AVRO AIRCRAFT LIMITED

PERIODIC PERFORMANCE REPORT 15

PERFORMANCE OF THE ARROW 2

~~SECRET~~ ANALYZED NOVEMBER 1958

(S)

SECRET

AIRCRAFT: ARROW 2

REPORT NO: Periodic Performance Report No. 15

FILE NO: 72/PERF/36

NO. OF SHEETS 49

TITLE:

ANALYZED

[redacted]

PERFORMANCE OF THE ARROW 2

PREPARED BY Performance Group R.G. Rose DATE Nov. 1958

RECOMMENDED FOR APPROVAL [signature] DATE Nov/58

APPROVED [signature] DATE Nov/58

APPROVED FOR RELEASE [signature] DATE Nov/58

INDEX

ARROW PERIODIC PERFORMANCE REPORT 15

PERFORMANCE OF THE ARROW 2

(C.G. at 29.5% MAC)

SUMMARY

The performance data given in this report are based on the drag data given in Avro Report 71-2/Aero Data/17 (Revised Arrow drag based on preliminary flight test results) and propulsion data given in 72/Int. Aero/33 (Developed Iroquois Series 2 with 8050 maximum N_H r.p.m. and developed afterburner). They represent the best estimate of the ultimate performance of the Arrow 2 as at present envisaged.

The main differences between this report and Periodic Performance Report Number 14 are:-

1. Revised drag data.
2. Revised Engine data.
3. Change of fire control system and missile load to Hughes MA-1, with MB-1 and GAR-3/4 missiles.
4. A decrease in operational weight empty of 758 lb. mainly due to (3).

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 and 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 the 19,433 lb. basic plus 2,180 lb. in the weapon pack. To allow for variations of O.W.E. and weapon pack fuel, the effects of 1,000 lb. reduction in operational weight empty, and an extra 1,000 lb. of fuel in the missile pack, on the combat radii of action and ferry range are quoted in the following table:-

Mission	Basic Dist. N.M. (Radius)	Effect of 1000# extra internal pack fuel = N.M.	Effect of 1000# reduction in O.W.E. = N.M.
1. Subsonic high altitude mission - subsonic combat	589	+ 35	+ 15
2. Subsonic high altitude mission - supersonic combat	506	+ 35	+ 15
3. Supersonic (1.5 M) high altitude mission - Supersonic (1.5M) combat	358	+ 25	+ 10
3A. Supersonic (1.8 M) high altitude mission - supersonic (1.8 M) combat	338	+ 25	+ 10
4. Combat Air Patrol - Supersonic combat	620	+ 35	+ 15
5. Subsonic low level mission (10,000') - subsonic combat	396	+ 25	+ 10
6. Ferry Mission (no armament) ventral tank carried throughout RANGE.	1500	+ 70	+ 30

The effect on g's available at 50,000 feet and 1.5M of 1,000 lb. additional pack fuel is -.015 g, and of 1,000 lb. decrease in O.W.E. +.03 g.

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.	45,892
	Maximum useable internal fuel	lb.	21,613
	Gross take-off weight (maximum internal fuel)	lb.	67,505
	Combat weight (1/2 max. internal fuel weight)	lb.	56,699
	Maximum external fuel and tank (500 gallons at 7.8 lb/gall. + drop tank)	lb.	4,242
	Maximum gross take-off weight (Combat mission)	lb.	71,747
†	Maximum gross take-off weight (Ferry mission)	lb.	70,411
	Normal design landing gross weight	lb.	49,958
	Maximum landing gross weight (Combat Mission)	lb.	67,505
	Wing loading at gross take-off weight	lb/sq. ft.	55.2
	Power loading at gross take-off weight	lb/lb thrust	1.55

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.	630
50,000 ft.	(i)	Maximum thrust, A/B lit	Kts.	1,147 ✱

✱ Placard speed

† Maximum gross take-off weight (Combat Mission) less 1336 lb. missiles

CEILING

Ceiling at combat weight, rate of climb 500 ft/min. with max. thrust at optimum Mach number (1.8 M) A/B Lit	ft.	61,400

RATE OF CLIMB

Steady state rate of climb at combat weight

Sea Level	(i)	Maximum thrust, A/B lit, at 0.92M	ft/min.	44,600
	(ii)	Maximum thrust, A/B unlit at 527 Kts TAS	ft/min.	18,600
50,000 ft.	(i)	Maximum thrust, A/B lit at 1.8 M	ft/min.	10,330

TIME TO HEIGHT

Time to reach 50,000 ft. and 1.5 M from engine start at gross take-off weight, max. thrust A/B lit	min.	4.8

MANOEUVRABILITY

Load factor at combat weight

1.	Maximum thrust A/B lit 1.5 M at 50,000 ft.	1.62
2.	Maximum thrust A/B lit 1.8 M at 50,000 ft.	1.77

TAKE-OFF DISTANCE

Take-off distance over 50 ft. obstacle at sea level at gross take-off weight

1.	Maximum thrust A/B lit , standard day (+15°C)	ft.	4,000
2.	Maximum thrust A/B unlit, standard day(+ 15°C)	ft.	5,070
3.	Maximum thrust A/B lit, hot day (+38°C)	ft.	4,870

