	3076	3379	3611	3773	3970	713	4256	4076	2.999	6093	.687	52.31	76.09	83.2	119
1182	1478	1795	2295	2731	3266	3696	835	3938	3805	4.885	8361	.942	37.53	93.03	71.4	120
1196	1492	1802	2252	2682	3175	3611	820	3827	3719	4.748	8146	.918	37.28	92.41	72.8	121
1229	1510	1813	2221	2630	3080	3502	801	3697	3564	4.610	7943	.895	37.01	92.19	75.1	122
1344	1619	1893	2245	2604	2963	3301	766	3490	3363	4.341	7413	.835	36.37	90.31	79.3	123
1436	1682	1929	2210	2471	2738	2992	731	3163	3046	3.939	6853	.772	34.82	86.48	82.0	124
1442	1660	1857	2068	2265	2434	2603	697	2759	2660	3.444	6313	.711	31.50	78.36	82.4	125
1322	1463	1576	1695	1773	1822	1899	628	2012	1942	2.512	5341	.602	23.99	59.63	81.9	126
1133	1217	1274	1323	1344	1330	1365	566	1433	1391	1.785	4349	.490	16.94	41.99	77.3	127

TABLE I - COMPRESSOR PERFORMANCE

Run	Altitude (ft)	Exhaust-nozzle-outlet area (sq in.)	Flight Mach number, M_0	Ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Tunnel static pressure, p_0 (lb/sq ft abs.)	Engine-inlet total temperature, T_1 (°R)	Engine-inlet total pressure, P_1 (lb/sq ft abs.)	Engine-inlet static pressure, p_1 (lb/sq ft abs.)	Compressor-inlet total pressure, P_2 (lb/sq ft abs.)	Compressor-inlet static pressure, p_2 (lb/sq ft abs.)	Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)					
												1	2	3	4	5	6
128	25,000	342	0.200	1.028	3147	776	458	798	791	796	786	790	825	846	875	917	952
129	25,000	342	.713	1.404	7895	778	471	1092	975	1041	847	623	750	870	989	1172	1376
130	25,000	342	.710	1.399	7695	780	473	1091	978	1043	850	632	766	886	1012	1209	1407
131	25,000	342	.710	1.399	7500	781	472	1093	978	1042	853	647	774	915	1056	1260	1457
132	25,000	342	.712	1.403	6993	785	471	1101	992	1053	876	729	869	1024	1186	1405	1609
133	25,000	342	.719	1.406	6459	781	472	1098	1004	1055	913	837	985	1147	1316	1520	1731
134	25,000	342	.709	1.397	5944	778	472	1087	1013	1049	945	905	1053	1207	1355	1545	1728
135	25,000	342	.709	1.397	5024	774	472	1081	1038	1051	1003	1020	1133	1246	1365	1492	1626
136	25,000	342	.719	1.407	4091	778	474	1095	1071	1067	1053	1067	1158	1229	1299	1383	1468
137	25,000	342	.970	1.836	7895	781	487	1434	1280	1358	1116	830	1006	1161	1323	1584	1844
138	25,000	342	.970	1.827	7692	780	487	1425	1275	1346	1115	850	1019	1188	1364	1632	1892
139	25,000	342	.965	1.823	7500	778	489	1418	1271	1338	1114	855	1024	1207	1412	1679	1933
140	25,000	342	.970	1.827	6993	780	491	1425	1287	1344	1145	984	1174	1378	1597	1871	2146
141	25,000	342	.965	1.819	6459	781	493	1421	1305	1338	1195	1119	1309	1520	1738	1992	2259
142	25,000	342	.970	1.827	5944	784	493	1432	1338	1359	1257	1220	1404	1601	1805	2037	2269
143	35,000	280	.210	1.032	7692	496	444	512	460	508	395	292	362	419	482	609	714
144	35,000	280	.215	1.034	7500	493	445	510	458	508	395	303	373	430	486	606	711
145	35,000	280	.220	1.036	6993	496	446	514	464	509	404	327	397	468	545	651	764
146	35,000	280	.210	1.032	6459	496	445	512	467	509	418	376	447	524	609	714	820
147	35,000	280	.205	1.030	5944	493	445	508	472	509	437	423	500	570	648	739	838
148	35,000	280	.205	1.030	5024	494	445	509	488	508	470	480	543	593	649	719	792
149	35,000	280	.195	1.028	4091	497	446	511	501	510	493	504	539	567	610	652	694
150	35,000	302	.200	1.030	7895	494	456	509	459	522	397	290	353	410	466	564	677
151	35,000	302	.203	1.032	7692	494	456	510	460	520	398	297	360	417	480	571	677
152	35,000	302	.200	1.030	7500	494	457	509	460	521	400	304	367	424	494	586	691
153	35,000	302	.198	1.028	6993	495	457	509	462	521	405	340	411	474	551	657	755
154	35,000	302	.198	1.028	6459	496	457	510	469	523	422	376	447	531	616	707	813
155	35,000	302	.200	1.030	5944	495	456	510	475	524	442	425	502	572	650	741	833
156	35,000	302	.198	1.028	5024	496	457	510	491	528	474	482	538	588	644	707	778
157	35,000	302	.200	1.030	4091	494	457	509	500	529	492	494	529	557	593	635	677
158	35,000	302	.198	1.028	3147	496	457	510	506	533	502	510	524	538	552	580	602
159	35,000	302	.203	1.032	2046	498	458	514	510	535	510	512	519	533	533	547	554
160	35,000	342	.205	1.030	7895	492	444	507	457	493	395	295	358	400	457	541	647
161	35,000	342	.210	1.032	7692	493	446	509	458	495	396	296	359	416	472	563	662
162	35,000	342	.205	1.030	7500	494	443	509	458	495	397	304	367	424	480	571	670
163	35,000	342	.200	1.028	6993	494	441	508	460	495	402	325	395	459	529	635	726
164	35,000	342	.190	1.026	6459	496	442	509	465	499	416	376	447	517	602	700	799
165	35,000	342	.200	1.028	5944	493	443	507	471	498	435	416	493	563	634	732	824
166	35,000	342	.200	1.028	5024	493	444	507	486	502	467	472	528	585	641	711	782
167	35,000	342	.200	1.028	4091	494	446	508	498	505	489	501	536	571	607	649	691
168	45,000	280	.225	1.037	7500	298	442	309	278	313	240	185	228	263	312	390	467
169	45,000	280	.200	1.029	6993	308	446	317	288	324	252	209	252	301	350	421	491
170	45,000	280	.225	1.037	6459	297	443	308	281	316	253	234	283	325	381	438	508
171	45,000	280	.210	1.033	5944	306	445	316	295	320	274	264	313	355	405	461	524
172	45,000	280	.205	1.030	5024	303	444	312	299	326	290	296	331	359	395	437	486
173	45,000	302	.210	1.032	7895	310	440	320	289	329	250	190	----	261	296	359	430
174	45,000	302	.185	1.026	7692	308	439	316	285	327	247	195	----	266	308	364	435
175	45,000	302	.215	1.034	7500	293	438	303	273	313	235	180	----	251	300	356	420
176	45,000	302	.210	1.033	6993	306	440	316	286	326	251	207	----	292	334	398	468
177	45,000	302	.210	1.032	6459	308	442	318	290	330	261	238	----	336	378	442	512
178	45,000	302	.180	1.023	5944	311	442	318	296	333	274	269	----	360	410	466	522
179	45,000	302	.205	1.030	5024	304	442	313	302	327	292	297	----	361	403	438	487
180	45,000	342	.190	1.026	7895	312	440	320	289	311	250	192	235	256	291	340	411
181	45,000	342	.190	1.026	7692	310	440	318	287	309	248	190	233	261	296	352	418
182	45,000	342	.200	1.029	7500	310	440	319	288	311	250	197	233	268	310	366	430
183	45,000	342	.190	1.026	6993	310	440	318	288	310	253	204	247	296	338	402	465
184	45,000	342	.190	1.026	6459	310	440	318	292	312	263	240	275	331	380	437	507
185	45,000	342	.190	1.026	5944	307	442	315	295	311	272	265	307	356	399	455	518
186	45,000	342	.200	1.029	5024	306	443	315	302	311	293	292	334	362	390	426	475
187	50,000	280	.190	1.027	7500	225	443	231	208	224	180	148	176	204	239	302	359
188	50,000	280	.185	1.025	6993	236	443	242	220	235	194	166	194	236	278	328	391
189	50,000	280	.185	1.025	6459	238	441	244	225	236	202	182	224	259	301	344	400
190	50,000	280	.185	1.025	5944	239	440	245	229	239	212	211	246	281	316	366	415

DATA FOR TURBOJET ENGINE - Concluded

Compressor-rotor-stage static pressure, p_{2a} (lb/sq ft abs.)						Straightening-vane static pressure, p_{2a} (lb/sq ft abs.)	Compressor-outlet total temperature, T_3 (°R)	Compressor-outlet total pressure, P_3 (lb/sq ft abs.)	Compressor-outlet static pressure, p_3 (lb/sq ft abs.)	Compressor pressure ratio, P_3/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$, (rpm)	Compressor Mach number, M_c	Air flow, $W_{a,1}$ (lb/sec)	Corrected air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$, (lb/sec)	Compressor efficiency, η_c, (percent)	Run
7	8	9	10	11	12											
973	1022	1044	1065	1065	1044	1051	526	1134	1070	1.421	3348	0.377	11.80	29.41	71.2	128
1588	1982	2397	3017	3608	4291	4889	835	5191	5099	4.755	8290	.934	51.83	95.66	72.7	129
1618	1998	2413	2984	3554	4187	4779	822	5058	4877	4.637	8054	.908	50.99	94.48	74.7	130
1675	2048	2435	2963	3505	4083	4632	805	4902	4720	4.485	7868	.887	51.43	94.92	76.0	131
1841	2200	2552	3000	3439	3883	4305	769	4572	4391	4.152	7343	.828	50.49	92.42	79.4	132
1943	2259	2555	2907	3217	3505	3787	731	4041	3947	3.680	6775	.764	47.18	86.67	82.3	133
1911	2179	2411	2658	2862	3010	3172	695	3405	3267	3.132	6235	.703	41.99	77.93	81.7	134
1746	1922	2041	2147	2203	2161	2217	624	2381	2285	2.202	5270	.594	32.18	60.04	78.7	135
1538	1644	1700	1728	1714	1581	1574	566	1685	1607	1.539	4279	.482	24.31	44.90	67.6	136
2119	2618	3161	3949	4716	5582	6371	848	6750	6507	4.708	8148	.918	66.93	95.73	75.2	137
2167	2660	3181	3892	4603	5370	6102	833	6462	6226	4.538	7938	.895	65.99	94.96	76.2	138
2221	2700	3200	3869	4523	5227	5889	819	6241	6004	4.402	7725	.871	65.18	94.42	78.2	139
2427	2892	3321	3885	4399	4927	5412	784	5757	5530	4.041	7189	.810	63.24	91.35	82.3	140
2513	2907	3259	3674	4019	4329	4632	746	4962	4727	3.492	6627	.747	58.44	84.81	83.8	141
2488	2812	3086	3368	3565	3684	3868	706	4162	3980	2.906	6099	.687	53.07	76.45	82.6	142
968	1165	1566	1820	2157	2411	2692	845	2862	2784	5.590	8315	.937	24.42	93.37	70.4	143
901	1120	1443	1739	2056	2267	2556	825	2717	2640	5.327	8100	.913	24.43	93.85	71.8	144
890	1101	1313	1594	1841	2143	2390	777	2515	2432	4.893	7545	.850	24.05	91.76	77.4	145
947	1130	1306	1524	1728	1953	2150	738	2256	2184	4.406	6976	.786	22.87	87.52	80.2	146
937	1091	1225	1387	1528	1676	1809	697	1903	1845	3.746	6420	.724	20.57	79.33	81.1	147
860	966	1036	1128	1198	1261	1311	627	1385	1339	2.721	5426	.612	15.99	61.55	81.1	148
736	793	835	877	898	912	933	568	980	962	1.918	4414	.497	11.23	43.10	74.8	149
846	1064	1395	1789	2022	2268	2529	861	2702	2622	5.308	8424	.949	23.65	92.14	68.9	150
818	1036	1282	1627	1909	2191	2444	833	2604	2527	5.106	8207	.925	23.70	92.16	71.8	151
818	1022	1240	1550	1803	2113	2353	813	2503	2427	4.917	7995	.901	23.43	91.37	74.1	152
882	1065	1255	1502	1734	1980	2213	774	2333	2253	4.583	7455	.840	23.01	89.73	78.7	153
932	1094	1263	1453	1636	1827	2003	739	2102	2035	4.122	6885	.776	21.59	84.03	80.9	154
931	1072	1199	1347	1474	1593	1713	699	1807	1745	3.543	6342	.715	20.15	78.35	81.8	155
841	940	1010	1087	1137	1186	1228	632	1299	1260	2.547	5356	.604	15.14	58.93	80.0	156
705	762	797	832	846	846	867	568	912	893	1.792	4361	.491	10.46	40.79	74.8	157
623	658	665	679	686	679	679	526	707	695	1.386	3355	.378	7.10	27.64	64.8	158
568	582	582	597	590	582	590	489	599	592	1.165	2177	.245	7.15	27.67	65.9	159
752	950	1168	1499	1794	2111	2393	826	2551	2468	5.032	8534	.962	23.86	92.13	68.2	160
768	958	1162	1457	1732	2056	2323	809	2474	2392	4.861	8300	.935	24.06	92.69	70.3	161
776	959	1163	1444	1705	2015	2289	792	2424	2338	4.762	8123	.915	24.15	92.70	71.4	162
846	1022	1205	1437	1670	1923	2148	753	2269	2189	4.467	7587	.855	23.51	90.25	75.5	163
911	1080	1235	1432	1608	1798	1974	726	2079	2003	4.084	7002	.789	22.70	87.05	77.1	164
915	1063	1190	1331	1465	1584	1704	683	1804	1743	3.558	6437	.725	20.57	79.28	80.8	165
845	944	1014	1091	1148	1190	1239	616	1312	1269	2.588	5431	.612	15.95	61.59	80.7	166
726	790	825	860	874	874	902	571	951	925	1.872	4414	.497	11.16	43.08	70.1	167
608	749	960	1124	1312	1460	1614	836	1714	1669	5.547	8130	.916	14.72	92.99	70.8	168
583	716	850	1026	1174	1343	1484	787	1561	1517	4.924	7545	.850	14.43	89.27	75.5	169
586	698	811	938	1057	1191	1311	741	1374	1336	4.461	6995	.788	13.78	87.41	79.3	170
588	686	771	869	954	1045	1123	702	1181	1146	3.737	6420	.724	12.42	77.00	79.3	171
521	585	627	683	718	754	789	632	832	812	2.667	5431	.612	9.81	61.55	76.5	172
556	697	922	1098	1303	1450	1619	859	1726	1680	5.394	8574	.752	15.01	91.40	65.1	173
540	674	864	1054	1244	1399	1554	831	1657	1608	5.244	8361	.942	14.97	92.22	67.9	174
504	638	772	969	1138	1307	1462	805	1551	1506	5.119	8168	.921	14.40	92.34	70.9	175
538	658	785	940	1080	1256	1404	769	1478	1430	4.677	7594	.856	14.71	90.70	74.2	176
583	695	794	920	1040	1167	1280	735	1348	1308	4.237	7002	.789	14.34	88.03	77.1	177
586	684	762	860	938	1029	1099	695	1163	1125	3.657	6443	.726	12.76	78.33	78.4	178
522	586	628	684	712	740	769	629	818	788	2.613	5446	.614	9.10	56.75	74.7	179
488	622	770	988	1178	1361	1523	830	1629	1579	5.091	8574	.966	15.01	91.40	66.8	180
493	620	754	951	1127	1317	1479	816	1575	1530	4.953	8354	.941	14.99	91.84	67.9	181
500	620	739	922	1077	1274	1429	796	1521	1470	4.768	8145	.918	15.04	91.86	69.6	182
535	655	761	908	1049	1204	1345	762	1420	1373	4.465	7594	.856	14.74	90.31	73.0	183
570	683	782	901	1007	1120	1225	731	1297	1253	4.079	7014	.790	13.85	84.86	74.8	184
575	673	751	842	912	990	1067	693	1127	1092	3.578	6443	.726	12.20	75.60	77.5	185
510	574	609	665	686	714	735	627	782	764	2.483	5441	.613	9.92	61.53	71.5	186
464	570	718	845	978	1091	1204	843	1276	1244	5.524	8123	.915	10.97	92.78	69.9	187
447	560	658	792	905	1032	1137	790	1204	1172	4.975	7573	.853	11.00	88.81	74.3	188
456	548	632	738	822	928	1019	740	1067	1038	4.373	7008	.790	10.34	82.64	77.4	189
457	542	605	683	753	823	887	702	936	912	3.820	6455	.727	9.62	76.51	78.5	190

