UNLIMITED

AVRO AIRCRAFT LIMITED

PERIODIC PERFORMANCE REPORT 15B

Classification cancelled / ~~Changed to~~

PERFORMANCE OF THE ARROW 2 DKDA

Date

SECRET NOVEMBER 1958

Unit / Rank / Appointment CRAD DSA DRDA

MEMORANDUM

2130-2-6 (DRDA 8)

20 Nov 86

DSIS 3

DOWNGRADING OF AVRO ARROW REPORTS

Reference: 2130-2-6 (DSIS-3), dated 14 Nov 86

1. As requested in the reference, the following two AVRO reports have been reviewed:

a. Periodic Performance Report 1B - Performance of the Arrow 2

b. Brochure FC - Flying Control System

2. This review revealed that the reports do not contain sensitive information and they have been declassified.

C.L. Gardner

C.L. Gardner
DRDA 8
995-7714

Enclosures: (2)

AVRO AIRCRAFT LIMITED

MALTON – ONTARIO

ANALYZED

TECHNICAL DEPARTMENT (Aircraft)

~~SECRET~~ UNLIMITED

AIRCRAFT: ARROW 2

REPORT NO: Periodic Performance Report No. 15B

FILE NO: 72/PERF/39

NO. OF SHEETS 30

Classification cancelled / ~~Changed to~~ UNLIMITED
By authority of DRDA
Date 1960 06
Signature
Unit / Rank / Appointment CRAD DS4 DRDA

TITLE:

PERFORMANCE OF THE ARROW 2

WITH IROQUOIS SERIES 2 PRODUCTION ENGINES 124

PREPARED BY Performance Group R.G. Rose DATE November, 1958

RECOMMENDED FOR APPROVAL DATE 11 Dec/58

APPROVED DATE 2 Dec/58

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PERFORMANCE

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ARROW PERIODIC PERFORMANCE REPORT 15B

PERFORMANCE OF THE ARROW 2 WITH IROQUOIS SERIES 2

PRODUCTION ENGINES 124

(C.G. at 29.5% MAC)

SUMMARY

The performance data given in this report are based on the drag given in AVRO Periodic Performance Report 15, and on propulsion data given in 72/INT.AERO/37 (Production Iroquois Series 2 with 7,800 maximum N_H rpm and derated afterburner.) They represent the best estimate of the initial performance of the production Arrow 2 (to the structural standards of aircraft 25206) fitted with the initial production Iroquois Series 2 engines (124).

The main differences between this report and Periodic Performance Report number 15 are:-

1. Partially derated engine and poor afterburner performance.

2. An increase in operational weight empty of 425 lb.

The loading and performance data, flight envelopes, and mission profiles are given in Figures 1 to 9(b) and in Tables 1 to 7 inclusive.

The Thermodynamic envelope is based on a recovery factor of 0.90. The Flight envelope limitations are based on strength & control considerations only, and do not necessarily represent the steady performance capabilities of the aircraft.

The Operational Weight Empty used in this report is considered to be conservative and approximate only, as is the internal fuel load in the weapon pack. The internal fuel has been assumed to be 19,146 lb. basic plus 2,180 lb. in the weapon pack.

The effects of a 1,000 lb. reduction in Operational Weight Empty and an increase of 1,000 lb pack fuel on the radii of action are of the same order as those quoted in Periodic Performance Report No. 15.

TABLE 1 LOADING AND PERFORMANCE

UNDER ICAO STANDARD ATMOSPHERE CONDITIONS
(Clean aircraft, i.e. no ventral tank, unless otherwise stated)

WEIGHT

	Operational weight empty	lb.	46,317
	Maximum useable internal fuel	lb.	21,326
	Gross take-off weight (maximum internal fuel)	lb.	67,643
	Combat weight ($\frac{1}{2}$ max. internal fuel weight)	lb.	56,980
	Maximum external fuel + tank (500 gallons at 7.8 lb/gal. + drop tank)	lb.	4,242
	Maximum gross take-off weight (Combat mission)	lb.	71,885
+	Maximum gross take-off weight (Ferry mission)	lb.	70,549
	Normal design landing gross weight	lb.	50,313
	Maximum landing gross weight (Combat mission)	lb.	67,643
	Wing loading at gross take-off weight	lb/sq.ft.	55.3
	Power loading at gross take-off weight	lb/lb thrust	1.75

SPEED

True airspeed in level flight at combat weight			
Sea Level	(i) Maximum thrust, A/B lit	kts.	700 *
	(ii) Maximum thrust, A/B unlit	kts.	669
50,000 ft.	(i) Maximum thrust, A/B lit	kts.	1,132

* Placard Speed

CEILING

	Ceiling at combat weight, rate of climb 500 ft/min. with max thrust A/B lit at optimum Mach number (1.65M)	ft.	56,300

RATE OF CLIMB

Steady state rate of climb at combat weight			
Sea Level	(i) Maximum thrust, A/B lit, at 0.92M	ft/min.	35,000
	(ii) Maximum thrust, A/B unlit, at 527kts.	ft/min.	16,400
50,000 ft.	(i) Maximum thrust, A/B lit at 1.65M	ft/min.	5,225

\+ Maximum gross take-off weight (Combat mission) less 1,336 lb. missiles.

