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SPECIFICATION NUMBER 112
JANUARY 15, 1962

X353-5B PROPULSION SYSTEM SPECIFICATION

V/STOL

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL ELECTRIC

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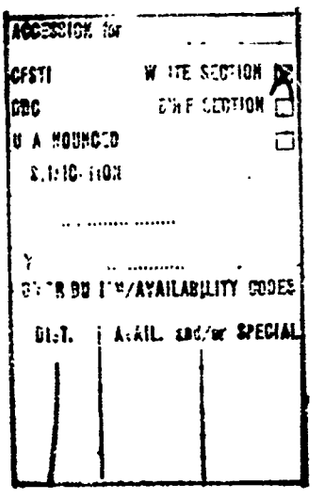
LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT DA44-177-TC-715



X353-5B

PROPULSION SYSTEM SPECIFICATION

Specification No. 112

January 15, 1962

APPROVAL STATUS: This specification was approved by U.S.Army TRECOM for use on this program with modifications incorporated on pages marked (1) as of _____, 1962.

GENERAL ELECTRIC COMPANY

FLIGHT PROPULSION LABORATORY DEPARTMENT

CINCINNATI, OHIO

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9 JUN 1966

Spec. No. 112

Date January 15, 1962

MODEL SPECIFICATION

CONVERTIBLE V/STOL LIFT FAN AIRCRAFT ENGINE
GENERAL ELECTRIC COMPANY
X353-5B

1. SCOPE

1.1 Scope: This specification covers the characteristics of the X353-5B convertible V/STOL propulsion system intended for use in a piloted flight research airplane.

1.2 Classification: The General Electric X353-5B Engine is a high lift-weight ratio convertible engine for turbojet operation and augmented lift operation. The basic X353-5B Engine comprises a turbojet engine modified for non-reheat operation, a tip-turbine lift fan augmenting turbojet thrust for V/STOL lift and propulsive thrusts, a gas diverter valve for selecting engine operating mode, and associated engine controls and accessories. The two part scroll on each lift fan permits incorporation of the X353-5B into an airplane powerplant configuration comprising two (2) basic X353-5B convertible engines pneumatically coupled such that each turbojet provides half of the required driving power for each of the lift fans. Rotors of the two lift fans rotate in opposite directions to minimize gyroscopic reactions. All performance figures, weights, quantities, etc., in this specification are given for one X353-5B (one turbojet engine, one fan, one diverter valve) unless specifically stated otherwise.

1.3 Basic Turbojet: The turbojet engine used in this specification is a Government furnished J85-GE-5 turbojet modified for non-reheat operation. Estimated conditions at turbine discharge at sea level static on an ARDC standard day at Military power when used in this system are:

$W_{g_{5.1}}$	44.1 pounds per second minimum
$T_{5.1}$	1236°F maximum
$P_{5.1}$	33.25 psia minimum

X353-5B performance given hereafter is based on the above conditions. Official performance test results will be corrected to this standard engine.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standards, drawings and publications with issue dates prior to June 1961 shall be used as a guide in the design of the propulsion system.

SPECIFICATIONS

Military

MIL-E-5007B Engines, Aircraft, Turbojet, General Specification for

PUBLICATIONS

Air Force-Navy Aeronautical Bulletin 343n dated 14 December 1960 entitled "Specifications and Standards Applicable to Aircraft Engines and Propellers, Use of."

3. REQUIREMENTS

3.3 Mock-Up: A full scale mock-up of an X353-5B system consisting of one (1) turbojet engine mock-up, one (1) lift fan mock-up, and one (1) diverter valve mock-up shall be prepared for installation in an airplane mock-up. The Mock-up components shall be for left-hand installation only.

3.4 Performance Characteristics: The ratings and curves shown are based on the terms and standard conditions defined in MIL-E-5007B as modified herein and on the use of a fuel having a lower heating value of 18400 BTU/lb and otherwise conforming to specification MIL-J-5161E and oil conforming to specification MIL-L-7808C-1.

These data indicate uninstalled performance of the powerplant under standard conditions without turbojet inlet losses, with no loading of accessory drives, no customer air being bled from the compressor discharge air bleed ports, no use of combustion gases for purging, 0.8 percent flow leakage at the diverter valves and a fixed area nozzle as shown on installation drawing 4012001-910 trimmed to produce rated temperature as shown in paragraph 3.4.4. Lift mode performance includes fan inlet losses in hover and cross flow consistent with an integral inlet configuration without a closure as shown in Drawing 4012001-911. In addition, an allowance has been made for airframe-supplied cross-duct losses at an average loss coefficient ($\bar{\omega}$) of 0.35, 10.6 percent of the diverter valve discharge gas flow being bled for pitch fan power during the lift mode and with the fan scroll nozzle areas trimmed to produce rated temperatures as shown in paragraph 3.4.4. No external effects such as reingestion or ground effect are included.

3.4.1 Fuel: The engine shall function satisfactorily throughout its complete operating range for any steady state and transient operating condition when using fuels conforming to and having any of the variations in characteristics permitted by MIL-J-5624D-JP-4.

3.4.1.1 Alternate Fuel: Not Applicable

3.4.1.2 Emergency Fuel: Not Applicable

3.4.3 Oil Consumption: The oil consumption shall not exceed the following:

0.40 lb/hr at normal rated speed

0.40 lb/hr at military rated speed

3.4.4 Ratings: The performance ratings shall be as listed in Tables I and II.

TABLE I

X353-5B PERFORMANCE RATINGS IN LIFT MODE AT STANDARD SEA LEVEL STATIC CONDITIONS
(Performance Given for One X353-5B System Except as Noted)

Ratings (Turbojet Power Setting)	Unvectored Louver Performance: Lift Thrust Pounds (Min.)	Fan Rotor rpm (Max.)	Turbojet Rotor rpm (Max.)	Fuel Flow lb/hr. (Max.)	Measured Gas Temp. °F (Max.)	Nominal Bleed Gas Flow lbs/sec.	Vectored Louver Performance ($\beta_s = 0^\circ$): Net Horizontal Thrust $\beta_v = 20^\circ$	Net Horizontal Thrust $\beta_v = 40^\circ$	Net Vertical Lift $\beta_v = 20^\circ$	Net Vertical Lift $\beta_v = 40^\circ$
Military	6570	2602***	16,500	2679	1236 **	4.64	2189	3681	6013	4387
Military, Single Engine*	3915	2020	16,500	2679	1236	4.64	-	-	-	-
95%	5172	2304	15,675	2111	-	4.26	1720	2882	4726	3434
90%	3237	1817	14,850	1466	-	3.58	1081	1843	2970	2197
85%	2273	1521	14,025	1156	-	3.08	-	-	-	-

Notes:
* "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out condition in a two-engine cross-ducted installation. Fuel flow is given for the one operating turbojet.

** Exhaust gas temperature setting selected to provide optimum performance at 2500 feet altitude on ANA 421 standard hot day with same fixed nozzle area.

*** 100% Fan speed is 2640 rpm. Corresponding estimated lift is 6844 lbs. and estimated bleed gas flow is 1.75 lbs/sec.

TABLE II

X353-5B PERFORMANCE RATINGS IN TURBOJET MODE
AT STANDARD SEA LEVEL STATIC CONDITIONS

Ratings	Thrust Pounds (Min.)	Turbojet Rotor rpm (Max.)	Fuel Flow lb/hr. (Max.)	Measured Gas Temp. °F (Max.)	Turbojet Airflow lbs/sec. ± 3%	SFC
Military	2658 2750	16,500	2679	1236*	43.7	1.08 ..
95%	2115 2235	15,675	2082	-	40.5	.955 ..
90%	1401 1454	14,850	1451	-	35.9	1.037 ..
75%	591	12,375	789	-	26.6	
Idle	153	7,425	499	-	-	

Note: * Exhaust gas temperature setting selected to match lift-mode operation at same conditions.

3.4.5 Estimates: Estimated performance and curves, shown in Tables III and IV and in Figures 1 to 26 inclusive, constitute part of this specification.

3.4.5.1.2 Performance Correction Curves: Data for correcting the estimated performance outlined in paragraph 3.4.5 are presented in Tables V and VI and Figures 27 through 36 (see paragraph 6.2.2.1 for symbols). This data is for use in correcting performance by the method outlined in paragraph 3.4.5.1.3.

Use of the Correction Factors beyond the specified range is not recommended. Since all corrections are made through a multiplication, the sequence of use is secondary. However, the use of a large number of corrections with large changes from the nominal is not recommended. The corrections are not true partial derivatives and the effect of one on any other is not truly represented at large changes from the normal.

TABLE III

X353-5B ESTIMATED STATIC PERFORMANCE IN LIFT MODE AT 2500 FT. ALTITUDE ANA 421 STANDARD DAY HOT
(Performance Given for One X353-5B System Except as Noted)

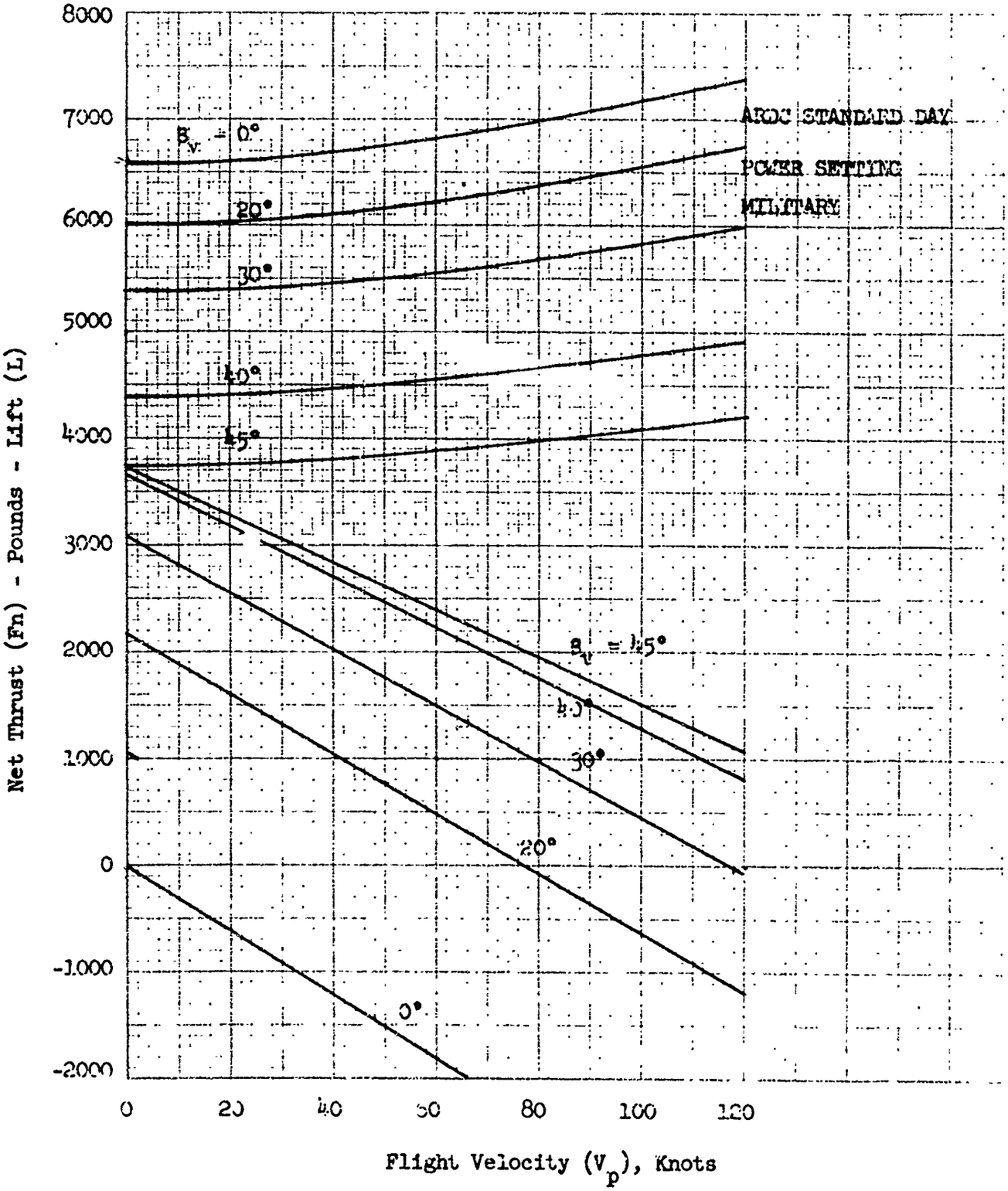
Ratings (Turbojet Power Setting)	Unvectored Louver Performance					Vectored Louver Performance ($\beta_s = 0^\circ$)			
	Lift Thrust Pounds (Min.)	Fan Rotor rpm (Max.)	Turbojet Rotor rpm (Max.)	Fuel Flow lb/hr. (Max.)	Measured Gas Temp. °F (Max.)	Nominal Bleed Gas Flow lbs/sec.	Net Horizontal Thrust $\beta_v = 20^\circ$	Net Horizontal Thrust $\beta_v = 40^\circ$	Net Vertical Lift $\beta_v = 20^\circ$	Net Vertical Lift $\beta_v = 40^\circ$
Military	5282 5375	2510**	16,500	2239 2240	1250	3.93	1758	2946	4829	3511
Military, Single Engine*	3130	1944	16,500	2239	1250	3.93	-	-	-	-
95%	3639 3840	2077	15,675	1622 1682	-	3.43	1209	2046	3324	2438
90%	2435 2570	1696	14,850	1218	-	2.92	815	1397	2237	815
85%	1783	1451	14,025	1017	-	2.53	-	-	-	-

Note: * "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out condition in a two-engine cross-ducted installation. Fuel flow is given for the one operating turbojet.
** Maximum fan speed at zero bleed flow is 2561 rpm. Corresponding estimated lift is 5611 lbs.

TABLE IV

X353-5B ESTIMATED PERFORMANCE IN TURBOJET MODE
STATIC, 2500 FT. ALTITUDE, ANA 421 STANDARD HOT DAY

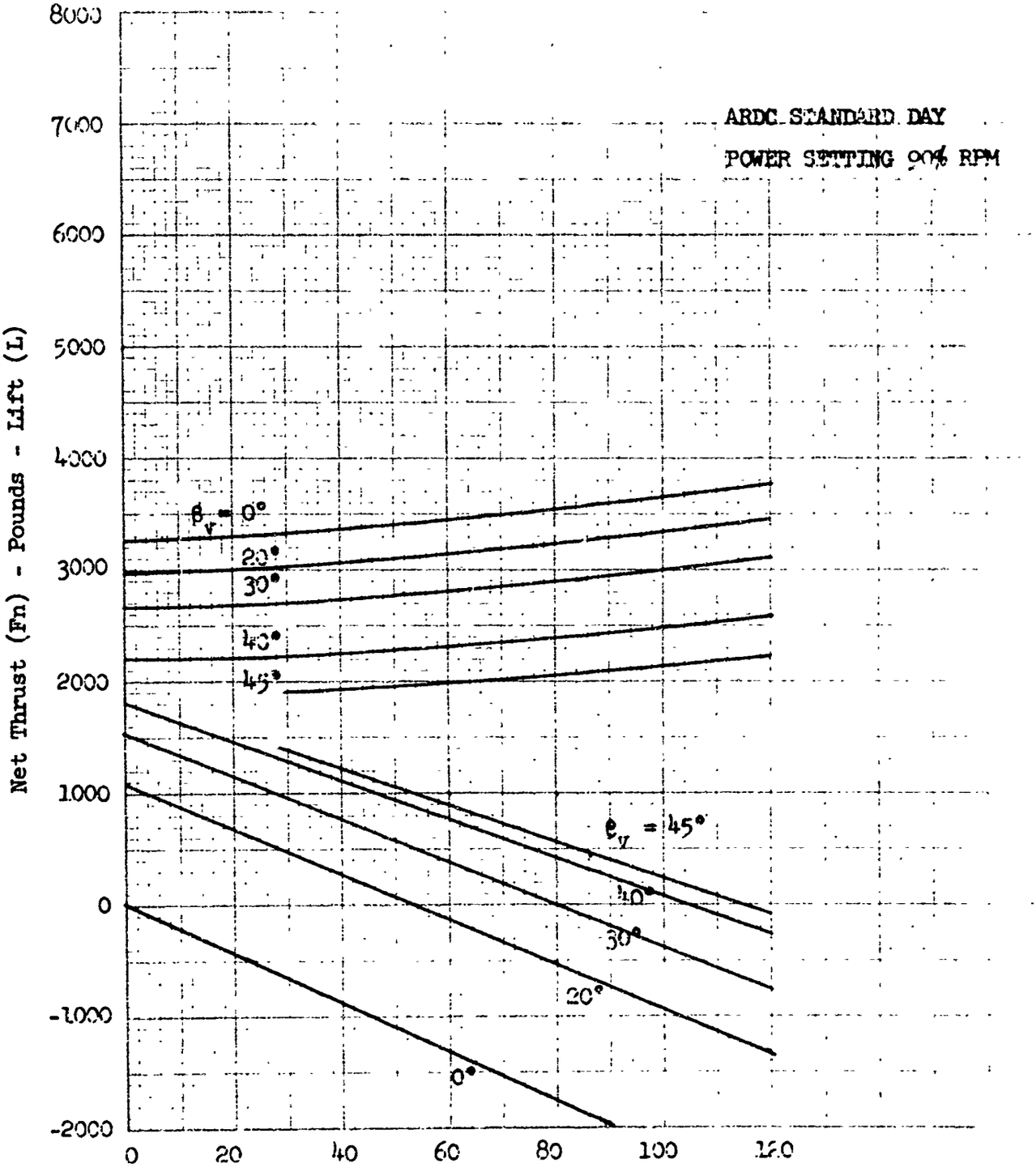
Ratings	Net Thrust Pounds (Min.)	Turbojet Rotor rpm (Max.)	Fuel Flow lb/hr. (Max.)	Measured Gas Temp. °F (Max.)	Turbojet Airflow lbs/sec. ± 3%
Military	2188	16,500	2258	1250	37.3
95%	1565	15,675	1609	1041	33.7
90%	1064	14,850	1196	930	29.9
75%	483	12,375	709	807	22.4