LANDING DISTANCE

Landing distance over 50 ft. obstacle at sea level at normal design landing gross weight	ft.	5,260

STALLING SPEED

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

MISSIONS

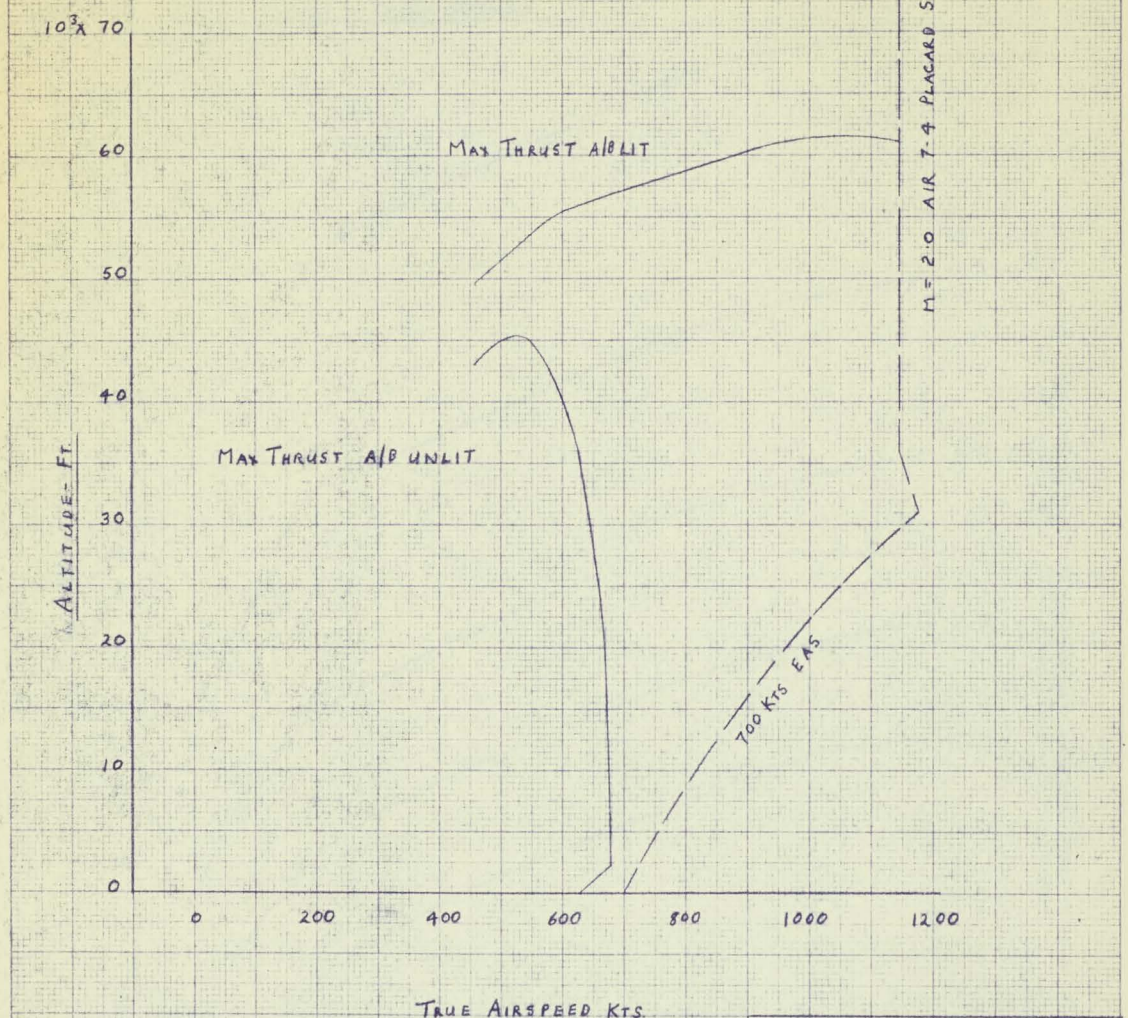
Combat radius of action, see mission profile for detail breakdown.

1.	Subsonic high altitude mission - subsonic combat	n.m.	589
2.	Subsonic high altitude mission - supersonic combat	n.m.	506
3.	Supersonic (1.5 M) high altitude mission - supersonic (1.5 M) combat	n.m.	358
3A.	Supersonic (1.8 M) high altitude mission - supersonic (1.8 M) combat.	n.m.	338
4.	Combat air patrol - supersonic combat	n.m.	620
5.	Subsonic low level mission (10,000 ft.) - subsonic combat	n.m.	396
6.	Ferry Mission (no armament) ventral tank carried throughout — Range	n.m.	1,500

ARROW 2

IROQUOIS SERIES 2 ENGINES

MAX LEVEL SPEED AT COMBAT WEIGHT (56,699 LB)



