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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

PRELIMINARY ALTITUDE PERFORMANCE CHARACTERISTICS OF THE J57-P-1 TURBOJET ENGINE WITH FIXED-AREA EXHAUST NOZZLE

By Harry E. Bloomer and Robert R. Miller

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Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An investigation to determine the altitude performance of the J57-P-1 turbojet engine and components was conducted at the NACA Lewis altitude wind tunnel. Data were obtained over a corrected inboard rotor speed range from 56 to 106 percent of rated speed, with intercompressor bleeds both open and closed, at altitudes from 15,000 to 50,000 feet and at a flight Mach number of 0.81. The corresponding range of Reynolds number indices was from 0.858 to 0.213. All data presented were obtained with a fixed-area exhaust nozzle sized according to the manufacturer's specification.

Over-all engine performance parameters are presented as functions of inboard rotor speed corrected on the basis of engine inlet temperature. Component parameters are presented as functions of their respective corrected rotor speeds. A tabulation of all performance data is included in addition to the graphical presentation.

Corrected net thrust is unusually sensitive to changes in corrected inboard rotor speed in the high speed region. A change of 1 percent in speed, at rated speed, produced a change of 6 percent in corrected net thrust.

At rated engine speed, increasing the altitude from 15,000 to 50,000 feet at a constant flight Mach number of 0.81 increased the specific fuel consumption 13 percent but did not affect corrected net thrust.

INTRODUCTION

At the request of the Navy Department, Bureau of Aeronautics, an investigation of the J57-P-1 turbojet engine performance was made in the altitude wind tunnel at the NACA Lewis laboratory. Presented herein are the engine performance data obtained with a fixed-area exhaust nozzle during the first phase of the investigation.

Data were obtained over a range of corrected inboard rotor speeds from 56 to 106 percent of rated speed, at altitudes from 15,000 to 50,000 feet, at a flight Mach number of 0.81. The corresponding range of Reynolds number indices was from 0.858 to 0.213.

At low rotor speeds, during normal engine operation, a portion of the engine air flow is bled overboard from between the compressors. This is done to avoid compressor surge which occurred at low rotor speeds. Data were obtained with and without compressor bleed over the entire range of rotor speeds investigated to allow an examination of the effects of bleed on surge and engine performance.

The purpose of this report is to make available the altitude performance data of the J57-P-1 turbojet engine in usuable form with a minimum time delay. Accordingly, all engine and component parameters, with the exception of ideal jet thrust, are presented only as functions of corrected rotor speed.

ENGINE INSTALLATION AND INSTRUMENTATION

Engine

A cross sectional view of the J57-P-1 turbojet engine is shown in figure 1. This is a two-spool turbojet engine; the outboard rotor comprises a 9-stage axial flow compressor driven by a 2-stage turbine; the inboard rotor is made up of a 7-stage axial-flow compressor and a single-stage turbine. The compressors were connected to their respective turbine units by means of co-axial shafting. The combustor is of the cannular type having eight tubular liners each with a piloting cone and six duplex fuel spray nozzles.

The engine is equipped with two compressor bleed ports, which bleed air from the discharge of the outboard compressor, thereby lowering the outboard compressor pressure ratio and avoiding compressor surge. Opening and closing of the compressor bleeds is scheduled by outboard rotor speed and engine inlet total temperature. Depending upon the value of engine inlet total temperature the bleeds are scheduled to open or close between 5195 and 5660 rpm of the outboard rotor.

The fixed-area exhaust nozzle, used during this phase of the engine performance evaluation, was fabricated with the hot discharge area, 2.58 square feet, prescribed in the manufacturer's Handbook of Overhaul Instructions, and was installed on the engine together with an elongated tail pipe. The purpose of the elongated tail pipe was to permit the measurement of accurate pressures and temperatures at the exhaust nozzle inlet.

The data presented in this report were obtained with an inboard turbine first stage nozzle and an engine fuel flow divider different than those installed on the engine at the time of the manufacturer's rating. The effects of these differences on engine thrust and specific fuel consumption were investigated and found to be negligible over the range of conditions tested. The manufacturer's rating of the J57-P-1 engine tested (serial no. P420 150) was 9500 pounds thrust at an inboard engine speed of 9602 rpm, sea level static conditions.

Instrumentation

The location of the instrumentation stations is shown in the cross-sectional view of the engine in figure 1. In addition, a table is included indicating the number of total and static pressures and the number of total temperatures measured at each station.

Installation

The J57-P-1 turbojet engine is shown installed in the altitude wind tunnel test section in figure 2. Ambient air was dried and either heated or refrigerated and then supplied to the engine by means of inlet ducting. The engine was supplied fuel of the type MIL-F-5624A grade JP-4 from the facility fuel system.

PROCEDURE

Performance data were obtained at a flight Mach number of 0.81 at altitudes from 15,000 to 50,000 feet. Inboard rotor speed was varied from 5100 to 9700 rpm at every altitude except where compressor surge, overtemperature operation of the turbine, minimum fuel flow (approximately 200 lb/hr, minimum allowable setting of test facility fuel control throttle), or combustor blow-out were limiting factors. Data were obtained over the entire operable range of engine speeds at all altitudes investigated with the compressor bleeds both open and closed independent of the bleed schedule.

Turbine temperature limit was determined from the average of four control thermocouples equally spaced at the outlet of the outboard turbine. The average turbine outlet temperature was not allowed to exceed 1100° F (1560° R). Engine inlet temperatures were set at standard NACA values for each flight condition.

Ideal jet thrust was calculated from pressures and temperatures at the exhaust nozzle inlet. Jet thrust was calculated by assuming an effective velocity coefficient of 0.975, see reference 1. The symbols used in this report are defined in the appendix.

RESULTS AND DISCUSSION

All of the fixed-area engine data obtained during the altitude performance investigation are compiled in table I.

Engine Performance

The relation between the inboard and the outboard corrected rotor speeds is shown in figure 3. A change in engine inlet Reynolds number did not change the speed match of the two rotors; but opening of the compressor bleeds does produce a small change in the speed match. Flagged symbols indicate operation with both compressor bleeds open and refer to the right hand ordinate.

The occurrence of compressor surge causes a discontinuity in the engine steady state operating line, with the bleeds closed, at each flight condition investigated. The boundaries of these surge regions are denoted in appropriate figures throughout this report by crossed symbols. For compressor surge information see reference 2.

Engine inlet corrected air flow is presented in figure 4 as a function of inboard rotor speed corrected with station one pressure and temperatures to sea level static conditions. The open data points represent engine air flow with bleeds closed. The flagged data points indicate the air entering the outboard compressor with bleeds open. The solid data points indicate the air entering the inboard compressor when the bleeds are open. Corrected air flow at rated corrected inboard rotor speed was 163 pounds per second at Reynolds number indices greater than 0.612. As Reynolds number index is decreased below a value of 0.612 air flow decreases (154 lb/sec at a Reynolds number index of 0.213).

The variations of corrected fuel flow, exhaust gas temperature, and engine pressure ratio are shown as functions of inboard corrected rotor speed in figures 5, 6, and 7. Fuel flow and exhaust gas temperature increase as Reynolds number index decreases. The limit marks at the high speed end of the temperature curves, figure 6, indicate the point of limiting turbine outlet temperature and will also appear where practical in following figures. Engine pressure ratio, figure 7, is not affected by Reynolds number as much as fuel flow and temperature but an increase in pressure ratio does occur at the low value of Reynolds number index, in the high speed range. As would be expected, bleeding air from the compressor has a pronounced effect in lowering engine pressure ratio.

The variations of corrected net thrust and specific fuel consumption with corrected inboard rotor speed are presented in figures 8 and 9. Although there is no effect of Reynolds number on jet thrust there is an increase in minimum specific fuel consumption from 1.057 to 1.169 in decreasing the Reynolds number index from 0.858 to 0.213. Thrust is very sensitive to changes in inboard corrected rotor speed in the high speed region. A speed change of 1 percent, near rated, produces a 6 percent change in net thrust.

Ideal jet thrust is presented as a function of exhaust nozzle pressure drop parameter, $1.25\ P_9 - p_0$, in figure 10. These data correlate to one straight line as predicted in reference 3.

Component Performance

Outboard compressor. - Outboard compressor corrected air flow, pressure ratio, and efficiency, are presented as functions of outboard corrected rotor speed in figures 11, 12, and 13. The air flow data (fig. 11) are similar in appearance to the data shown in figure 4 where the same air flow was plotted against inboard corrected speed. There is little effect of Reynolds number on pressure ratio (fig. 12) but opening the bleeds drops the pressure ratio from 3.60 to 3.25 at a speed of 6000 rpm and a Reynolds number index of 0.858. Open bleeds, however, allowed the compressor to operate stall free over the complete range of engine speeds and Reynolds number indices. (See ref. 2.) Outboard compressor efficiency, figure 13, changes from a maximum of 88.3 percent at a Reynolds number index of 0.858 to a peak value of 85.2 percent at an index of 0.213 with closed bleeds. Opening the bleeds improves the peak compressor efficiency at all values of Reynolds number index but the peak is also shifted farther from the design speed. Crossed symbols denote the boundaries of the compressor surge region.

Inboard compressor. - Inboard compressor corrected air flow, pressure ratio, and efficiency are presented as functions of corrected inboard rotor speed in figures 14, 15, and 16. The trends in the air flow curves, figure 14, are the same as those shown in figure 4 with about the same percent effect of engine inlet Reynolds number. Inboard compressor pressure ratio, figure 15, is affected more by changes in engine inlet

Reynolds number than is outboard pressure ratio. Opening the compressor bleeds does not affect inboard pressure ratio appreciably. Reynolds number, again, has a sizeable effect on inboard compressor efficiency as shown in figure 16. Maximum efficiency changes from 87.5 to 83.5 percent over the range of Reynolds number index investigated. Opening the compressor bleeds, in the case of the inboard compressor, lowers efficiency; this is contrary to the trend shown in outboard compressor efficiency.

Over-all compressor unit. - Over-all compressor air flow is presented in figure 4 and was discussed previously. Over-all compressor pressure ratio and efficiency are presented as functions of corrected inboard rotor speed in figures 17 and 18. Pressure ratio is affected by engine inlet Reynolds number only at the high speed end and drops about 10 percent when the bleeds are opened at rated speed. Over-all compressor efficiency, shows the same trends as the individual compressor efficiencies; namely a decrease in efficiency with a decrease in Reynolds number index.

Combustor. - The variation of combustion efficiency and combustor total pressure loss as functions of corrected inboard rotor speed are presented in figure 19. Combustion efficiency decreases with the lower combustor pressures, associated with low Reynolds number indices. At rated speed, peak efficiency changes from 99.4 to 97.1 percent over the range of Reynolds number indices covered. Combustor total pressure loss decreases from a value of about 8 percent at the lower corrected speeds and levels off to 5.5 percent at rated engine speed.

Over-all turbine unit. - Over-all turbine pressure ratio, corrected gas flow, and turbine efficiency as functions of corrected inboard rotor speed are shown in figure 20. Turbine pressure ratio rises to a maximum value of about 4.43 at a corrected inboard speed of 8500 rpm and remains essentially constant over the rest of the high speed range. A constant value of corrected gas flow indicates that the turbine is operating with choked flow over the range of speeds investigated. Over-all turbine efficiency shows a definite effect of engine inlet Reynolds number, especially at the lower value of corrected rotor speed. At the highest values of Reynolds number index the turbine efficiency is almost constant at 85 percent over the range of speeds investigated. The low values of Reynolds number index bring about a decrease in efficiency to 83 percent at rated speed.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, April 26, 1954

APPENDIX - SYMBOLS

The following symbols are used in this report:

F_j jet thrust, lb

$F_{j,i}$ ideal jet thrust lb, calculated from pressure and temperatures at the exhaust nozzle inlet, lb

F_n net thrust, lb

g acceleration due to gravity, 32.2 ft/sec^2

M Mach number

N rotor speed, rpm

P total pressure, lb/sq ft

p static pressure, lb/sq ft

R gas constant

T total temperature, °R

t static temperature, °R

V velocity, ft/sec

W_a air flow, lb/sec

W_f fuel flow, lb/hr

W_g gas flow, lb/sec

γ ratio of specific heats

β function of γ, $\frac{\gamma^*}{\gamma_4} \frac{\left(\frac{\gamma_4 + 1}{2}\right)^{\frac{\gamma_4}{\gamma_4-1}}}{\left(\frac{\gamma^* + 1}{2}\right)^{\frac{\gamma^*}{\gamma^*-1}}}$, where $\gamma^* = 1.4$

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

η efficiency

ρ density, slugs/cu ft

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

φ ratio of absolute viscosity of air in engine to the absolute viscosity of air of NACA standard atmosphere at sea level

$\frac{\delta}{\varphi\sqrt{\theta}}$ Reynolds number index

Subscripts:

a air

b combustor

c combined

cr critical

i ideal

in inboard

out outboard

t turbine

0 altitude test condition

1 outboard compressor inlet

2 inboard compressor inlet

3 inboard compressor discharge

4 inboard turbine inlet

5 outboard turbine inlet

6 outboard turbine discharge

9 exhaust nozzle inlet

REFERENCES

1. Wallner, Lewis E., and Wintler, John T.: Experimental Investigation of Typical Constant- and Variable-Area Exhaust Nozzles and Effects on Axial-Flow Turbojet-Performance. NACA RM E51D19, 1951.

2. Wallner, Lewis E., and Saari, Martin J.: Preliminary Altitude Operational Characteristics of a J57-P1 Turbojet Engine. NACA RM SE54C31, 1954.

3. Sivo, Joseph N., and Fenn, David B.: A Method of Measuring Jet Thrust of Turbojet Engines in Flight Installations. NACA RM E53J15, 1954.