X353-5B ESTIMATED FLIGHT PERFORMANCE

LIFT MODE - SEA LEVEL

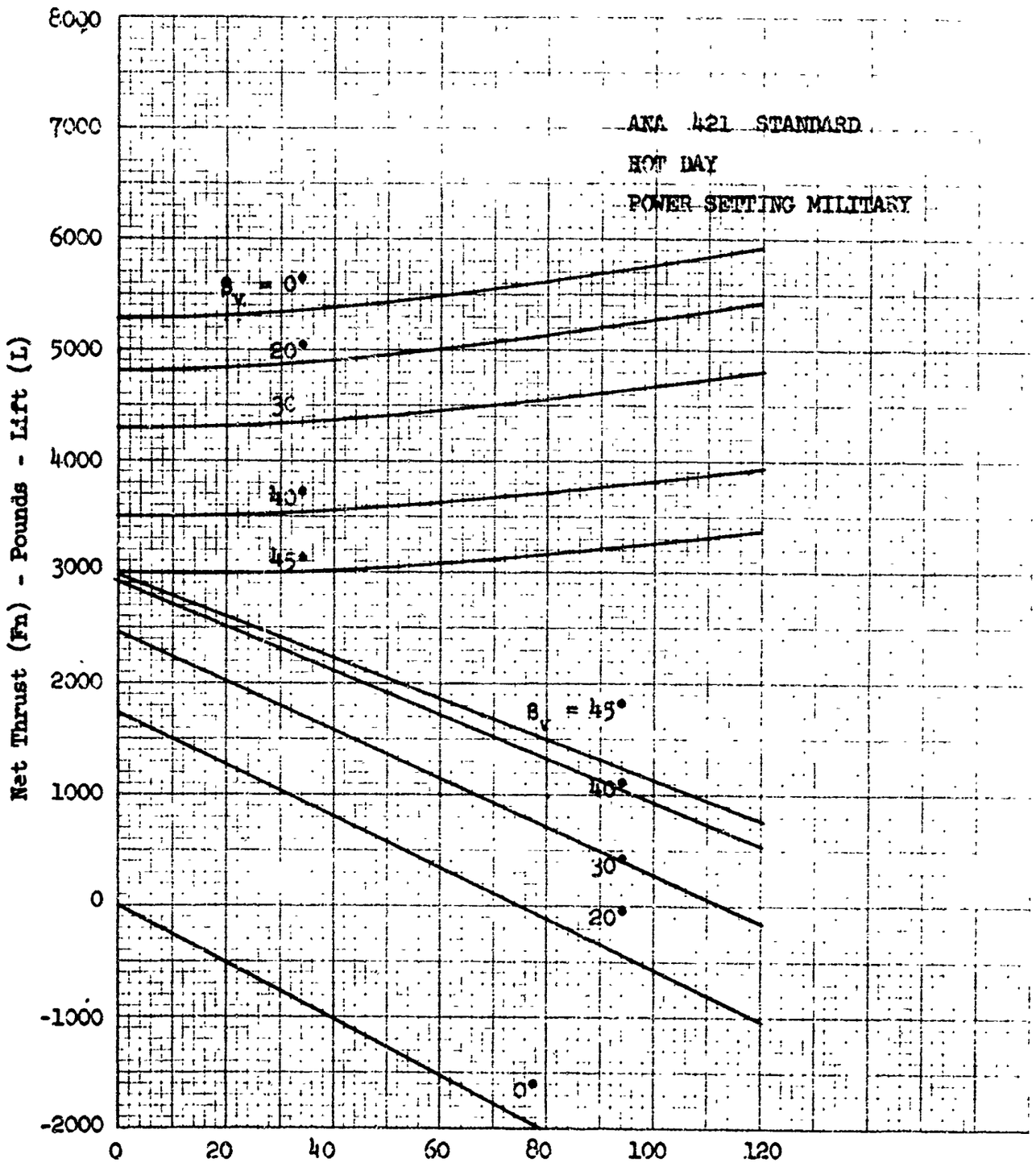
Figure 1



X353-5B ESTIMATED FLIGHT PERFORMANCE

LIFT MODE - SEA LEVEL

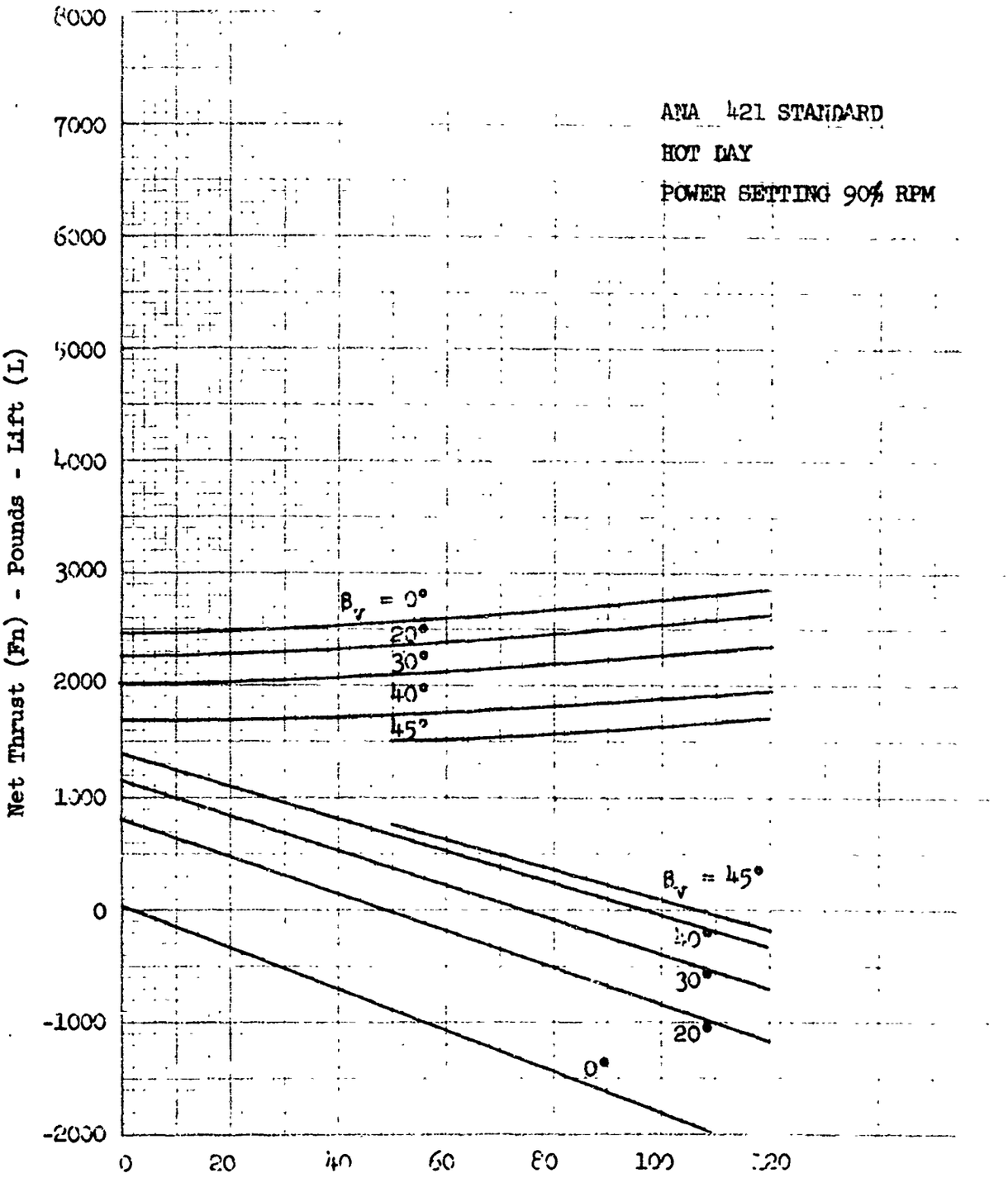
Figure 2



X353-5B ESTIMATED FLIGHT PERFORMANCE

LIFT MODE - 2500 FT. ALTITUDE

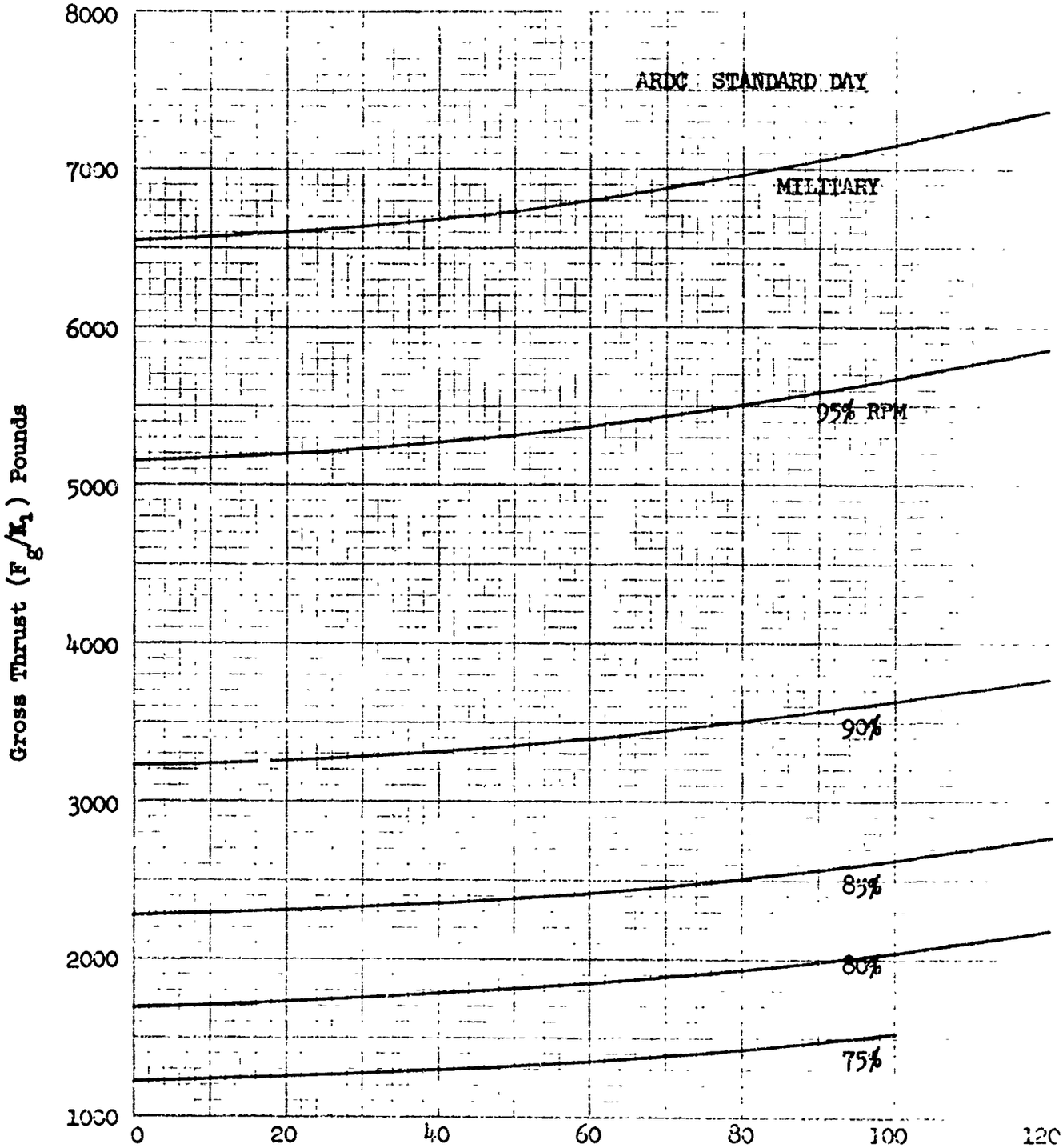
Figure 3



X353-5B ESTIMATED FLIGHT PERFORMANCE

LIFT MODE - 2500 FT. ALTITUDE

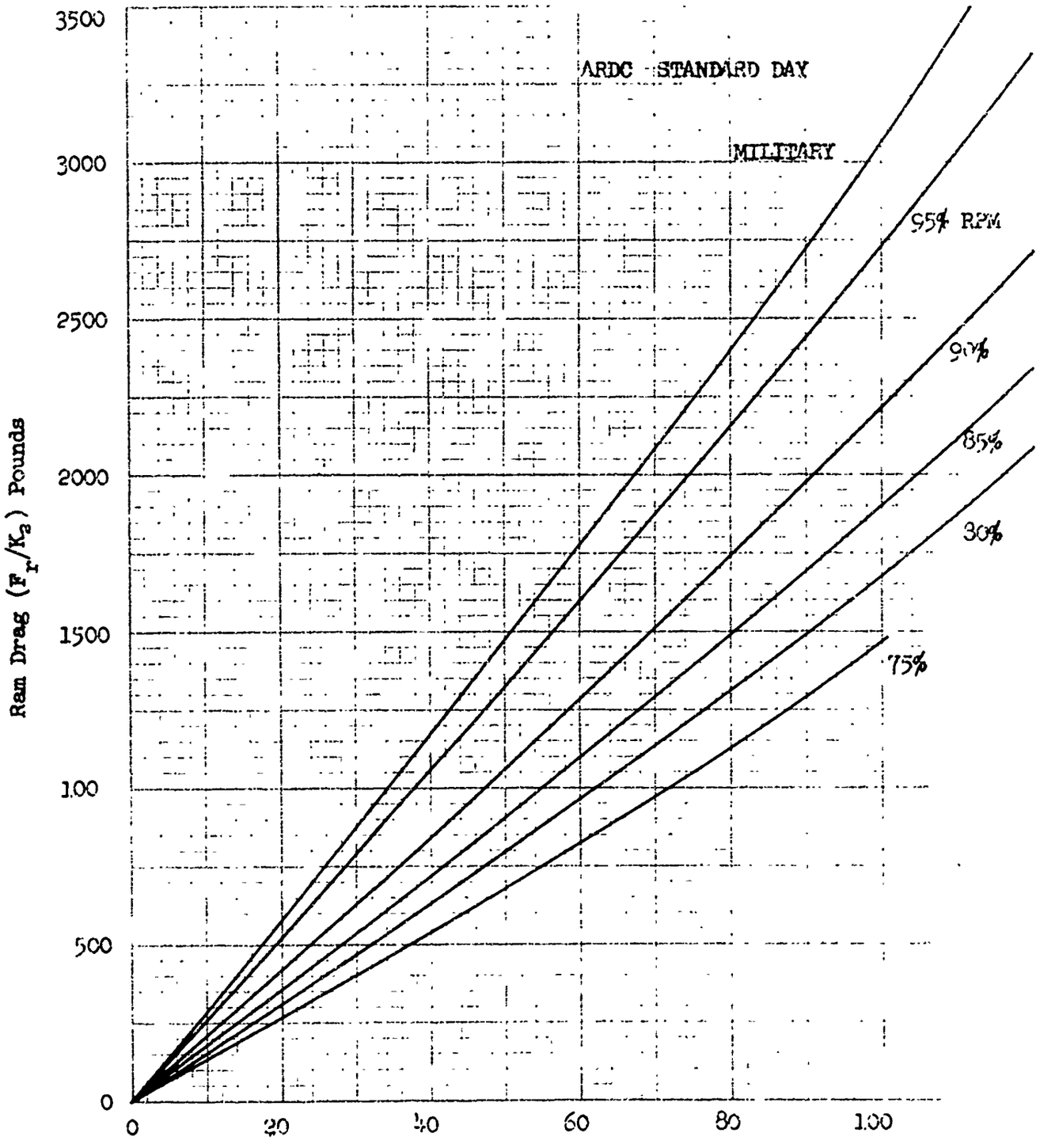
Figure 4



GROSS THRUST vs FLIGHT VELOCITY

LIFT MODE - SEA LEVEL

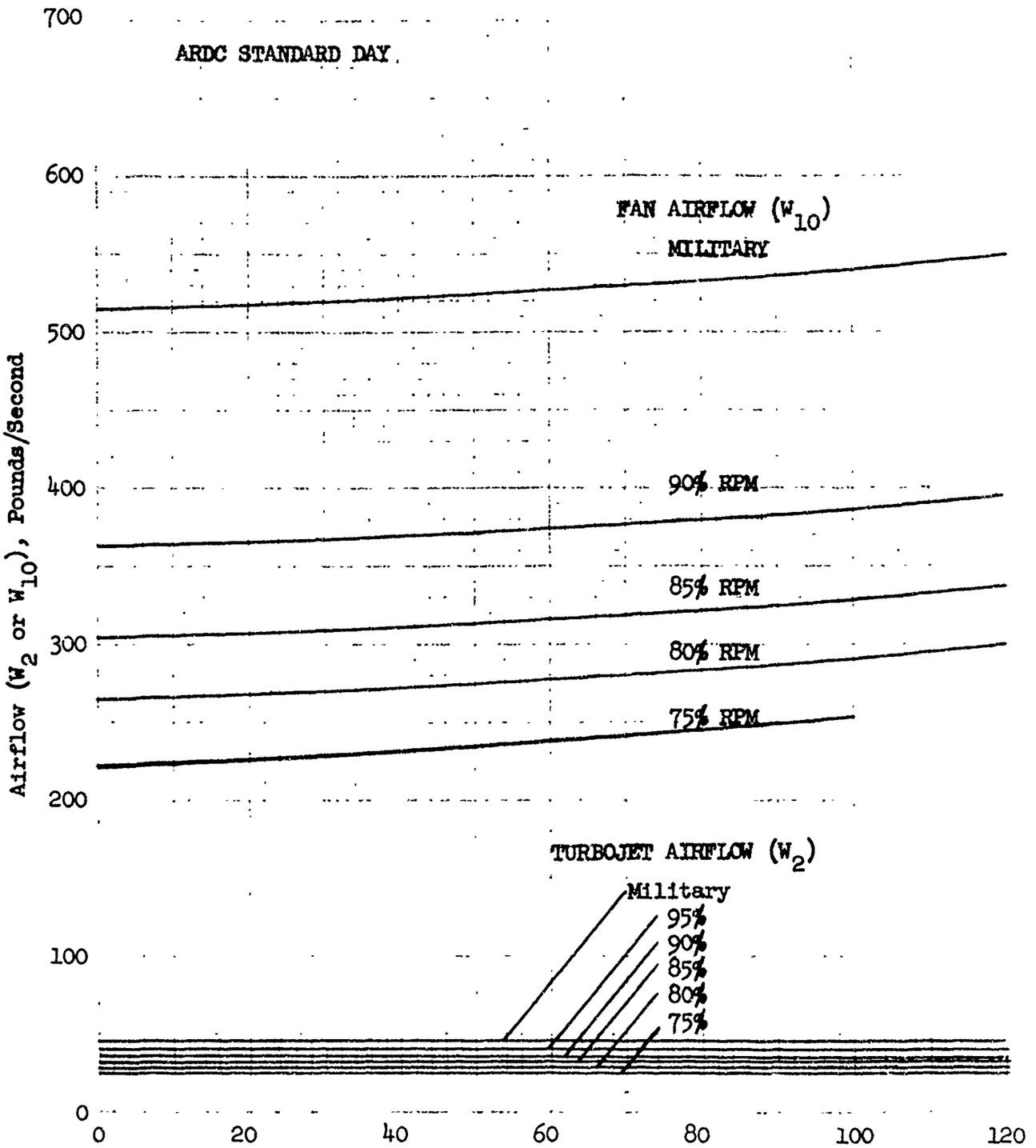
Figure 5



RAM DRAG vs FLIGHT VELOCITY

LIFT MODE - SEA LEVEL

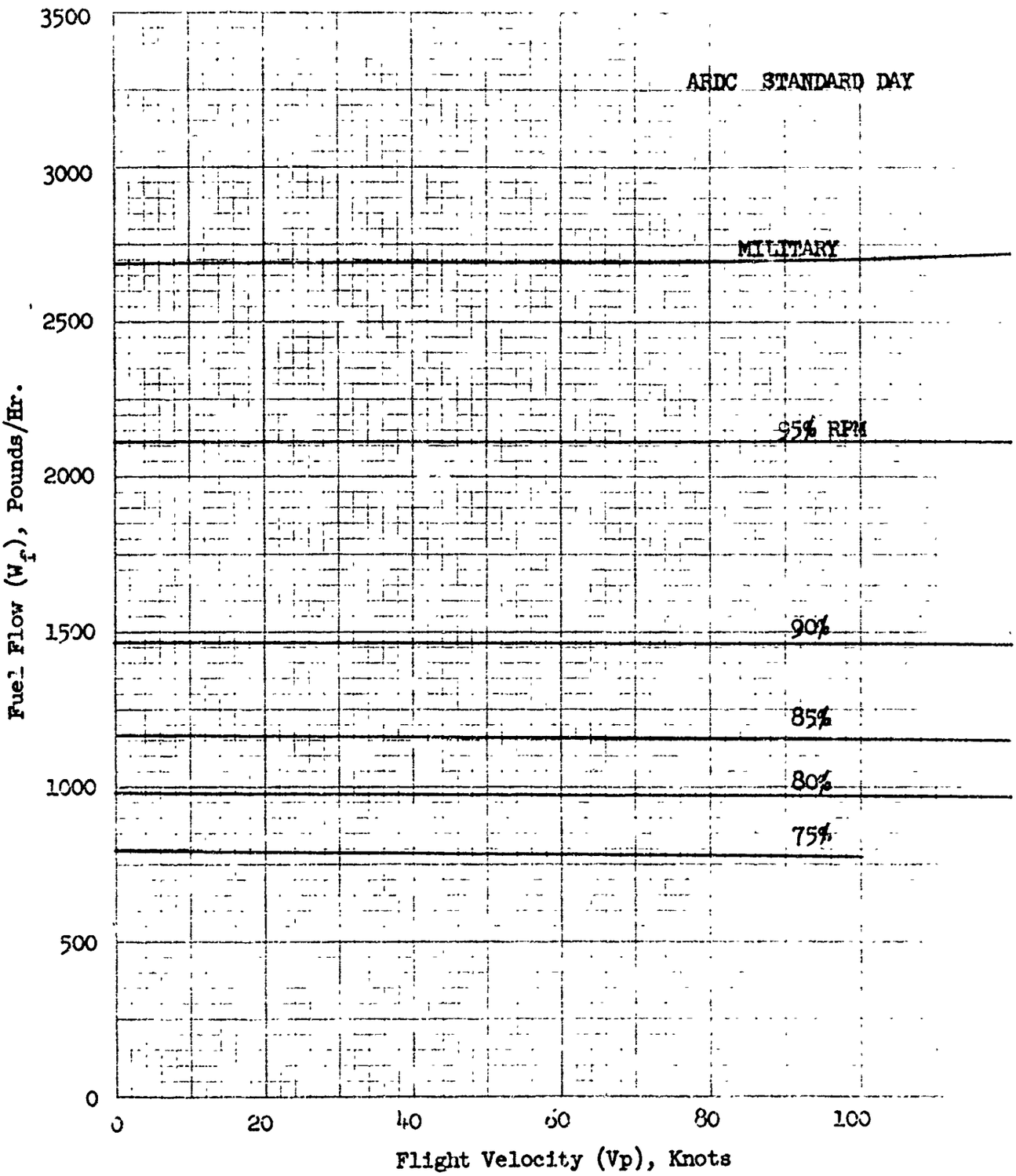
Figure 6



AIRFLOW vs FLIGHT VELOCITY

LIFT MODE - SEA LEVEL

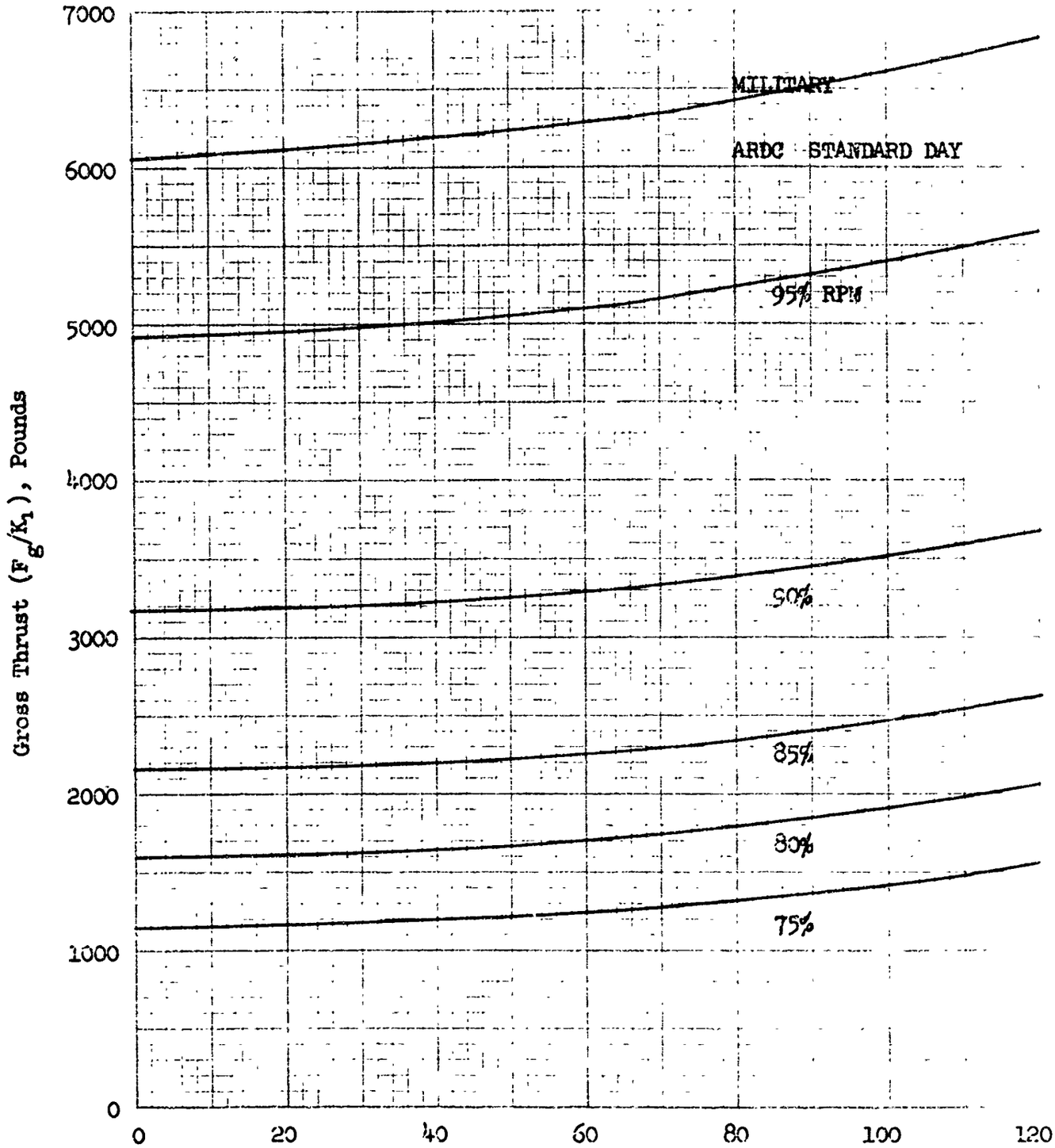
Figure 6 a



FUEL FLOW vs FLIGHT VELOCITY

LIFT MODE - SEA LEVEL

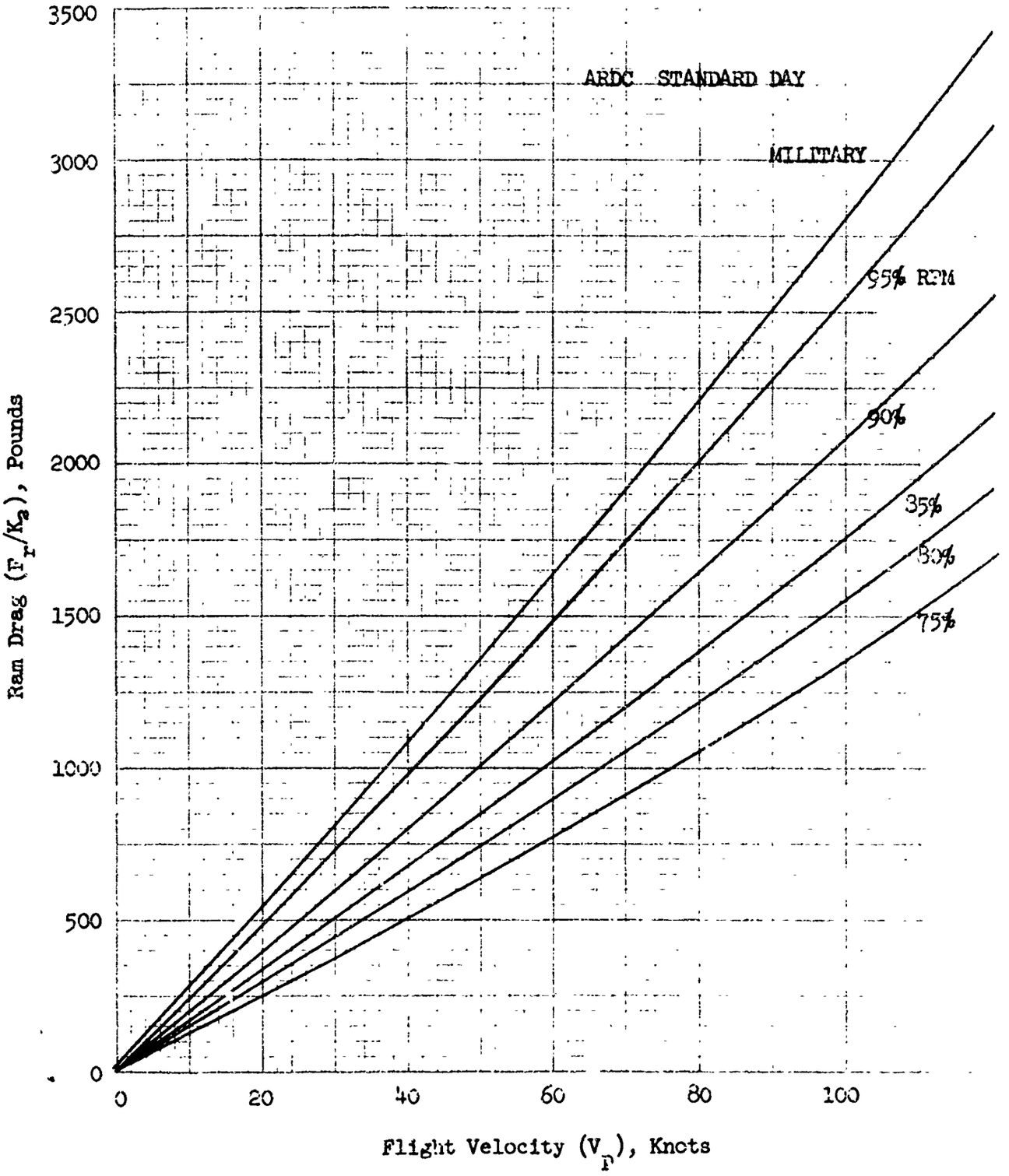
Figure 7



GROSS THRUST vs FLIGHT VELOCITY

LIFT MODE - 3000 FT. ALTITUDE

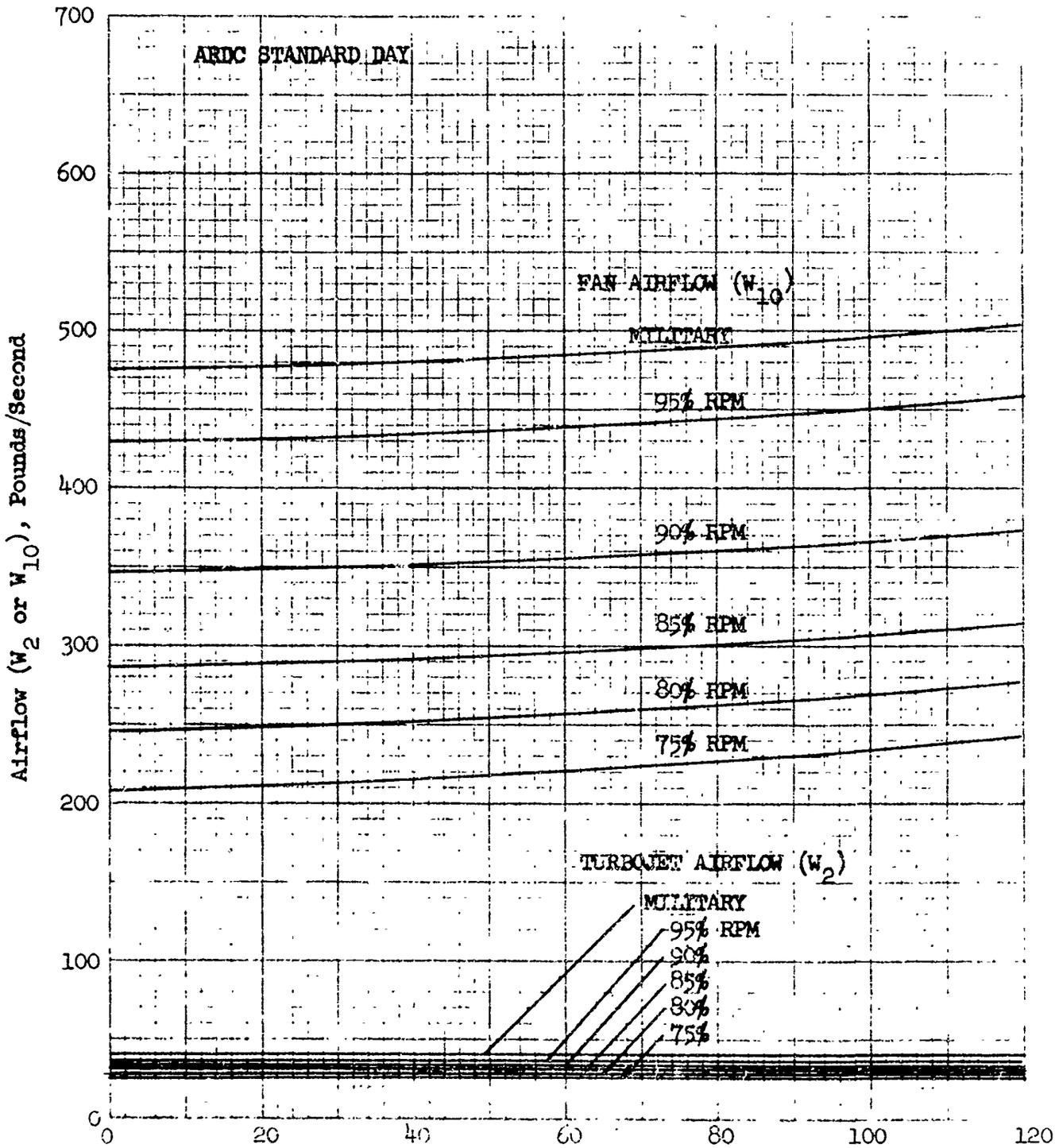
Figure 8



RAM DRAG vs FLIGHT VELOCITY

LIFT MODE - 3000 FT. ALTITUDE

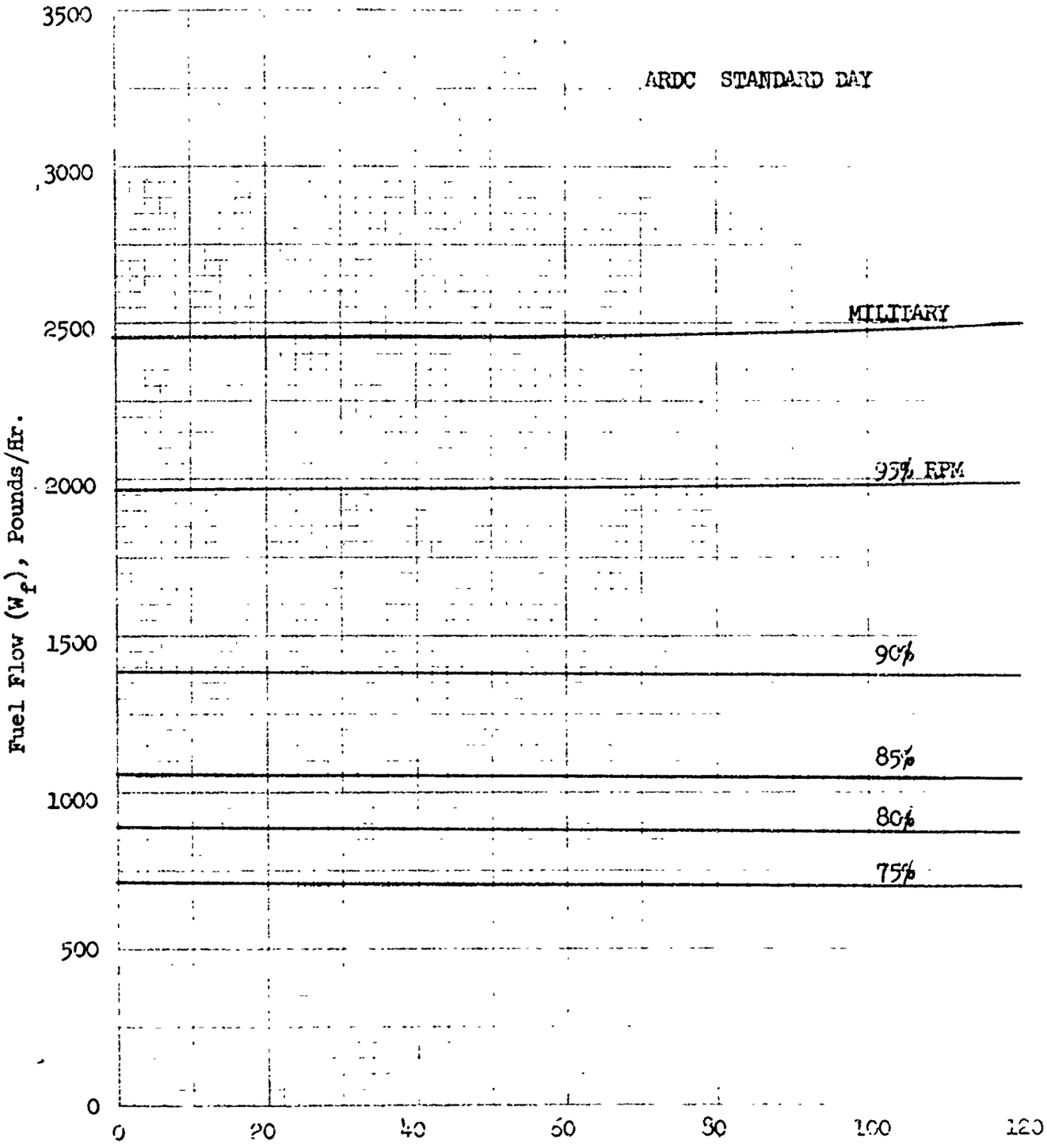
Figure 9



AIRFLOW vs FLIGHT VELOCITY

LIFT MODE - 3000 FT ALTITUDE

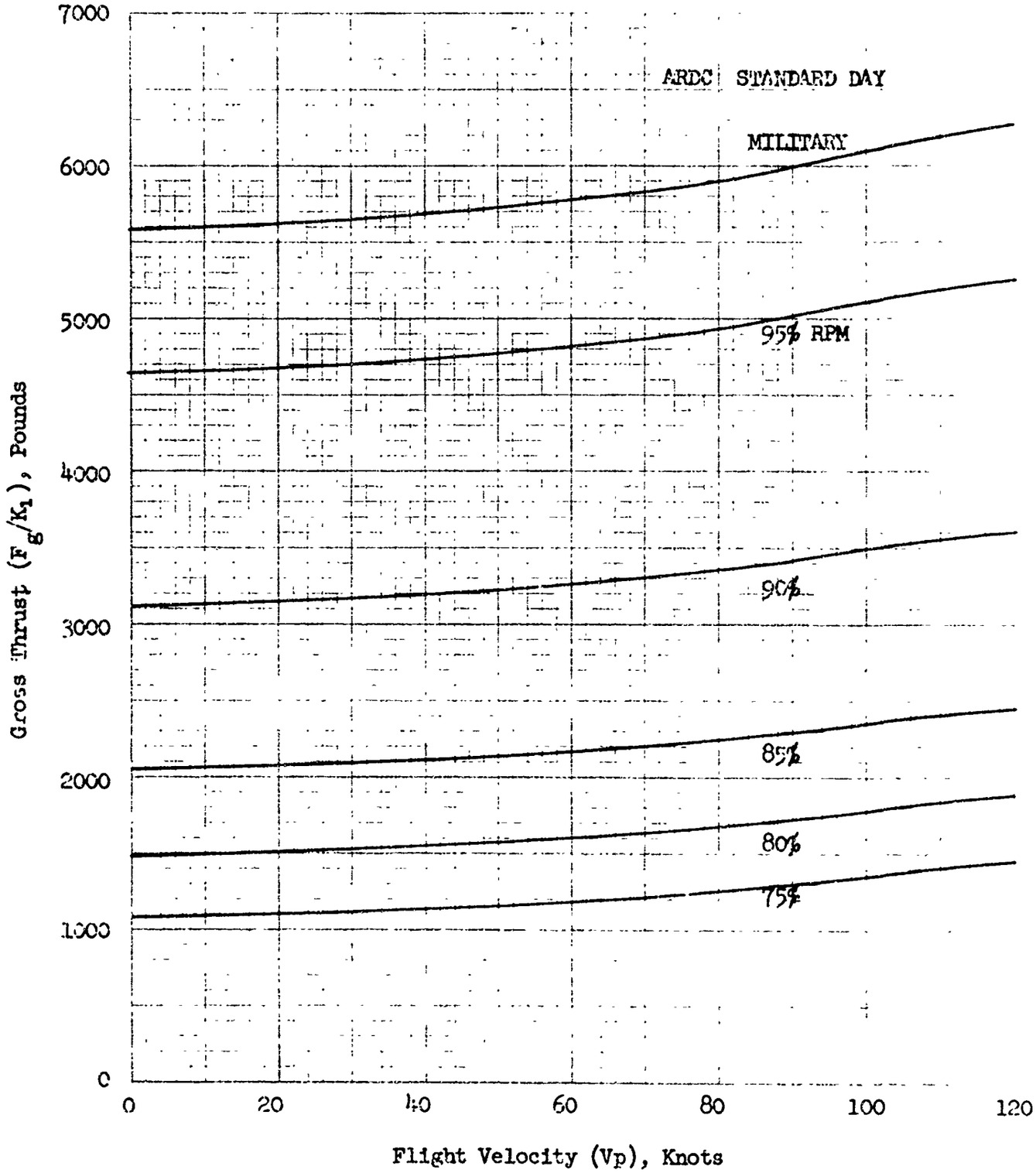
Figure 9 a



FUEL FLOW vs FLIGHT VELOCITY

LIFT MODE - 3000 FT. ALTITUDE

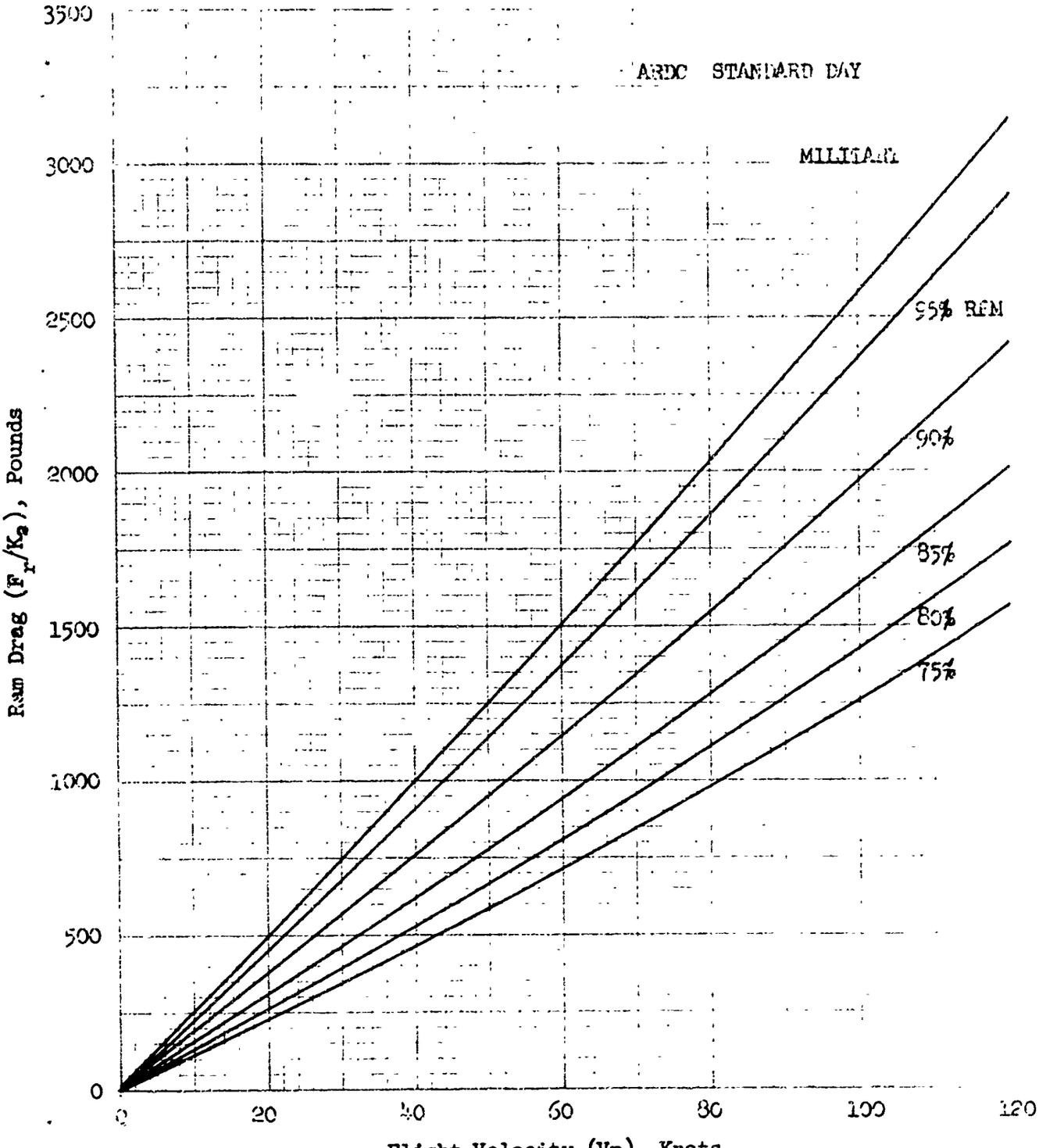
Figure 10



GROSS THRUST vs FLIGHT VELOCITY

LIFT MODE - 6000 FT. ALTITUDE

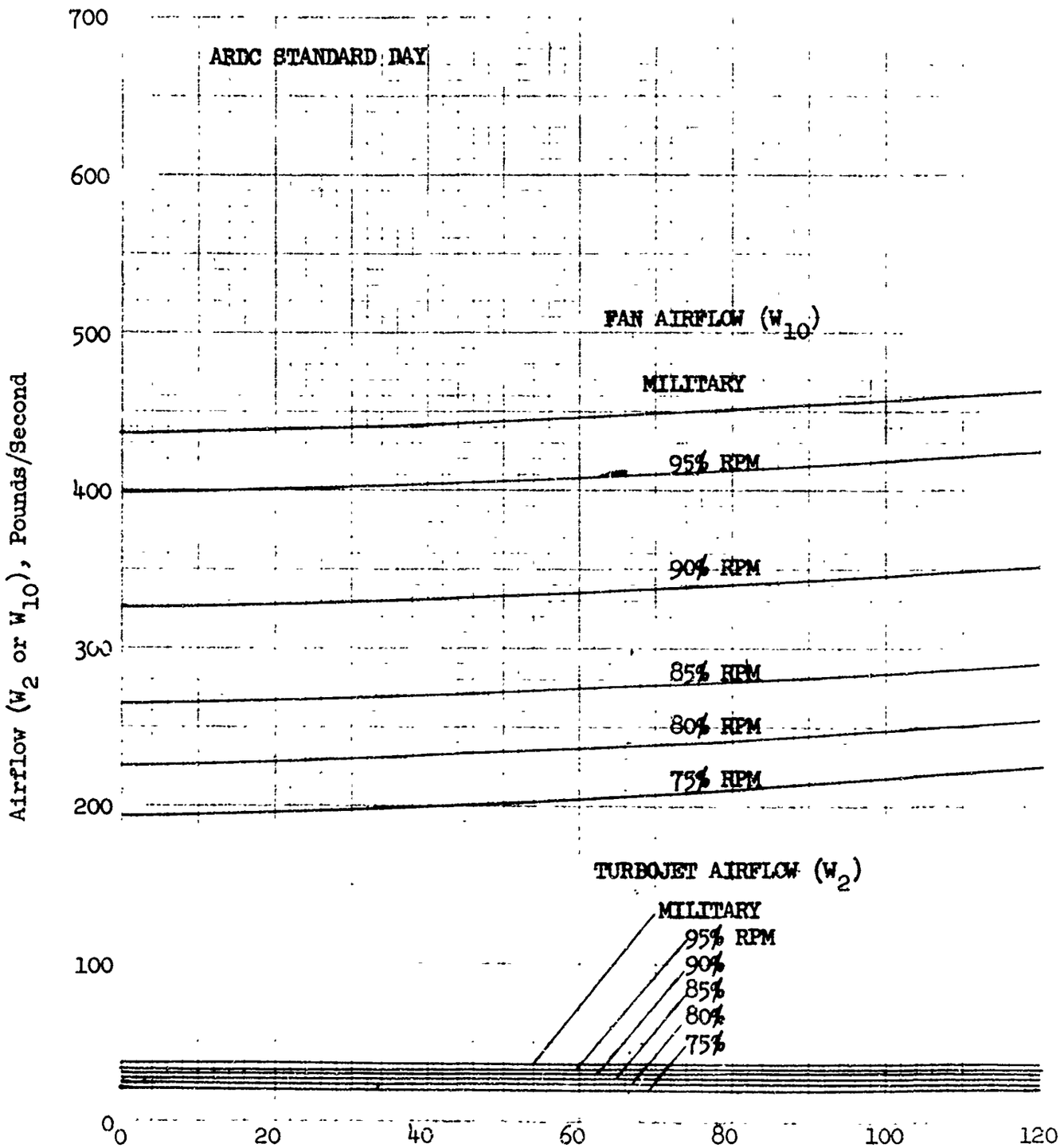
Figure 11



RAM DRAG vs FLIGHT VELOCITY

LIFT MODE - 6000 FT. ALTITUDE

Figure 12

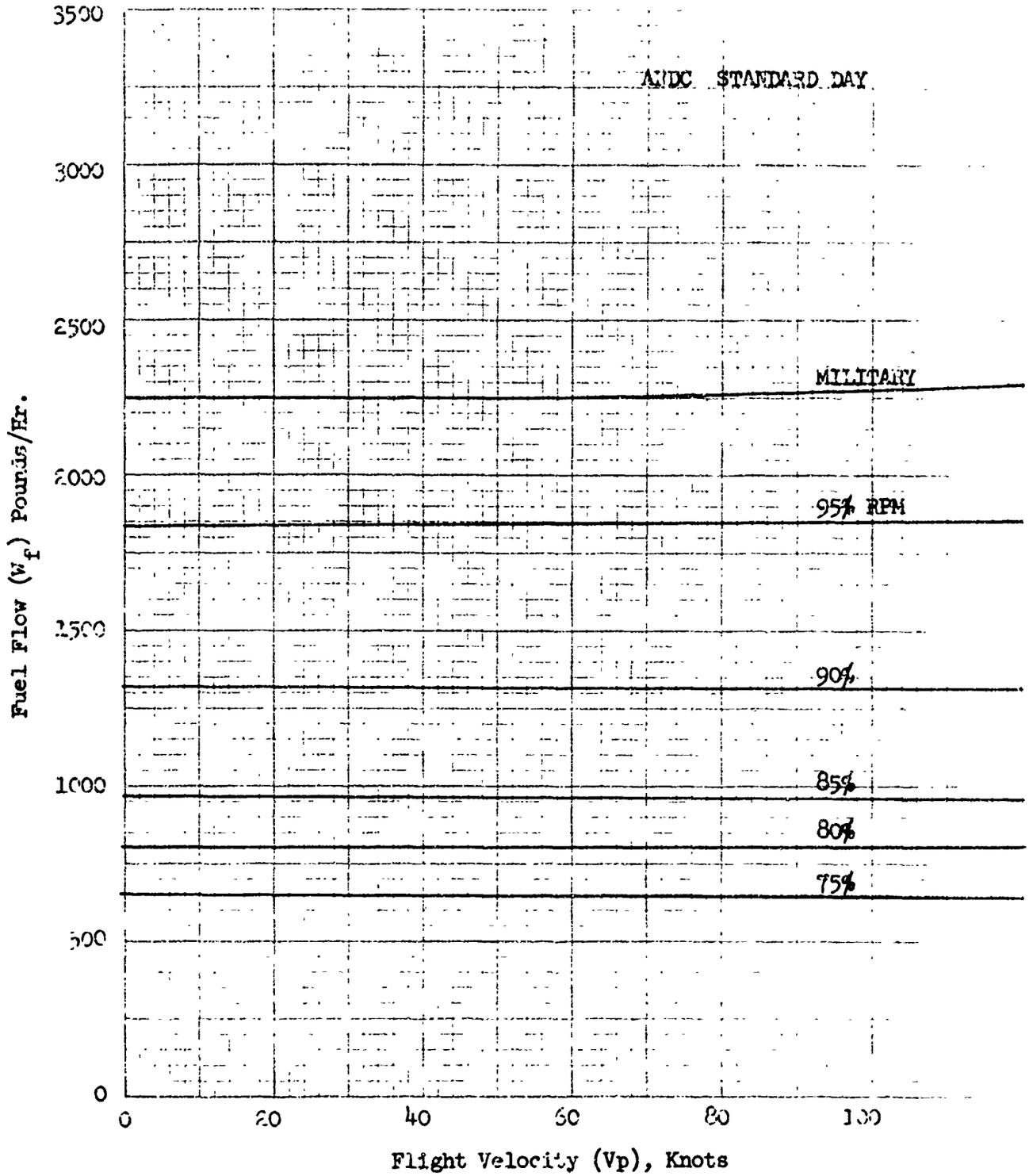


AIRFLOW vs FLIGHT VELOCITY

LIFT MODE - 6000 FT. ALTITUDE

Figure 12 a

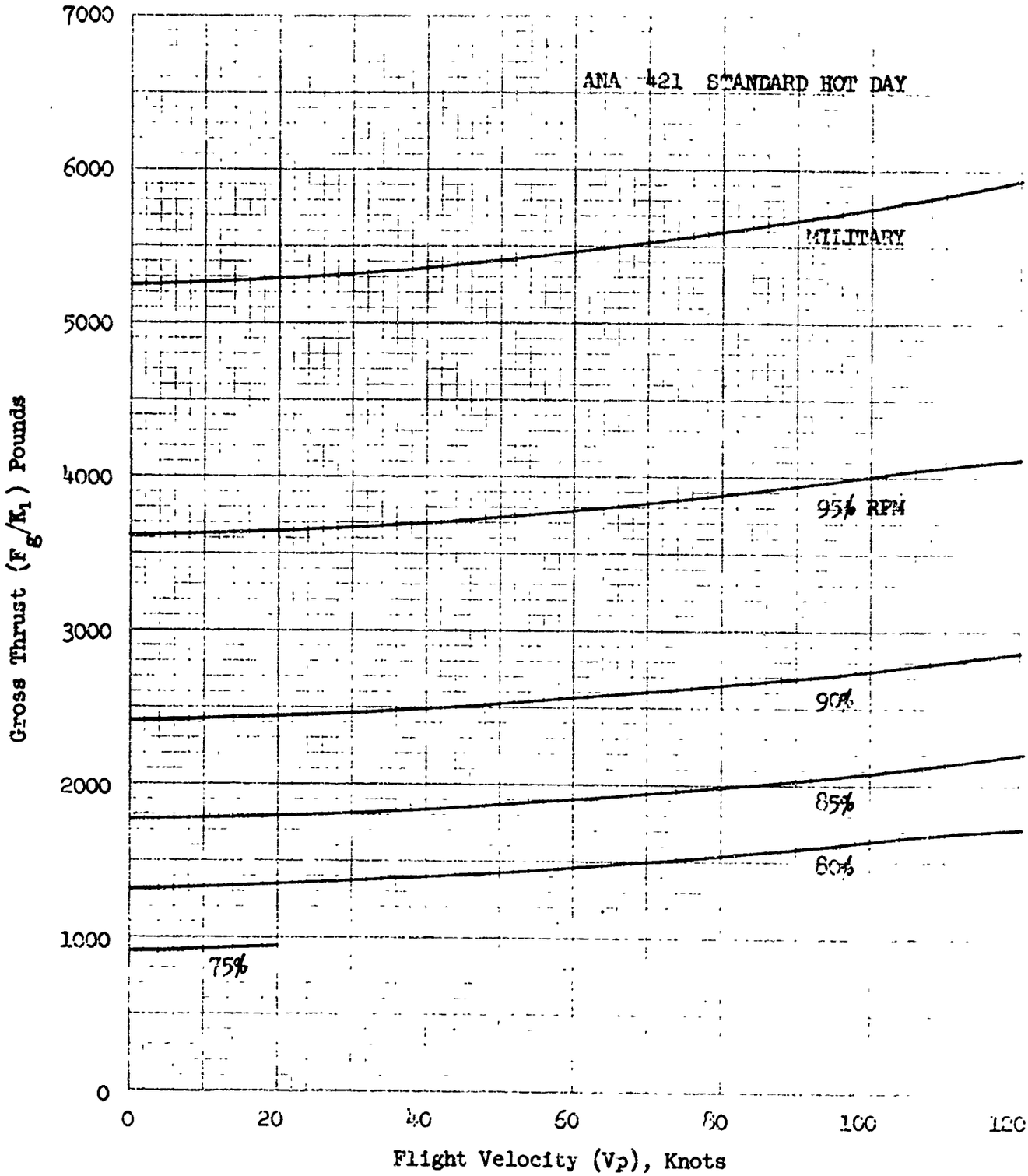
1



FUEL FLOW vs FLIGHT VELOCITY

LIFT MODE - 6000 FT. ALTITUDE

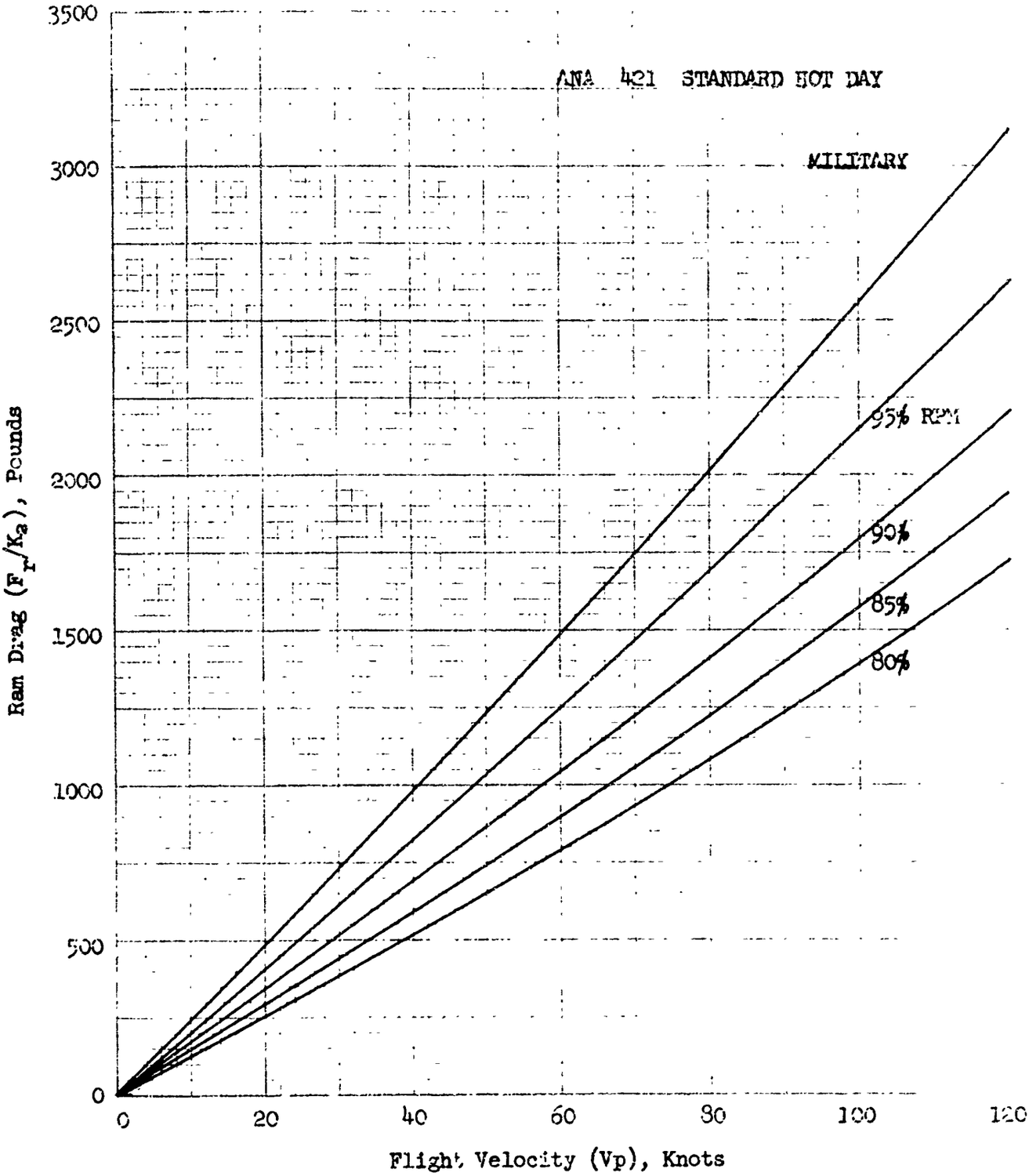
Figure 13



GROSS THRUST vs FLIGHT VELOCITY

LIFT MODE - 2500 FT. ALTITUDE

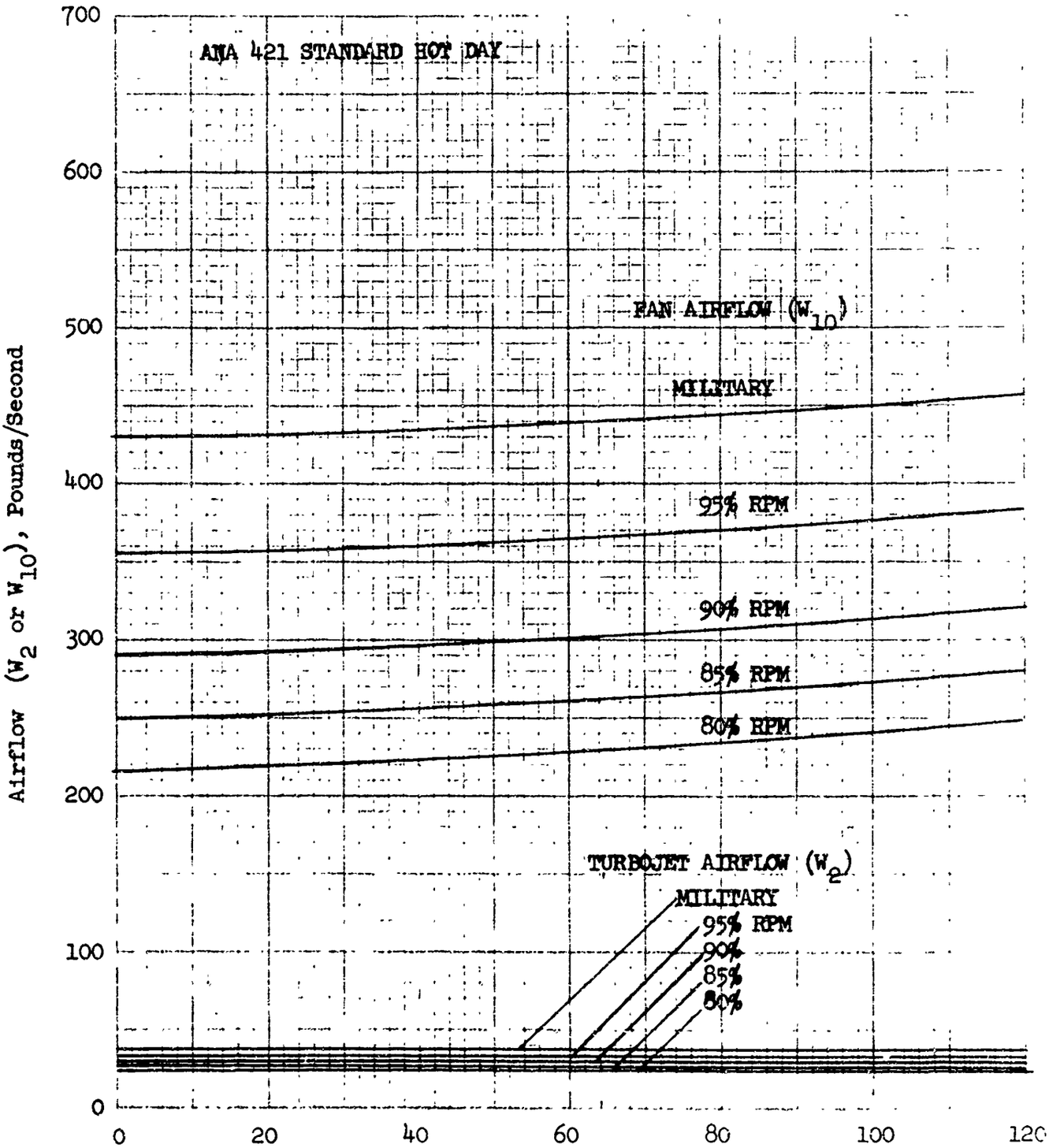
Figure 14



RAM DRAG vs FLIGHT VELOCITY

LIFT MODE - 2500 FT. ALTITUDE

Figure 15

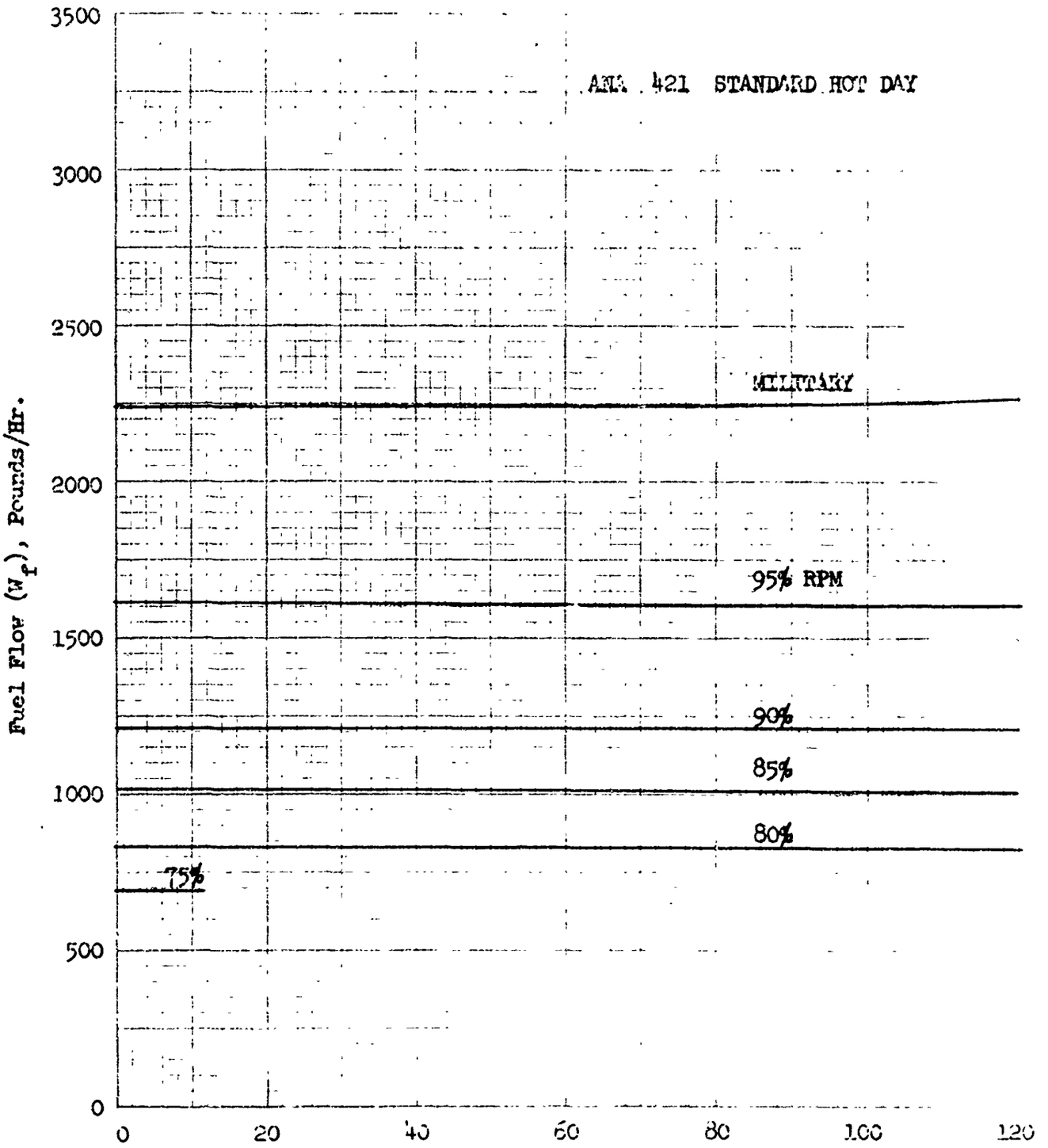


Flight Velocity (V_p), Knots

AIRFLOW vs FLIGHT VELOCITY

LIFT MODE - 2500 FT. ALTITUDE

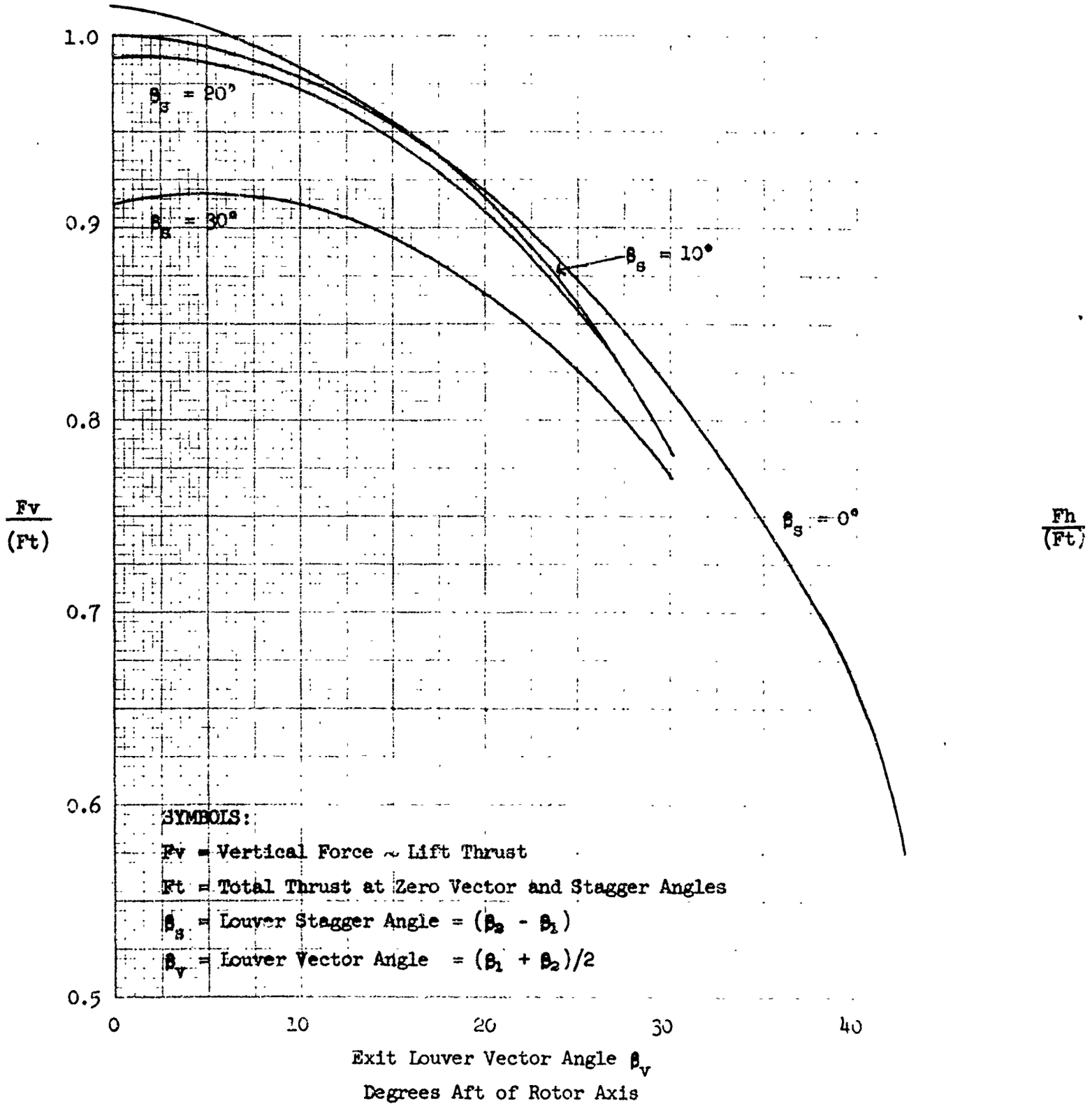
Figure 15 a