DRAG - 71-2/AERO. DATA/17
PROPULSION - 72/INT. AERO/33

SECRET

FIG 1

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

MANOEUVRABILITY — STEADY G's AVAILABLE

AT COMBAT WEIGHT MAX THRUST A/B LIT

COMBAT WEIGHT = 56699 LB

REF:
DRAG - 71-2/AERO DATA/17
THRUST - 72/INT AERO/33

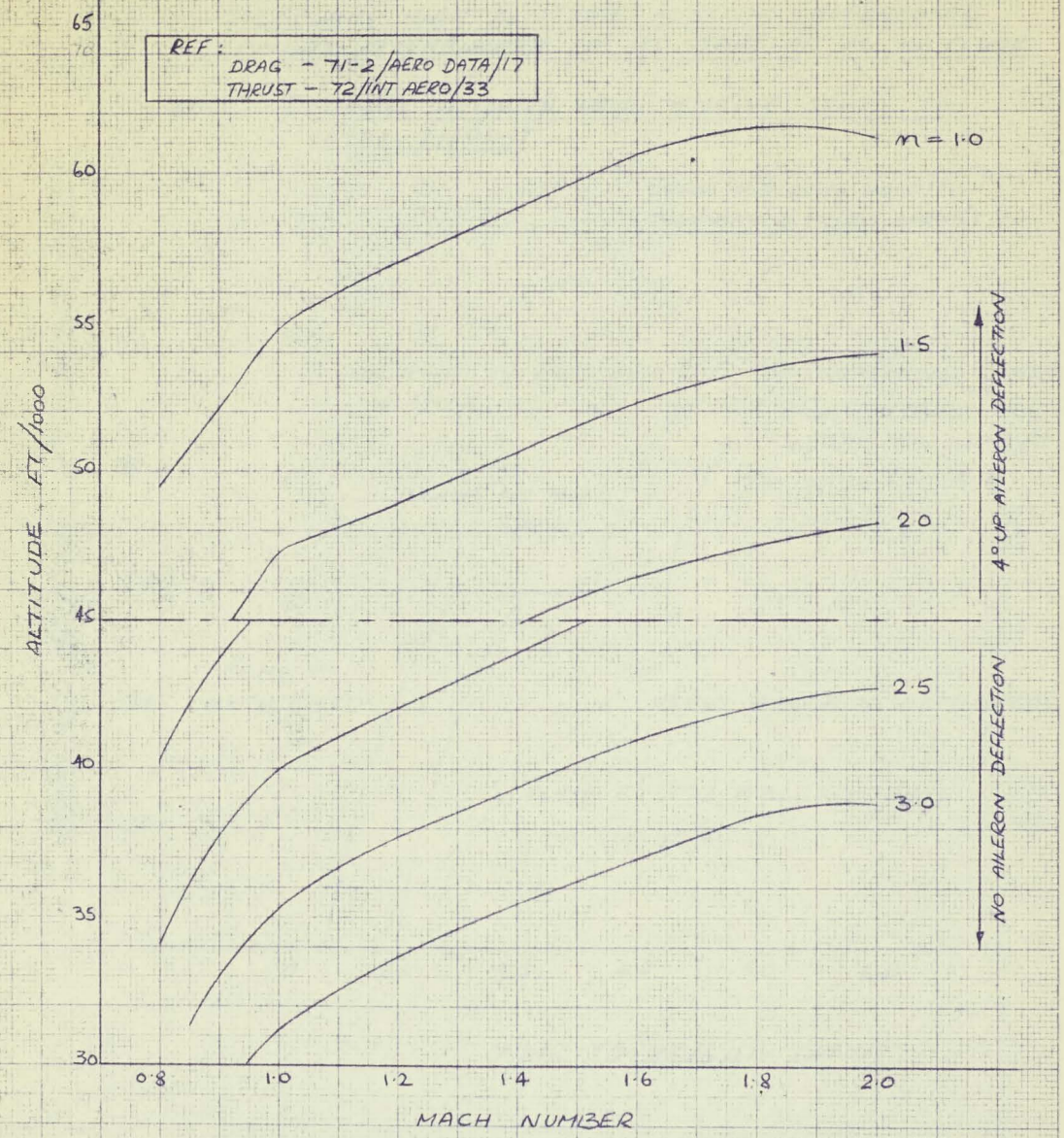


FIG. 2

SECRET

REPORT NO: 72/PERF/36

ARROW 2

TIME TO HEIGHT IROQUOIS SERIES 2 ENGINES

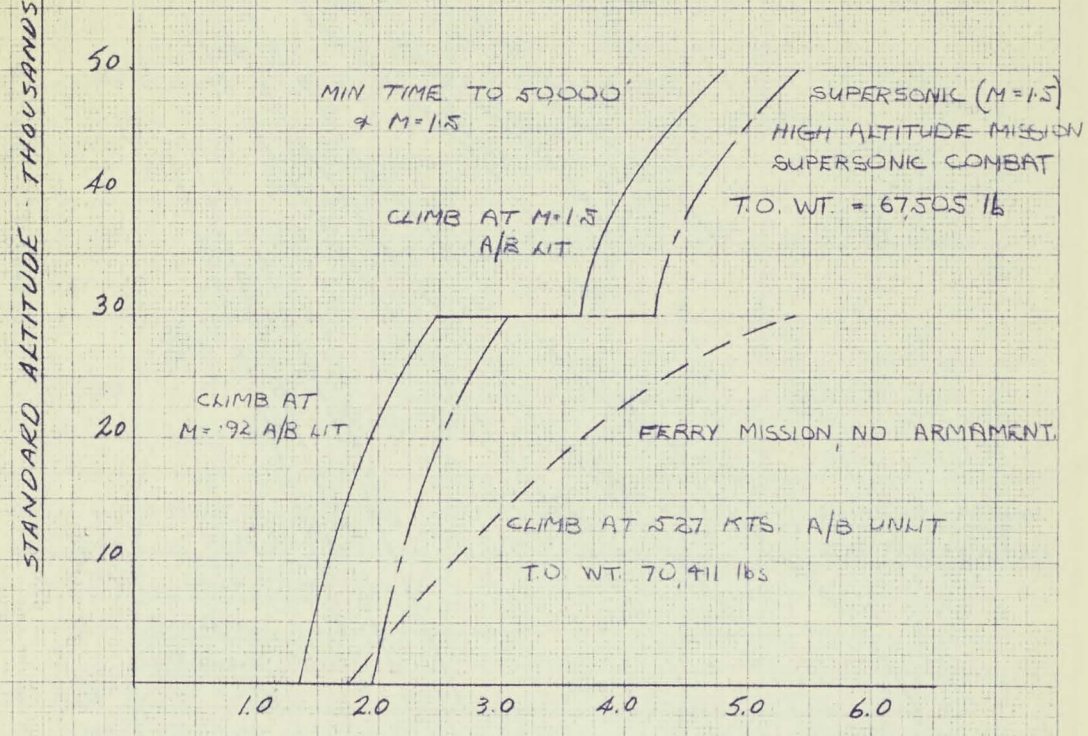
– – – – FERRY MISSION VENTRAL TANK CARRIED THROUGHOUT NO ARMAMENT AFTERBURNER UNLIT

