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RESEARCH MEMORANDUM

COMPRESSOR PERFORMANCE CHARACTERISTICS OF A PYTHON TURBINE-PROPELLER ENGINE INVESTIGATED IN ALTITUDE WIND TUNNEL

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COMPRESSOR PERFORMANCE CHARACTERISTICS OF A PYTHON TURBINE-PROPELLER ENGINE INVESTIGATED IN ALTITUDE WIND TUNNEL

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SUMMARY

An investigation has been conducted in the NACA Lewis altitude wind tunnel to determine the performance of the Python turbine-propeller engine. Compressor-performance data were obtained for a range of simulated altitudes at a single cowl-inlet ram pressure ratio while the engine was run over its full operable range of engine speeds. At each engine speed, data were obtained over a range of compressor pressure ratios by extracting various amounts of power from the turbine.

Over the range of conditions investigated at each altitude, the variation in compressor efficiency was small, which allowed the compressor a wide range of operation close to optimum efficiency. At constant corrected engine speed and turbine-inlet temperature, compressor efficiency decreased approximately 0.04 for an increase in altitude from 10,000 to 40,000 feet. The maximum compressor efficiency obtained was 0.804 and occurred at an altitude of 10,000 feet, a corrected air flow of 42.8 pounds per second, and a compressor pressure ratio of 3.8, which corresponds to a corrected engine speed of 7000 rpm and a turbine-outlet temperature of 1264° R.

The velocity profile at the compressor outlet was in general unaffected by changes in altitude, turbine-inlet temperature, or engine speed.

INTRODUCTION

An investigation to determine the static and dynamic performance characteristics at altitude of a Python turbine-propeller engine has been conducted in the NACA Lewis altitude wind tunnel.

As part of this investigation, performance data for the compressor operating as an integral component of the engine were obtained over a range of altitudes and engine speeds at a single cowl-inlet ram pressure ratio; at each engine speed, data were obtained over a range of compressor pressure ratios by extracting various amounts of power from the turbine.

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The performance of the 14-stage axial-flow compressor is presented graphically to show the effects of variations in compressor pressure ratio and in engine speed and to show a general trend with altitude. Compressor performance deterioration caused by oil and dust accumulation on the compressor blades is discussed. A complete tabulation of the compressor performance data is also presented.

APPARATUS AND PROCEDURE

Engine

The Python turbine-propeller production engine has a static sea-level nominal rating of 3670 shaft horsepower and 1150 pounds of jet thrust at an engine speed of 8000 rpm and a turbine-outlet temperature of 590° C (1554° R). The maximum diameter of the engine is $54\frac{1}{2}$ inches and the net dry weight is 3150 pounds. The main components of the engine include propeller-reduction gearing, a 14-stage axial-flow compressor, 11 combustors spaced around the compressor casing, a two-stage turbine, a tail pipe, and a fixed-area exhaust nozzle.

Compressor

The compressor has an air-flow capactiy of approximately 54.2 pounds per second and a pressure ratio of 5.1 when the engine is operating at rated sea-level static conditions.

Air enters the engine through an inlet duct, which forms an annulus around the outer diameter of the engine (fig. 1) and is located approximately 60 inches aft of the rear propeller. A screen installed in this annulus prevents foreign objects from entering the compressor. From the inlet annulus, the air-flow passage is divided into 11 convergent throats and is turned inward

180° to the entry annulus of the compressor. The air passes forward through the compressor into the diffuser annulus, where it is turned outward 90° with the aid of guide vanes; the annulus is then divided
2059 into 11 combustion-chamber-inlet elbows, where the air is turned rearward 90° with the aid of guide vanes and passes into the combustion chambers.

To assist in starting and accelerating to an operable engine speed, air is bled from the compressor outlet to the atmosphere through a blow-off valve. During normal operation this blow-off valve remains closed. Air is bled from the fifth stage of the compressor to cool the rear bearing and the rear face of the turbine. Air is bled from the tenth stage to cool the front face of the turbine. Air leakage through labyrinth seals at the compressor outlet is piped back into the tail pipe.

Photographs of the compressor rotor and stator are presented in figures 2 and 3, respectively. The rotor blades of the first five stages are fastened on a uniformly tapered hub, whereas those of the final nine stages are fastened on a constant-diameter hub. The rotor-tip diameter is 20.35 inches through the first five stages and tapers to 17.75 inches at the fourteenth stage. The hub-tip ratios of the first, fifth, and fourteenth stages are about 0.61, 0.74, and 0.85, respectively.

Installation and Instrumentation

The engine was mounted in a wing section that spanned the 20-foot-diameter test section of the altitude wind tunnel (fig. 4). Refrigerated air was supplied to the engine from the tunnel air stream.

Pressures and temperatures were measured by instrumentation installed at several stations throughout the engine (fig. 1). Detail sketches showing the locations of instrumentation at stations 1, 2, 3, and 5 are presented in figures 5, 6, 7, and 8, respectively. Compressor-stage static-pressure wall orifices were located in the planes of the leading edges of the rotor stages throughout the compressor.

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Procedure

Performance data were obtained at an average cowl-inlet ram pressure ratio of 1.03 at pressure altitudes of 10,000, 20,000, 30,000 and 40,000 feet. Engine speed was varied from 6800 to 8000 rpm; at each engine speed, data were obtained over a range of compressor pressure ratio, which was changed by varying turbine-inlet temperature. The minimum engine flight idling speed was approximately 6500 rpm and was regulated by the engine control mechanism, which was preset at sea-level conditions. As altitude was increased to 40,000 feet, the minimum operable engine speed increased to approximately 7200 rpm. A power check run was made each day at a pressure altitude of 10,000 feet, cowl-inlet ram pressure ratio of 1.03, engine speed of 8000 rpm, and engine-inlet temperature of 59° F for four turbine temperatures. Preceding the power check run each day, kerosene was sprayed into the compressor inlet for 30 minutes while the engine was operating at idle speed in an attempt to clean the compressor-blade surfaces.

For all flight conditions except those of the power check runs, refrigerated air was supplied to the engine at the standard NACA temperature for each flight condition except that the minimum air temperature was about -25° F.

The symbols and the methods of calculation are given in the appendix.

RESULTS AND DISCUSSION

The air-flow passage through the engine makes two 180° turns, one ahead and the other aft of the compressor rotor. The engine manufacturer furnished information that the energy loss caused by the turn ahead of the compressor rotor is 18 percent of the compressor-inlet velocity head (station 1) and that the energy loss resulting from the turn aft of the compressor is 34 percent of the compressor-outlet velocity head (station 2). Because of structural limitations of the engine, the compressor-inlet and compressor-outlet stations (stations 1 and 2) had to be so located as to include these energy losses in the pressure and temperature measurements. The inclusion of these losses in the compressor performance resulted in a reduction in compressor efficiency of less than 0.01 for all conditions investigated.

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Deterioration of Compressor Performance

Oil leakage from the accessory gear box could enter the compressor inlet and provide a sticky surface on the compressor blades and turning vanes, which permitted an accumulation of foreign particles from the tunnel air stream on these surfaces. The use of kerosene sprayed into the compressor-inlet as a cleaning solution at the most retarded but did not eliminate the accumulation of foreign particles on the compressor surfaces. This accumulation of foreign particles resulted in a progressive decrease in compressor performance with increasing engine operational time. The decrease in compressor performance is shown in figure 9 for an engine operational time interval in the altitude wind tunnel of approximately 32 hours. At each altitude and engine speed as engine operation time increased, air flow and compressor pressure ratio decreased for a given turbine-inlet temperature. The reduction in air flow required a decrease in engine fuel flow in order that the constant turbine-inlet temperature could be maintained. For this deterioration, however, the value of compressor efficiency remained unchanged. In order for the efficiency to remain constant, the actual work per pound of air of the compressor must decrease by the same ratio that the ideal work per pound of air decreases. An explanation of this characteristic is that in one or several of the leading stages of the compressor, the efficiency may decrease in such a manner as to improve the existing conditions of the air flow at some of the latter stages, with the over-all result that the compressor efficiency remained approximately constant. The loss in air flow and compressor pressure ratio with increasing engine operational time caused substantial reductions in shaft horsepower at a given turbine-inlet temperature.

The deterioration effect was determined only for the rated engine speed at the four altitudes investigated and the information is insufficient to permit adjusting the data for all engine speeds. Because of this deterioration, quantitative evaluation of variations in performance cannot be made for various altitudes. For any given altitude except 10,000 feet, however, the performance data were obtained over an engine operational time interval of $3\frac{1}{2}$ hours or less. Performance data for the rated engine speed at an altitude of 10,000 feet were obtained 10 hours earlier than the performance data for the other engine speeds at this altitude. The maximum change in compressor characteristics for the time interval of $3\frac{1}{2}$ hours is a 1-percent decrease in corrected air flow and in compressor pressure ratio while the compressor efficiency remained approximately constant. Quantitative evaluation of variations in performance can therefore be individually made for each altitude.

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Compressor Performance

Compressor efficiency. - Compressor efficiency is presented in figure 10 as a function of corrected turbine-inlet temperature for the four altitudes investigated. The turbine-inlet temperature is used as the independent variable because at constant engine speed with a choked turbine nozzle the temperature is proportional to the square of the compressor-outlet total pressure and thus provides a connecting link for the compressor performance with engine and turbine performance. In general, the change in compressor efficiency was relatively small over the range of conditions investigated at each altitude, which allows the compressor a wide range of operation near optimum efficiency. For all altitudes and flight conditions investigated, the compressor efficiency variation was only from 0.804 to 0.695. The maximum compressor efficiency of 0.804 was obtained at an altitude of 10,000 feet, a corrected air flow of 42.8 pounds per second, and a compressor pressure ratio of 3.8, which corresponds to a corrected engine speed of 7000 rpm and a turbine-outlet temperature of 1264° R. At each altitude, the decrease in compressor efficiency that accompanied a change from minimum to maximum engine speed at constant corrected turbine-inlet temperature varied between 0.03 and 0.06; at any given engine speed the trend was for an efficiency rise of from 0.01 to 0.04 as turbine-inlet temperature was varied from minimum to the maximum allowable value.

The data in figure 10 are cross-plotted in figure 11 to illustrate the effect of altitude on compressor efficiency at constant corrected engine speed and turbine-inlet temperature. At constant values of corrected engine speed and turbine-inlet temperature, compressor efficiency decreased a maximum of only 0.04 for an altitude increase from 10,000 to 40,000 feet. Because compressor performance deterioration did not affect compressor efficiency, the loss in efficiency with increasing altitude may be largely attributed to the Reynolds number effect on the compressor performance.

Compressor performance maps. - Compressor performance maps with contours of constant compressor efficiency and lines of constant corrected turbine-inlet temperature superimposed are presented in figure 12 for altitudes of 10,000, 20,000, 30,000, and 40,000 feet. If the corrected turbine-inlet temperature is decreased at constant corrected engine speed, the corrected air flow increases, with the

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increase in air flow being greater at low engine speeds. A decrease in corrected engine speed at constant corrected turbine-inlet temperature results in decreases in corrected air flow and in compressor pressure ratio. Because the altitude effect and compressor deterioration effect are inseparable, it is not possible to accurately evaluate the shift in lines of constant corrected engine speed and contours of constant compressor efficiency with changes in altitude. At constant corrected engine speed and turbine-inlet temperature the general trend of the compressor performance with increase in altitude is a decrease in air flow and in compressor pressure ratio.

Velocity and Static-Pressure Profiles

The velocity profiles at the compressor outlet are shown in figure 13. Figure 13(a) represents the compressor-outlet velocity profile for a single engine and flight condition. Individual radial pressure measurements for rakes equally spaced circumferentially from a radial center line through the compressor-outlet passage have been averaged. Figures 13(b) to 13(d) represent the velocity profiles at the compressor outlet for various operating conditions. In every case the velocity is lower at the inner wall, which may be caused by the elbow preceding this station. The data indicated no general effect on the velocity profile with variations in altitude, corrected turbine-inlet temperature, or corrected engine speed.

The rotor-stage static-pressure ratios for ranges of altitude, corrected turbine-inlet temperature, and corrected engine speed are presented in figure 14.

A complete tabulation of compressor performance data is presented in table I and compressor performance deterioration data in table II.

SUMMARY OF RESULTS

From an investigation of a Python turbine-propeller engine in the NACA Lewis altitude wind tunnel over a range of simulated altitudes and at a cowl-inlet ram pressure ratio of 1.03, the following results relating to the compressor were obtained:

1. The variation in compressor efficiency was small for all operating conditions investigated at each altitude, thereby permitting the compressor a wide range of operation close to optimum efficiency.

2. Increasing altitude from 10,000 to 40,000 feet at a given corrected engine speed decreased compressor efficiency approximately 0.04 for all corrected turbine-inlet temperatures. This loss in compressor efficiency with increasing altitude may be largely attributed to the Reynolds number effect on the compressor performance.

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3. The maximum compressor efficiency of 0.804 was obtained at an altitude of 10,000 feet, a corrected air flow of 42.8 pounds per second, and a compressor pressure ratio of 3.8, which corresponds to a corrected engine speed of 7000 rpm and a turbine-outlet temperature of 1264° R.

4. In general, the velocity profiles at the compressor outlet were unaffected by changes in altitude, turbine-inlet temperature, and engine speed.

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APPENDIX - CALCULATIONS

Symbols

The following symbols are used in the calculations:

A	area, sq ft
a	stagnation speed of sound in air, ft/sec
c_p	specific heat at constant pressure, Btu/(lb)(°R)
C_T	thermal expansion ratio, ratio of hot exhaust-nozzle area to cold exhaust-nozzle area
D	compressor rotor-blade tip-diameter, ft
ghp	gear horsepower
g	acceleration due to gravity, 32.2 ft/sec^2
H	enthalpy, Btu/lb
M	Mach number
N	engine speed, rpm
P	total pressure, lb/sq ft absolute
p	static pressure, lb/sq ft absolute
R	gas constant, 53.4 ft-lb/(lb)(°R)
shp	shaft horsepower
T	total temperature, °R
T_i	indicated temperature, °R
t	static temperature, °R
U	compressor rotor tip speed, ft/sec
V	velocity, ft/sec
W_a	air flow, lb/sec
W_f	fuel flow, lb/hr

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W_g	gas flow, lb/sec
W_c	compressor leakage air flow, lb/sec
W_{rb}	rear bearing cooling air flow, lb/sec
W_t	turbine cooling air flow, lb/sec
γ	ratio of specific heats
δ_1	ratio of absolute total pressure at cowl inlet to absolute static pressure at NACA standard atmospheric sea-level conditions
θ_1	ratio of absolute total temperature at cowl inlet to absolute static temperature at NACA standard atmospheric sea-level conditions
η_c	adiabatic compressor efficiency

Subscripts:

c	compressor
t	turbine
0	free-stream conditions
1	cowl or compressor inlet
1a	compressor rotor stages
2	compressor outlet
3	turbine inlet
4	turbine outlet
5	tail pipe

Generalizing parameters:

$N/\sqrt{\theta_1}$	corrected engine speed, rpm
T_3/θ_1	corrected turbine-inlet total temperature, $^{\circ}R$
$W_{a,1}\sqrt{\theta_1}/\delta_1$	corrected engine-inlet air flow, lb/sec

Methods of Calculation

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

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

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where 0.85 is the impact recovery factor for the type of thermocouple used.

Temperature measurements were obtained by means of thermocouples at all stations except the turbine inlet, station 3. The high temperature level and difficulty of installing instrumentation at this station would not permit the measurement of temperature with thermocouples. The turbine-inlet total temperature was therefore evaluated in the following manner: The work of the turbine is equal to the work of the compressor plus the work available for the propeller along with the gear losses. In terms of total enthalpy the relation is

$$W_{g,3}(H_3 - H_4) = \frac{550}{778}(shp + ghp) + (W_{a,2}\,H_2 - W_{a,1}\,H_1) \qquad (2)$$

where

$$W_{a,2} = W_{g,3} - \frac{W_f}{3600}$$

and

$$H_3 = c_p T_3$$

The shaft horsepower was obtained from a torquemeter reading. The gear horsepower was obtained from a curve supplied by the engine manufacturer showing gear horsepower as a function of shaft horsepower.

Gas flow. - Gas flow through the tail pipe of the engine may be determined using pressure and temperature measurements at station 5 by the equation

$$W_{g,5} = p_5\, C_T\, A_5 \sqrt{\frac{2\gamma_5 g}{(\gamma_5-1)Rt_5}\left[\left(\frac{P_5}{p_5}\right)^{\frac{\gamma_5-1}{\gamma_5}} - 1\right]} \tag{3}$$

where C_T is the correction for thermal expansion of the exhaust nozzle. The turbine gas flow is

$$W_{g,3} = W_{g,5} - W_c - W_t$$

where compressor leakage and all cooling air flow were determined from pressure and temperature measurements. This calculation of gas flow gave values having the correct magnitude but the scatter was excessive owing to the difficulty in measuring the small dynamic pressures.

Because the turbine nozzle was choked for the range of conditions investigated allowing the assumption to be made that the turbine-nozzle vena contracta area is constant, the following equation was used to obtain the final calculated gas flow:

$$W_{g,3} = \sqrt{\frac{g}{R}}\ \frac{P_3}{\sqrt{T_3}}\ \frac{A_{3,av}\sqrt{\gamma_3}}{\left(\frac{1+\gamma_3}{2}\right)^{\frac{\gamma_3+1}{2(\gamma_3-1)}}} \tag{4}$$

in which the average turbine-nozzle vena contracta area was calculated from equation (4) using the tail-pipe (station 5) gas flows and turbine-inlet total temperature based on tail-pipe gas flow. Using this average effective turbine-throat area and turbine-inlet temperature, the turbine gas flow was determined from equation (4). With this turbine gas flow, a recalculation was made for turbine-inlet temperature, which showed a negligible change in the recalculated temperature from the original calculated temperature. The error in turbine gas flow is the square root of the ratio of the two temperatures and therefore can be neglected.

Air flow. - Engine-inlet air flow is

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$$W_{a,1} = W_{g,3} + W_{rb} + W_c + W_t - \frac{W_f}{3600} \tag{5}$$

which is the air flow used throughout this report.

Compressor efficiency. - Adiabatic compressor efficiency was calculated using the following equation:

$$\eta_c = \frac{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\left(\frac{T_2}{T_1} - 1\right)} \tag{6}$$

where γ is based on the average temperature of the air in the compressor.

