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RESEARCH MEMORANDUM

for the

Air Research and Development Command, U. S. Air Force

SOME ALTITUDE OPERATIONAL CHARACTERISTICS OF A

PROTOTYPE IROQUOIS TURBOJET ENGINE

COORD. NO. AF-P-6

By Daniel J. Peters and John E. McAulay

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

An investigation of the early developmental Iroquois turbojet engine was conducted in an altitude test chamber. As a part of the overall investigation, the following information was obtained: the engine steady-state windmilling characteristics, engine altitude-ignition limits, high-engine-speed altitude reignition characteristics after simulated combustor blowout, and information pertaining to engine operation at relatively high engine-inlet temperatures.

The steady-state corrected parameters of windmilling drag, rotor speeds, and airflow approach maximum values at a flight Mach number between 1.6 and 1.8. Decreasing the exhaust-nozzle area at a constant flight Mach number results in lower values of corrected rotor windmilling speeds, airflow, and drag. Engine altitude-ignition limits with the standard spark ignition system were markedly affected by variations in exhaust-nozzle area, compressor discharge bleeds, inlet-air temperature, and flight Mach number. With the aid of oxygen enrichment, successful ignition was obtained with all engine variables up to an altitude of 63,000 feet, which was the maximum altitude obtainable with the facility. The investigation of high-speed altitude reignition characteristics demonstrated that reignition of the engine is possible after a simulated combustor blowout. After 64 minutes of continuous engine operation, with inlet temperatures between 235° and 338° F, no operating difficulties or damage to the engine was observed.

INTRODUCTION

An investigation of the performance and operating characteristics of an early developmental Iroquois twin-spool turbojet engine has been conducted in an NACA Lewis altitude test chamber at the request of the Air Research and Development Command, U.S. Air Force. A discussion of the engine performance and some of the operating characteristics influencing engine performance is presented in reference 1. The engine steady-state windmilling characteristics, ignition characteristics at altitude

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windmilling conditions, high-speed altitude reignition characteristics, and information relative to engine operation at relatively high inlet temperatures, all obtained as a part of the over-all investigation, are presented herein.

Steady-state windmilling data were obtained over a range of flight Mach numbers from 0.48 to 1.72 at altitudes of 35,000 and 50,000 feet and are presented in terms of rotor speeds, airflow, compressor pressure ratio, and windmilling drag. Engine ignition characteristics at altitude windmilling conditions were investigated over a range of flight Mach numbers from 0.5 to 1.5; the altitude ignition limits for the spark ignition system with and without an oxygen-boost system are presented. A number of high-engine-speed reignitions were attempted; with the engine operating at near-rated conditions, the fuel flow and ignition were turned off to simulate a combustor blowout, which might occur during armament firing, as discussed in reference 2. After various delay times following fuel cut-off, attempts were made to reignite the engine. A summary of this investigation is presented herein. Finally, a time history is presented for engine-inlet temperature, rotor speed, and ambient test-section temperature during operation of the engine at inlet temperatures up to 348°F.

APPARATUS

Installation

The installation of an Iroquois engine in a 14-foot-diameter altitude test chamber is shown in figure 1. A forward bulkhead, which incorporates a labyrinth seal around the engine-inlet air duct, provided a means of maintaining a pressure differential across the engine. The engine was mounted on a bedplate supported by flexure plates. Jet thrust was measured with a calibrated null-type thrust cell after accounting for forces due to the pressure differential across the front bulkhead labyrinth seal. The engine-inlet air temperatures and pressures and ambient exhaust pressures were regulated to simulate the desired altitude flight conditions.

Engine

The prototype Iroquois engines used in this investigation have a sea-level static thrust rating of approximately 18,000 pounds. The Iroquois engine is a twin-spool turbojet engine that includes a three-state, transonic, axial flow, low-pressure compressor driven by a single-stage turbine; a seven-stage, axial-flow, high-pressure compressor driven by a two-stage turbine; an annular vaporizing combustion chamber; and an afterburner with a fully modulated convergent exhaust nozzle. The maximum

low- and high-pressure rotor speeds are 5740 and 7800 rpm, respectively.
The rated turbine-discharge gas temperature is 1275° F (1735° R) as indi-
cated by 25 Chromel-Alumel thermocouples located at the turbine discharge.
The maximum and minimum exhaust-nozzle areas are 1020 and 649 square
inches, respectively. The engine had two high-pressure compressor dis-
charge bleed valves, each 3.75 inches in diameter, which could be opened
to permit acceleration of the engine through the part-speed compressor
stall region.

The high-energy capacitor-type standard engine ignition system em-
ployed two ignitor plugs, firing separately at an average rate of 1.8
sparks per second. Two pilot fuel nozzles, each having two concentric
passages, were located in the vicinity of the ignitor plugs. Pilot fuel
was fed through the center passage and oxygen (when used) through the
annulus. An oxygen boost system was employed for a portion of the en-
gine altitude ignition investigation and a number of the high-engine-
speed reignitions. Oxygen was supplied and controlled manually from
outside the test section and fed through the annulus of the pilot fuel
nozzles at a pressure of 40 pounds per square inch gage.

A main engine-fuel-line purge system was incorporated for the high-
engine-speed reignition investigation as an aid toward obtaining complete
combustor blowout. When the fuel valve was closed to simulate blowout,
pressurized air purged the remaining fuel from the line between the fuel
valve and the main engine fuel nozzles.

The steady-state engine windmilling characteristics were evaluated
with the AX 103/1 engine and the altitude ignition and high-speed alti-
tude reignition characteristics were evaluated with the AX 102/2A en-
gine; both engines were models of the "original" configurations of ref-
erence 1. The high inlet-temperature investigation was evaluated with
the AX 102/3C engine, which is termed the "Modified B" configuration in
reference 1. This engine (AX 102/3C) incorporated several modifications
of engines of the "original" configuration. These modifications in-
cluded increased turbine-stator areas, variable guide vanes between the
low- and high-pressure compressors, and minor compressor changes. En-
gine AX 102/3C was operated with the compressor bleed valves in the
closed position.

Instrumentation

Instrumentation for measuring steady-state pressures and tempera-
tures was installed at various stations throughout the engine. A sche-
matic cross-section of the engine showing station locations is presented
in figure 2. Steady-state engine speeds were recorded with tachometer-
generators and electronic pulse counters. Engine fuel flow was measured
with a calibrated Potter flowmeter.

Transient recordings of pressures, engine speeds, and turbine-discharge temperature were obtained with a multichannel oscillograph. Pressures were recorded with differential type transducers, the turbine-discharge temperature with a single bare-wire Chromel-Alumel thermocouple, and engine speeds with tachometer generators.

PROCEDURE

Steady-State Engine Windmilling Characteristics

Steady-state windmilling data were obtained at simulated altitudes of 35,000 and 50,000 feet over a range of flight Mach numbers from 0.48 to 1.72 with various combinations of exhaust-nozzle areas and compressor bleed valve positions. At each altitude and engine configuration setting, steady-state windmilling data were obtained while increasing the flight Mach number.

Altitude Ignition Characteristics

Altitude ignition data were obtained from steady-state windmilling conditions with the standard spark ignition system over a range of flight Mach numbers from 0.5 to 1.5. At each desired flight Mach number, the altitude was varied until it was possible to determine an altitude increment above which ignition did not occur and below which ignition was successful. Fuel flow was preset according to the manufacturer's ignition fuel-flow schedule given in figure 3. The fuel valve was then opened and the ignition was energized simultaneously. The time allowed for ignition was 10 seconds, and upon starting, the engine was immediately shut down. The engine acceleration characteristics were not investigated because of the critical stall characteristics of the engine (ref. 1). The altitude ignition characteristics were then re-evaluated to determine the effects of oxygen enrichment to the combustor. Oxygen was introduced in the combustor simultaneously with the opening of the fuel valve and the energizing of the ignition system.

High-Engine-Speed Reignition Characteristics

A number of high-engine-speed reignitions were attempted at various altitudes and flight Mach numbers. With the engine operating at near-rated speed, the fuel flow was turned off and the fuel manifold purge system was activated to simulate a combustor blowout such as might occur during armament firing (ref. 2). Then, after short periods of delay time (0.20 to 2.04 sec), attempts were made to reignite the engine by energizing the ignition system and by opening the fuel valve with the fuel flow regulated to a reduced value. This reduced fuel-flow value corresponded

to the predetermined steady-state fuel-flow rate for the engine speed to which the engine had decayed at the time reignition was initiated. The reason for this fuel-flow reduction was to attempt to avoid compressor stall upon reignition. As it was, stall occurred frequently during the reignition investigation.