FUEL FLOW vs FLIGHT VELOCITY

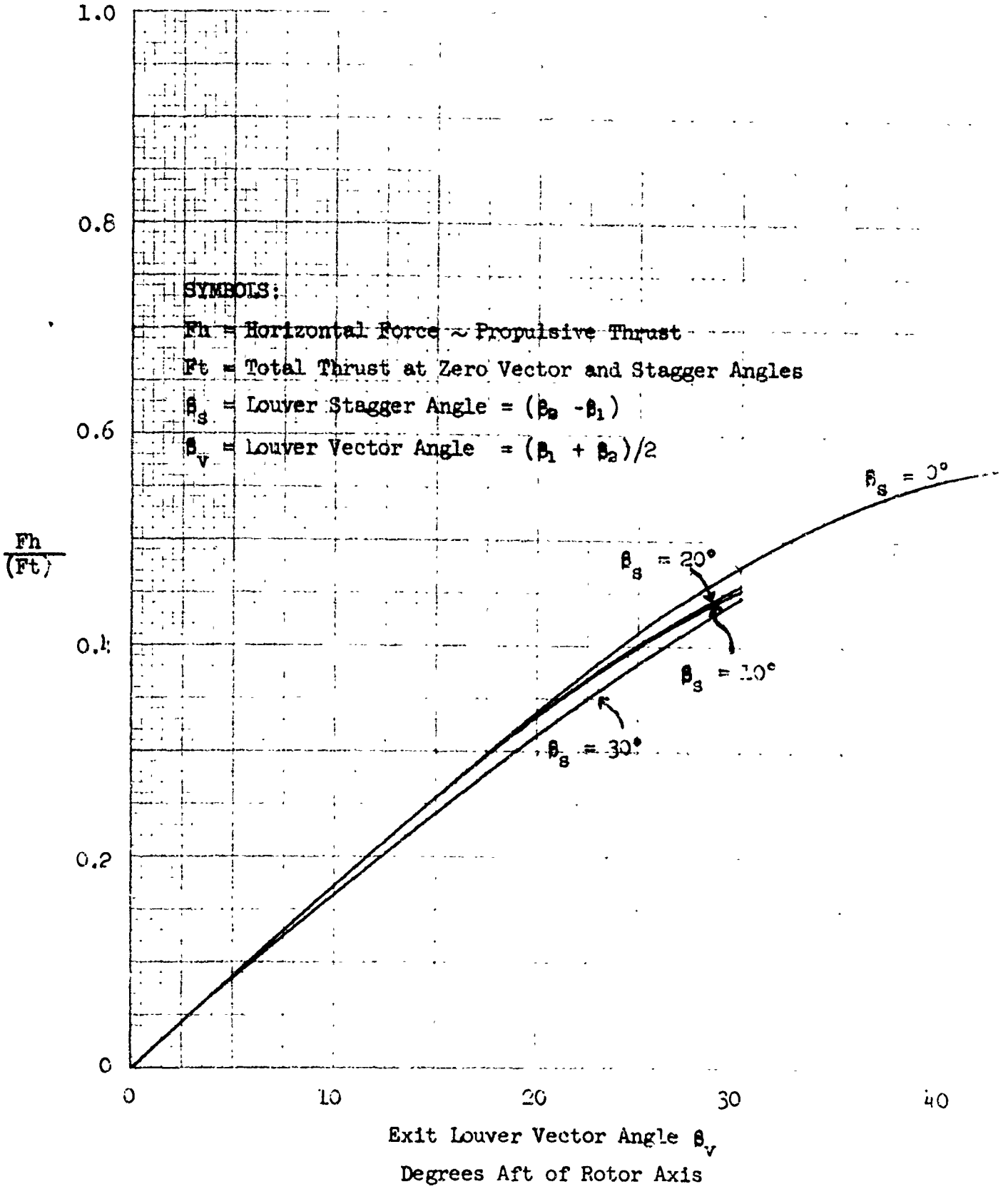
LIFT MODE - 2500 FT. ALTITUDE

Figure 16



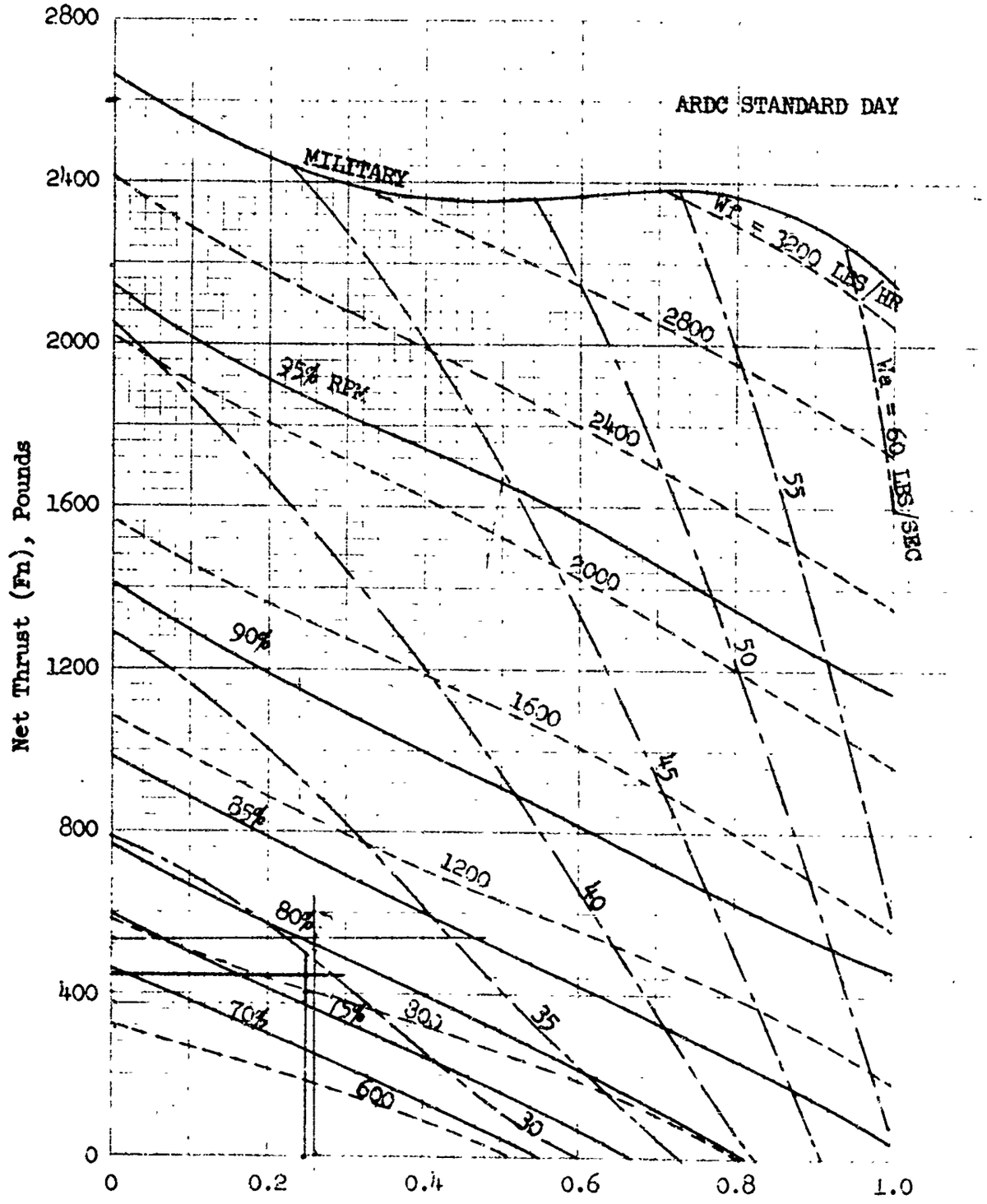
X353-5B STAGGERED EXIT LOUVER SYSTEM ESTIMATED PERFORMANCE

Figure 17



X353-5B STAGGERED EXIT LOUVER SYSTEM ESTIMATED PERFORMANCE

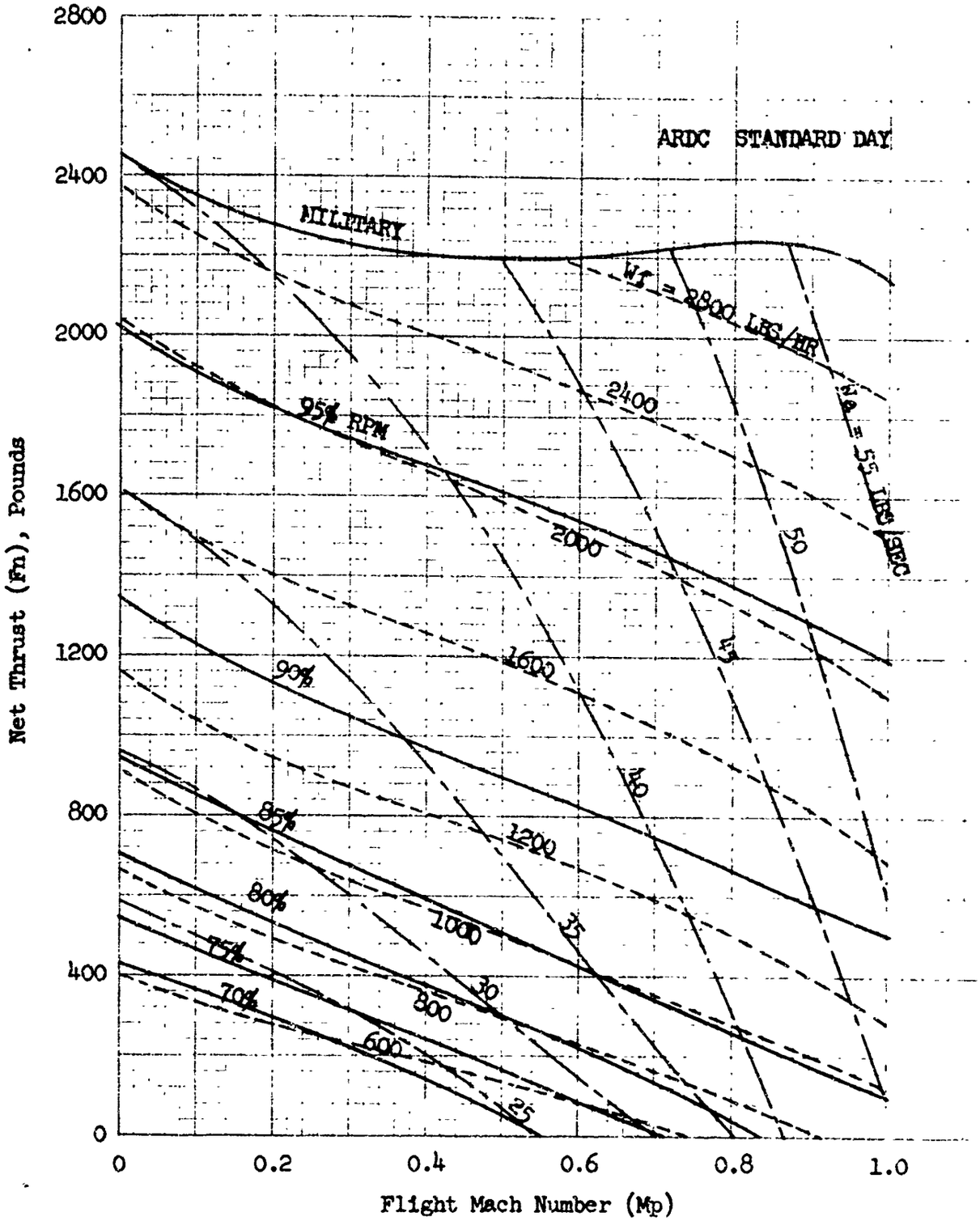
Figure 18



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - SEA LEVEL

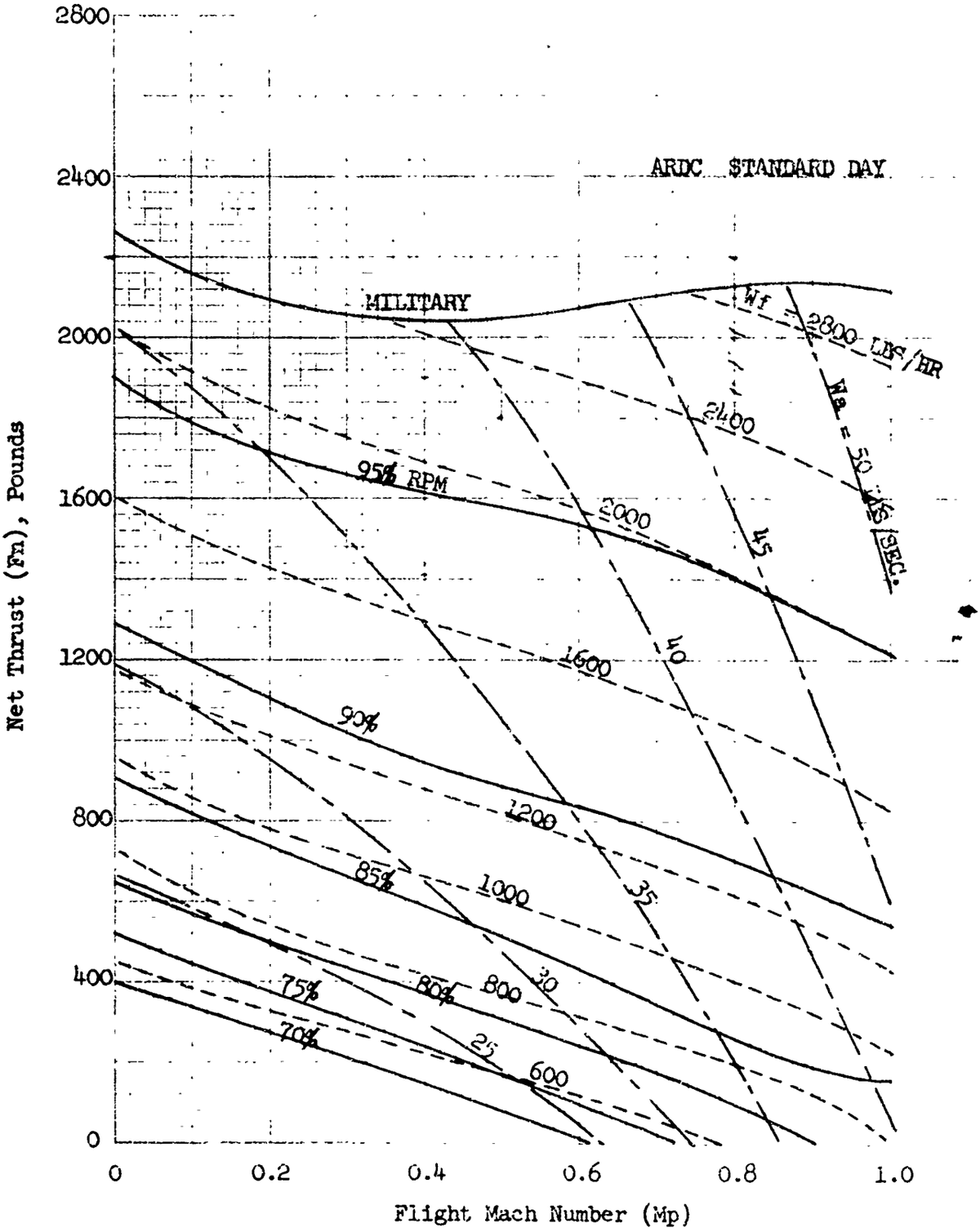
Figure 19



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 3000 FT ALTITUDE

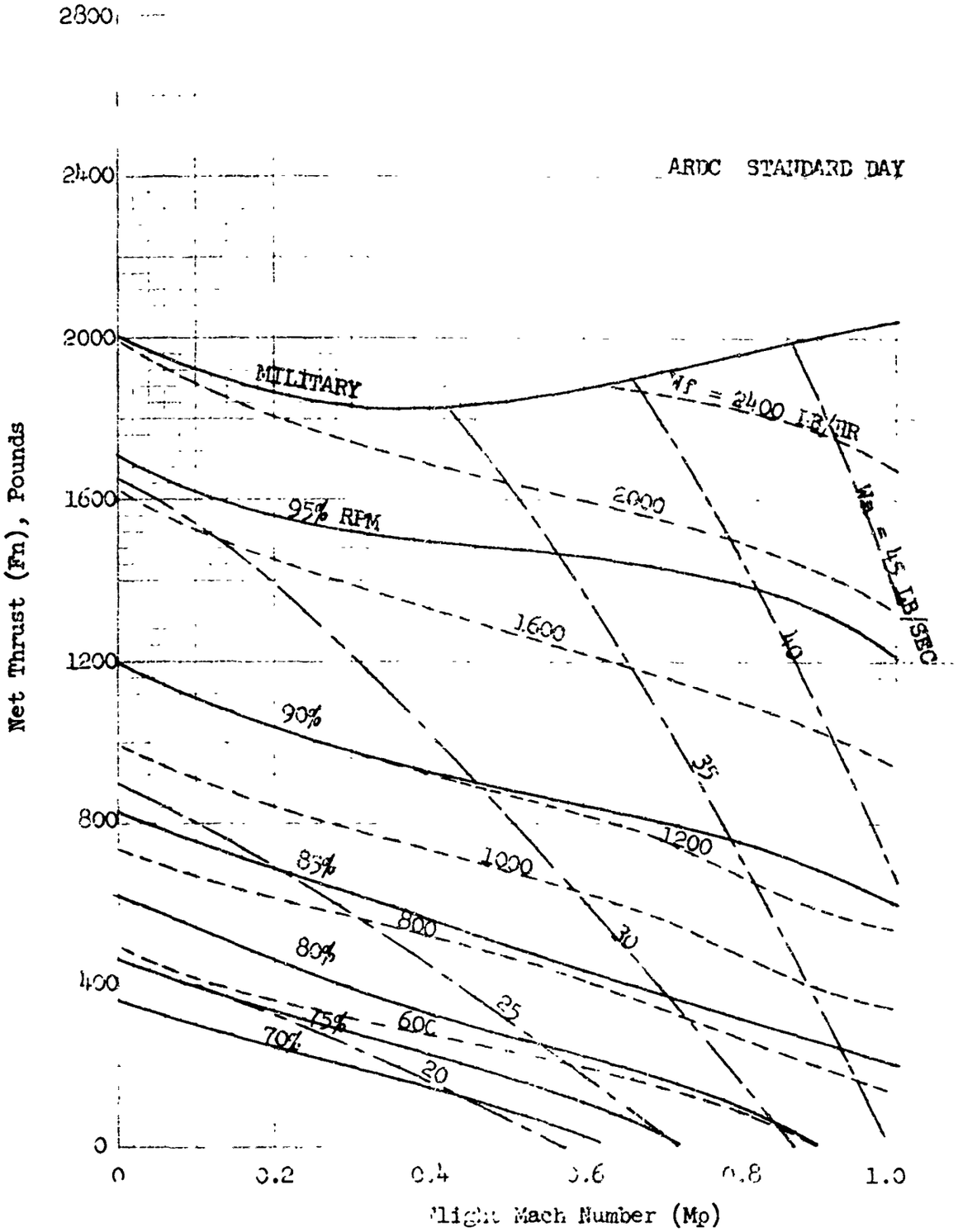
Figure 20



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 6000 FT. ALTITUDE

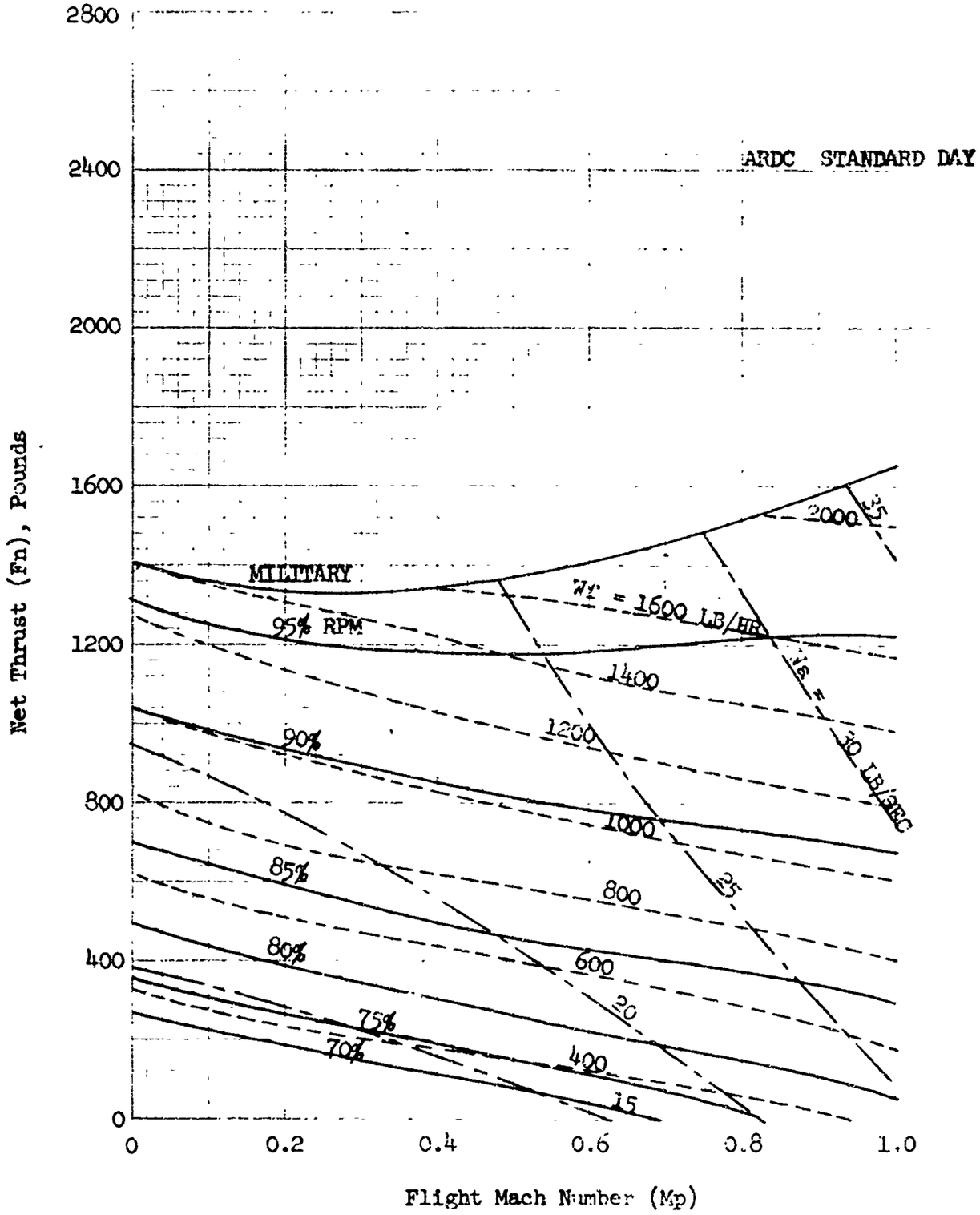
Figure 21



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 10,000 FT. ALTITUDE

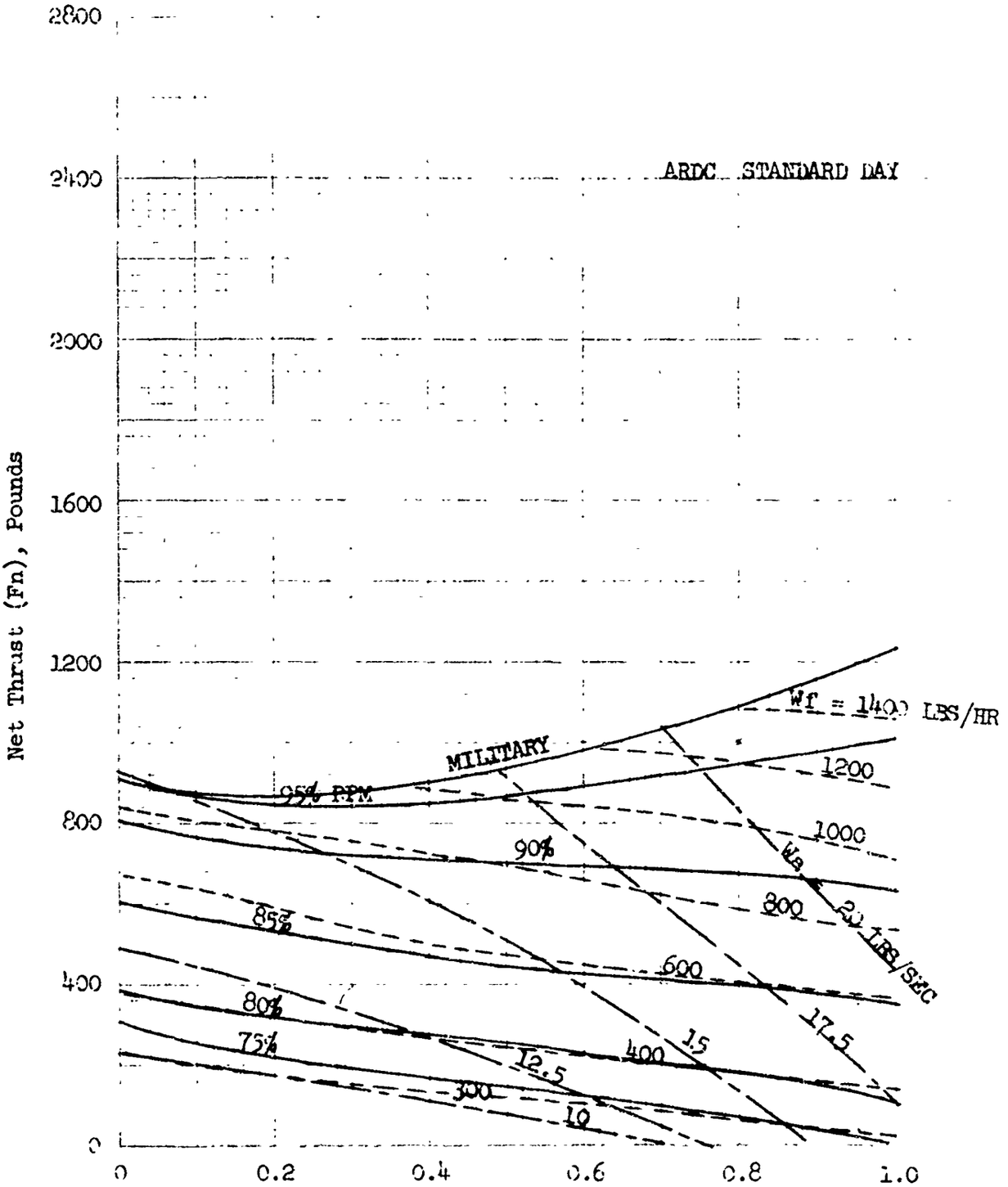
Figure 22



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 20,000 FT. ALTITUDE

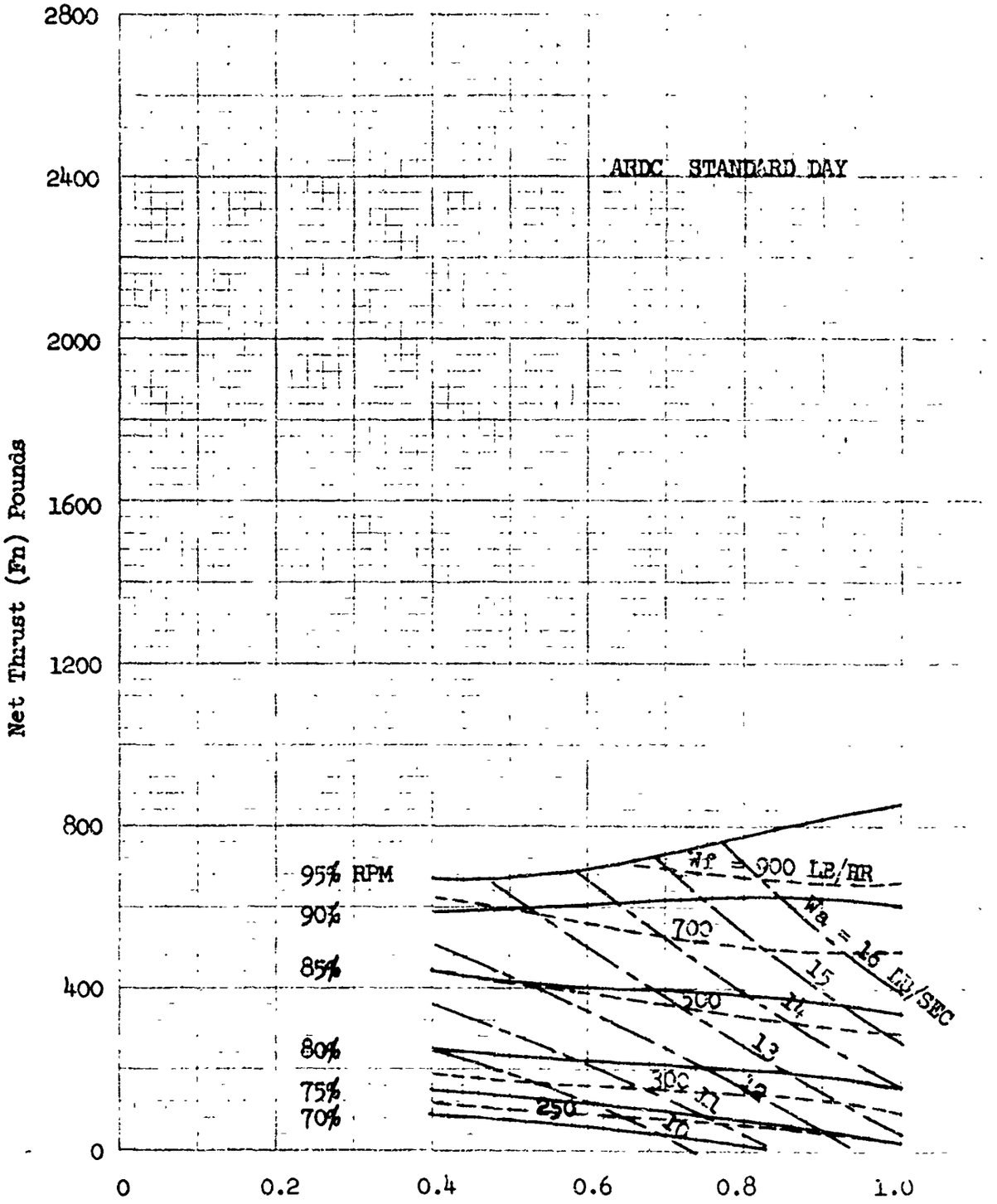
Figure 23



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 30,000 FT. ALTITUDE

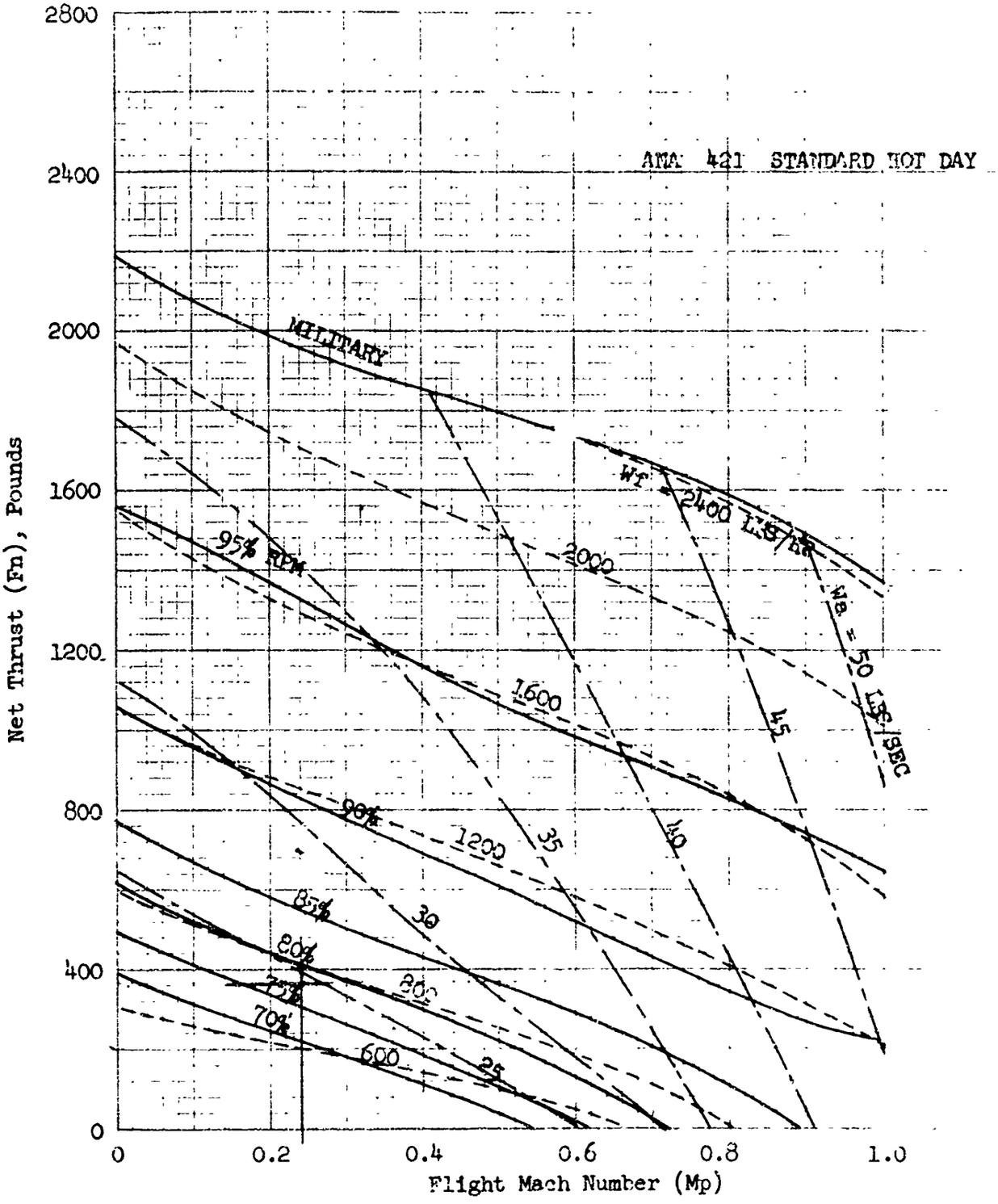
Figure 24



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 36,089 FT. ALTITUDE

Figure 25



X353-5B ESTIMATED FLIGHT PERFORMANCE

TURBOJET MODE - 2500 FT. ALTITUDE

Figure 26

TABLE V

CORRECTION FACTORS FOR LIFT PERFORMANCE

Symbol	Use	Value	Range
Δ_1	Ambient Temperature Correction Factor to Gross Thrust	See Fig. 27	$0^\circ \pm 60^\circ$
Δ_2	Ambient Temperature Correction Factor to Ram Drag	See Fig. 27	$0^\circ \pm 60^\circ$
Δ_3	Ambient Temperature Correction Factor to Fuel Flow	See Fig. 27	$0^\circ \pm 60^\circ$
Δ_4	Fan Inlet Velocity Head Loss Correction Factor to Gross Thrust	-0.0060	0 - 15%
Δ_5	Fan Inlet Velocity Head Loss Correction Factor to Ram Drag	-0.0032	0 - 15%
Δ_6	Cross-ducting Total Pressure Loss Correction Factor to Gross Thrust	-0.0086	0 - 5%
Δ_7	Cross-ducting Total Pressure Loss Correction Factor to Ram Drag	-0.0045	0 - 5%
Δ_8	Turbojet Inlet Total Pressure Loss Correction Factor to Gross Thrust	-0.0148	0 - 10%
Δ_9	Turbojet Inlet Total Pressure Loss Correction Factor to Ram Drag	-0.0075	0 - 10%
Δ_{10}	Turbojet Inlet Total Pressure Loss Correction Factor to Fuel Flow	-0.0100	0 - 10%