TABLE I. - ALTITUDE PERFORMANCE DATA OF THE J-57-P1 TURBOJET ENGINE

Run	Altitude, ft	Flight Mach number, M_0	Ambient static pressure, p_0, $\frac{lb}{sq\ ft\ abs}$	Equivalent ambient air temperature, t_0, °R	Engine inlet indicated temperature, T_1, °R	Reynolds number index (station 1), $\delta_1/\phi_1\sqrt{\theta_1}$	Reynolds number index (station 2), $\delta_2/\phi_2\sqrt{\theta_2}$	Outboard engine speed		
								N_{out}, rpm	Adjusted, $\frac{N_{out}}{\sqrt{\theta_a}}$, rpm	Corrected, $\frac{N_{out}}{\sqrt{\theta_1}}$, rpm
1	15,000	0.776	1173	459	514	0.8351	1.853	6152	6189	6183
2		-----	----	---	525	------	-----	5925	----	5891
3		.793	1185	465	524	.8380	1.671	5429	5429	5403
4		.817	1186	462	524	.8584	1.617	5156	5171	5131
5		.816	1185	459	520	.8650	1.440	4580	4607	4575
6		.811	1172	460	521	.8490	-----	3974	3994	3966
7		.823	1180	460	522	.8639	1.070	3035	3050	3026
8		.804	1184	457	516	.8627	1.743	5989	6043	6007
9		.814	1186	457	517	.8701	1.597	5207	5254	5217
10		.821	1180	456	517	.8716	1.319	4189	4231	4197
11		.815	1184	459	520	.8635	1.060	2974	2992	2971
12	25,000	0.809	774	431	487	0.6085	1.368	6223	6216	6422
13		.816	776	431	488	.6129	1.344	5918	5911	6101
14		.810	777	431	488	.6105	1.285	5596	5589	5769
15		.812	777	430	487	.6120	1.220	5258	5258	5426
16		.813	776	430	487	.6120	.9787	4503	4503	4647
17		.815	775	430	487	.6130	.8041	3315	3315	3421
18		.815	774	431	488	.6109	.6863	2301	2298	2372
19		.814	771	433	490	.6044	.6439	1778	1772	1830
20		.815	774	425	481	.6216	1.268	6013	6049	6248
21		.815	774	432	489	.6092	1.180	5354	5342	5515
22		.815	775	429	486	.6147	.9732	4337	4341	4480
23		.815	775	429	486	.6147	.7707	3137	3140	3241
24		.814	774	429	486	.6133	.6807	2320	2322	2397
25	35,000	-----	491	---	---	-----	-----	6242	----	----
26		-----	---	---	---	-----	-----	6241	----	----
27		.820	488	401	455	.4225	.9304	5760	5709	6152
28		.826	486	400	455	.4231	.8880	5410	5369	5778
29		.819	488	400	454	.4231	.7495	4657	4622	4978
30		.840	488	396	452	.4344	.5080	2532	2525	2714
31		.852	483	396	454	.4331	.4600	1754	1749	1875
32		.826	488	396	450	.4306	.8970	6052	6036	6500
33		.828	487	398	452	.4283	.8524	5456	5428	5849
34		.833	489	397	450	.4322	.7255	4504	4487	4828
35		.832	487	396	451	.4311	.5754	3402	3393	3650
36		.825	483	397	451	.4248	.4750	2300	2291	2468
37	45,000	0.825	295	386	439	0.2683	0.6148	6079	6134	6608
38		.828	293	390	443	.2642	.5873	5729	5752	6205
39		.831	299	389	443	.2705	.6013	5700	5729	6173
40		.838	290	388	443	.2642	.4885	4856	4885	5259
41		.847	290	387	443	.2665	.3217	2730	2752	2957
42		.822	289	391	444	.2583	.2972	2300	2305	2486
43		.828	291	388	441	.2639	.5507	5900	5935	6402
44		.844	290	387	442	.2666	.4908	4915	4954	5328
45		.843	289	387	442	.2655	.3607	3518	3546	3814
46	50,000	0.822	230	388	440	0.2077	0.4776	6092	6129	6616
47		.806	242	396	447	.2111	.4849	6071	6048	6538
48		.844	226	385	440	.2089	.4604	5736	5793	6229
49		.847	229	385	440	.2124	.4495	5403	5457	5868
50		.829	234	388	441	.2124	.3953	4913	4942	5331
51		.829	236	385	438	.2159	.4525	5890	5949	6414
52		.830	235	387	440	.2142	.3773	4745	4783	5153
53		.823	247	388	440	.2234	.3148	3685	3707	4002
54		.847	231	385	440	.2142	.2633	2942	2971	3195

TABLE I. - Continued. ALTITUDE PERFORMANCE DATA OF THE J-57-P1 TURBOJET ENGINE

Inboard engine speed				Engine total pressure ratio, P_9/P_1	Engine total temperature ratio, T_9/T_1	Net thrust			Jet thrust				Run
N_{in}, rpm	Adjusted, $\frac{N_{in}}{\sqrt{\theta_a}}$	Corrected (station 1), $\frac{N_{in}}{\sqrt{\theta_1}}$	Corrected (station 2), $\frac{N_{in}}{\sqrt{\theta_2}}$			F_n, lb	Adjusted, F_n/δ_a, lb	Corrected, F_n/δ_1, lb	Ideal, $F_{j,i}$, lb	F_j, lb	Adjusted, F_j/δ_a, lb	Corrected F_j/δ_1 lb	
9707	9765	9756	7893	2.380	2.907	6339	6414	7689	10145	9891	10013	11998	1
9556	----	9502	----	-----	-----	----	----	----	-----	----	-----	-----	2
9094	9094	9050	7570	1.769	2.385	3741	3741	4410	6947	6773	6773	7986	3
8804	8830	8762	7428	1.532	2.181	2781	2779	3201	5818	5673	5668	6530	4
8201	8250	8193	7155	1.147	1.825	1134	1133	1308	3543	3454	3452	3983	5
7701	7740	7686	----	.8947	1.591	105	107	124	1823	1777	1797	2084	6
6980	7015	6960	6547	0.7702	1.308	-387	-388	-445	1040	1014	1018	1165	7
9766	9854	9795	8076	2.098	2.888	4978	4983	5815	8872	8650	8658	10103	8
8994	9075	9012	7701	1.552	2.309	2615	2612	3020	5878	5731	5726	6619	9
8000	8080	8016	7193	1.004	1.702	297	297	342	2616	2551	2557	2941	10
7021	7063	7014	6659	.7724	1.333	-549	-548	-634	976	952	951	1099	11
9670	9658	9879	7975	2.551	3.140	4870	4931	8669	7664	7472	7566	13286	12
9396	9385	9687	7864	2.313	2.898	4155	4188	7325	6821	6650	6705	11719	13
9111	9100	9393	7730	2.053	2.676	3352	3373	5925	5766	5622	5656	9945	14
8789	8789	9070	7573	1.781	2.439	2555	2571	4517	4739	4621	4649	8170	15
8010	8010	8266	7170	1.170	1.891	826	832	1459	2410	2350	2360	4154	16
7025	7025	7250	6691	.8265	1.452	-114	-115	-202	928	905	912	1597	17
6063	6056	6251	6011	.7235	1.205	-324	-326	-573	409	399	402	705	18
5267	5249	5420	5304	.6868	1.094	-347	-349	-514	221	215	217	340	19
9660	9718	10037	8145	2.2821	3.158	3818	3854	6752	6513	6350	6411	11227	20
9010	8989	9280	7831	1.779	2.579	2336	2355	4127	4666	4549	4591	8043	21
7993	8001	8257	7295	1.113	1.872	481	484	849	2124	2071	2084	3655	22
7008	7015	7239	6789	.8040	1.442	-285	-286	-503	790	770	775	1359	23
6140	6146	6343	6140	.7232	1.228	-416	-418	735	387	377	380	668	24
9533	----	10181	----	------	-----	----	----	----	----	----	----	-----	25
9522	----	10208	----	------	-----	----	----	----	----	----	----	-----	26
9095	9015	9713	7843	2.361	2.925	2668	2697	7438	4364	4255	4310	11863	27
8791	8725	9389	7714	2.068	2.675	2120	2153	5898	3676	3584	3644	9978	28
8012	7952	8565	7313	1.367	2.099	868	877	2424	1998	1948	1968	5439	29
6155	6139	6598	6266	.7339	1.270	-192	-193	-524	351	342	344	936	30
5105	5092	5457	5319	.6688	1.075	-216	-218	-587	149	145	147	396	31
9558	9533	10265	8242	2.476	3.371	2787	2821	7730	4610	4495	4545	12464	32
8967	8921	9613	7970	1.996	2.808	1898	1921	5264	3507	3419	3461	9482	33
8009	7979	8586	7461	1.274	2.091	585	588	1606	1771	1727	1738	4745	34
7022	7004	7535	6929	.8460	1.543	-120	-121	-332	653	637	643	1759	35
5964	5941	6399	6173	.7152	1.257	-264	-268	-740	245	239	243	670	36
9294	9378	10105	7991	2.744	3.364	2068	2142	9489	3190	3110	3225	14276	37
9016	9052	9764	7848	2.431	3.079	1706	1782	7849	2746	2677	2794	12343	38
9004	9049	9751	7843	2.413	3.065	1714	1748	7721	2768	2699	2752	12150	39
8167	8216	8845	7436	1.573	2.391	761	793	3505	1520	1482	1546	6832	40
6200	6250	6715	6318	.7559	1.372	-87	-91	-398	247	241	252	1101	41
5720	5731	6183	5892	.7400	1.268	-117	-122	-551	204	199	208	935	42
9290	9346	10080	8116	2.445	3.422	1634	1712	7586	2704	2636	2762	12233	43
8385	8452	9089	7702	1.639	2.566	746	779	3418	1589	1549	1617	7096	44
7046	7102	7638	6953	.8848	1.724	-21	-106	-95	469	457	479	2103	45
9287	9343	10086	7963	2.793	3.459	1653	1738	9757	2522	2459	2587	14535	46
9283	9248	9998	7926	2.736	3.383	1664	----	9493	2543	2479	----	14142	47
9000	9090	9774	7840	2.456	3.186	1368	1459	8038	2189	2134	2275	12545	48
8700	8787	9448	7703	2.158	2.916	1111	1169	6424	1873	1826	1921	10557	49
8178	8227	8873	7435	1.619	2.503	649	668	3740	1247	1216	1252	7010	50
9263	9356	10087	8111	2.465	3.491	1344	1372	7683	2208	2153	2198	12312	51
8168	8233	8870	7577	1.488	2.514	488	501	2802	1103	1075	1102	6167	52
7165	7208	7781	7025	.9299	1.843	21	21.2	117	429	418	408	2299	53
6493	6558	7051	6590	.7832	1.595	-81	-72.2	-465	244	238	248	1364	54

TABLE I. - Continued. ALTITUDE PERFORMANCE DATA OF THE J-57-P1 TURBOJET ENGINE

Run	Air Flow							Fuel flow			Specific fuel consumption		
	$W_{a,out}$, lb/sec	Adjusted, $\frac{W_{a,out}\sqrt{\theta_a}}{\delta_a}$, lb/sec	Corrected $\frac{W_{a,out}\sqrt{\theta_1}}{\delta_1}$, lb/sec	$W_{a,bleed}$, lb/sec	$W_{a,in}$, lb/sec	Corrected (station 1), $\frac{W_{a,in}\sqrt{\theta_1}}{\delta_1}$, lb/sec	Corrected (station 2), $\frac{W_{a,in}\sqrt{\theta_2}}{\delta_2}$, lb/sec	W_f, lb/hr	Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$, lb/hr	Corrected, $\frac{W_f}{\delta_1\sqrt{\theta_1}}$, lb/hr	W_f/F_n, $\frac{lb/hr}{lb\ thrust}$	Adjusted, $\frac{W_f}{F_n\sqrt{\theta_a}}$, $\frac{lb/hr}{lb\ thrust}$	Corrected, $\frac{W_f}{F_n\sqrt{\theta_1}}$, $\frac{lb/hr}{lb\ thrust}$
1	140.22	141.06	169.25		140.22		56.10	6745	6867	8223	1.064	1.071	1.069
2	------	------	------		------		-----	5933	----	----	-----	-----	-----
3	116.35	116.35	137.87		116.35		53.30	4073	4073	4778	1.089	1.089	1.083
4	108.06	107.65	125.03		108.06		52.13	3175	3179	3637	1.142	1.144	1.136
5	87.08	86.49	100.49		87.08		49.47	1770	1778	2039	1.561	1.569	1.559
6	------	------	------		63.15		-----	987	1002	1154	9.224	9.364	9.306
7	52.02	58.92	59.98		52.07		44.24	407	410	466	-----	-----	-----
8	140.19	139.08	163.32	13.53	126.66	147.56	55.11	6318	6376	7402	1.269	1.28	1.273
9	117.55	116.41	135.54	11.33	106.22	122.47	52.97	3557	3583	4116	1.36	1.372	1.363
10	84.39	83.81	97.13	9.10	75.29	86.66	48.80	1346	1362	1555	4.532	4.586	4.547
11	56.41	56.03	65.21	7.19	49.22	56.90	43.34	455	457	526	-----	-----	-----
12	101.73	103.05	175.18		101.73		56.17	5155	5211	9459	1.059	1.057	1.081
13	96.70	97.57	165.26		96.70		55.51	4292	4321	7797	1.033	1.032	1.064
14	88.60	89.22	151.95		88.60		54.26	3435	3451	6264	1.025	1.023	1.057
15	80.63	81.11	138.12		80.63		53.16	2650	2666	4835	1.037	1.037	1.070
16	59.36	59.72	101.68		59.36		50.46	1216	1223	2219	1.472	1.47	1.521
17	39.58	39.90	67.68		39.58		45.79	440	444	801	-----	-----	6.675
18	28.03	28.23	48.04		28.03		40.28	220	221	401	-----	-----	-----
19	21.78	22.04	37.61		21.78		34.19	188	189	343	-----	-----	-----
20	98.89	99.09	168.31	9.59	89.30	151.99	54.90	4760	4827	8745	1.247	1.252	1.295
21	85.73	86.59	147.11	8.79	76.94	132.03	53.10	2930	2947	5336	1.254	1.251	1.293
22	61.78	62.09	105.52	7.07	54.71	93.44	49.10	1158	1166	2111	2.407	2.409	2.486
23	41.02	41.23	70.06	5.05	35.97	61.43	44.49	405	408	738	-----	-----	-----
24	30.87	31.02	52.85	4.33	26.54	45.44	38.99	225	227	400	-----	-----	-----
25	-----	------	------		-----		-----	3621	----	----	-----	-----	-----
26	-----	------	------		-----		-----	3642	----	----	-----	-----	-----
27	63.41	64.74	165.50		63.41		54.86	2716	2724	8088	1.018	1.01	1.087
28	58.16	59.58	151.62		58.16		53.88	2195	2213	6526	1.035	1.028	1.106
29	43.24	44.02	112.90		43.24		50.37	1049	1051	3130	1.209	1.198	1.291
30	20.99	21.18	53.55		20.99		42.40	222	223	651	-----	-----	-----
31	13.95	14.16	35.59		13.95		32.22	201	203	586	-----	-----	-----
32	68.20	69.22	176.09	6.58	61.62	159.70	55.30	3360	3390	10008	1.206	1.202	1.294
33	60.44	61.47	156.42	5.85	54.59	141.28	53.84	2271	----	-----	1.197	-----	-----
34	45.19	45.64	115.87	5.25	39.94	102.41	49.53	1010	1012	2976	1.726	1.721	1.853
35	30.03	30.42	77.33	3.88	26.15	67.33	44.53	404	407	1196	-----	-----	-----
36	20.06	20.46	52.42	2.86	17.20	44.94	38.17	239	242	718	-----	-----	-----
37	42.14	43.32	177.87		42.14		54.95	2225	2328	11103	1.076	1.087	1.170
38	39.00	40.56	166.10		39.00		54.17	1785	1871	8911	1.046	1.05	1.145
39	39.43	40.02	163.99		39.42		53.55	1790	1835	8729	1.044	1.05	1.131
40	28.65	29.74	122.02		28.65		51.05	856	899	4273	1.125	1.134	1.219
41	12.94	13.46	54.63		12.94		41.34	220	233	1088	-----	-----	-----
42	12.75	13.34	55.45		12.75		44.84	134	140	682	-----	-----	-----
43	40.33	42.02	172.49	4.02	36.31	155.30	54.10	2082	2195	10482	1.274	1.282	1.381
44	31.77	32.91	134.26	3.48	28.29	119.55	50.87	1014	1067	5033	1.359	1.37	1.472
45	18.92	19.68	80.32	2.52	16.40	69.62	44.56	350	370	1743	-----	-----	-----
46	32.68	34.18	177.88		32.68		54.61	1815	1920	11651	1.098	1.105	1.194
47	33.34	33.47	176.50		33.34		54.54	1819	1812	11174	1.093	-----	1.177
48	30.39	32.06	164.47		30.39		53.91	1465	1578	9352	1.071	1.082	1.163
49	28.24	29.43	150.32		28.24		52.55	1196	1271	7510	1.077	1.087	1.170
50	22.78	23.33	121.08		22.78		50.07	752	780	4705	1.159	1.168	1.258
51	32.68	33.04	171.67	3.28	29.40	154.44	53.45	1708	1761	10637	1.271	1.284	1.384
52	23.59	23.99	124.56	2.60	20.99	110.83	49.79	714	738	4444	1.463	1.473	1.586
53	16.09	15.61	81.43	2.08	14.01	70.90	43.19	332	326	1984	15.81	15.38	16.957
54	12.60	13.02	66.53	1.69	10.91	57.60	42.35	167	176	1038	------	------	------