——— MINIMUM TIME TO HEIGHT + 1.5M AFTERBURNER LIT THROUGHOUT FLIGHT

— – — SUPERSONIC HIGH ALTITUDE MISSION - SUPERSONIC COMBAT - AFTERBURNER LIT AT START OF M=.92 CLIMB

NOTE - $\frac{1}{2}$ MINUTE ALLOWED FROM ENGINE START TO MAX. THRUST

DRAG 71-2/AERO DATA/17
PROPULSION - 72/INT AERO/33



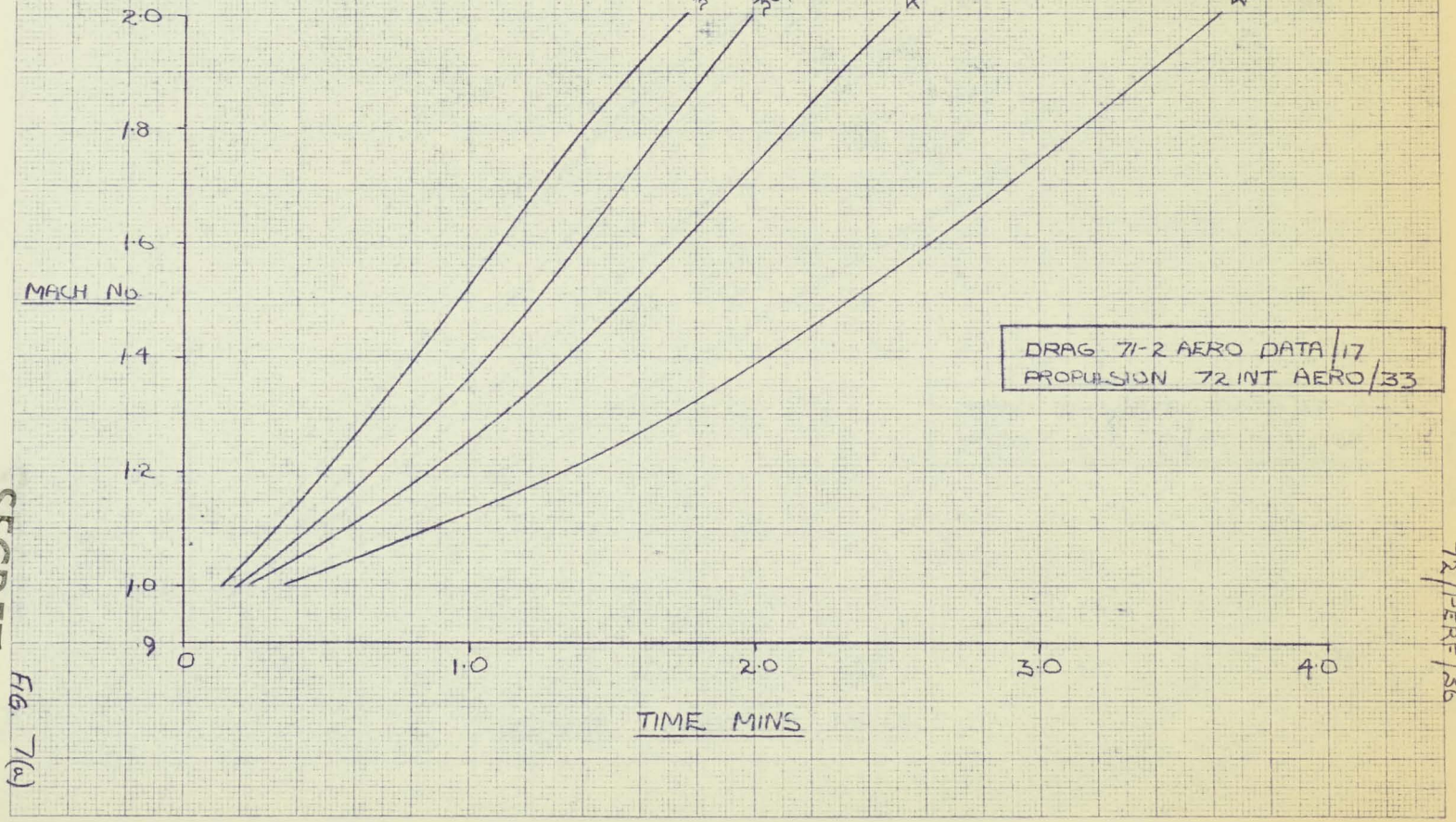
SECRET

FIG 3

ARROW 2 IROQUOIS SERIES 2

TIME TO ACCELERATE M = .92 M = 2.0

AT COMBAT WT = 56,699



DRAG 71-2 AERO DATA/17
PROPULSION 72 INT AERO/33

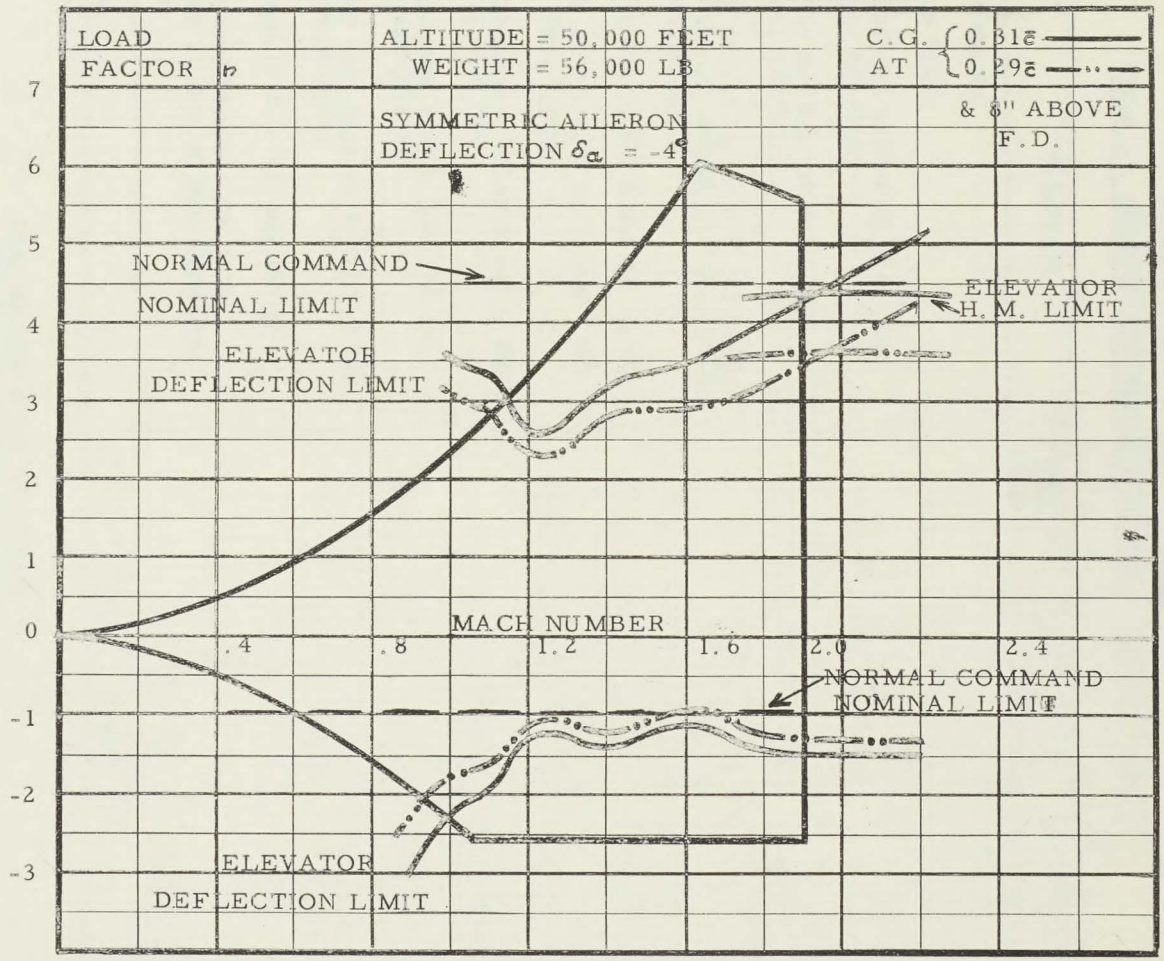
72/PERF/36

SECRET

Fig 7(a)