TIME TO HEIGHT

Time to reach 50,000 ft. and 1.5M from engine start at gross take-off weight, max thrust A/B lit.	min.	6.3

MANOEUVRABILITY

Load factor at combat weight		
(i) Maximum thrust A/B lit 1.5M at 50,000 ft.		1.38
(ii) Maximum thrust A/B lit 1.65M at 50,000 ft.		1.39

TAKE-OFF DISTANCE

Take-off distance over 50 ft. obstacle at sea level at gross take-off weight		
(i) Maximum thrust A/B lit, standard day (+ 15°C)	ft.	4,720
(ii) Maximum thrust A/B unlit, standard day (+ 15°C)	ft.	5,370
(iii) Maximum thrust A/B lit, hot day (+ 38°C)	ft.	6,010

LANDING DISTANCE

Landing distance over 50 ft. obstacle at sea level at normal design landing gross weight	ft.	5,300

STALLING SPEED

True stalling speed in landing configuration at combat weight at sea level	kts.	117

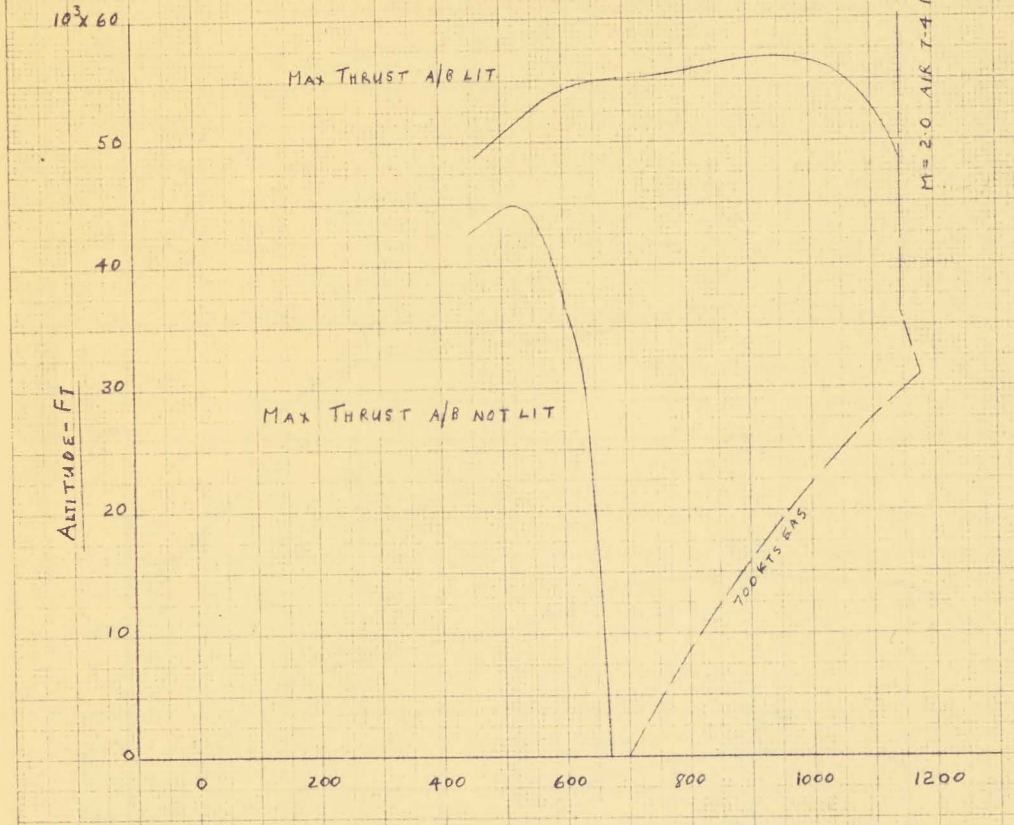
MISSIONS

	Combat radius of action, see mission profile for detail breakdown.		
1.	Subsonic high altitude mission - subsonic combat	n.m.	567
2.	Subsonic high altitude mission - supersonic (1.5M) combat	n.m.	476
3.	Supersonic (1.5M) high altitude mission - supersonic (1.5M) combat	n.m.	339
4.	Combat air patrol - supersonic (1.5M) combat	n.m.	598
5.	Subsonic low level mission (10,000 ft.) - subsonic combat	n.m.	398
6.	Ferry mission (no armament) - ventral tank carried throughout	n.m.	1,478

ARROW 2

IROQUOIS SERIES 2 FIRST PRODUCTION ENGINES: 124

MAX LEVEL SPEED AT COMBAT WEIGHT - (56980 LBS)



DRAG: 71-2/AERO DATA/17
PROPULSION: 72/INT. AERO/37

FIG. 1.