Because of the low firing frequency of the ignitor plugs (1.8 sparks/sec), a spark would not always be present at the same instant reignition was initiated, thus further delaying reignition. Consequently, some attempts were made in which fuel was fed through two pilot fuel nozzles to maintain a constant source of ignition when reignition was initiated. However, the nozzles became clogged with carbon from the combustor and this method of obtaining a constant source of ignition was abandoned.

Oxygen was introduced into the combustor through the annulus of the pilot fuel nozzles, during a number of the reignition attempts, as an aid to obtaining successful reignition. The same oxygen boost system was used for evaluating both the altitude ignition characteristics and the high-engine-speed reignition characteristics.

High Inlet-Temperature Operation

The engine was operated for a period of 64 minutes with engine-inlet temperatures between 235° and 338° F. Of this 64 minutes the engine was operated 34 minutes at 235° F, 22 minutes while the temperature was increased to 338° F, 4 minutes at 338° F, and 4 minutes while reducing the temperature back to 235° F.

RESULTS AND DISCUSSION

Steady-State Engine Windmilling Characteristics

The steady-state engine windmilling data are presented in table I and figures 4 to 8. Corrected parameters of engine-windmilling drag and low-pressure rotor windmilling speed are presented in figures 4 and 5, respectively, as functions of flight Mach number. Corrected parameters of high-pressure rotor windmilling speed and engine-inlet airflow and compressor pressure ratio are presented in figures 6, 7, and 8, respectively, as functions of corrected low-pressure rotor windmilling speed. Because these latter parameters more nearly generalize as functions of corrected low-pressure rotor windmilling speed, they are presented in this manner rather than as functions of flight Mach number.

It is estimated from their trends that the corrected parameters of windmilling drag, rotor speeds, and airflow would reach maximum values

at a flight Mach number between 1.6 and 1.8, because of choking in the compressor. By decreasing the nozzle area at a constant flight Mach number, the flow is restricted so that corrected engine windmilling speeds are reduced with an accompanying reduction in corrected airflow and drag. In the event of combustor blowout at supersonic Mach numbers, closing the exhaust nozzle results in a reduction in internal engine drag of as much as 35 percent.

Altitude Ignition Characteristics

The engine altitude ignition characteristics with and without oxygen enrichment are summarized in figure 9 for various combinations of exhaust-nozzle areas and compressor bleeds and for two engine-inlet air temperatures. Altitude ignition with the standard spark ignition system was markedly affected by variations in flight Mach number, exhaust-nozzle area, compressor discharge bleed, and inlet temperature. With the aid of oxygen enrichment, successful ignition was obtained up to an altitude of 63,000 feet, which was the maximum altitude obtainable with the facility. The engine acceleration characteristics were not investigated because of the critical stall characteristics of the engine (ref. 1).

High-Engine-Speed Reignition Characteristics

The high speed reignition characteristics were investigated to determine whether ignition was possible after a simulated combustor blowout. Figure 10 illustrates the change in several engine variables during a representative high-speed reignition. Ignition and fuel were turned off at zero time and a high-pressure rotor speed of 7434 rpm. The initial rise in the curves is the result of the short burst of fuel being purged out of the line. The slight oscillation in the compressor- and turbine-discharge total pressures is caused by a mild stall that occurred because of the additional short burst of fuel. At 1.25 seconds, ignition was turned on along with a fuel flow corresponding to the engine fuel requirements at a high-pressure rotor speed of 6500 rpm. The engine relit at approximately 1.8 seconds as indicated by the sudden increase in compressor-discharge total pressure. The lag in the turbine-discharge total-temperature trace in figure 10 is due to the slow response of the thermocouple used. Table II summarizes the high-speed reignitions that were attempted during this investigation. This investigation was only of a preliminary nature and was conducted primarily to determine whether or not high-speed altitude reignition was feasible.

High Inlet-Temperature Operation

Figure 11 presents the time history of the high inlet-temperature test and shows the variation of engine-inlet temperature, approximate

ambient test section temperature, and high-pressure rotor speed. For a period of time of 64 minutes, the engine was operated at engine inlet temperatures of 235° F (695° R) or higher. Of this 64 minutes, 34 minutes of operation were at a temperature of 235° F, 22 minutes during an increase in the temperature to 338° F, and 4 minutes at a temperature of 338° F. The temperature then was reduced rather quickly. No difficulties were encountered in the operation of the engine during the investigation and no apparent damage resulted from it. Steady-state performance data are presented in reference 1.

SUMMARY OF RESULTS

From an investigation of the engine steady-state windmilling characteristics, ignition characteristics at altitude windmilling conditions, high-speed altitude reignition characteristics, and high inlet-temperature operation the following results were obtained:

1. The steady-state corrected parameters of windmilling drag, rotor speeds, and airflow approached maximum values at a flight Mach number between 1.6 and 1.8. Decreasing the nozzle area at a constant flight Mach number results in a reduction in corrected rotor speeds, airflow, and drag. In the event of combustor blowout at supersonic Mach numbers, closing the exhaust nozzle will result in a reduction in internal engine drag of as much as 35 percent.

2. Engine altitude ignition limits obtained with the standard spark ignition system were markedly affected by variations in flight Mach number, exhaust-nozzle area, compressor discharge bleeds, and engine-inlet temperature. With the aid of oxygen enrichment, successful ignition was obtained with all engine variables up to an altitude of 63,000 feet, which was the maximum altitude obtainable with the facility.

3. The brief investigation of high-speed reignition characteristics shows that reignition at high speeds is possible after simulating combustor blowout due to armament firing.

4. After 34 minutes of operation with engine-inlet temperatures of 235° F, 22 minutes with temperatures from 235° to 338° F, 4 minutes at 338° F, and 4 minutes from 338° to 235° F no operating difficulties or visual damage to the engine occurred.

Lewis Flight Propulsion Laboratory
    National Advisory Committee for Aeronautics
        Cleveland, Ohio, June 30, 1958

APPENDIX - SYMBOLS

A   area, sq in.

D_W windmilling drag, or negative net thrust $D_W = - F_N = F_{JS} - \dfrac{w_{a_1}}{g} V_1,$
         lb

F_N net thrust, lb

F_{JS} jet scale thrust measured by null balance thrust cell

g   acceleration due to gravity at sea level, 32.172 ft/sec^2

M   flight Mach number

N   rotor speed, rpm

P   total pressure, lb/sq ft abs

p   static pressure, lb/sq ft abs

R   gas constant for air, 53.3 $ft/^{O}R$

T   total temperature, ^{O}F or ^{O}R

V   velocity, obtained from velocity parameter, $V/\sqrt{gRT}$ (ref. 3)

w   weight flow, lb/sec

δ   ratio of absolute total pressure to absolute static pressure of
         standard NACA atmosphere at sea level

θ   ratio of absolute total temperature to absolute static temperature
         of standard NACA atmosphere at sea level

Subscripts:

a   air

f   fuel

HP   high-pressure rotor

LP   low-pressure rotor

N   nozzle

w   windmilling

0   free stream

1   low-pressure compressor inlet

2   low-pressure compressor discharge

3   high-pressure compressor discharge

4   high-pressure turbine inlet

5   low-pressure turbine inlet

6   low-pressure turbine discharge

9   tailpipe

10   exhaust-nozzle outlet

REFERENCES

1. McAulay, John E., and Groesbeck, Donald E.: Investigation of a Proto-
   type Iroquois Turbojet Engine in an Altitude Test Chamber. NACA RM
   SE58E26, 1958.

2. Anon.: Proceedings of Symposium on Effects of Armament Firing Upon
   Turbojet Engines. NOTS 1850, Naval Ord. Test Station, China Lake
   (Calif.), 1957.