FORM 1749 A.2

ARROW 2 FLIGHT ENVELOPE LIMITATIONS



All 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(b)

SECRET

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

TABLE 2 - SUBSONIC HIGH ALTITUDE MISSION - SUBSONIC COMBAT

CONDITION	DISTANCE (N.M.)	TIME (MIN.)	FUEL (LB.)	A/C WEIGHT (LB.)
Start Weight	-	-	-	67,505
Engine Start	-	0.5	100	67,405
Take-Off to Unstick at S.L., Max. Thrust, A/B Unlit	-	0.32	192	67,213
Acc. to 527 Kts. at S.L., Max. Thrust, A/B Unlit	5.0	0.85	609	66,604
Climb at 527 Kts. T.A.S. to 35,000' Max. Thrust, A/B Unlit (Opt. Cruise Out Altitude)	39.5	4.55	1,910	64,694
Cruise Out at M = 0.905 at 35,000'	526.0	60.50	7,260	57,434
Climb at M = 0.92 to 50,000', A/B Lit, Max. Thrust	18.5	2.10	990	56,444
Combat at M = .92 at 50,000', Max. Thrust, A/B Lit	-	5.0	1,650	53,458 ✱
Cruise Back at M = 0.905 at Opt. Altitude (39,000')	589.0	68.0	6,623	46,835
Loiter over Base at 39,000' at Max. Endurance Speed	-	15.0	1,250	45,585
Descend to S.L. at Idle Thrust	-	4.05	204	45,381
Land with Reserves for 5 Min. Loiter at S.L. at Max. Endurance Speed	-	5.0	825	44,556
TOTAL	1178.0	165.87	21,613	

Fuel density = 7.8 lb./gallon

✱ 1,336 lb. missiles fired at combat

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITION	DIST. N.M.	TIME MINS	FUEL LB.	A/C WT. LB.
Start weight	-	-	-	67,505
Engine start	-	0.5	100	67,405
Take-off to unstick at sea level max. thrust A/B unlit	-	0.32	192	67,213
Acc. to 527 kts. at sea level max. thrust A/B unlit	5.0	0.85	609	66,604
Climb at 527 Kts. TAS to 35,000' max. thrust A/B unlit (opt. cruise-out alt.)	39.5	4.55	1910	64,694
Cruise-out at M = 0.905 at 35,000'	435.4	50.0	6078	58,616
Acc. to 1.5M at 35,000' max. thrust A/B lit	14.1	1.22	1135	57,481
Climb to 50,000' at 1.5M max. thrust A/B lit	12.0	0.83	750	56,731
Combat at 1.5M at 50,000' max. thrust A/B lit	-	5.0	3060	52,335*
Cruise back @ M = 0.905 at optimum alt. (39,000')	506.0	58.7	5500	46,835
Loiter over base at 39,000' at max. endurance speed	-	15.0	1250	45,585
Descend to sea level @ idle thrust	-	4.05	204	45,381
Land with reserves for 5 min. loiter at sea level at max. endurance speed	-	5.0	825	44,556
TOTAL	1012.0	146.02	21,613	

Fuel density = 7.8 lb./gallon

* 1,336 lb. missiles fired at combat

~~SECRET~~

TABLE 4 - ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITION	DIST. N.M.	TIME MIN.	FUEL LBS	A/C WT. lb.
Start weight.	-	-	-	67,505
Engine start.	-	0.5	100	67,405
Take-off to unstick at sea level max. thrust A/B unlit.	-	0.32	192	67,213
Acc. to .92 M at S.L. Max thrust A/B unlit.	7.5	1.10	815	66,398
Climb @ .92 M to 35,000' Max thrust, A/B lit.	12.2	1.50	1,840	64,558
Acc. to 1.5 M at 35,000' Max thrust, A/B lit.	15.8	1.39	1,270	63,288
Climb @ 1.5M to 50,000' Max thrust, A/B lit.	14.5	0.98	860	62,428
Cruise out @ 1.5M at 50,000'	308.0	21.5	7,280	55,148
Combat @ 1.5M at 50,000' Max thrust, A/B lit.	-	5.0	3,060	50,752 *
Cruise back @ .905M at optimum altitude (39,000')	358.0	41.4	3,917	46,835
Loiter over base at 39,000' at max. endurance speed.	-	15.0	1,250	45,585
Descend to S.L. at idle thrust.	-	4.05	204	45,381
Land with reserves for 5 min. loiter at max. endurance speed at S.L.	-	5.0	825	44,556
	716.0	97.74	21,613	

Fuel density = 7.8 lb/gallon.