ARROW 2

IROQUOIS SERIES 2 : FIRST PRODUCTION ENGINES : 124

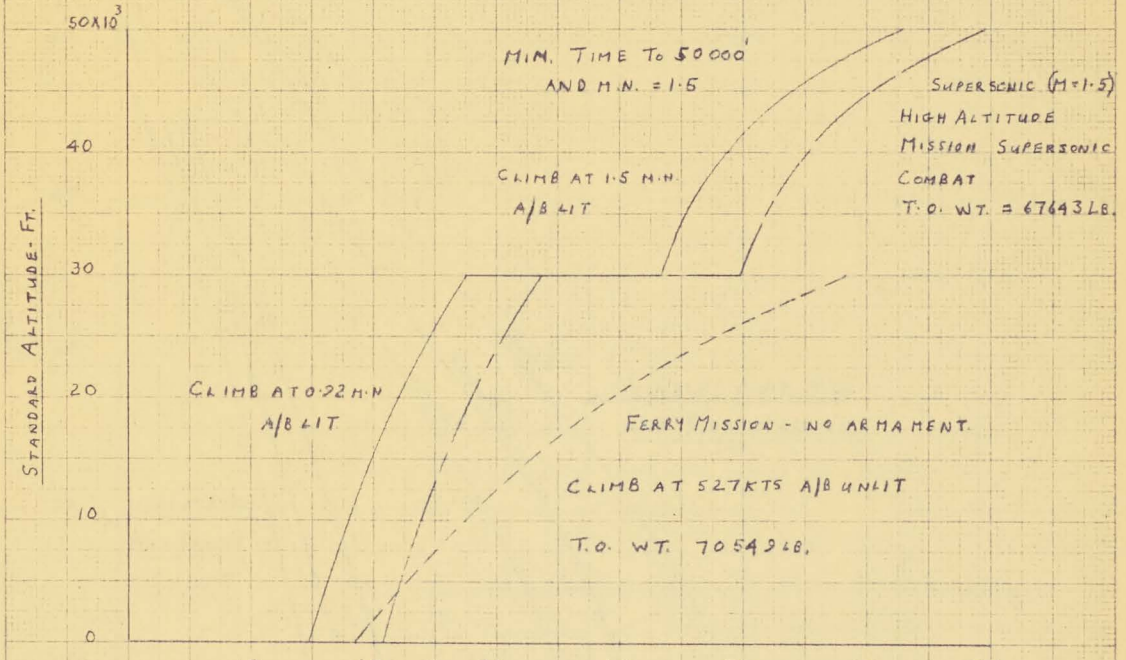
TIME TO HEIGHT

_ _ _ _ _ FERRY MISSION VENTRAL TANK CARRIED THROUGHOUT
NO ARMAMENT AFTERBURNER UNLIT

_____ MINIMUM TIME TO HEIGHT + 1·5 M·N AFTERBURNER LIT
THROUGHOUT FLIGHT

___ _ ___ SUPERSONIC HIGH ALTITUDE MISSION - SUPERSONIC COMBAT
AFTERBURNER LIT AT START OF 0·92 M·N CLIMB

NOTE:- ½ MINUTE ALLOWED FROM ENGINE START TO MAX THRUST



DRAG 11-2 / AERO DATA/17
PROPULSION 72 / INT AERO/37

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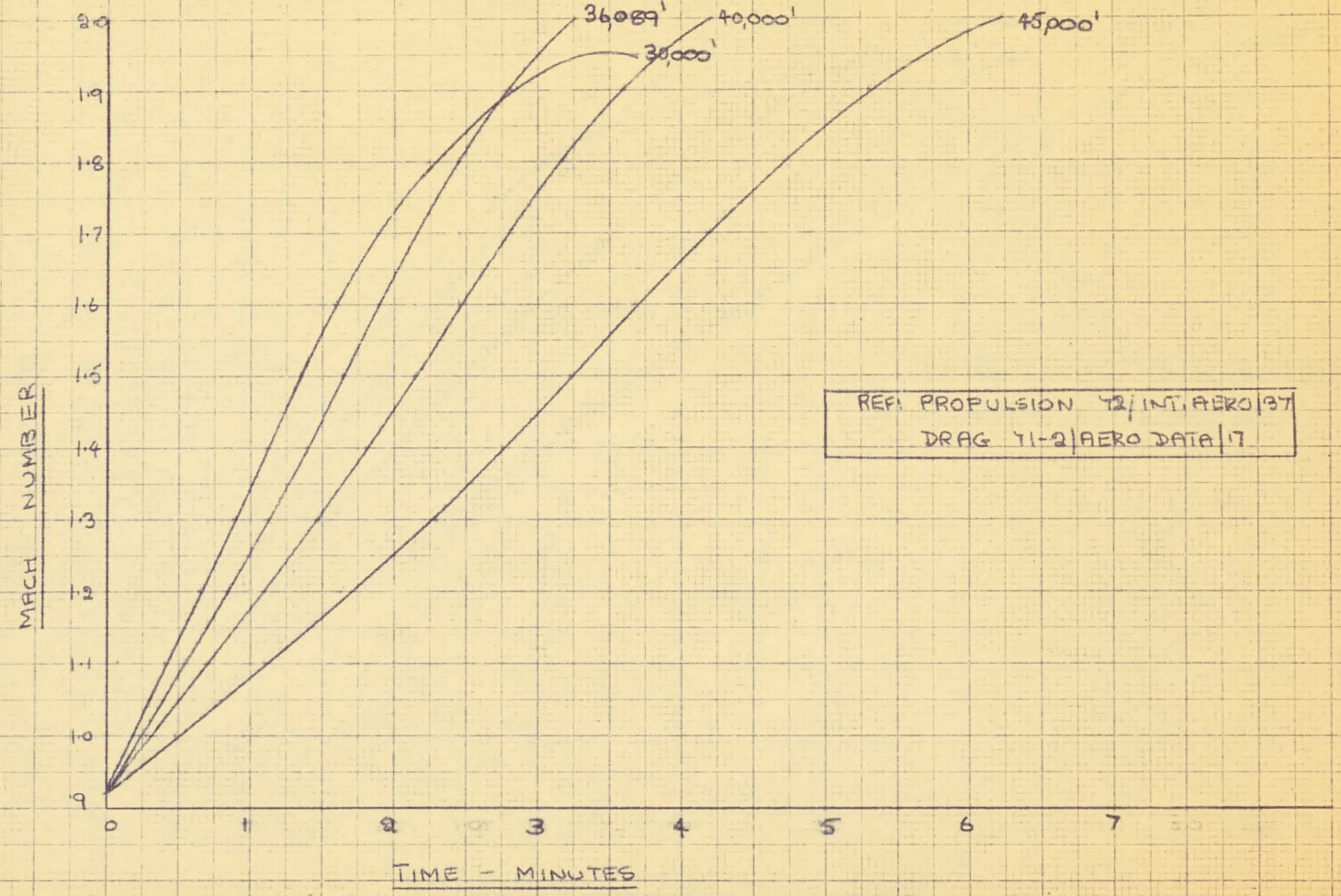
FIG. 3