TABLE I. - Concluded. ALTITUDE PERFORMANCE DATA OF THE J-57-P1 TURBOJET ENGINE

Exhaust-gas total temperature			Compressor pressure ratio			Compressor efficiency			Combined turbine pressure ratio, P_4/P_6	Combined turbine efficiency, η_T	Turbine corrected gas flow, $\frac{W_{g,T}\sqrt{\theta_{4,cr}}\,\beta}{\delta_4}$, lb/sec	Thrust meter parameter, $(1.25\ P_9-p_0)$	Combustor pressure drop, $\frac{P_3-P_4}{P_3}$	Combustion efficiency, η_b	Run
T_9, °R	Adjusted, T_9/θ_a, °R	Corrected, T_9/θ_1, °R	Outboard, P_2/P_1	Inboard, P_3/P_2	Combined, P_3/P_1	Outboard, $\eta_{c,out}$	Inboard, $\eta_{c,in}$	Combined, $\eta_{c,comb.}$							
1494	1513	1509	3.728	3.136	11.69	0.8609	0.8777	0.8473	4.486	0.8506	31.15	4018	0.0550	1.004	1
----	----	----	-----	-----	-----	------	------	------	-----	------	-----	----	------	-----	2
1250	1250	1238	3.093	2.797	8.649	.8838	.8683	.8566	4.471	.8389	30.93	2783	.0511	1.000	3
1143	1150	1132	2.828	2.659	7.519	.8826	.8659	.8504	4.454	.8507	30.79	2333	.0512	1.013	4
949	961	947	2.326	2.404	5.593	.8766	.8514	.8480	4.384	.8455	30.44	1446	.0561	.981	5
829	838	826	-----	-----	4.143	-----	-----	-----	3.807	-----	-----	847	.0699	.927	6
683	691	679	1.442	1.953	2.816	.8528	.8301	.8238	3.302	.8387	30.13	593	.0770	.915	7
1490	1517	1499	3.245	3.197	10.37	.8589	.8515	.8238	4.482	.8514	30.63	3569	.0589	.998	8
1194	1215	1199	2.705	2.827	7.648	.8888	.8555	.8546	4.462	.8500	30.63	2368	.0552	1.002	9
880	898	884	1.977	2.376	4.698	.8867	.8501	.8551	4.212	.8485	30.20	1124	.0624	.986	10
693	702	692	1.384	1.977	2.735	.8971	.8214	.8347	3.206	.8387	29.58	585	.0748	.915	11
1529	1525	1628	3.903	3.218	12.56	0.8358	0.8599	0.8207	4.465	0.8483	31.27	3021	0.0563	.996	12
1414	1411	1503	3.668	3.096	11.36	.8654	.8523	.8365	4.433	.8537	31.28	2697	.0553	.991	13
1306	1303	1388	3.406	2.961	10.09	.8750	.8546	.8441	4.470	.8431	31.03	2292	.0532	.995	14
1188	1188	1265	3.113	2.809	8.744	.8782	.8493	.8440	4.447	.8561	31.03	1888	.0525	.998	15
921	921	981	2.358	2.436	5.745	.843	.806	.8055	4.409	.8624	30.80	974	.0582	.991	16
707	707	753	1.601	2.070	3.315	.8227	.8320	.8170	3.597	.8429	30.68	464	.0742	.914	17
588	587	625	1.240	1.675	2.076	.7708	.7652	.7582	2.607	-----	-----	309	.0809	----	18
536	532	568	1.123	1.381	1.552	.7547	.6667	.6866	2.036	-----	-----	252	.0877	----	19
1519	1537	1640	3.410	3.296	11.24	.8097	.8254	.7883	4.465	.8588	30.52	2641	.0580	.990	20
1261	1255	1338	2.948	2.991	8.817	.8929	.8414	.8481	4.467	.8435	30.35	1889	.0582	1.009	21
910	911	971	2.153	2.488	5.358	.8693	.8409	.8391	4.327	.8571	30.04	894	.0590	.986	22
700	702	748	1.472	2.090	3.077	.8509	.8010	.8085	3.446	.8507	29.68	430	.0724	.931	23
597	598	637	1.204	1.728	2.081	.8101	.7881	.7797	2.609	-----	-----	307	.0796	----	24
----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2137	-----	----	25
----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----	-----	----	26
1331	1308	1519	3.738	3.112	11.632	0.8545	0.8522	0.8300	4.462	0.8581	30.78	1752	0.0555	0.987	27
1217	1199	1389	3.426	2.959	10.139	.8764	.8507	.8422	4.445	-----	30.78	1479	.0530	.965	28
953	939	1089	2.623	2.558	6.708	.8519	.8042	.8056	4.436	.8673	30.75	807	.0535	.961	29
574	571	660	1.329	1.803	2.397	.7778	.8216	.7941	2.967	-----	-----	222	.0771	-----	30
488	486	558	1.133	1.390	1.575	.6667	.6933	.6873	2.128	-----	-----	166	.0859	-----	31
1517	1509	1749	3.585	3.384	12.130	.7970	.8171	.776	4.467	.8523	30.41	1873	.0545	.997	32
1269	1256	1458	3.164	3.125	9.887	.8577	.8310	.8228	4.460	.8523	30.66	1417	.0595	.977	33
945	938	1086	2.378	2.618	6.225	.8686	.8270	.8286	4.409	.8559	29.95	737	.0545	.952	34
696	692	801	1.644	2.188	3.597	.8426	.8163	.8126	3.821	.8493	29.03	323	.0679	.774	35
567	563	653	1.220	1.744	2.127	.8125	.7952	.7993	2.706	-----	-----	192	.0766	-----	36
1477	1504	1746	4.095	3.289	13.47	.8275	.8342	.8022	4.435	.8421	30.56	1286	.0549	.960	37
1364	1375	1600	3.813	3.142	11.98	.8520	.8399	.8205	4.490	.8365	30.69	1102	.0558	.979	38
1358	1372	1593	3.806	3.148	11.98	.8549	.8420	.8235	4.445	.8418	30.19	1119	.0545	.979	39
1059	1073	1242	2.841	2.713	7.708	.8428	.8275	.8137	4.432	.8374	30.86	613	.0568	.968	40
608	618	713	1.404	-----	-----	.7883	.8434	.8152	3.188	-----	29.40	148	.0703	.433	41
563	566	658	1.298	-----	------	.7570	.8382	.8050	2.754	-----	-----	127	.0785	-----	42
1509	1529	1776	3.568	3.352	11.96	.8080	.8084	.7788	4.421	.8391	30.30	1103	.0554	.949	43
1134	1152	1332	2.775	2.892	8.024	.8651	.8236	.8234	4.415	.8397	29.98	656	.0567	.952	44
762	774	895	1.715	2.237	3.837	.8119	.8019	.7883	3.885	.8250	29.59	220	.0647	.729	45
1522	1542	1794	4.126	3.299	13.61	0.8263	0.832	0.796	4.427	-----	-----	1020	0.0542	0.956	46
1512	1501	1754	4.084	3.264	13.353	.8336	.8405	.8100	4.431	.8333	30.59	1027	.0537	.958	47
1402	1431	1653	3.806	3.161	12.03	.8396	.8349	.8095	4.431	.8385	30.77	879	.0554	.972	48
1283	1310	1513	3.511	3.012	10.58	.8555	.8324	.8214	4.428	.8378	30.50	759	.0540	.955	49
1104	1118	1299	2.886	2.717	7.839	.8348	.8256	.8064	4.390	.8268	30.63	509	.0539	.948	50
1529	1561	1813	3.592	3.355	12.05	.8066	.8084	.7778	4.431	.8295	30.18	904	.0550	.954	51
1106	1124	1304	2.607	2.796	7.290	.8517	.8109	.8094	4.417	.8268	30.36	451	.0591	.967	52
811	822	956	1.818	2.301	4.184	.8208	.8037	.7936	4.046	.8161	28.61	201	.0633	.759	53
702	717	828	1.455	2.024	2.946	.7843	.7889	.7717	3.399	.8000	30.18	130	.0681	.825	54

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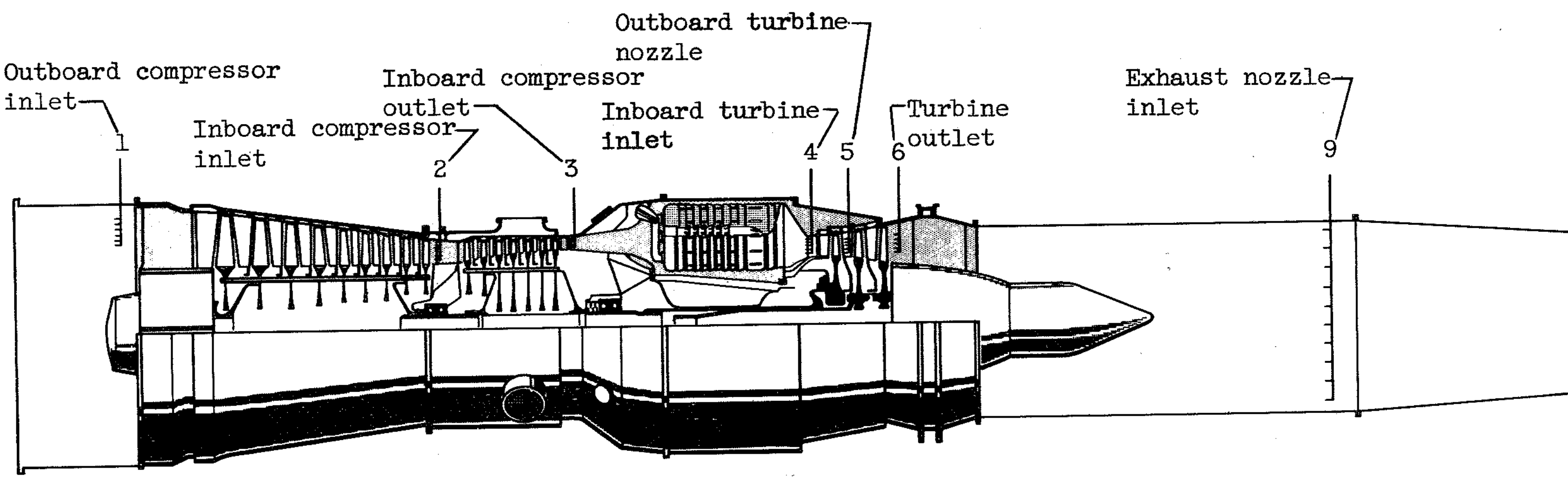

Station	Number of rakes	Total pressure tubes	Static pressure tubes	Number of thermocouples	Wall static pressure orifices	Annular area, sq ft
1	4	36	16	16	4	5.800
2	4	24	0	12	0	1.637
3	4	24	0	12	0	.952
4	2 Rakes; 8 single pressure probes	18	0	8	0	
5	4	16	0	0	0	
6	8	24	0	24	8	3.142
9	4	24	0	24	4	4.550

CD-3605

Figure 1. - Cross-section of engine showing location of instrumentation.