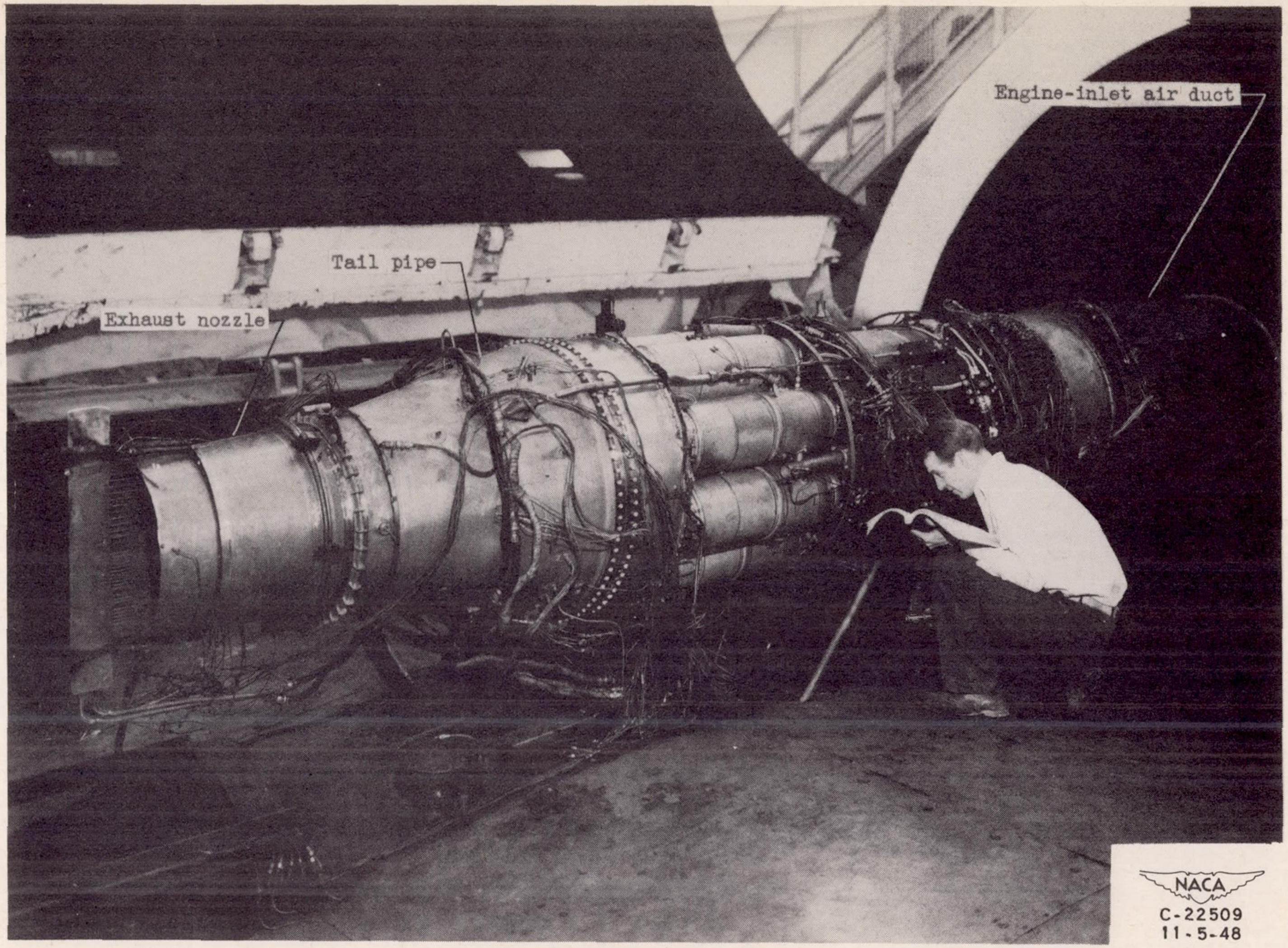

Figure 1. - Installation of turbojet engine in altitude wind tunnel.

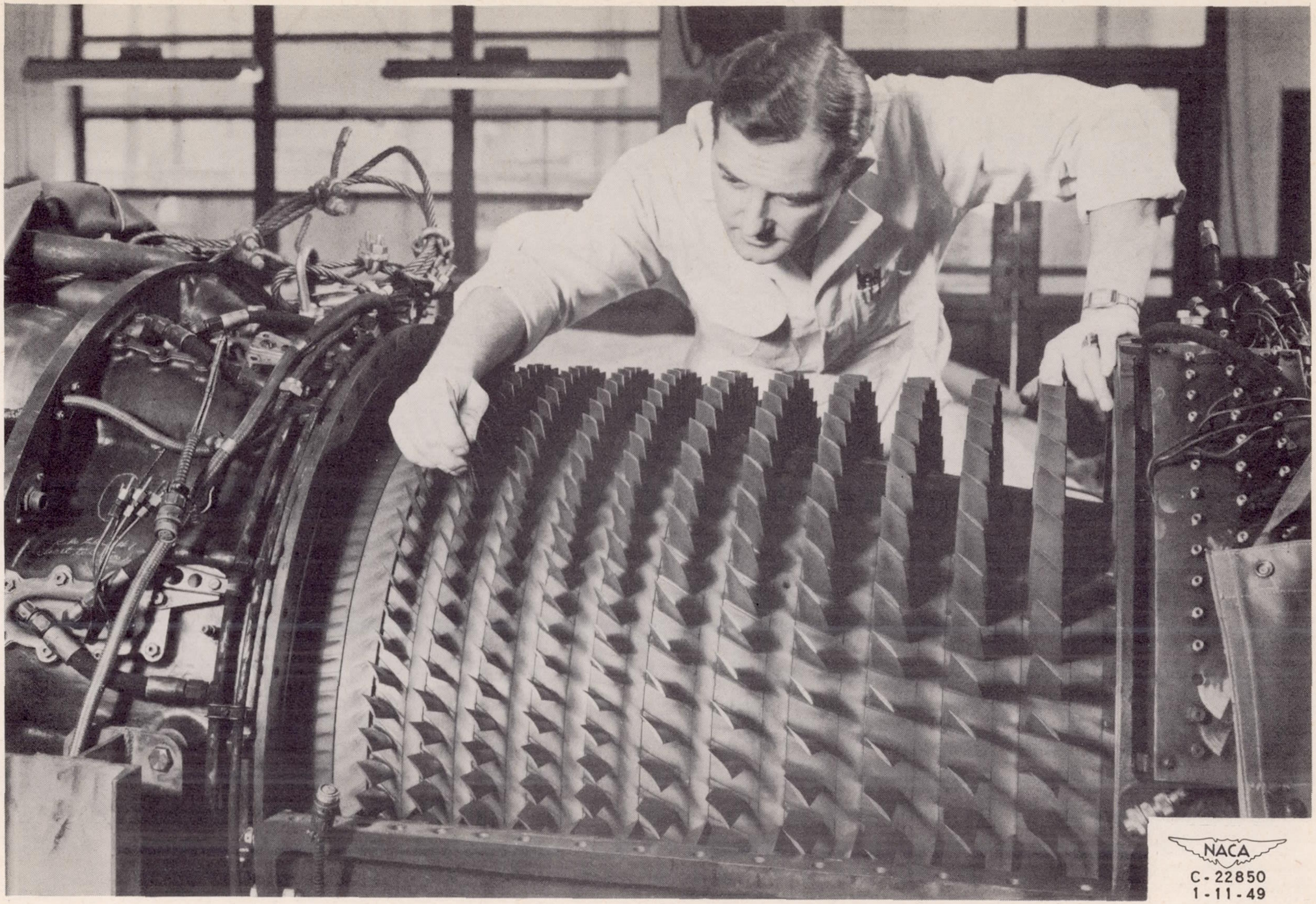

Figure 2. - Compressor installation with one-half of stator casing removed.