* 1336 lb missiles fired at combat

TABLE 4A- ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

SUPERSONIC (1.8M) HIGH ALTITUDE MISSION - SUPERSONIC (1.8M) COMBAT

CONDITION	DIST. N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start weight	-	-	-	67,505
Engine start	-	0.5	100	67,405
Take-off to unstick at sea level max thrust, A/B unlit.	-	0.32	192	67,213
Acc. to 0.92 M at S.L. max. thrust, A/B unlit.	7.5	1.10	815	66,398
Climb @ 0.92 M to 35,000' max thrust A/B lit.	12.2	1.50	1,840	64,558
Acc. to 1.80 M @ 35,000' max thrust A/B lit.	26.0	2.0	1,970	62,588
Climb @ 1.8 M to 53,000' max thrust A/B lit.	17.7	1.03	1,028	61,560
Cruise out @ 1.8 M @ 53,000' partial A/B	274.6	16.0	6,240	55,320
Combat @ 1.8M@53,000' max thrust A/B lit.	-	5.0	3,450	50,534 *
Cruise back at .905 M at optimum altitude (39,000')	338	39.1	3,699	46,835
Loiter over base at 39,000' at max. endurance speed.	-	15.0	1,250	45,585
Descend to S.L. at idle thrust	-	4.05	204	45,381
Land with reserves for 5 min. loiter at max. endurance speed at S.L.	-	5.0	825	44,556
	676	90.6	21,613	

Fuel density = 7.8 lb/gallon.

* 1336 lb. missiles fired at combat.

~~SECRET~~

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITION	DIST. N.M.	TIME MINS.	FUEL LB.	A/C WT. LB.
Start Weight	--	--	--	71,747
Engine Start	--	0.5	100	71,647
Take-off to unstick at sea level maximum thrust, A/B unlit	--	0.35	215	71,432
Acc. to 527 Kts. at S.L., max thrust A/B unlit	5.6	0.93	674	70,758
Climb at 527 Kts. to 35,000' max thrust A/B unlit (opt. cruise out alt.)	45.0	5.14	2150	68,608
Cruise out at 0.905Mat 35,000'	541	62.0	7947	60,319+
Acc. to 1.5 M at 35,000' max thrust A/B lit	14.8	1.28	1180	59,139
Climb to 50,000' at 1.5 M, max thrust A/B lit	13.6	0.86	805	58,334
Combat at 50,000' at 1.5 M, max thrust A/B lit	--	5.0	3140	53,858*
Cruise back at .905 M at optimum alt. (39,000')	620	71.8	7023	46,835
Loiter over base at 39,000' at max endurance speed	--	15.0	1250	45,585
Descend to S.L. at idle thrust	--	4.05	204	45,381
Land with reserves for 5 min loiter at S.L. at max end. speed	--	5.0	825	44,556
TOTAL	1240	171.91	25,513	

Fuel density 7.8 lb/gallon
+ 342 lb. ventral D.T. Jettisoned
* 1336 lb. missiles fired at combat.

SECRET

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB.	A/C WT. LB.
Start Weight				67,505
Engine Start		0.50	100	67,405
Take-off to Unstick at S.L. Max Thrust A/B Unlit		0.32	192	67,213
Acc. to 527 K. at S.L. Max. Thrust A/B Unlit	5.0	0.85	609	66,604
Climb at 527 K. TAS to 10,000' Max. Thrust A/B Unlit	6.0	0.72	490	66,114
Cruise at M=0.70 at 10,000' (Opt. Cruise Speed)	381.0	51.20	9280	56,834
Acc. to M=0.92 at 10,000' Max. Thrust A/B Unlit	4.0	0.43	260	56,574
Combat at M=.92 at 10,000' Max. Thrust A/B Unlit		5.0	3140	52,098 x
Climb to 39,000' at 527 KTS TAS Max. Thrust A/B Unlit	30.0	3.7	1240	50,858
Cruise back at M=0.905 at optimum Altitude (39,000 ft.)	366.0	42.4	4023	46,835
Loiter over base at 39,000 ft. at max. endurance speed		15.0	1250	45,585
Descend to S.L. at idle thrust		4.05	204	45,381
Land with reserves for 5 mins. Loiter at S.L. at Max. Endurance Speed		5.0	825	44,556
TOTAL	792	129.17	21,613	

Fuel density 7.8 lb./gallon.

x 1336 lb. missiles fired at combat.

~~SECRET~~

ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

TABLE 7 - FERRY MISSION (NO ARMAMENT)

VENTRAL TANK CARRIED THROUGHOUT

CONDITION	DISTANCE (N.M.)	TIME (MIN.)	FUEL (LB.)	A/C WEIGHT (LB.)
Start Weight	-	-	-	70,411
Engine Start	-	0.50	100	70,311
Take-Off to Unstick, Max. Thrust, A/B Unlit	-	0.34	205	70,106
Acc. to 527 Kts. at S.L., Max. Thrust, A/B Unlit	5.5	0.91	656	69,450
Climb to 35,000' at 527 Kts. T.A.S. Max. Thrust, A/B Unlit	43.5	5.0	2,100	67,350
Cruise Climb to 40,000' at M = .905	1451.0	168.2	20,052	47,298
Loiter over Base at 40,000' at Max. Endurance Speed	-	15.0	1,330	45,968
Descend to S.L. at Idle Thrust	-	4.1	205	45,763
Land with Reserves for 5 Mins. Loiter at S.L. at Max. Endurance Speed	-	5.0	865	44,898
TOTAL	1,500	199.05	25,513	

Fuel Density = 7.8 lb./gallon

SECTION 2 DRAG DATA

The drag data used in this report are presented in the form of D/p_a, W/p_a vs M carpets in the following four figures. They are based on a mean c.g. position of 29.5% $\bar{c}$.