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

$$M_c = \frac{U}{a_1} = \frac{\pi DN}{60\sqrt{\gamma g R T_1}} \tag{7}$$

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

$$V_2 = \sqrt{\frac{2\gamma}{\gamma-1} gRT_2\left[1 - \left(\frac{p_2}{P_2}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

where individual total pressures and average static pressures and total temperatures were used.

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TABLE I - PERFORMANCE DATA OF PYTHON TURBINE-PROPELLER

Run	Altitude (ft)	Cowl-inlet ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Engine fuel flow, W_f (lb/hr)	Shaft horsepower, shp	Tunnel static pressure, p_0 (lb/sq ft abs.)	Cowl inlet: Total temperature, T_1 (°R)	Cowl inlet: Total pressure, P_1 (lb/sq ft abs.)	Cowl inlet: Static pressure, p_1 (lb/sq ft abs.)	Compressor-rotor-stage static pressure, (lb/sq ft abs.) Stages: 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	10,000	1.028	8006	2330	2578	1451	485	1492	1445	1116	1278	1517	1743	1982	2285	2623	3052	3524	4031	4650	5270	6072	6776
2		1.028		2170	2398	1454	485	1494	1447	1099	1268	1514	1726	1965	2254	2584	3014	3472	3964	4584	5189	5957	6640
3		1.027		2055	2139	1455	483	1495	1448	1107	1269	1508	1720	1952	2233	2564	2980	3430	3930	4529	5120	5887	6556
4		1.028		1645	1419	1448	484	1488	1441	1083	1231	1463	1667	1893	2153	2456	2850	3272	3730	4293	4849	5574	6180
5		1.028		1125	410	1456	479	1497	1448	1082	1216	1448	1631	1842	2082	2349	2715	3102	3504	4039	4539	5200	5721
6		1.026	7806	2240	2491	1453	489	1491	1449	1168	1366	1605	1823	2055	2337	2668	3076	3506	3984	4562	5118	5836	6463
7		1.026		2080	2316	1437	486	1475	1433	1152	1343	1575	1800	2032	2314	2631	3039	3462	3926	4489	5031	5721	6320
8		1.026		1920	2085	1451	488	1489	1447	1167	1350	1583	1801	2026	2308	2618	3019	3427	3885	4434	4976	5652	6236
9		1.026		1510	1317	1449	484	1487	1443	1133	1309	1535	1746	1964	2217	2513	2886	3287	3710	4231	4738	5392	5920
10		1.027		1010	316	1446	490	1485	1441	1122	1298	1509	1699	1897	2136	2389	2727	3079	3459	3924	4368	4945	5381
11		1.026	7606	2060	2289	1450	485	1488	1448	1201	1398	1630	1848	2081	2348	2672	3066	3482	3925	4460	4967	5608	6164
12		1.026		1975	2139	1448	484	1486	1447	1180	1391	1616	1834	2067	2341	2651	3045	3453	3904	4425	4932	5572	6122
13		1.026		1820	1924	1451	488	1489	1449	1190	1394	1619	1823	2055	2323	2626	3006	3407	3837	4358	4850	5484	6012
14		1.026		1420	1165	1448	486	1485	1444	1167	1365	1583	1780	1991	2252	2533	2885	3258	3660	4138	4603	5194	5659
15		1.027		900	241	1440	482	1479	1437	1138	1328	1540	1730	1927	2173	2427	2757	3095	3454	3884	4299	4827	5207
16		1.026	7406	1880	1978	1451	488	1489	1453	1232	1443	1661	1879	2098	2351	2661	3034	3407	3823	4301	4766	5343	5836
17		1.026		1810	1852	1444	487	1481	1445	1218	1429	1640	1851	2070	2330	2619	2992	3365	3773	4245	4703	5280	5759
18		1.025		1660	1641	1457	490	1494	1457	1225	1429	1647	1851	2070	2323	2612	2971	3337	3731	4203	4639	5216	5674
19		1.026		1310	1045	1449	493	1486	1449	1206	1403	1607	1811	2015	2262	2529	2860	3205	3564	4008	4423	4951	5359
20		1.025		910	289	1451	487	1487	1449	1190	1387	1584	1774	1964	2196	2450	2759	3090	3428	3830	4210	4695	5033
21		1.025	7205	1675	1658	1453	490	1489	1456	1255	1452	1656	1860	2065	2318	2593	2945	3282	3670	4099	4521	5049	5486
22		1.025		1600	1524	1452	490	1489	1455	1255	1459	1663	1860	2065	2311	2585	2923	3268	3641	4078	4486	5014	5437
23		1.026		1470	1314	1448	486	1485	1451	1245	1442	1646	1843	2047	2287	2561	2892	3230	3596	4033	4434	4962	5370
24		1.025		1220	889	1452	487	1489	1454	1237	1434	1631	1828	2018	2251	2504	2828	3152	3497	3905	4292	4778	5158
25		1.025		875	302	1439	491	1475	1440	1220	1410	1593	1783	1959	2184	2417	2712	3008	3325	3698	4043	4479	4789
26		1.027	6805	1400	1235	1447	490	1486	1458	1294	1484	1646	1843	2026	2245	2491	2780	3068	3378	3744	4096	4526	4870
27		1.026		1360	1148	1455	491	1493	1465	1295	1478	1675	1837	2027	2253	2485	2795	3090	3407	3780	----	4555	4893
28		1.026		1220	965	1452	490	1490	1462	1286	1469	1659	1828	2011	2215	2455	2736	3018	3321	3680	4018	4426	4757
29		1.027		1050	686	1454	489	1493	1464	1283	1459	1649	1748	2001	2219	2452	2726	3008	3304	3656	----	4388	4683
30		1.026		810	307	1449	487	1487	1457	1266	1449	1618	1801	1970	2174	2385	2646	----	----	----	3800	4173	4434
31	20,000	1.029	8006	1810	2013	993	456	993	961	732	830	999	1154	1323	1527	1774	2076	2414	2780	3245	----	4259	4773
32		1.028		1680	1883	973	456	1000	968	726	831	979	1155	1317	1521	1761	2056	2394	2760	3211	----	4210	4717
33		1.028		1550	1699	975	455	1002	970	729	813	968	1137	1292	1496	1721	2010	2341	2693	3143	----	4122	4622
34		1.027		1265	1204	968	455	994	962	716	800	955	1103	1251	1434	1638	1912	2208	2539	2954	----	3877	4327
35		1.027		840	361	972	454	998	966	711	781	929	1070	1196	1372	1541	1788	2048	2330	2696	----	3534	3921
36		1.028	7806	1675	1891	969	456	996	966	757	855	1053	1186	1355	1559	1799	2094	2418	2756	3200	----	4143	4608
37		1.028		1555	1740	976	457	1003	973	749	869	1024	1193	1348	1552	1785	2080	2397	2735	3165	----	4087	4544
38		1.027		1420	1545	976	457	1002	972	751	863	1025	1173	1342	1532	1765	2039	2342	2666	3088	----	3989	4433
39		1.028		1385	1522	971	453	998	967	746	851	1020	1161	1323	1513	1731	2013	2323	2654	3062	----	3970	4421
40		1.027		1125	1024	969	454	995	964	732	837	999	1133	1281	1464	1668	1928	2210	2520	2907	----	3759	4174
41		1.026		750	292	975	452	1000	968	734	818	973	1100	1233	1402	1578	1818	2064	2232	2684	----	3444	3796
42		1.027	7606	1515	1701	970	456	996	968	772	906	1068	1215	1384	1589	1821	2102	2405	2722	3123	----	3982	4398
43		1.027		1430	1565	979	461	1005	977	782	909	1085	1232	1401	1599	1824	2105	2408	2725	3119	----	3943	4327
44		1.027		1420	1565	969	456	995	967	779	906	1068	1222	1384	1582	1814	2095	2398	2715	3109	----	3940	4341
45		1.027		1315	1392	977	457	1003	974	780	900	1069	1216	1371	1575	1794	2068	2357	2660	3047	----	3878	4279
46		1.027		1065	949	966	455	992	963	757	869	1024	1179	1327	1517	1714	1975	2242	2531	2870	----	3671	4037
47		1.027		717	296	968	455	994	964	742	854	995	1136	1270	1453	1622	1861	2107	2354	2685	----	3396	3699
48		1.027	7406	1415	1556	971	454	997	972	802	943	1105	1260	1415	1619	1837	2119	2400	2710	3062	----	3822	4181
49		1.026		1345	1444	965	452	990	965	796	937	1085	1247	1409	1606	1824	2091	2373	2676	3028	----	3774	4126
50		1.027		1250	1303	971	450	997	971	796	944	1092	1247	1409	1606	1824	2091	2359	2655	3014	----	3753	4105
51		1.027		1010	883	966	454	992	966	793	920	1075	1215	1370	1553	1758	2011	2264	2546	2877	----	3560	3870
52		1.025		680	272	973	452	997	970	781	908	1055	1182	1330	1506	1682	1914	2154	2407	2703	----	3336	3583
53		1.027	7205	1285	1345	968	454	994	971	828	969	1117	1272	1427	1617	1835	2088	2356	2638	2954	----	3637	3954
54		1.027		1270	1308	966	456	992	970	833	974	1122	1284	1439	1629	1854	2115	2382	2664	2973	----	3621	3917
55		1.027		1250	1262	964	458	990	967	824	972	1120	1268	1423	1606	1817	2077	2338	2612	2929	----	3577	3880

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ENGINE WITH STANDARD TAIL-PIPE CONFIGURATION

Compressor					Tail pipe									Corrected				
Outlet straightening-vane static pressure (lb/sq ft abs.)	Outlet total temperature, T_2 (°R)	Outlet total pressure, P_2 (lb/sq ft abs.)	Outlet static pressure, p_2 (lb/sq ft abs.)	Turbine-inlet total pressure, P_3 (lb/sq ft abs.)	Total temperature, T_5 (°R)	Total pressure, P_5 (lb/sq ft abs.)	Static pressure, p_5 (lb/sq ft abs.)	Compressor pressure ratio, P_2/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$ (rpm)	Compressor Mach number, M_c	Tail-pipe air flow, $W_{a,5}$ (lb/sec)	Turbine-inlet air flow, $W_{a,3}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$ (lb/sec)	Turbine-inlet total temperature, T_3/θ (°R)	Compressor efficiency, η_c (percent)	Average engine running time in altitude wind tunnel (hr)	Run
7255	869	8063	7910	7762	1452	1636	1478	5.404	8278	0.659	39.80	39.27	39.68	54.42	2094	77.4	3.2	1
7090	868	7905	7755	7608	1389	1630	1478	5.291	8278	.659	39.97	39.32	39.71	54.38	2016	76.4	3.2	2
7007	863	7826	7674	7533	1352	1625	1477	5.235	8302	.661	39.84	39.60	39.99	54.57	1966	76.0	3.2	3
6560	855	7417	7260	7130	1206	1602	1465	4.985	8286	.660	40.63	39.83	40.19	55.22	1760	75.2	3.2	4
6010	831	6953	6777	6662	1012	1584	1467	4.645	8334	.663	41.03	41.00	41.34	56.11	1487	74.3	3.2	5
6871	860	7627	7492	7341	1486	1620	1476	5.115	8040	.640	37.51	36.90	37.30	51.39	2108	77.5	13.1	6
6707	851	7465	7329	7184	1410	1597	1458	5.061	8064	.642	37.47	37.07	37.47	52.05	2023	77.8	13.1	7
6602	850	7373	7234	7095	1352	1603	1471	4.952	8056	.641	37.69	37.41	37.81	52.06	1936	77.4	13.1	8
6230	835	7054	6907	6779	1186	1583	1462	4.744	8079	.643	38.51	38.37	38.74	53.26	1713	76.7	13.1	9
5571	832	6488	6324	6213	1014	1555	1456	4.369	8032	.639	37.68	38.40	38.74	53.65	1443	74.4	13.1	10
6523	835	7240	7111	6969	1435	1602	1470	4.866	7865	.626	36.37	35.77	36.18	49.76	2041	78.5	13.9	11
6467	832	7199	7066	6925	1391	1598	1469	4.845	7872	.627	36.59	36.09	36.50	50.22	1987	78.5	13.9	12
6336	833	7077	6947	6815	1341	1591	1470	4.753	7849	.625	35.95	36.25	36.65	50.46	1904	78.6	13.9	13
5926	822	6713	6572	6450	1160	1570	1460	4.521	7857	.625	37.03	37.04	37.42	51.62	1661	77.2	13.9	14
5355	806	6250	6088	5985	960	1543	1451	4.226	7895	.628	37.19	38.06	38.42	52.97	1390	75.3	13.9	15
6132	821	6809	6688	6557	1416	1585	1470	4.573	7643	.608	34.07	34.12	34.52	47.53	1982	79.0	14.6	16
6054	817	6738	6615	6484	1374	1575	1462	4.550	7643	.608	34.06	34.22	34.62	47.92	1932	79.2	14.6	17
5949	820	6652	6527	6399	1313	1582	1472	4.452	7621	.607	35.06	34.57	34.97	48.12	1840	78.3	14.6	18
5577	816	6317	6185	6072	1166	1564	1459	4.251	7599	.605	36.16	35.04	35.41	49.15	1624	77.5	14.6	19
5146	797	5996	5845	5742	978	1546	1460	4.032	7643	.608	35.81	36.36	36.71	50.62	1383	76.3	14.6	20
5746	806	6392	6278	6155	1358	1567	1467	4.293	7414	.590	32.45	32.83	33.22	45.88	1880	79.6	14.8	21
5683	805	6339	6222	6101	1322	1565	1465	4.257	7414	.590	32.93	33.34	33.73	46.58	1829	79.1	14.8	22
5603	799	6279	6158	6043	1249	1558	1460	4.228	7443	.592	33.53	33.74	34.14	47.10	1752	78.7	14.8	23
5341	792	6058	5928	5818	1134	1557	1459	4.069	7436	.592	35.25	34.16	34.53	47.55	1590	78.3	14.8	24
4881	788	5671	5530	5435	989	1526	1448	3.845	7407	.590	33.59	34.40	34.76	48.52	1377	77.1	14.8	25
5068	773	5645	5543	5437	1292	1541	1456	3.799	7002	.557	30.71	30.12	30.41	42.08	1756	79.9	17.6	26
5076	773	5671	5565	5474	1264	1550	1463	3.798	6996	.557	31.38	30.76	31.05	42.80	1715	80.4	17.6	27
4919	766	5531	5425	5323	1192	1546	1457	3.712	7002	.557	32.79	30.82	31.10	42.92	1626	80.2	17.6	28
4803	764	5468	5352	5254	1106	1535	1460	3.662	7009	.558	31.28	31.64	31.91	43.90	1515	79.3	17.6	29
4504	754	5223	5097	5007	990	1527	1453	3.512	7023	.559	32.84	31.96	32.22	44.43	1366	78.3	17.6	30
5125	844	5673	5575	5456	1539	1101	983	5.713	8542	.680	27.14	26.81	27.10	54.12	2344	75.2	19.6	31
5062	839	5620	5532	5407	1461	1105	989	5.620	8542	.680	27.58	27.22	27.50	54.54	2246	75.5	19.6	32
4953	834	5531	5442	5316	1389	1102	991	5.520	8550	.681	27.75	27.47	27.74	54.86	2150	75.1	19.6	33
4644	827	5222	5119	5017	1252	1079	980	5.254	8550	.681	27.61	27.41	27.67	55.16	1943	73.7	19.6	34
4139	812	4788	4678	4587	1041	1072	977	4.798	8558	.681	29.63	27.74	27.97	55.47	1619	71.3	19.6	35
4932	827	5460	5368	5251	1479	1095	986	5.482	8329	.663	26.73	26.32	26.59	52.93	2264	76.4	20.2	36
4861	821	5398	5303	5189	1410	1098	981	5.382	8321	.662	27.20	26.63	26.90	53.24	2167	76.9	20.2	37
4735	819	5280	5184	5080	1345	1092	990	5.269	8321	.662	27.08	26.78	27.04	53.57	2067	76.3	20.2	38
4730	813	5277	5179	5075	1309	1086	985	5.288	8360	.665	27.45	27.10	27.36	54.16	2037	76.1	20.2	39
4428	807	5005	4906	4808	1175	1071	979	5.030	8345	.664	27.44	27.22	27.46	54.64	1826	74.9	20.2	40
3986	793	4623	4513	4431	989	1064	977	4.623	8360	.665	29.17	27.57	27.78	54.89	1547	72.4	20.2	41
4679	809	5176	5088	4985	1427	1084	984	5.197	8116	.646	26.06	25.56	25.82	51.40	2177	77.2	20.9	42
4598	812	5105	5015	4913	1384	1089	993	5.080	8070	.642	26.07	25.61	25.85	51.29	2090	77.0	20.9	43
4595	804	5106	5016	4913	1362	1078	983	5.132	8116	.646	25.94	25.78	26.02	52.16	2086	77.5	20.9	44
4532	802	5058	4969	4870	1305	1082	989	5.043	8108	.645	26.21	26.11	26.35	52.16	1997	77.3	20.9	45
4242	793	4800	4704	4612	1172	1057	975	4.839	8123	.647	25.84	26.22	26.45	52.83	1802	76.1	20.9	46
3846	781	4464	4359	4280	979	1051	971	4.491	8123	.647	27.88	26.89	27.10	54.02	1510	74.3	20.9	47
4428	789	4887	4805	4704	1405	1074	984	4.902	7917	.630	24.70	24.41	24.64	48.91	2131	77.5	21.5	48
4351	785	4825	4741	4648	1364	1064	977	4.874	7932	.631	24.65	24.50	24.73	49.34	2083	77.1	21.5	49
4323	780	4811	4727	4633	1288	1068	983	4.825	7954	.633	25.08	25.09	25.32	50.03	1984	76.9	21.5	50
4038	776	4555	4462	4378	1167	1050	974	4.592	7917	.630	25.06	25.07	25.28	50.44	1786	76.4	21.5	51
3681	761	4251	4169	4095	961	1044	976	4.264	7932	.631	26.30	26.07	26.27	52.05	1477	74.8	21.5	52
4144	772	4591	4514	4423	1377	1059	980	4.619	7702	.613	23.60	23.33	23.54	46.88	2070	77.7	22.0	53
4086	773	4519	4443	4353	1392	1054	977	4.555	7688	.612	23.00	22.90	23.11	46.20	2075	77.4	22.0	54
4056	775	4502	4417	4330	1364	1052	975	4.547	7666	.610	23.27	22.98	23.19	46.58	2028	77.7	22.0	55