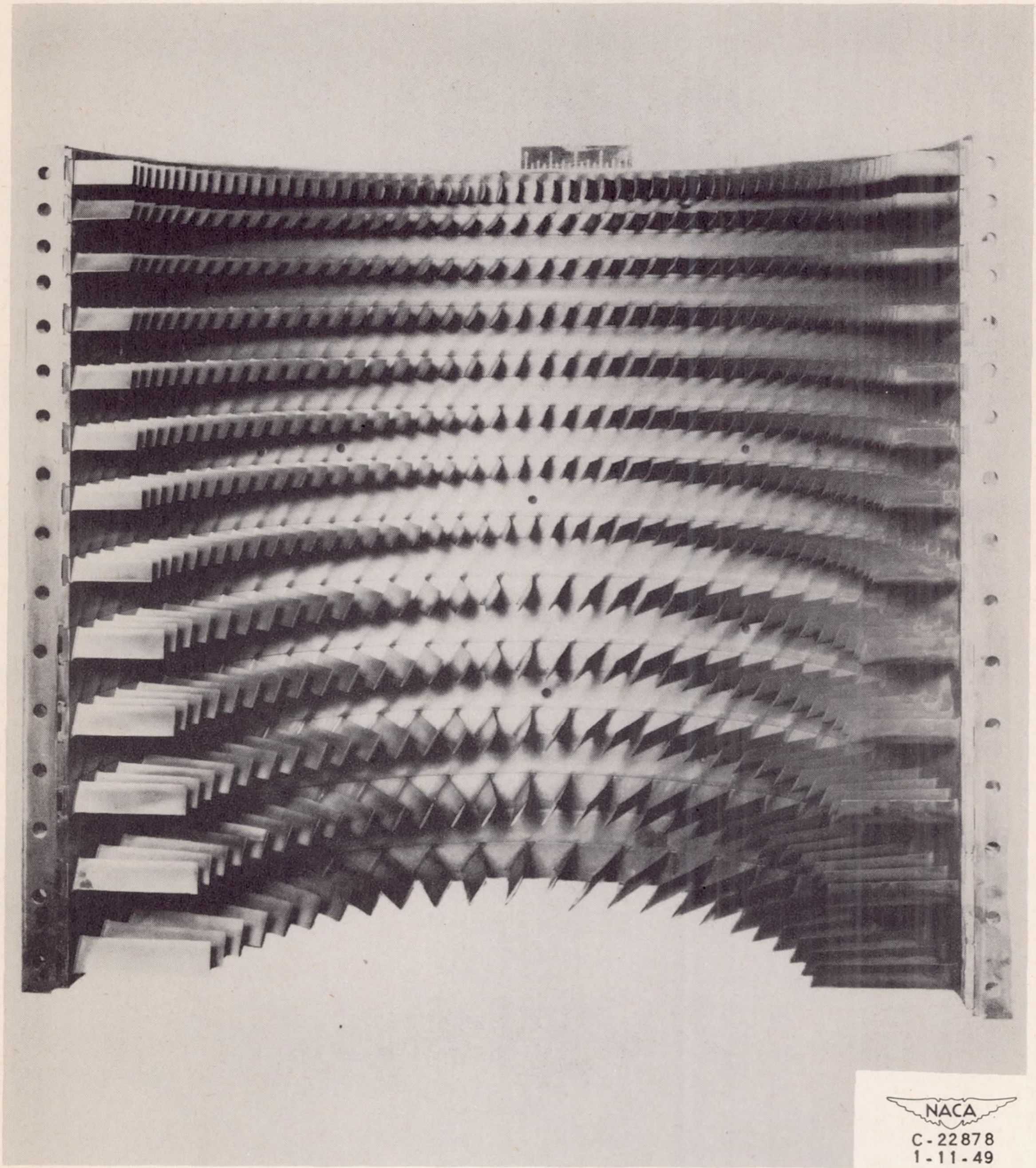

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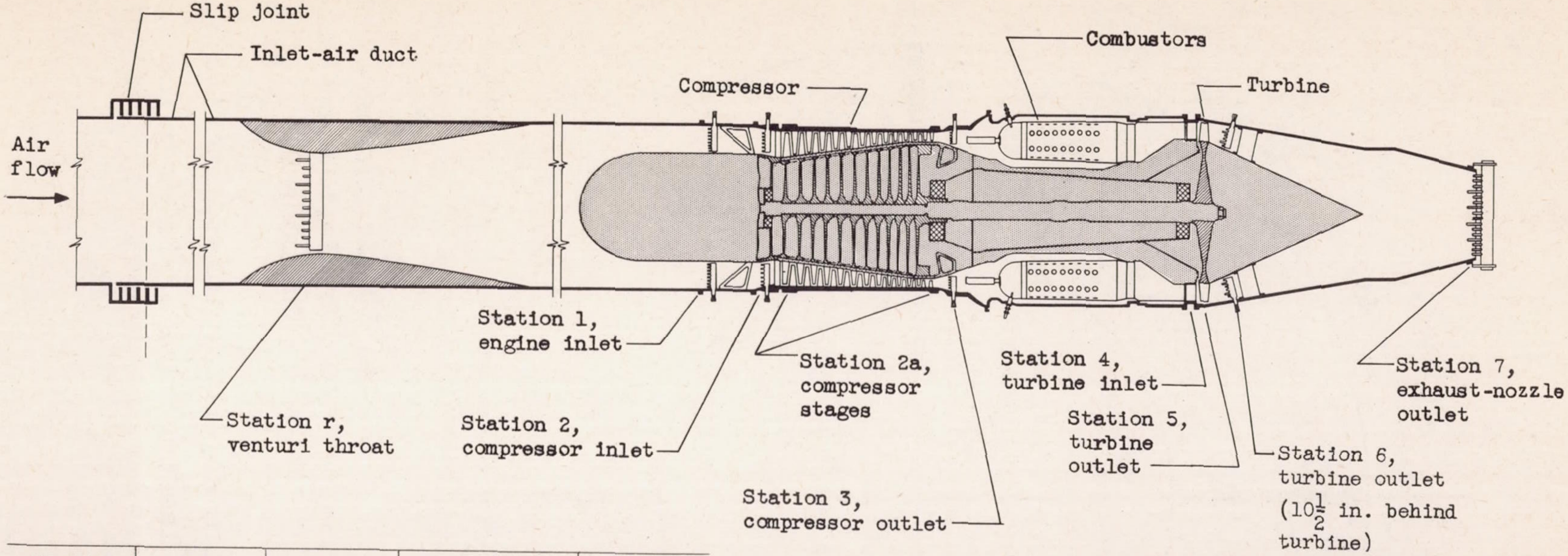
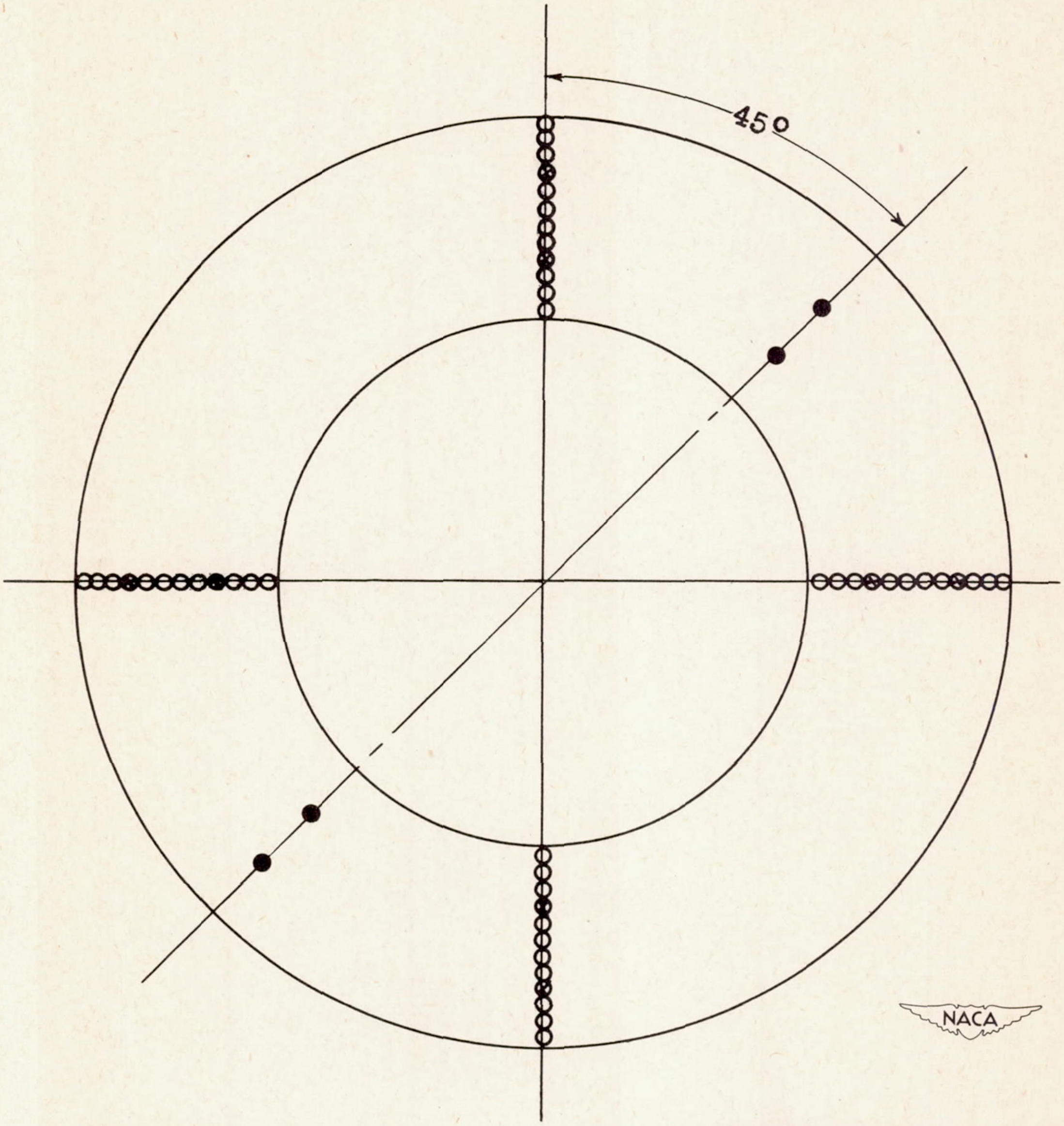
Figure 3. - Top half of compressor-casing assembly showing stator blades and outlet guide vanes.



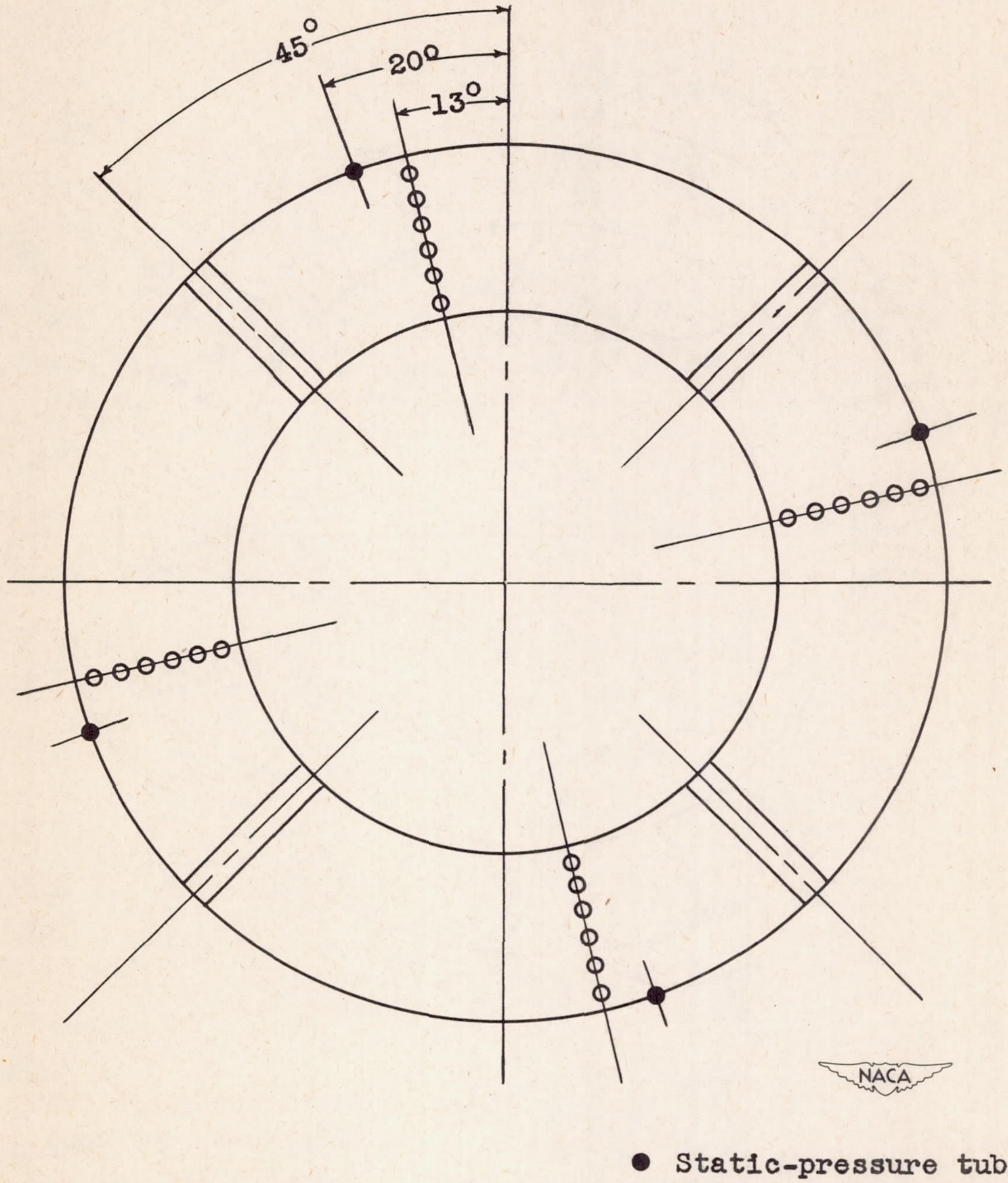
Station	Total-pressure tubes	Static-pressure tubes	Wall static-pressure orifices	Thermo-couples
r	12	4	4	6
1	40	4	0	8
2	24	0	4	0
2a	0	0	13	0
3	20	0	4	6
4	5	0	0	0
5	0	0	0	8
6	30	0	2	33
7	18	5	4	14

Figure 4. - Cross section of turbojet-engine installation showing instrumentation installations.



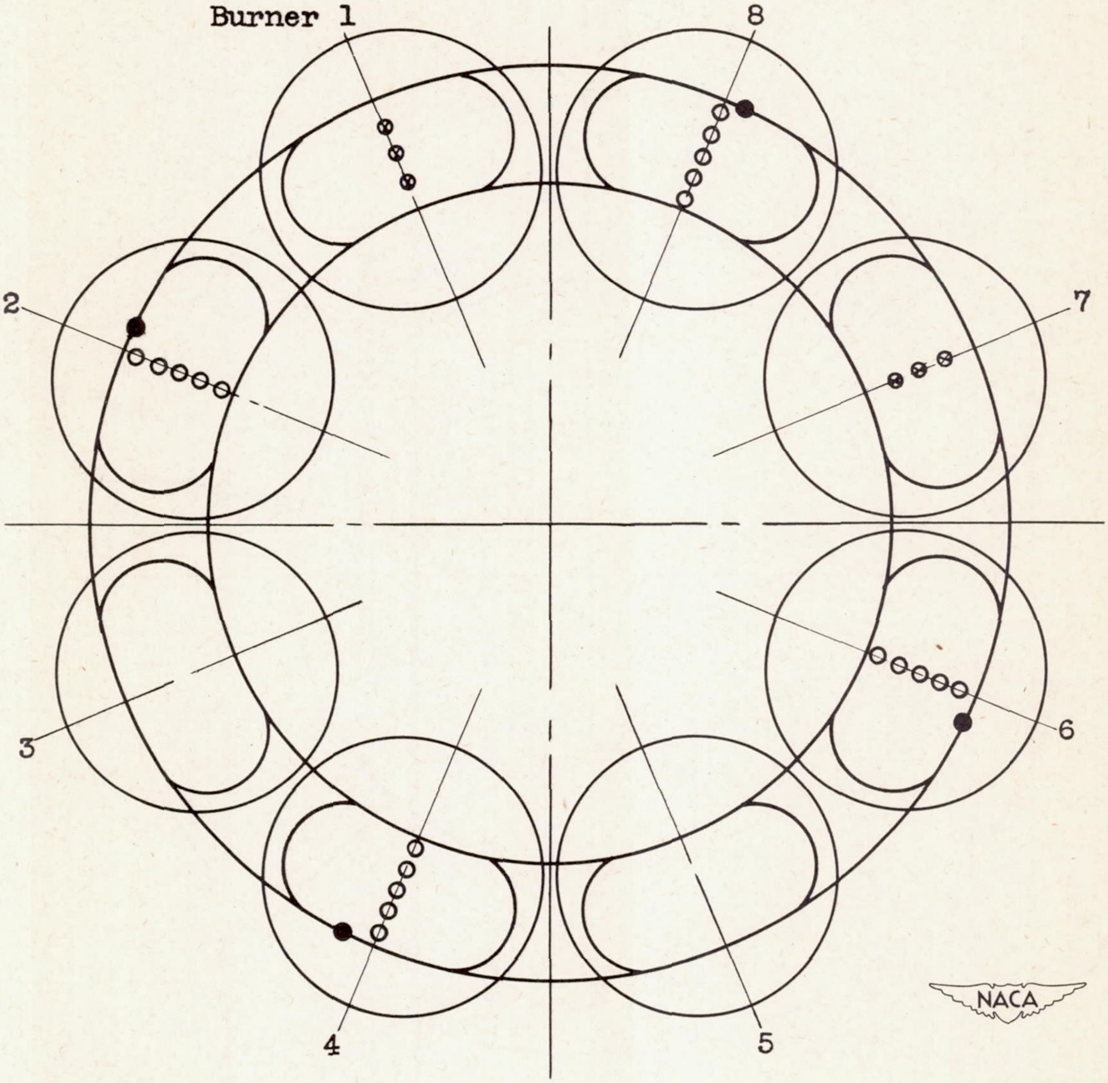
● Static-pressure tube
○ Total-pressure tube
⊗ Thermocouple

Figure 5. - Instrumentation at engine inlet, station 1, $18\frac{7}{8}$ inches upstream of leading edge of inlet guide vanes. Viewed from upstream.



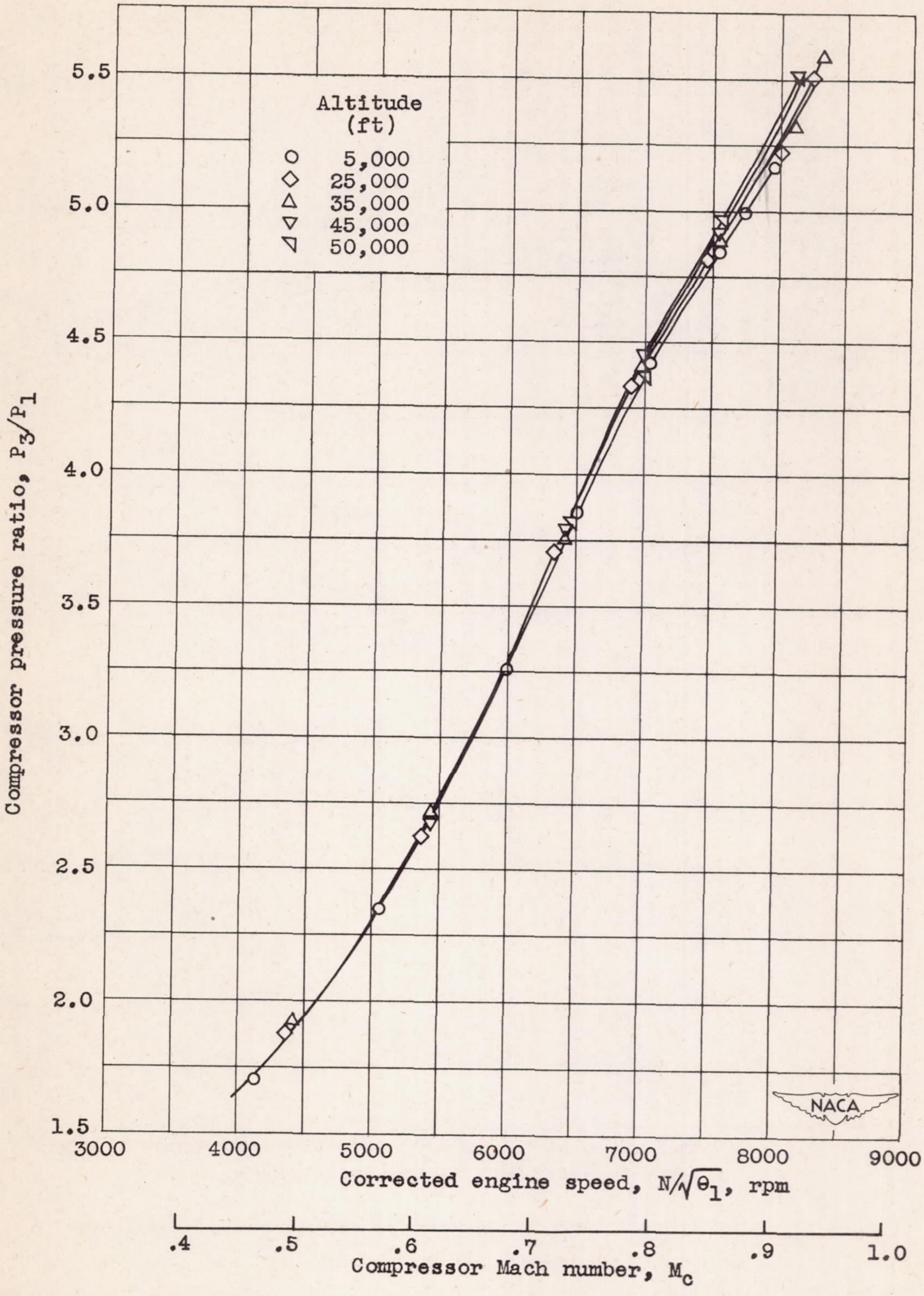
● Static-pressure tube
○ Total-pressure tube

Figure 6. - Instrumentation at compressor inlet, station 2, 5 inches upstream of leading edge of inlet guide vanes. Viewed from upstream.