Δ_{11}	Compressor Discharge Bleed Correction Factor to Gross Thrust	-0.0244	0 - 6%
Δ_{12}	Compressor Discharge Bleed Correction Factor to Ram Drag	-0.0123	0 - 6%
Δ_{13}	Compressor Discharge Bleed Correction Factor to Fuel Flow	-0.0162	0 - 6%
K_1	Exit Louver Deflection Angle Correction Factor to Gross Thrust	See Fig. 28	See Fig. 56

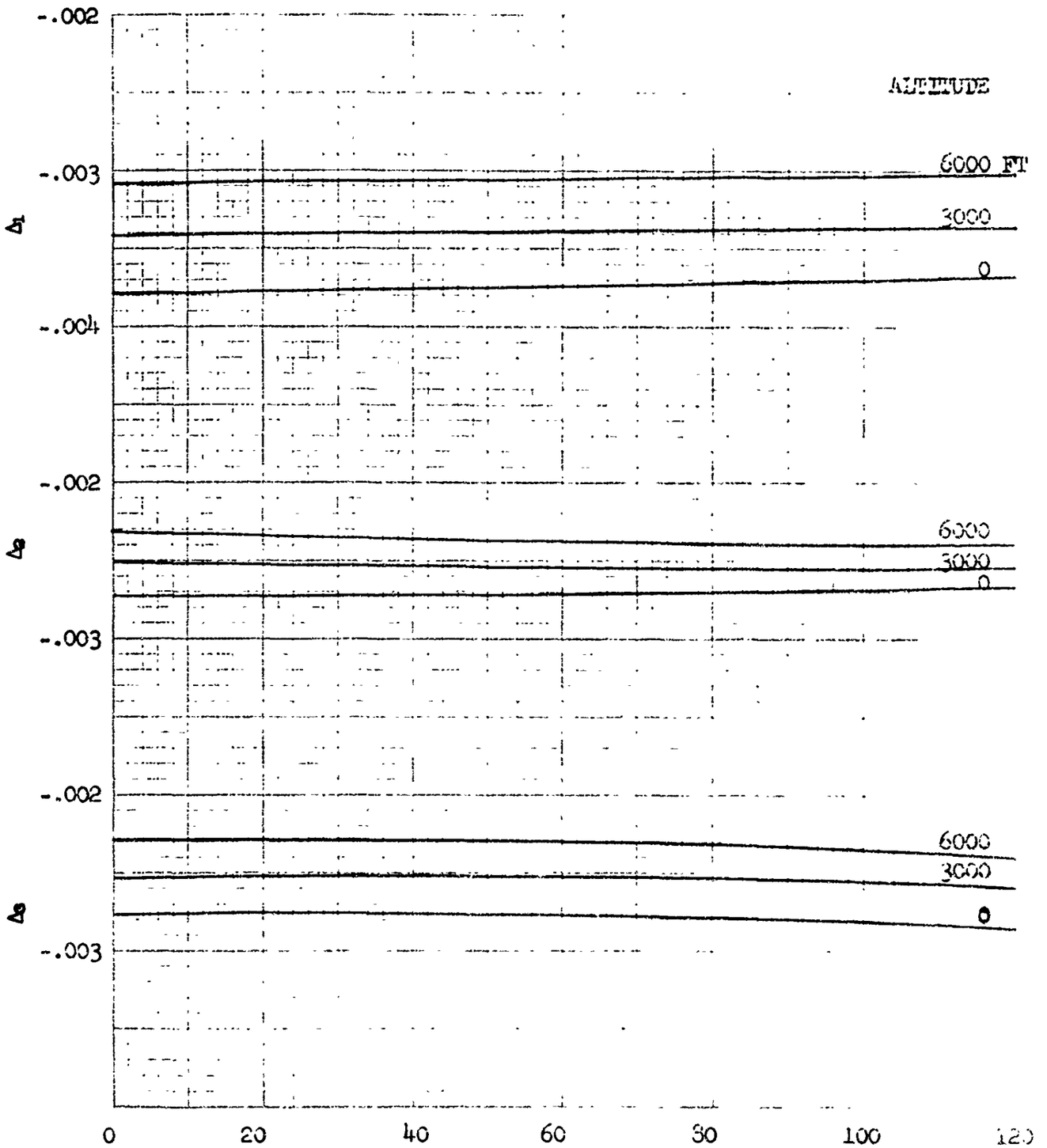
TABLE V - (Continued)

Symbol	Use	Value	Range
K_2	Exit Louver Deflection Angle Correction Factor to Ram Drag	See Fig. 28	See Fig. 56
K_3	Turbojet Turbine Discharge Continuous Bleed Correction Factor	See Fig. 29	10.6 - 40%
K_4	Turbojet Turbine Discharge Continuous Bleed Correction Factor to Ram Drag	See Fig. 29	10.6 - 40%
K_5	Turbojet Turbine Discharge Variable Bleed Correction Factor to Gross Thrust	See Fig. 30	0 - 9%
K_6	Turbojet Turbine Discharge Variable Bleed Correction Factor to Ram Drag	See Fig. 30	0 - 9%
K_7	Turbojet Turbine Discharge Variable Bleed Correction to Fuel Flow	See Fig. 30	0 - 9%
C_1	Turbojet Horsepower Extraction Correction Factor to Gross Thrust	-0.0202	0 - 100 HP
C_2	Turbojet Horsepower Extraction Correction Factor to Ram Drag	-0.0109	0 - 100 HP
C_3	Turbojet Horsepower Extraction Correction Factor to Fuel Flow	-0.0035	0 - 100 HP

TABLE VI

CORRECTION FACTORS FOR TURBOJET PERFORMANCE

Symbol	Use	Value	Range
Δ_{14}	Ambient Temperature Correction Factor to Net Thrust	See Fig. 33	$0^\circ \pm 60^\circ$
Δ_{15}	Ambient Temperature Correction Factor to Fuel Flow	See Fig. 33	$0^\circ \pm 60^\circ$
Δ_{16}	Inlet Duct Total Pressure Loss Correction Factor to Net Thrust	See Fig. 34	0 - 10%
Δ_{17}	Inlet Duct Total Pressure Loss Correction Factor to SFC	See Fig. 34	0 - 10%
Δ_{18}	Inlet Duct Total Pressure Loss Correction Factor to Airflow	-0.010	0 - 10%
Δ_{19}	Compressor Discharge Bleed Correction Factor to Net Thrust	See Fig. 35	0 - 6%
Δ_{20}	Compressor Discharge Bleed Correction Factor to SFC	See Fig. 35	0 - 6%
Δ_{21}	Tailpipe Total Pressure Loss Correction Factor to Net Thrust	See Fig. 36	0 - 6%
C_4	Turbojet Horsepower Extraction Correction Factor to Net Thrust	-0.02	0 - 100 HP
C_5	Turbojet Horsepower Extraction Correction Factor to SFC	+0.03	0 - 100 HP