ARROW 2 - IROQUOIS SERIES 2 FIRST PRODUCTION ENGINES, 124

TIME TO ACCELERATE FROM M = 0.92 TO M = 2.0 A/B LIT

AT COMBAT WEIGHT = 56,980 lb



REF: PROPULSION 72/INT.AERO/37
DRAG 71-2/AERO DATA/17

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REPORT NO: 70/PERF/37

Fig. 7a

FORM 1749 A-2

AT/SB 25-8-1958

THERMODYNAMIC ENVELOPE

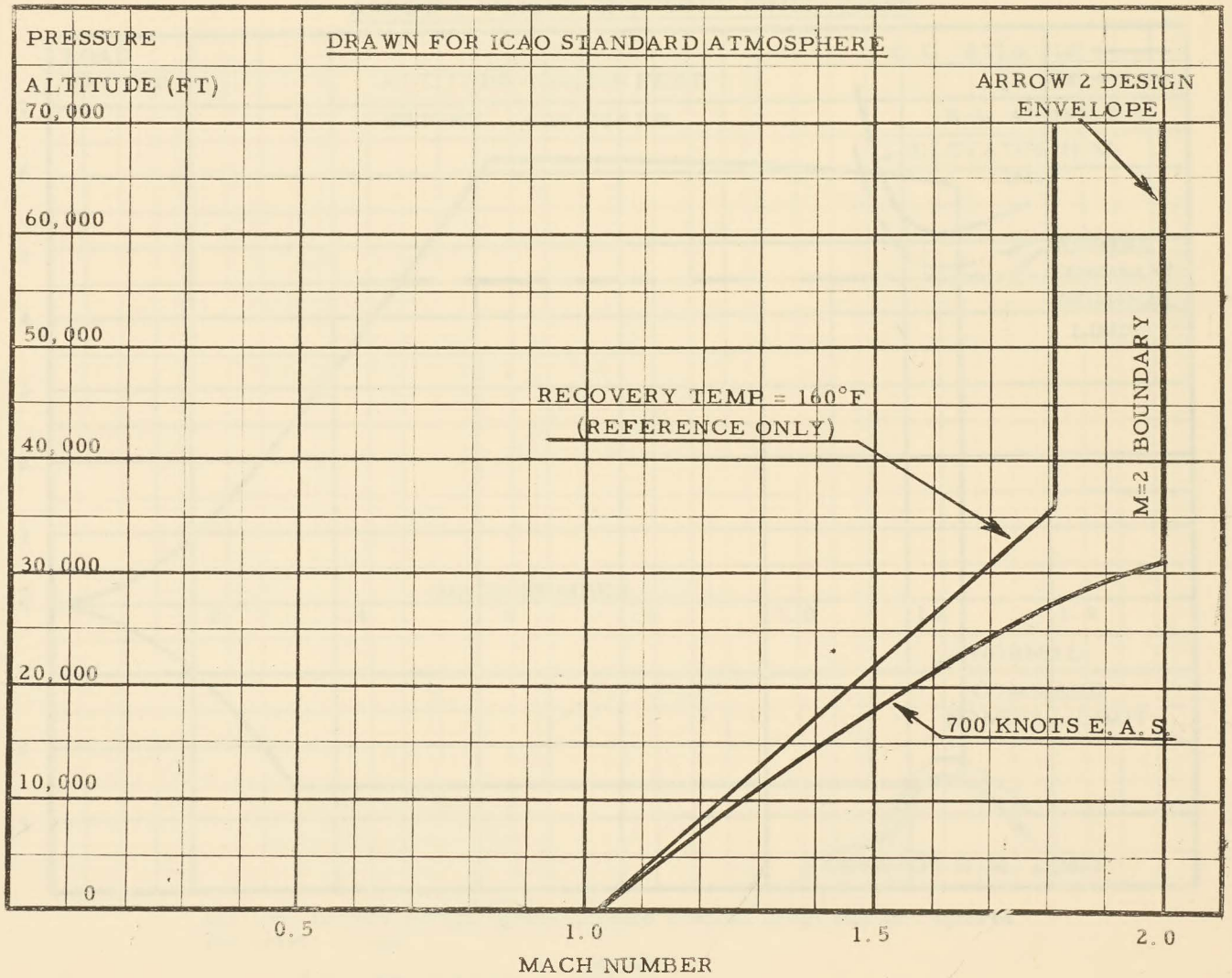


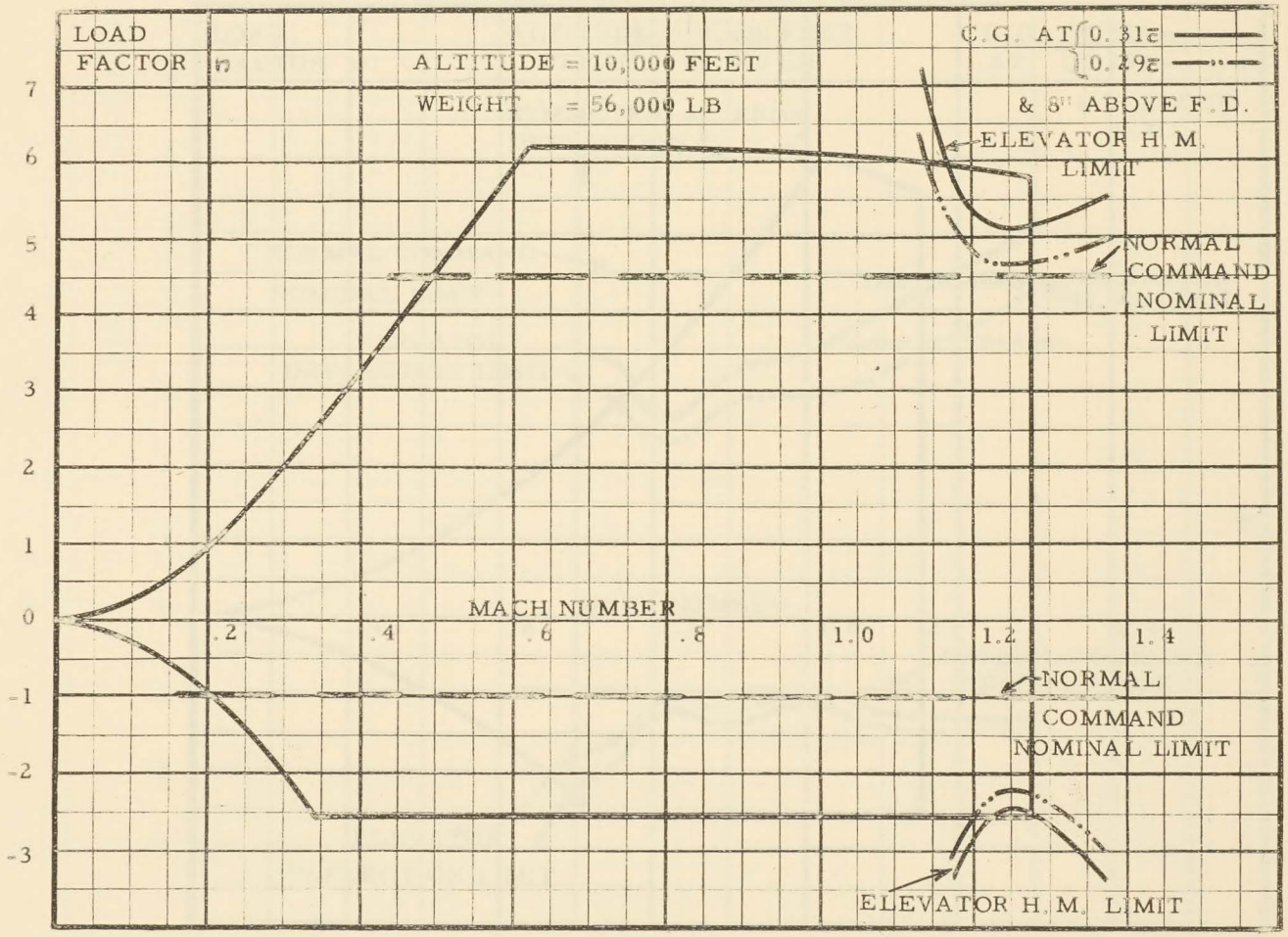
FIG. 8

UNLIMITED

AVRO AIRCRAFT

FORM 1749 A-2

ARROW 2 FLIGHT ENVELOPE LIMITATIONS



All load factors except Normal Command Nominal Limit can be factored for weight change