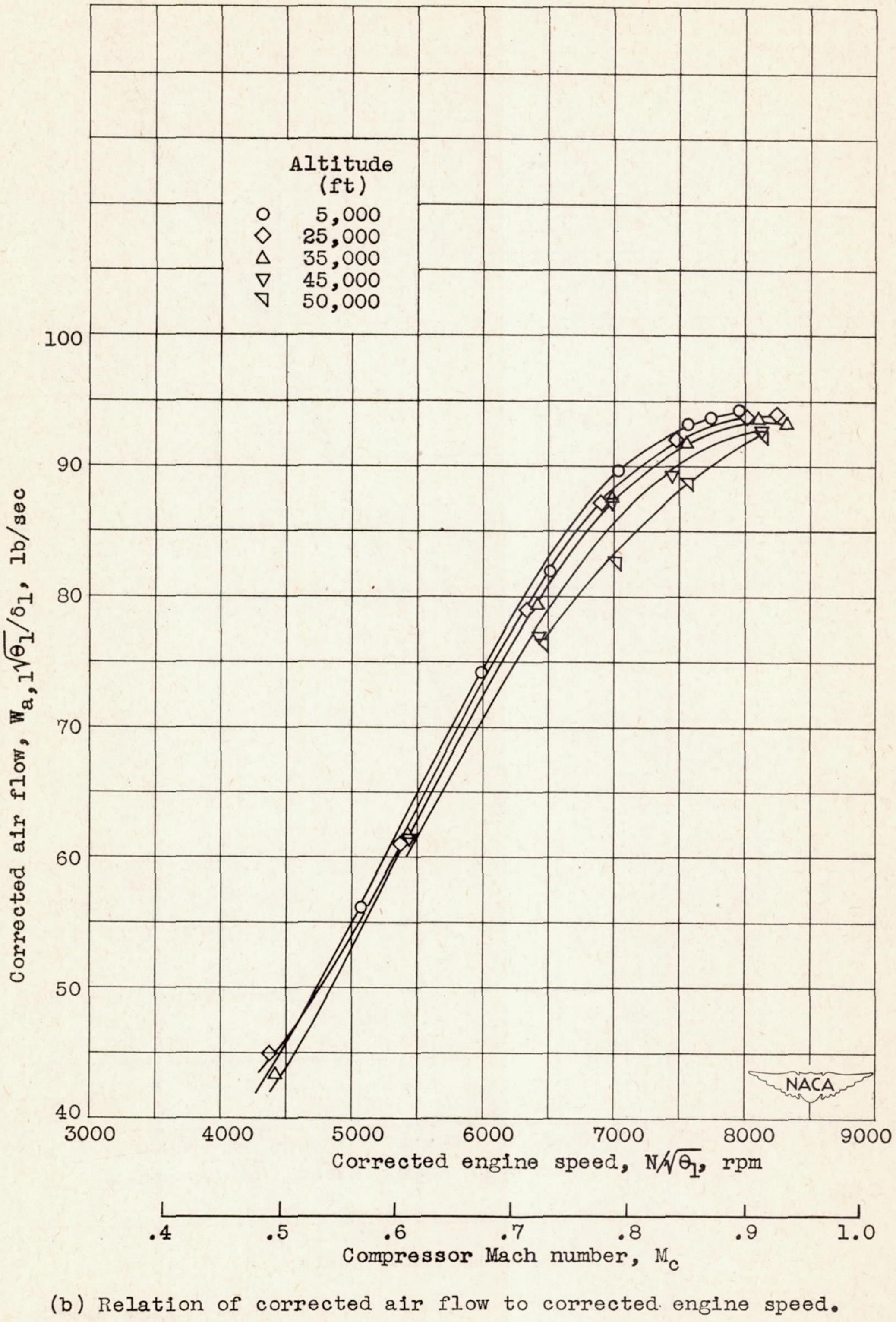
● Static-pressure tube
○ Total-pressure tube
⊗ Thermocouple

Figure 7. - Instrumentation at compressor outlet, station 3, $3\frac{1}{4}$ inches downstream of trailing edge of outlet guide vanes. Viewed from upstream.



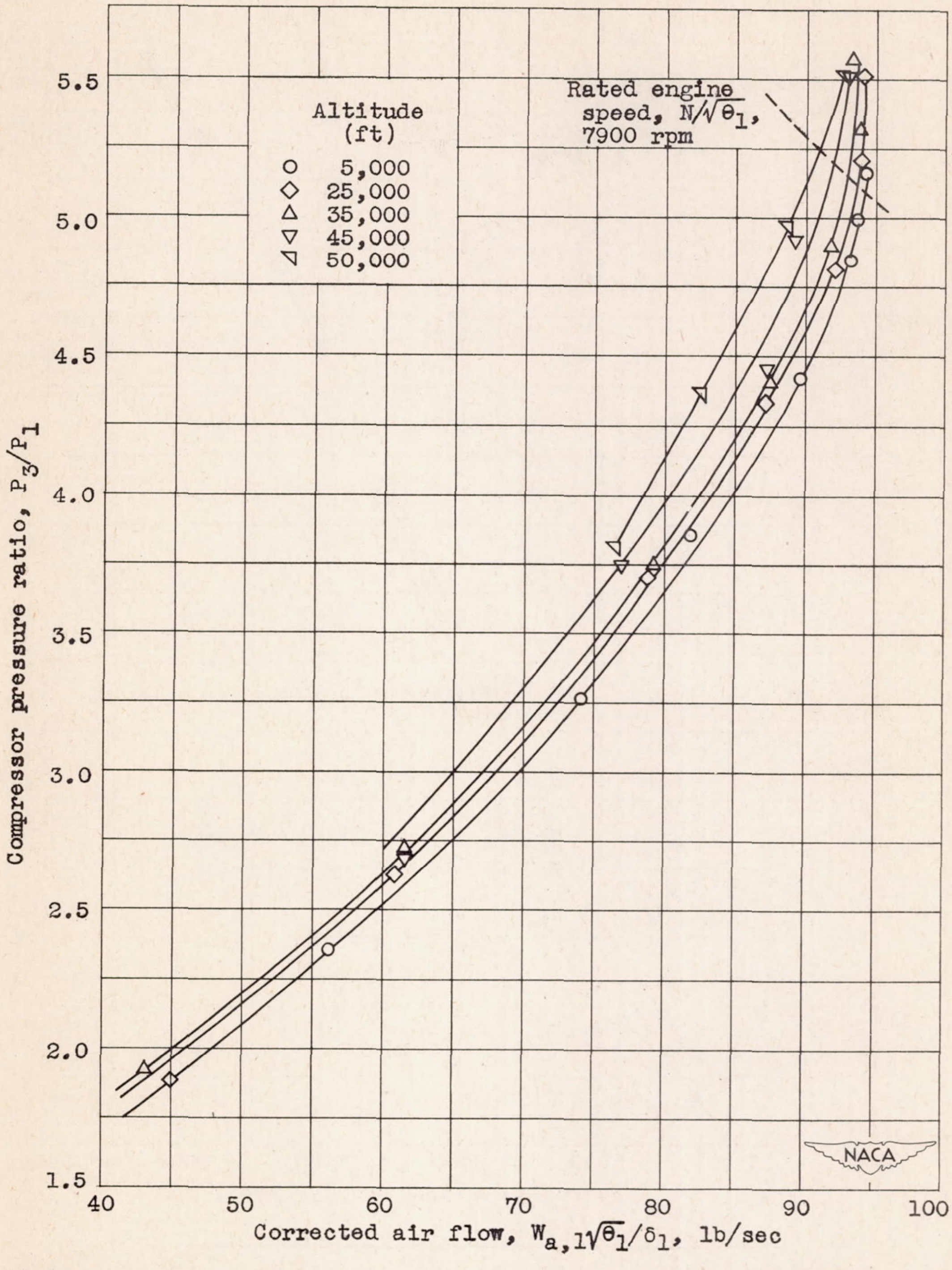
(a) Relation of compressor pressure ratio to corrected engine speed.

Figure 8. - Effect of altitude on compressor operating line. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.



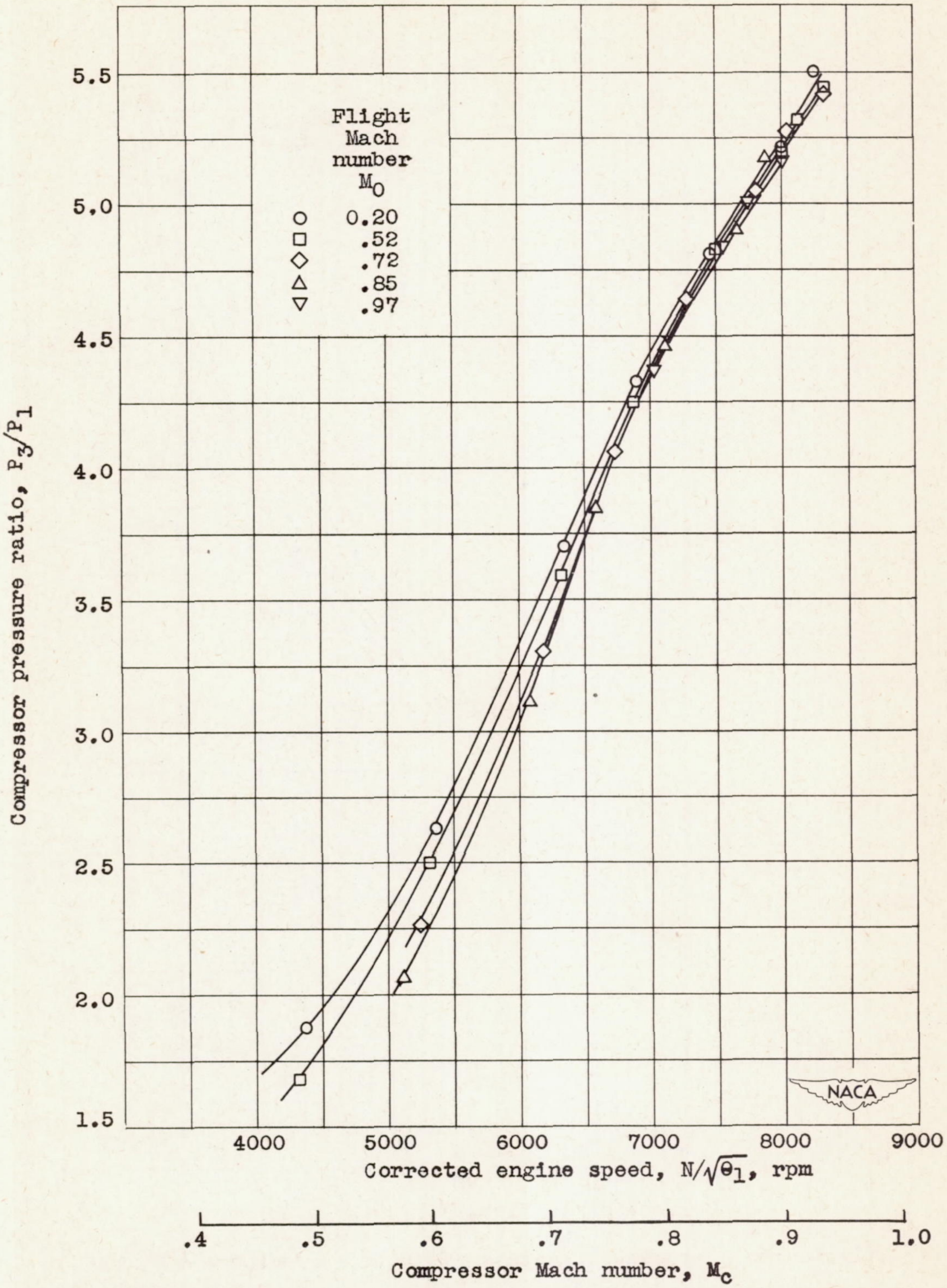
(b) Relation of corrected air flow to corrected engine speed.

Figure 8. - Continued. Effect of altitude on compressor operating line. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.



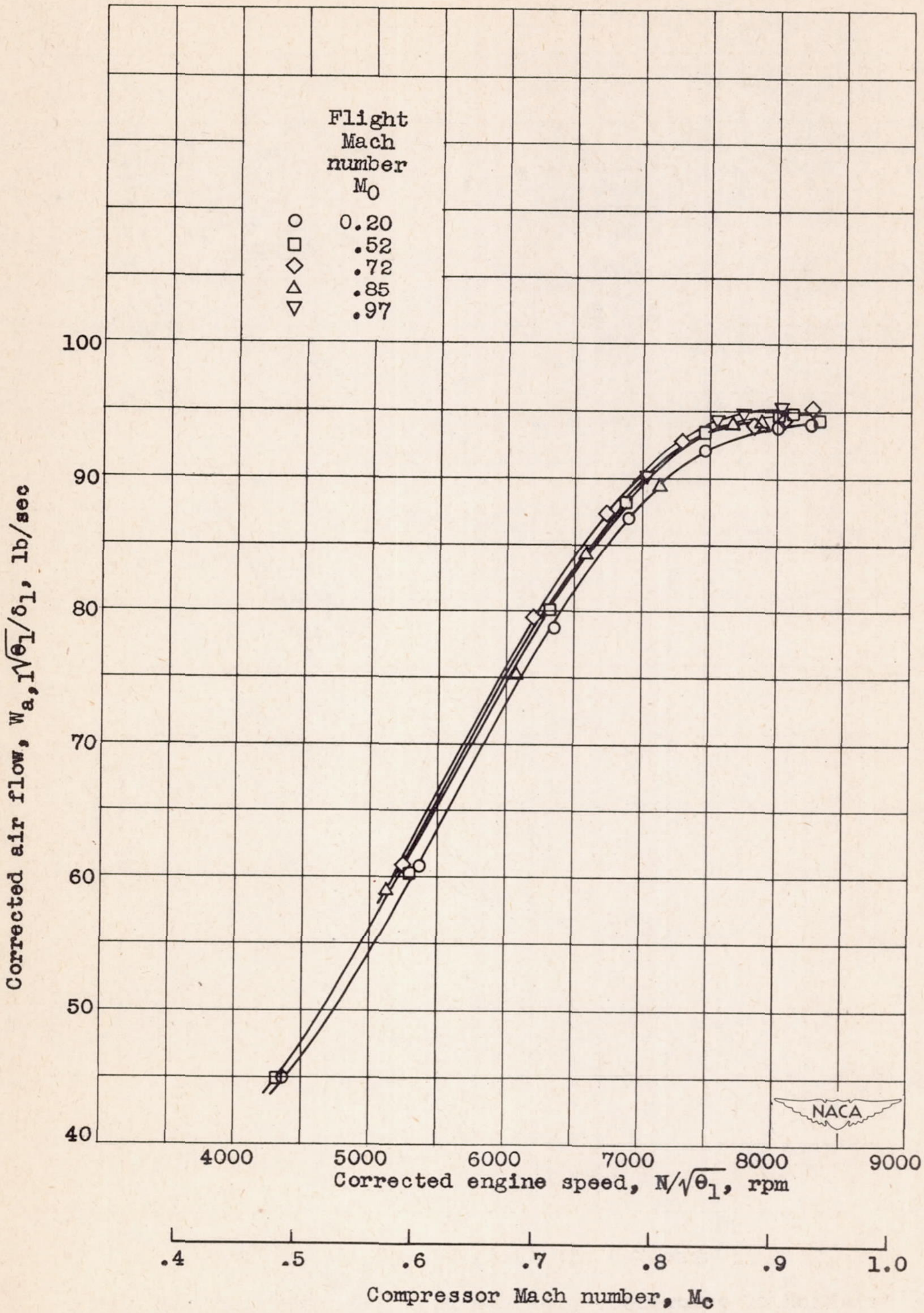
(c) Relation of compressor pressure ratio to corrected air flow.