NACA

TABLE I - PERFORMANCE DATA OF PYTHON TURBINE-PROPELLER

Run	Altitude (ft)	Cowl-inlet ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Engine fuel flow, W_f (lb/hr)	Shaft horsepower, shp	Tunnel static pressure, p_0 (lb/sq ft abs.)	Cowl inlet			Compressor-rotor-stage static pressure, (lb/sq ft abs.)													
							Total temperature, T_1 (°R)	Total pressure, P_1 (lb/sq ft abs.)	Static pressure, p_1 (lb/sq ft abs.)	Stages 1	2	3	4	5	6	7	8	9	10	11	12	13	14
56	20,000	1.026	7205	1225	1246	963	458	988	966	837	971	1119	1274	1429	1619	1837	2083	2344	2625	2935	----	3583	3872
57		1.027		1150	1134	971	455	997	974	832	966	1114	1262	1417	1600	1811	2064	2332	2599	2916	----	3585	3881
58		1.026		925	773	972	456	997	973	813	954	1095	1243	1390	1573	1778	2017	2263	2531	2827	----	3439	3700
59		1.025		645	249	965	454	989	965	788	929	1070	1203	1337	1513	1696	1914	2140	2386	2701	----	3217	3428
60		1.028	6805	940	816	973	455	1000	980	863	997	1124	1265	1398	1574	1757	1976	2201	2433	2675	----	3236	3461
61		1.028		875	720	967	454	994	973	851	985	1112	1253	1386	1555	1738	1957	2189	2414	2629	----	3203	3407
62		1.027		800	582	964	455	990	970	848	982	1109	1243	1376	1538	1714	1933	2144	2369	2574	----	3136	3333
63		1.026		595	255	970	454	995	974	842	969	1110	1229	1356	1518	1694	1898	2102	2321	2239	----	3046	3201
64	30,000	1.027	8006	1265	1376	626	437	643	623	472	528	641	754	873	1035	1218	1444	1690	1944	2239	----	2901	3225
65		1.027		1170	1303	626	438	643	623	465	528	634	747	866	1021	1197	1408	1648	1901	2204	----	2838	3154
66		1.027		1085	1173	628	437	645	625	467	523	629	735	854	1002	1171	1382	1615	1861	2150	----	2783	3086
67		1.027		885	869	627	436	644	623	460	509	608	714	819	960	1115	1312	1530	1755	2044	----	2643	2931
68		1.026		575	266	621	436	637	617	450	492	584	682	781	894	1027	1203	1400	1598	1844	----	2365	2604
69		1.026	7806	1160	1287	627	438	643	624	486	564	669	782	902	1056	1232	1437	1669	1901	2190	----	2795	3084
70		1.027		1095	1215	626	438	643	623	472	528	648	761	880	1021	1204	1416	1641	1873	2162	----	2774	3070
71		1.027		983	1077	625	437	642	623	479	536	655	754	873	1014	1190	1380	1606	1838	2112	----	2711	2992
72		1.027		815	773	623	437	640	620	471	527	633	732	844	971	1126	1316	1527	1745	2013	----	2569	2837
73		1.027		570	336	619	436	636	616	469	525	624	716	814	934	1068	1237	1427	1624	1856	----	2363	2581
74		1.027	7606	1050	1173	624	439	641	623	491	569	681	794	914	1054	1230	1428	1639	1864	2125	----	2695	2969
75		1.024		1020	1114	630	438	645	627	496	574	679	792	905	1045	1214	1419	1630	1848	2123	----	2693	2967
76		1.025		935	1016	628	444	644	626	495	573	678	784	897	1037	1192	1389	1586	1805	2058	----	2593	2854
77		1.027		774	742	622	440	639	620	484	555	660	759	857	991	1139	1322	1512	1723	1956	----	2470	2716
78		1.026		540	276	618	437	634	615	475	532	637	722	820	940	1067	1236	1412	1602	1820	----	2362	2489
79		1.025	7406	960	1052	628	437	644	627	509	594	706	805	918	1058	1220	1403	1601	1812	2051	----	2565	2811
80		1.027		910	995	626	437	643	626	515	586	705	804	917	1043	1198	1381	1571	1776	2008	----	2522	2747
81		1.026		845	889	625	436	641	624	500	578	690	789	902	1028	1183	1366	1556	1760	2000	----	2493	2732
82		1.027		720	664	626	438	643	625	502	580	685	777	882	1002	1157	1326	1509	1699	1931	----	2403	2621
83		1.027		525	302	623	437	640	622	494	565	663	755	853	966	1100	1262	1431	1614	1825	----	2275	2458
84		1.027	7205	840	870	626	437	643	627	522	600	713	811	917	1043	1184	1360	1543	1740	1952	----	2423	2641
85		1.026		805	824	626	435	642	626	529	600	705	811	910	1043	1191	1367	1543	1740	1959	----	2430	2641
86		1.027		765	761	625	435	642	626	515	586	698	797	903	1022	1110	1339	1522	1712	1930	----	2388	2606
87		1.027		665	573	623	436	640	623	507	585	690	775	880	1000	1141	1303	1472	1662	1873	----	2317	2514
88		1.026		500	288	623	436	639	623	508	579	684	769	860	973	1100	1255	1409	1585	1783	----	2184	2353
89		1.027	6805	670	580	623	441	640	627	550	620	719	803	895	1000	1127	1275	1430	1592	1768	----	2141	2317
90		1.026		635	551	624	436	640	627	543	620	719	803	888	1000	1127	1275	1423	1584	1760	----	2134	2303
91		1.027		595	481	630	440	647	633	550	634	726	810	887	1007	1127	1268	1423	1577	1760	----	2127	2281
92		1.027		525	366	624	438	641	627	538	615	706	791	875	988	1101	1242	1382	1544	1720	----	2079	2227
93		1.025		472	262	629	439	645	631	543	620	704	789	873	979	1092	1232	1380	1528	1697	----	2049	2190
94	40,000	1.025	8006	755	799	396	441	406	394	307	328	391	475	553	644	757	891	1039	1194	1370	----	1771	1968
95		1.025		720	764	396	443	406	394	291	327	411	482	552	643	749	883	1024	1178	1362	----	1742	1939
96		1.028		660	671	392	441	403	391	288	331	401	464	535	626	725	852	999	1147	1323	----	1703	1894
97		1.026		560	507	390	439	400	389	288	324	387	457	521	598	697	809	943	1084	1253	----	1612	1788
98		1.026		410	232	389	446	399	387	288	324	380	436	493	570	647	753	873	999	1154	----	1492	1647
99		1.025	7806	700	745	397	434	407	397	308	329	399	484	561	652	758	885	1026	1173	1349	----	1708	1899
100		1.025		670	699	394	436	404	393	305	333	396	481	551	642	748	875	1009	1149	1318	----	1684	1860
101		1.020		630	632	391	437	399	388	302	323	386	470	541	625	731	851	984	1125	1294	----	1660	1836
102		1.023		400	237	395	438	404	393	300	329	399	455	512	596	674	772	892	1019	1166	----	1490	1645
103		1.028	7606	620	626	391	438	402	391	316	351	414	492	562	639	745	865	991	1125	1280	----	1618	1787
104		1.030		590	593	394	438	406	395	313	348	418	489	552	636	735	848	974	1108	1270	----	1601	1763
105		1.028		550	515	391	442	402	391	303	338	401	479	535	619	711	823	950	1077	1239	----	1563	1725
106		1.025		490	426	398	439	408	397	317	352	415	486	542	626	711	823	943	1077	1225	----	1549	1703
107		1.026		400	253	390	439	400	389	295	338	401	464	521	591	676	774	887	1007	1147	----	1450	1591
108		1.028	7406	520	491	394	442	405	394	320	369	432	496	559	636	721	826	946	1066	1200	----	1502	1643
109		1.028		470	515	393	442	404	394	313	362	418	482	545	622	707	812	918	1045	1178	----	1467	1601
110		1.030		390	268	394	444	406	394	321	377	426	483	539	616	687	785	891	1003	1137	----	1412	1546

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ENGINE WITH STANDARD TAIL-PIPE CONFIGURATION - CONCLUDED

Compressor					Tail pipe										Corrected					
Outlet straightening-vane static pressure (lb/sq ft abs.)	Outlet total temperature, T_2 (°R)	Outlet total pressure, P_2 (lb/sq ft abs.)	Outlet static pressure, p_2 (lb/sq ft abs.)	Turbine-inlet total pressure, P_3 (lb/sq ft abs.)	Total temperature, T_5 (°R)	Total pressure, P_5 (lb/sq ft abs.)	Static pressure, p_5 (lb/sq ft abs.)	Compressor pressure ratio, P_2/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$ (rpm)	Compressor Mach number, M_c	Tail-pipe air flow, $W_{a,5}$ (lb/sec)	Turbine-inlet air flow, $W_{a,3}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$ (lb/sec)	Turbine-inlet total temperature, T_3/θ (°R)	Compressor efficiency, η_c (percent)	Average engine running time in altitude wind tunnel (hr)	Run
4048	775	4482	4408	4318	1356	1050	974	4.536	7666	0.610	23.24	23.01	23.22	46.75	2016	77.5	22.0	56
4050	769	4513	4435	4346	1296	1058	981	4.527	7695	.613	23.91	23.72	23.93	47.55	1952	77.7	22.0	57
3812	764	4318	4230	4149	1145	1047	979	4.331	7688	.612	23.83	24.13	24.33	48.39	1728	76.4	22.0	58
3477	753	4033	3939	3865	973	1030	970	4.078	7702	.613	24.50	24.61	24.79	49.63	1470	74.7	22.0	59
3560	736	3986	3916	3838	1208	1039	980	3.986	7268	.579	21.69	21.93	22.11	43.81	1789	78.0	22.5	60
3484	732	3928	3852	3779	1159	1032	973	3.952	7275	.579	22.25	22.05	22.23	44.27	1723	78.2	22.5	61
3333	731	3844	3767	3691	1100	1031	968	3.883	7268	.579	23.34	22.16	22.33	44.68	1632	77.8	22.5	62
3201	722	3708	3623	3557	962	1026	976	3.727	7275	.579	22.40	22.98	23.15	46.06	1430	76.9	22.5	63
3436	831	3795	3734	3651	1545	718	638	5.902	8727	.695	17.88	17.83	18.02	54.41	2468	72.8	26.2	64
3359	827	3715	3656	3574	1486	713	637	5.778	8719	.694	17.80	17.83	18.01	54.43	2376	72.8	26.2	65
3283	823	3649	3587	3508	1420	712	638	5.657	8727	.695	17.99	17.91	18.08	54.42	2286	72.1	26.2	66
3100	814	3496	3481	3358	1262	703	635	5.429	8735	.695	18.25	18.17	18.33	55.21	2060	71.3	26.2	67
2717	798	3139	3070	3007	1052	684	625	4.928	8735	.695	18.60	18.08	18.22	55.48	1708	69.1	26.2	68
3281	817	3617	3561	3482	1505	710	638	5.625	8501	.677	17.22	17.28	17.46	52.76	2400	73.3	26.7	69
3253	813	3603	3543	3470	1437	709	636	5.603	8501	.677	17.72	17.65	17.83	53.88	2299	73.8	26.7	70
3161	806	3529	3469	3395	1340	703	635	5.497	8509	.677	17.73	17.82	17.99	54.40	2167	73.7	26.7	71
2991	800	3372	3308	3241	1211	694	631	5.269	8509	.677	17.98	17.95	18.12	54.96	1967	72.7	26.7	72
2680	784	3087	3016	2958	1044	676	623	4.854	8516	.678	17.68	17.81	17.97	54.80	1700	71.0	26.7	73
3138	799	3465	3410	3337	1434	701	634	5.406	8268	.658	17.04	17.03	17.22	52.29	2278	75.1	27.1	74
3143	800	3479	3424	3349	1399	705	638	5.394	8283	.659	17.23	17.28	17.46	52.60	2235	74.3	27.1	75
3009	795	3346	3288	3221	1340	699	636	5.196	8222	.654	17.14	17.02	17.20	52.28	2116	75.6	27.1	76
2843	785	3203	3142	3081	1203	687	629	5.013	8260	.657	17.30	17.23	17.40	53.05	1924	74.2	27.1	77
2573	767	2975	2916	2858	1006	673	621	4.692	8291	.660	17.85	17.64	17.80	54.51	1622	73.1	27.1	78
2952	781	3273	3219	3149	1391	698	636	5.082	8073	.643	16.56	16.34	16.52	49.80	2214	74.7	27.6	79
2888	774	3205	3153	3088	1355	693	634	4.984	8073	.643	16.47	16.28	16.46	49.70	2154	75.2	27.6	80
2859	772	3200	3142	3081	1272	690	632	4.992	8080	.643	16.85	16.74	16.92	51.19	2041	75.3	27.6	81
2727	764	3083	3022	2965	1167	685	632	4.795	8065	.642	16.86	16.94	17.11	51.71	1857	75.5	27.6	82
2536	760	2927	2862	2803	1016	676	626	4.573	8073	.643	17.51	17.23	17.39	52.74	1631	73.2	27.6	83
2761	761	3080	3027	2965	1306	687	633	4.790	7853	.625	15.92	15.99	16.16	48.79	2063	75.8	28.0	84
2768	758	3087	3033	2985	1269	686	632	4.808	7868	.626	16.24	16.32	16.49	49.77	2023	75.9	28.0	85
2712	755	3047	2991	2933	1221	684	632	4.746	7868	.626	16.20	16.36	16.53	49.89	1951	75.9	28.0	86
2619	753	2961	2905	2848	1136	676	629	4.627	7861	.626	16.02	16.51	16.68	50.54	1810	75.2	28.0	87
2416	740	2780	2719	2667	1011	673	626	4.351	7861	.626	16.92	16.55	16.72	50.74	1607	74.6	28.0	88
2401	729	2689	2642	2585	1207	668	628	4.202	7383	.588	14.39	14.67	14.83	45.19	1861	77.3	28.5	89
2387	723	2681	2632	2578	1173	668	628	4.189	7424	.591	14.58	14.88	15.04	45.57	1831	76.5	28.5	90
2359	725	2664	2613	2562	1138	673	634	4.117	7390	.588	14.70	15.03	15.19	45.74	1760	76.6	28.5	91
2290	720	2607	2555	2501	1068	667	628	4.067	7411	.590	14.98	15.19	15.35	46.53	1659	76.3	28.5	92
2246	716	2573	2521	2466	1019	673	631	3.989	7397	.589	16.11	15.43	15.58	47.03	1575	76.5	28.5	93
2088	840	2320	2284	2231	1517	450	401	5.714	8687	.691	11.22	10.99	11.10	53.32	2413	70.9	31.6	94
2058	832	2287	2257	2198	1498	447	400	5.633	8662	.689	11.10	10.93	11.04	53.18	2361	72.3	31.6	95
2006	824	2244	2204	2157	1410	441	397	5.568	8687	.691	11.04	11.06	11.17	54.06	2245	72.4	31.6	96
1879	817	2130	2089	2042	1290	435	394	5.325	8703	.693	11.05	10.97	11.07	53.87	2074	70.7	31.6	97
1732	813	1995	1952	1908	1121	425	391	5.000	8638	.688	10.85	11.08	11.17	54.90	1768	70.5	31.6	98
2011	814	2233	2195	2152	1470	446	402	5.486	8540	.680	10.83	10.81	10.93	51.94	2363	71.1	30.4	99
1973	812	2196	2155	2113	1425	441	399	5.436	8516	.678	10.72	10.77	10.88	52.24	2290	71.7	30.4	100
1942	809	2171	2136	2087	1365	436	395	5.441	8509	.677	10.80	10.89	10.98	53.42	2197	72.6	30.4	101
1760	797	1975	1934	1890	1120	430	397	4.889	8501	.677	10.73	11.03	11.13	53.53	1792	69.5	30.4	102
1871	802	2095	2061	2013	1413	435	395	5.211	8283	.659	10.45	10.38	10.48	50.66	2238	72.0	32.0	103
1861	799	2077	2042	1998	1361	438	398	5.116	8283	.659	10.74	10.48	10.59	50.68	2174	71.6	32.0	104
1816	800	2036	2000	1956	1308	432	395	5.065	8245	.656	10.47	10.48	10.58	51.38	2071	72.3	32.0	105
1788	791	2019	1983	1937	1243	438	401	4.949	8268	.658	10.83	10.68	10.78	51.43	1974	71.8	32.0	106
1654	783	1901	1862	1820	1131	423	392	4.753	8268	.658	10.29	10.57	10.67	51.93	1795	71.1	32.0	107
1728	776	1934	1900	1857	1310	431	397	4.775	8028	.639	10.07	10.02	10.13	48.83	2046	74.1	32.8	108
1678	773	1889	1861	1816	1251	430	396	4.676	8028	.639	10.32	10.04	10.15	49.05	1957	73.6	32.8	109
1609	772	1836	1801	1763	1122	424	396	4.522	8006	.637	9.93	10.31	10.41	50.19	1750	72.6	32.8	110