$$\text{i.e. } n_{NEW} = n_{Curve} \times \frac{56,000}{W_{NEW}}$$

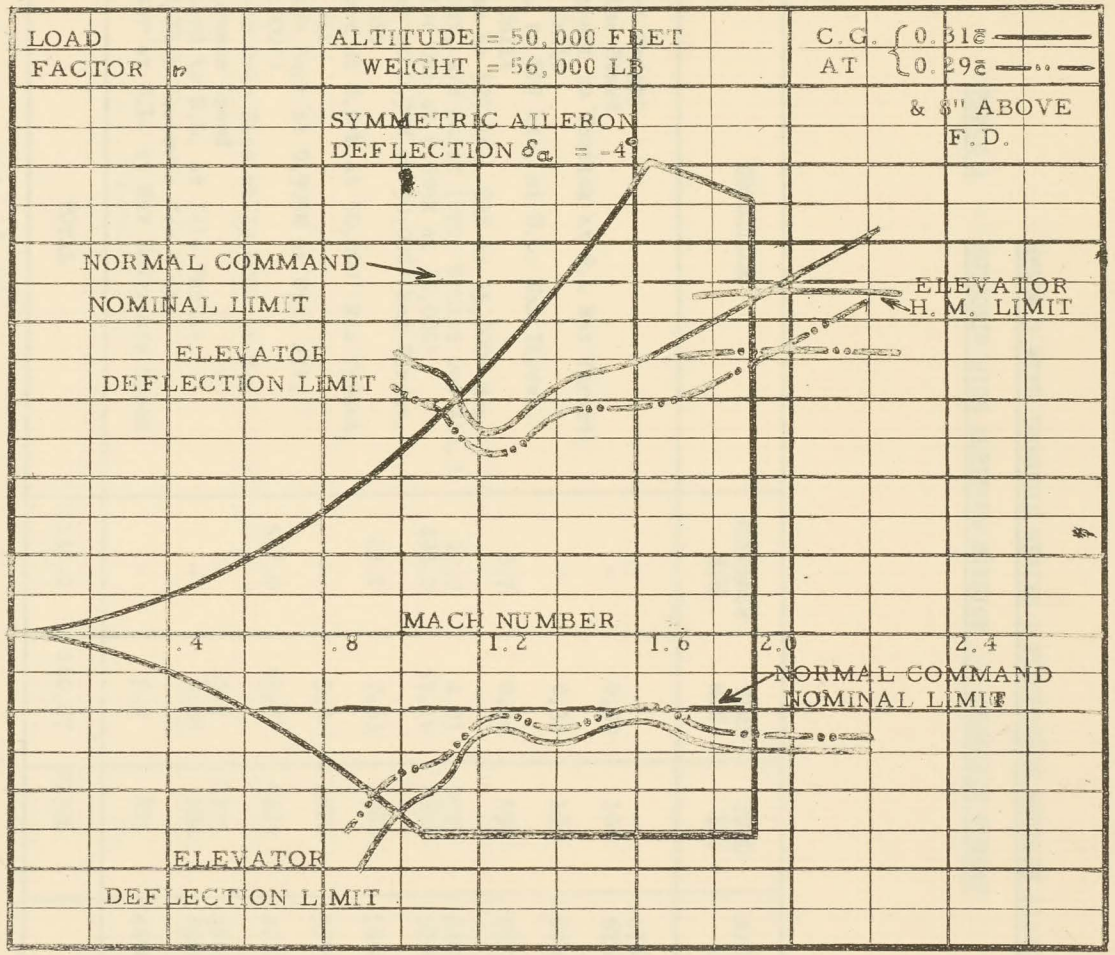
FIG. 9(a)

UNLIMITED

AVRO AIRCRAFT

FORM 1749 A-2

ARROW 2 FLIGHT ENVELOPE LIMITATIONS



Load factors except Normal Command Nominal Limit can be factored for weight change

i.e. $n_{NEW} = n_{Curve} \times \frac{56,000}{W_{NEW}}$

FIG. 9(5)

UNLIMITED

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ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 2 - SUBSONIC HIGH ALTITUDE MISSION - SUBSONIC COMBAT

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	67643
Engine Start	-	0.50	100	67543
Take-off to Unstick at S.L Max Thrust, A/B Unlit	-	0.34	184	67359
Acc. to 527 kts. at S.L. Max Thrust, A/B Unlit	5.7	0.94	596	66763
Climb at 527 kts. TAS to 35,000' Max Thrust, A/B Unlit (Opt. Cruise Out Alt.)	42.0	4.81	1905	64858
Cruise Out at 0.905M at 35,000'	496.2	57.10	6898	57960
Climb at 0.92M to 50,000' Max Thrust, A/B Lit	23.1	2.63	1280	56680
Combat at 0.92M at 50,000' Max Thrust, A/B Lit	-	5.0	1620	53724 *
Cruise Back at 0.905M at Opt. Alt. (39,000')	567.0	65.5	6439	47285
Loiter Over Base at 39,000' at Max Endurance Speed	-	15.0	1275	46010
Descend to S.L. at Idle Thrust	-	4.05	204	45806
Land With Reserves for 5 min. Loiter at S.L. at Max Endurance Speed	-	5.0	825	44981
TOTAL	1134.0	160.87	21326	

Fuel Density = 7.8 lb/gallon

* 1,336 lb. Missiles Fired at Combat

ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 3 - SUBSONIC HIGH ALTITUDE MISSION - SUPERSONIC COMBAT (1.5M)

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	67643
Engine Start	-	0.50	100	67543
Take-off to Unstick at S.L. Max. Thrust, A/B Unlit	-	0.34	184	67359
Acc. to 527 kts. at S.L. Max. Thrust, A/B Unlit	5.7	0.94	596	66763
Climb at 527 kts. TAS to 35,000' Max. Thrust A/B Unlit (Opt. Cruise Out Alt.)	42.0	4.81	1905	64858
Cruise Out at 0.905M at 35,000'	389.1	44.80	5500	59358
Acc. to 1.5M at 35,000' Max. Thrust, A/B Lit	18.2	1.60	1405	57953
Climb to 50,000' at 1.5M, Max. Thrust, A/B Lit	21.0	1.46	1160	56793
Combat at 1.5M at 50,000' Max. Thrust, A/B Lit	-	5.0	2844	52613*
Cruise Back at 0.905M at Opt. Alt.(39,000')	476.0	55.0	5328	47285
Loiter Over Base at 39,000' at Max. Endurance Speed	-	15.0	1275	46010
Descend to S.L. at Idle Thrust	-	4.05	204	45806
Land With Reserves for 5 min. Loiter at S.L. at Max. Endurance Speed	-	5.0	825	44981
TOTAL	952.0	138.50	21326	

Fuel Density = 7.8 lb/gallon

* 1,336 lb. Missiles Fired at Combat

ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 4 - SUPERSONIC (1.5M) HIGH ALTITUDE MISSION - SUPERSONIC (1.5M) COMBAT