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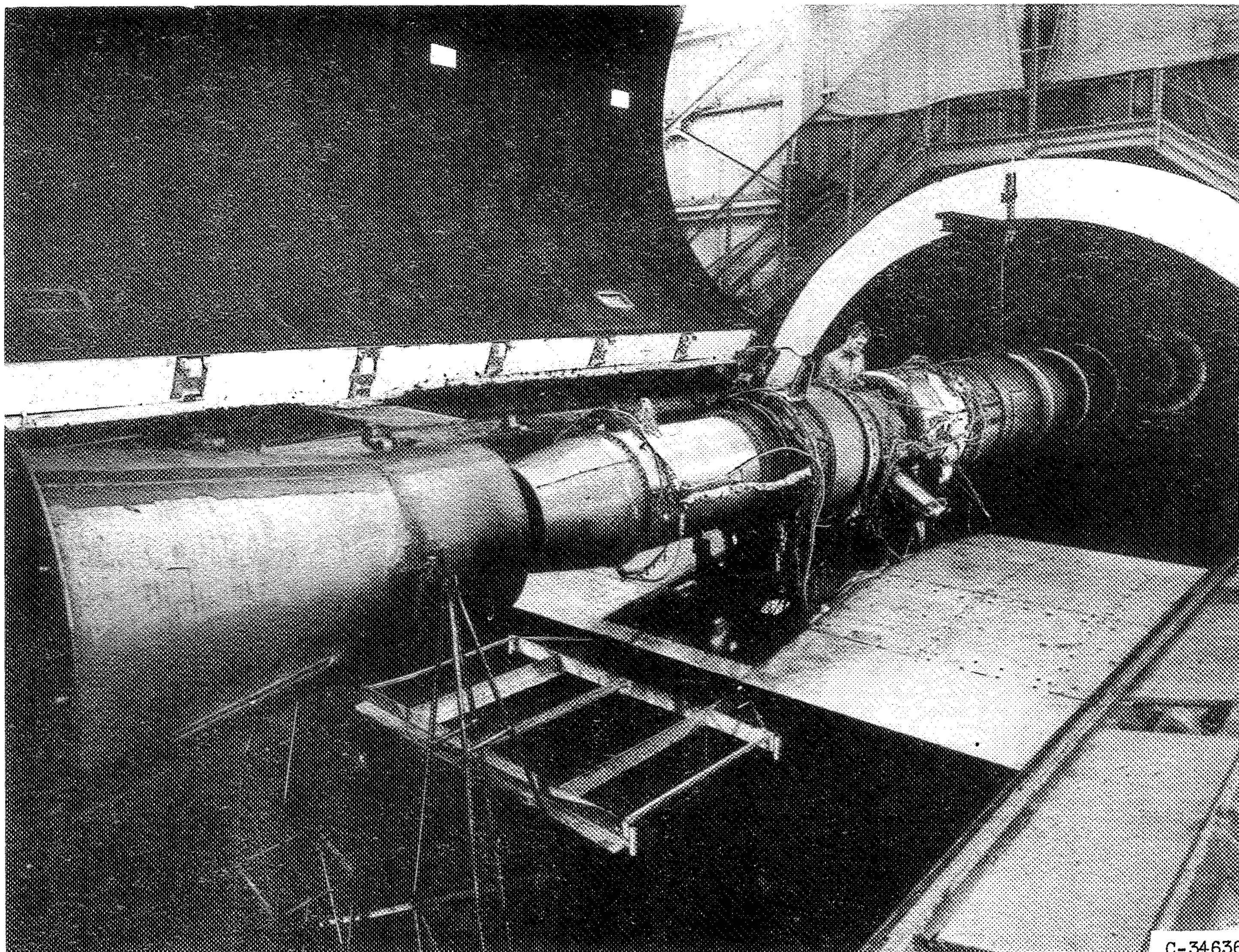

Figure 2. - J57-P-1 turbojet engine installed in altitude wind tunnel.

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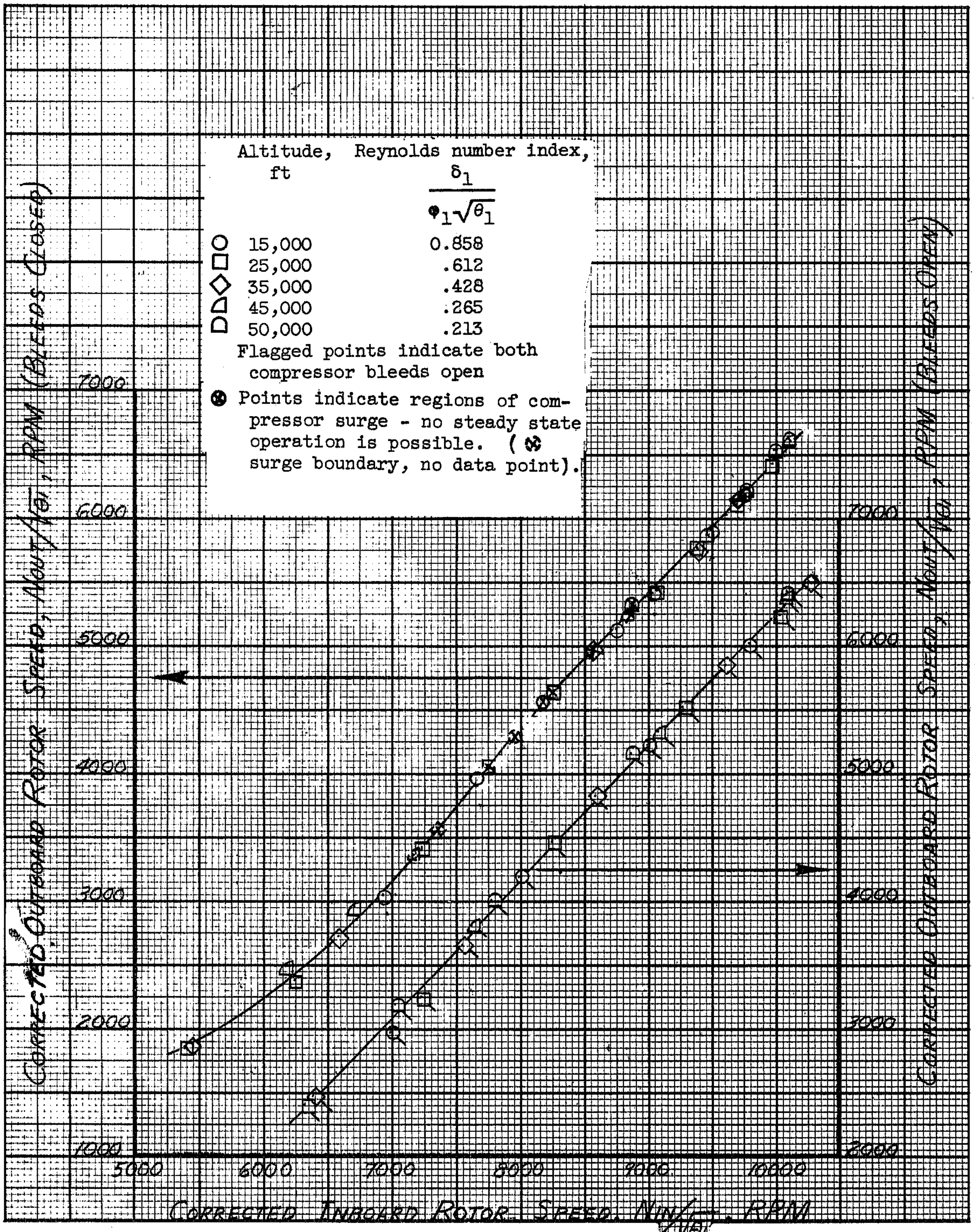

Figure 3. - The variation of corrected outboard rotor speed with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

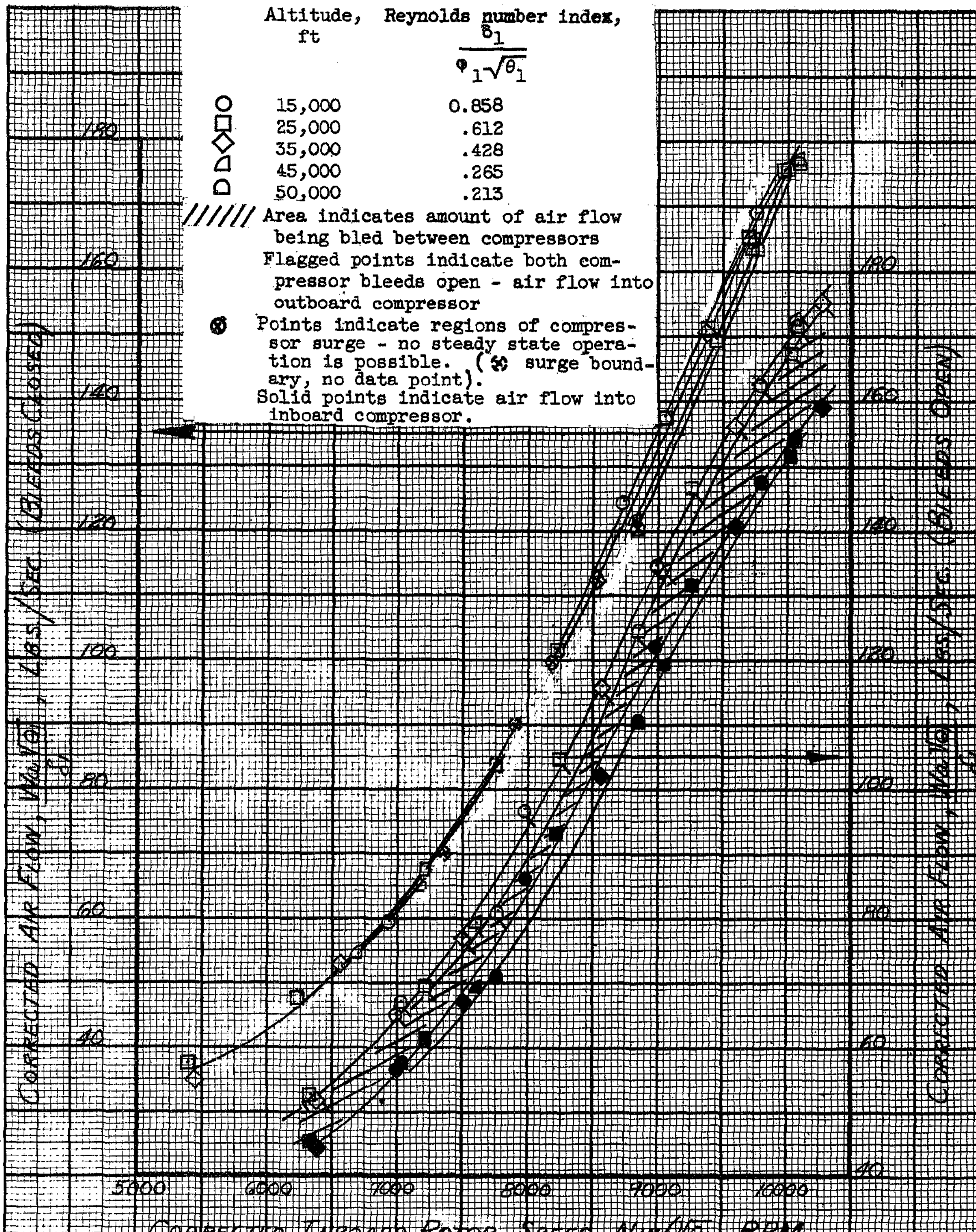

Figure 4. - The variation of corrected air flow with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

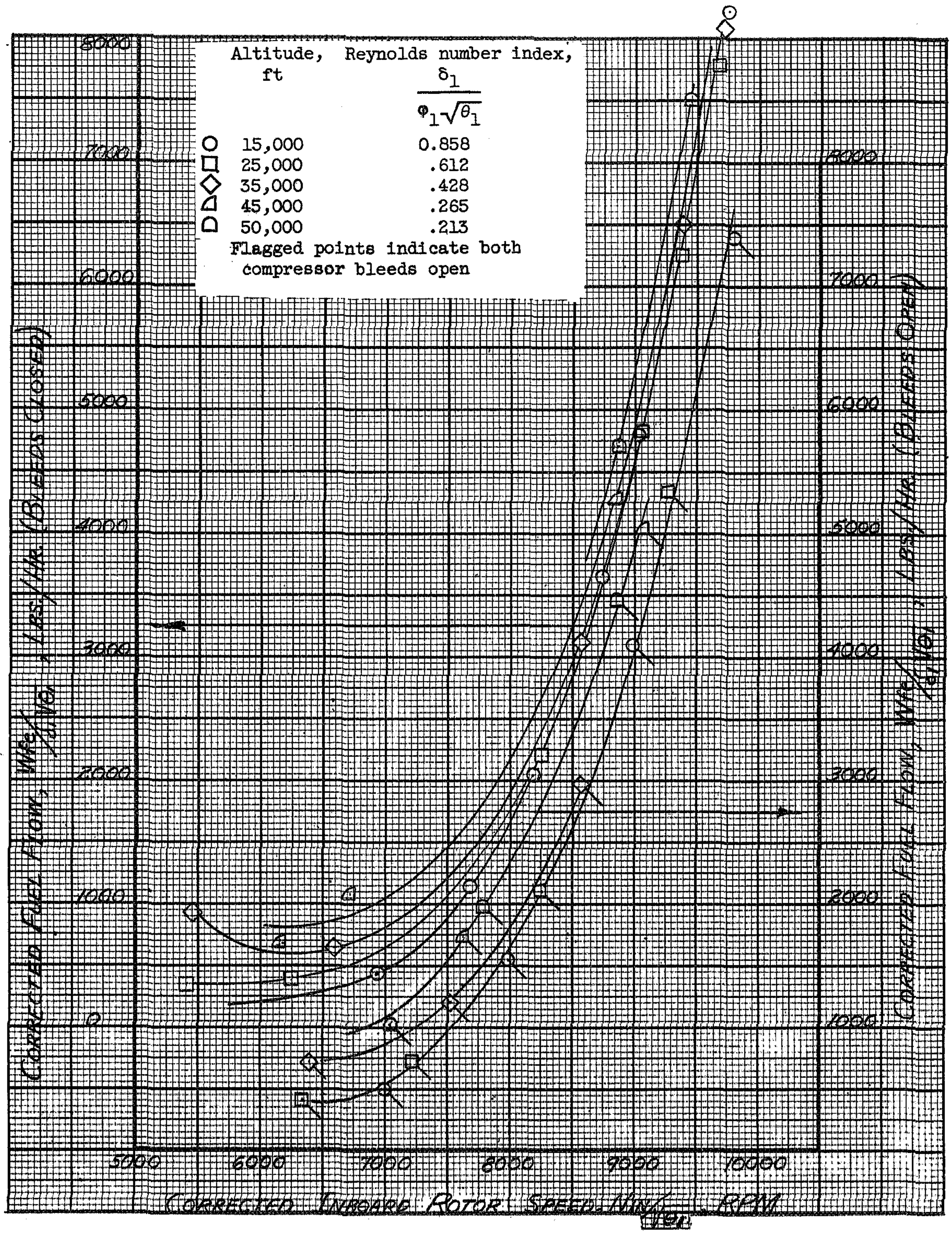

Figure 5. - The variation of corrected fuel flow with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