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TABLE II - PERFORMANCE DETERIORATION DATA FOR PYTHON

Run	Altitude (ft)	Cowl-inlet ram pressure ratio, P_1/p_0	Engine speed, N (rpm)	Engine fuel flow, W_f (lb/hr)	Shaft horsepower, shp	Tunnel static pressure, p_0 (lb/sq ft abs.)	Cowl inlet: Total temperature, T_1 (°R)	Cowl inlet: Total pressure, P_1 (lb/sq ft abs.)	Cowl inlet: Static pressure, p_1 (lb/sq ft abs.)	Compressor-rotor-stage static pressure, (lb/sq ft abs.) Stages: 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Average engine running time, 2.0 hrs.																							
1	10,000	1.027	8006	2320	2589	1466	518	1505	1461	1152	1342	1582	1800	2032	2328	2652	3081	3539	4032	4644	5228	5968	6608
2		1.027		2100	2246	1453	518	1492	1447	1140	1316	1549	1760	1992	2281	2591	3006	3435	3914	4477	5047	5759	6378
3		1.027		1850	1831	1458	520	1497	1452	1133	1316	1542	1753	1978	2253	2555	2942	3372	3808	4372	4914	5604	6195
4		1.026		1560	1328	1460	522	1498	1454	1137	1320	1538	1743	1961	2221	2510	2876	3284	3693	4228	4742	5396	5924
Average running time, 6.3 hrs.																							
5	10,000	1.027	8006	2320	2510	1458	517	1498	1455	1159	1364	1603	1828	2060	2349	2673	3088	3532	3996	4588	5137	5862	6482
6		1.026		2100	2195	1447	514	1485	1442	1149	1332	1572	1783	2008	2290	2593	2994	3423	3881	4465	5007	5718	6324
7		1.027		1870	1831	1455	525	1494	1449	1151	1334	1567	1771	1996	2264	2559	2939	3355	3798	4347	4883	5572	6150
8		1.026		1580	1374	1450	520	1488	1444	1134	1296	1528	1733	1944	2197	2479	2845	3246	3662	4204	4711	5372	5914
9		1.026		1195	595	1459	510	1497	1451	1119	1288	1513	1703	1908	2154	2414	2759	3140	3534	4041	4505	5132	5625
Average engine running time, 16.1 hrs.																							
10	10,000	1.025	8006	2290	2488	1466	523	1503	1464	1174	1372	1618	1857	2097	2392	2730	3139	3568	4033	4596	----	5821	6412
11		1.027		2020	2116	1457	517	1496	1454	1166	1364	1603	1814	2039	2328	2638	3039	3454	3898	4447	----	5644	6221
12		1.026		1600	1363	1452	520	1490	1447	1150	1333	1566	1770	1981	2249	2537	2910	3298	3713	4220	----	5339	5860
13		1.026		1100	349	1458	517	1496	1452	1133	1309	1534	1739	1943	2196	2457	2802	3168	3555	4013	----	4998	5442
Average engine running time, 24.7 hrs.																							
14	10,000	1.026	8006	2010	2039	1450	521	1488	1448	1181	1399	1624	1856	2103	2405	2757	3166	3602	4053	4574	----	5665	6165
15		1.026		1610	1376	1456	520	1494	1452	1175	1351	1612	1830	2070	2358	2682	3076	3485	3921	4428	----	5463	5906
16		1.025		1155	554	1452	519	1489	1447	1161	1351	1598	1795	2013	2288	2590	2971	3351	3745	4210	----	5153	5498
Average engine running time, 4.5 hrs.																							
17	20,000	1.028	8006	1730	1922	975	451	1002	970	728	812	974	1129	1291	1495	1734	2044	2389	2762	3212	3677	4262	4790
18		1.027		1610	1790	971	449	997	965	716	807	962	1117	1279	1476	1708	2004	2335	2708	3151	3602	4179	4686
19		1.028		1475	1556	969	450	996	964	723	800	955	1103	1251	1448	1666	1955	2278	2630	3067	3503	4067	4566
20		1.027		1265	1146	969	450	995	962	723	786	941	1082	1222	1406	1603	1877	2180	2518	2933	3349	3884	4355
21		1.028		885	469	968	451	995	963	713	769	917	1050	1184	1353	1515	1769	2043	2332	2712	3085	3585	3986
Average engine running time, 9.3 hrs.																							
22	30,000	1.029	8006	1230	1345	625	441	643	622	471	527	633	732	844	978	1147	1344	1583	1830	2133	2442	2823	3175
23		1.027		1130	1237	631	442	648	627	463	526	625	724	829	963	1125	1322	1540	1787	2096	2399	2786	3138
24		1.027		1045	1107	624	441	641	621	457	506	605	711	802	929	1077	1274	1492	1731	2020	2316	2689	3034
25		1.029		870	824	623	440	641	620	457	506	598	696	781	908	1034	1210	1415	1640	1914	2196	2548	2872
26		1.027		610	306	629	443	646	626	465	493	585	676	768	866	979	1134	1317	1514	1760	2014	2331	2612
Average engine running time, 10.1 hrs.																							
27	40,000	1.026	8006	745	768	390	442	400	388	285	321	384	454	511	602	694	820	961	1116	1299	1489	1715	1926
28		1.026		725	746	387	438	397	385	298	333	389	452	516	600	692	818	959	1114	1290	1480	1706	1910
29		1.028		665	678	386	439	397	384	289	325	388	444	508	585	677	796	937	1078	1254	1444	1662	1866
30		1.028		570	526	387	441	398	386	291	327	383	439	496	573	658	763	897	1031	1200	1383	1587	1784
31		1.028		450	300	396	440	407	395	287	323	379	435	492	562	639	738	865	991	1153	1315	1512	1695

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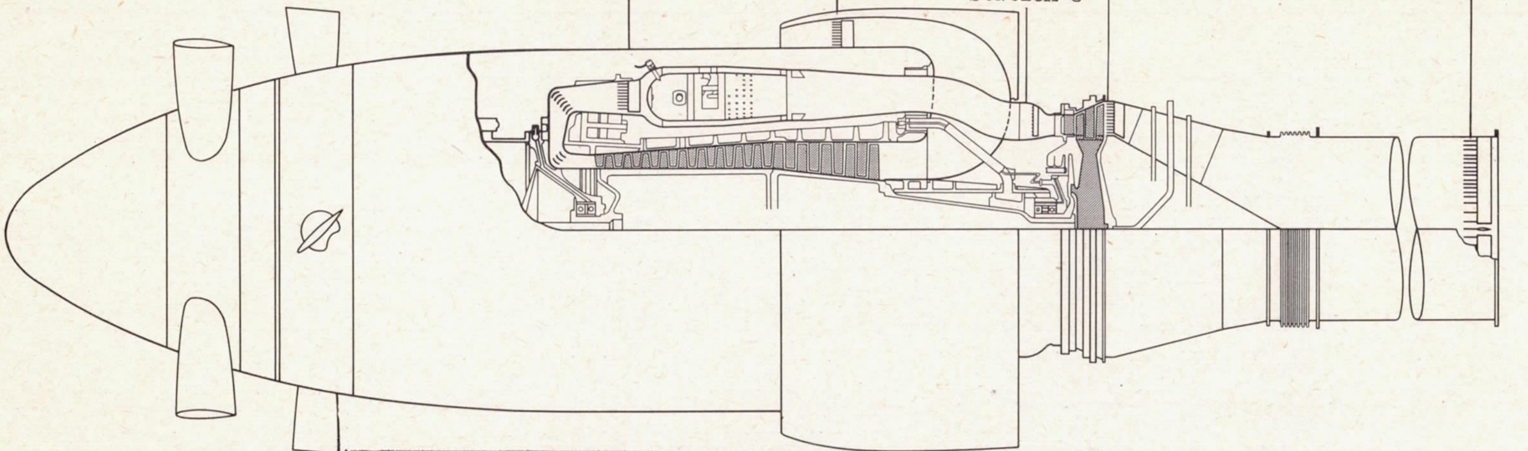
TURBINE-PROPELLER ENGINE WITH STANDARD TAIL-PIPE CONFIGURATION

Compressor					Tail pipe									Corrected			
Outlet straightening-vane static pressure (lb/sq ft abs.)	Outlet total temperature, T_2 (°R)	Outlet total pressure, P_2 (lb/sq ft abs.)	Outlet static pressure, p_2 (lb/sq ft abs.)	Turbine-inlet total pressure, P_3 (lb/sq ft abs.)	Total temperature, T_5 (°R)	Total pressure, P_5 (lb/sq ft abs.)	Static pressure, p_5 (lb/sq ft abs.)	Compressor pressure ratio, P_2/P_1	Corrected engine speed, $N/\sqrt{\theta_1}$ (rpm)	Compressor Mach number, M_c	Tail-pipe air flow, $W_{a,5}$ (lb/sec)	Turbine-inlet air flow, $W_{a,3}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}$ (lb/sec)	Cowl-inlet air flow, $W_{a,1}\sqrt{\theta_1}/\delta_1$ (lb/sec)	Turbine-inlet total temperature, T_3/θ (°R)	Compressor efficiency, η_c (percent)	Run
Average engine running time, 2.0 hrs.																	
7017	911	7798	7657	7509	1531	1638	1490	5.181	8014	0.638	37.38	37.08	37.46	52.62	2056	78.0	1
6786	902	7556	7427	7275	1439	1616	1475	5.064	8014	.638	37.65	37.10	37.48	53.09	1940	78.7	2
6575	899	7363	7217	7086	1344	1607	1476	4.919	7998	.637	37.79	37.50	37.87	53.56	1803	78.2	3
6248	898	7066	6916	6795	1252	1594	1474	4.717	7983	.635	37.30	37.38	37.74	53.48	1674	76.6	4
Average engine running time, 6.3 hrs.																	
6897	908	7651	7516	7367	1552	1627	1483	5.107	8022	.639	36.66	36.22	36.63	51.65	2076	77.6	5
6725	901	7497	7358	7215	1448	1608	1469	5.048	8046	.641	37.25	36.72	37.11	52.62	1957	77.2	6
6523	906	7313	7172	7038	1374	1603	1474	4.895	7960	.634	36.93	36.84	37.22	53.01	1823	78.0	7
6259	895	7075	6926	6801	1258	1585	1464	4.755	7998	.637	37.32	37.31	37.67	53.62	1692	76.9	8
5885	873	6780	6621	6503	1096	1580	1467	4.529	8078	.643	38.71	38.39	38.74	54.25	1508	75.0	9
Average engine running time, 16.1 hrs.																	
6799	911	7542	7412	7261	1570	1628	1488	5.018	7976	.635	35.98	35.58	35.98	50.85	2065	77.8	10
6608	897	7366	7232	7090	1453	1610	1476	4.924	8022	.639	36.58	36.11	36.50	51.51	1944	77.6	11
6177	891	6977	6838	6712	1284	1585	1464	4.683	7998	.637	36.82	36.57	36.94	52.51	1711	76.9	12
5653	875	6537	6377	6264	1084	1568	1466	4.370	8022	.639	37.28	37.47	37.81	53.36	1454	74.8	13
Average engine running time, 24.7 hrs.																	
6446	904	7210	7075	6932	1476	1597	1467	4.845	7991	.636	35.81	35.07	35.46	50.52	1954	76.6	14
6118	894	6934	6789	6658	1305	1586	1467	4.641	7998	.637	36.36	36.01	36.38	51.57	1735	75.7	15
5611	881	6477	6324	6208	1127	1561	1457	4.350	8006	.638	36.56	36.32	36.68	52.12	1503	74.0	16
Average engine running time, 4.5 hrs.																	
5163	837	5725	5619	5505	1457	1114	993	5.714	8590	.684	28.27	27.76	28.02	55.15	2270	75.0	17
5052	829	5613	5509	5404	1404	1104	987	5.630	8606	.685	28.43	27.76	28.01	55.29	2203	74.9	18
4911	825	5480	5375	5272	1314	1094	985	5.502	8598	.685	28.41	28.00	28.24	55.85	2069	74.9	19
4679	819	5260	5152	5059	1221	1079	982	5.286	8598	.685	27.80	27.95	28.19	55.83	1923	73.7	20
4240	808	4871	4758	4675	1036	1066	976	4.895	8590	.684	29.00	28.21	28.43	56.36	1638	72.0	21
Average engine running time, 9.3 hrs.																	
3407	833	3765	3705	3615	1510	716	637	5.855	8687	.692	18.06	17.85	18.02	54.66	2403	73.4	22
3364	828	3729	3663	3585	1444	719	643	5.755	8679	.691	18.18	18.13	18.30	55.12	2299	73.8	23
3252	825	3626	3566	3486	1382	709	635	5.657	8687	.692	18.27	18.02	18.17	55.28	2216	73.1	24
3076	817	3457	3392	3324	1256	700	633	5.393	8695	.692	18.19	18.09	18.24	55.44	2025	71.7	25
2788	808	3196	3125	3063	1071	692	635	4.947	8670	.690	18.31	18.21	18.35	55.51	1710	69.9	26
Average engine running time, 10.1 hrs.																	
2060	839	2282	2247	2196	1515	442	395	5.705	8679	.691	10.89	10.84	10.94	53.39	2400	71.3	27
2043	834	2274	2235	2184	1487	440	393	5.728	8719	.694	10.98	10.90	11.00	53.84	2377	71.0	28
2000	831	2224	2188	2138	1419	435	391	5.602	8703	.693	10.87	10.89	10.99	53.89	2276	70.8	29
1904	826	2144	2105	2060	1310	433	395	5.387	8687	.692	10.62	10.95	11.03	54.05	2095	70.3	30
1808	818	2059	2014	1973	1166	436	400	5.059	8695	.692	11.05	11.21	11.30	54.10	1867	68.2	31



Station	Total-pressure tubes	Static-pressure tubes	Static-pressure wall orifice	Thermo-couples
1	42	9	18	18
Compressor rotor stages	--	-	15	--
2	1 integrating 36 regular	-	6	18
3	5 integrating 3 regular	-	--	--
4	28	-	4	24
5	34	8	4	23

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Figure 1. - Cross section of Python turbine-propeller engine showing location of instrumentation.

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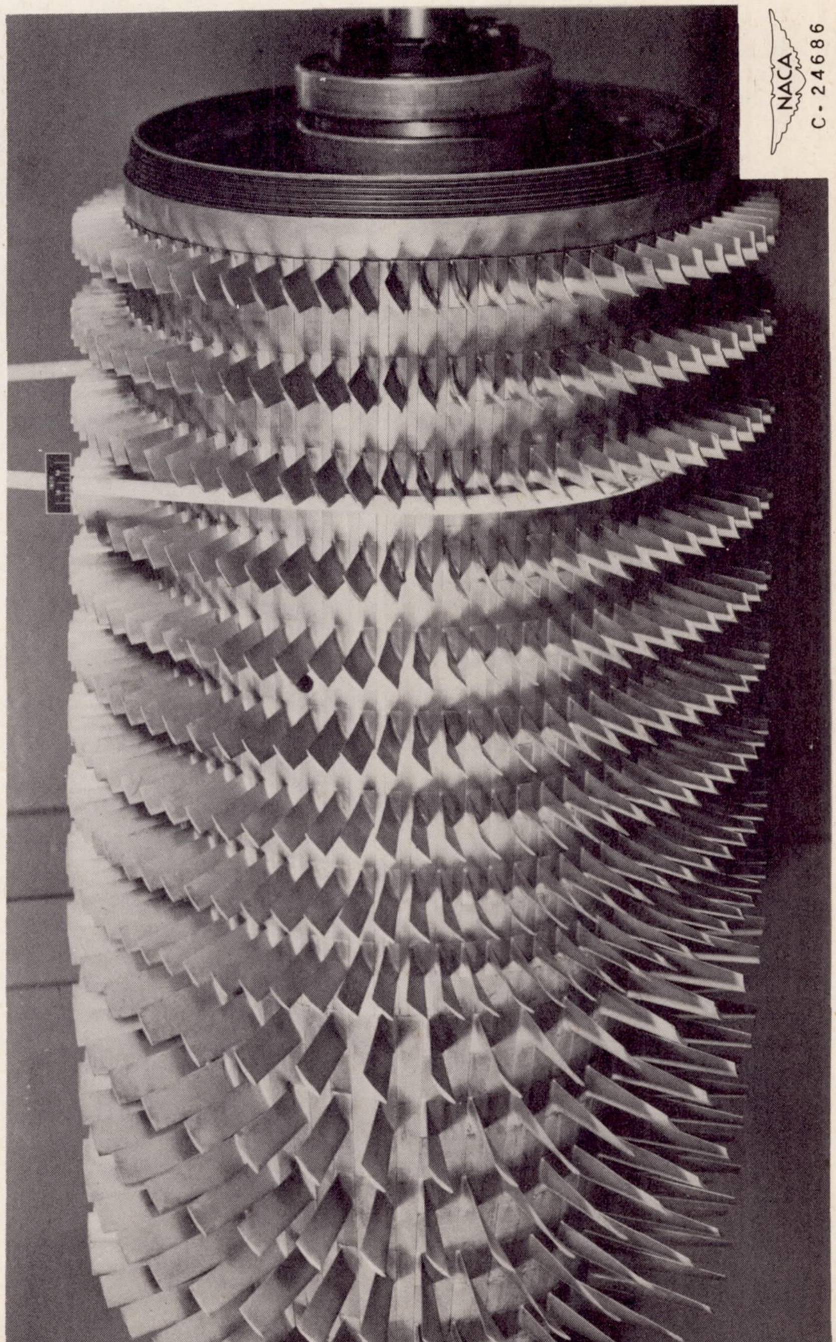

Figure 2. - Compressor rotor.

2059

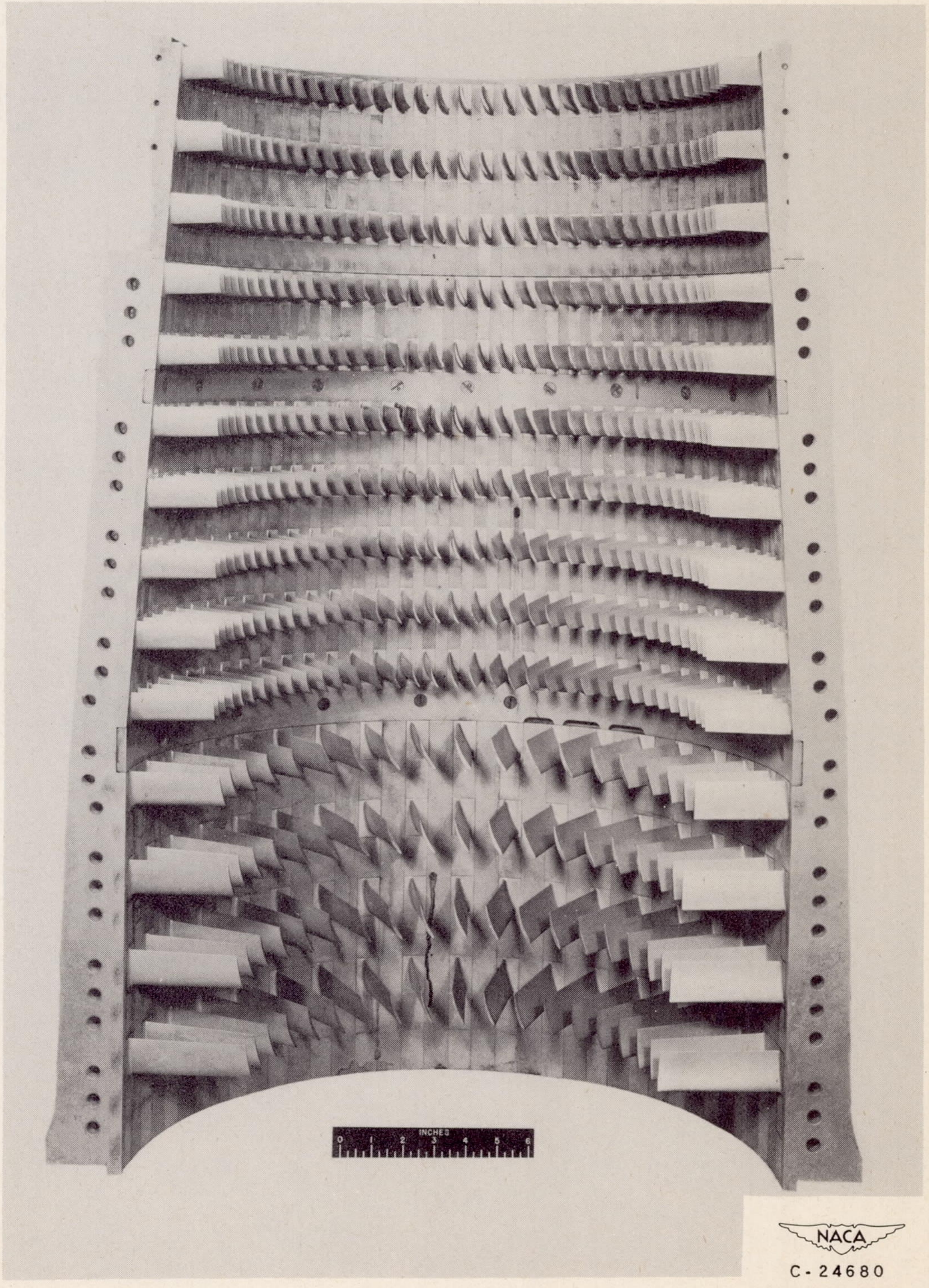

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Figure 3. - Compressor stator (lower half).