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

TABLE I. – STEADY-STATE ENGINE WINDMILLING DATA

Simulated altitude, ft	Simulated flight Mach number, M_0	Bleed valves	Exhaust nozzle	Corrected low-pressure rotor speed, $\frac{N_{LP}}{\sqrt{\theta_1}}$, rpm	Corrected high-pressure rotor speed, $\frac{N_{HP}}{\sqrt{\theta_1}}$, rpm	Corrected engine-inlet airflow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_1}$, pps	Corrected engine windmilling drag, D_w/δ_1, lb	Low-pressure compressor-inlet total pressure, P_1, lb/sq ft abs	Low-pressure compressor-discharge total pressure, P_2, lb/sq ft abs	High-pressure compressor-discharge total pressure, P_3, lb/sq ft abs	Turbine-discharge total pressure, P_6, lb/sq ft abs	Exhaust-nozzle exit total pressure, P_9, lb/sq ft abs	Altitude static pressure, P_0, lb/sq ft abs	Low-pressure compressor inlet total temperature, T_1, °R	Compressor pressure ratio, P_3/P_1	Turbine-inlet total pressure, P_4, lb/sq ft abs	Exhaust nozzle outlet static pressure, P_{10}, lb/sq ft abs
35,000	1.46	Open	Closed	2460	4460	101.8	1738	1769	2065	2877	856	828	509	474	1.626	2371	507
	.89			1035	2762	58.0	1409	837	858	811	527	524	501	474	.9687	714	499
	.69			715	2042	45.6	1089	688	694	632	512	510	502	475	.9194	586	501
	.48			475	1402	34.4	750	589	590	552	506	506	503	475	.9371	533	502
	.48	Closed		496	1431	32.8	738	587	588	558	506	506	502	475	.9504	538	502
	.69			765	2135	47.1	1051	689	697	651	514	512	501	474	.9443	601	501
	.89			1138	2933	60.4	1343	843	869	874	536	533	503	473	1.037	762	503
	1.43	Open	Open	2561	4552	104.9	1514	1674	1977	2912	867	839	504	472	1.740	2416	502
	.49	Open	Open	488	1434	31.8	749	591	592	553	504	503	502	475	.9367	534	502
	.69			730	2079	45.0	1147	689	695	630	506	504	501	475	.9156	585	501
	.89			1104	2902	61.9	1641	838	862	832	514	510	503	472	.9926	725	503
	1.24			2715	4514	103.3	2675	1283	1525	2141	587	562	503	471	1.669	1766	503
	.49	Closed		502	1451	32.8	768	586	587	556	503	503	502	475	.9500	536	501
	.69			788	2191	48.6	1215	688	697	654	506	505	501	475	.9497	601	501
	.89			1253	2136	66.3	1685	842	875	913	517	513	503	471	1.084	785	502
	1.20			2930	4627	106.9	2541	1215	1478	2225	593	566	502	471	1.831	1845	501
50,000	1.53	Open	Open	3331	4591	109.8	2800	943	1204	1721	384	325	246	459	1.826	1402	245
	.69			742	2098	51.8	1545	334	336	304	244	243	243	485	.9122	281	242
	.79			898	2458	52.7	1543	370	376	343	248	247	246	486	.9271	308	244
	.88			1082	2843	58.3	1741	409	419	398	251	248	246	484	.9734	345	244
	.99			1381	3367	68.8	2060	461	483	507	254	251	245	483	1.099	425	244
	1.09			1786	3875	80.5	2352	517	560	665	261	256	244	488	1.285	549	243
	1.19			2380	4342	98.7	2674	586	676	917	276	267	246	485	1.565	750	244
	1.29			2875	4517	104.6	2799	668	807	1132	293	278	245	480	1.694	926	244
	1.72		Closed	2653	4500	103.9	----	1228	1456	2047	572	550	241	478	1.666	1689	240
	.68			715	2032	49.7	1307	336	339	309	250	249	246	481	.9173	287	245
	.89			1012	2710	57.6	1558	410	418	359	256	255	244	480	.9490	342	243
	1.09			1472	3501	71.1	1813	515	543	586	277	273	244	480	1.137	489	243
	1.30			2081	4160	90.2	1866	673	750	961	329	321	242	478	1.429	789	241
	1.30	Closed		2283	4334	95.9	1740	673	767	1072	350	340	244	476	1.593	885	243
	1.10			1688	3763	78.6	1730	517	555	664	286	281	243	475	1.285	553	241
	.88			1114	2877	62.8	1627	411	423	419	261	259	247	475	1.020	365	246
	.69			757	2108	45.5	1183	336	339	313	249	249	244	476	.9316	289	244
	.69		Open	784	2173	44.4	1251	338	341	316	247	246	245	476	.9351	290	244
	.90			1189	3020	61.6	1762	409	422	428	250	248	243	476	1.046	367	243
	1.09			2095	4176	89.2	2356	516	576	765	267	261	245	475	1.483	633	244
	1.30			3222	4649	109.7	2698	672	844	1262	306	286	244	477	1.880	1041	243

TABLE II. - HIGH-ENGINE-SPEED REIGNITION DATA

Ignition system	Simulated altitude, ft	Simulated flight Mach number, M_O	Engine-inlet total temperature, T_1, °F	Exhaust-nozzle area, A_N, sq in.	Compressor bleed valves	Initial high pressure rotor speed, N_{NP}, rpm	High pressure rotor speed corresponding to fuel flow preset for reignition	High pressure rotor speed (at reignition), N_{HP}, rpm	Delay time, sec	Comments
None	25,000	0.9	115	692	Closed	7514	7000	7110	0.51	Reignition
	25,000	.9	260	678		7527	6690	----	.75	No reignition
	25,000	.9	260	678		7578	6520	----	1.00	No reignition
	35,000	.9	122	682		7524	7190	7300	.20	Reignition
Standard ignition system	35,000	.9	107	683		7713	6420	6350	.65	Reignition
	35,000	.9	107	683		7757	6412	5700	.65	
	50,000	.9	104	663	Open	7485	6390	6540	.65	
	50,000	.9	110	684		7434	6400	6480	1.25	
	55,000	.9	108	684		6990	6200	6620	.65	
	56,000	1.55	110	680		7530	6250	6500	1.21	
	56,000	1.55	110	673		7450	6453	----	2.05	No reignition
Standard ignition system and oxygen enrichment	50,000	.9	104	663		7420	6408	6650	.65	Reignition
	50,000	.9	110	683		7455	6408	6600	1.25	
	55,000	.9	108	684		6970	6270	6500	.65	
Pilot fuel	35,000	.9	---	683	Closed	7800	7590	----	.60	No reignition
	45,000	1.0	---	679	Closed	7771	6600	----	1.11	No reignition
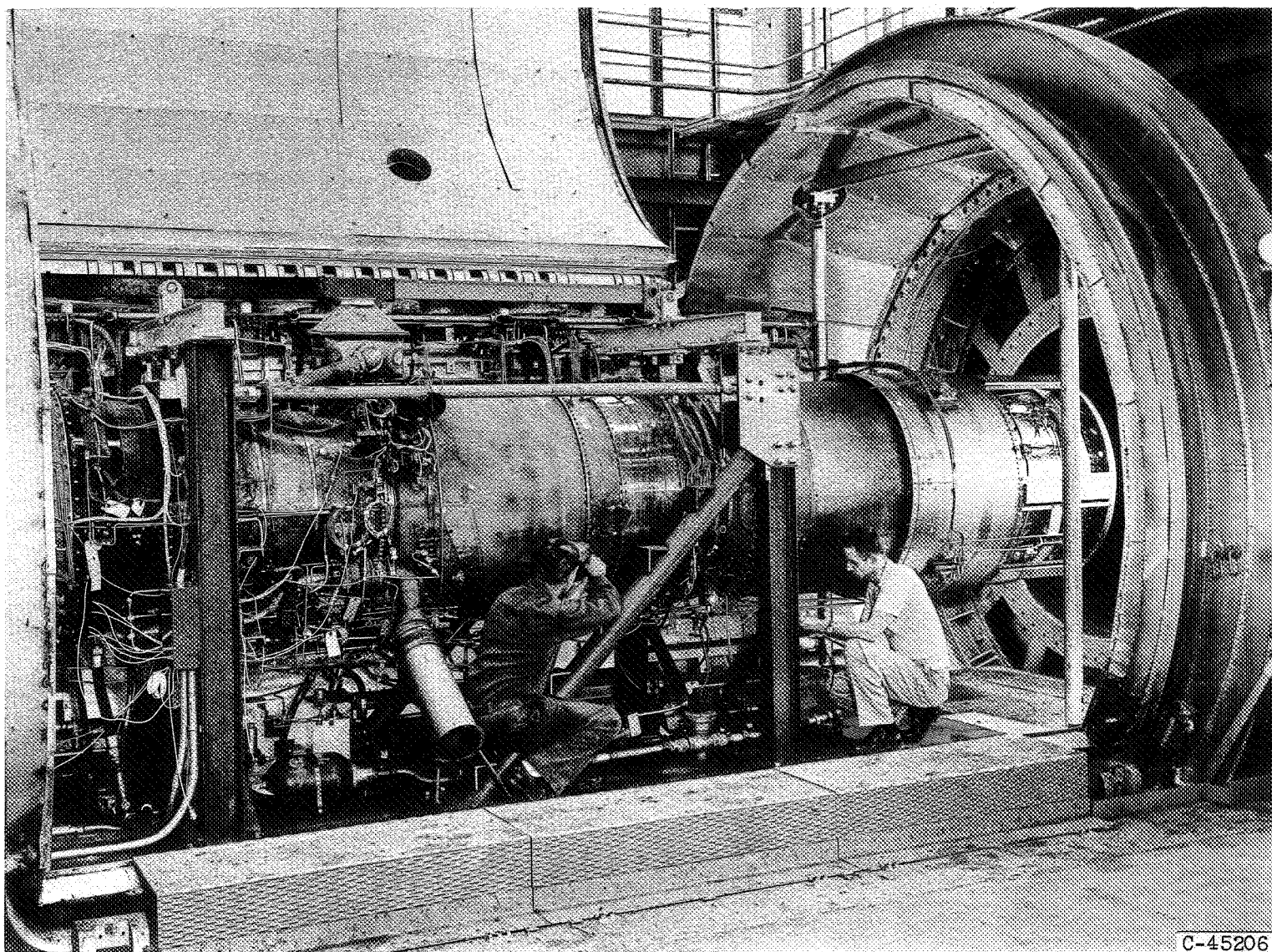
Figure 1. - Iroquois turbojet engine installed in altitude test chamber.