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	67643
Engine Start	-	0.50	100	67543
Take-off to Unstick at S.L. Max Thrust, A/B Unlit	-	0.34	184	67359
Acc. to 0.92M at S.L. Max Thrust, A/B Unlit	8.4	1.23	800	66559
Climb at 0.92M to 35,000' Max Thrust, A/B Lit	16.3	1.72	2060	64499
Acc. to 1.5M at 35,000' Max Thrust, A/B Lit	21.4	1.87	1655	62844
Climb at 1.5M to 50,000' Max Thrust, A/B Lit	25.1	1.77	1380	61464
Cruise Out at 1.5M at 50,000' Partial A/B	267.6	18.65	6270	55194
Combat at 1.5M at 50,000' Max Thrust, A/B Lit	-	5.0	2844	51014 *
Cruise Back at 0.905M at Opt. Alt. (39,000')	339.0	39.2	3729	47285
Loiter Over Base at 39,000' at Max Endurance Speed	-	15.0	1275	46010
Descend to S.L. at Idle Thrust	-	4.05	204	45806
Land with Reserves for 5 min.				
Loiter at Max Endurance Speed at S.L.	-	5.0	825	44981
TOTAL	678.0	94.33	21326	

Fuel Density = 7.8 lb/gallon

* 1,336 lb. Missiles Fired at Combat

ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 5 - COMBAT AIR PATROL - SUPERSONIC (1.5M) COMBAT

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	71885
Engine Start	-	0.50	100	71785
Take-off to Unstick at S.L Max Thrust, A/B Unlit	-	0.37	200	71585
Acc. to 527 kts. at S.L. Max Thrust, A/B Unlit	6.0	1.00	610	70975
Climb at 527 kts. TAS to 35,000' Max Thrust, A/B Unlit (Opt. Cruise Out Alt.)	49.8	5.7	2270	68705
Cruise Out at 0.905M at 35,000'	500.8	57.6	7425	60938 +
Acc. to 1.5M at 35,000' Max Thrust, A/B Lit	19.6	1.70	1512	59426
Climb to 50,000' at 1.5M Max Thrust, A/B Lit	21.8	1.54	1210	58216
Combat at 50,000' at 1.5M Max Thrust, A/B Lit	-	5.0	2844	54036 *
Cruise Back at 0.905M at Optimum Alt. (39,000')	598.0	69.5	6751	47285
Loiter Over Base at 39,000' at Max Endurance Speed	-	15.0	1275	46010
Descend to S.L. at Idle Thrust	-	4.05	204	45806
Land With Reserves for 5 min. Loiter at S.L. at Max Endurance Speed	-	5.0	825	44981
TOTAL	1196	166.96	25226	

Fuel Density = 7.8 lb/gallon

+ 342 lb. Ventral D.T. Jettisoned When Empty

* 1,336 lb. Missiles Fired at Combat

ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 6 - SUBSONIC LOW LEVEL MISSION (10,000') - SUBSONIC COMBAT

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	67643
Engine Start	-	0.50	100	67543
Take-off to Unstick at S.L. Max Thrust, A/B Unlit	-	0.34	184	67359
Acc. to 527 kts. at S.L. Max Thrust, A/B Unlit	5.7	0.94	596	66763
Climb at 527 kts. TAS to 10,000' Max Thrust, A/B Unlit	6.9	0.81	500	66263
Cruise at 0.70M at 10,000' (Opt. Cruise Speed)	381.6	51.25	9320	56943
Acc. to 0.92M at 10,000', Max Thrust, A/B Unlit	3.8	0.45	239	56704
Combat at 0.92M at 10,000', Max Thrust A/B Unlit	-	5.0	2814	52554 *
Climb to 39,000' at 527 kts. TAS, Max Thrust, A/B Unlit	30.6	3.68	1211	51343
Cruise Back at 0.905M at Optimum Alt. (39,000')	367.4	42.40	4058	47285
Loiter Over Base at 39,000' at Max Endurance Speed	-	15.0	1275	46010
Descend to S.L. at Idle Thrust	-	4.05	204	45806
Land With Reserves for 5 min. Loiter at S.L. at Max Endurance Speed	-	5.0	825	44981
TOTAL	796.0	129.42	21326	

Fuel Density = 7.8 lb/gallon

* 1,336 lb. Missiles Fired at Combat

ARROW 2 WITH IROQUOIS SERIES 2 PRODUCTION ENGINES (124)

TABLE 7 - FERRY MISSION (NO ARMAMENT)

VENTRAL TANK CARRIED THROUGHOUT

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight	-	-	-	70549
Engine Start	-	0.50	100	70449
Take-off to Unstick, Max Thrust, A/B Unlit	-	.37	200	70249
Acc. to 527 kts. at S.L. Max Thrust, A/B Unlit	5.9	.98	600	69649
Climb to 35,000' at 527 kts. TAS Max Thrust, A/B Unlit	48.4	6.9	2205	67444
Cruise Climb to 40,000' at 0.905M	1423.7	164.50	19697	47707
Loiter Over Base at 40,000' at Max Endurance Speed	-	15.0	1355	46352
Descend to S.L. at Idle Thrust	-	4.05	204	46148
Land with Reserves for 5 min.				
Loiter at S.L. at Max Endurance Speed	-	5.0	865	45323
TOTAL	1478	197.3	25226	

Fuel Density = 7.8 lb/gallon

NOTE: A range of 1,500 n.m. can be exceeded if the ventral drop tank is jettisoned when empty.

SECTION 2 PROPULSION DATA

INTRODUCTION

The propulsion system consists of an engine derated to a maximum high pressure rotor R.P.M. of 7800 as limited by handling and vibration problems at the anticipated state of development for engine No.124 and afterburner derated to efficiencies obtainable at present state of development as given by Tullahoma test.