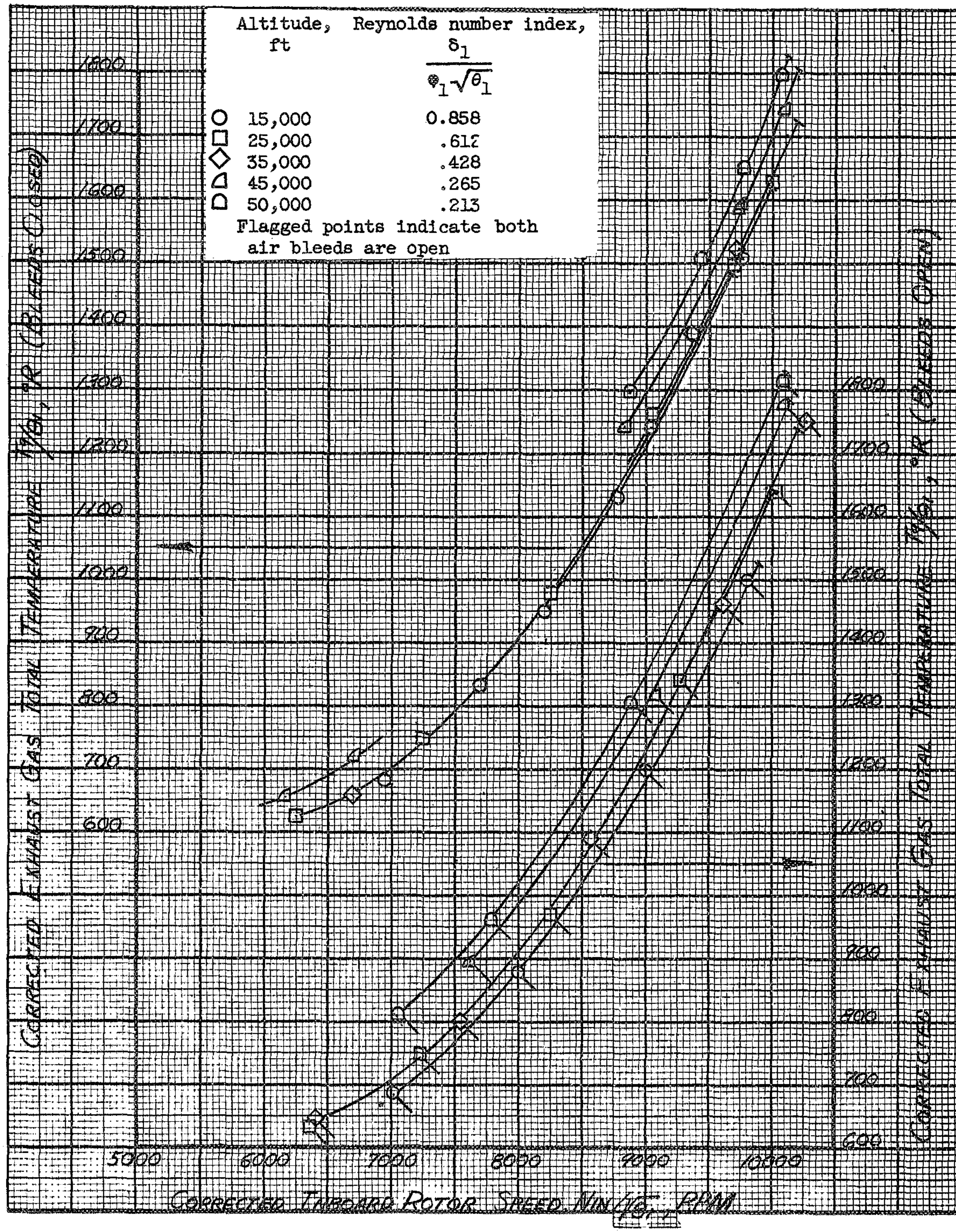

Figure 6. - The variation of corrected exhaust gas total temperature with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

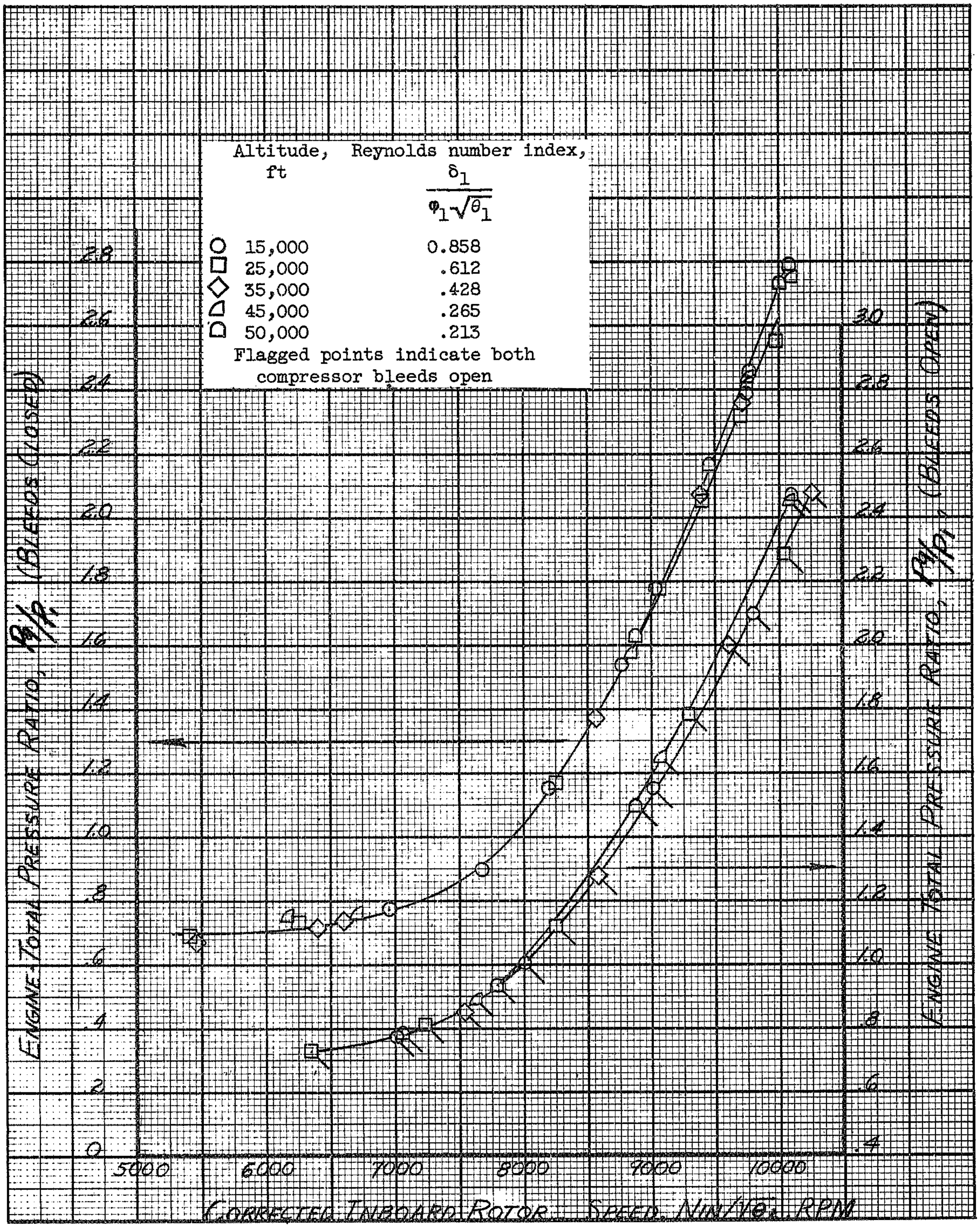

Figure 7. - The variation of engine total pressure ratio with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

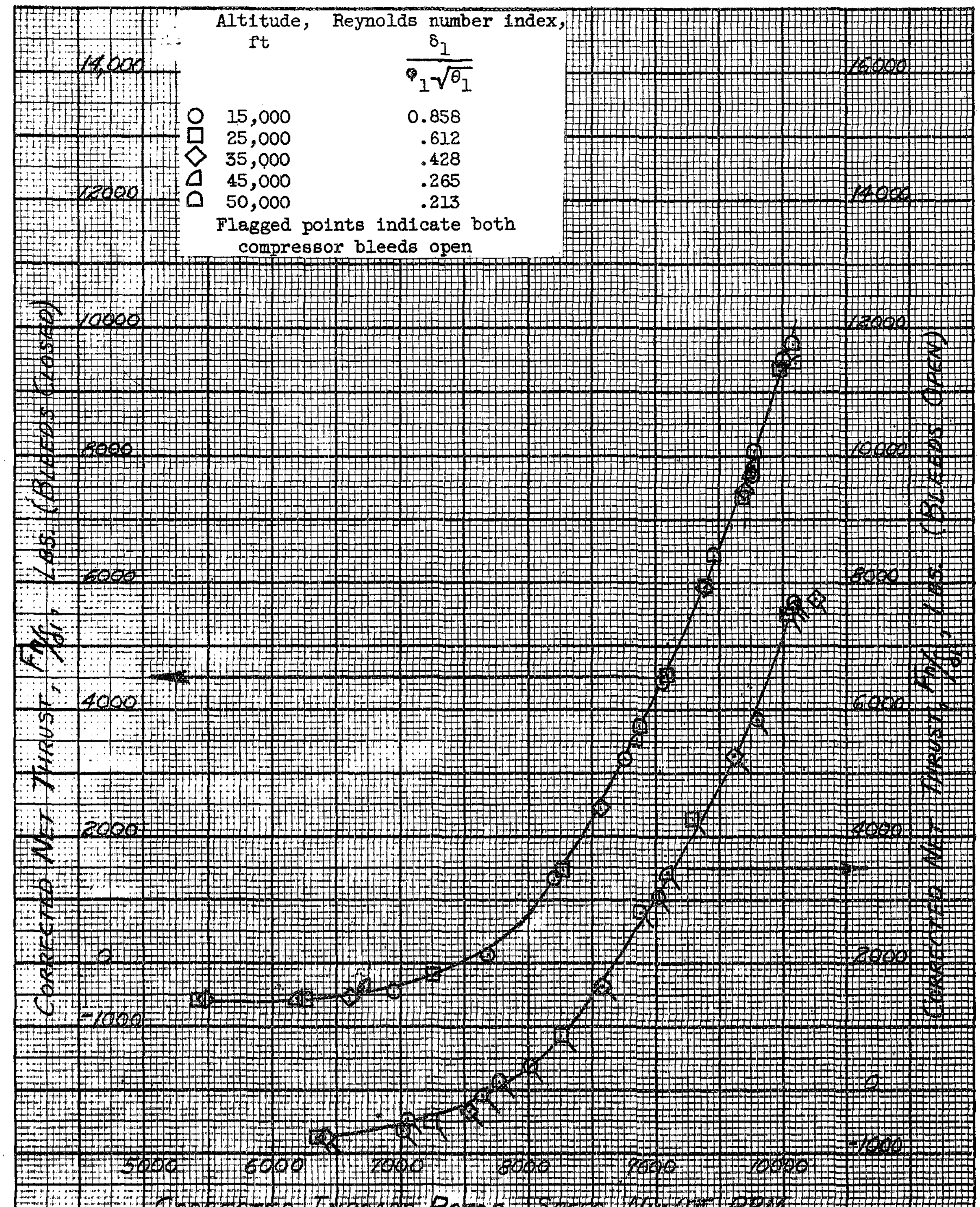

Figure 8. - The variation of corrected net thrust with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

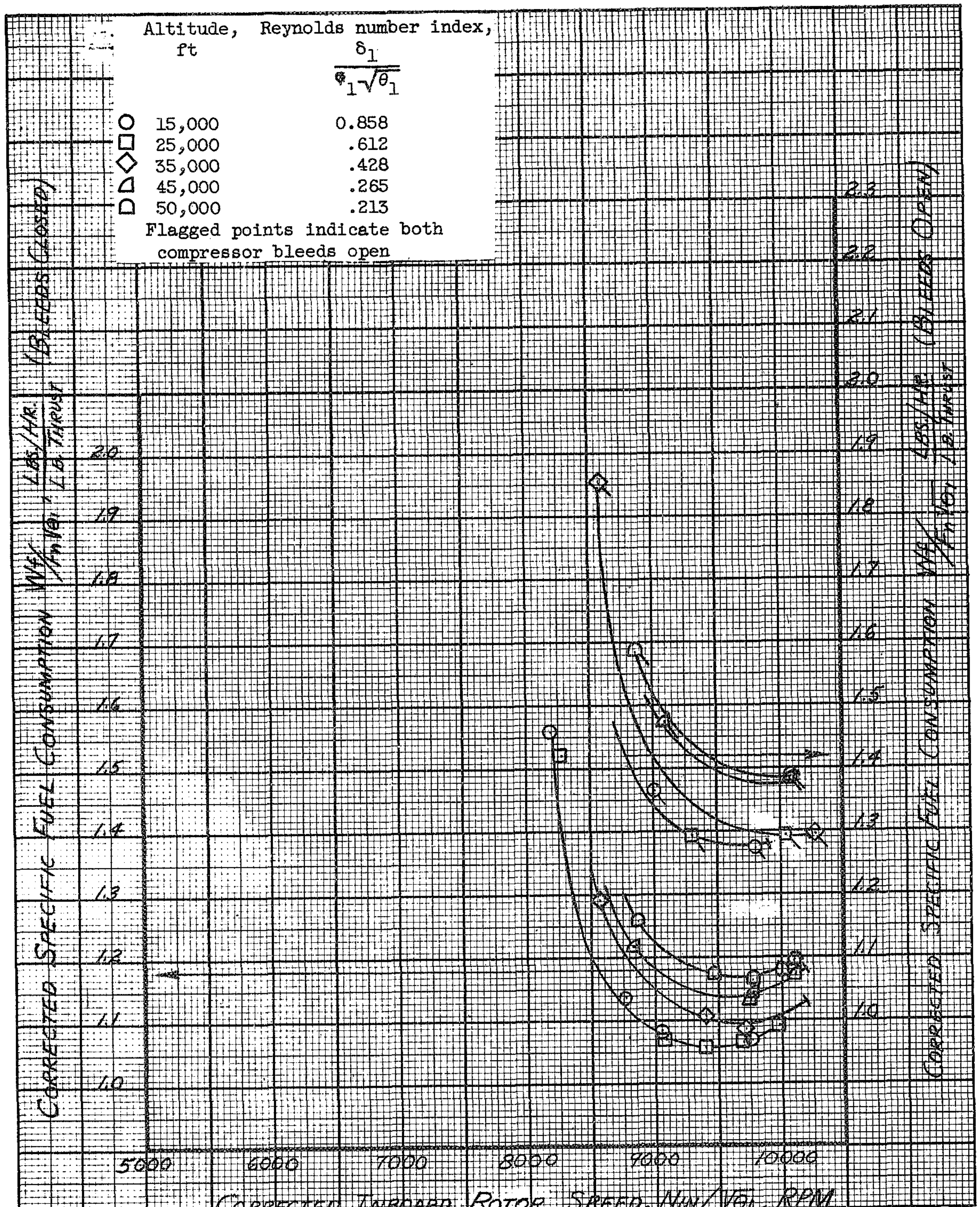

Figure 9. - The variation of corrected specific fuel consumption with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