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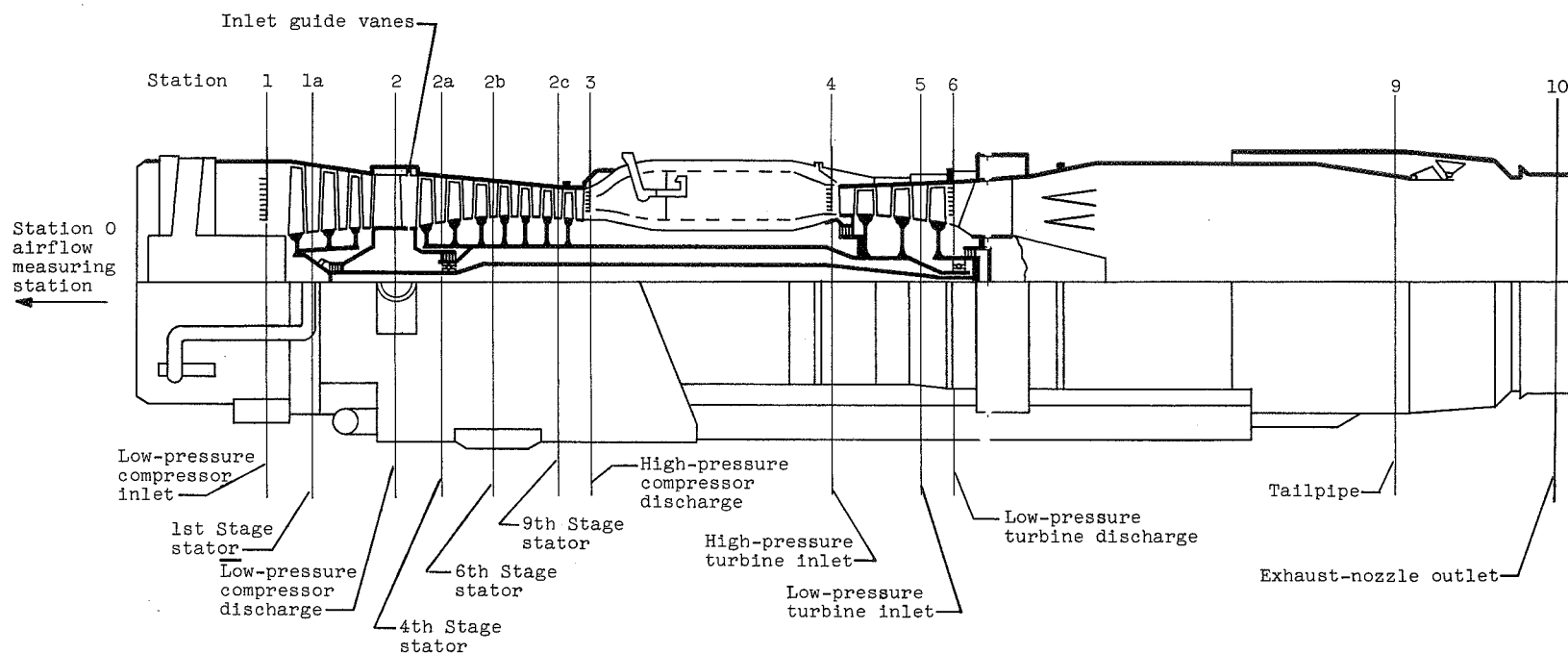
Station	Measurements		
	Total pressure	Static pressure	Total temperature
0	20	8	
1	20	4	10
2	20	4	20
3	20		20
4	10		
5	10		
6	25		25
9	20	4	20
10		4	