Figure 8. - Concluded. Effect of altitude on compressor operating line. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.



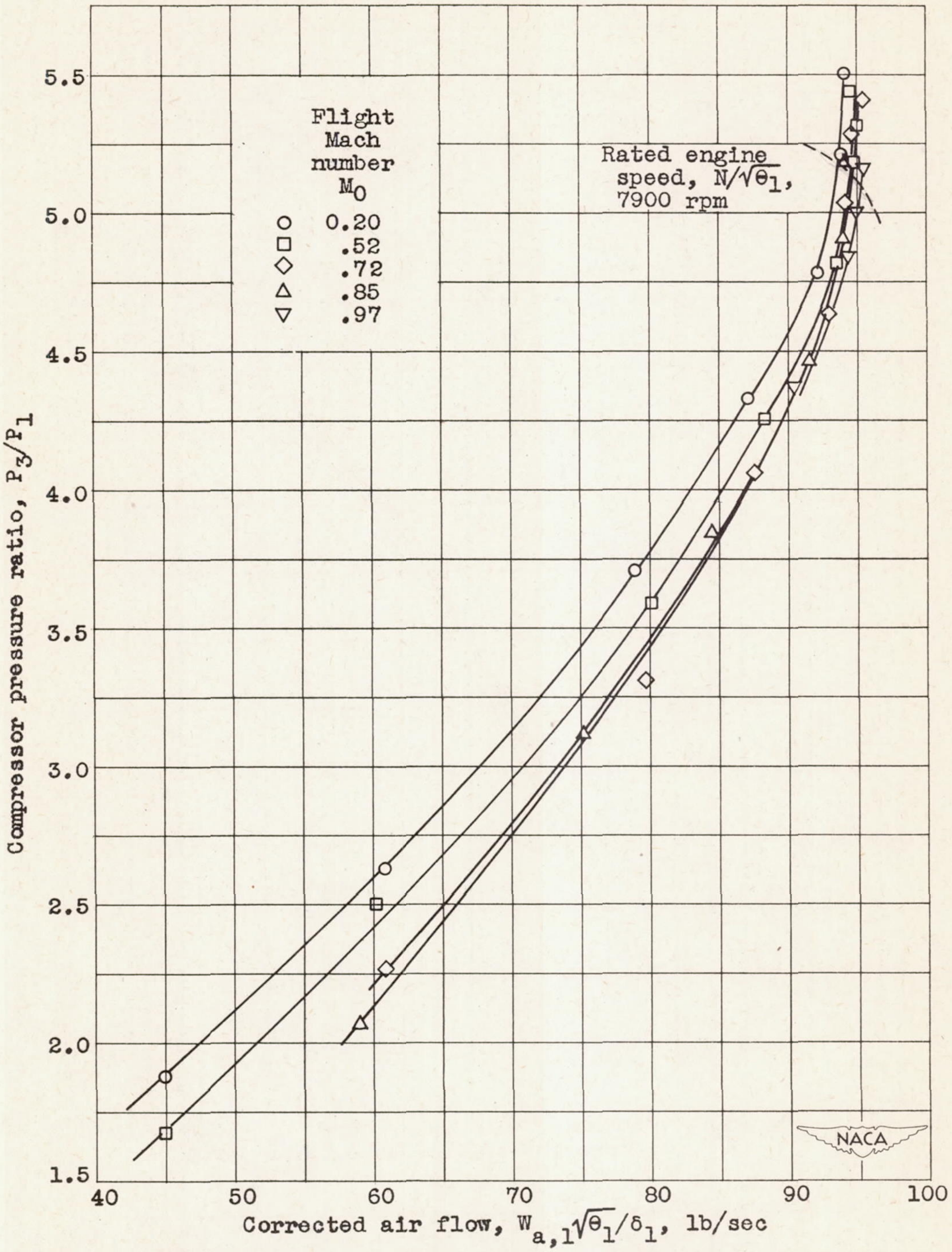
(a) Relation of compressor pressure ratio to corrected engine speed.

Figure 9. - Effect of flight Mach number on compressor operating line. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches.



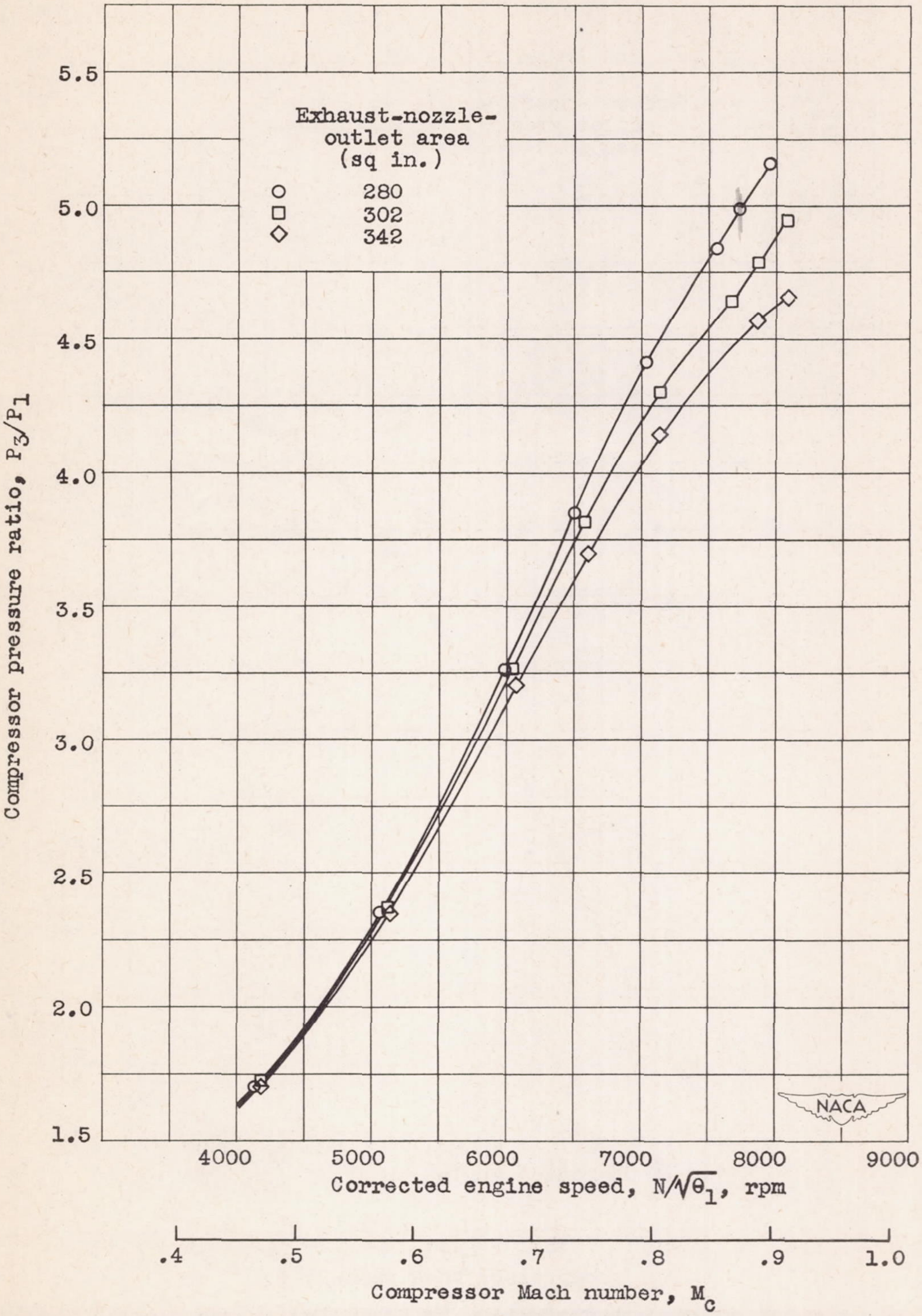
(b) Relation of corrected air flow to corrected engine speed.

Figure 9. - Continued. Effect of flight Mach number on compressor operating line. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches.



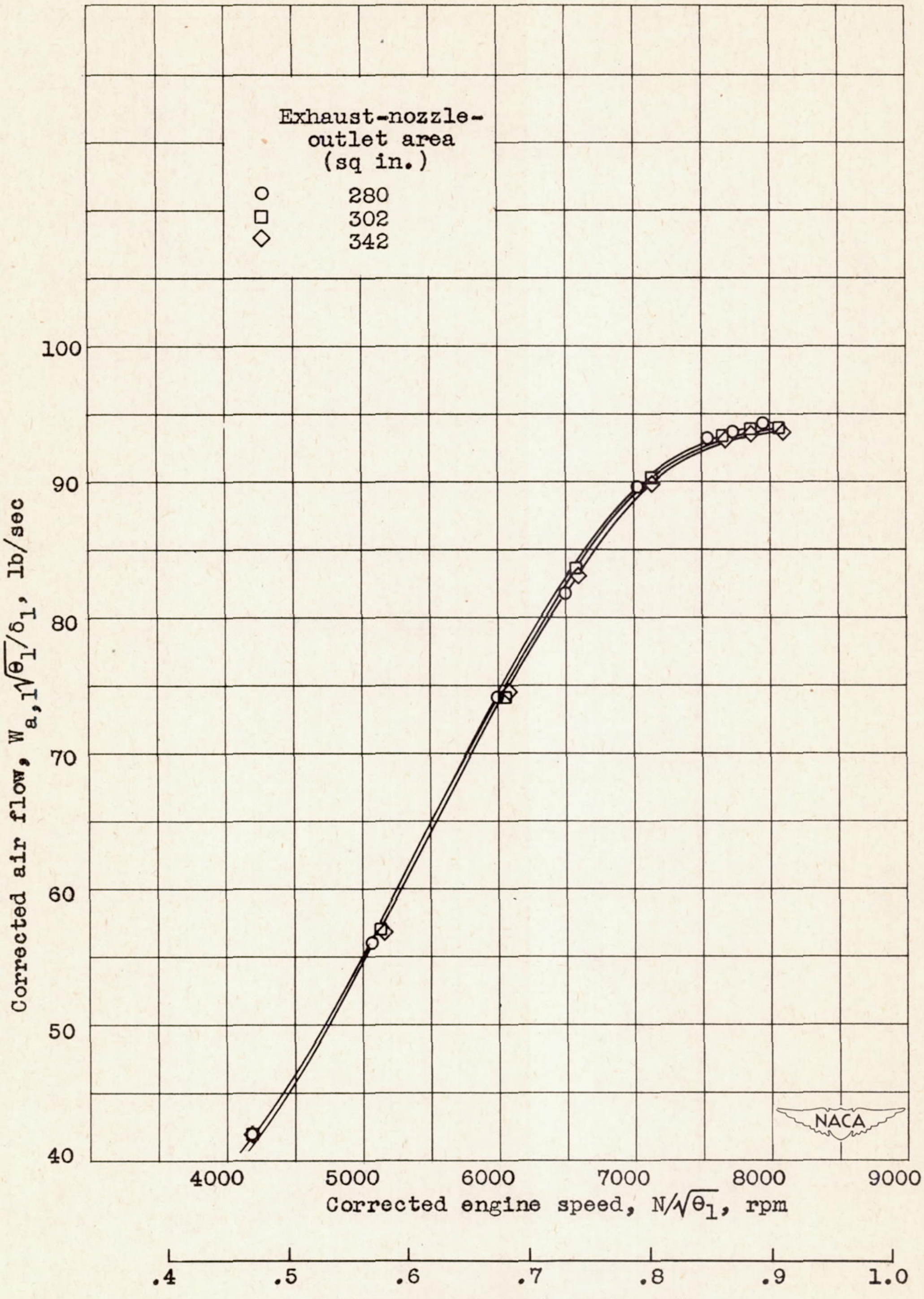
(c) Relation of compressor pressure ratio to corrected air flow.

Figure 9. - Concluded. Effect of flight Mach number on compressor operating line. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches.



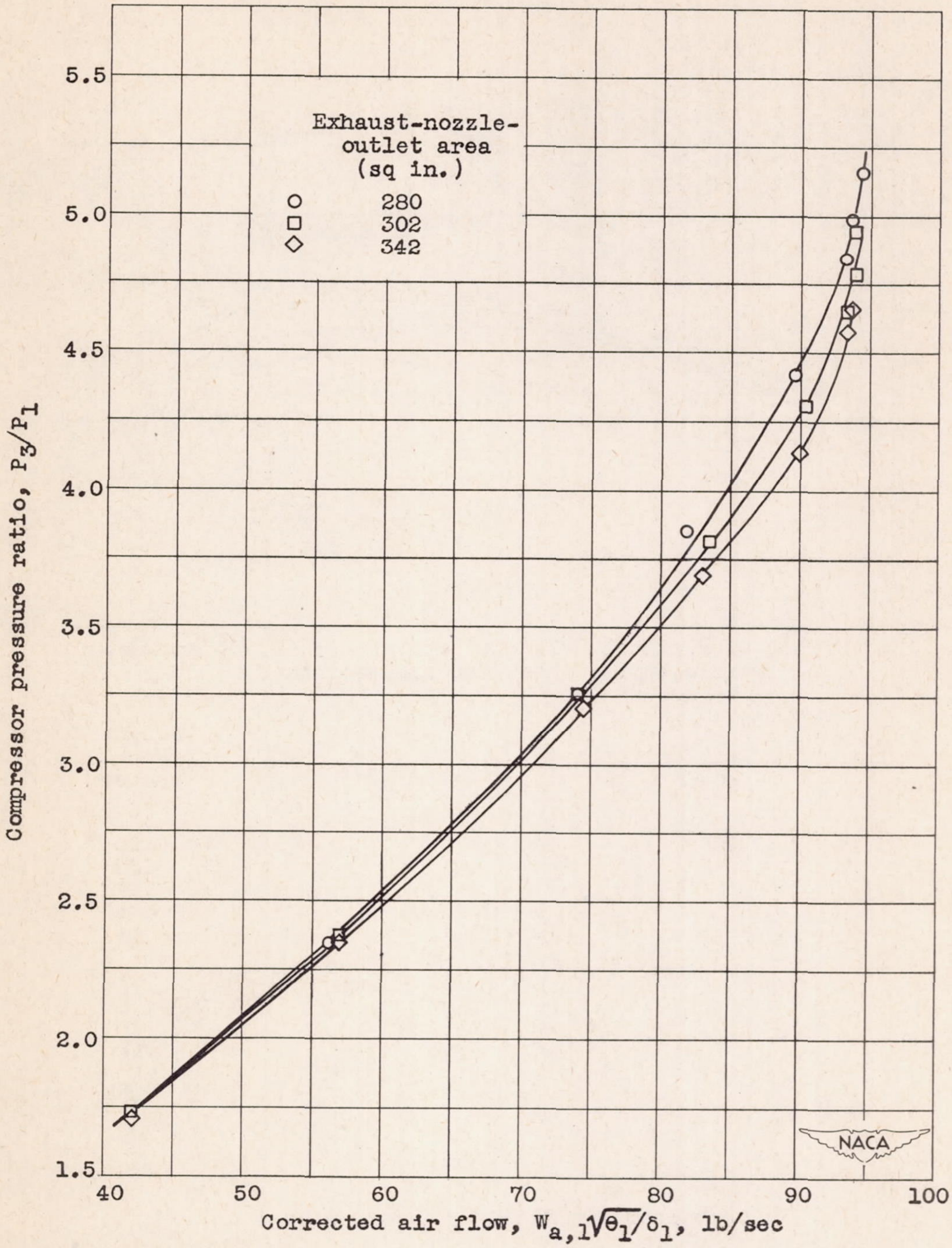
(a) Relation of compressor pressure ratio to corrected engine speed.