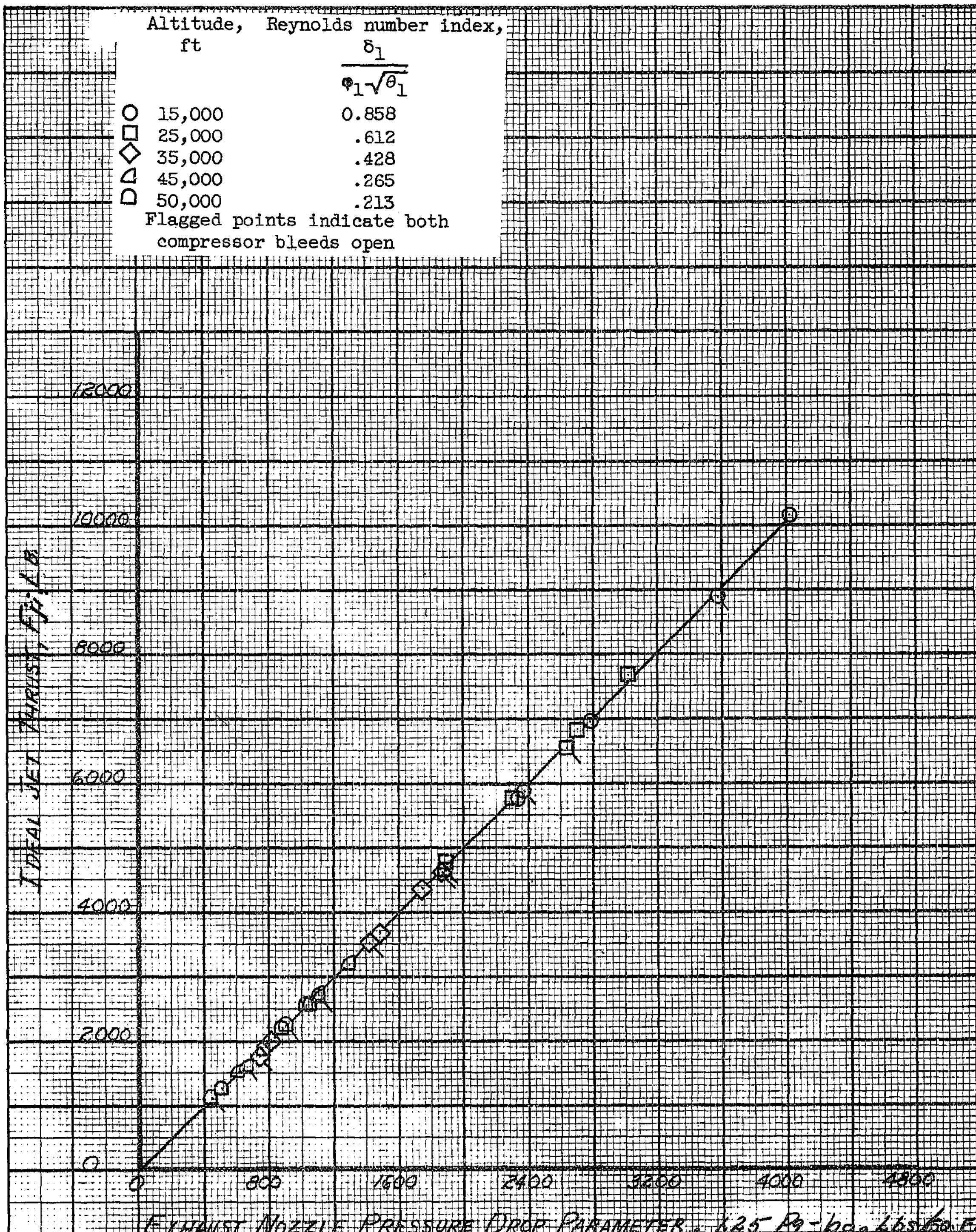

Figure 10. - The variation of ideal jet thrust with exhaust nozzle pressure drop parameter over a range of Reynolds number indices. Flight Mach number 0.81.

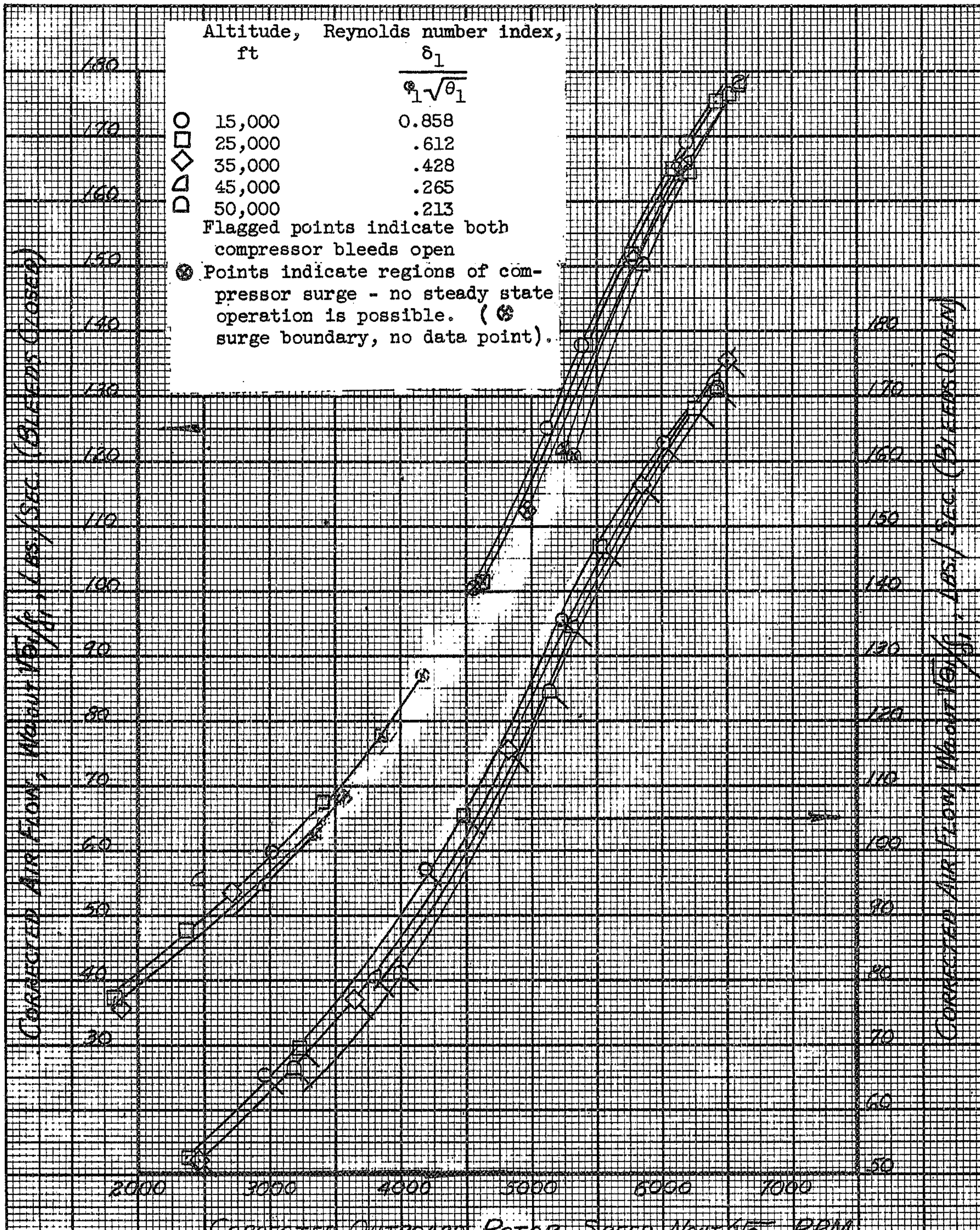

Figure 11. - The variation of corrected air flow with corrected outboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

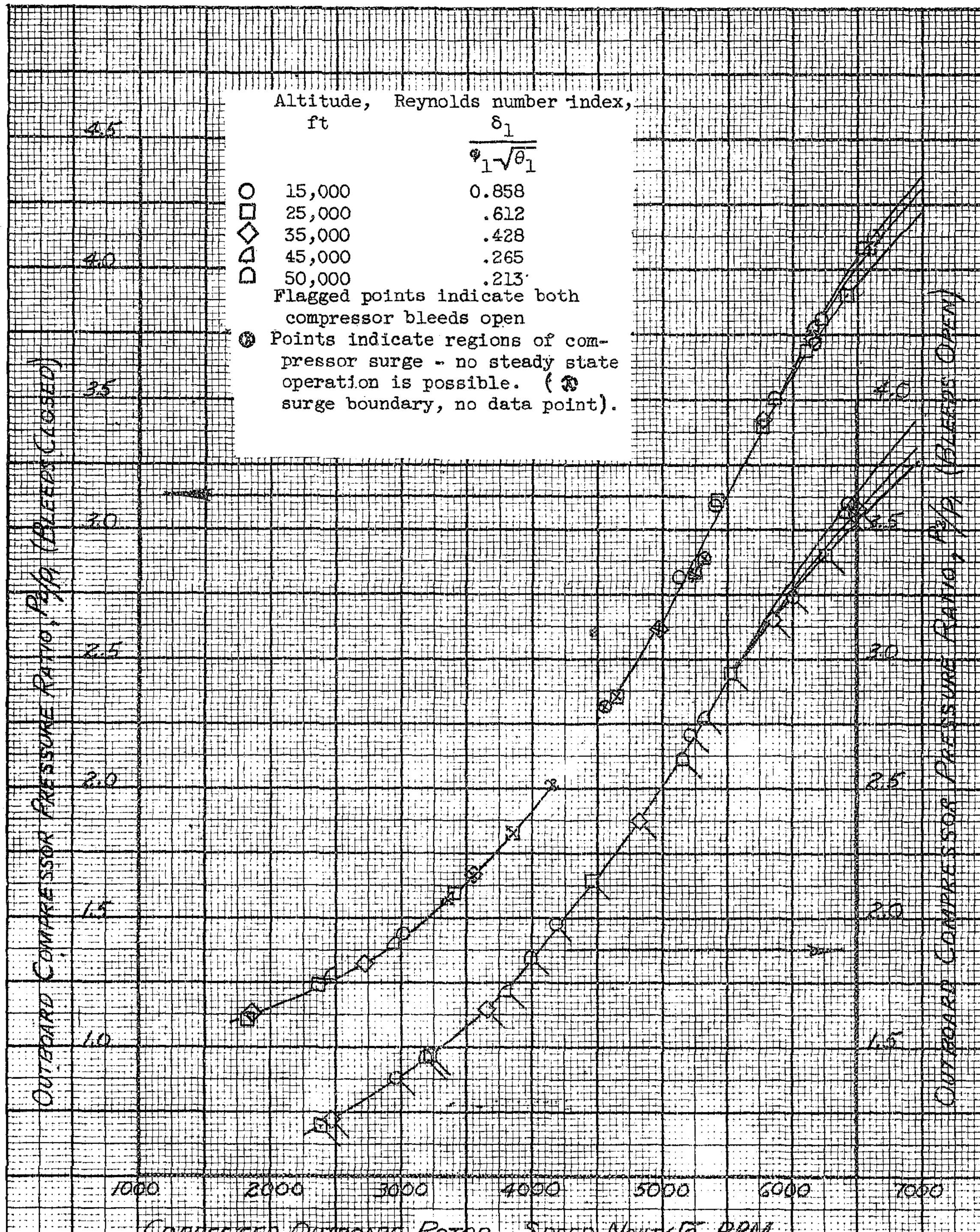

Figure 12. - The variation of outboard compressor pressure ratio with corrected outboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

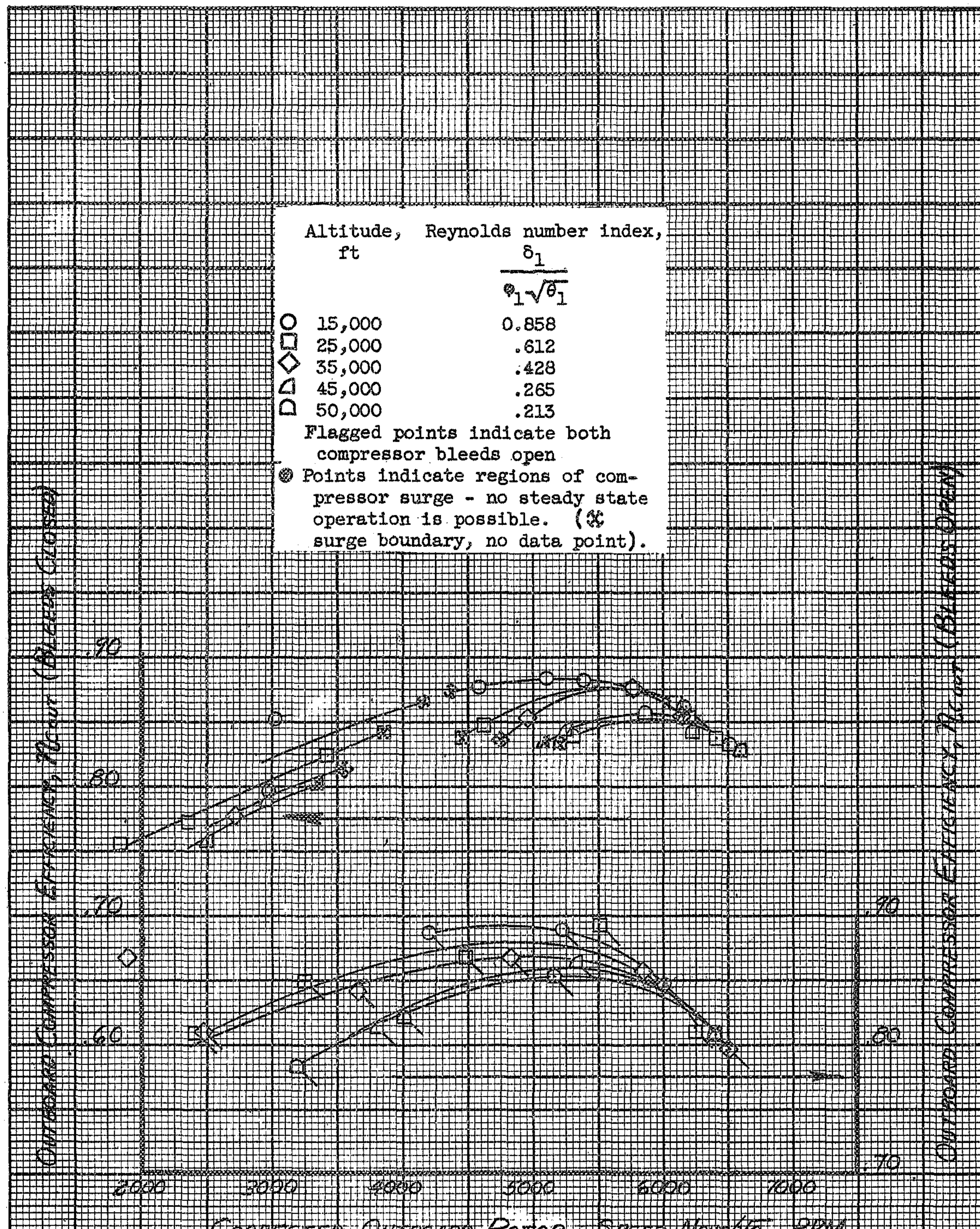

Figure 13. - The variation of outboard compressor efficiency with corrected outboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