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Figure 2. - Schematic diagram of Iroquois turbojet engine showing steady-state instrumentation stations.
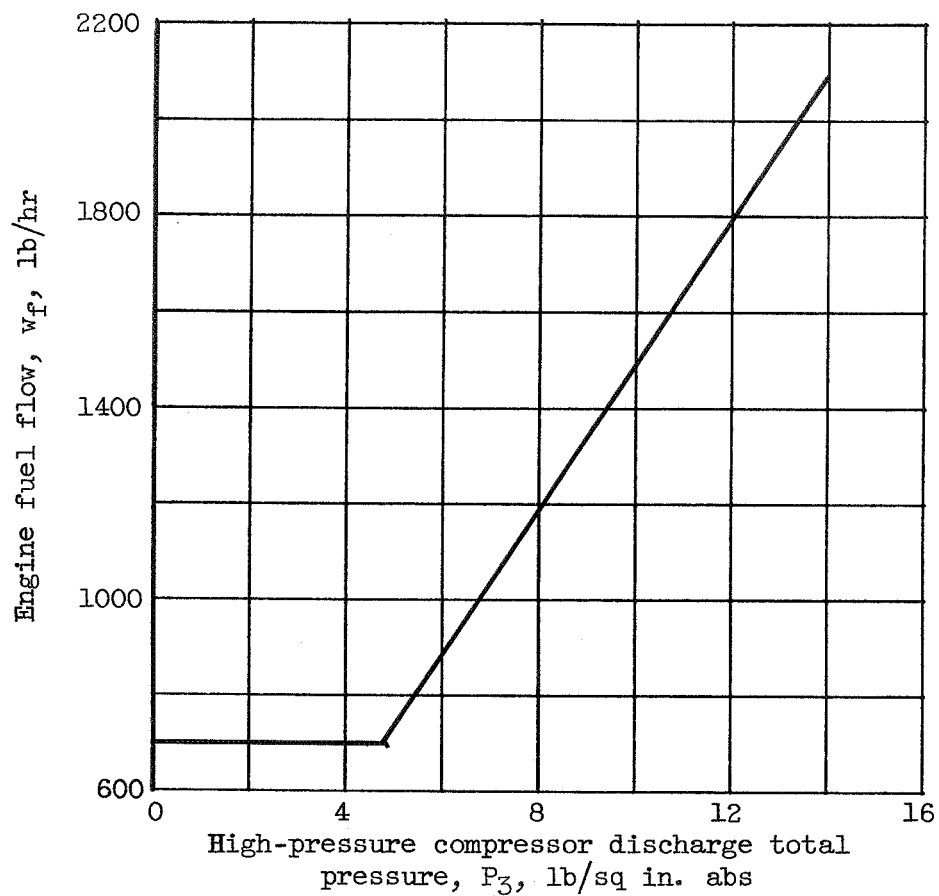
Figure 3. - Fuel flow schedule for altitude
ignition investigation.
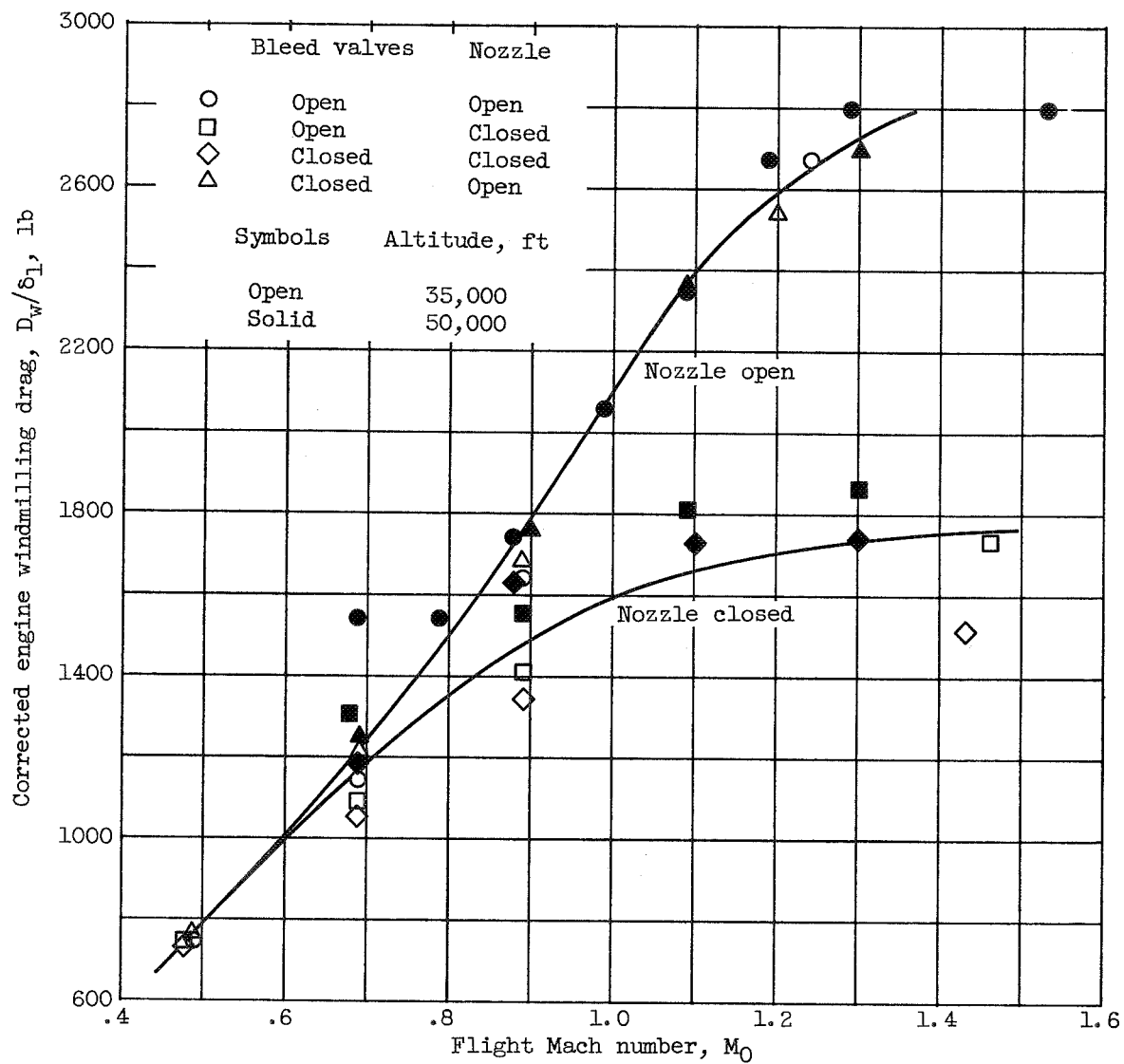
Figure 4. - Variation of corrected engine windmilling drag with flight Mach number.
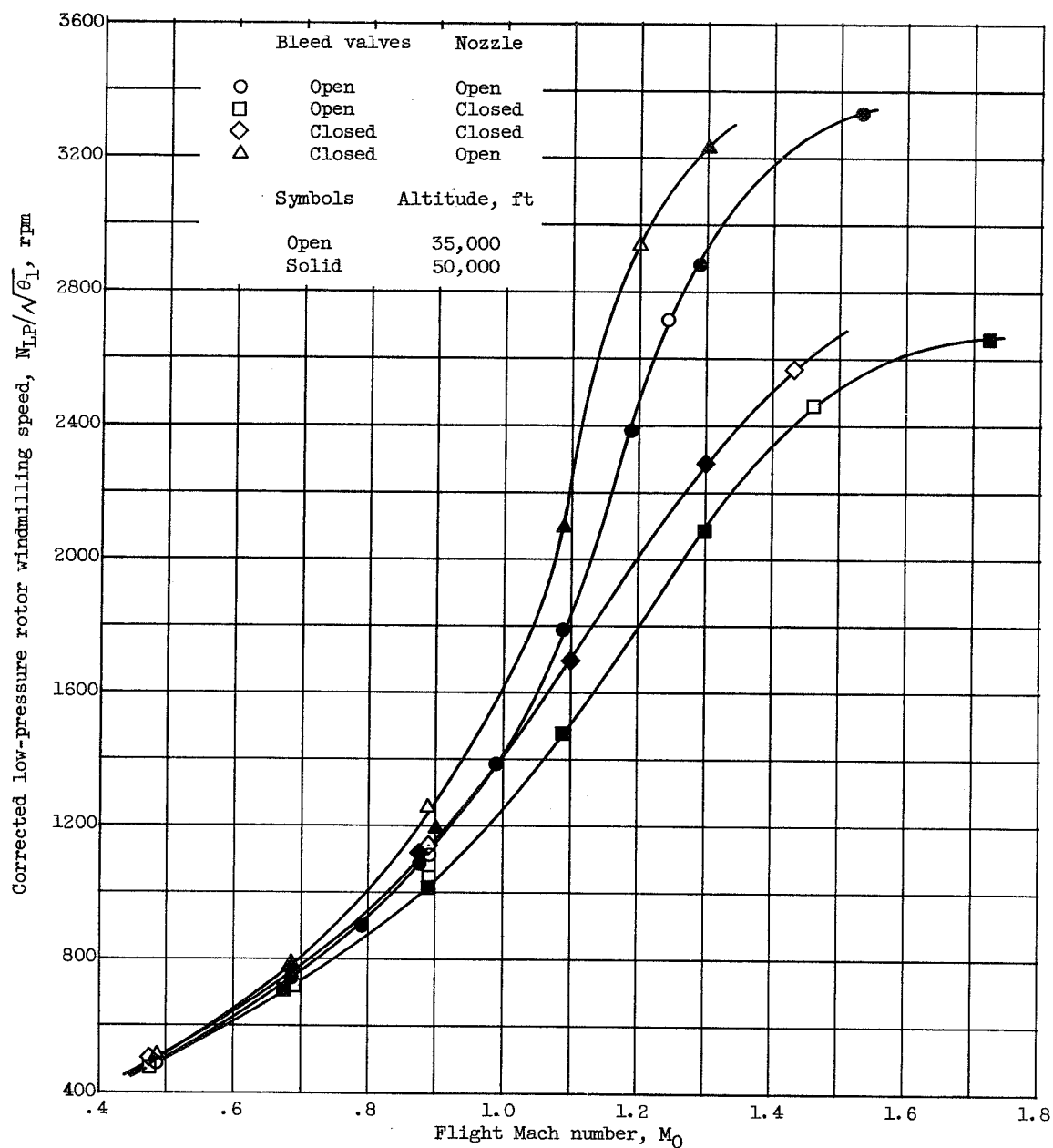