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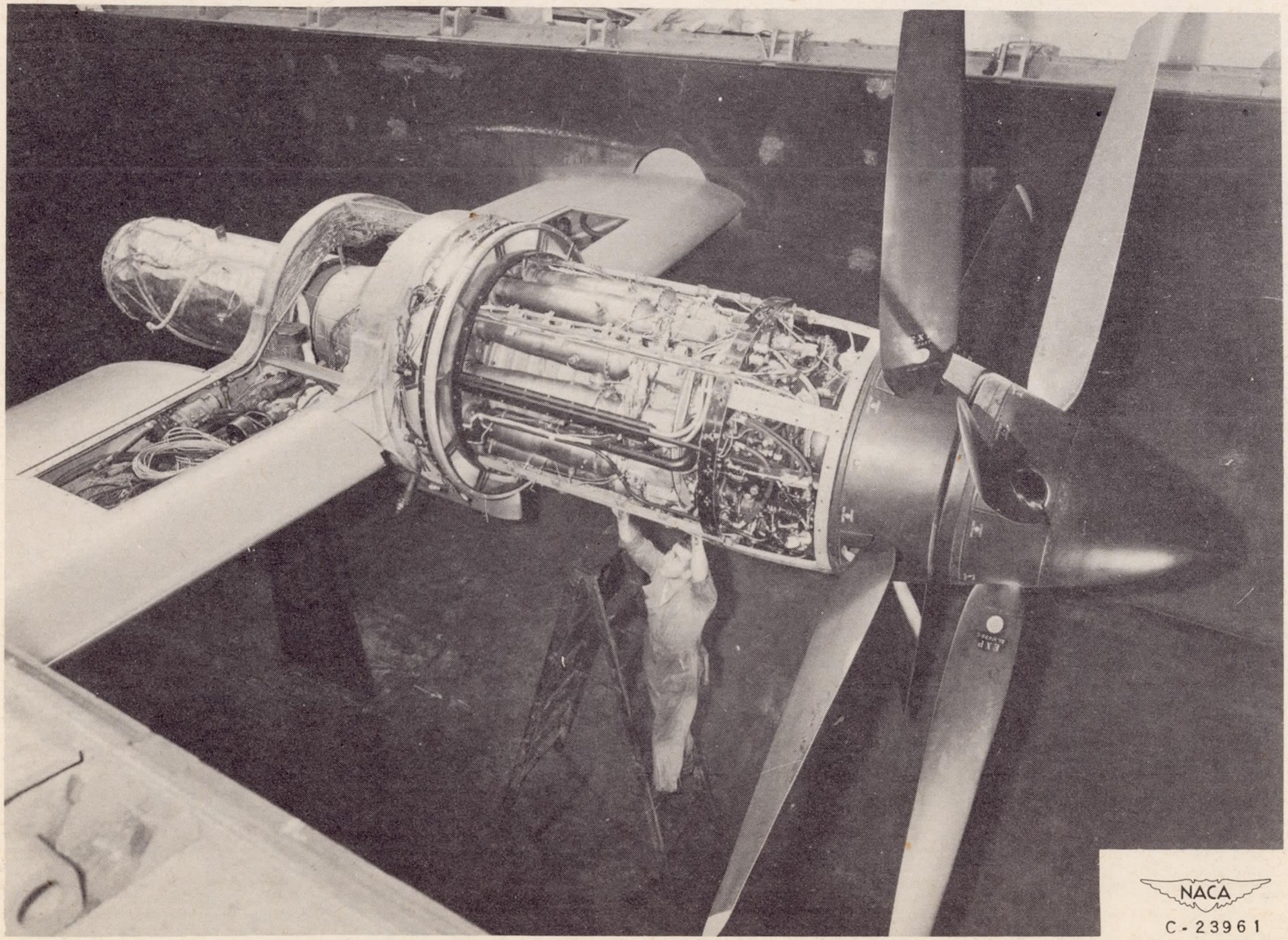

Figure 4. - Gas-turbine-propeller-engine installation in altitude wind tunnel.

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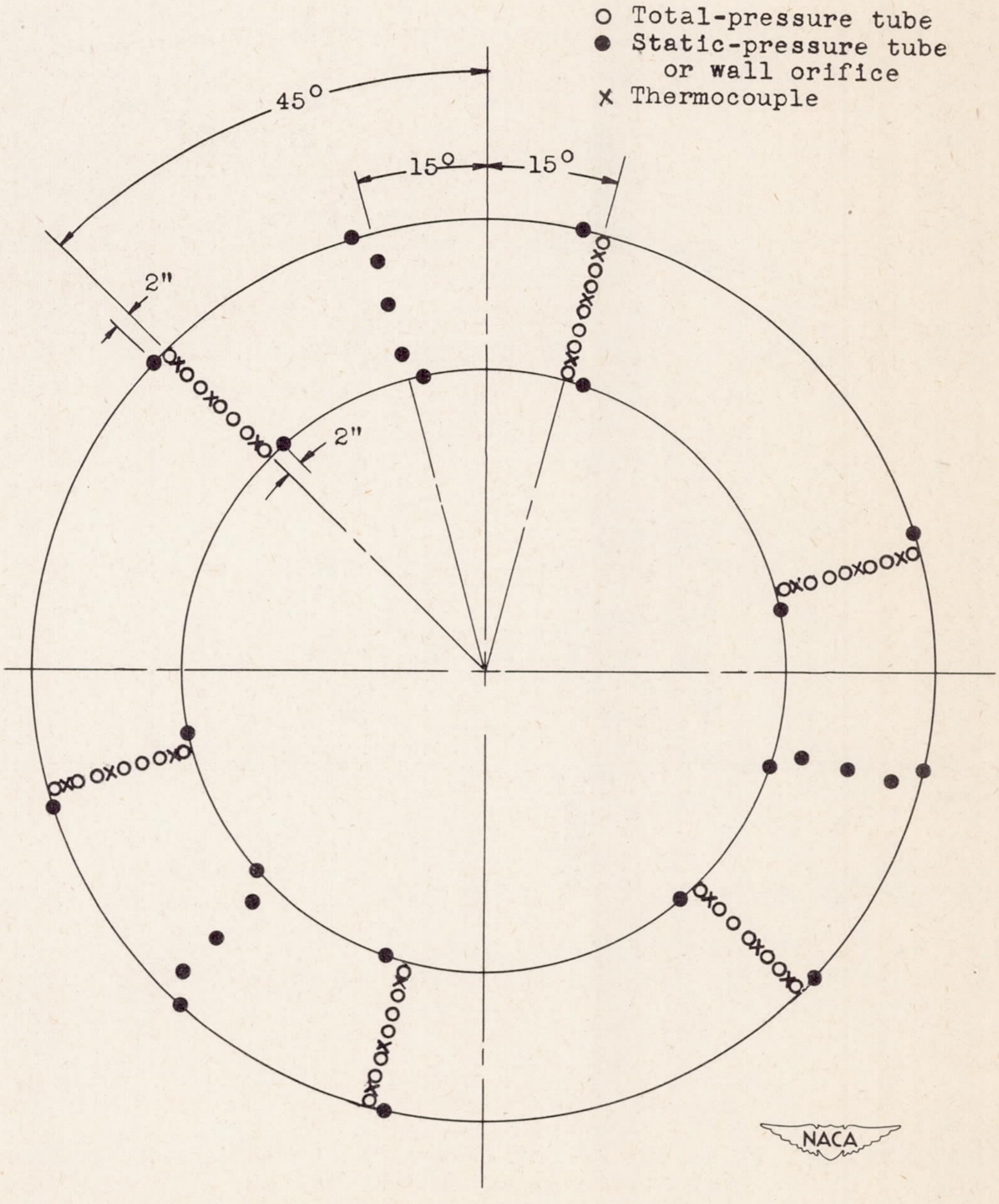
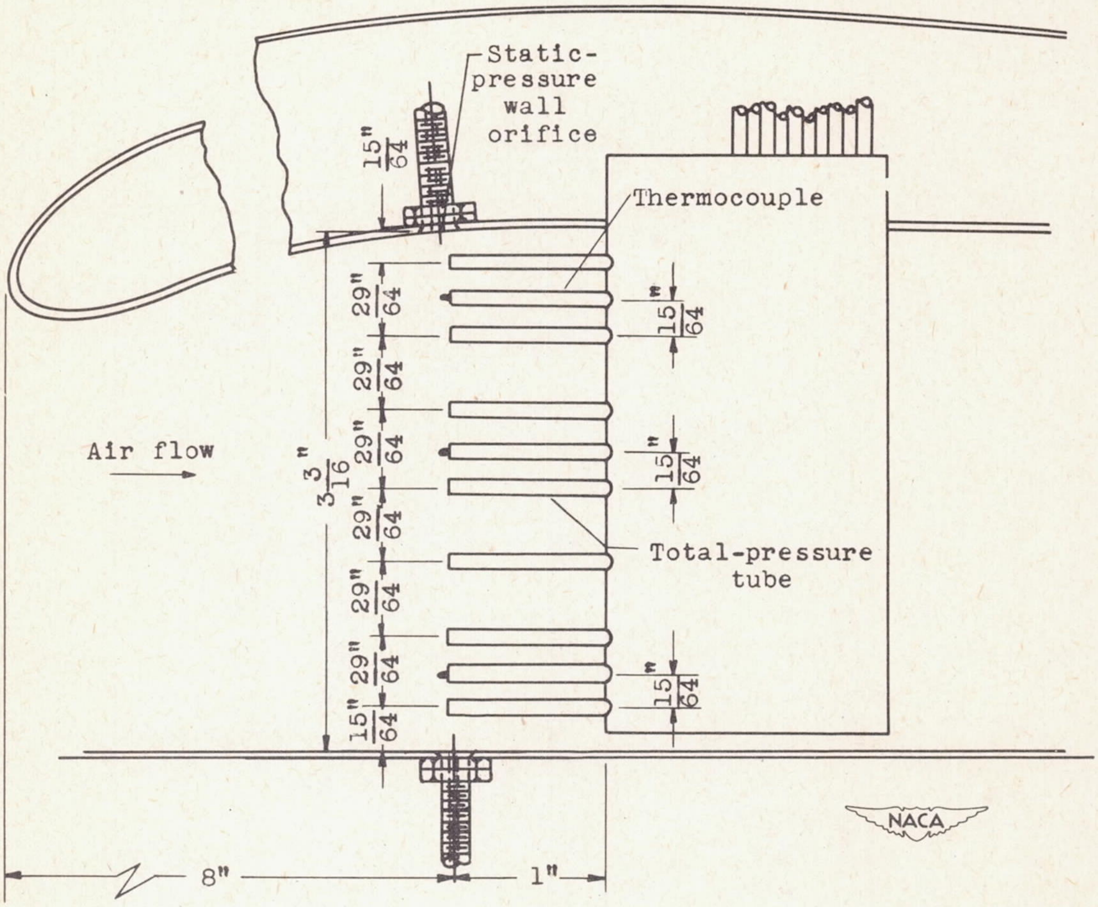


(a) Schematic diagram; viewed from upstream.

Figure 5. - Instrumentation at engine inlet, station 1, 8 inches behind tip of cowling.

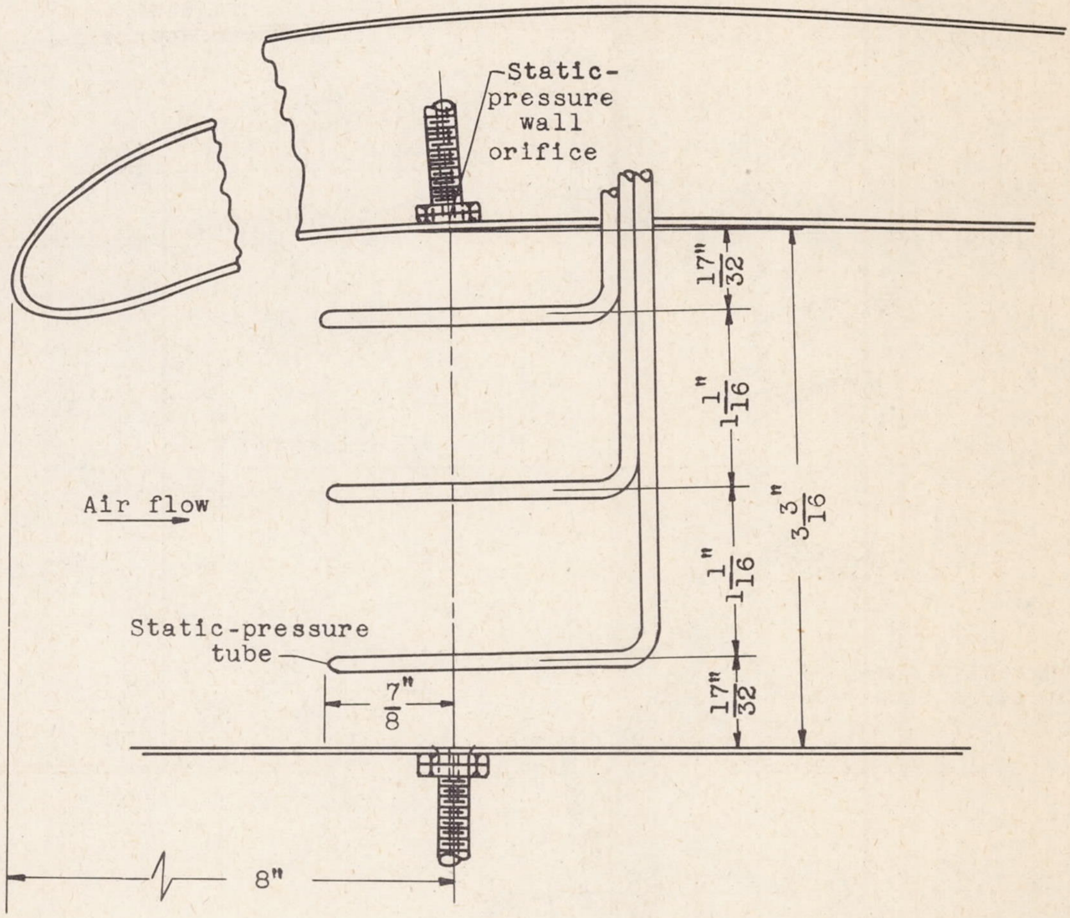
2059



(b) Typical detail sketch of total-pressure tubes, static-pressure wall orifices, and thermocouples.

Figure 5. - Continued. Instrumentation at engine inlet, station 1, 8 inches behind tip of cowling.

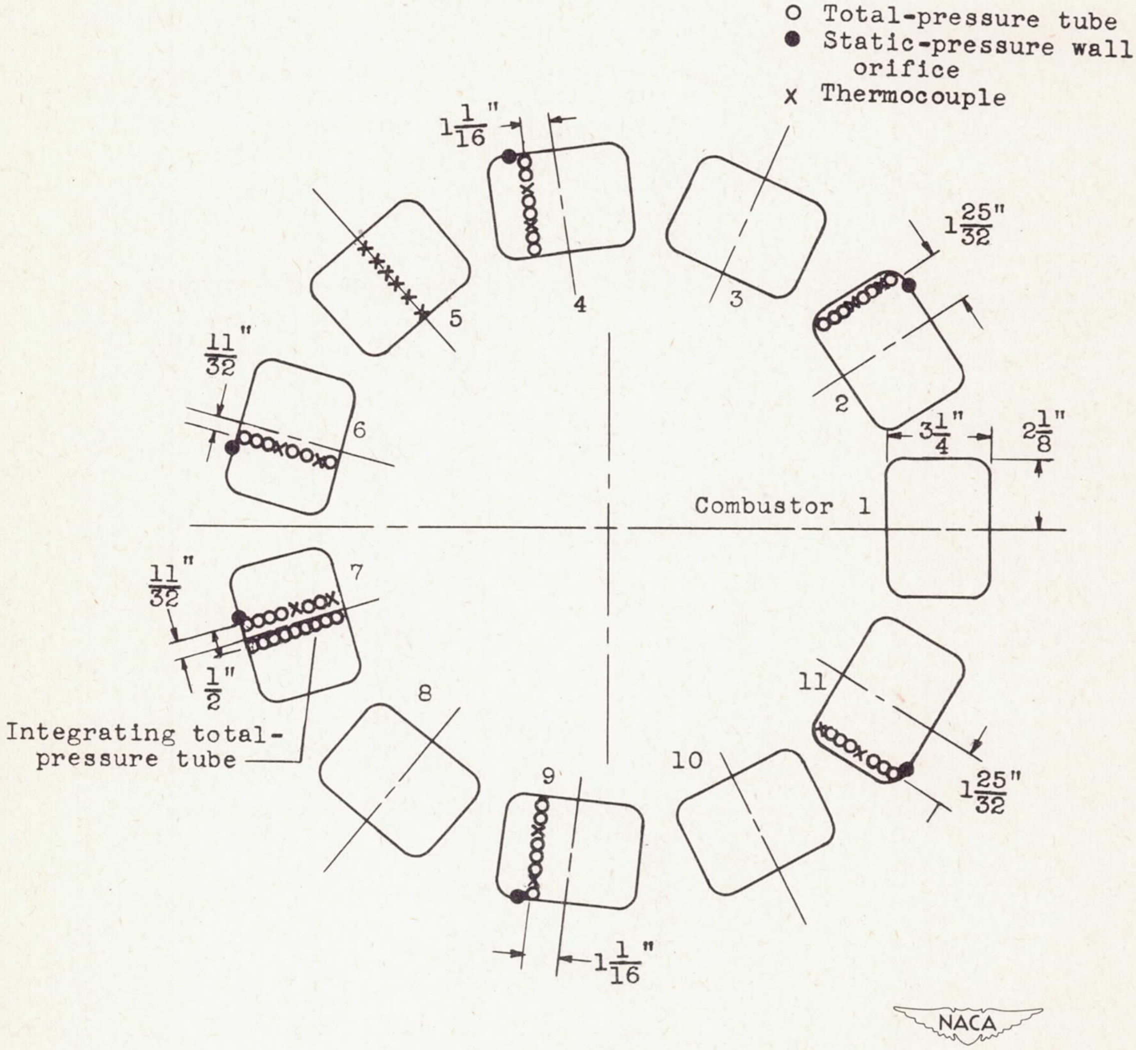
2059



(c) Typical detail sketch of static-pressure tubes and wall orifices.