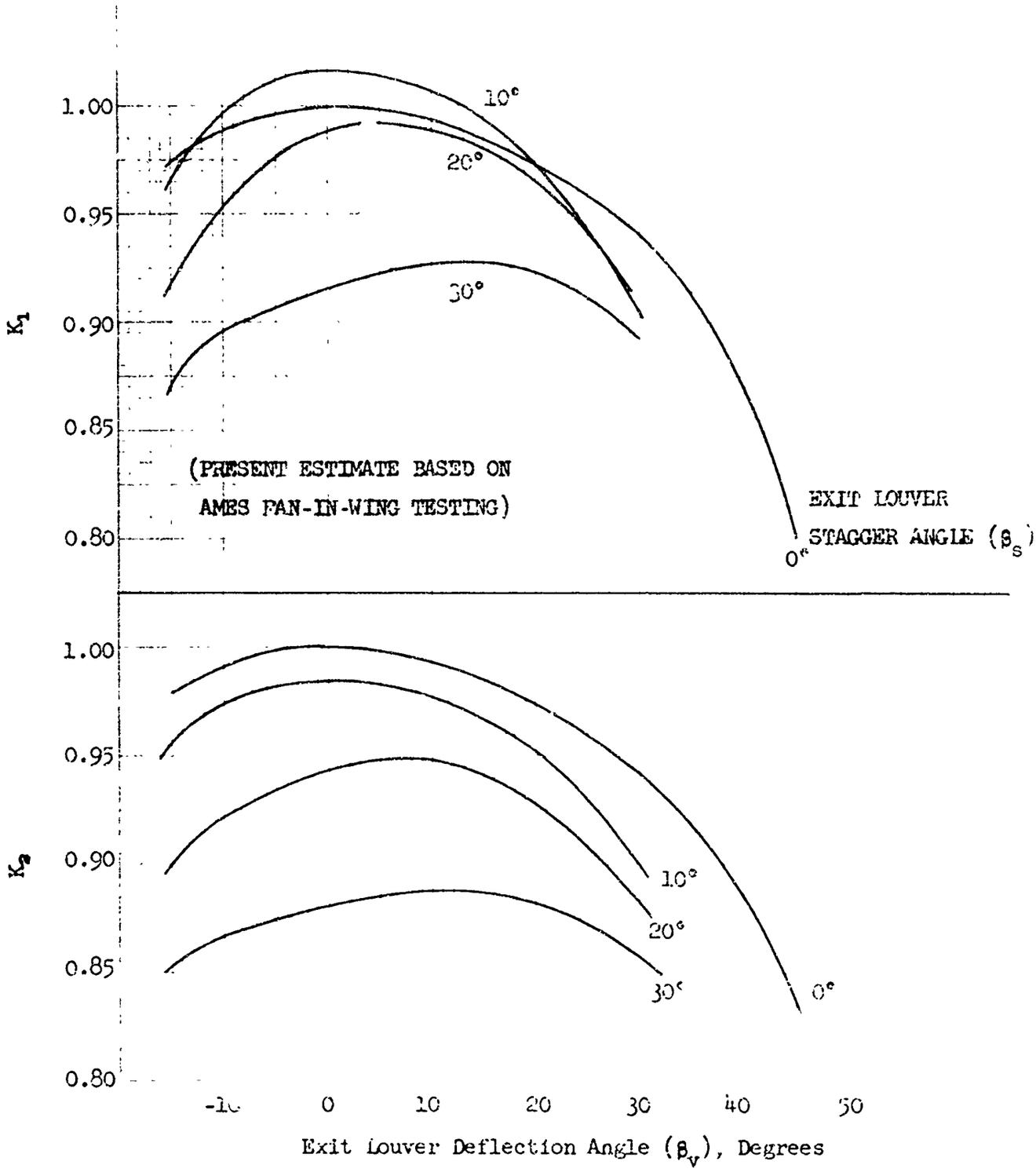


CORRECTION FACTORS TO Fg, Fr & Wf

FOR AMBIENT TEMPERATURE

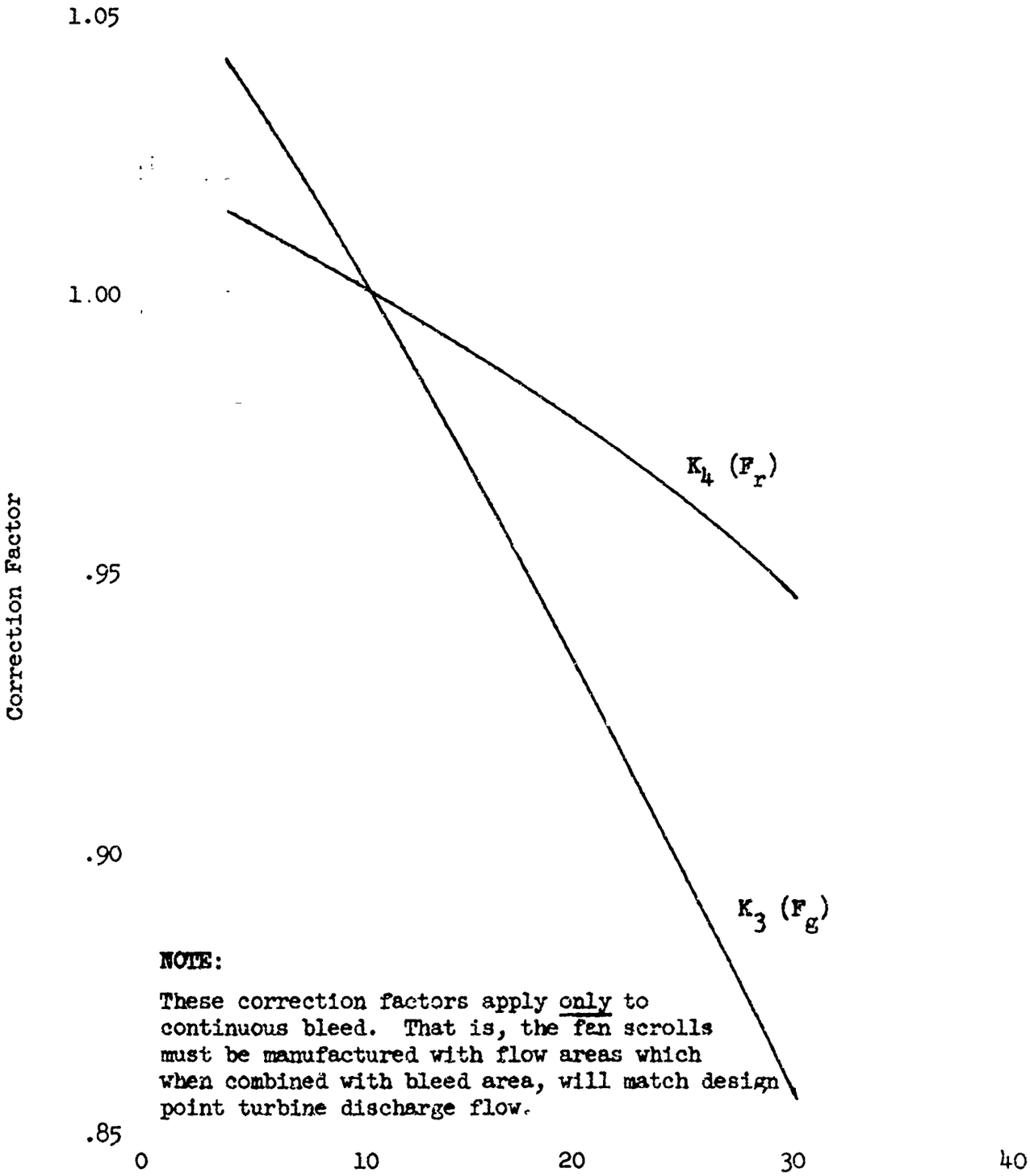
LIFT MODE

Figure 27



CORRECTION FACTORS TO GROSS THRUST AND RAM DRAG
FOR LOUVER VECTOR AND STAGGER ANGLES

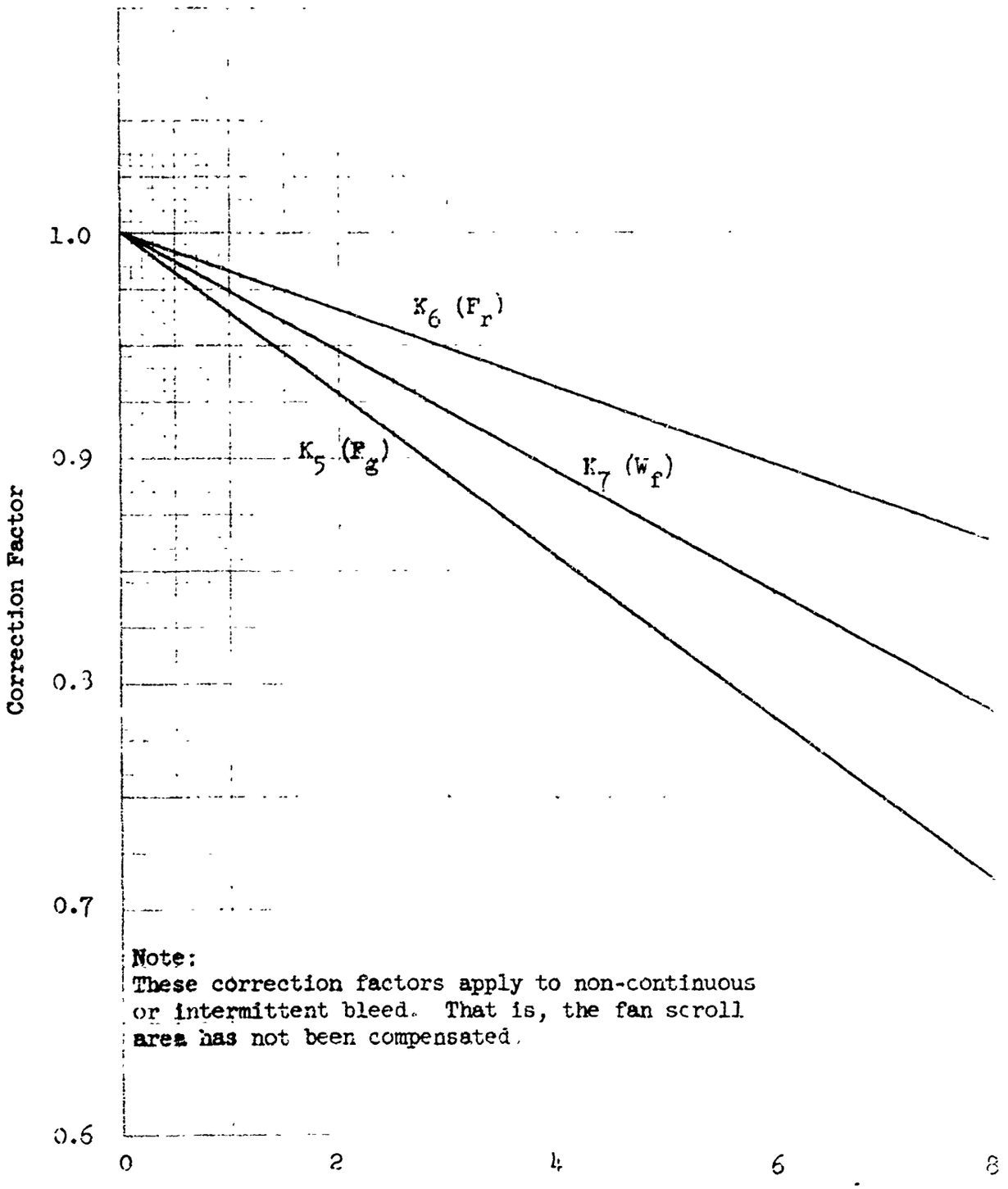
Figure 28



CORRECTION FACTORS FOR GROSS THRUST AND RAM DRAG vs

PERCENT TURBOJET TURBINE DISCHARGE BLEED - LIFT MODE

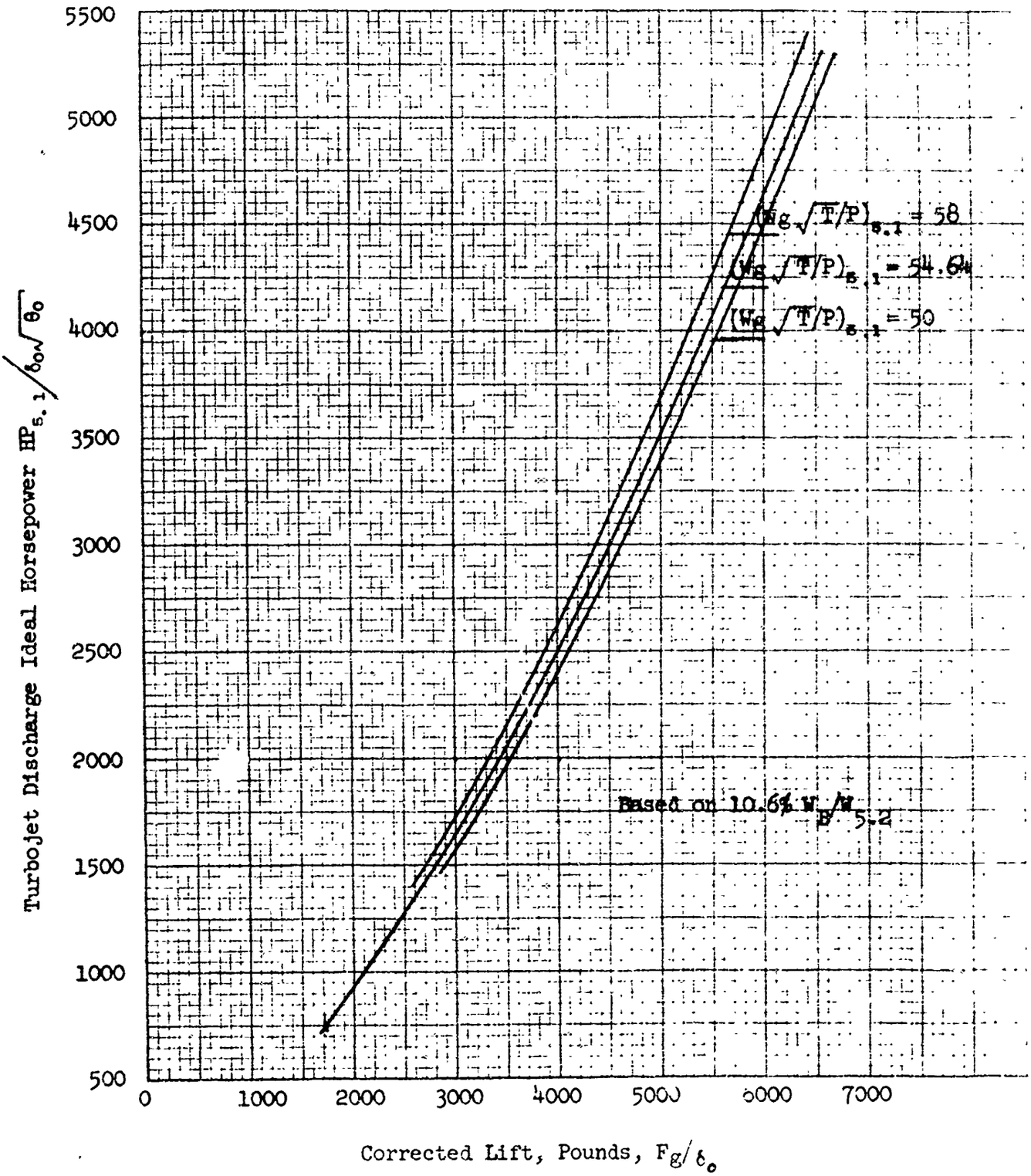
Figure 29



CORRECTION FACTORS FOR GROSS THRUST AND RAM

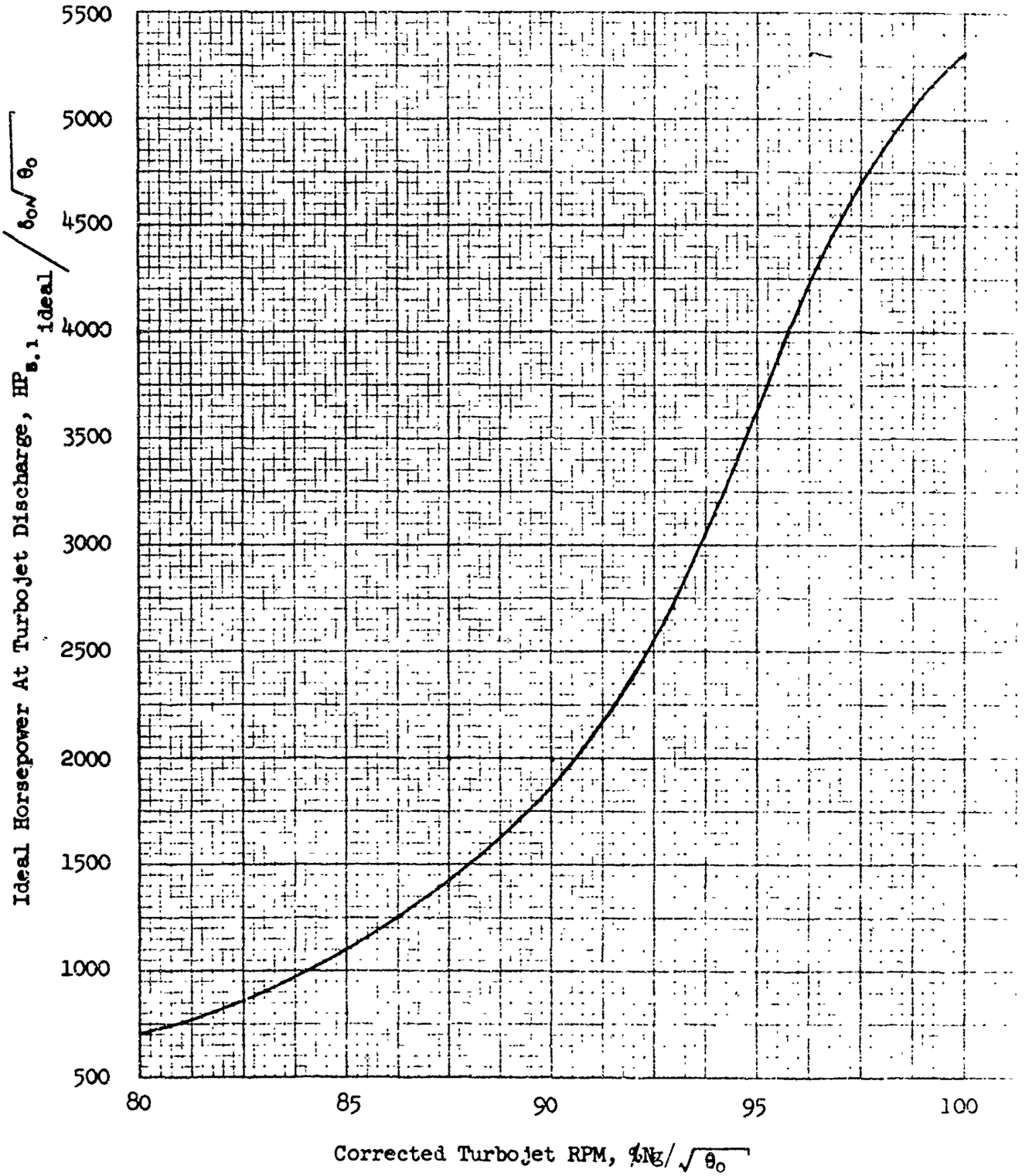
DRAG vs PERCENT TURBOJET TURBINE DISCHARGE BLEED - LIFT MODE

Figure 30



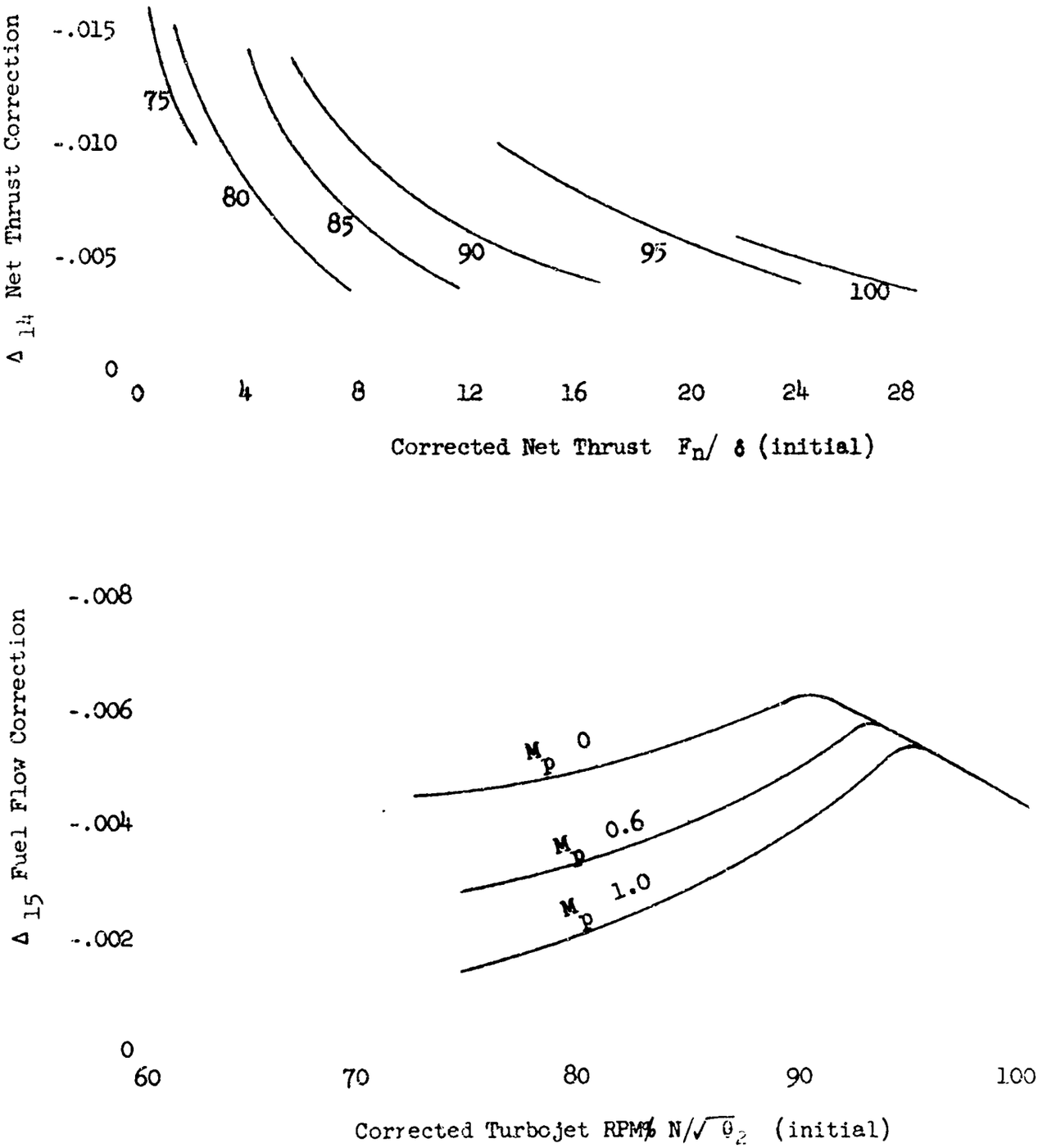
LIFT vs TURBOJET DISCHARGE IDEAL HORSEPOWER

Figure 31



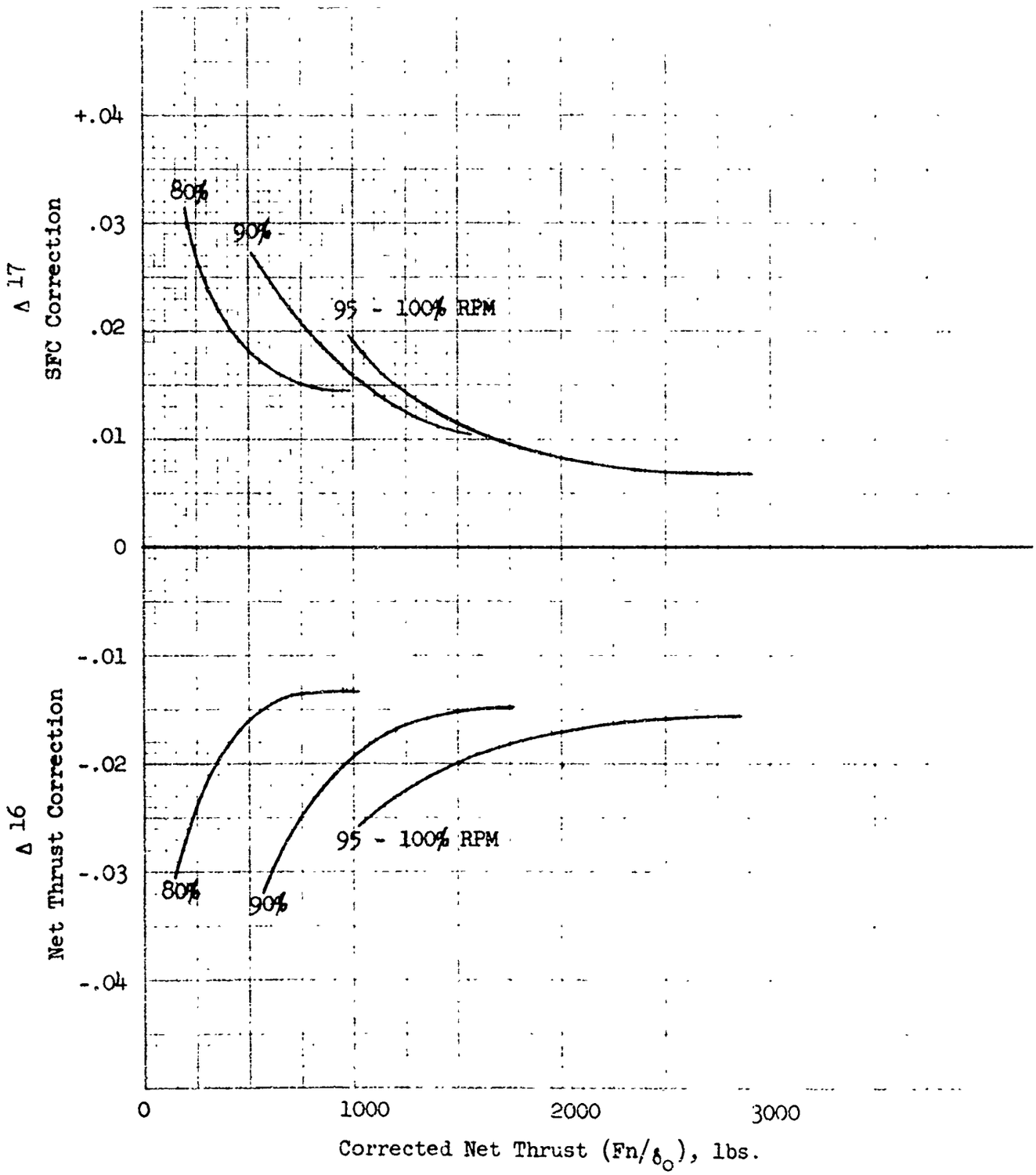
BASIC IDEAL HORSEPOWER AT TURBOJET DISCHARGE vs TURBOJET RPM

Figure 32



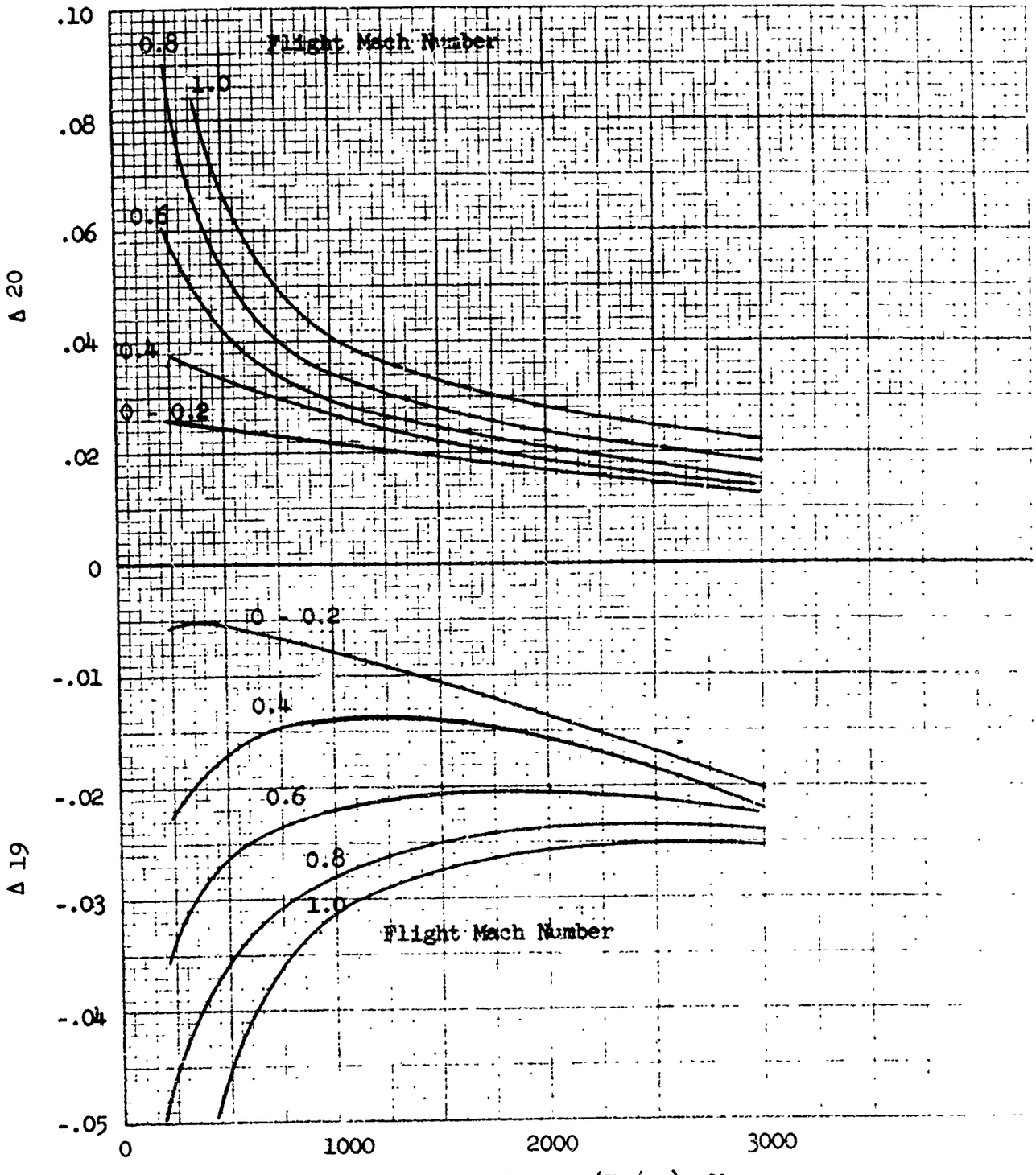
AMBIENT TEMPERATURE CORRECTION FACTORS TO NET THRUST AND FUEL FLOW

Figure 33



INLET DUCT TOTAL PRESSURE LOSS CORRECTION FACTORS FOR NET THRUST AND SPECIFIC FUEL CONSUMPTION - TURBOJET MODE

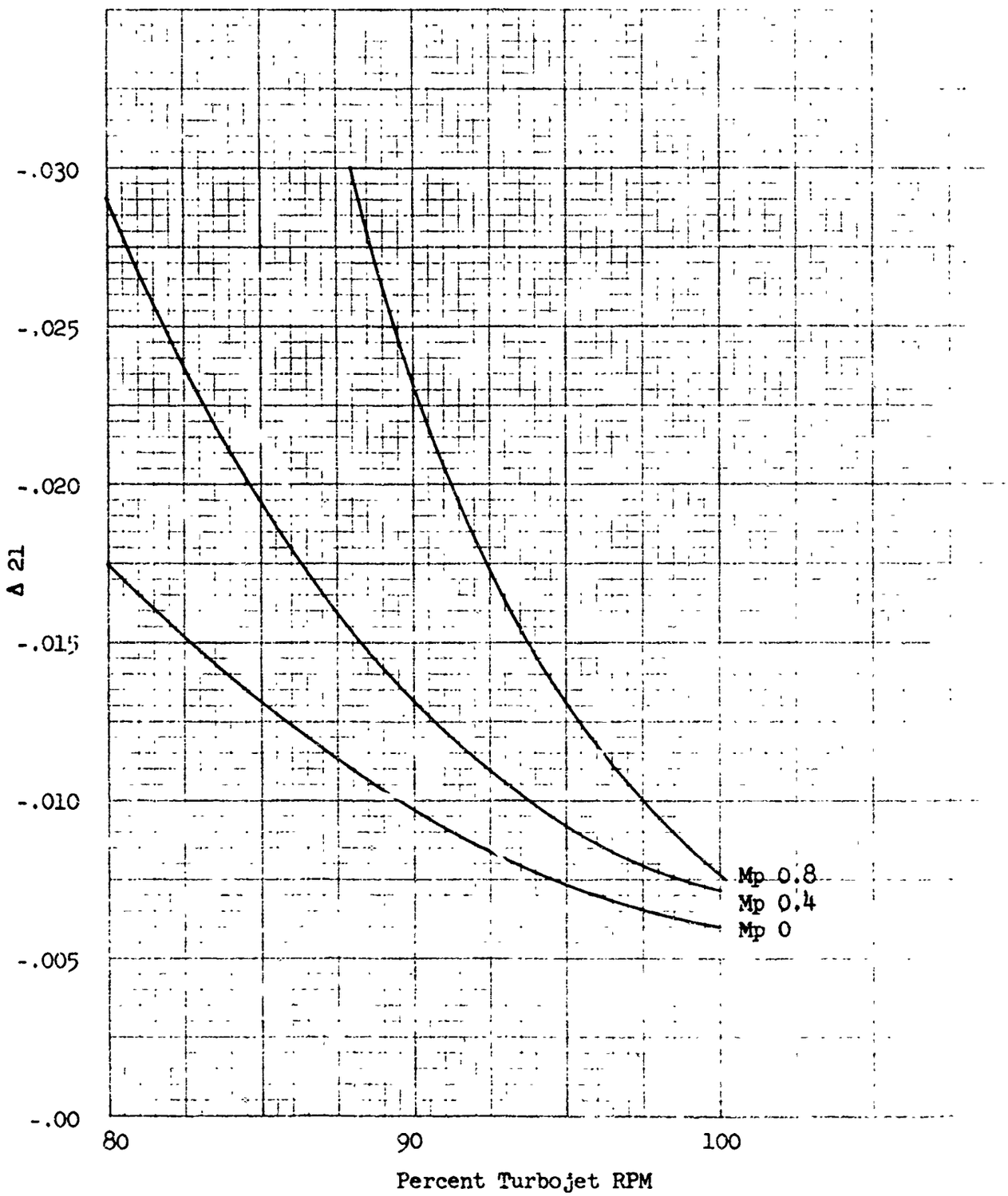
Figure 34



COMPRESSOR BLEED CORRECTION FOR NET THRUST AND

SPECIFIC FUEL CONSUMPTION - TURBOJET MODE

Figure 35



TAILPIPE TOTAL PRESSURE LOSS CORRECTION FACTOR TO NET THRUST

Figure 36

3.4.5.1.3 Method For Correcting Estimated Performance: The following equations illustrate the use of the correction factors in 3.4.5.1.2 for use in correcting estimated performance as shown in the paragraph 3.4.5. Subscript c is used to denote the corrected value.

Equations For Correction Of Lift Mode Performance

Lift and Net Thrust

1. $L = F_{gc} \text{ Cos } \beta_v$

2. $F_n = F_{gc} \text{ Sin } \beta_v - F_{rc}$

Exit Louver Angle Correction

3. $F_g = (F_g/K_1)\ (K_1)$

4. $F_r = (F_r/K_2)\ (K_2)$

Turbine Discharge Bleed Correction

5. $F_{gc} = F_g(Kn);\ n = 3,5$

6. $F_{rc} = F_r(K_n);\ n = 4,6$

7. $W_{fc} = W_f(K_7)$

Ambient Temperature Correction

8. $F_{gc} = F_g\ [1 + (\Delta 1)\ (T_{am} - T_s)]$

9. $F_{rc} = F_r\ [1 + (\Delta 2)\ (T_{am} - T_s)]$

10. $W_{fc} = W_f\ [1 + (\Delta 3)\ (T_{am} - T_s)]$

Internal Loss Corrections

11. $F_{gc} = F_g\ [1 + (\Delta n)\ (\%\ \text{Loss})];\ \Delta n = 4, 6, 8, 11$

12. $F_{rc} = F_r\ [1 + (\Delta m)\ (\%\ \text{Loss})];\ \Delta m = 5, 7, 9, 12$

13. $W_{fc} = W_f\ [1 + (\Delta n)\ (\%\ \text{Loss})];\ \quad = 10, 13$

Gas Generator Horsepower Extraction Correction, Lift Mode

14. $F_{gc} = F_g\ [1 + (C_1)\ (\text{HP extracted}/100)]$

15. $F_{rc} = F_r\ [1 + (C_2)\ (\text{HP extracted}/100)]$

16. $W_{fc} = W_f\ [1 + (C_3)\ (\text{HP extracted}/100)]$

Ideal Horsepower at turbojet turbine discharge

17. $(HP_{5.1})_{Ideal} = \frac{778}{550} T_{5.1} c_{p\,5.1} \left[1 - \left(\frac{Pam}{P_{5.1}}\right)^{\frac{\gamma-1}{\gamma}} \right] W_{5.1}$

(Limited to use with turbojet discharge conditions approximately as shown in Figure 32a.)

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Equations For Correction Of Turbojet Mode Performance

Ambient Temperature Correction

18. $F_{nc} = F_n [1 + (\Delta 14) (T_{am} - T_s)]$

19. $W_{fc} = W_f [1 + (\Delta 15) (T_{am} - T_s)]$

Inlet Duct Total Pressure Loss Correction

20. $F_{nc} = F_n [1 + (\Delta 16) (\% \text{ Loss})]$

21. $SFC_c = SFC [1 + (\Delta 17) (\% \text{ Loss})]$

22. $W_{ac} = W_a [1 + (\Delta 18) (\% \text{ Loss})]$

Compressor Discharge Customer Bleed Correction

23. $F_{nc} = F_n [1 + (\Delta 19) (\% \text{ Bleed})]$

24. $SFC_c = SFC [1 + (\Delta 20) (\% \text{ Bleed})]$

Tailpipe Total Pressure Loss Correction

25. $F_{nc} = F_n [1 + (\Delta 21) (\% \text{ Loss})]$

Gas Generator Horsepower Extraction Correction

26. $F_{nc} = F_n [1 + (C_4) (\text{HP extracted}/100)]$

27. $W_{fc} = W_{fc} [1 + (C_5) (\text{HP extracted}/100)]$

SAMPLE CALCULATIONS

The correction factors are of three types, K corrections, Δ corrections and C corrections. All corrections of each type are handled in a similar fashion - as shown below:

1. Corrections by K factors

Example: Exit louver angle correction ($K_1 K_2$)

Assume: Altitude = 3000 feet

Power Setting = Military

Vp = 50 knots

$\beta_V = 30°$

$\beta_S = 20°$

$Fg_1 = (Fg/K_1)\ (K_1)$

From figure 8 @ 50 knots, Military power, read $Fg/K_1 = 6230$

From figure 28 @ $\beta_V = 30°$, $\beta_S = 20°$ read $K_1 = 0.905$

$Fg_1 = (6230)\ (0.905)$

$= 5638$ lbs.

$Fr_1 = (Fr/K_2)\ (K_2)$

From figure 9 @ 50 knots, Military power, read $Fr/K_2 = 1360$

From figure 28 @ $\beta_V = 30°$, $\beta_S = 20°$, read $K_2 = 0.881$

$Fr_1 = (1360)\ (0.881)$

$= 1198$ lbs.

Wf = Wf (no correction required for louver angle)

From figure 10 @ 50 knots, Military power, read Wf = 2460

$Wf_1 = 2460$ lbs/hr

$L = Fg_1 \cos \beta_V$

$= (5638)\ (0.866)$

$= 4883$ lbs.

$Fn_1 = Fg\ ,\ \text{Sin}\ \beta_V - Fr_1$

$= (5638)\ (0.500) - (1198)$

$= 1621$ lbs.

2. Correction by Λ factors

The product of the Λ factor times the change in the variable is the percent change in the basic performance number.

Example: Ambient temperature correction (Λ_1 Λ_2 Λ_3)

Assume: Same conditions as 1 above except Tam = 90° F

$$Fg_2 = Fg_1 \left[1 + (\Lambda_1)\ (Tam - Ts)\right]$$

From figure 27 @ 3000 ft. altitude, 50 knots, read $\Lambda_1 = -0.0034$

$$Fg_2 = 5638 \left[1 + (-0.0034)\ (90-48.3)\right]$$
$$= 4846 \text{ lbs.}$$

$$Fr_2 = Fr_1 \left[1 + (\Lambda_2)\ (Tam - Ts)\right]$$

From figure 27 @ 3000 ft. altitude, 50 knots, read $\Lambda_2 = -0.00255$

$$Fr_2 = 1198 \left[1 + (-0.00255)\ (90-48.3)\right]$$
$$= 1072 \text{ lbs.}$$

$$Wf_2 = Wf_1 \left[1 + (\Lambda_3)\ (Tam - Ts)\right]$$

From figure 27 @ 3000 ft. altitude, 50 knots, read $\Lambda_3 = -0.00252$

$$Wf_2 = 2460 \left[1 + (-0.00252)\ (90 - 48.3)\right]$$
$$= 2202 \text{ lbs/hr}$$

L_2 and Fn_2 are then computed from Fg_2 and Fr_2 as done in example 1 above.

3. Correction by C correction factors

The product of the C factor times the ratio of the change to an arbitrary basic change in the variable is the percent change in the basic performance number.

Example: Turbojet horsepower extraction correction (C_1, C_2, C_3)

Assume: Same conditions as in 2 above, except horsepower extracted = 25 HP.

$$Fg_3 = Fg_2 \left[1 + C_1(\text{HP extracted}/100)\right]$$

From table of correction factors read $C_1 = -0.0202$

$$Fg_3 = 4846 \left[1 + (-0.0202)\ (25/100)\right]$$
$$= 4822 \text{ lbs.}$$

$Fr_3 = Fr_2 [1 + C_2 (HP \text{ extracted}/100)]$

From table of correction factors read $C_2 = -0.0109$

$Fr_3 = 1072 [1 + (-0.0109 (25/100)]$

$Fr_3 = 1069$ lbs.

$Wf_3 = Wf_2 [1 + C_3 (HP \text{ extracted}/100)]$

From table of correction factors read $C_3 = -0.0035$

$Wf_3 = 2202 [1 + (-0.0035) (25/100)]$

$Wf_3 = 2200$ lbs/hr.

ve.

3.4.5.3 Electronic automatic machine performance presentation: Performance presentation with electronic automatic machines is furnished in the "X353-5B Customer Deck."

3.4.6 Altitude-temperature limits for flight starting and operating: The estimated engine turbojet-mode starting and operating limits curves are shown in Figures 37 and 38.

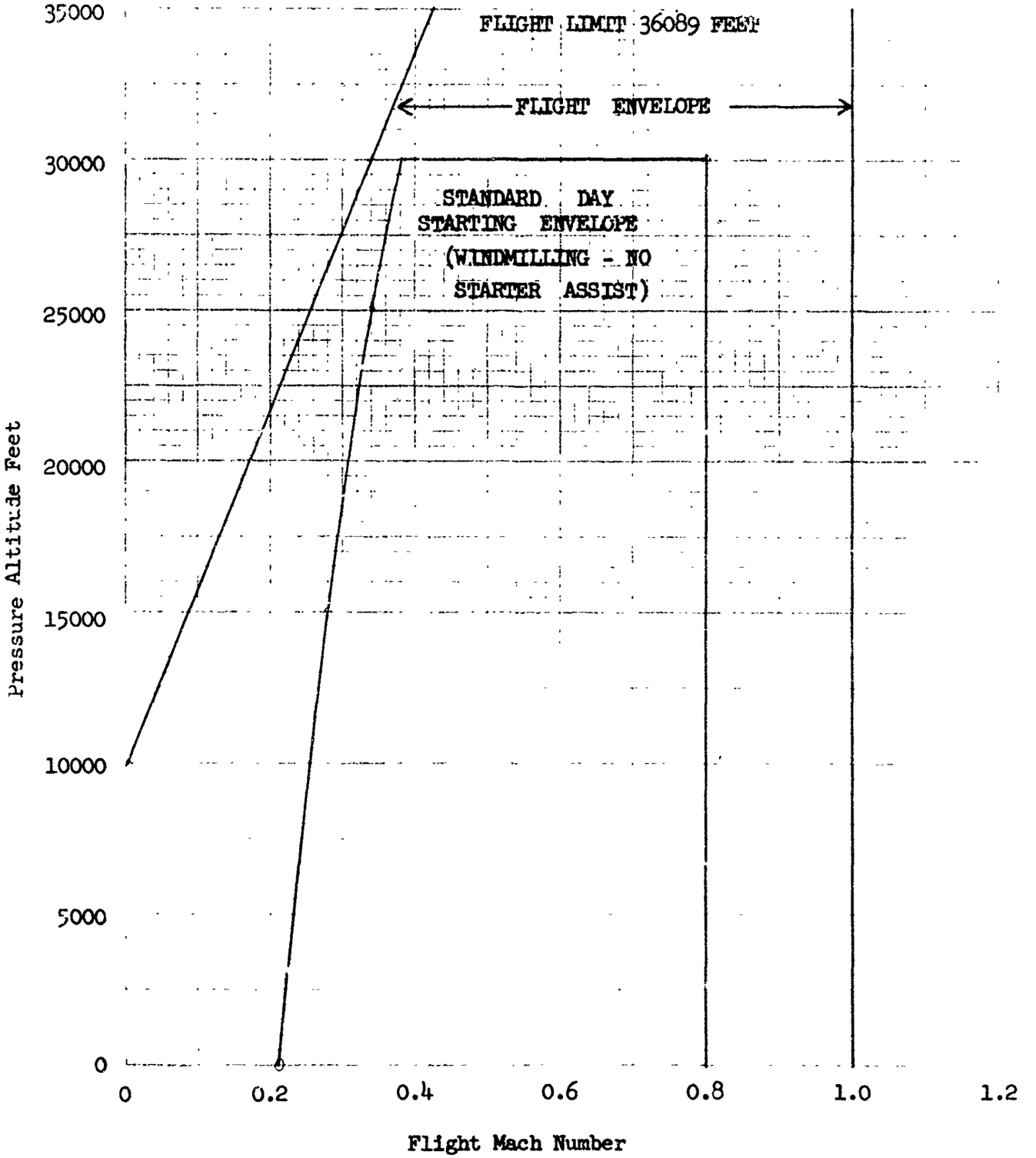
3.4.6.1 Sea Level Operating Limits: The engine shall function satisfactorily in the turbojet mode up to and including a ram pressure ratio of 1.89 at sea level standard conditions up to and including a ram pressure ratio of 1.30 at -65°F and up to and including a ram pressure ratio of 2.20 at 103°F ambient temperature.