Figure 5. - Variation of corrected low-pressure rotor windmilling speed with flight Mach number.
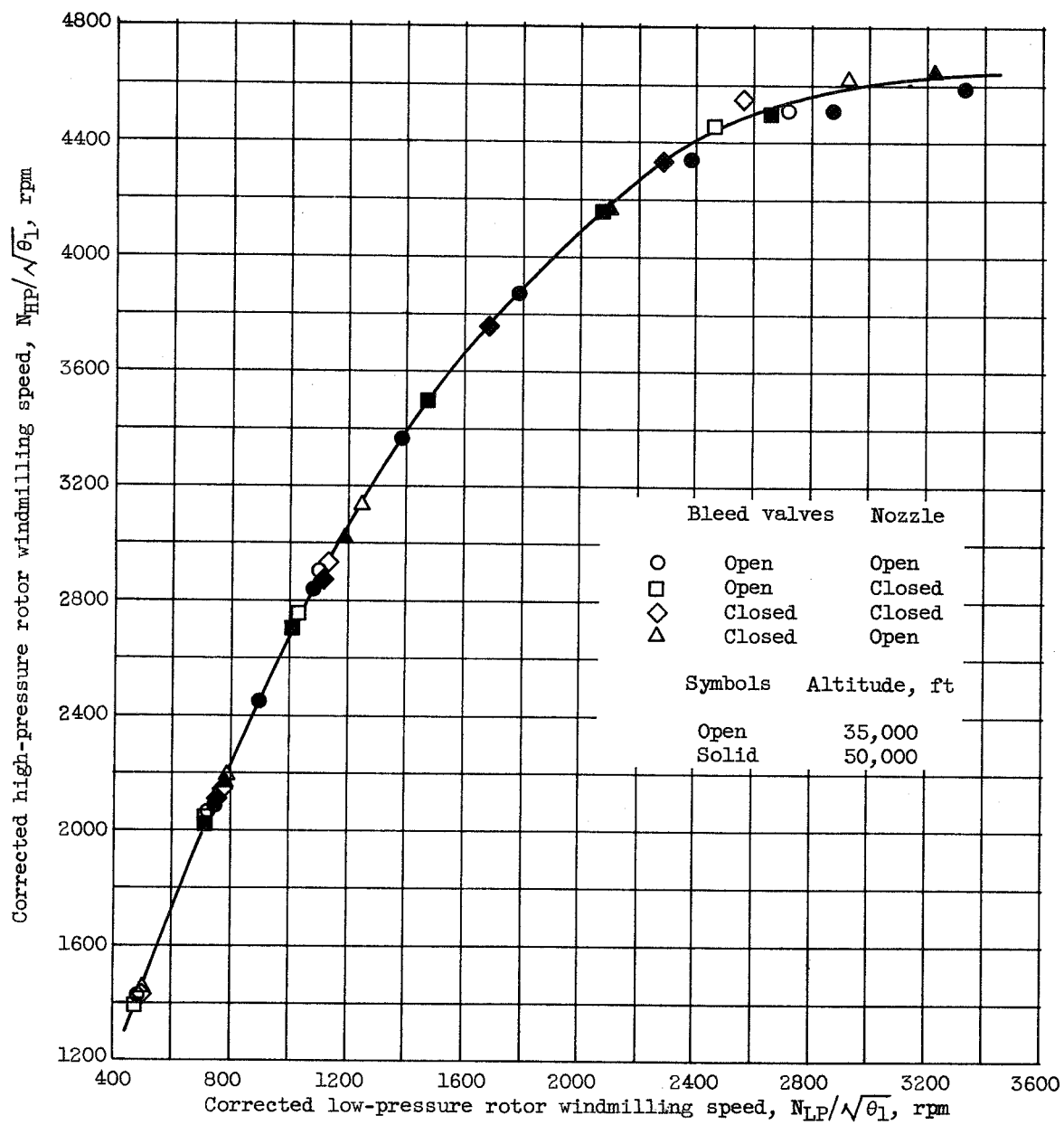
Figure 6. - Variation of corrected high-pressure rotor windmilling speed with corrected low-pressure rotor windmilling speed.
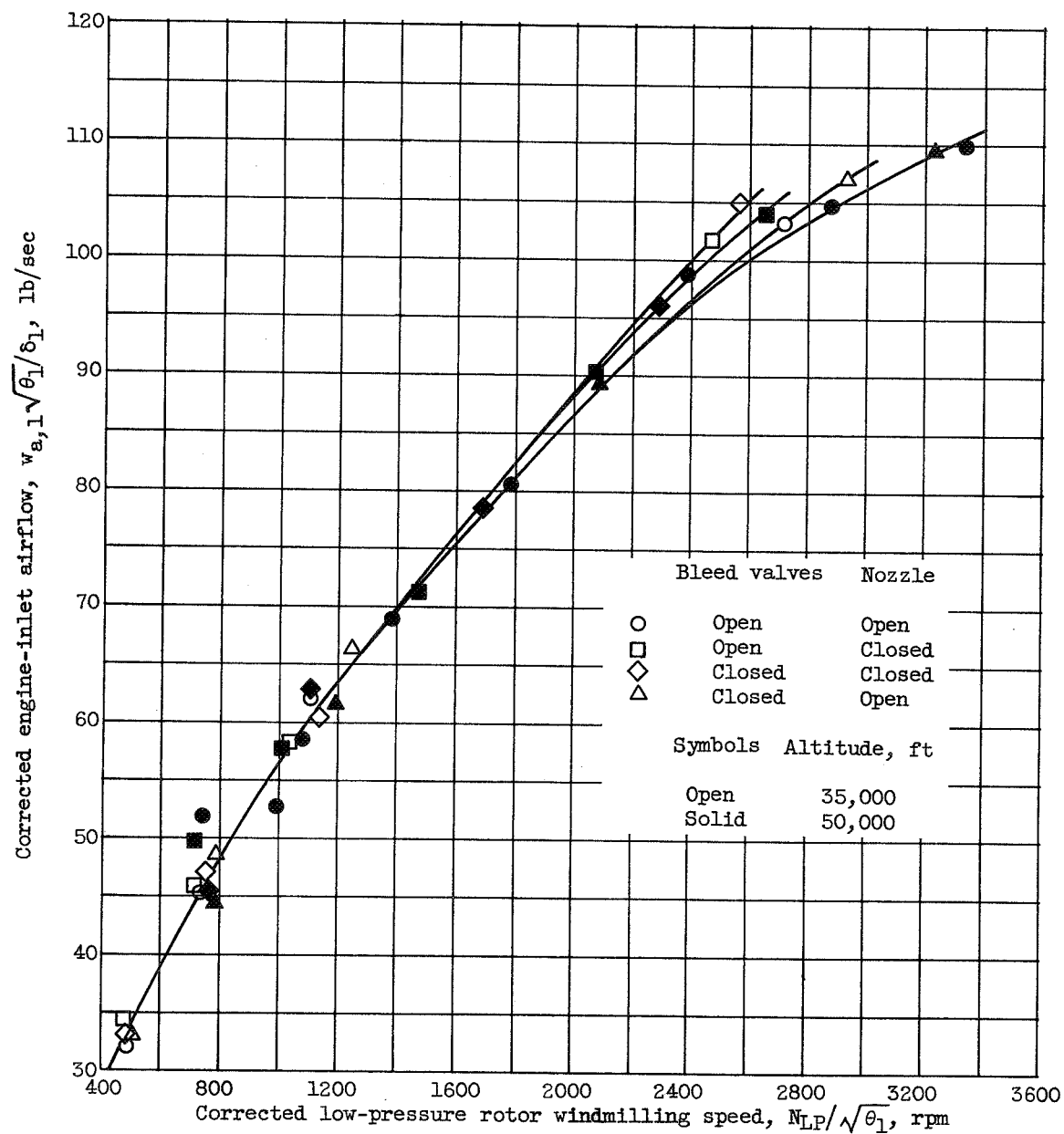
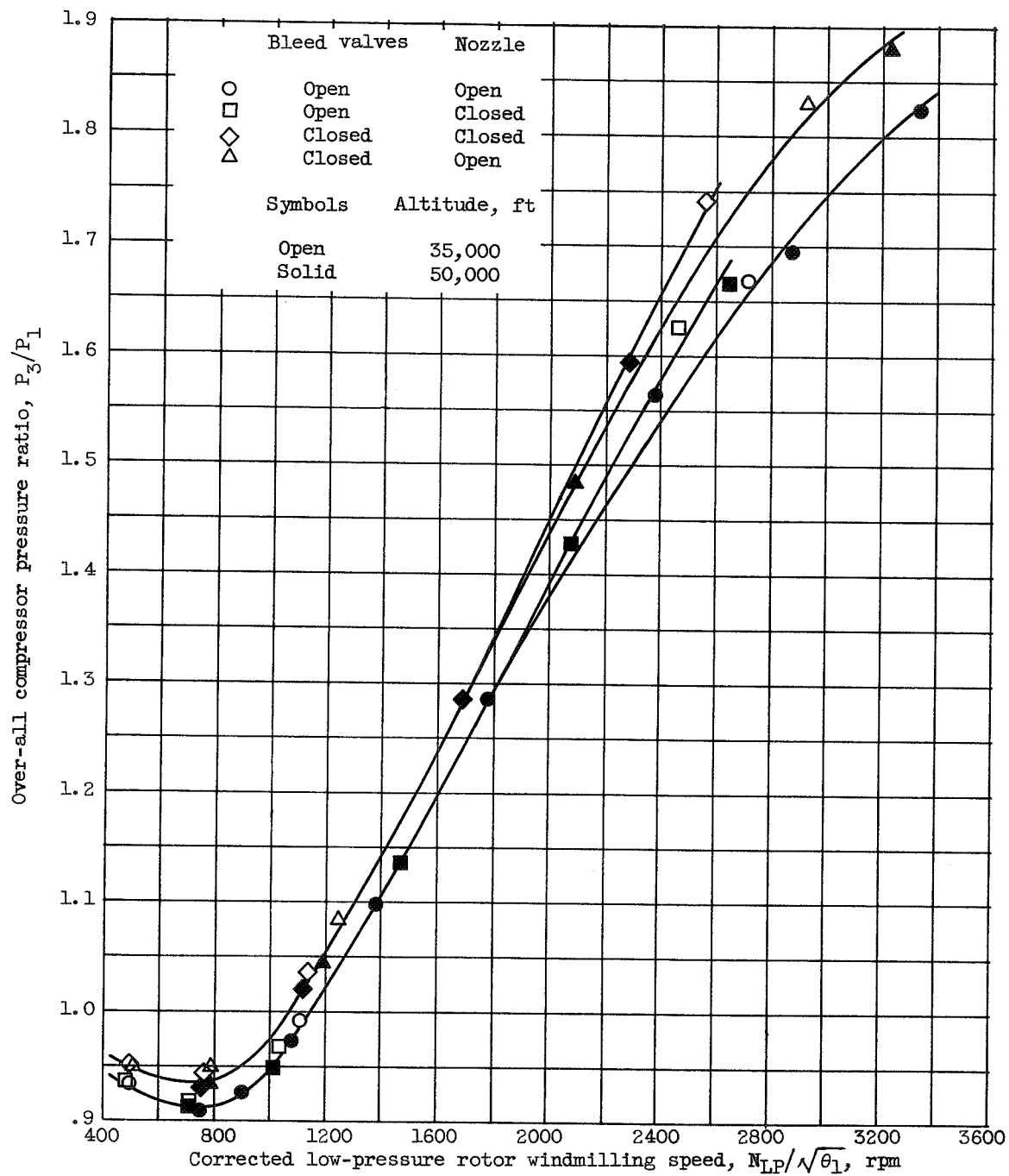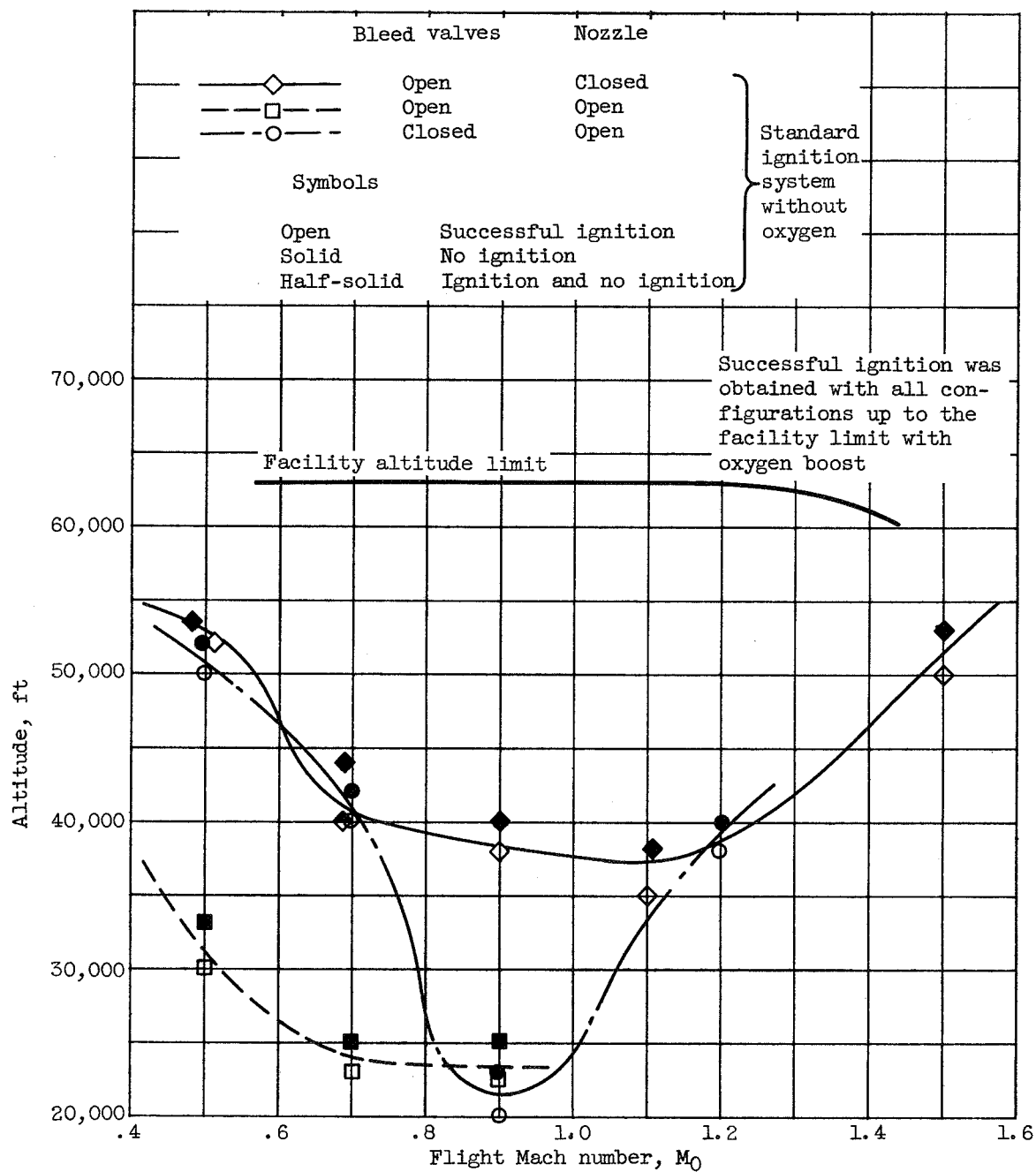Figure 7. - Variation of corrected engine-inlet airflow with corrected low-pressure rotor windmilling speed.