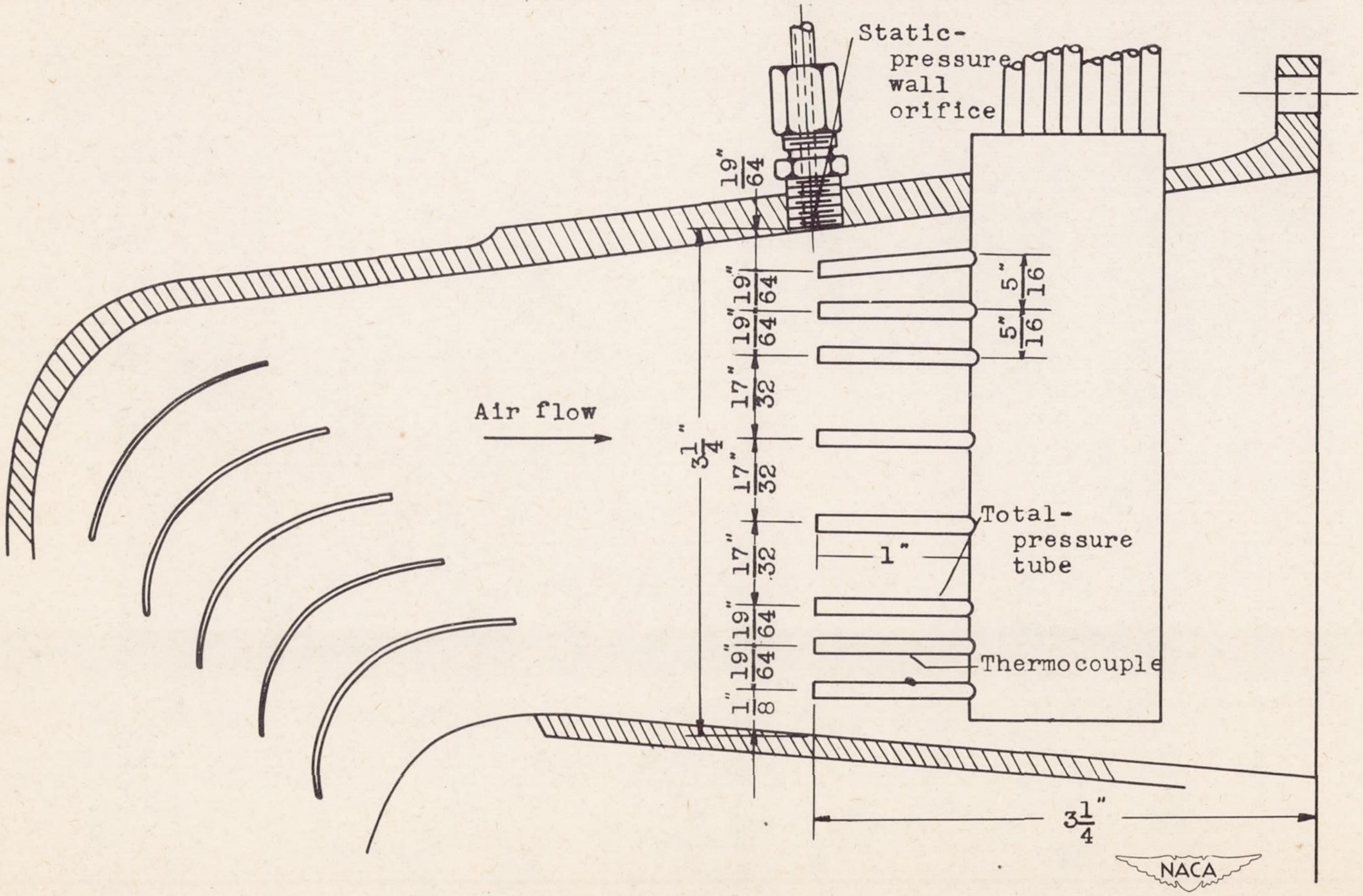
Figure 5. - Concluded. Instrumentation at engine inlet, station 1, 8 inches behind tip of cowling.

2059



(a) Schematic diagram; viewed from upstream.

Figure 6. - Instrumentation at compressor outlet, station 2, $3\frac{1}{4}$ inches upstream of burner-inlet flange.



(b) Typical detail sketch of total-pressure tubes, static-pressure wall orifices, and thermocouples.

Figure 6. - Concluded. Instrumentation at compressor-outlet, station 2, $3\frac{1}{4}$ inches upstream from burner-inlet flange.

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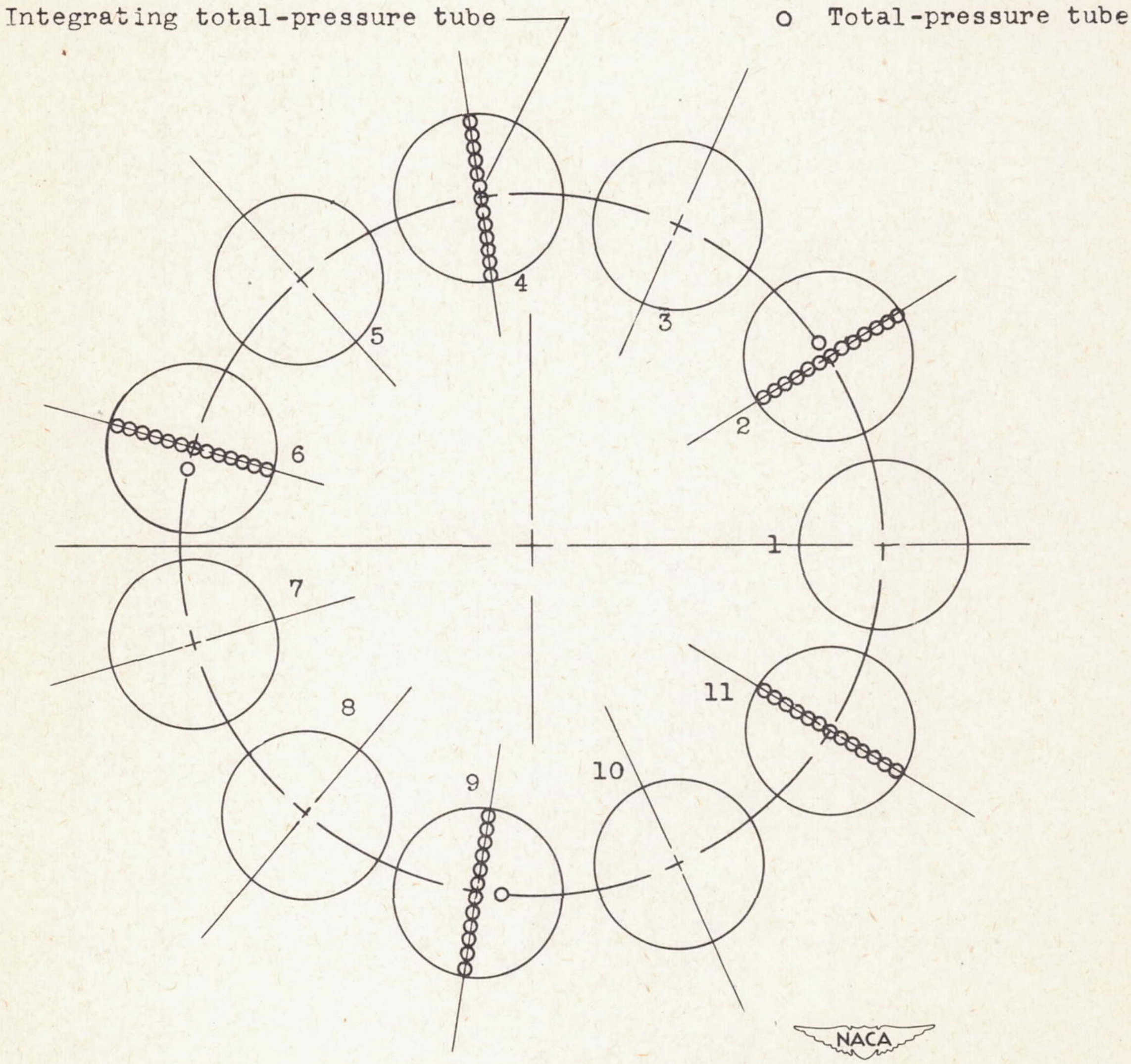

Figure 7. - Location of instrumentation at turbine inlet, station 3, 3 inches upstream of turbine flange. Viewed from upstream.

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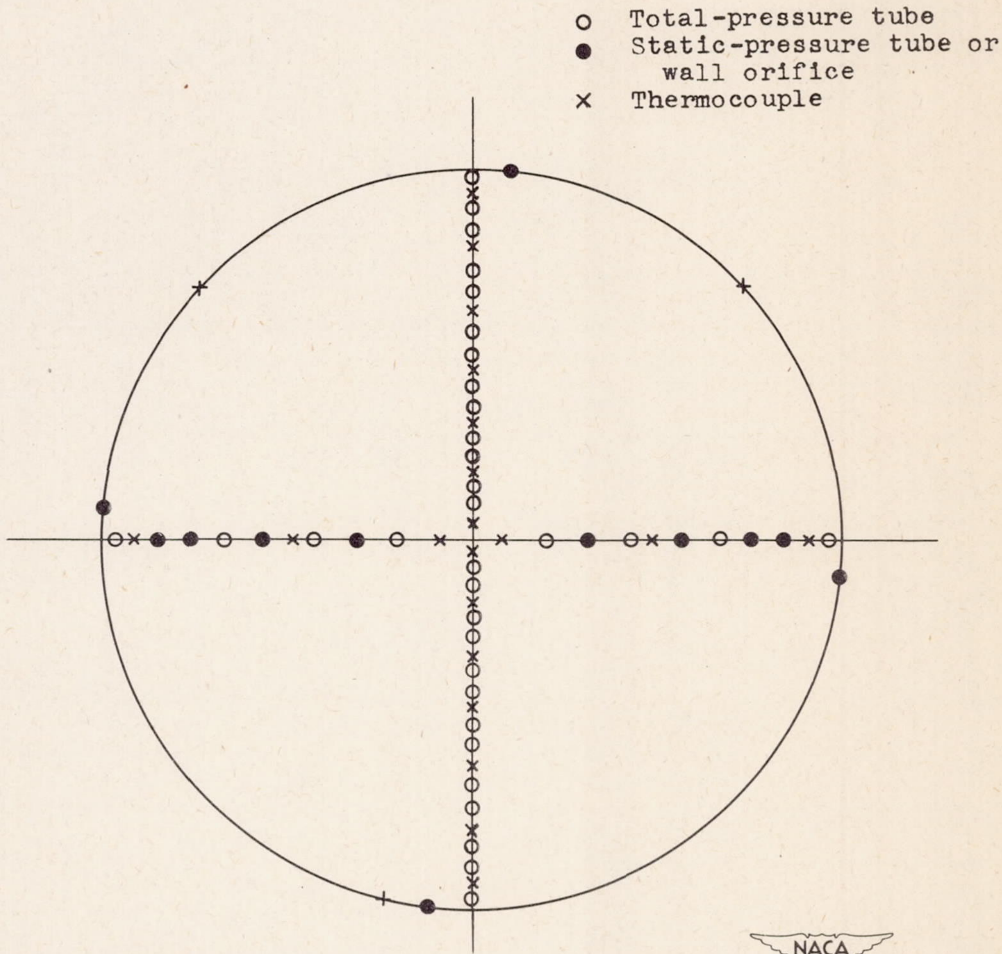

Figure 8. - Location of instrumentation in tail pipe, station 5, $5\frac{1}{4}$ inches upstream of exhaust-nozzle outlet. Viewed from upstream.

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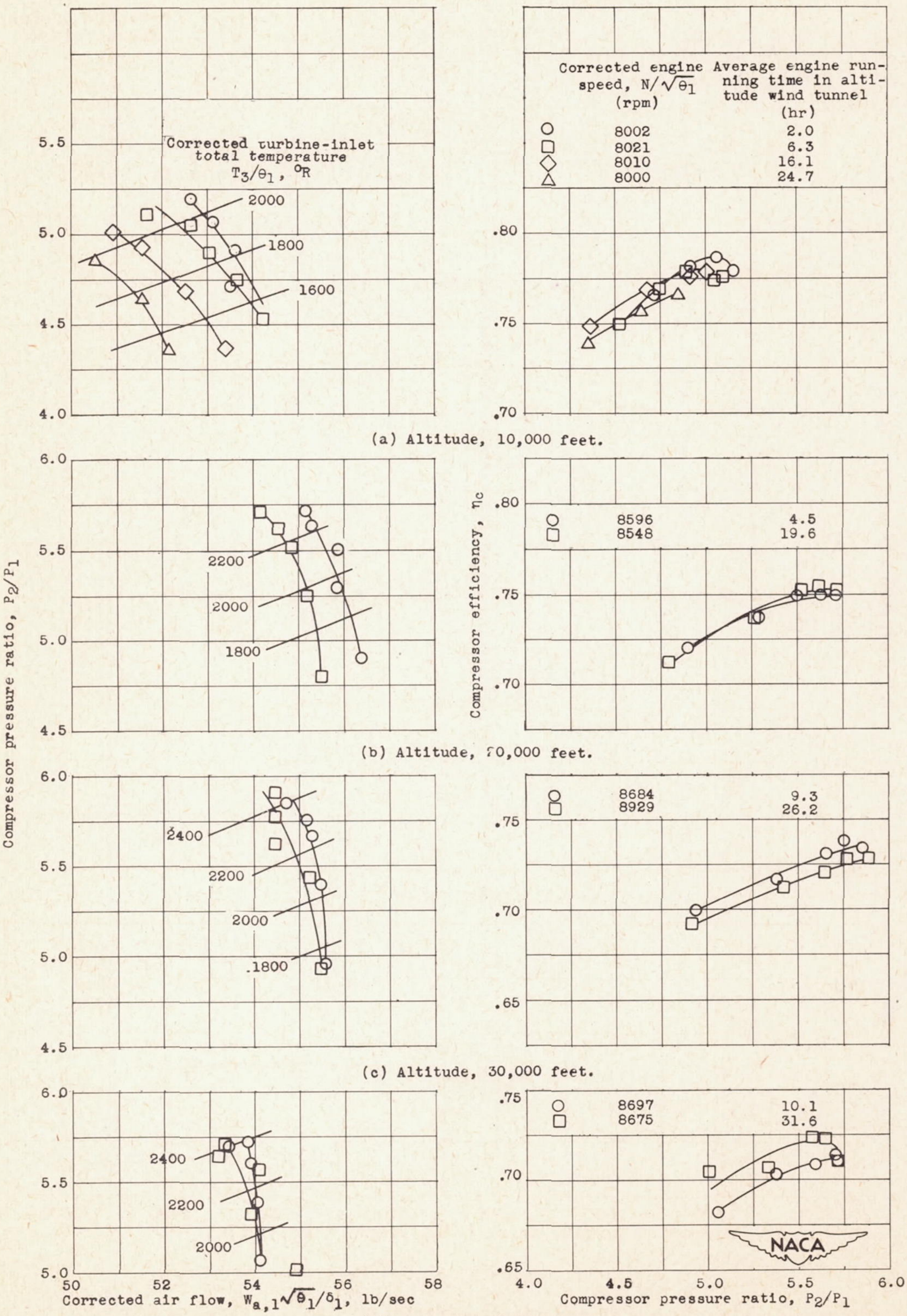

Figure 9. - Variation of compressor performance with engine operational time in altitude wind tunnel. Cowl-inlet ram pressure, 1.03.