3.4.6.2 Flight Starting Limits: The engine shall be capable of air starts in the turbojet mode up to and including an altitude or simulated altitude of 30,000 feet between a ram pressure ratio of 1.10 and 1.52. Starter assist is not required. A maximum of one horsepower may be extracted during a windmilling start.

3.4.6.3 Altitude-Temperature Limits for Lift-mode Operation: The estimated lift-mode operating limits curves are shown in Figures 39 and 40.

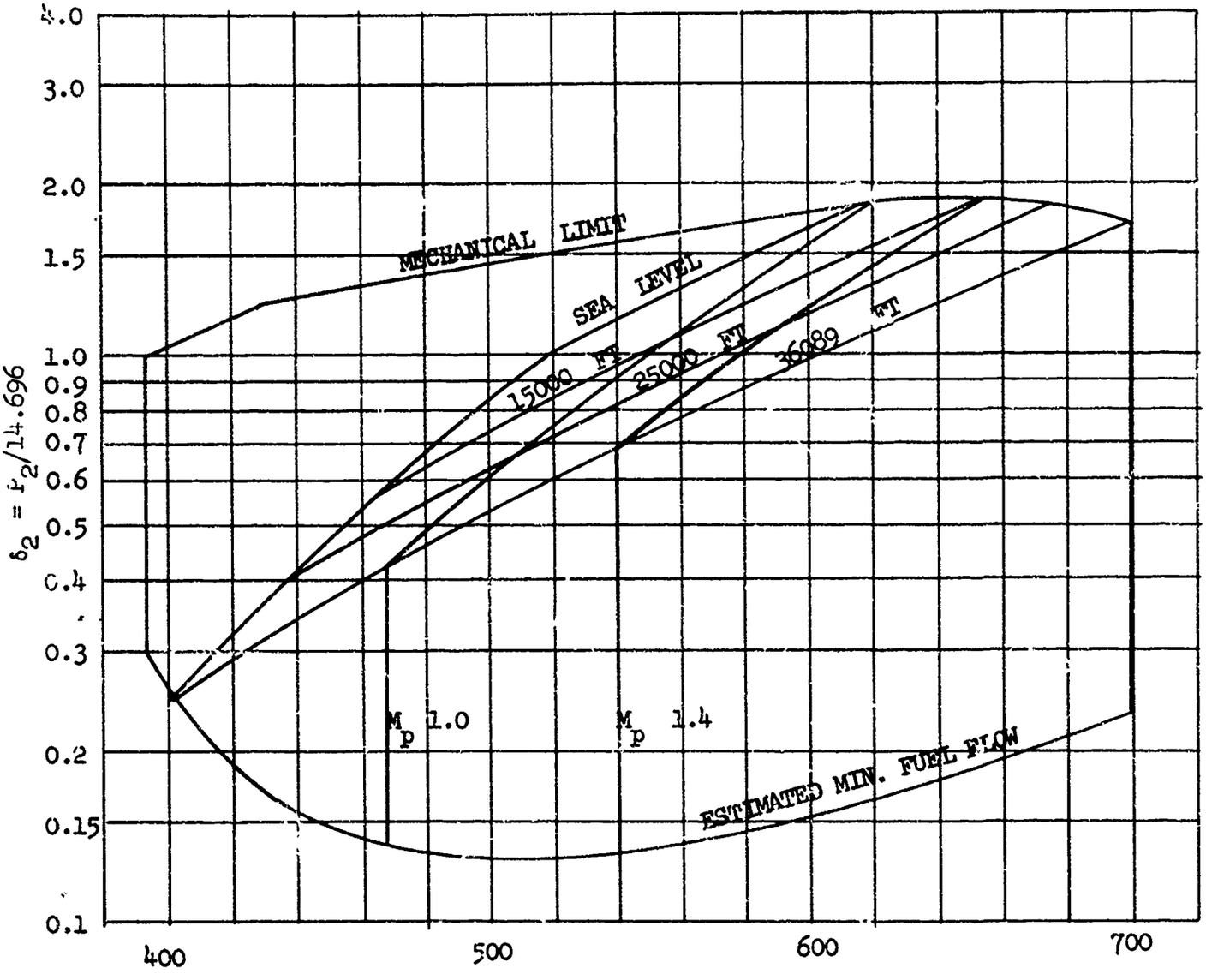
3.4.6.4 Absolute Altitude: The absolute altitude of the engine in the turbojet mode shall be not less than 36089 feet at a ram pressure ratio between 3.54 and 7.02 which includes AIA standard ram recovery.

3.4.6.10 Reverse Thrust: No thrust reverser is provided for turbojet mode operation. Negative thrust in lift mode can be achieved through vectoring the fan exhaust forward as described in paragraph 3.27.7.1.



X353-5B FLIGHT ENVELOPE - TURBOJET MODE

Figure 37

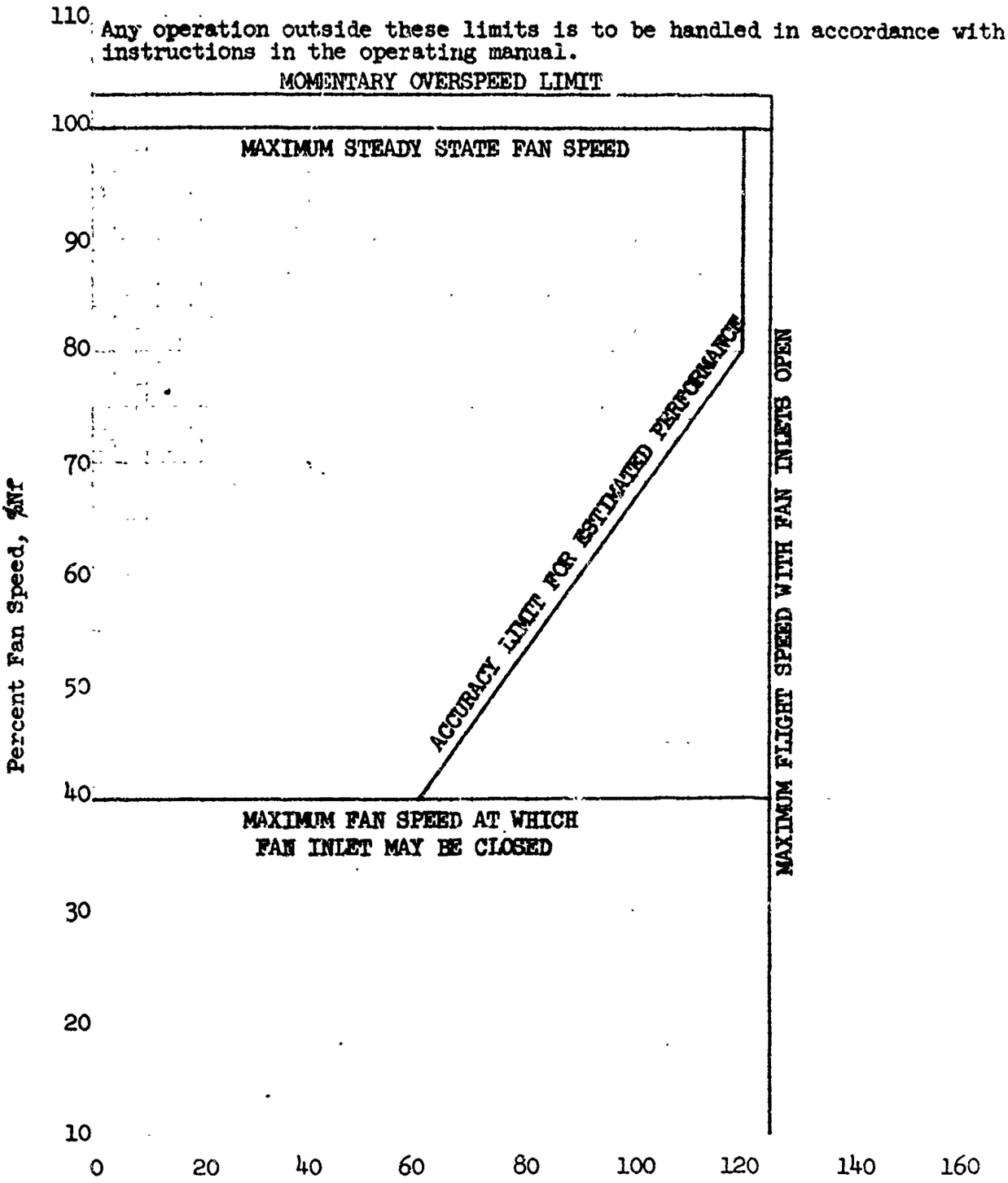


NOTE: ALTITUDE AND MACH NUMBER (M_p) PROFILES ARE BASED ON ARDC STANDARD ATMOSPHERE AND 100% RAM RECOVERY

X353-5B ENGINE OPERATING LIMITS
TURBOJET MODE

Figure 38

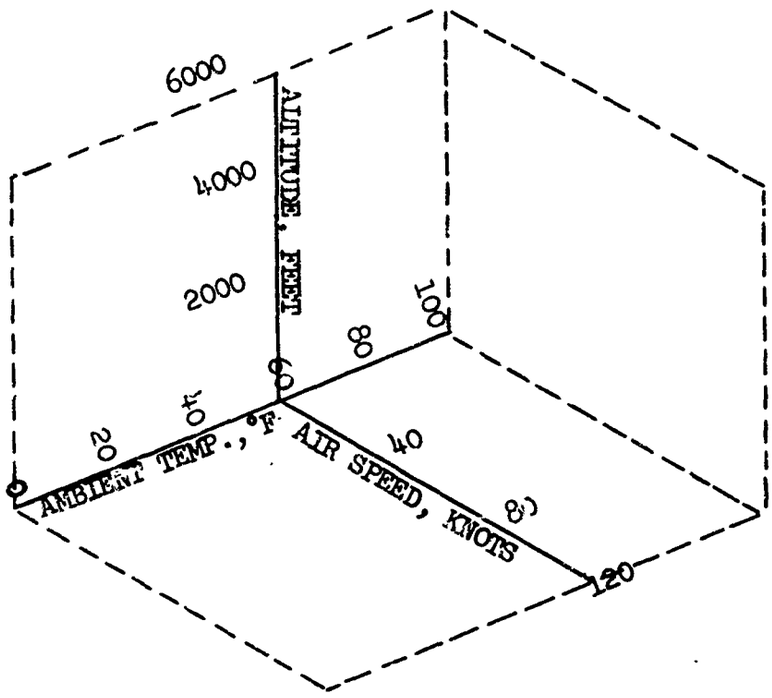
Any operation outside these limits is to be handled in accordance with instructions in the operating manual.



X353-5B FAN OPERATING LIMITS

Figure 39

1



X353-5B PROPULSION SYSTEM OPERATING LIMITS

LIFT MODE

Figure 40

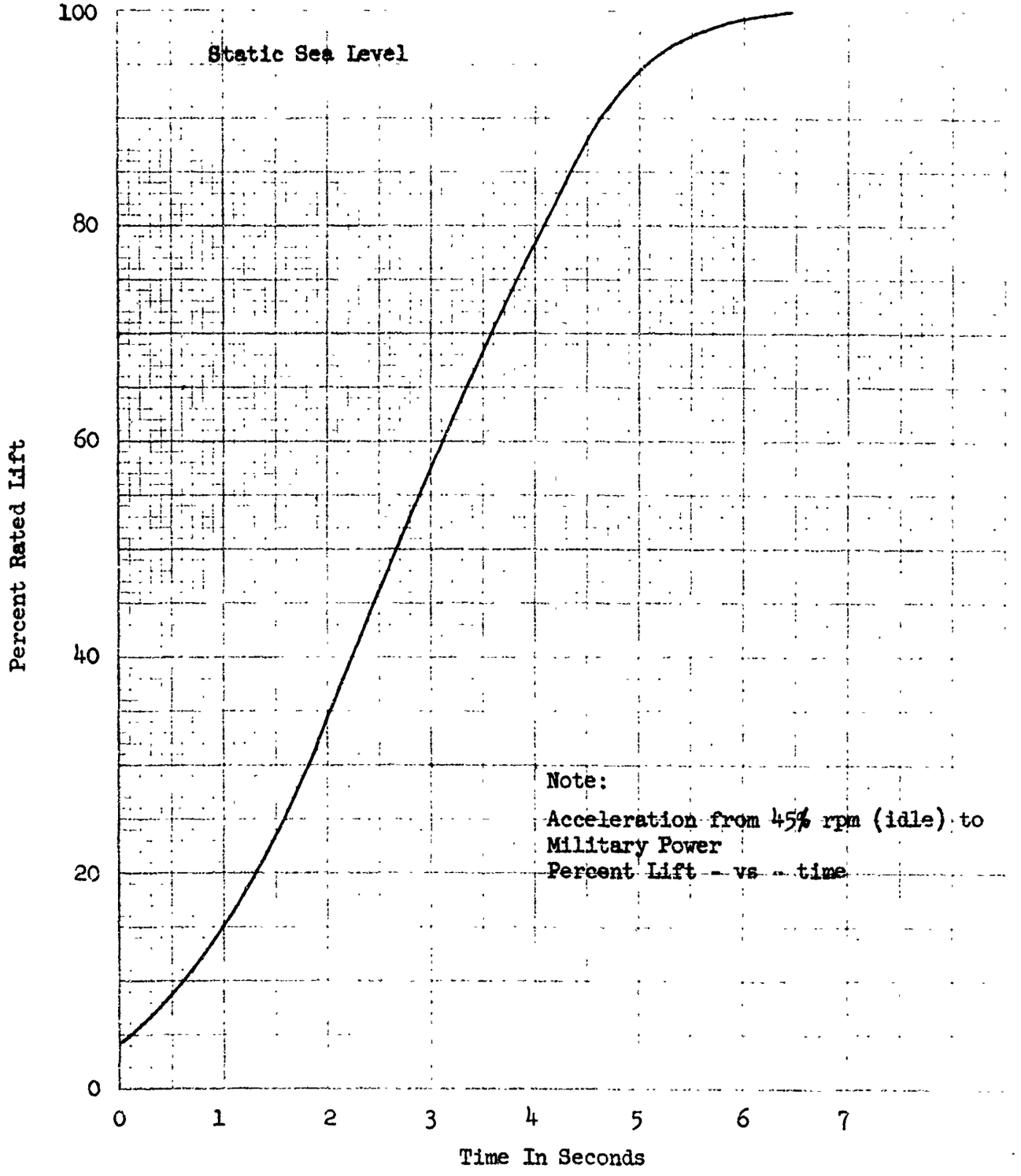
3.4.11 Thrust Transients: All times specified below are based on the time required to accomplish 95 percent of the change based on a control lever movement in one second or less.

3.4.11.1 Thrust Transients, Turbojet Mode: The total time required to accomplish each specified transient safely in the turbojet mode shall not exceed the value specified in MIL-E-5007B. These ratings are based on no loading of the accessory drives and no customer air being bled from the customer compressor discharge bleed ports.

3.4.11.2 Thrust Transients, Lift-Mode: The total time required to accelerate from idle conditions to maximum fan rpm available or to decelerate from maximum fan rpm available to idle conditions shall not exceed six (6) seconds. Estimated transients are shown in Figures 41 and 42. Estimated transient performance for small turbojet power setting changes (ninety five percent fan lift plus and minus five percent fan lift) is shown in Figure 42a.

3.4.11.3 Thrust Transients, Conversion: The total time required to convert from full military thrust available to maximum fan rpm available by changing diverter valve position at military power level of the turbojet shall not exceed six (6) seconds. The total time required to convert from maximum fan rpm available to full military thrust available by changing diverter valve position at military power level of the turbojet shall not exceed three(3) seconds for decay of fan rpm and one second for increase of turbojet thrust. Estimated transients are shown in Figures 43, 44, 45 and 46.

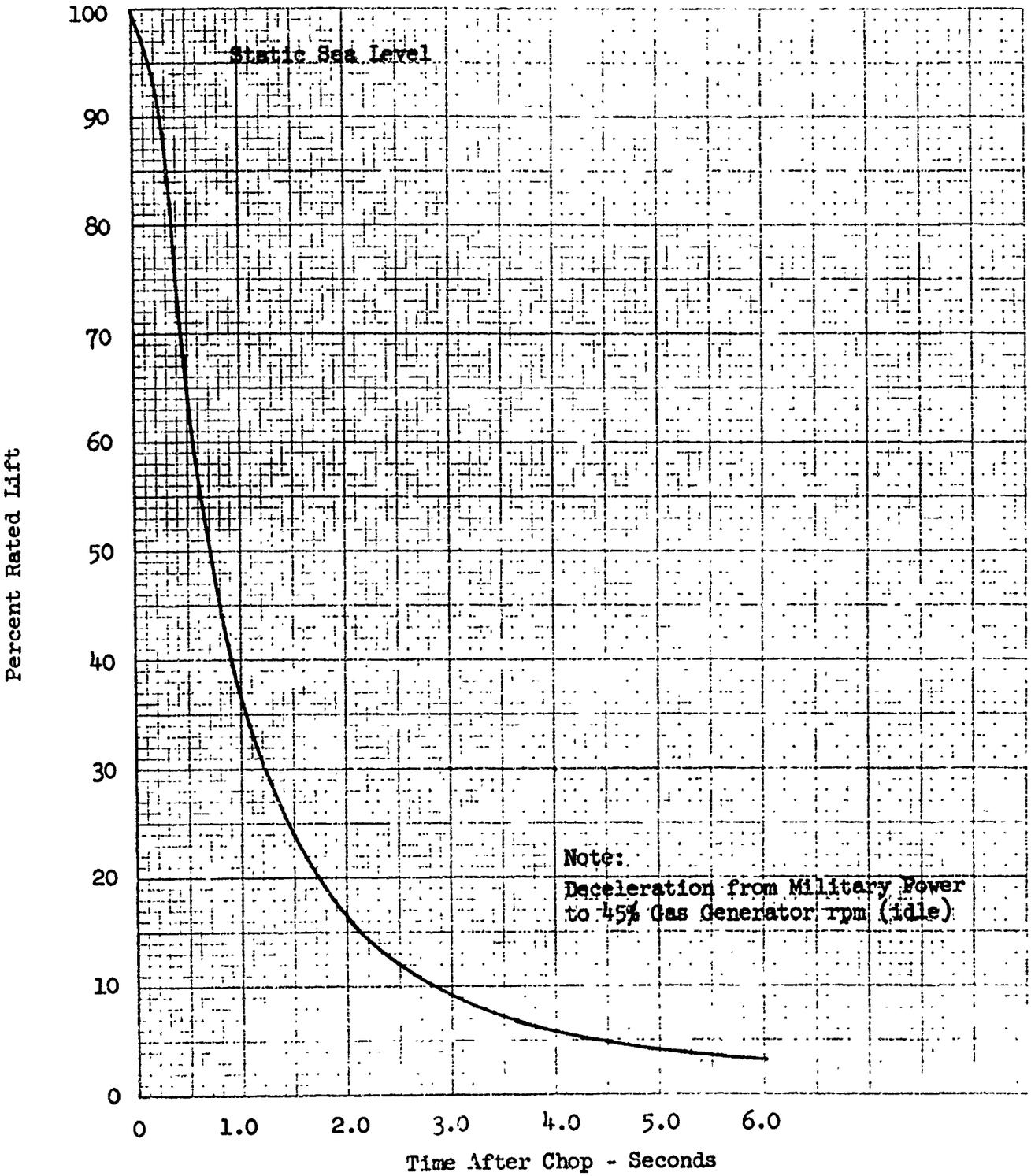
3.4.12 Stability: Under steady state conditions within the operating limits defined in the model specification, any engine thrust oscillation in either turbojet or lift mode shall not exceed $\pm$ 1 percent of the thrust at the given condition of $\pm$ 0.4 percent of the military thrust available in that mode at the given condition, whichever is the greater.



ESTIMATED TRANSIENT PERFORMANCE

TURBOJET ACCELERATION, LIFT MODE

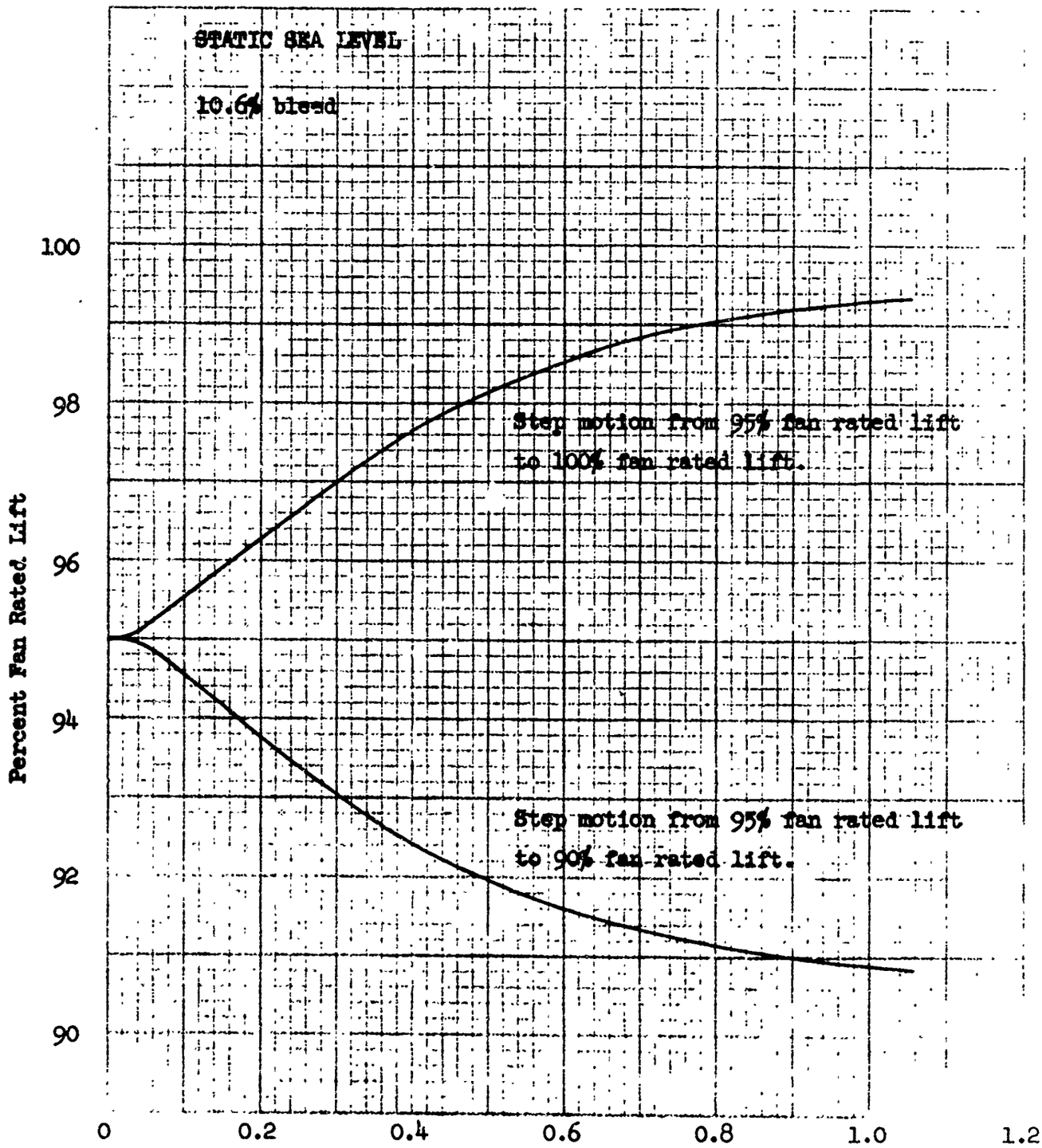
Figure 41



ESTIMATED TRANSIENT PERFORMANCE

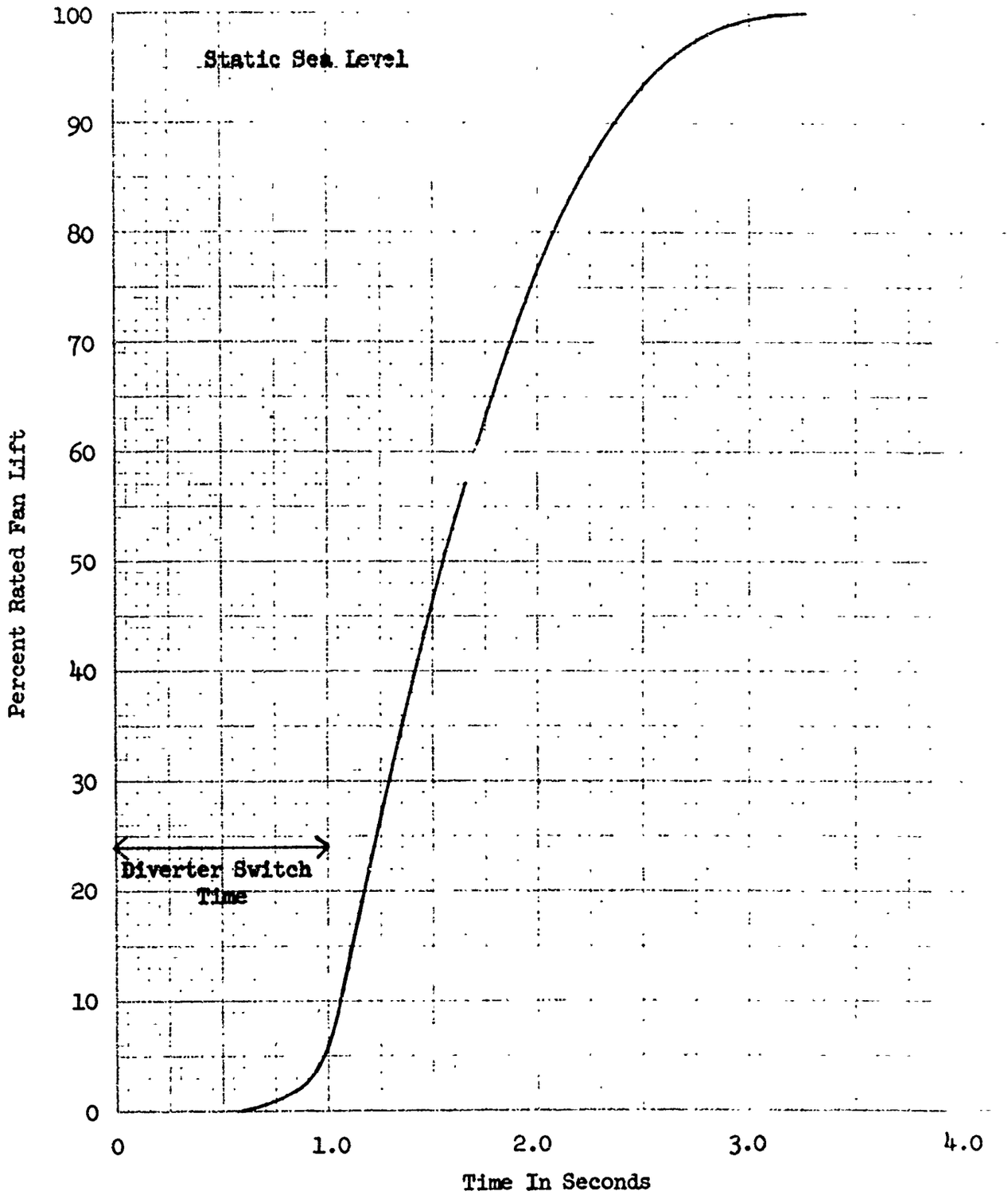
MILITARY THROTTLE CHOP, LIFT MODE

Figure 42



ESTIMATED TRANSIENT PERFORMANCE IN RESPONSE TO STEP MOTION OF TURBOJET THROTTLE

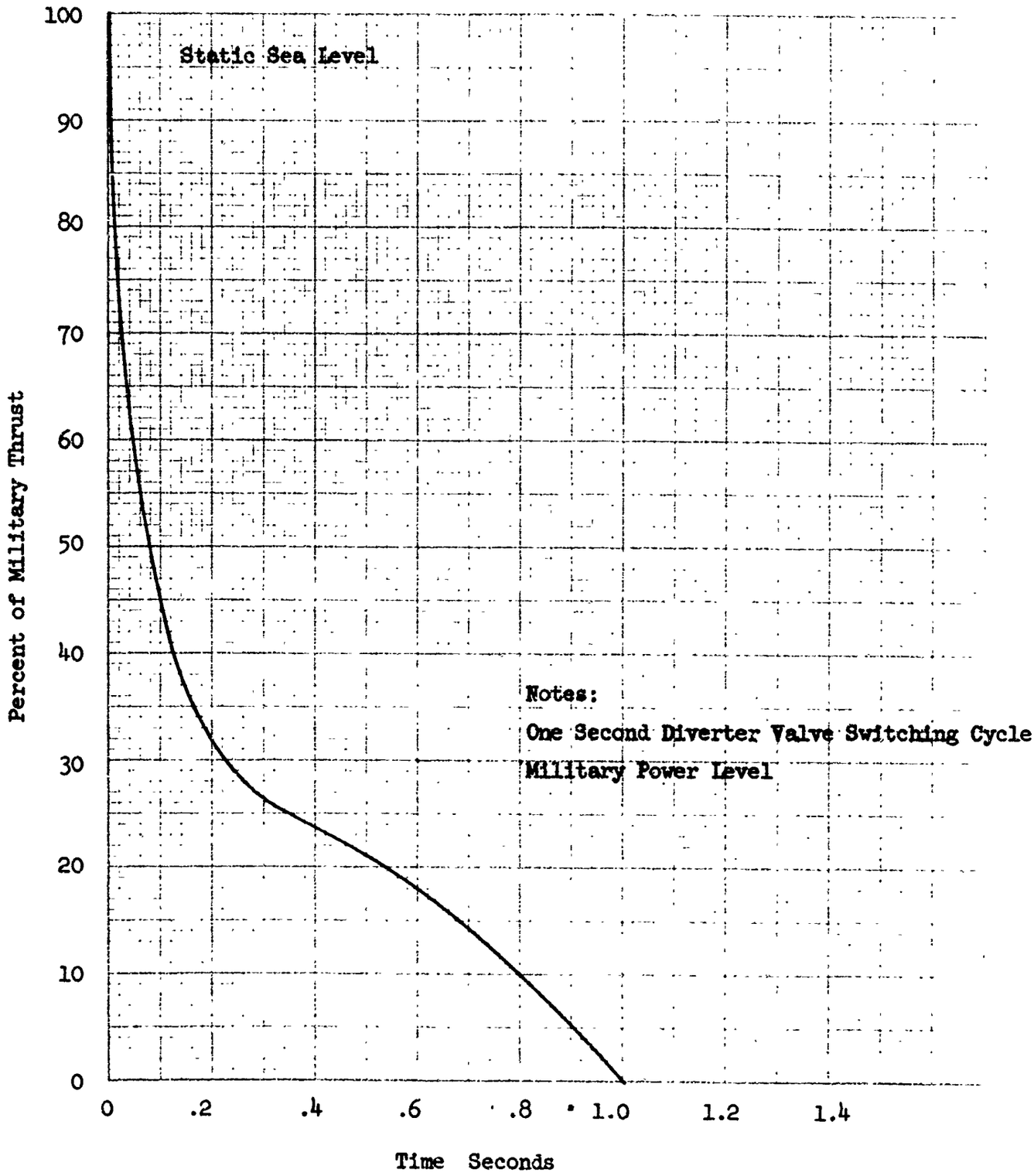
Figure 42 a



ESTIMATED TRANSIENT PERFORMANCE

TURBOJET MODE TO LIFT MODE

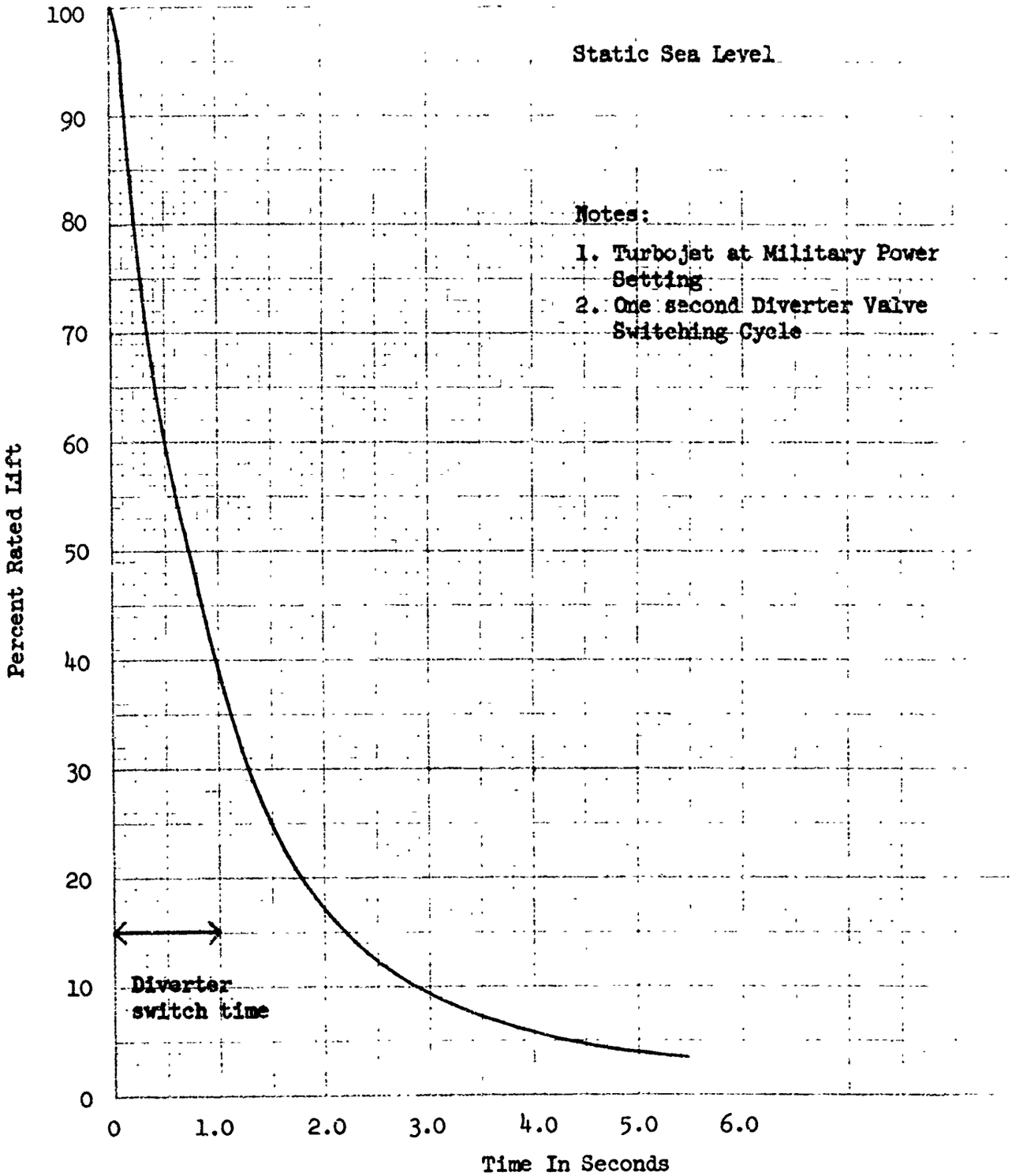
Figure 43



ESTIMATED TRANSIENT PERFORMANCE

TURBOJET MODE TO LIFT MODE

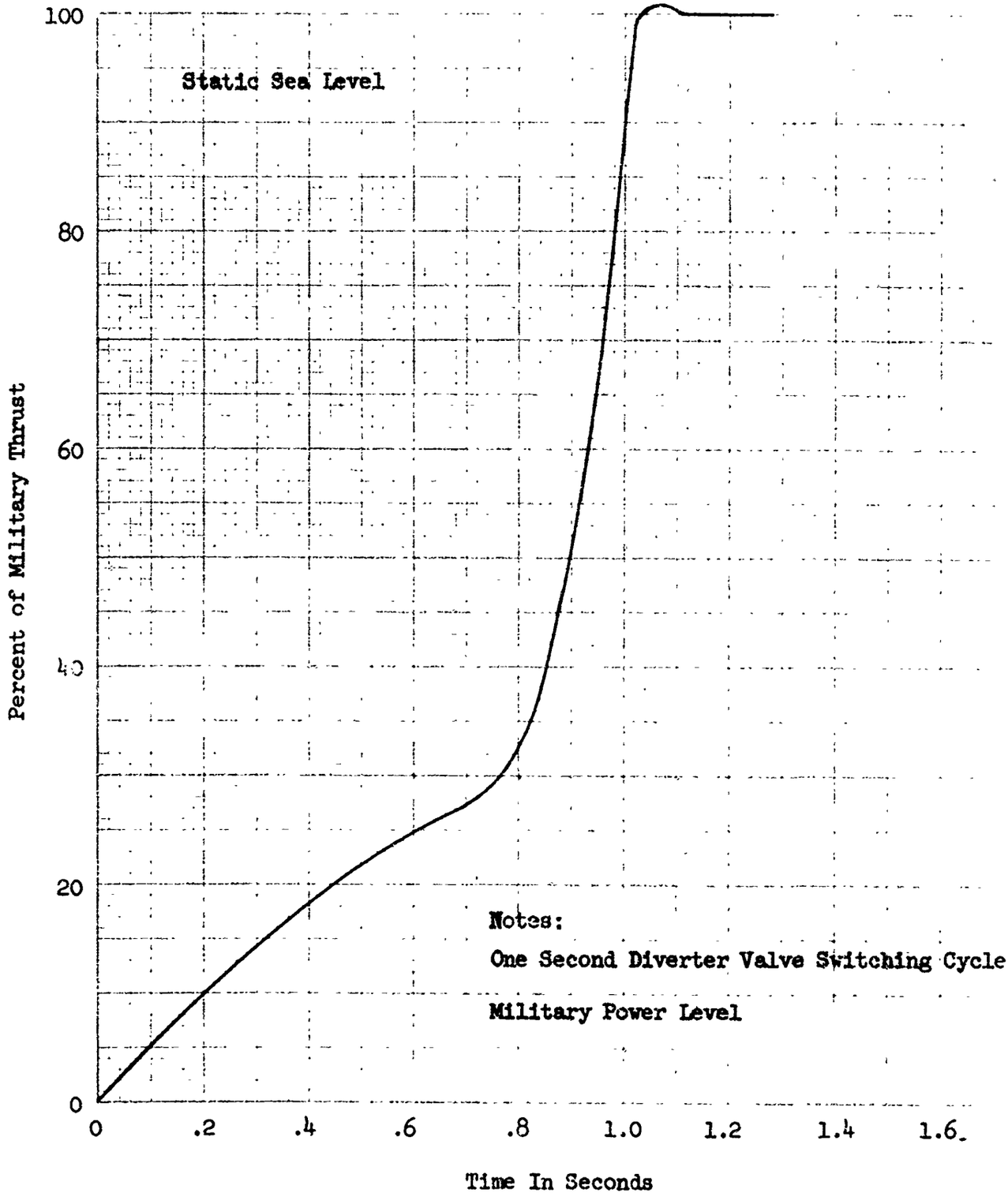
Figure 44



ESTIMATED TRANSIENT PERFORMANCE

LIFT MODE TO TURBOJET MODE

Figure 45



ESTIMATED TRANSIENT PERFORMANCE

LIFT MODE TO TURBOJET MODE

Figure 46

3.4.15 Measured Gas Temperature: The maximum allowable exhaust gas temperature shall be as follows:

Condition	Minimum Time	Temperature °F
Military Thrust	30 minutes	1250
Normal Rated and Below		1230

The maximum allowable measured transient gas temperatures shall be as follows:

Time	Temperature °F
20 seconds	1300
10 seconds	1390
5 seconds	1550
0 seconds	1800

The estimated allowable turbojet exhaust transient temperatures are shown in Figure 47.