Figure 10. - Effect of exhaust-nozzle-outlet area on compressor operating line. Altitude, 5000 feet; flight Mach number, 0.20.



(b) Relation of corrected air flow to corrected engine speed.

Figure 10. - Continued. Effect of exhaust-nozzle-outlet area on compressor operating line. Altitude, 5000 feet; flight Mach number, 0.20.



(c) Relation of compressor pressure ratio to corrected air flow.

Figure 10. - Concluded. Effect of exhaust-nozzle-outlet area on compressor operating line. Altitude, 5000 feet; flight Mach number, 0.20.

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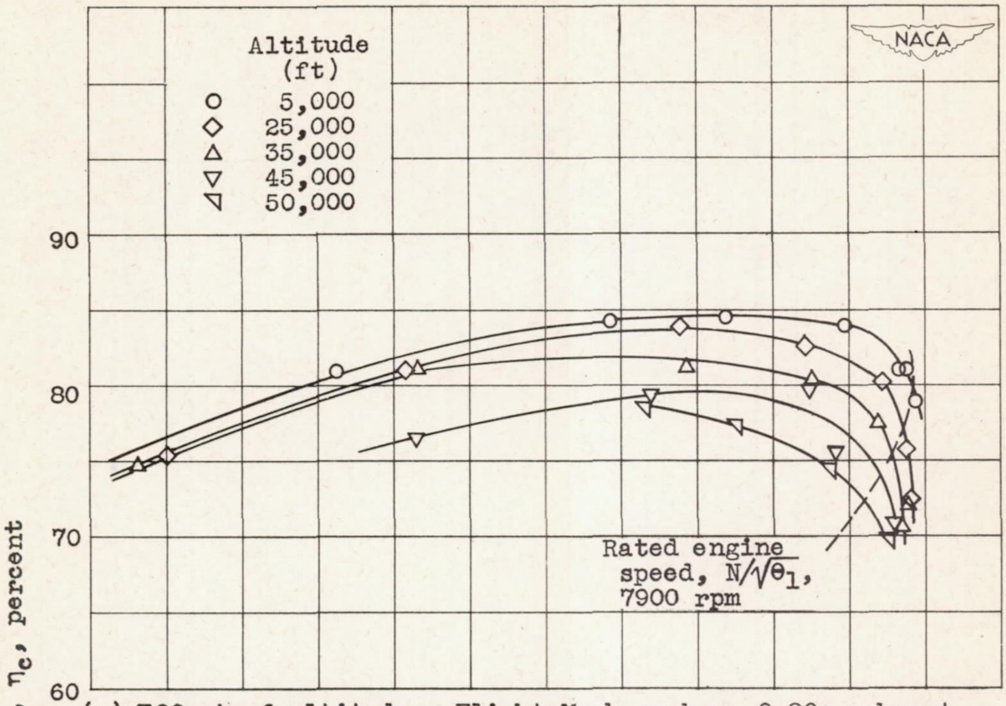
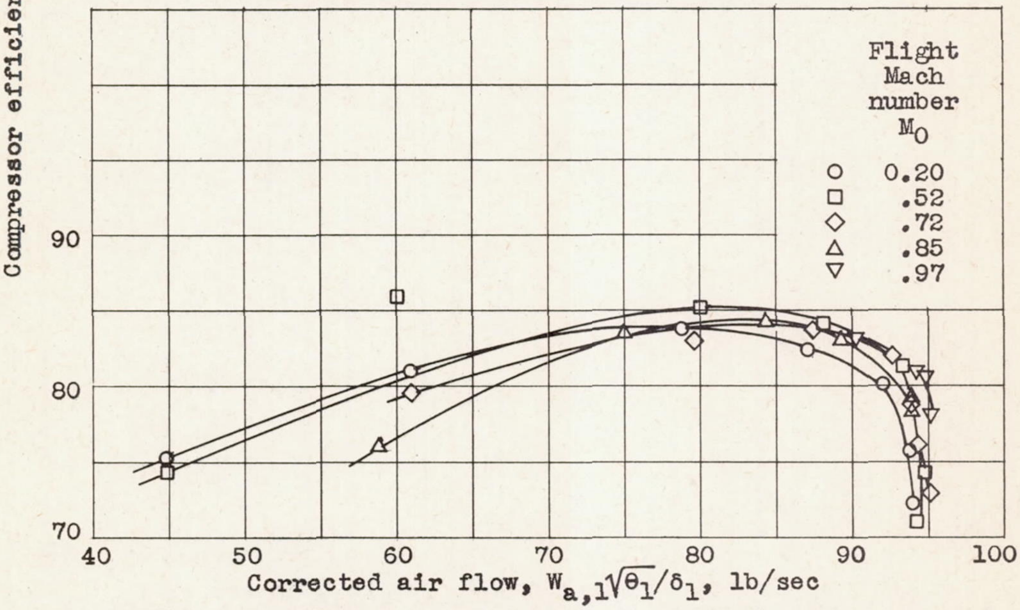
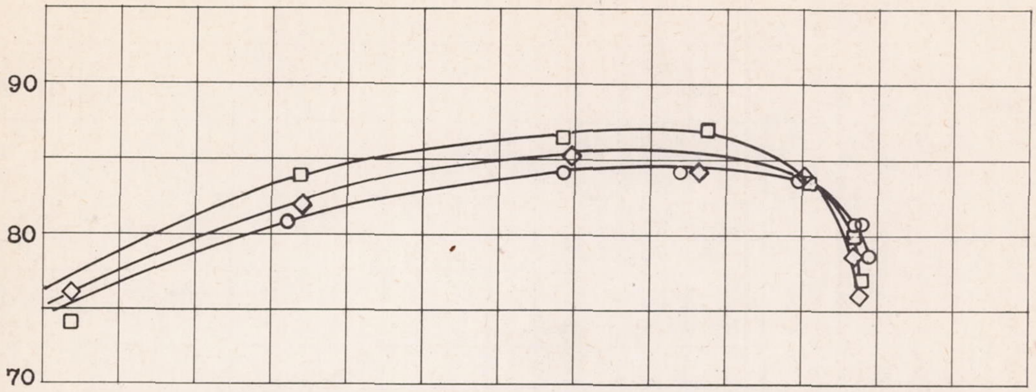


(a) Effect of altitude. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.

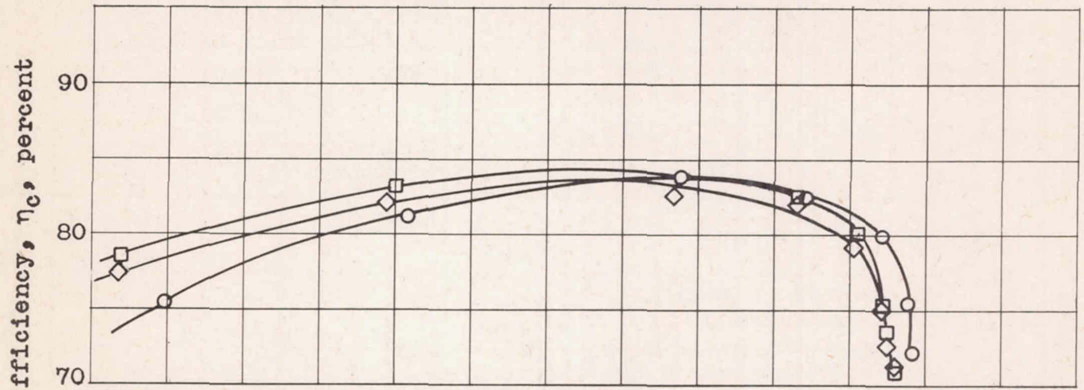


(b) Effect of flight Mach number. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches.

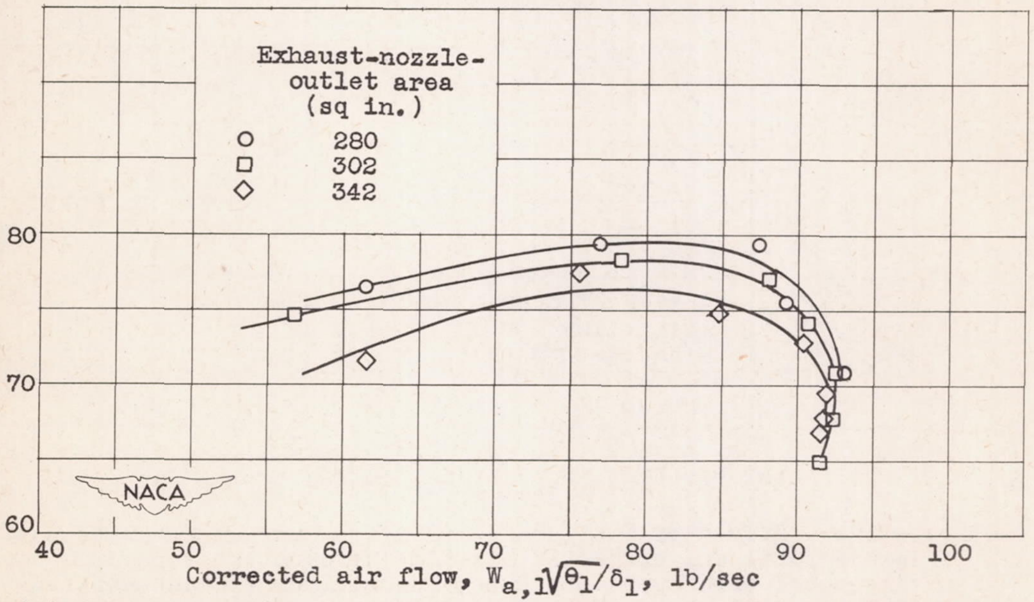
Figure 11. - Relation between compressor efficiency and corrected air flow.



(c) Effect of exhaust-nozzle-outlet area. Altitude, 5000 feet; flight Mach number, 0.20.



(d) Effect of exhaust-nozzle-outlet area. Altitude, 25,000 feet; flight Mach number, 0.20.



(e) Effect of exhaust-nozzle-outlet area. Altitude, 45,000 feet; flight Mach number, 0.20.

Figure 11. - Concluded. Relation between compressor efficiency and corrected air flow.