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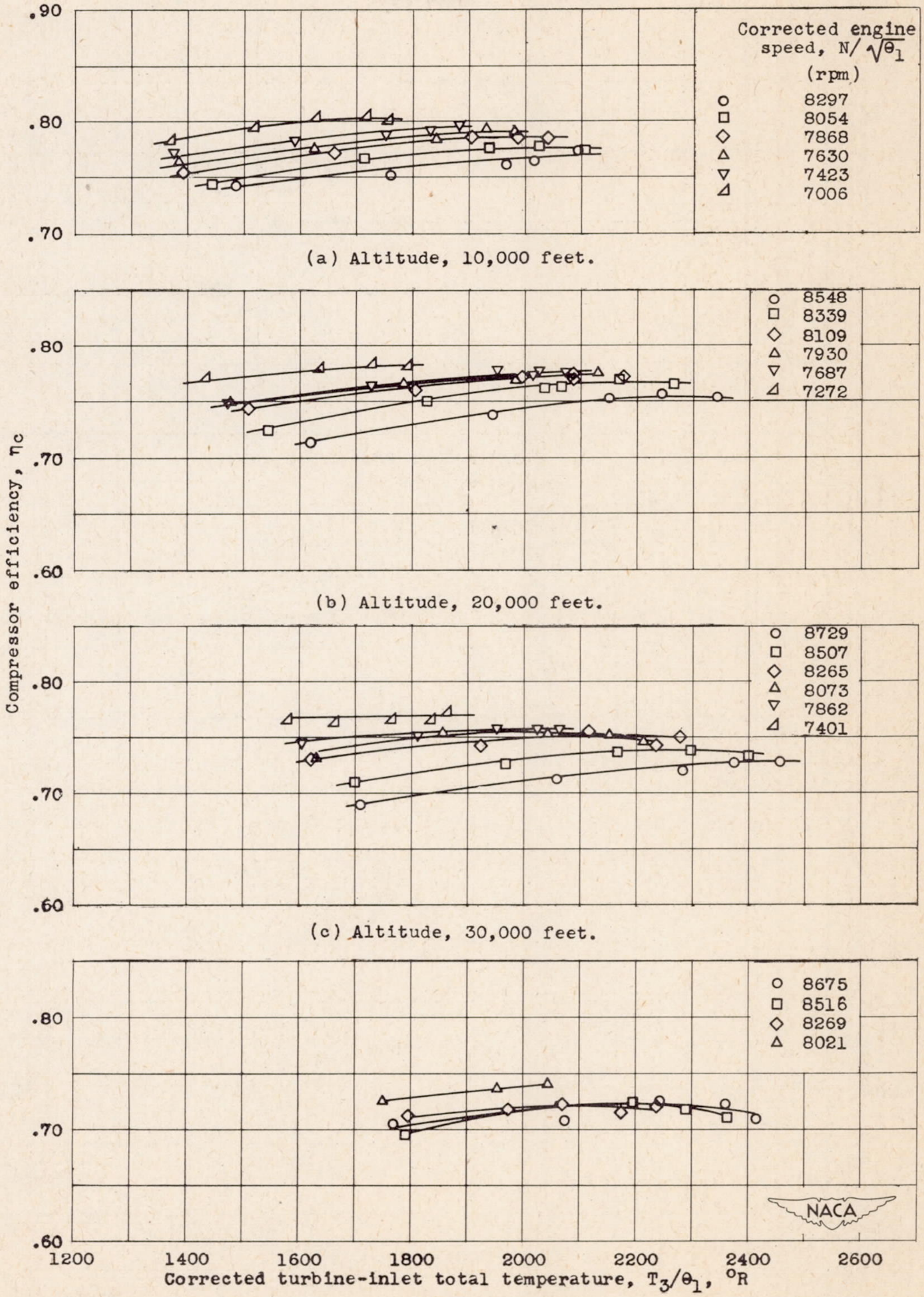

(d) Altitude, 40,000 feet.

Figure 10. - Variation of compressor efficiency with corrected turbine-inlet temperature. Cowl-inlet ram pressure ratio, 1.03.

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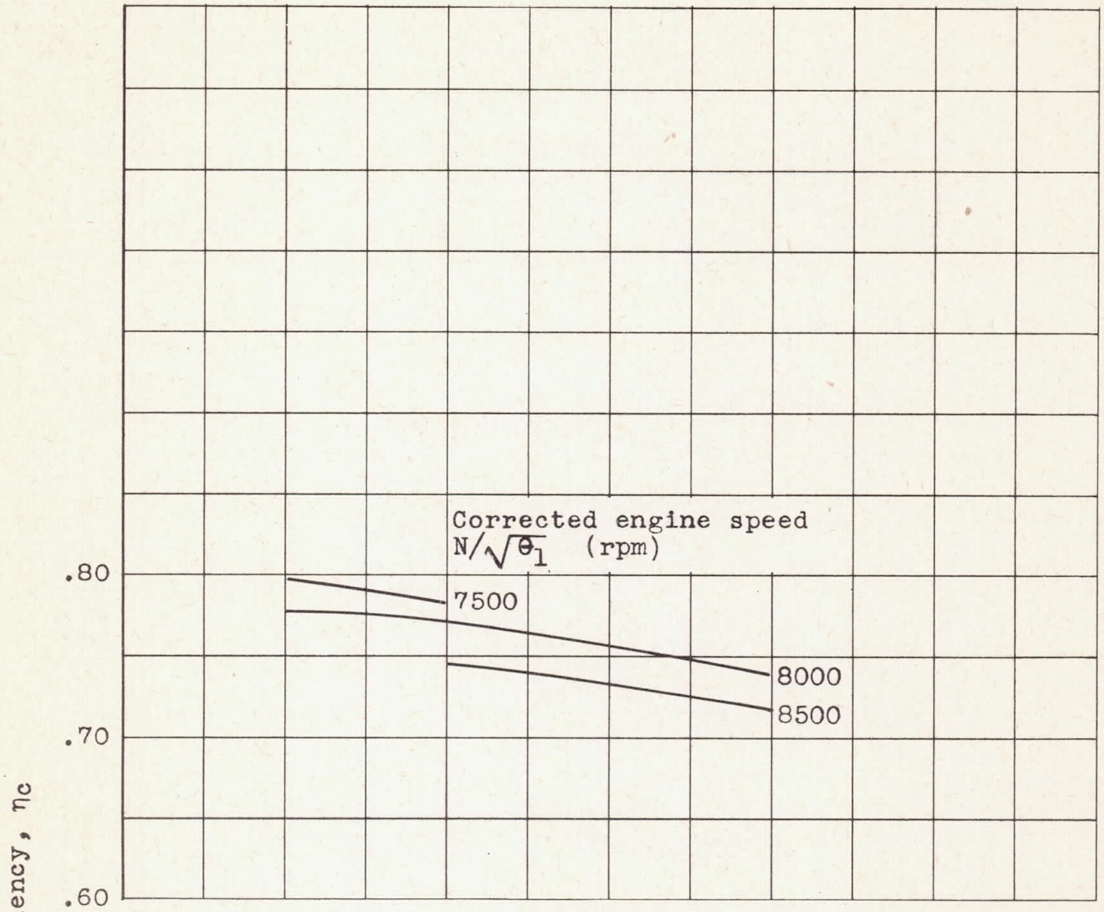
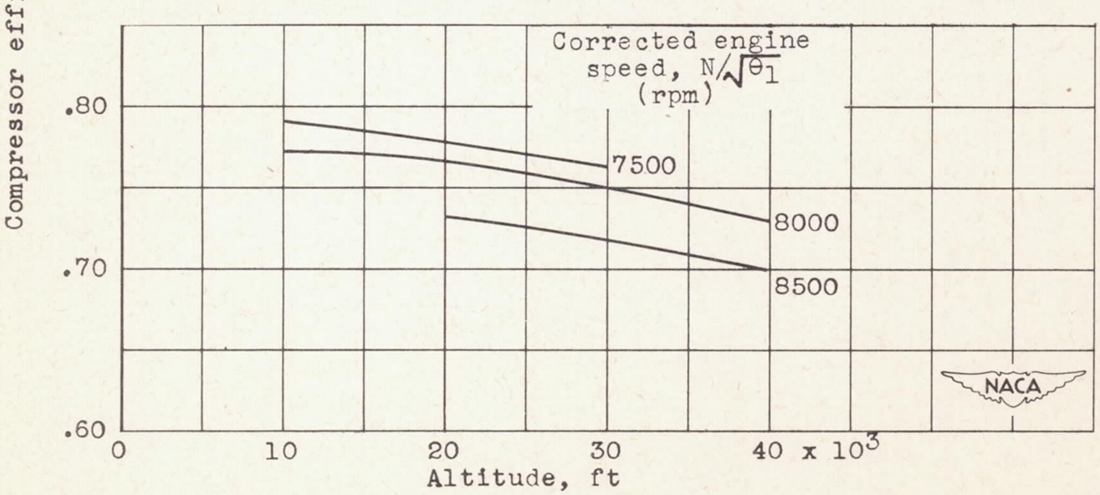


(a) Corrected turbine-inlet total temperature, T_3/θ_1, 2000° R.



(b) Corrected turbine-inlet total temperature, T_3/θ_1, 1800° R.

Figure 11. - Variation of compressor efficiency with altitude. Cowl-inlet ram pressure ratio, 1.03.

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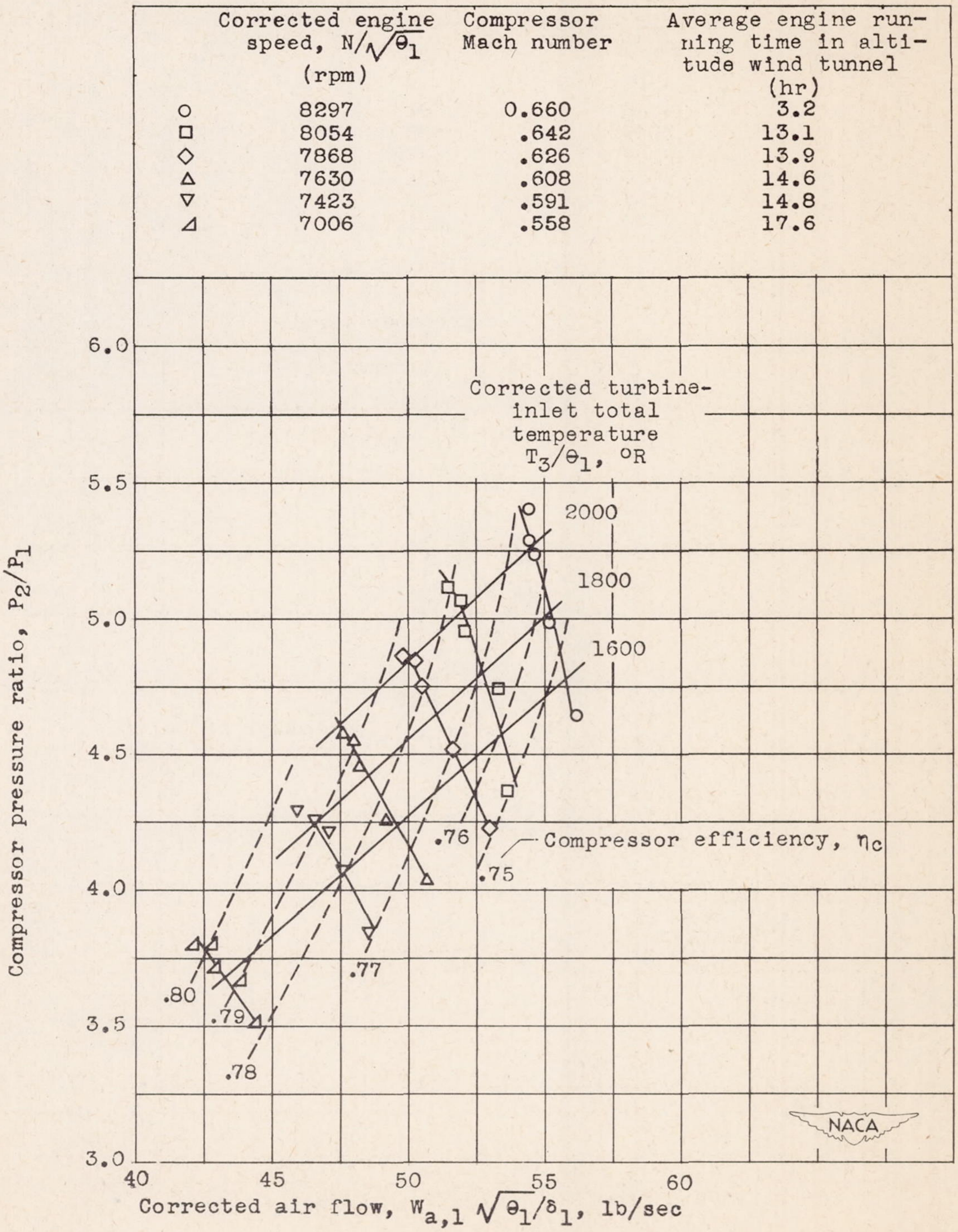

(a) Altitude, 10,000 feet.

Figure 12. - Compressor performance map. Cowl-inlet ram pressure ratio, 1.03.

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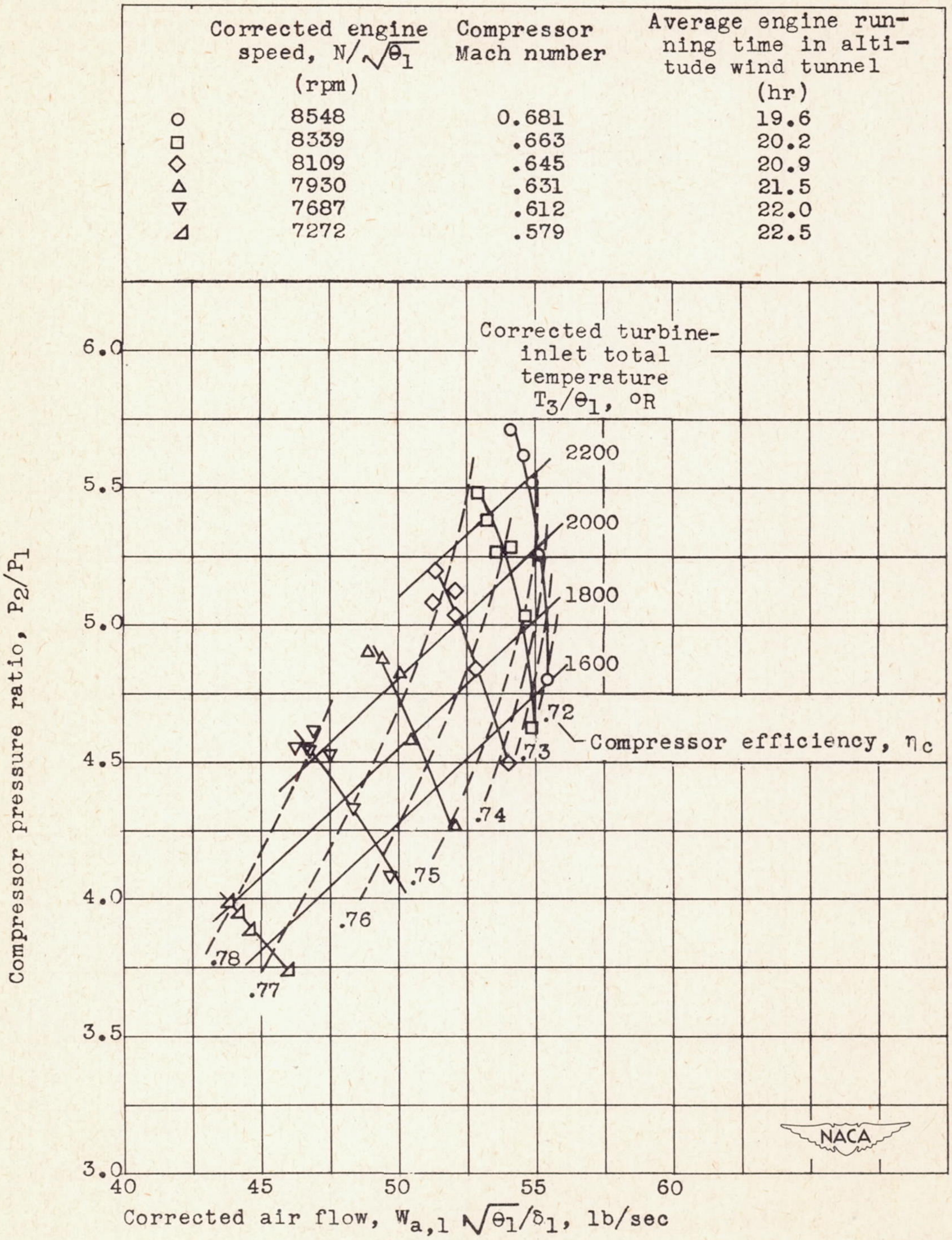

(b) Altitude, 20,000 feet.

Figure 12. - Continued. Compressor performance map. Cowl-inlet ram pressure ratio, 1.03.