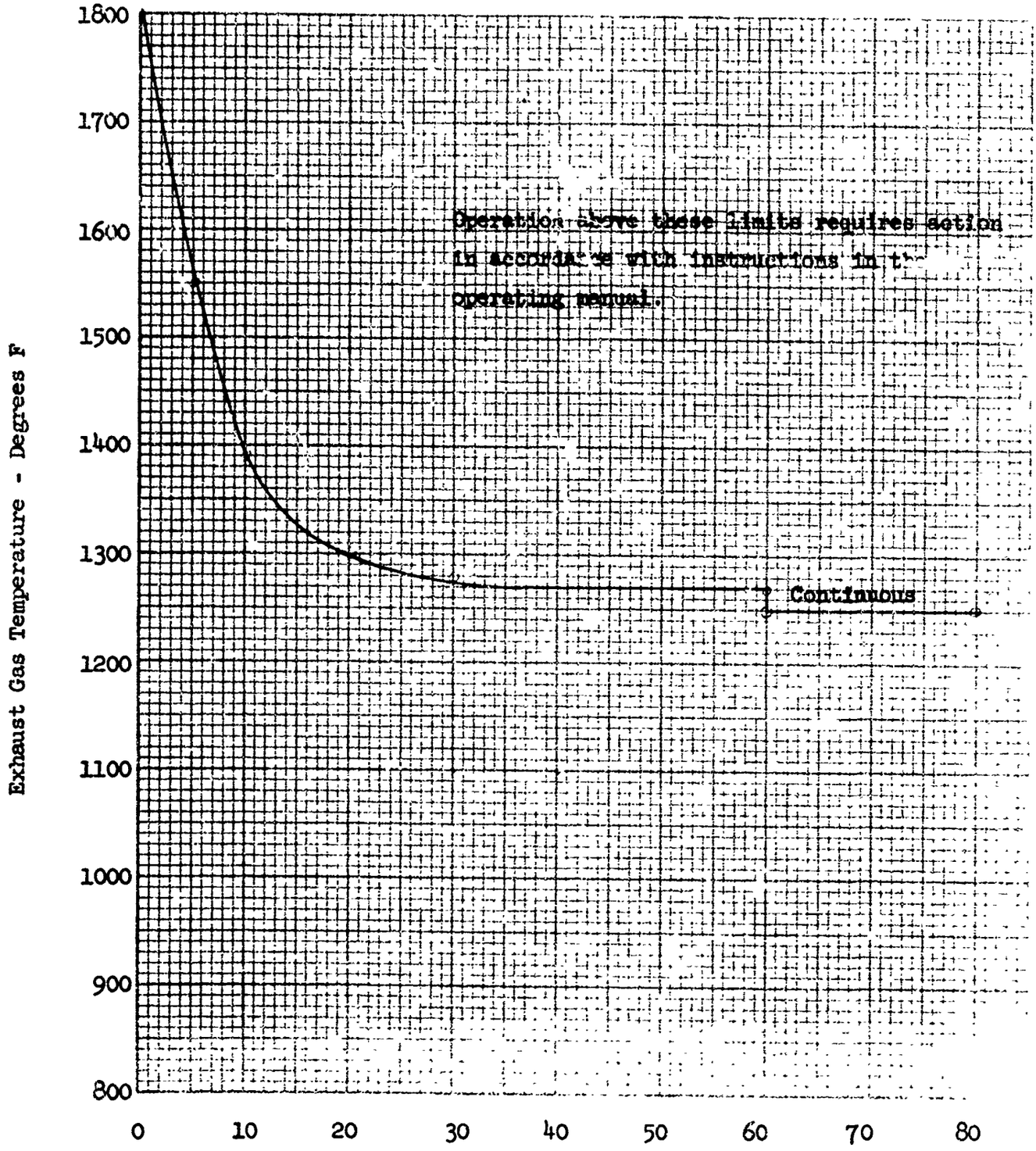
3.4.15.1 Measurement: The engine shall provide a compatible signal for operation of an AN standard tailpipe temperature indicator having a temperature range of 0 - 1000°C.

3.4.16.2 Starting Torque and Speed Requirements: Information for determining starting torque and speed requirements is shown in Figures 48 and 49.

3.4.16.3 Restart Time: The minimum allowable time between restart attempts is 30 seconds after the rotor coasts to a complete stop.

3.4.17 Thrust Indication: Not applicable.

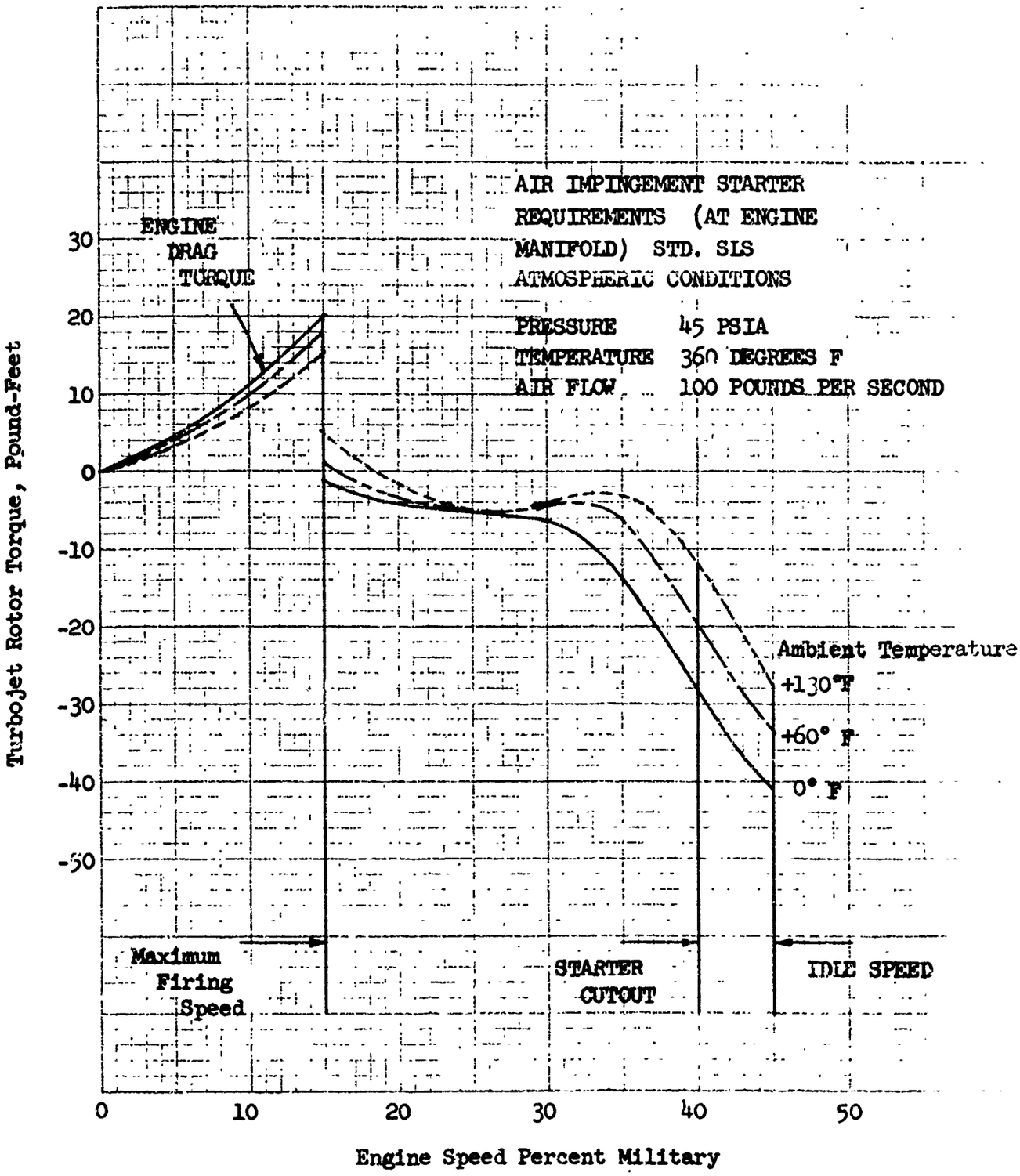
3.5 Materials and Processes: Materials and processes used in the manufacture of the X353-5B lift fan engine shall be of high quality, suitable for the purpose.



MEASURED EXHAUST GAS OVER TEMPERATURE LIMIT
(ALL OPERATING CONDITIONS INCLUDING STARTING)

Figure 47

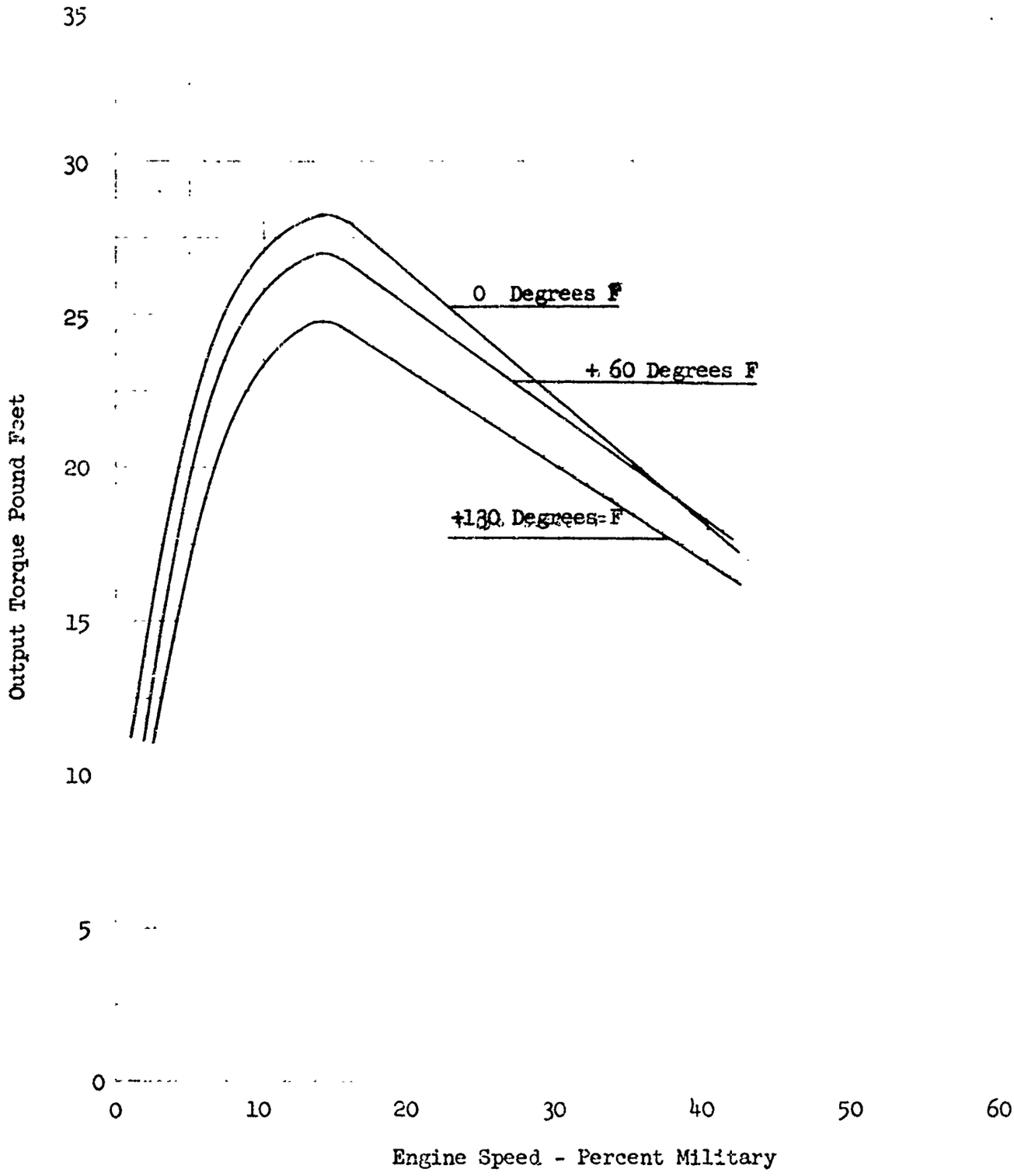
1



X353-5B TURBOJET TORQUE CHARACTERISTICS

Figure 48

1



X353-5B AIR IMPINGEMENT STARTER PERFORMANCE
WITH MA-1A STARTCART

Figure 49

3.5.1 Critical Materials: The use of critical materials, particularly chromium, cobalt, niobium molybdenum, nickel and tungsten shall be held to a minimum. Reporting of the gross and net weights of each of these materials required in the construction of the engine shall not be required.

3.7 Drawings and Diagrams: The following General Electric Company drawings and diagrams form a part of this specification:

System Installation	4012001-910
Diverter Valve Installation	4012001-912
Installation J85-5 (Dry)	4012028-441
Lift Fan Installation,X353-5B	4012001-911

3.8 Engine Design and Construction Changes: Changes to the design of this hardware which shall require change in this specification (including performance commitment, weight, envelope and limits) shall be submitted to U. S. Army TRECOM for approval before final incorporation in the propulsion system. Changes not so affecting the specification shall be at General Electric's discretion during the research program and shall not require approval of a Government Agency.

3.11.1.1 External Electrical Power: Table VII defines the estimated electrical power from external sources required by the engine.

3.11.1.2 External Hydraulic Power: Aircraft supplied hydraulic power will be required for diverter valve actuation as follows:

System maximum pressure	3000 psi
Maximum demand, diverter valve	2.75 gpm
Continuous flow, diverter valve	0.2 gpm

TABLE VII

ELECTRIC POWER REQUIREMENTS, X353-5B

Component	Voltage	Frequency	Power
Ignition Generator	103-127 VAC	320-480 cps	160 volt-amps*
Anti-Icing Valve	104-126 VAC	320-480 cps	75 volt-amps
Fuel Flowmeter**	115 VAC	400 cps	15 volt-amps
Oil Pressure Tranducer***	24-28 VAC	380-420 cps	(Negligible)
Fan rpm Sensor and Overspeed Control	28 VDC	-	(Negligible)
Exit Louver Position Transmitter	28 VAC	400 cps	(Negligible)
Diverter Valve Position Transmitter	28 VAC	400 cps	(Negligible)

* at 115 volts, 400 cps

** G.E. Model No. 8T J6 1GAB1 (Airframe Furnished)

*** U.S. Gage Co., Model No. ST-504-A (Airframe Furnished)

3.11.1.3 Exit Louver Actuation: The exit louver system defined by Installation Drawing 4012001-911 is to be actuated by means of two separate airframe provided actuators located at opposite ends of the rear frame main strut. Each actuator is to provide 3000 pound maximum force and 4 inch stroke.

3.12 Dry Weight of Complete Engine: The dry weight of the complete engine system consisting of one turbojet engine and fixed nozzle, one diverter valve and one lift fan shall not exceed 1312.5 pounds. Table VIII shows powerplant weight total and breakdown by major component groups as shown on Installation Drawing 4012001-910
Fan, engine and diverter valve mount hardware other than that shown on the installation drawings as well as all pneumatic ducting and flexible joints between the diverter valve exit flange and the scroll inlet flange are considered aircraft components; their weights are not included in the Table.
Weight of the turbojet engine is for a complete dry engine including overspeed governor, oil tank and cooler, tachometer generator, bullet-nose, oil pressure and temperature transmitters, insulation blanket, ignition system, exhaust thermocouple harness and Marman Clamp.

3.12.1 Weights of Additional Equipment: An estimated total of 36.1 pounds of research instrumentation will be installed on the propulsion systems during initial flight testing. Of this total no more than 22.6 pounds will be installed on one fan assembly, the remainder being installed on the other fan assembly, diverter valves or turbojet engines.

TABLE VIII

WEIGHT BREAKDOWN

Lift Fan Group:	
Rotor	
Front Frame including integral mounts and inlet vanes and modifications shown on drawings for incorporation of double butterfly closure; but not including closure or its actuation.	
Rear Frame including exit louver system and linkage but not including actuators.	
Scroll	
Insulation (scroll, front frame and rear frame as shown on the drawings)	
Total	838.6 Pounds
Gas Generator - Diverter Valve Group:	
J85-5 Gas Generator with overspeed governor	
Diverter Valve including actuation linkage, actuator and insulation	
Total	460.9 Pounds
Miscellaneous Controls and Instrumentation Group:	
Fan rpm pickups	
Fan bearing, temperature thermocouples	
Exit louver position transmitters	
Diverter valve mode pickup	
Leads and connectors to periphery of propulsion system envelope only	
Fan overspeed governor	
Total	13 Pounds

3.12.1.1 Weights of Additional Equipment Not Included: Items specifically not included in the weight and therefore to be furnished by the airframe contractor are:

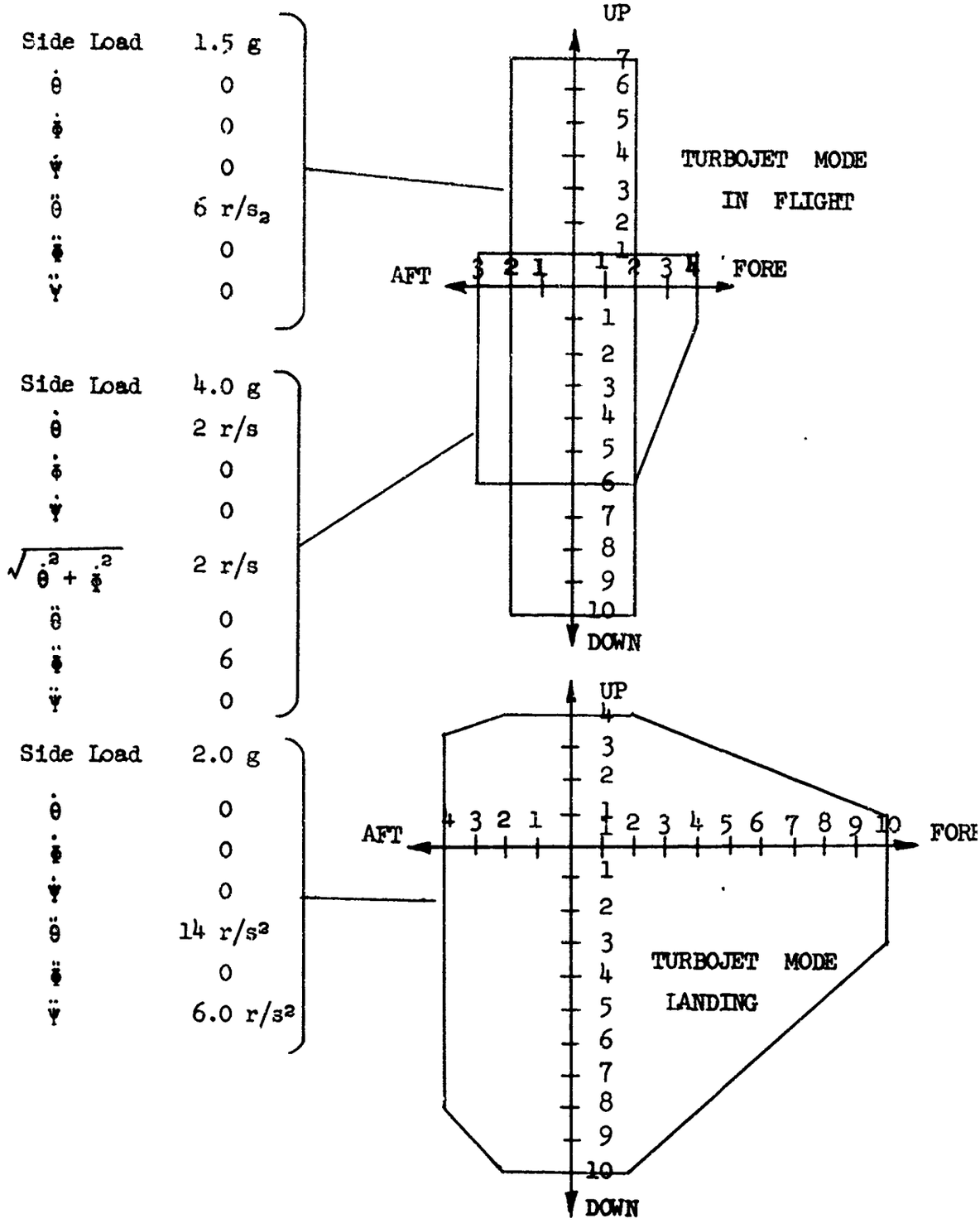
Hydraulic power supply
Inlet closure with actuator and control
Exit louver actuators and control
Diverter valve control (other than actuator cylinder supplied with diverter valve)
Fan and engine - diverter valve mounts other than integral mounts shown in Installation Drawing 4012001-910
All pneumatic ducting and flexible joints between the diverter valve exit flange and the scroll inlet flange.
Engine air-start air shut-off valve.
Turbojet mode tailpipe between diverter valve and conical nozzle shown in Installation Drawing 4012001-910
Fuel flowmeter
Oil pressure transducer

3.12.2 Weight of Residual Fluids: The estimated weight of residual fluids after engine operation and drainage is 3.5 pounds.

3.14 Flight Maneuver Forces: The engine and its supports shall withstand, without permanent deformation, the conditions specified in Figure 50 while operating in the turbojet mode and the conditions specified in Figure 51 while in the lift mode.

3.16.1 Mass Moment of Inertia of Rotating Parts: The effective mass moment of inertia of the fan rotating parts, about the fan rotor axis, is 30.20 slug-feet squared. Gyroscopic moments are computed at a fan speed of 2640 rpm (100 percent rpm). The effective mass moment of inertia about the rotor axis of the masses to be rotated by the air impingement starter shall be 0.49 slug-feet squared.

(1)



MANEUVER LOADS - TURBOJET MODE

Figure 50

Side Load	2.0g
$\dot{\theta}$	0.8 r/s
$\dot{\phi}$	0.8 r/s
$\dot{\psi}$	0.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\phi}^2}$	1.13 r/s
$\ddot{\theta}$	2.0 r/s²
$\ddot{\phi}$	2.0 r/s²

Side Load	1.0 g
$\dot{\theta}$	0.8 r/s
$\dot{\phi}$	0.8 r/s
$\dot{\psi}$	3.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\phi}^2}$	1.13 r/s
$\ddot{\theta}$	2.0 r/s²
$\ddot{\phi}$	2.0 r/s²

Side Load	1.5 g
$\dot{\theta}$	0.8 r/s
$\dot{\phi}$	0.8 r/s
$\dot{\psi}$	0.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\phi}^2}$	1.13 r/s
$\ddot{\theta}$	9.0 r/s²
$\ddot{\phi}$	16.0 r/s²
$\ddot{\psi}$	6.0 r/s²

MANEUVER LOADS - LIFT MODE

Figure 51

3.16.2 Moments of Inertia: Table IX defines three-axis moments of inertia of the major separable powerplant components. These moments of inertia are computed with respect to the centers of gravity defined in paragraph 3.36.1. Orientation of components with respect to aircraft axes is shown on Installation Drawing 4012001-910.

TABLE IX

MOMENTS OF INERTIA

Component	Moment of Inertia - lb. sec.^{2}ft. Roll Axis	Pitch Axis	Yaw Axis
Turbojet, Diverter Valve and Conical Nozzle attached to diverter valve flange	6.2	39.3	39.2
Lift fan	104	91	140

3.17 Engine Vibrations: The maximum permissible engine case vibration displacements shall be as follows:

TURBOJET (vibrations at frequencies below 70 cps to be filtered out)

Location	Maximum Displacement
Compressor stator forward flange	4 mils steady
	5 mils peaking
Turbine frame forward flange	3 mils steady
	4 mils peaking

LIFT FAN (directions given with respect to fan axis)

Location	Maximum Displacement
Forward end of forward strut	10 mils steady
axial displacement	20 mils maximum instantaneou reading during transient
Bulletnose axial displacement	10 mils steady
	20 mils maximum instantaneou reading during transient
Outboard strut outboard end tangential	10 mils steady
and radial displacements	20 mils maximum instantaneou reading during transient

3.18 Compressor Customer Air Bleed: Compressor air bleed pressure and temperature ratios shall be as shown on Figures 52 and 53. The maximum permissible quantity excluding anti-icing which can be bled from each of the four ports in the midframe section of the engine shall not exceed 1-1/2 percent of engine airflow. There shall be no airflow bled during starting.

3.18.1 Compressor Interstage Bleed: Compressor interstage bleed required for engine operation is discharged at two manifolds mounted on the compressor casing. Flow conditions of this bleed flow in the manifold are as shown in Figure 54.

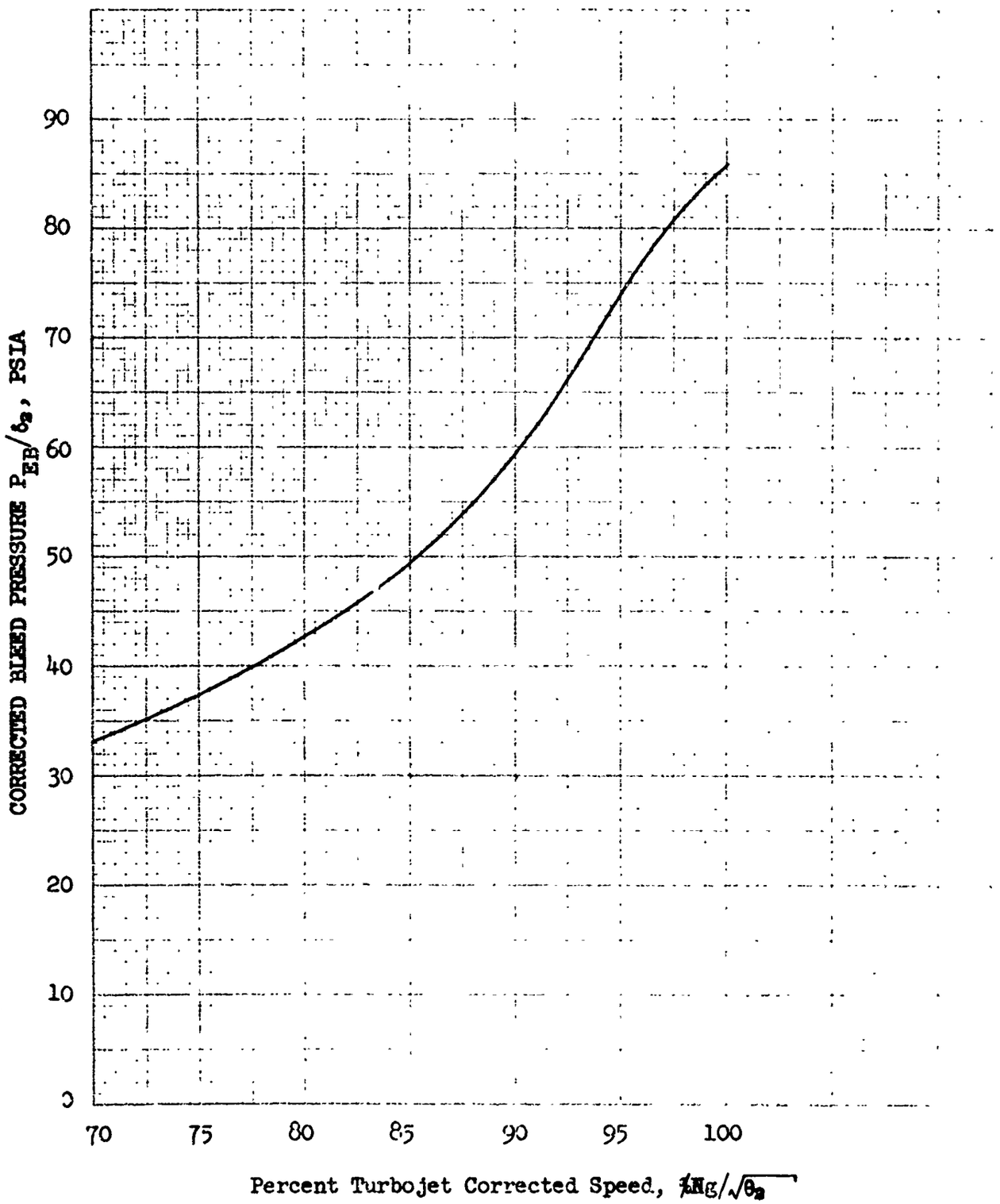
3.19.2 Engine Component Limiting Temperature: The maximum allowable operating surface temperatures of the turbojet engine are as follows:

Zone	Maximum Allowable Surface Temperature
Compressor Inlet	250°F
Compressor Discharge	750°F
Combustion Section	850°F
Turbine Casing	1150°F

The following are the maximum operating temperatures for certain turbojet engine mounted components:

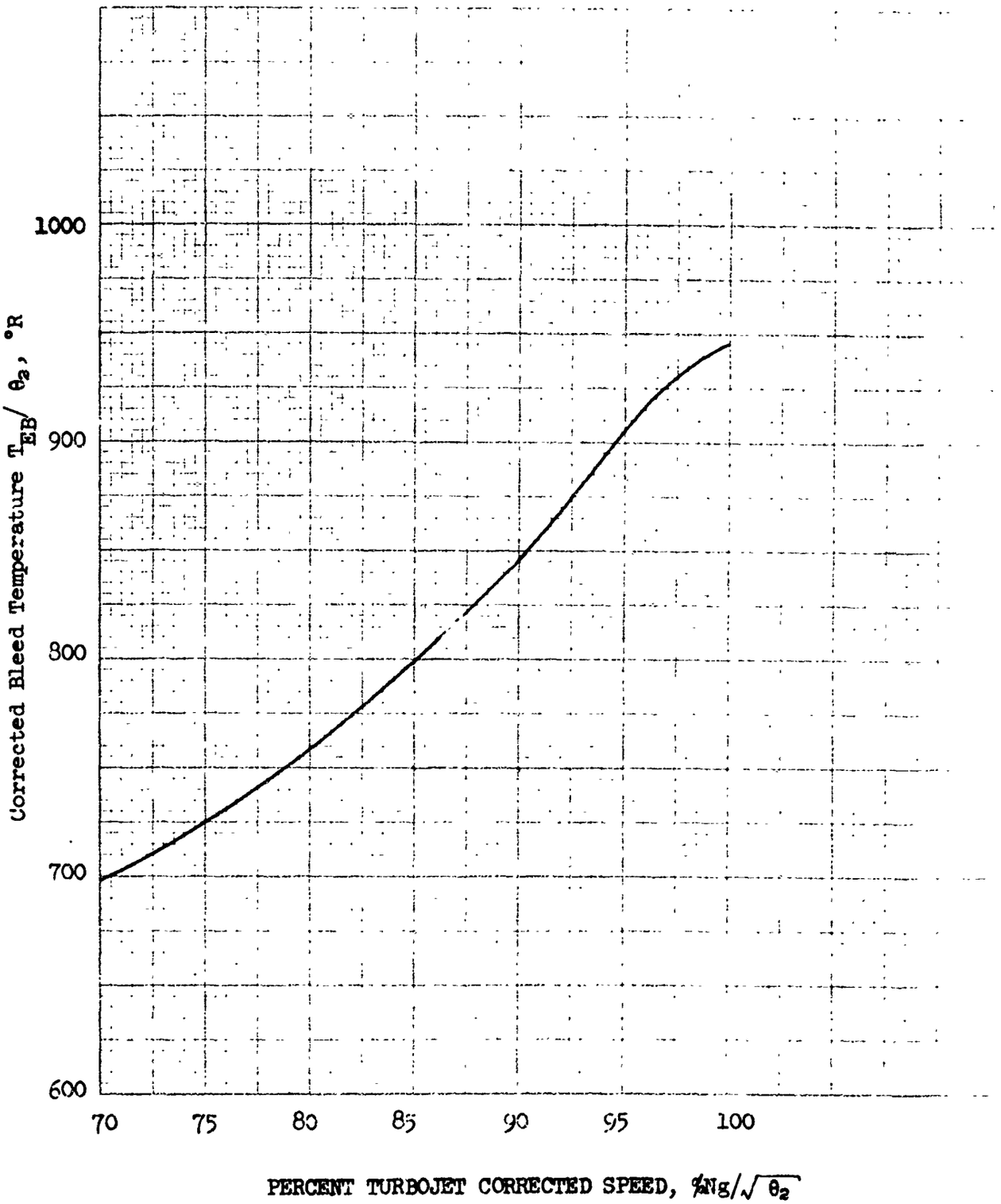
Component	Temperature (ambient)
Ignition generator	350
T5 Harness disconnect	350
Power Pack	300
Tachometer-Generator Alternator	285
Anti-Icing Valve	275
Junction Box	300

All other turbojet engine components are designed for continuous operation when surrounded by air at an ambient temperature of 250°F.