The significant parameters as suggested by Orenda Engines Limited are:-

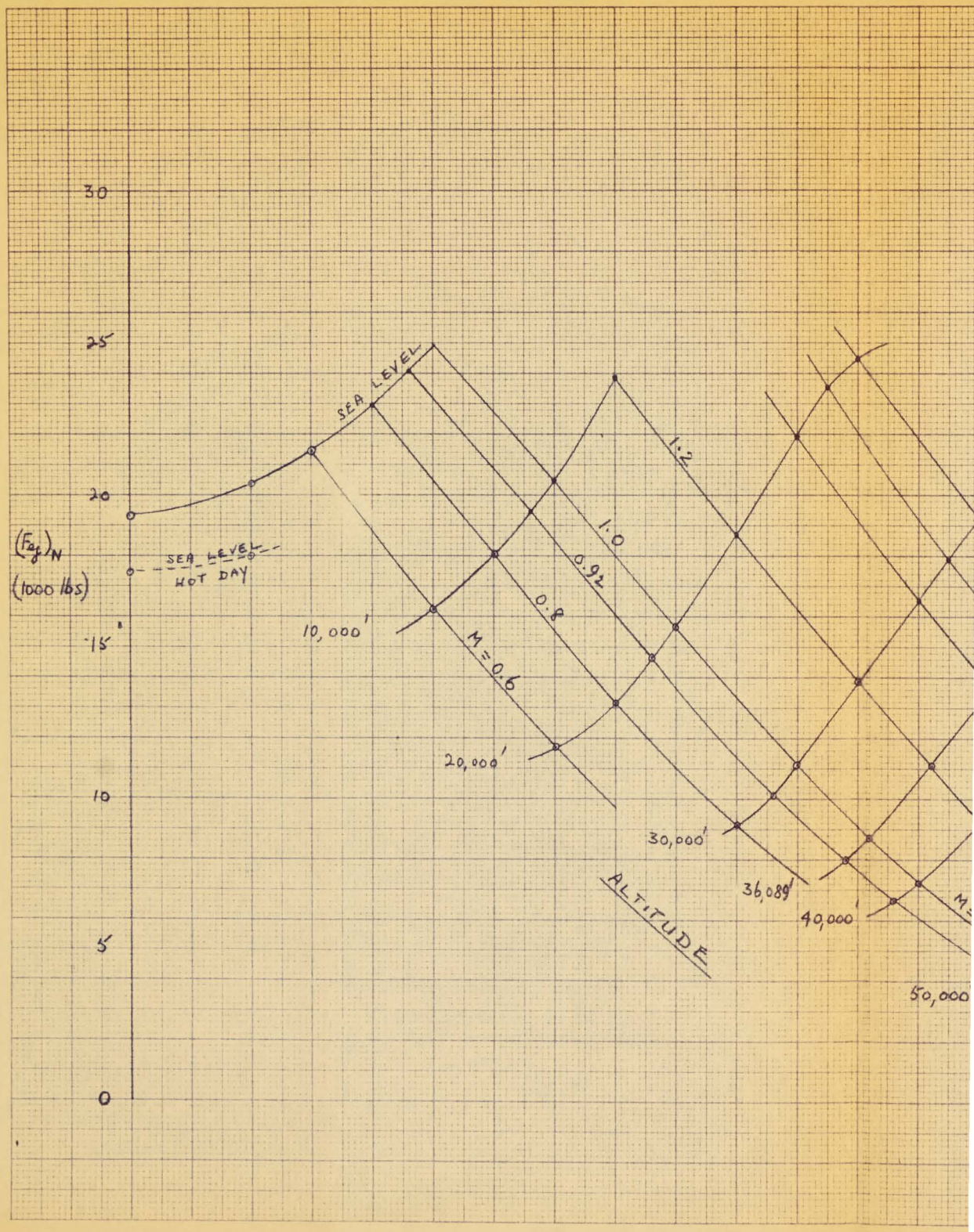
(a) The maximum high pressure rotor speed is 7800 R.P.M. The engine non-dimensional charts OEL-X-16479 through OEL-X-16493 (basis of EMS-8-2 performance)were used but with N_H factored by 8150/8050. Thus on the charts 7800 R.P.M. gives a swallowing capacity identical to 7900 R.P.M.

(b) The final nozzle area was taken to be constant at 668 sq.in. However, the actual geometric area of the final nozzle to pass the internal flows, afterburner off, is 760 sq.in. This implies a final nozzle flow coefficient of 88°/o rather than the 98.5°/o used to date. A flow coefficient of 88°/o was also used afterburner lit, where the maximum geometric final nozzle area remains at 1075 sq.in.

(c) The afterburner efficiency used is that given from Tullahoma test on OEL-X-18942, a deterioration of the order of 25°/o from that used to date.

The propulsion system geometry is comprised of a fixed intake with throat area of 6.0 sq.ft., bypass inlet of 180 sq.in., restrictor flow area varying between 95 and 250 sq.in. as determined by the spring characteristic of OEL-X-18894, a fixed divergent ejector of throat 40 in. and exit 49 in. diameter.

Prepared by Internal Aero Group -
November, 1958


30
25
20
15
10
5
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$(F_{g_i})_N$
(1000 lbs)
SEA LEVEL
SEA LEVEL
HOT DAY
10,000'
20,000'
30,000'
36,089'
40,000'
50,000
M=0.6
0.8
0.92
1.0
1.2
ALTITUDE