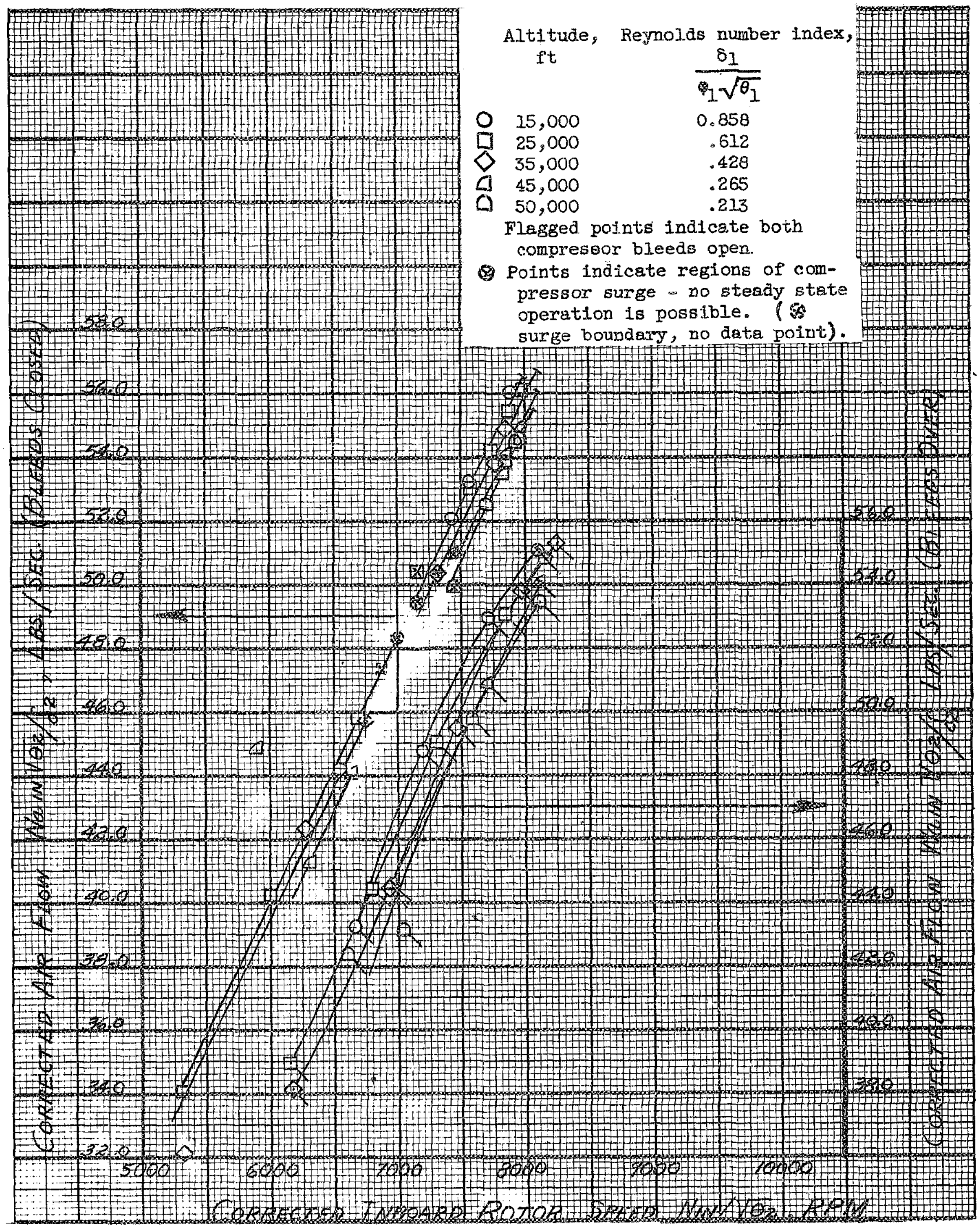

Figure 14. - The variation of corrected inboard air flow with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

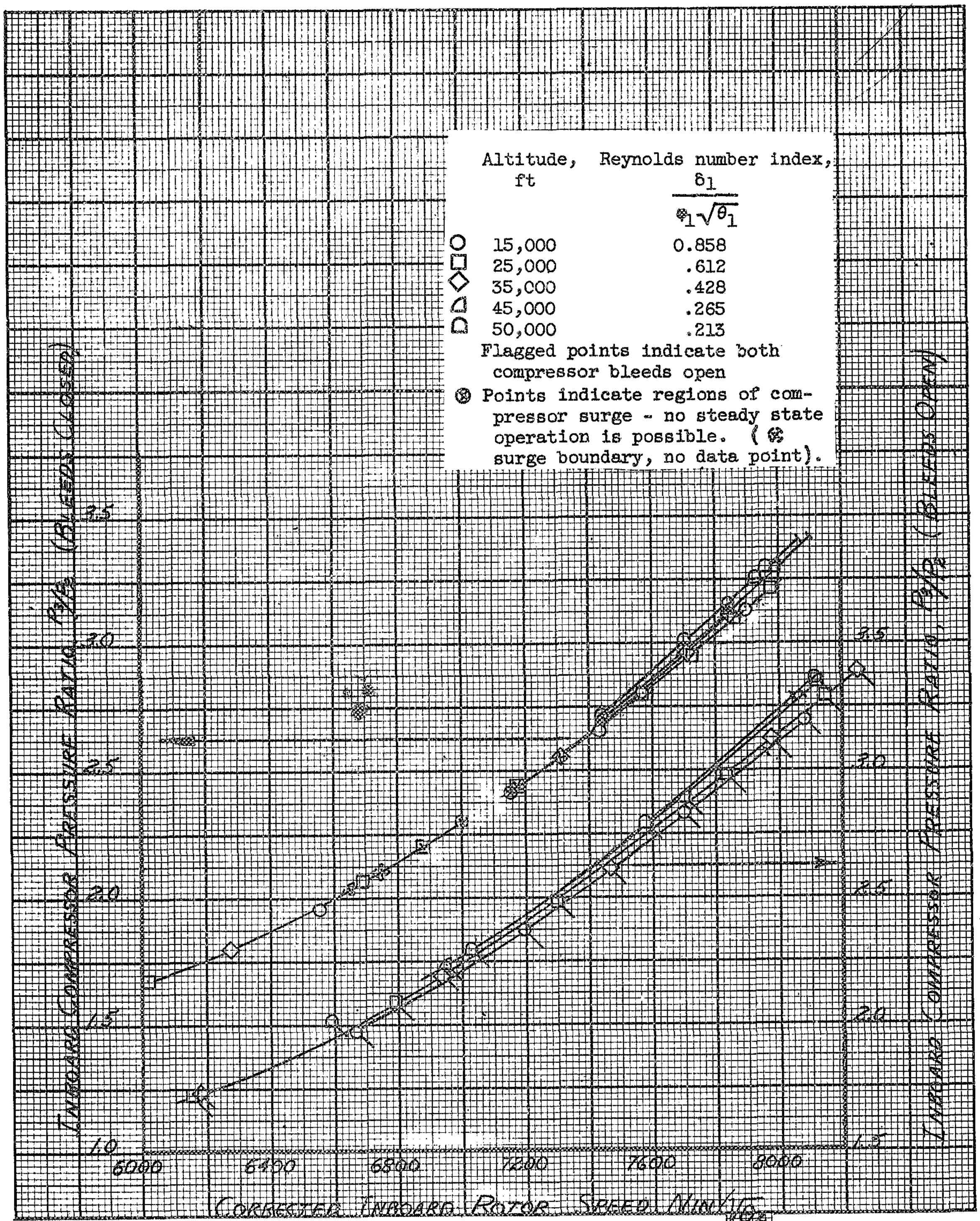

Figure 15. - The variation of inboard compressor pressure ratio with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

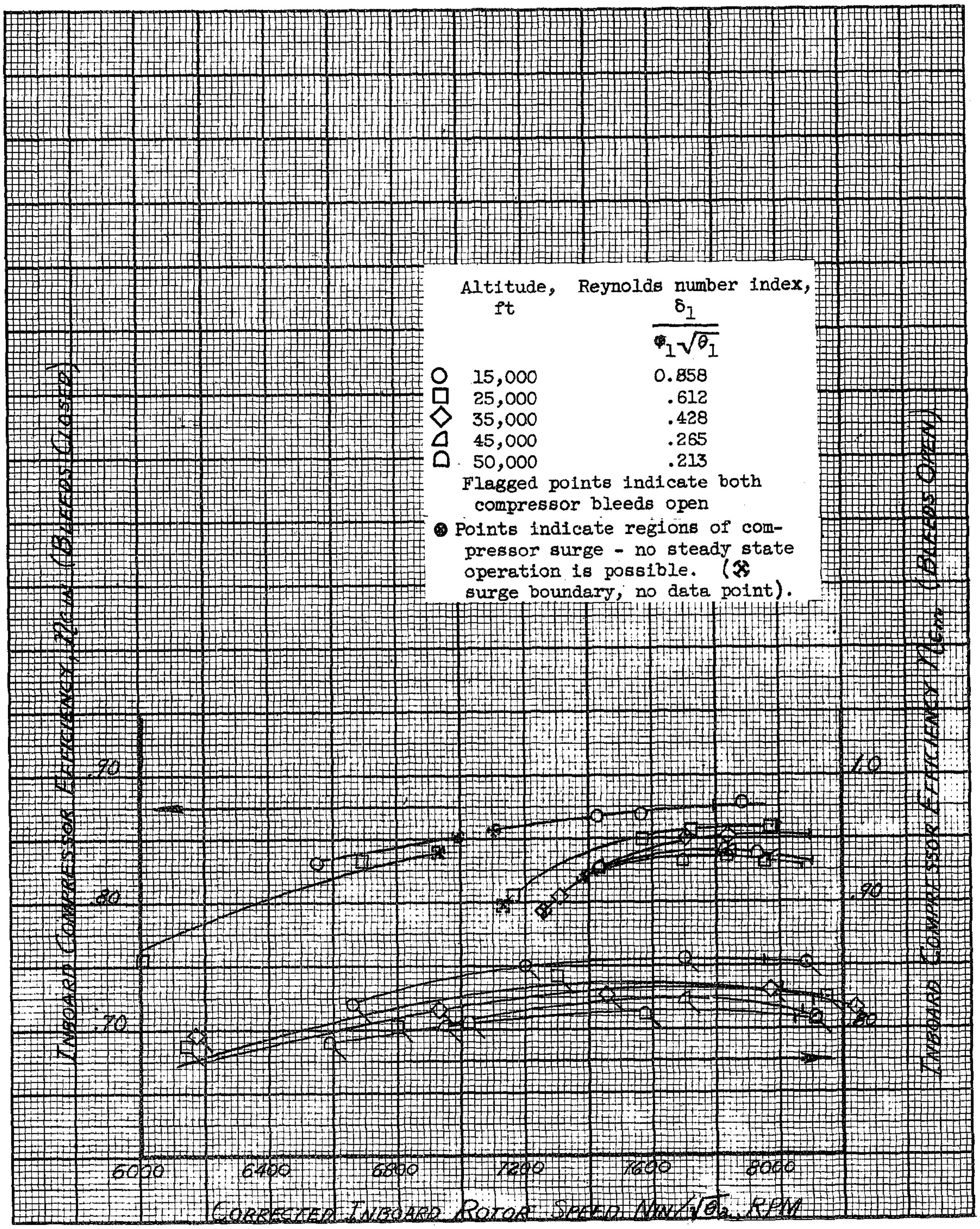

Figure 16. - The variation of inboard compressor efficiency with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