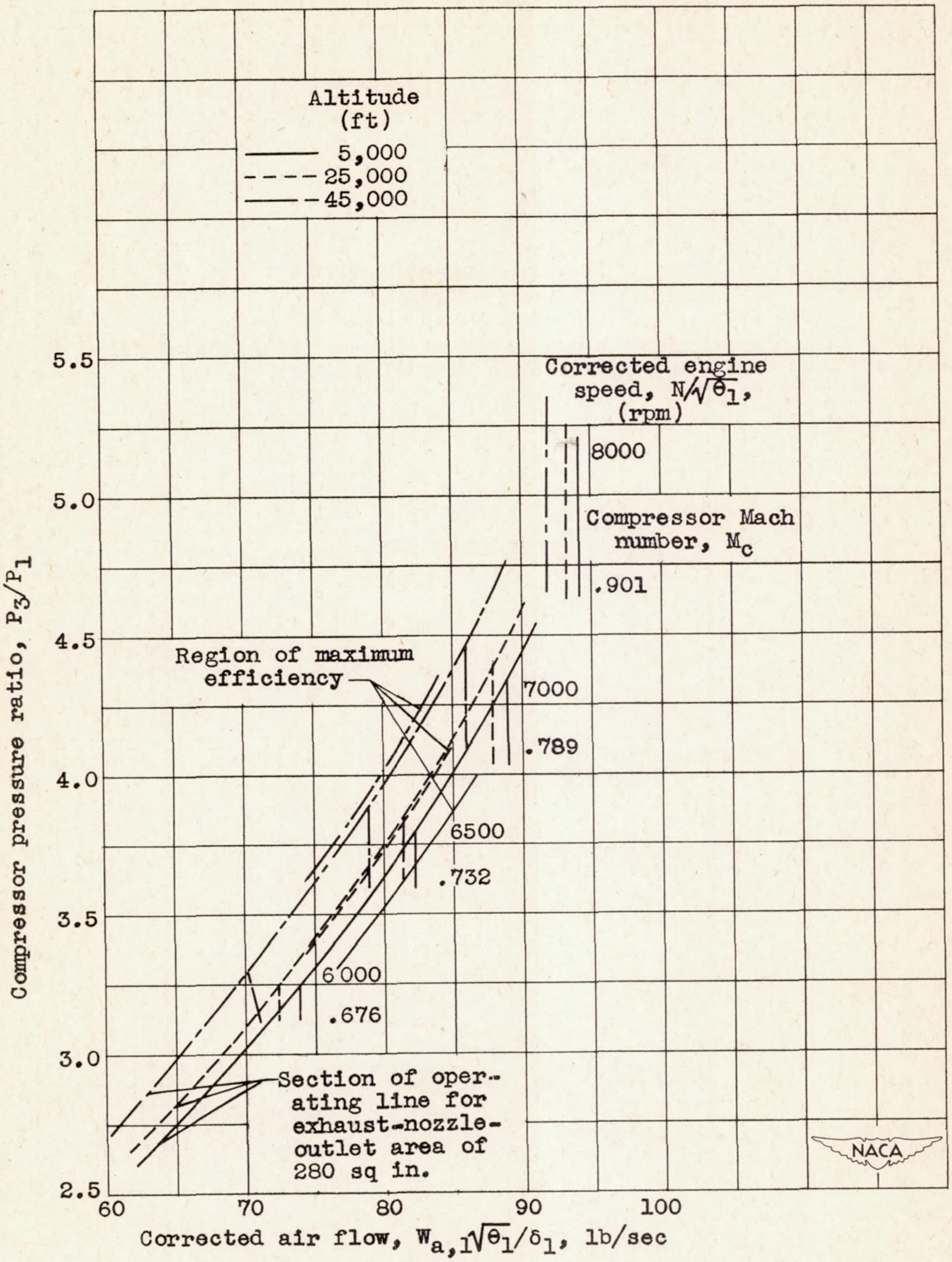
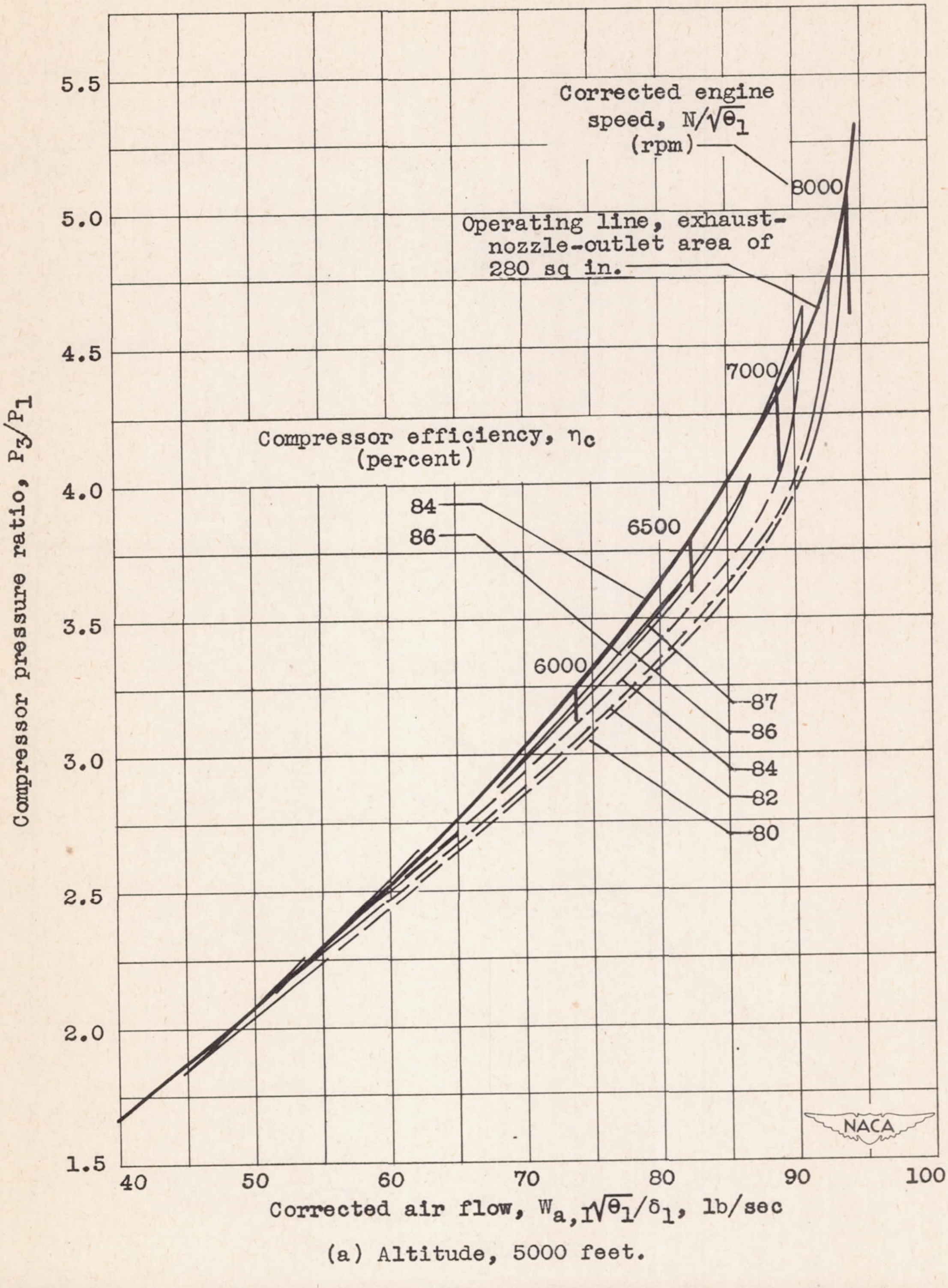
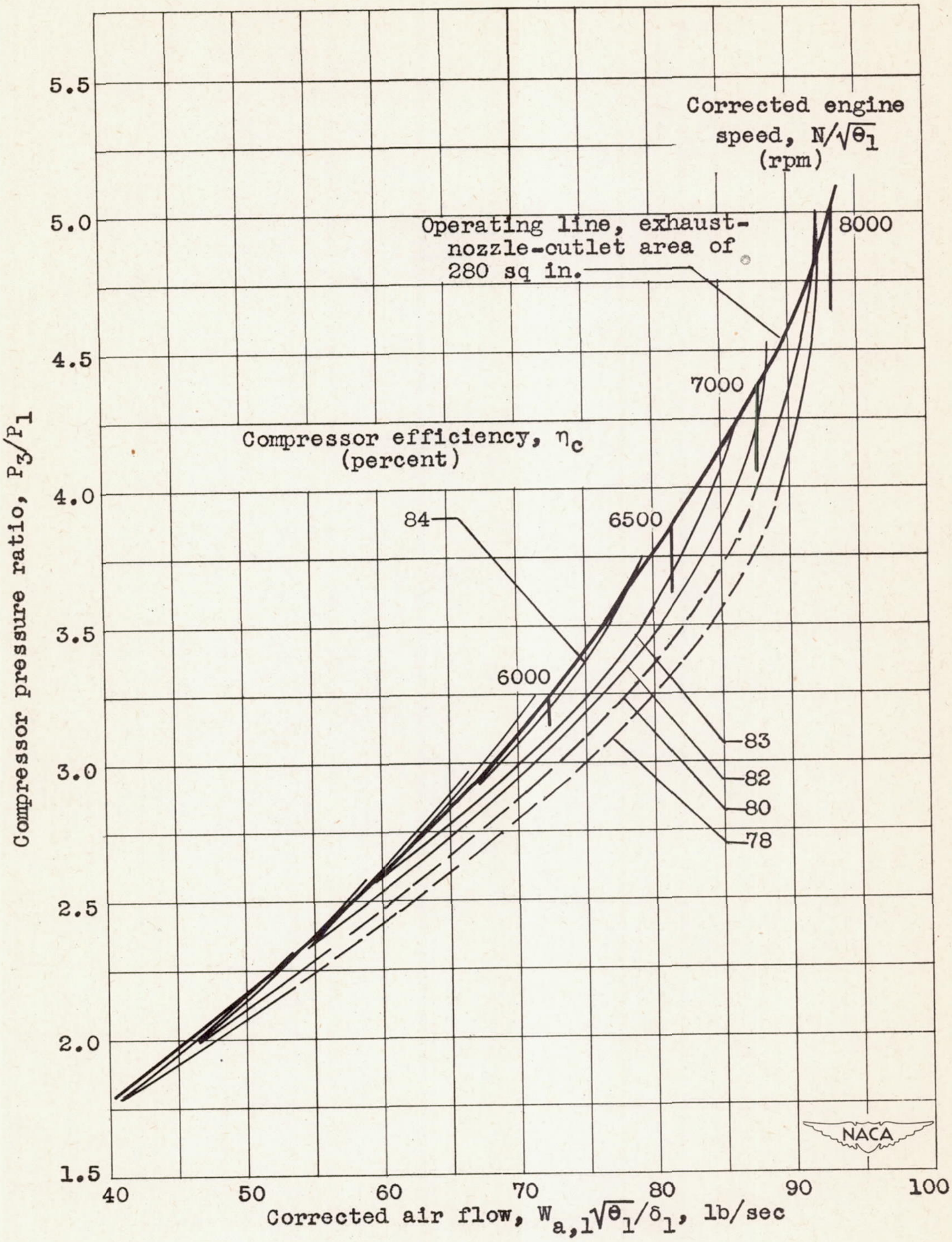


Figure 12. - Effect of altitude on relation between compressor pressure ratio and corrected air flow at constant corrected engine speed with operating lines for minimum exhaust-nozzle-outlet area and lines of region of maximum efficiency superimposed. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 to 342 square inches.



(a) Altitude, 5000 feet.

Figure 13. - Effect of altitude on compressor-performance characteristics with operating line for minimum exhaust-nozzle-outlet area superimposed. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 to 342 square inches.



(b) Altitude, 25,000 feet.

Figure 13. - Continued. Effect of altitude on compressor-performance characteristics with operating line for minimum exhaust-nozzle-outlet area superimposed. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 to 342 square inches.

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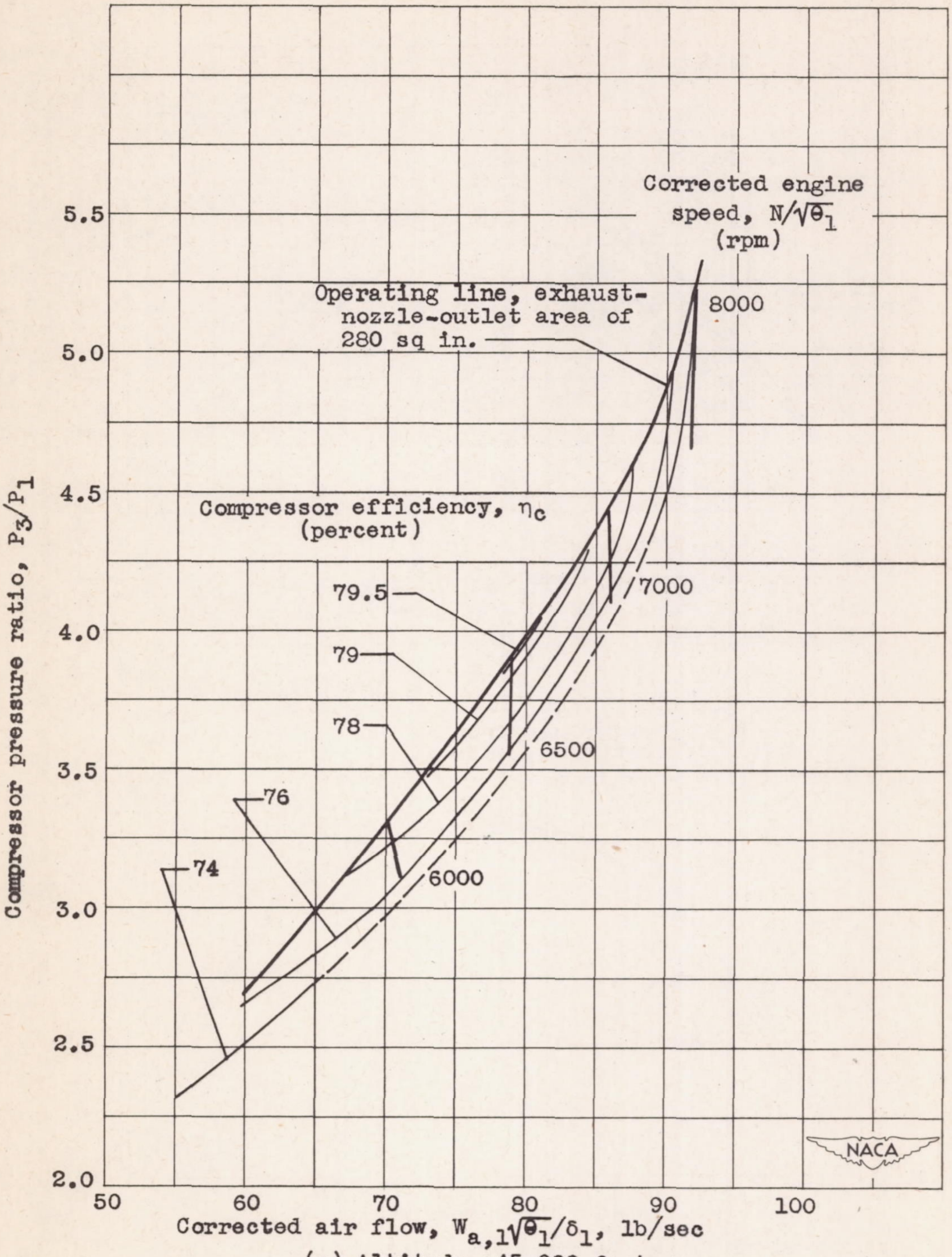
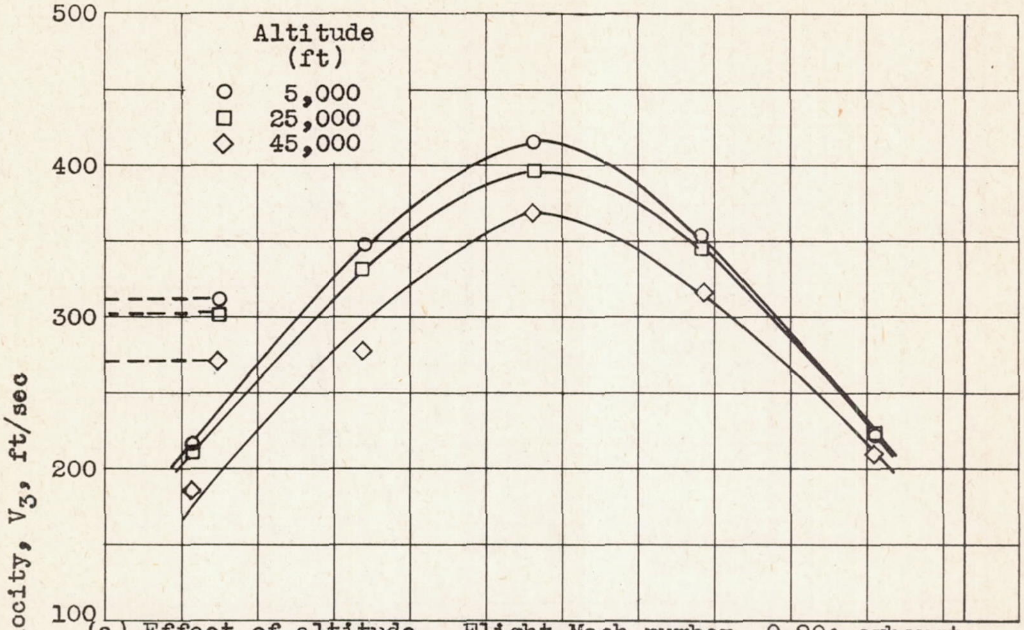
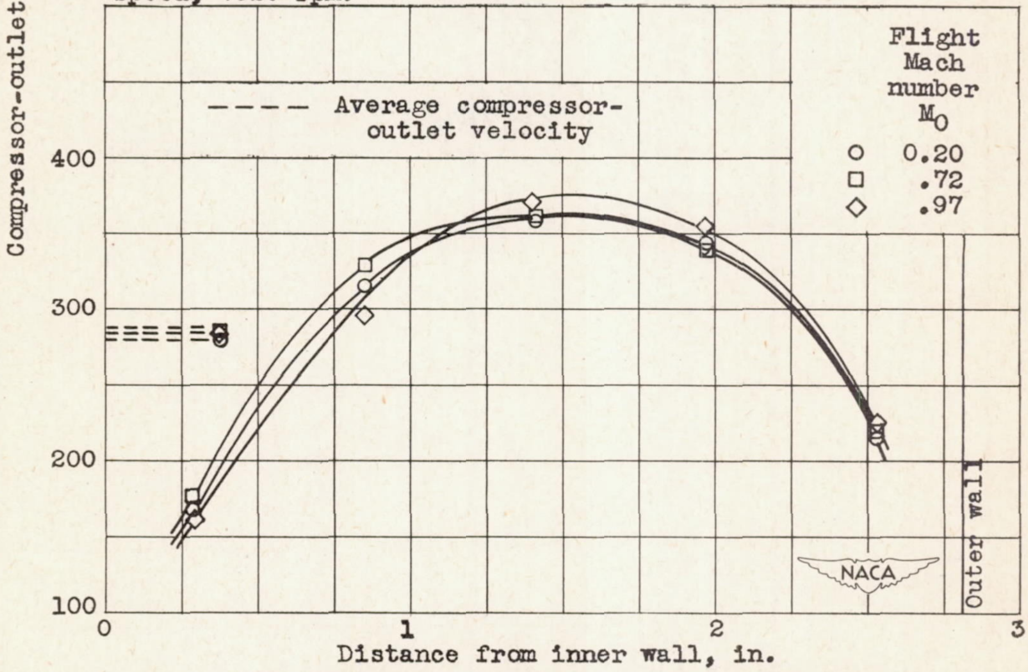


(c) Altitude, 45,000 feet.

Figure 13. - Concluded. Effect of altitude on compressor-performance characteristics with operating line for minimum exhaust-nozzle-outlet area superimposed. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 to 342 square inches.