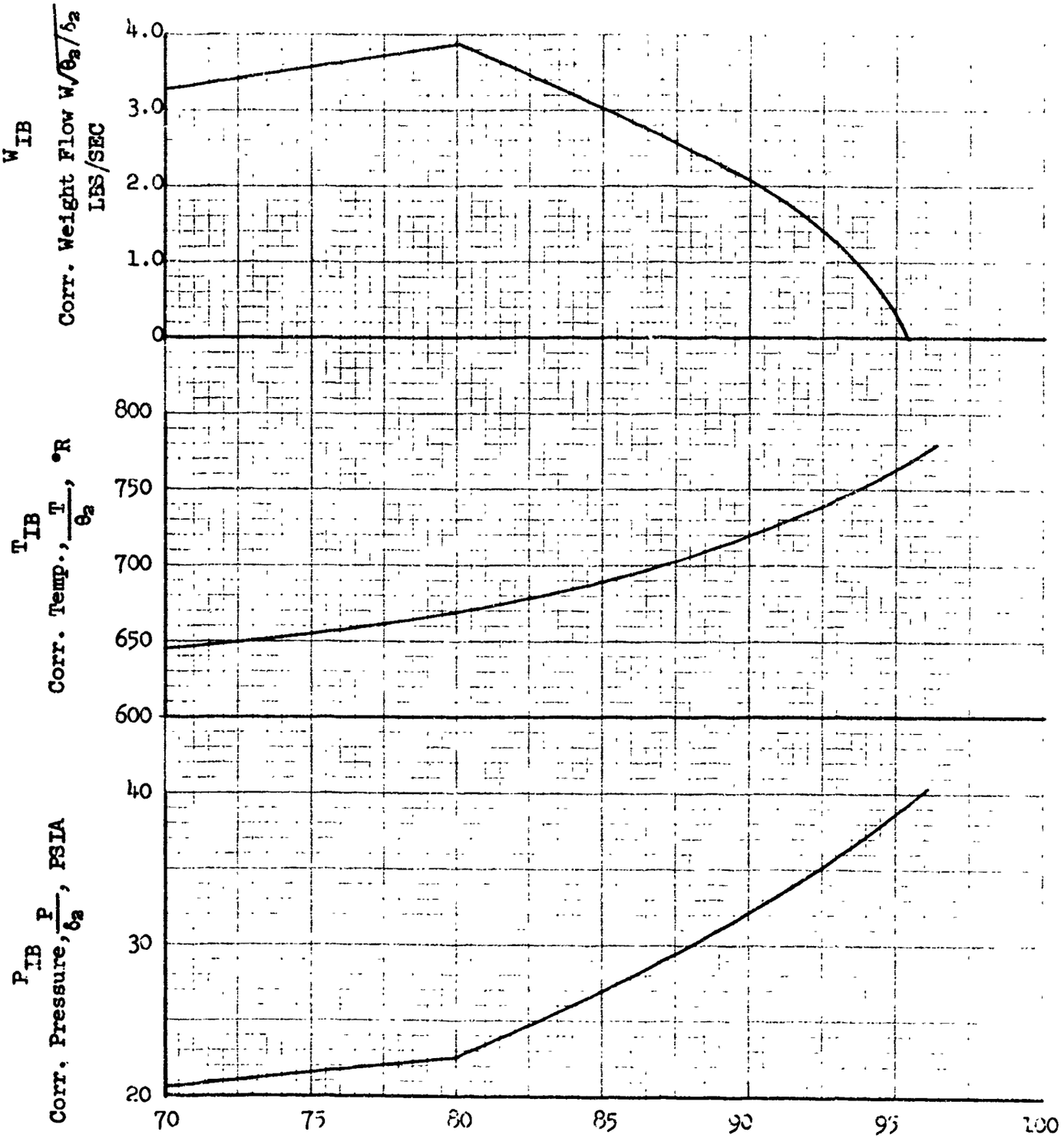
TURBOJET CUSTOMER COMPRESSOR BLEED PRESSURES

Figure 52



TURBOJET CUSTOMER COMPRESSOR BLEED TEMPERATURES

Figure 53



TURBOJET COMPRESSOR INTERSTAGE BLEED FLOW PROPERTIES

Figure 54

These zone temperatures are based on convection cooling only; however, the accessories must be placed in an area where they are exposed to induced air flows except for short transient periods which may occur in certain installations.

The diverter valve, scroll and the inboard (scroll) side of the fan rear frame are designed to operate at gas temperature and therefore no special cooling is needed to maintain these parts within their temperature limits.

The outboard side of the rear frame structure that forms the bucket channel has insulation on the inside. The temperature of this structure must not exceed 300°F. The remainder of the fan components must not exceed 250°F at any time.

3.19.3 Insulation Properties: The scroll and rear frame insulation blankets are 1/2 inch thick and have a conductivity of 0.8 BTU/hr/ft^2/inch/degree Farenheit at a mean insulation temperature of 900°F. The diverter valve insulation blanket is 1/4 inch thick and has a conductivity of 0.4 BTU/hr/ft^2/inch/degree Farenheit at a mean insulation temperature of 900°F.

3.20.1 Inlet Protection: Air inlet screens will not be provided for the turbojet engine or lift fan and no provisions will be made to incorporate them as an integral part of the basic engine or lift fan.

3.20.3 Turbojet Inlet Air Pressure and Temperature Variation: The turbojet engine shall operate satisfactorily at all altitudes and flight speeds within the engine flight envelope with inlet air pressure and temperature distribution limits at the engine face as stated below. These limits will apply within the complete engine face area except for the annular areas within 3 percent of the engine inlet radius from the inner hub and from the outer wall, respectively, where boundary layer air normally exists.

(a) Maximum Non-Uniformity in Total Pressure

The difference between maximum and minimum total pressure at the compressor inlet will not exceed ten percent of the average total pressure

(b) Maximum Non-Uniformity in Static Pressure

The difference between maximum and minimum static pressure at the inside wall of the compressor inlet will not exceed five percent of the average total pressure.

For each individual installation, it is necessary for the General Electric Company and the airframe manufacturer to jointly establish compatibility between the airframe duct and the engine within the flight envelope of the airplane-engine combination.

3.20.3.1 Lift Fan Inlet Air Pressure: For each individual installation it is necessary for the General Electric Company and the airframe manufacturer to jointly establish compatibility between the airframe and fan inlet to assure satisfactory operation.

3.20.4.1 Allowable Turbojet Inlet Connection Stresses: The turbojet engine intake duct attachment shall be of the quick disconnect type. A flexible type connection is recommended. The following values apply under any flight condition:

Maximum shear	60 pounds
Maximum bending moment	500 pound-inches
Maximum Axial Load	500 pounds

3.20.4.2 Allowable Fan Inlet Connection Stresses: The X353-5B lift fan inlet bellmouth connection shall be of a flexible type so as not to transmit airframe loads to the fan front frame.

3.21.1 Type of Anti-Icing: Anti-icing provisions are made for the turbojet engine only. The lift fan shall have no anti-icing provisions. The solenoid valve for the turbojet anti-icing duct is a normally opened valve. Anti-icing of the engine inlet will be cockpit controlled, non-continuous. An ice detector will not be supplied with the engine.

3.22 Fire Shield Attachment: No fire shield attachment is provided.

3.24.1.1 Allowable Diverter Valve Exhaust Connection Stresses: The diverter valve axial (turbojet mode) exhaust duct attachment shall be of the quick-disconnect type. The diverter valve diverted (lift mode) exhaust attachment shall be of the bolted type. Both duct attachments must incorporate sufficient flexibility such that airframe and ducting loads are not transmitted to the diverter valve. Nominal loads of the flexible connection not to exceed the following may be accepted:

	Axial Flange	Diverted Flange
Shear	500 pounds	200 pounds
Axial	1000 pounds	500 pounds
Bending moment	7000 pound-inches	2400 pound-inches
Torque	6000 pound-inches	2600 pound-inches

3.24.1.2 Allowable Scroll Duct Connection Stresses: The scroll duct attachments shall be of the quick-disconnect type. Both attachments must incorporate sufficient flexibility such that no airframe or ducting loads are transmitted to the scroll. Nominal loads of the flexible connection not to exceed the following may be accepted:

Shear	350 pounds
Axial	700 pounds
Bending Moment	2400 pound-inches

3.24.1.3 Allowable Lift Fan Exhaust Connection Stresses: The X353-5B lift fan exhaust connection shall be of the flexible type so as not to transmit airframe loads to the fan rear frame.

3.25.1 Oil Supply: The capacity of the oil reservoir of the turbojet shall be:

Useable	0.700 gallons
Unuseable	0.175 gallons
Expansion Space	0.219 gallons

3.25.5 Oil Pressure and Temperature: The operating oil pressure at normal rated thrust shall be 35 psig ± 15 psig at 225°F oil temperature. The oil pressure and temperature indicator ranges required for cockpit indicators are 0 to 100 psig and 0 to 310°F respectively.

3.26.1.1 Performance With Assistance From Airplane Boost Pump: The engine fuel system shall supply the required amount of fuels at the required pressures throughout the operating range of the engine including starting and augmentation with the following conditions at the fuel inlet connections on the engine:

(a) Fuel temperature - from a minimum of -65°F to a maximum of 110°F

(b) Fuel pressure - from 10 psi absolute to 50 psi gage. Engine pump inlet pressure must equal or exceed airplane fuel tank pressure at all times.

3.26.1.2 Performance With No Assistance From Airplane Boost Pump: The entire fuel system shall supply the required amount of fuel at the required pressures for engine operation up to a minimum of 6000 feet altitude, including air starting and augmentation under the following conditions:

(a) Compressor inlet ram pressure ratio at 1.15
(b) Ambient air temperature at standard day condition
(c) Fuel temperature at the fuel inlet connection at 110°F
(d) Vapor/liquid ratio of fuel at the fuel inlet connections from zero to 0.45.

3.26.6 Flowmeter: The engine shall include provisions for installing an airframe-furnished fuel flowmeter transmitter, General Electric model number 8TJ61CAB1 or equivalent, in the high pressure side of the main engine fuel system.

3.27 Engine Control System Turbojet-Mode: The control system for the Government furnished turbojet engine shall be used for all turbojet-mode operation. Removal of afterburner and variable nozzle controls shall be permitted in modifying to non-afterburning configuration. Otherwise, the control shall be unmodified. Adjustments shall be permitted as defined in the turbojet model specification.

3.27.3 Engine Control System Lift-Mode: During lift-mode operation the turbojet throttle quadrant, controlling turbojet rpm directly, provides open-loop control of lift fan thrust level.

3.27.7.1 Potential Aircraft Control: The exit louvers of each lift fan are capable of independently spoiling and vectoring fan thrust. The combination of independent spoiling and vectoring action may be utilized in a V/STOL aircraft for any or all of the following control functions as shown in Figure 55:

Altitude or vertical acceleration (symmetrical spoiling)
Horizontal acceleration (symmetrical vectoring)
Roll Control (differential spoiling)
Yaw Control (differential vectoring)

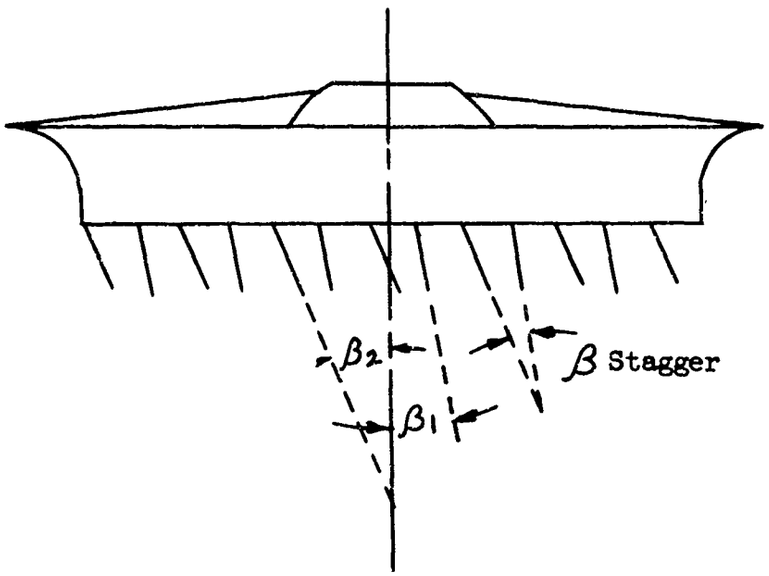
The limits of movement are -10 degress to +45 degrees of vectoring, and 0 to 40 degrees of spoiling, as shown in Figure 56.

3.27.7.2 Operating Mode Selection: The lift or turbojet modes of power plant operation are selected by controlling position of diverter valve. The control device is to be provided by the airframe manufacturer. The selection is nominally a two position choice; diverter valve position dwell between through-flow and diverted flow is not provided for.

3.27.7.2.1 Inlet Closure Control: The inlet closure control is to be provided by the airframe manufacturer and must be integrated with the operating mode selection control so as to prevent closure at fan speeds above 40 percent rpm.

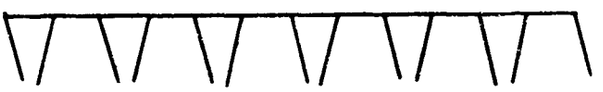
3.27.7.2.2 Exit Louver Control: The exit louver control is to be provided by the airframe manufacturer and must be integrated with the operating mode selection control so as to prevent closure at fan speeds above 40 percent rpm.

Dual Actuated - Staggered Exit Louver Nomenclature



Zero Vector Discharge Flow

Zero Vector Discharge Flow
Plus Thrust Magnitude Control



Simple Thrust Vectoring

Thrust Vectoring Plus
Thrust Magnitude Control

EXIT LOUVER SYSTEM

Figure 55

3.27.7.4 Lift Trim: Means are provided in the propulsion system for ground adjustment of scroll nozzle area in order to balance lift between pairs of lift fans and to assure operation of turbojet engines at their design conditions.

3.27.7.4.2 Fan Overspeed Control: Provision will be made for incorporation of fan overspeed protection through positive reduction of power to fan preventing continuous operation at fan speeds in excess of 103 percent.

3.27.7.6.1 Reliability Analysis: A flight safety and system reliability analysis shall be jointly conducted by the General Electric Company and the airframe contractor and a report submitted to U.S. Army TRECOM.

3.29 Accessory Drives: The types of each drive, the number used, and the gear ratio to the engine turbine shaft, the maximum permissible torque in pound-inches for continuous operation, the maximum permissible static torque in pound-inches, and the direction of rotation when looking at the drive on the engine shall be as shown on Table X. Maximum shaft power available shall be as shown in Figure 57.

3.34 Identification of Product: Major parts shall be identified with part and serial numbers. Additional nameplates shall not be required.

3.36 General Additional Information

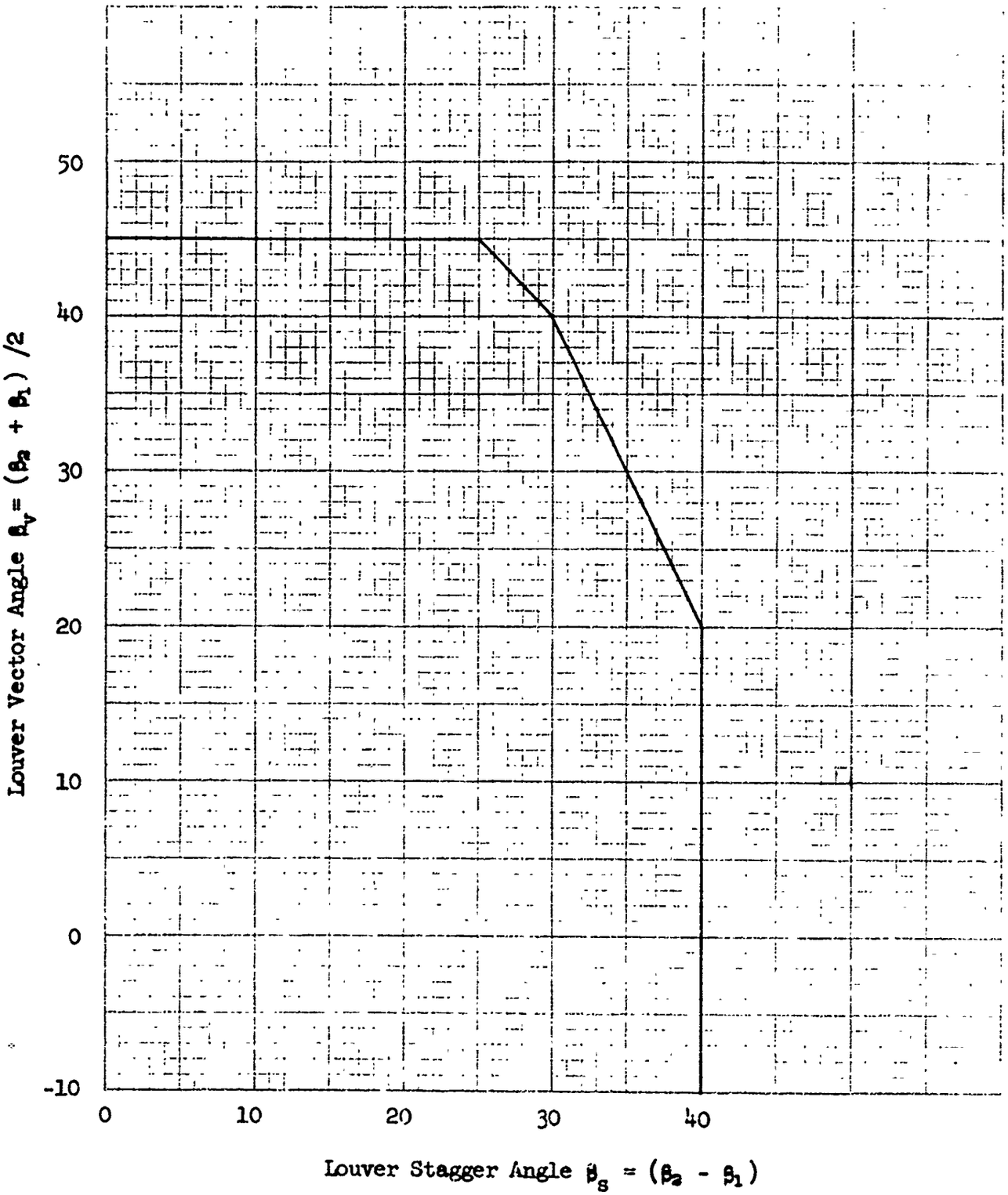
TABLE X

POWER TAKEOFF DATA FOR X353-5B TURBOJET
634E900 GEARBOX

Axis	Name of Pad	AND No.	Type	Ratio to Mainshaft	Max. rpm	Max. Cont. Torque in/lb.	Max. Static Torque in/lbs.	Direction of Rotation	Horsepower
N Front	PTO (Customer)	Special	-	0.473/1	7811	500*	2200**	CCW	62
N Rear	Customer	20002	X11D	0.430/1	7088	500	2200	CW	31
P Front	Customer	Special	-	1.45/1	23921	79	-	CCW	30

* 500 inch pounds and 52 horsepower torque allowance

** 2000 inch pounds additional allowed as maximum momentary overload



LIMITS OF OPERATION OF X353-5B FAN EXIT LOUVERS

Figure 56

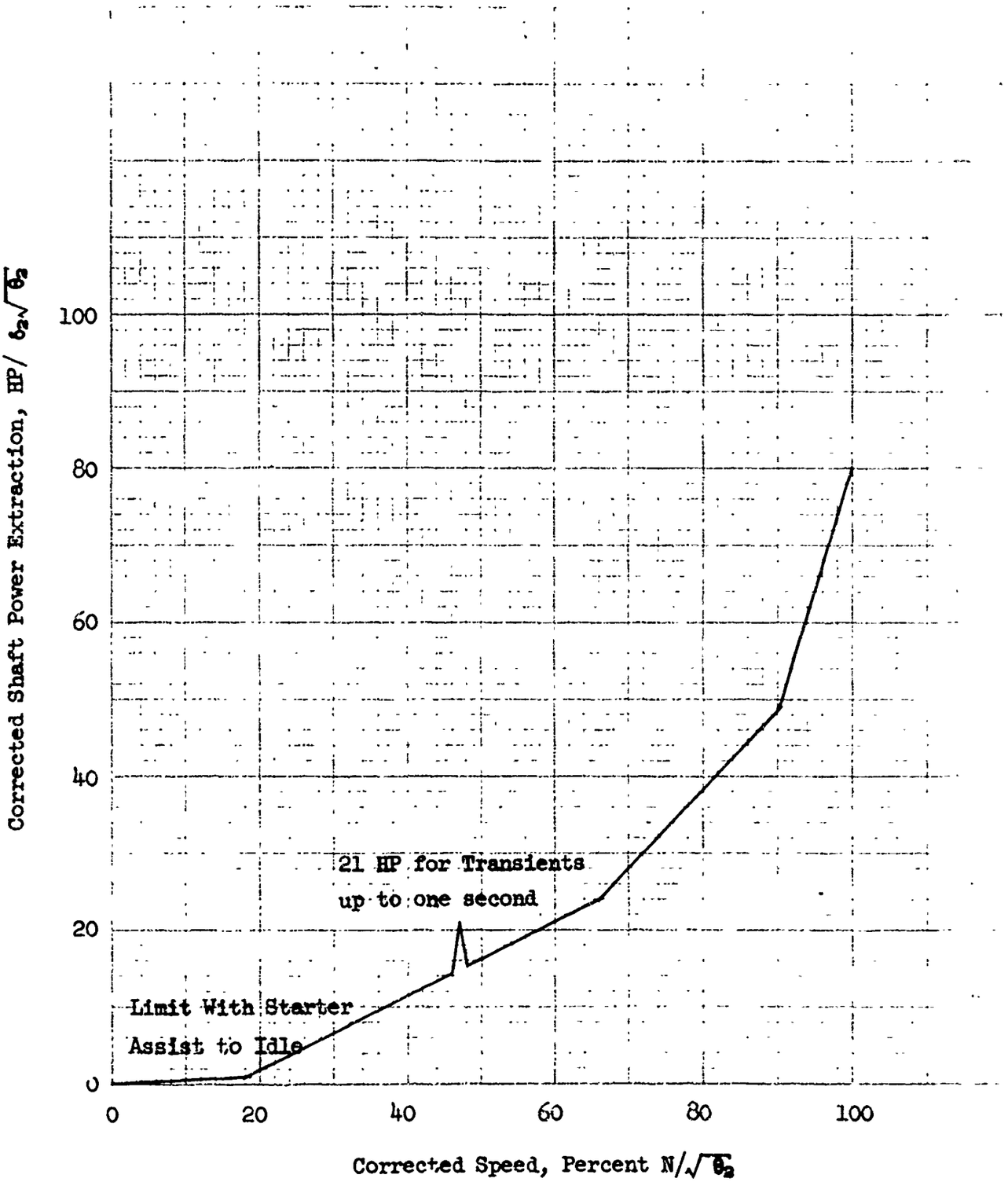

Corrected Shaft Power Extraction, HP/ $\delta_2\sqrt{\theta_2}$
100
80
60
40
20
0
0
20
40
60
80
100
Corrected Speed, Percent $N/\sqrt{\theta_2}$
21 HP for Transients
up to one second
Limit With Starter
Assist to Idle

Figure 57

3.36.1 Center of Gravity: Table XI in conjunction with Installation Drawing 4012001-910 defines centers of gravity of the major components.

TABLE XI

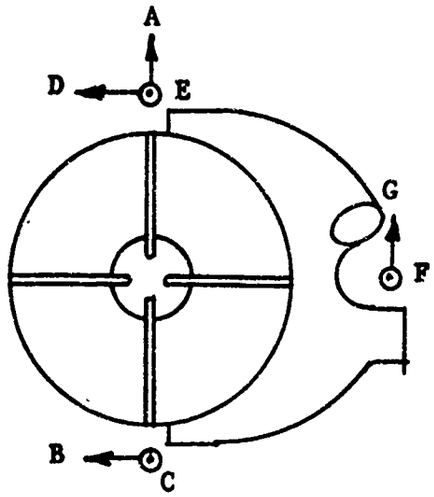
WEIGHT AND CENTER OF GRAVITY

Component Group	Weight	C.G. Location
J85 Gas Generator, Diverter Valve, Plus Instruments	462.9	The turbojet engine/ diverter valve C.G. is located 22.80" aft of the engine front flange, 1.10" below the horizontal engine centerline and .20" to starboard of the vertical engine centerline.
Lift fan plus instruments	849.6	The lift fan C.G. is located 5.3" from fan rotating axis on minor strut centerline and vertically 0.62" above rotor centerline.

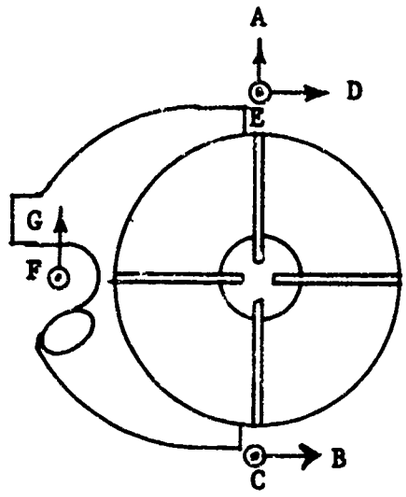
3.36.3 Mount Loads: Reaction forces on powerplant component mounting points are defined in Tables XII and XIII. Values are presented for unit load factors and maneuvers at steady-state military power level, ARDC standard sea level atmosphere and do not imply operating limits. Limits are defined in paragraph 3.14.

TABLE XII

X353-5B FAN MOUNT RELATIONS



LEFT HAND FAN



RIGHT HAND FAN

Maneuver	A	B	C	D	E	F	G
1 rad/sec. Pitch			$\mp$ 1195		$\mp$ 1195	$\pm$ 2360	
1 rad/sec. Roll			$\pm$ 1240		$\pm$ 1240		
1 g vertical			$\pm$ 383		$\pm$ 383	$\pm$ 93	
1 g side		$\pm$ 429	$\pm$ 37	$\pm$ 429	$\pm$ 37	$\mp$ 74	
1 g axial	$\pm$ 770		$\mp$ 37		$\pm$ 37		$\pm$ 88
Cross Flow Effect*							
Left Hand Fan	+ 308		+ 210		+ 210	- 420	
Right Hand Fan	- 308		- 210		- 210	+ 420	
Lift (β = 0)							
Left Hand Fan							
Right Hand Fan							
Lift (β = 40°)							
Left Hand Fan							
Right Hand Fan							

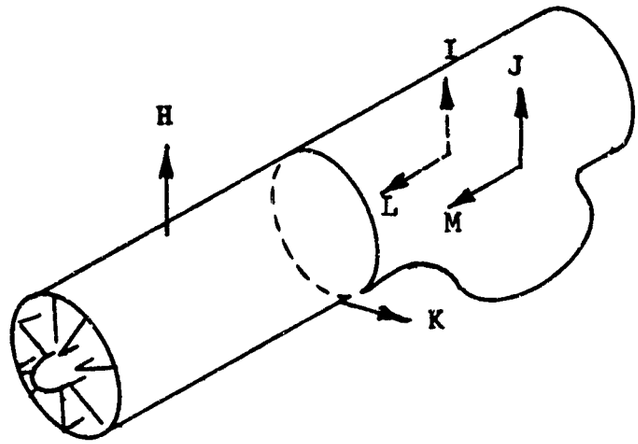
* At 120 knots, military power.

Note: Forces are positive (+) in the directions shown and are forces acting on the fan.

TABLE XIII

TURBOJET AND DIVERTER VALVE MOUNT REACTIONS

Reactions given with respect to turbojet axis.



Maneuver	Reaction					
	H	I	J	K	L	M
1 g vertical	± 357	± 56	± 56			
1 g side		± 222	∓ 222	± 468	∓ 250	± 250
1 g axial					± 234	± 234
1 rad/sec. Pitch					± 560	∓ 560
1 rad/sec. Yaw	± 276	∓ 138	∓ 138			
Axial Thrust*					- 2630	- 2630
Diverted Thrust **	- 157	- 3470	- 3470		- 312	- 312

* Slip Joint Connection, SLS, Standard Day.

** Bellows Connection, SLS, Standard Day.

Note: Forces are positive (+) in the directions shown and are forces acting on the engine.

3.36.4 Interconnecting Duct Design Data: Flexible joints and connecting ducting between the discharge flange of the diverter valve and the inlet flange of the scroll are to be supplied by the aircraft contractor. Basic system design and mount loads are based on zero shear, moment and axial loads at both diverter valve exit and scroll inlet flanges. Therefore, duct connection loads should be negotiated with the engine manufacturer.

Duct mechanical design should be based upon:

Maximum gas temperature =	1250°F average
Maximum gas pressure =	38 psia

3.36.5 Diverter Valve Actuation: Diverter valve actuation is provided on either right or left hand side to suit installation requirements.

3.36.6 Instrumentation: The X353-5B will incorporate permanent instrumentation for flight safety and operating convenience. Instrumentation will include fan rpm pickup, fan bearing temperature thermocouples, exit louver position transmitters and a diverter valve mode pickup. Additional instrumentation required for turbojet engines was described in paragraphs 3.4.15.1, 3.25.5 and 3.26.6.

3.36.7 Fan Contribution to Stability: The estimated aerodynamic force derivative for any translation of the fan along the X, Y or Z axis is $-2.374 \sqrt{L\ \rho o}$ lb/ft/sec. The estimated aerodynamic moment derivative for any angular velocity of the fan about the pitch or roll axes is $-1.607 \sqrt{L\ \rho o}$ lb-ft/rad/sec and about the yaw axis is $-3.214 \sqrt{L\ \rho o}$ lb-ft/rad/sec. These moments and forces are taken about the center of the fan inlet. These derivatives are all negative (i.e., they oppose the motion).

3.36.8 Exit Louver Leakage Area: The exit louvers do not seal when closed. The estimated leakage area is twenty seven (27) square inches.

3.36.9 Diverter Valve Leakage: The diverter valve gas seal maximum leakage is 0.8 percent. This leakage gas must be purged from the fan cavity during horizontal flight to prevent fan cavity ambient temperatures from exceeding 250°F.

3.36.10 Scroll Seal Leakage: During lift mode operation the scroll seal estimated maximum leakage will be 0.2 percent.

4. QUALITY ASSURANCE PROVISIONS

4.1 The requirements for quality assurance shall be as specified in MIL-E-5007B 22 January 1959, as modified herein.

4.3 Qualification Tests: Not applicable

4.4 Flightworthiness Test: Prior to aircraft flight, a Flightworthiness Test will be accomplished on an X353-5B engine in accordance with Specification 114.

4.5 Acceptance Tests: Acceptance tests shall be conducted on each engine in accordance with Specification 116.

5. PREPARATION FOR DELIVERY

5.1 Preparation for Shipment: Shipping containers shall be provided for the lift fans and diverter valves and other items to be transported which shall adequately protect the equipment en route. Containers for extended time storage shall not be required.

6. NOTES

6.2.1 Definitions: Except as noted below, the definitions and symbols used in this specification shall be as specified in MIL-E-5007B.

6.2.1.1 Qualification Tests: Not Applicable

6.2.1.2 Flightworthiness Tests: Flightworthiness tests shall be those tests conducted to demonstrate the suitability of the propulsion system for limited use in research aircraft flight testing.

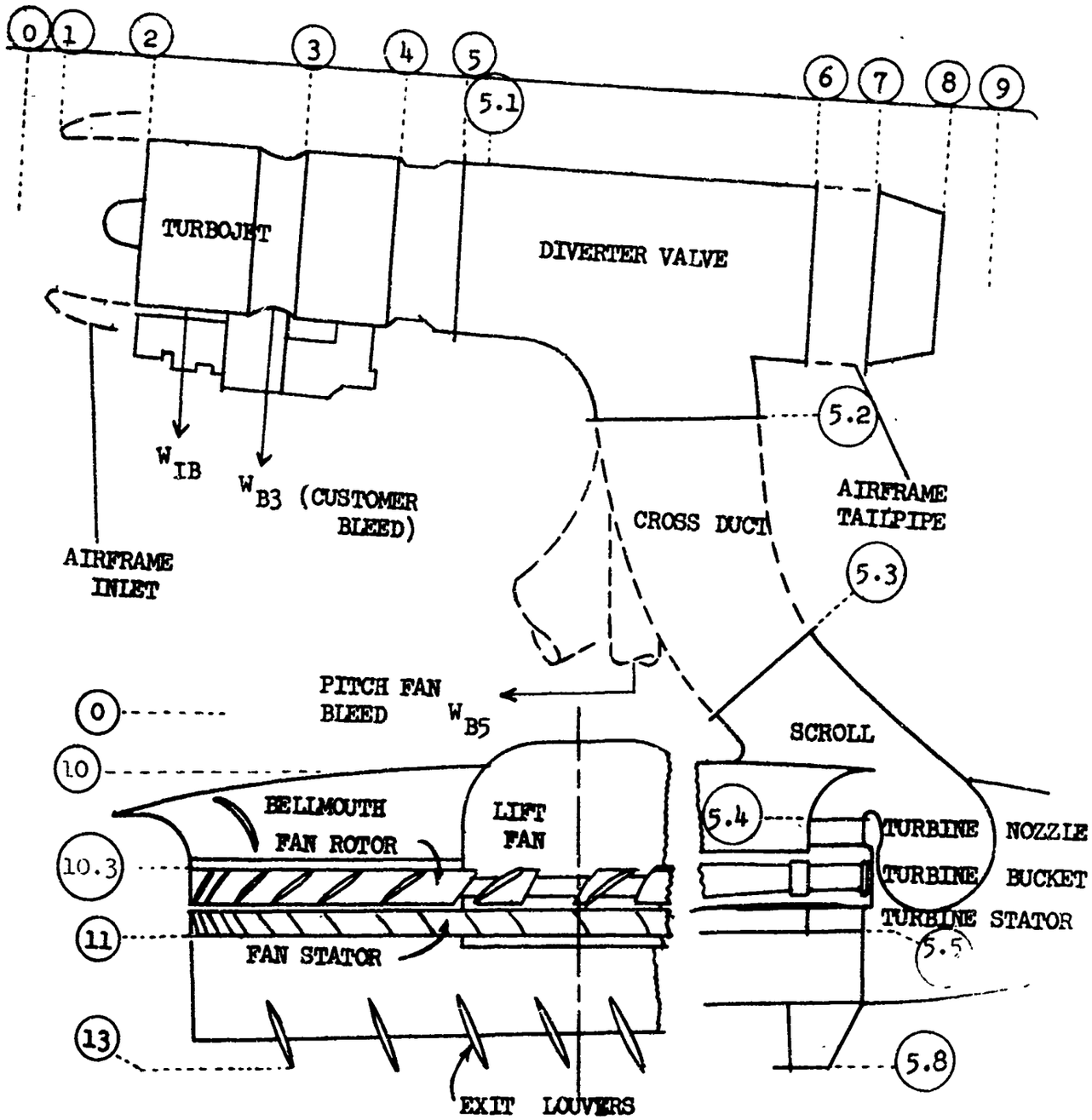
6.2.2.1 Symbols:

Symbol	Quantity	Units
Fg	Gross Thrust	pounds
Fn	Horizontal Net Thrust	pounds
Fr	Ram drag	pounds
$HP_{8.1}$	Ideal Horsepower at Turbojet discharge	horsepower
L	Vertical Lift	pounds
Nf	Fan speed	percent rpm
Ng	Turbojet engine speed	percent rpm
Pt	Total Pressure	PSIA
SFC	Specific Fuel Consumption (lbs. Fuel/Hour/Pound Net Thrust)	
Tam	Ambient Temperature	°F
Ts	ARDC Standard Ambient Temperature	°F
Vp	Flight Speed	knots
Mp	Flight Mach Number	
W_2	Engine Compressor Inlet Airflow	pounds/second
Wf	Fuel Flow	pounds/hour
Wa	Turbojet Air Flow	pounds/second
Wg	Gas Flow	pounds/second
W_B	Bleed Gas Flow	pounds/second
W_{10}	Fan Air Flow	pounds/second
θ_V	Angle of Exit Louver Deflection	Degrees Relative to A Axis of Fan Rotor.
θ_S	Louver Stagger Angle	degrees
δ_0	P ambient (psia)/14.696	
δ_2	P inlet (psia)/14.696	
θ_0	T ambient °R/518.7	
θ_2	T inlet °R/518.7	
$\bar{\omega}_{10.3}$	Percent of Fan Inlet Velocity Head Lost	Percent

Symbol	Quantity	Units

Station designation by subscript numbers is shown in Figure 58

Λ)		
K)	Correction Factors	
C)		
$\dot{\theta}$	Pitch Velocity	Radians per second
$\dot{\phi}$	Roll Velocity	Radians per second
$\dot{\psi}$	Yaw Velocity	Radians per second
$\ddot{\theta}$	Pitch Acceleration	Radians per second
$\ddot{\phi}$	Roll Acceleration	Radians per second 2
$\ddot{\psi}$	Yaw Acceleration	Radians per second 2



STATION DESIGNATIONS

Figure 58