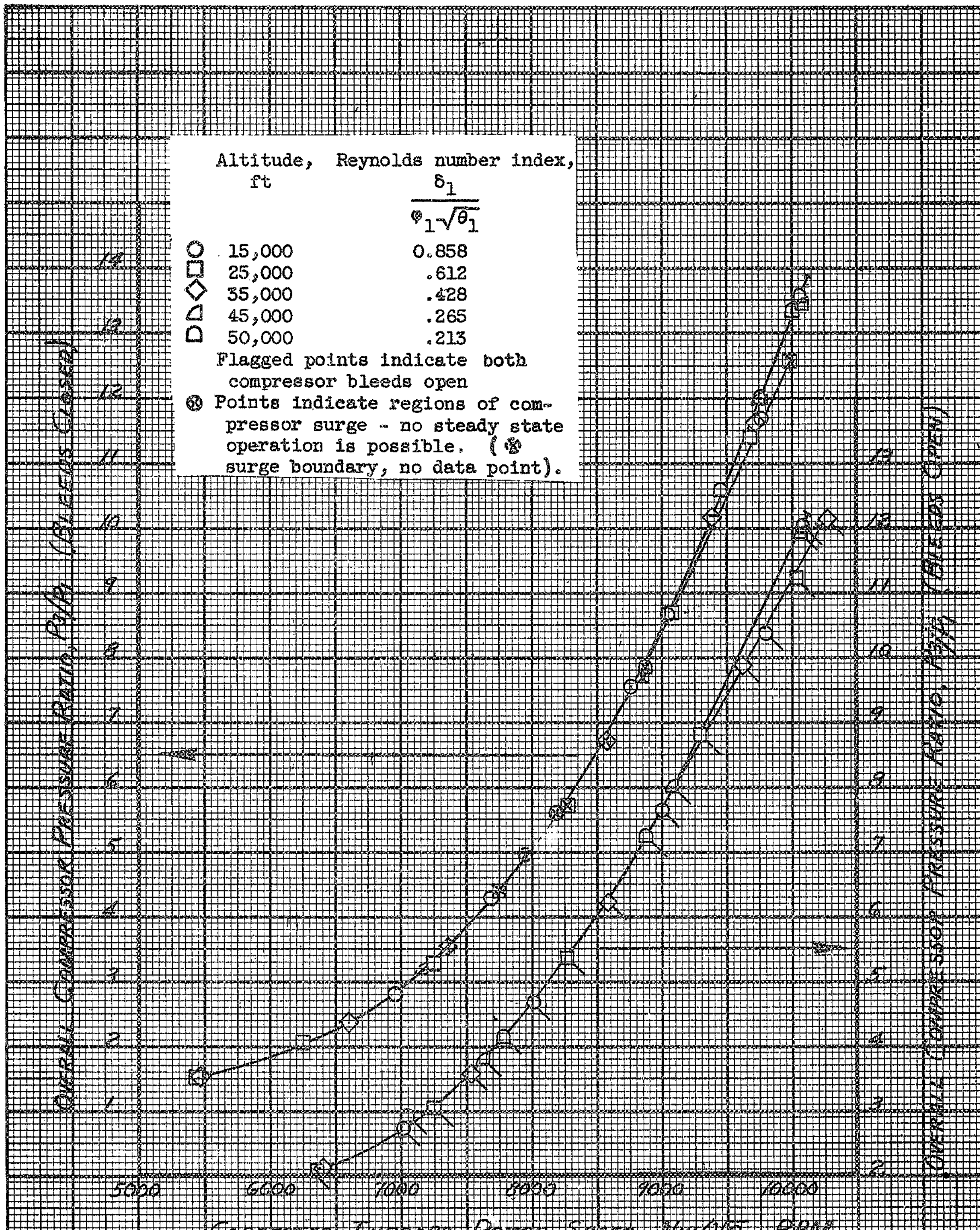

Figure 17. - The variation of over-all compressor pressure ratio with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

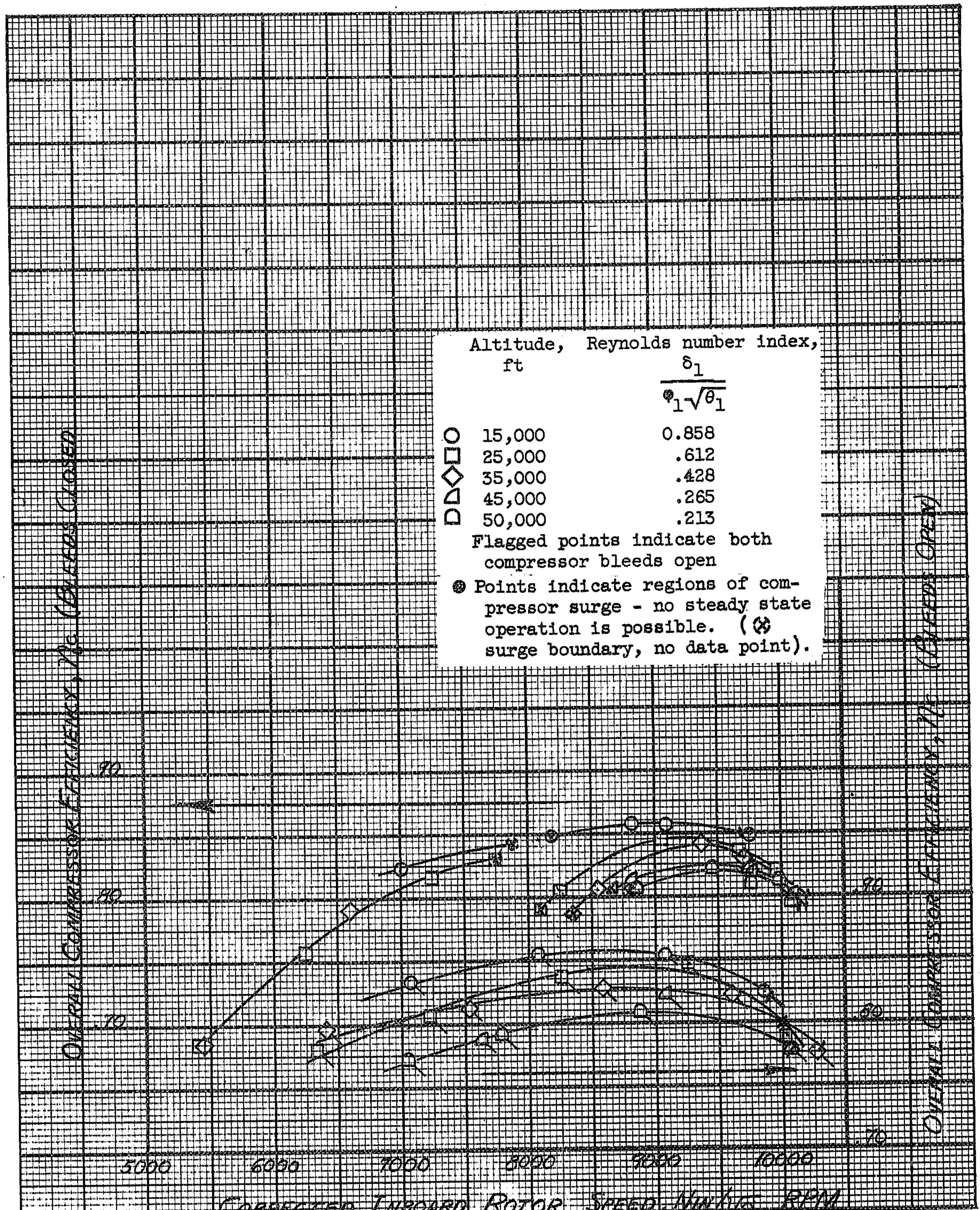

Figure 18. - The variation of over-all compressor efficiency with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

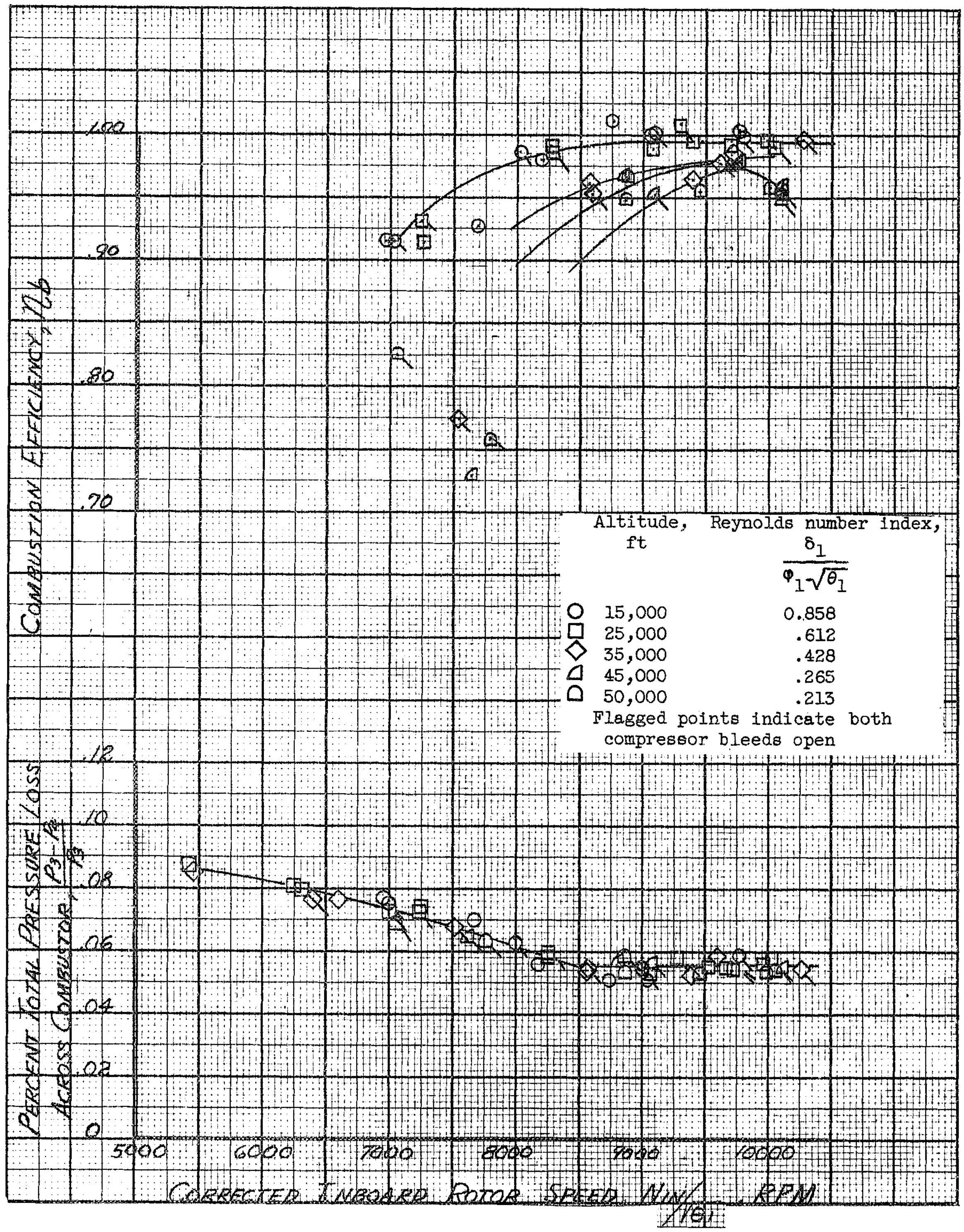

Figure 19. - The variation of combustion performance parameters with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

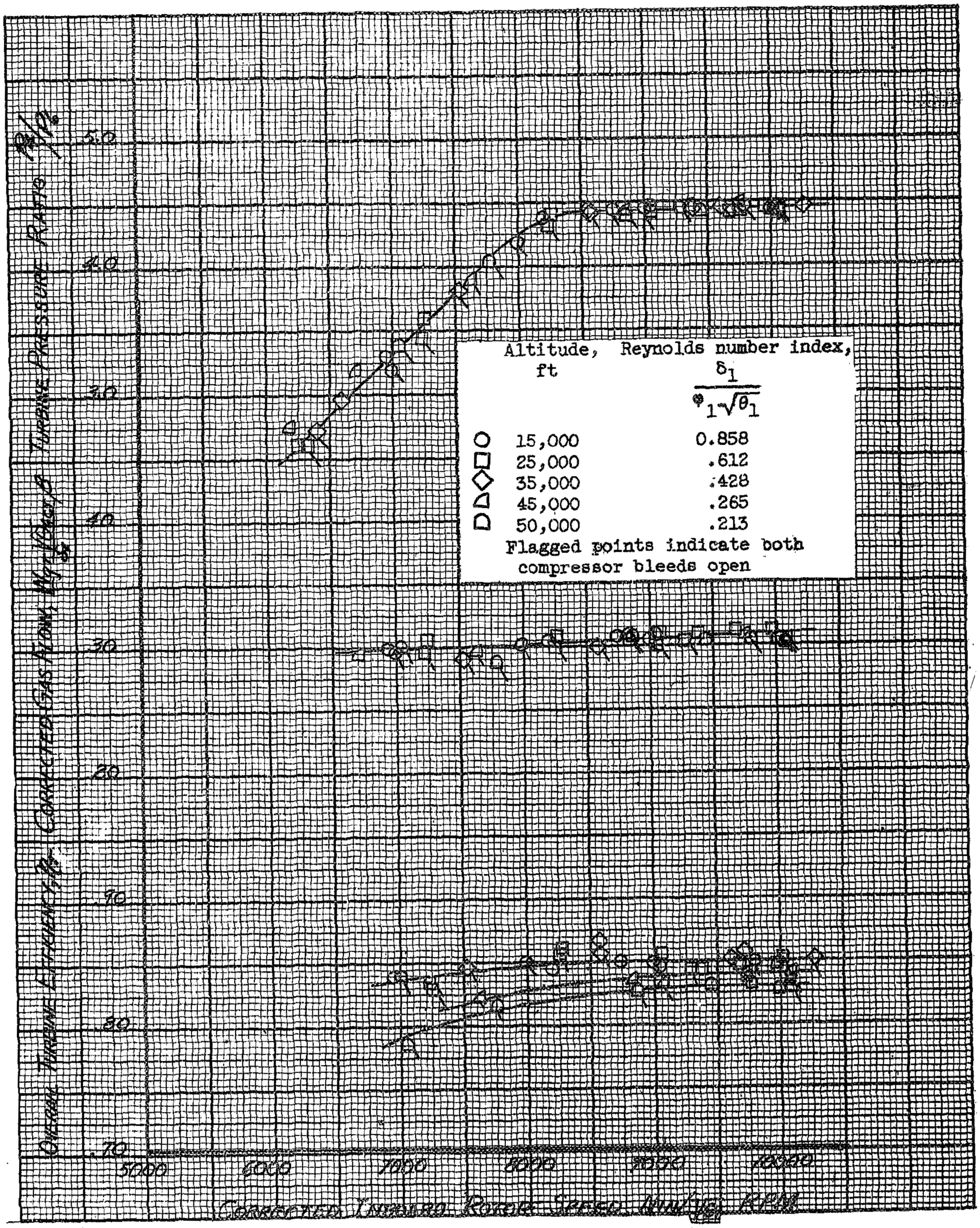

Figure 20. - The variation of turbine performance parameters with corrected inboard rotor speed over a range of Reynolds number indices. Flight Mach number 0.81.

PRELIMINARY ALTITUDE PERFORMANCE CHARACTERISTICS OF THE J57-P1

TURBOJET ENGINE WITH FIXED-AREA EXHAUST NOZZLE

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