Figure 8. - Variation of over-all compressor pressure ratio with corrected low-pressure rotor windmilling speed.

(a) Effect of nozzle area and bleed valves; inlet temperature, T_1, 15° F.

Figure 9. - Altitude ignition characteristics.
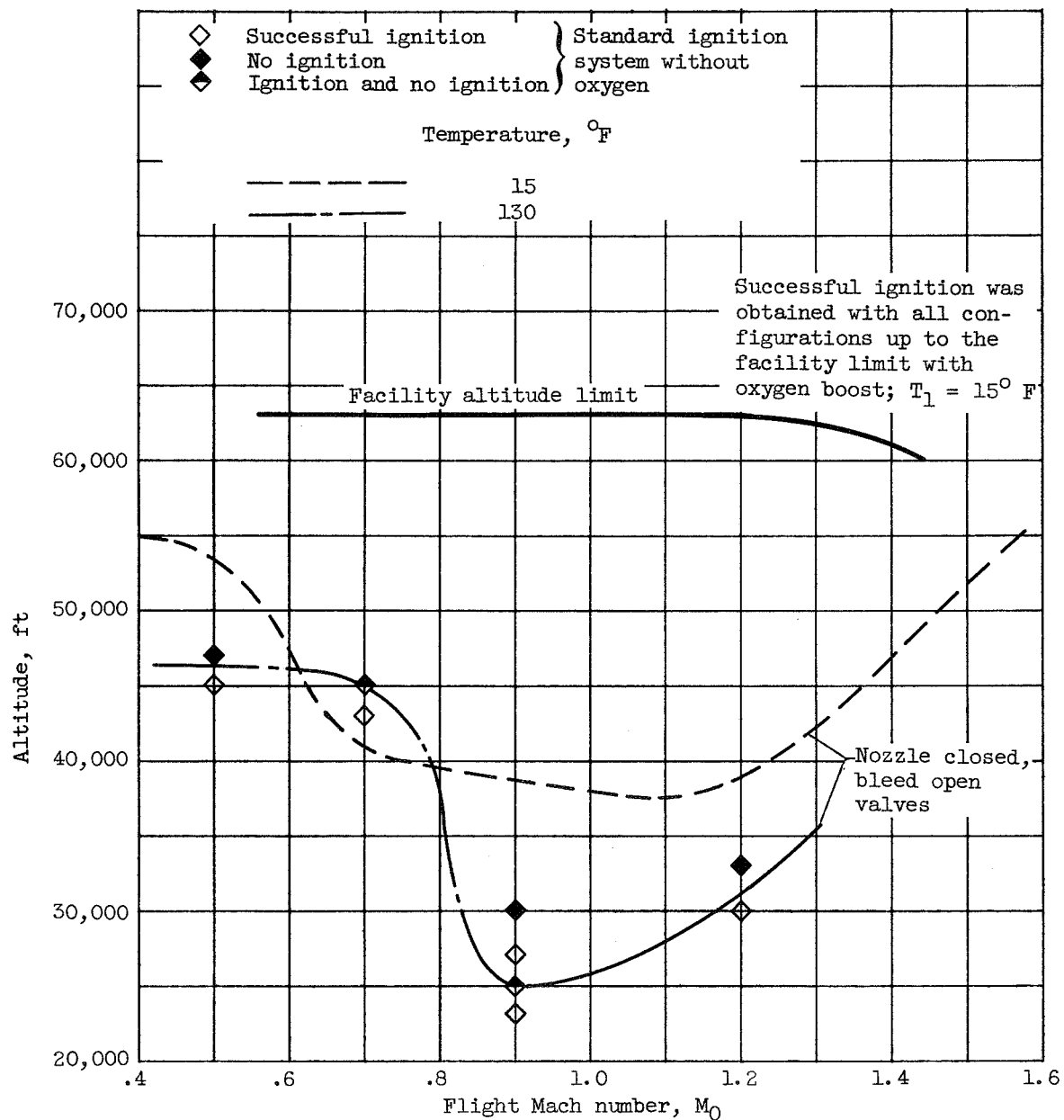
(b) Effect of engine-inlet temperature, T_1