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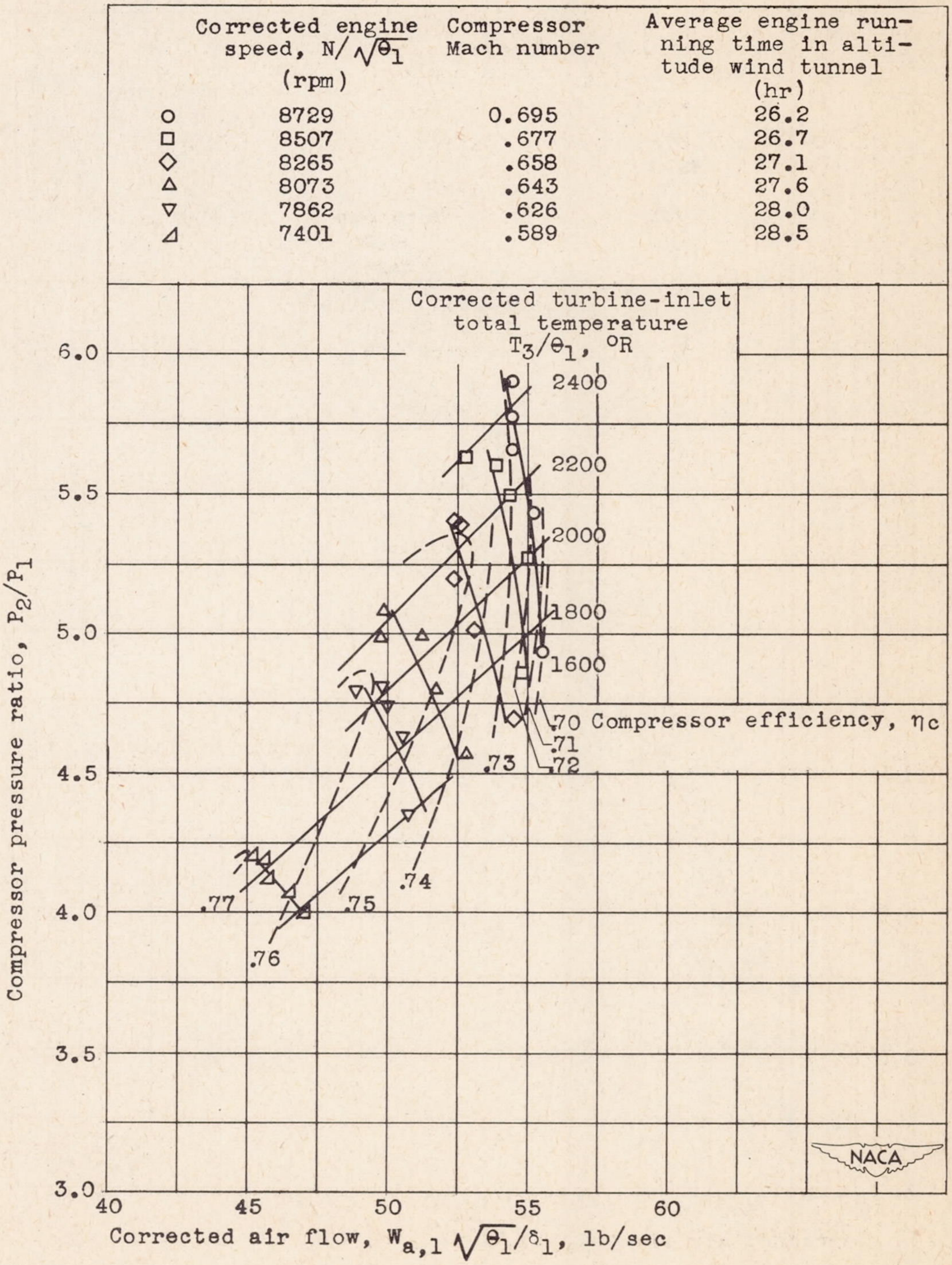
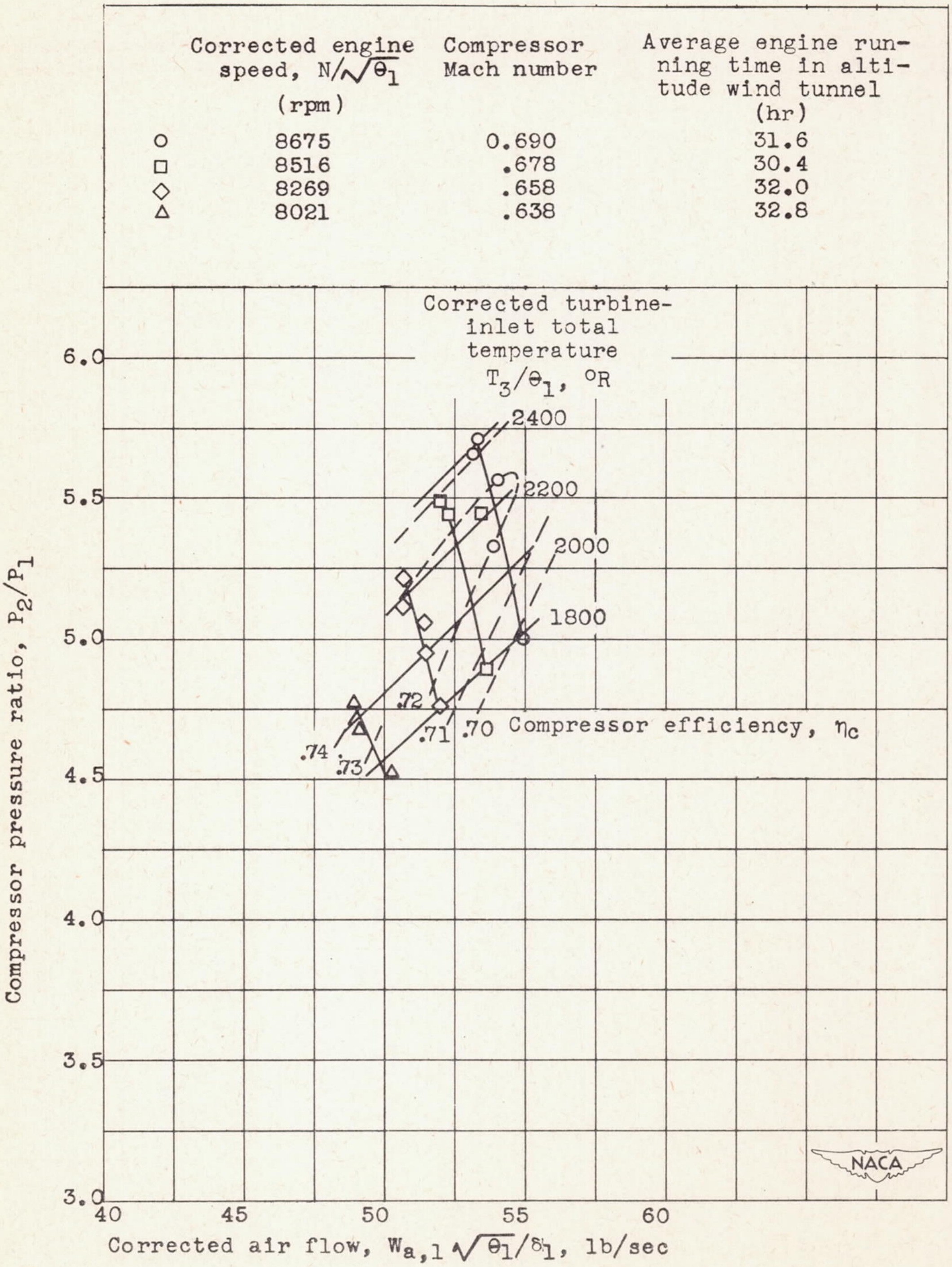


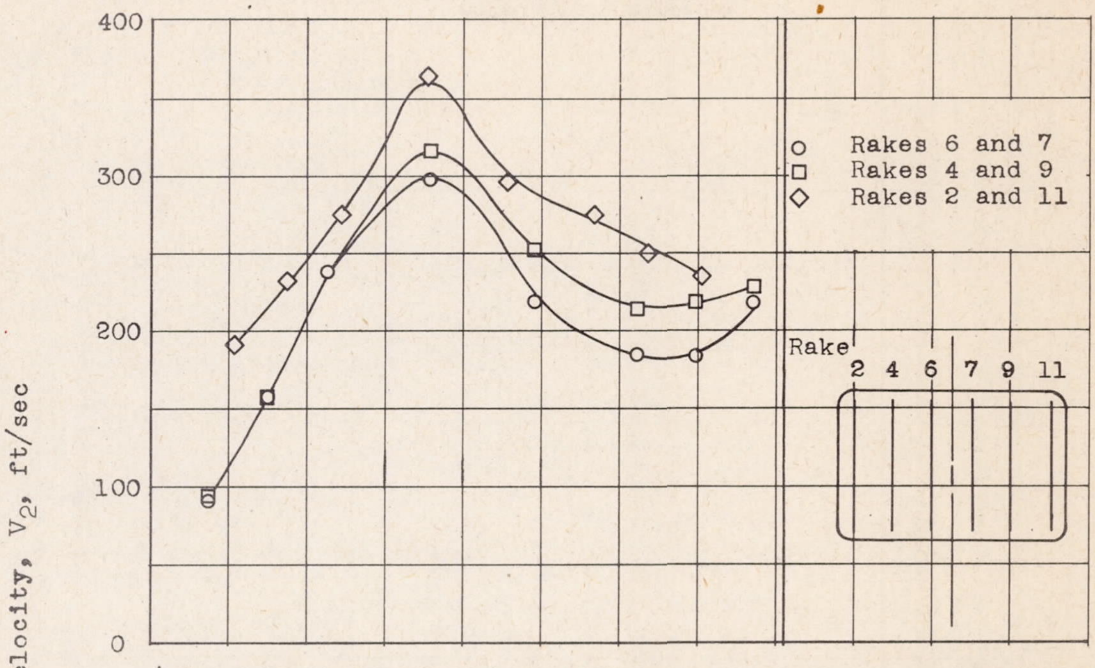
(c) Altitude, 30,000 feet.

Figure 12. - Continued. Compressor performance map. Cowl-inlet ram pressure ratio, 1.03.

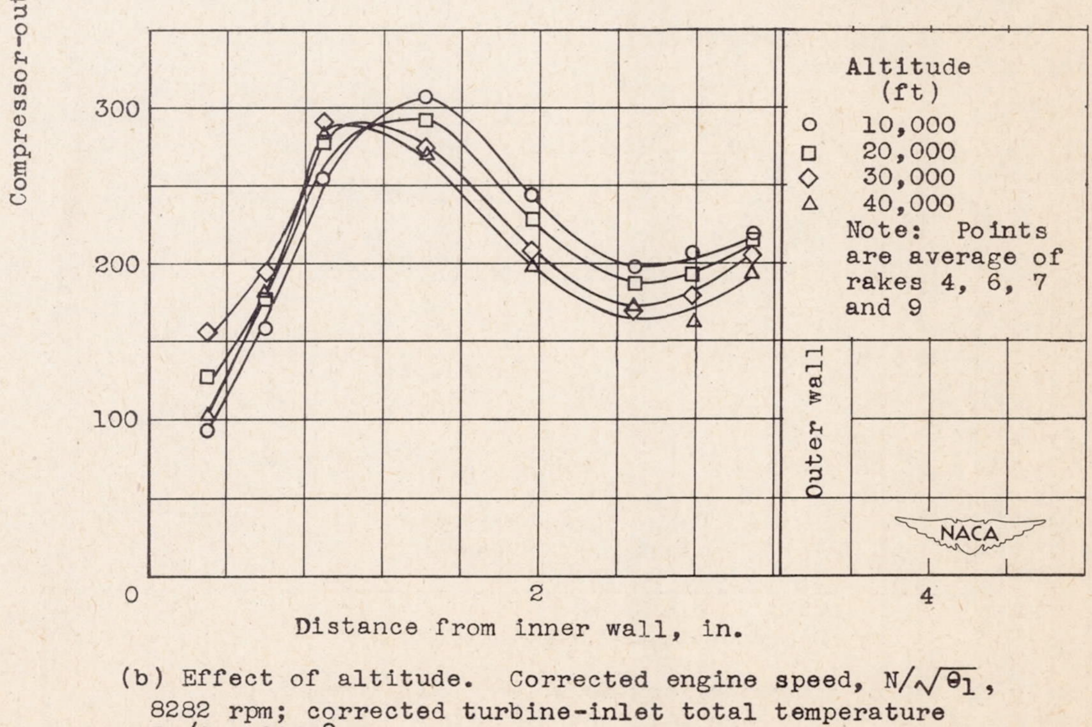


(d) Altitude, 40,000 feet.

Figure 12. - Concluded. Compressor performance map. Cowl-inlet ram pressure ratio, 1.03.

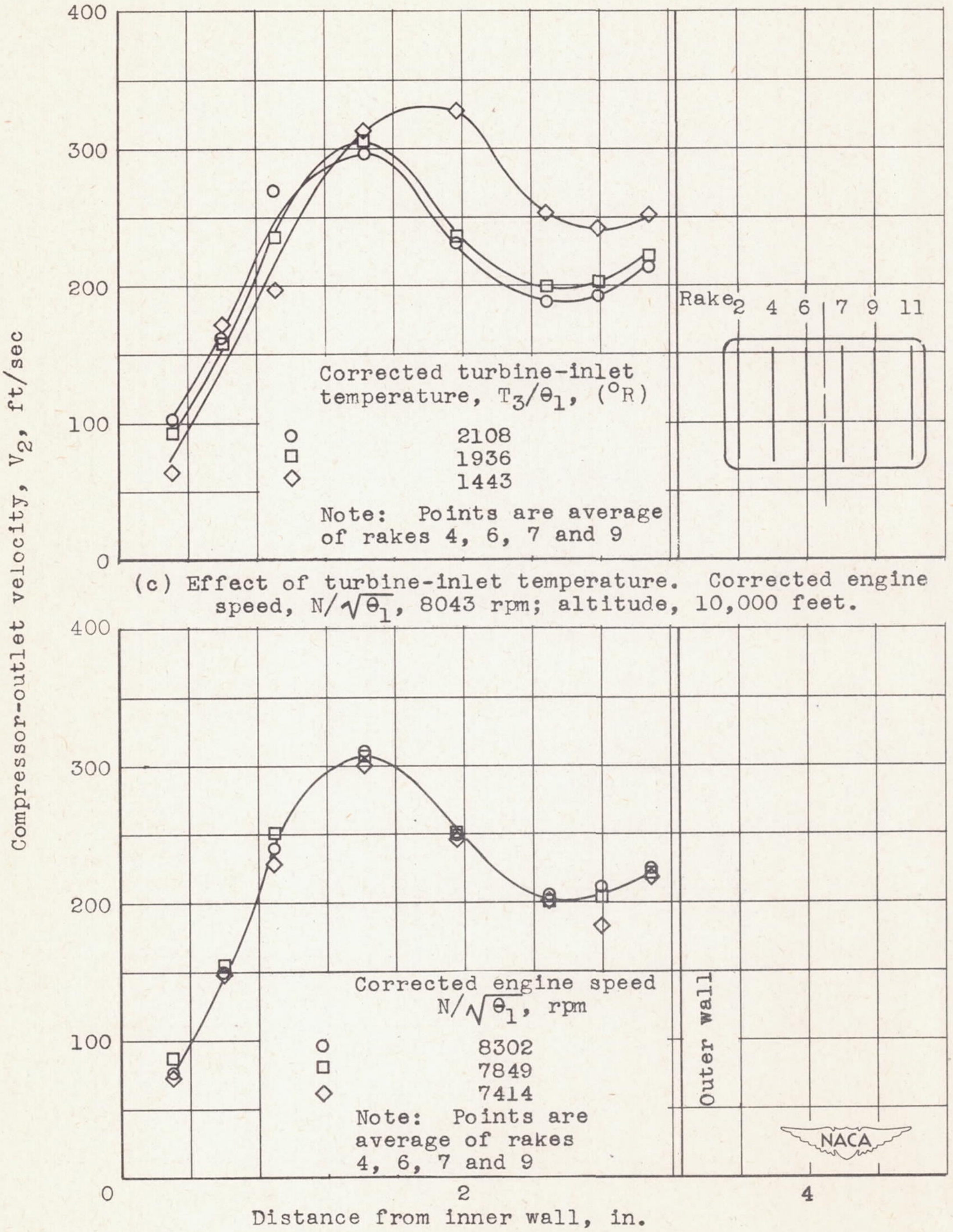


(a) Typical velocity profile at compressor outlet. Altitude 10,000 feet; corrected engine speed, $N/\sqrt{\theta_1}$, 8056 rpm; corrected turbine-inlet total temperature, T_3/θ_1, 1936° R.



(b) Effect of altitude. Corrected engine speed, $N/\sqrt{\theta_1}$, 8282 rpm; corrected turbine-inlet total temperature T_3/θ_1, 2035° R.

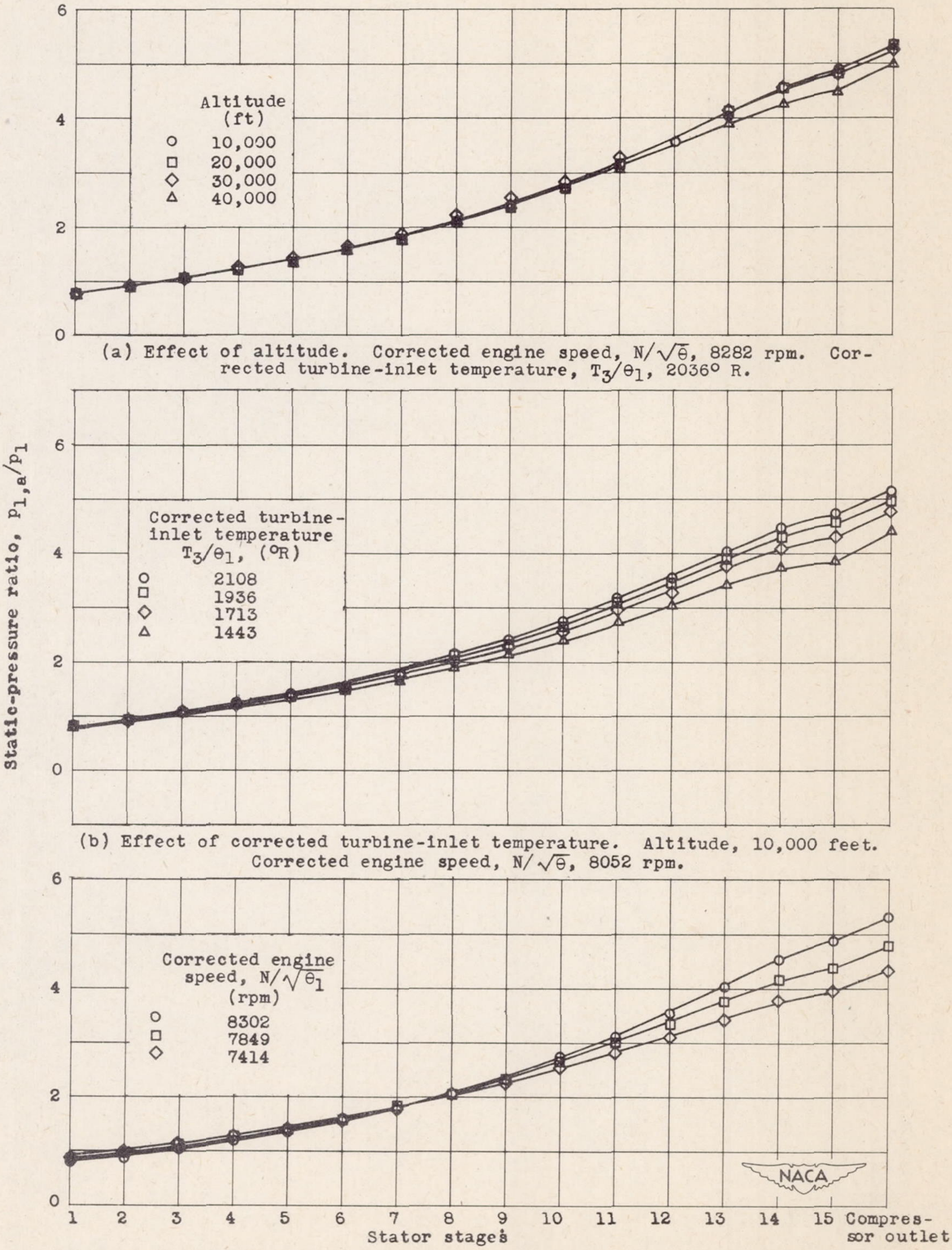
Figure 13. - Velocity profiles at compressor-outlet. Cowl-inlet ram pressure ratio, 1.03.



(c) Effect of turbine-inlet temperature. Corrected engine speed, $N/\sqrt{\theta_1}$, 8043 rpm; altitude, 10,000 feet.

(d) Effect of corrected engine speed. Altitude, 10,000 feet; corrected turbine-inlet temperature, T_3/θ_1, 1916° R.

Figure 13. - Concluded. Velocity profiles at compressor outlet. Cowl-inlet ram pressure ratio, 1.03.



(a) Effect of altitude. Corrected engine speed, $N/\sqrt{\theta}$, 8282 rpm. Corrected turbine-inlet temperature, T_3/θ_1, 2036° R.

(b) Effect of corrected turbine-inlet temperature. Altitude, 10,000 feet. Corrected engine speed, $N/\sqrt{\theta}$, 8052 rpm.

(c) Effect of engine speed. Altitude, 10,000 feet. Corrected turbine-inlet temperature (T_3/θ_1), 1916° R.

Figure 14. - Compressor-rotor stage static-pressure ratio profile. Cowl-inlet ram pressure ratio, 1.03.

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