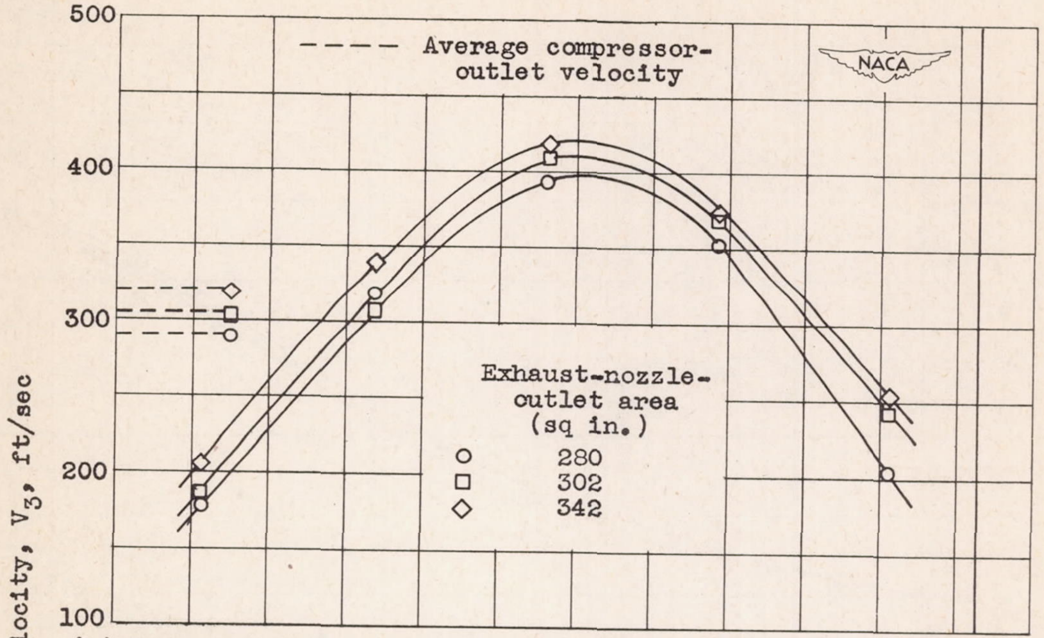


(a) Effect of altitude. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches; corrected engine speed, 7520 rpm.

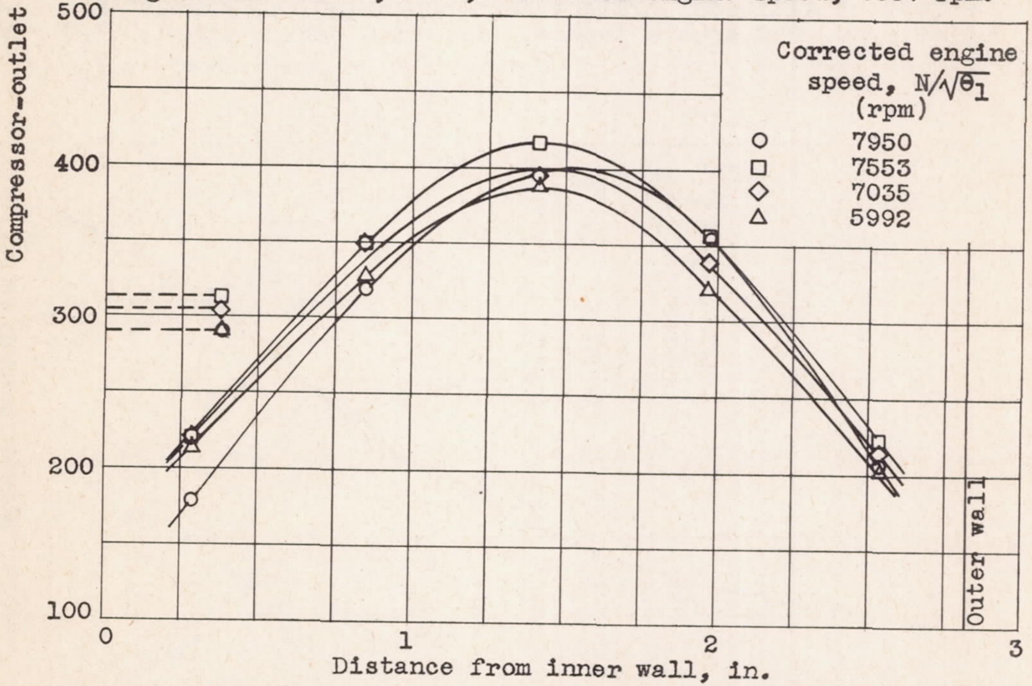


(b) Effect of flight Mach number. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches; corrected engine speed, 8026 rpm.

Figure 14. - Velocity profile at compressor outlet.



(c) Effect of exhaust-nozzle-outlet area. Altitude, 5000 feet; flight Mach number, 0.20; corrected engine speed, 8037 rpm.



(d) Effect of engine speed. Altitude, 5000 feet; flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.

Figure 14. - Concluded. Velocity profile at compressor outlet.

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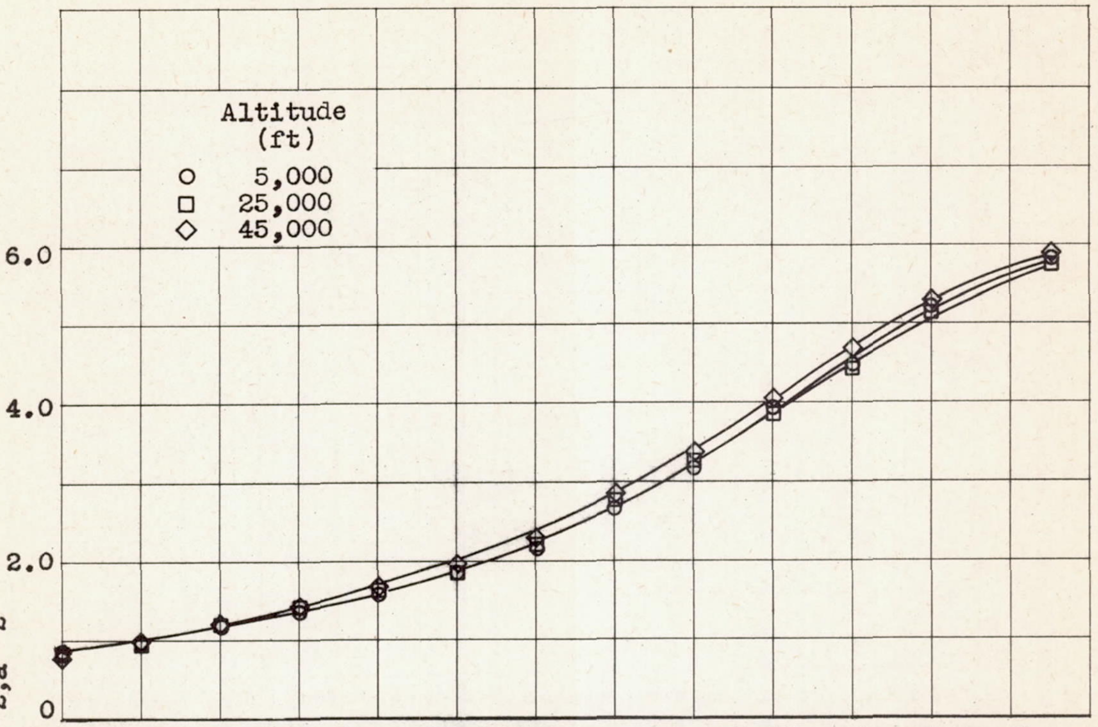
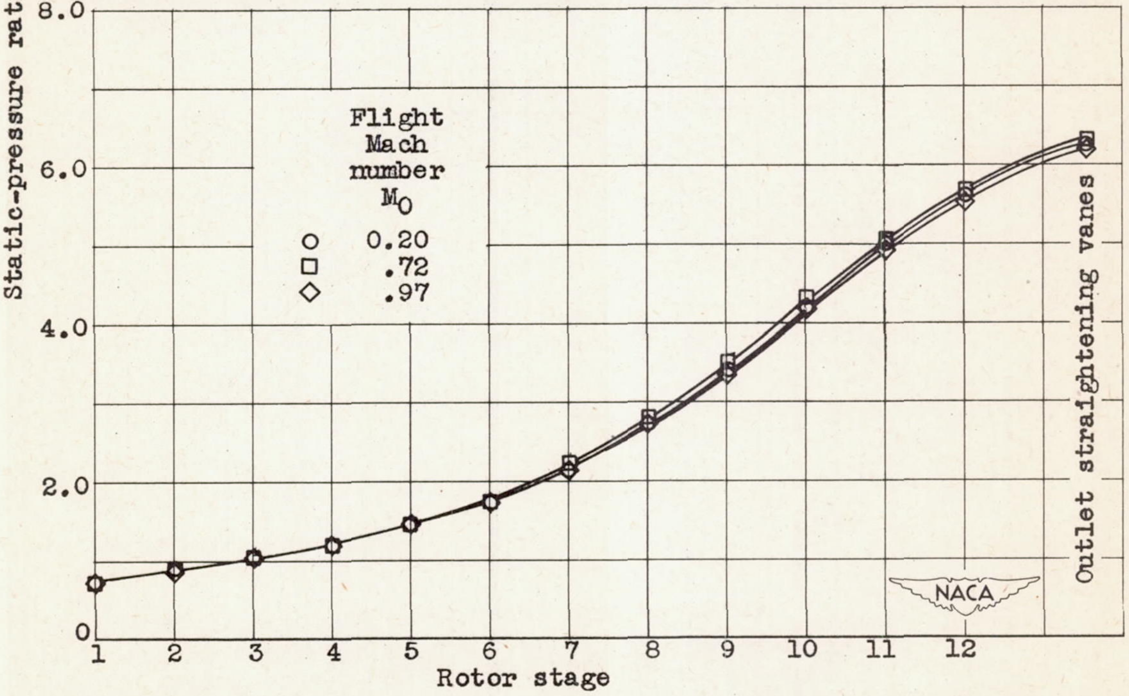
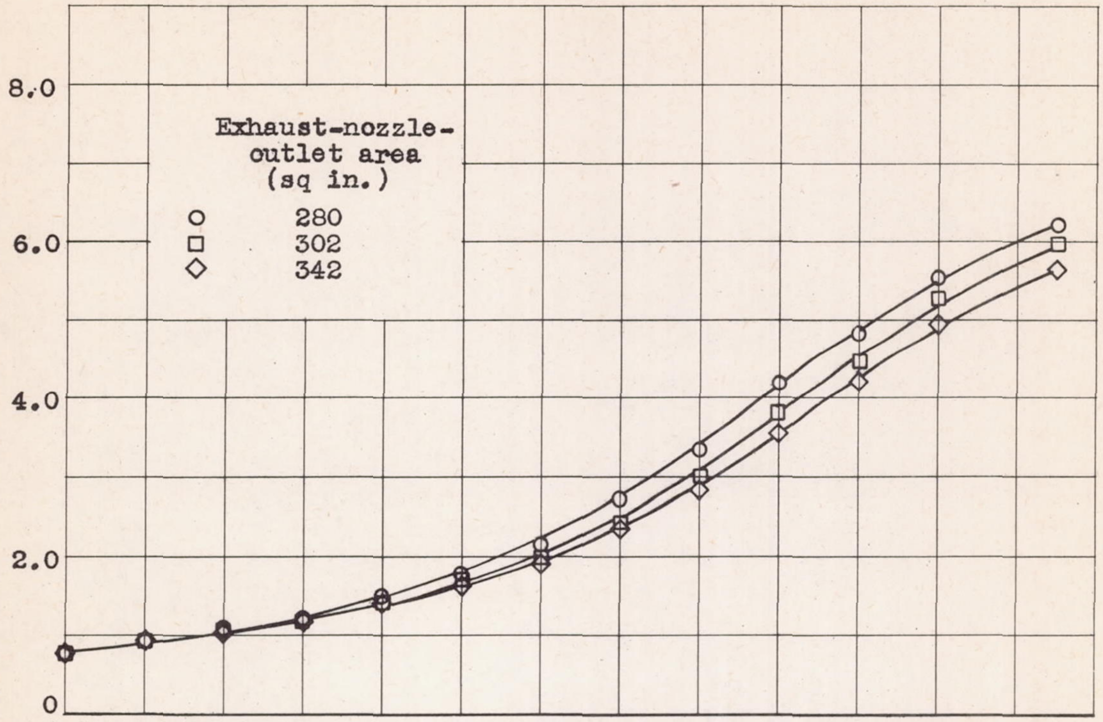


(a) Effect of altitude. Flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches; corrected engine speed, 7520 rpm.

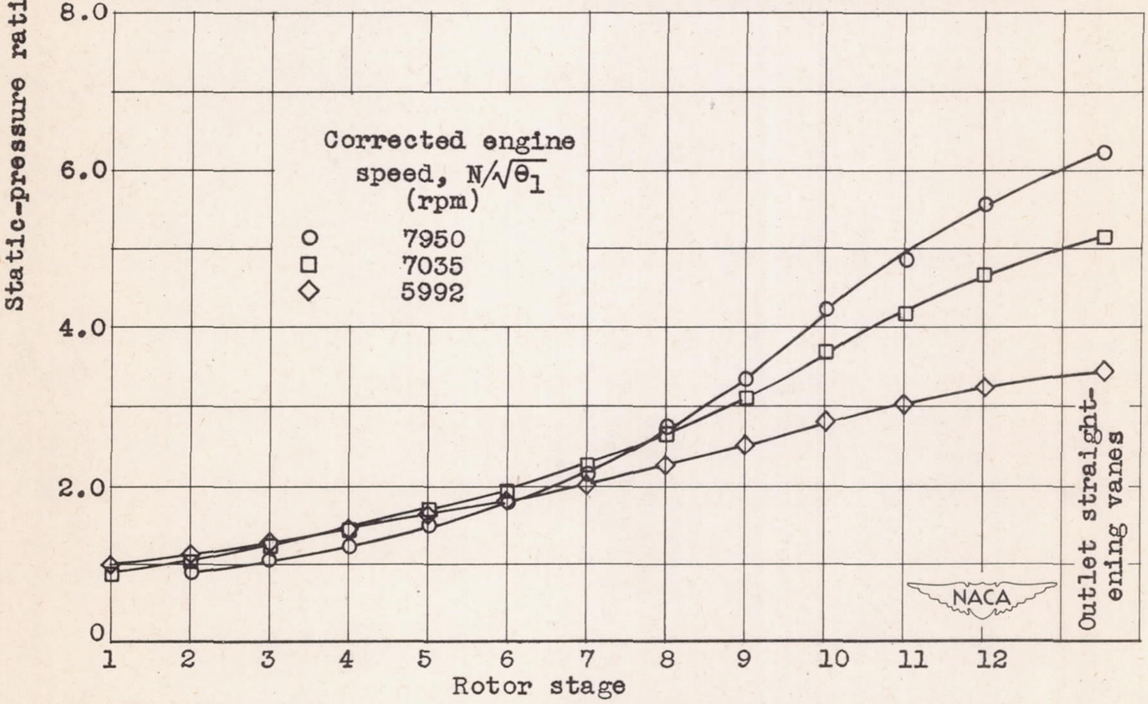


(b) Effect of flight Mach number. Altitude, 25,000 feet; exhaust-nozzle-outlet area, 280 square inches; corrected engine speed, 8026 rpm.

Figure 15. - Compressor-rotor-stage static-pressure-ratio profile.



(c) Effect of exhaust-nozzle-outlet area. Altitude, 5000 feet; flight Mach number, 0.20; corrected engine speed, 8037 rpm.



(d) Effect of engine speed. Altitude, 5000 feet; flight Mach number, 0.20; exhaust-nozzle-outlet area, 280 square inches.

Figure 15. - Concluded. Compressor-rotor-stage static-pressure-ratio profile.

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