Figure 9. - Concluded.　Altitude ignition characteristics.
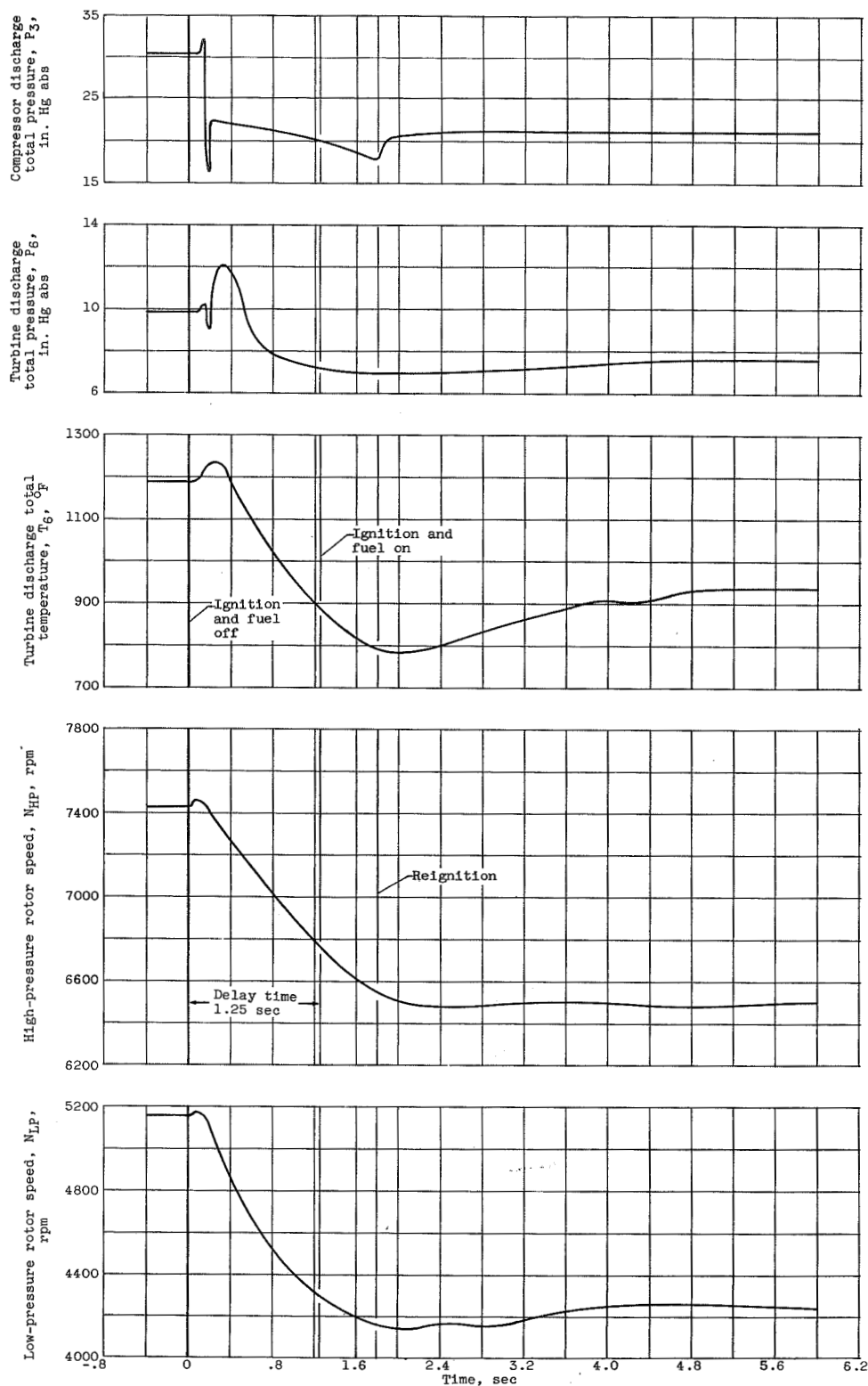
Figure 10. - Variation of engine speeds, compressor discharge total pressure, and turbine discharge total temperature and pressure during typical high-speed reignition. Engine, AX 102/2A; bleed valves, open; nozzle area, 684 square inches (90.6% closed); engine-inlet temperature, 105° F; altitude, 50,000 feet; flight Mach number, 0.90.
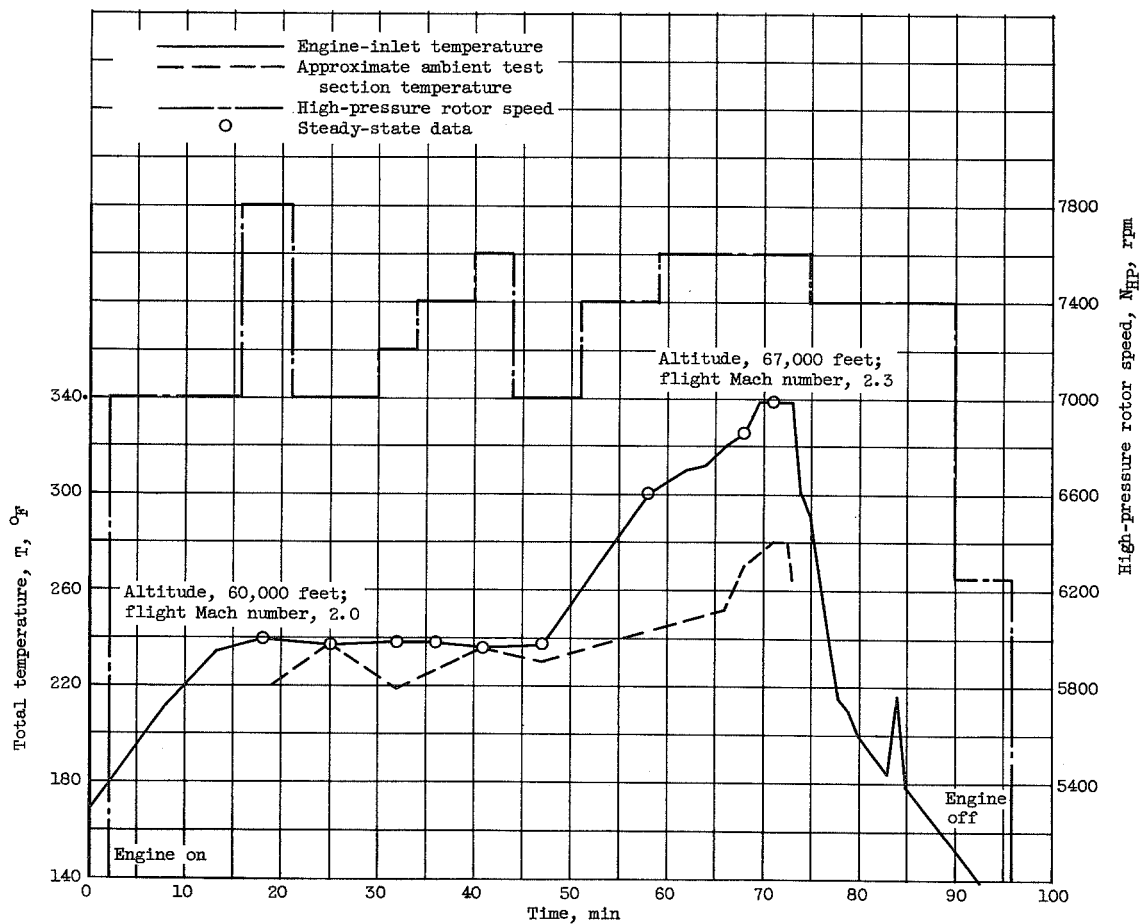
Figure 11. - Variation of high-pressure rotor speed, engine-inlet temperatures, and approximate ambient temperature during high-temperature test.

SOME ALTITUDE OPERATIONAL CHARACTERISTICS

OF A PROTOTYPE IROQUOIS TURBOJET ENGINE

By Daniel J. Peters and John E. McAulay

ABSTRACT

The evaluation of the altitude operational characteristics was part of the over-all investigation of the early developmental Iroquois engine. Engine steady-state windmilling characteristics were evaluated over a range of flight Mach numbers from 0.48 to 1.72 at altitudes of 35,000 and 50,000 feet. Engine altitude ignition limits were obtained over a range of flight Mach numbers from 0.5 to 1.5 with the standard engine ignition system and also with an oxygen boost system. A short investigation of high-speed altitude reignition following combustor blowout was conducted.

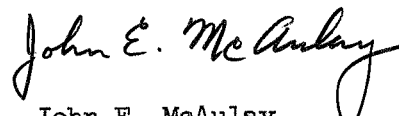INDEX HEADINGS

Engines, Turbojet   3.1.3

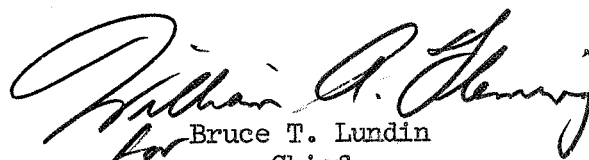Combustion, Turbine Engines   3.5.2.2

Ignition Systems   3.12.2

(Title, Unclassified)

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OF A PROTOTYPE IROQUOIS TURBOJET ENGINE

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