Basically, the estimated data of Periodic Performance Report Number 12 have been modified in the light of flight tests carried out on Aircraft 25202 and 25203.

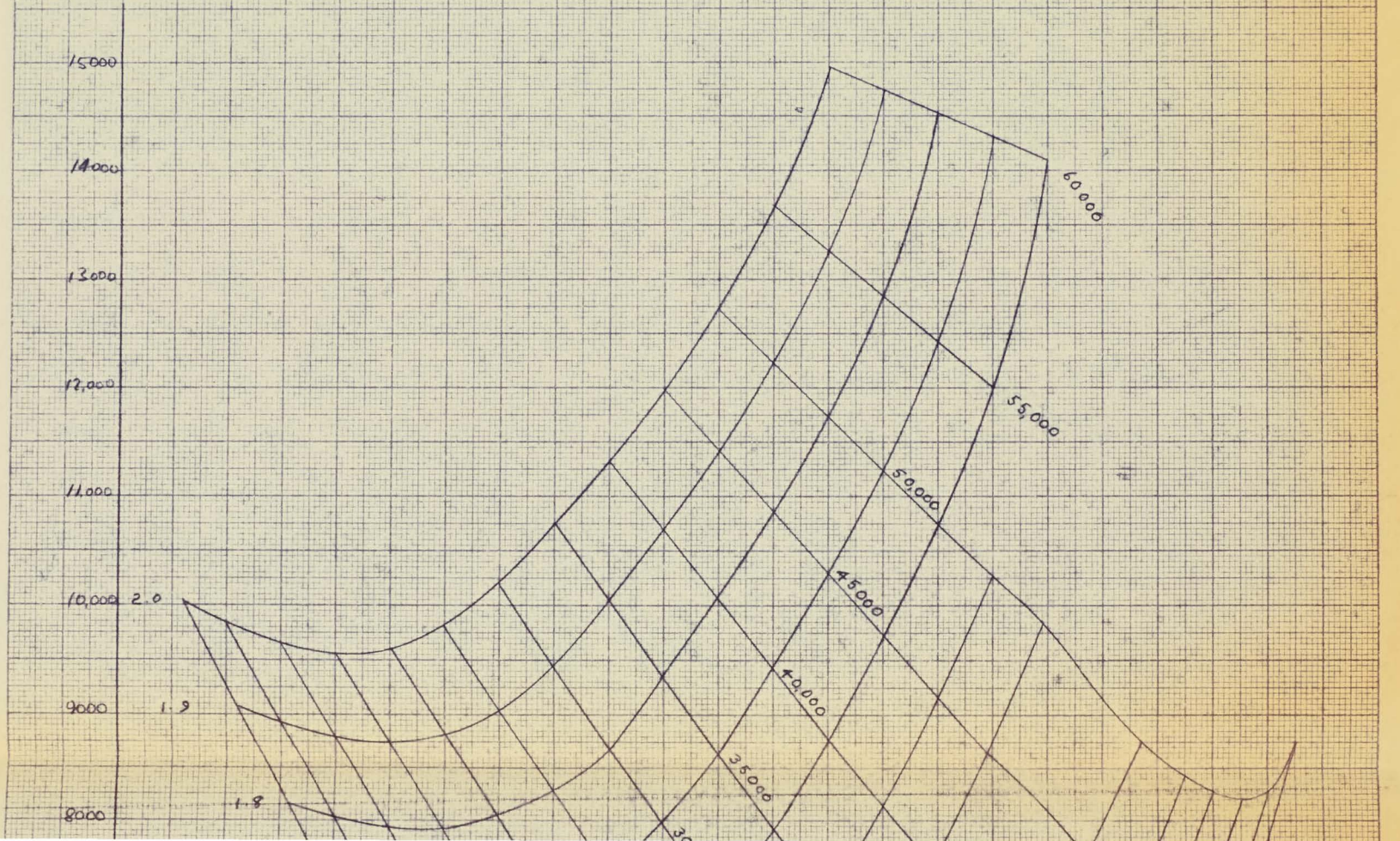
Aircraft 25203 was partially instrumented for performance flight testing, and carried out some preliminary performance tests. In view of the approximate nature of the tests, a conservative view was maintained whilst analysing the results, and the drag reductions claimed are considered to be the minimum as evidenced by the tests. The drag reductions are considered in two fields only: (1) a reduction in negative elevator angle to trim, and hence in transonic trim drag, between Mach numbers of 0.80 and 1.2. (2) a reduction in boat tail drag over the whole supersonic range.

ARROW

REVISED D/Pa – W/Pa & M. OCTOBER/58

NO AILERON DEFLECTION

C.G. AT 29.5% M.A.C.

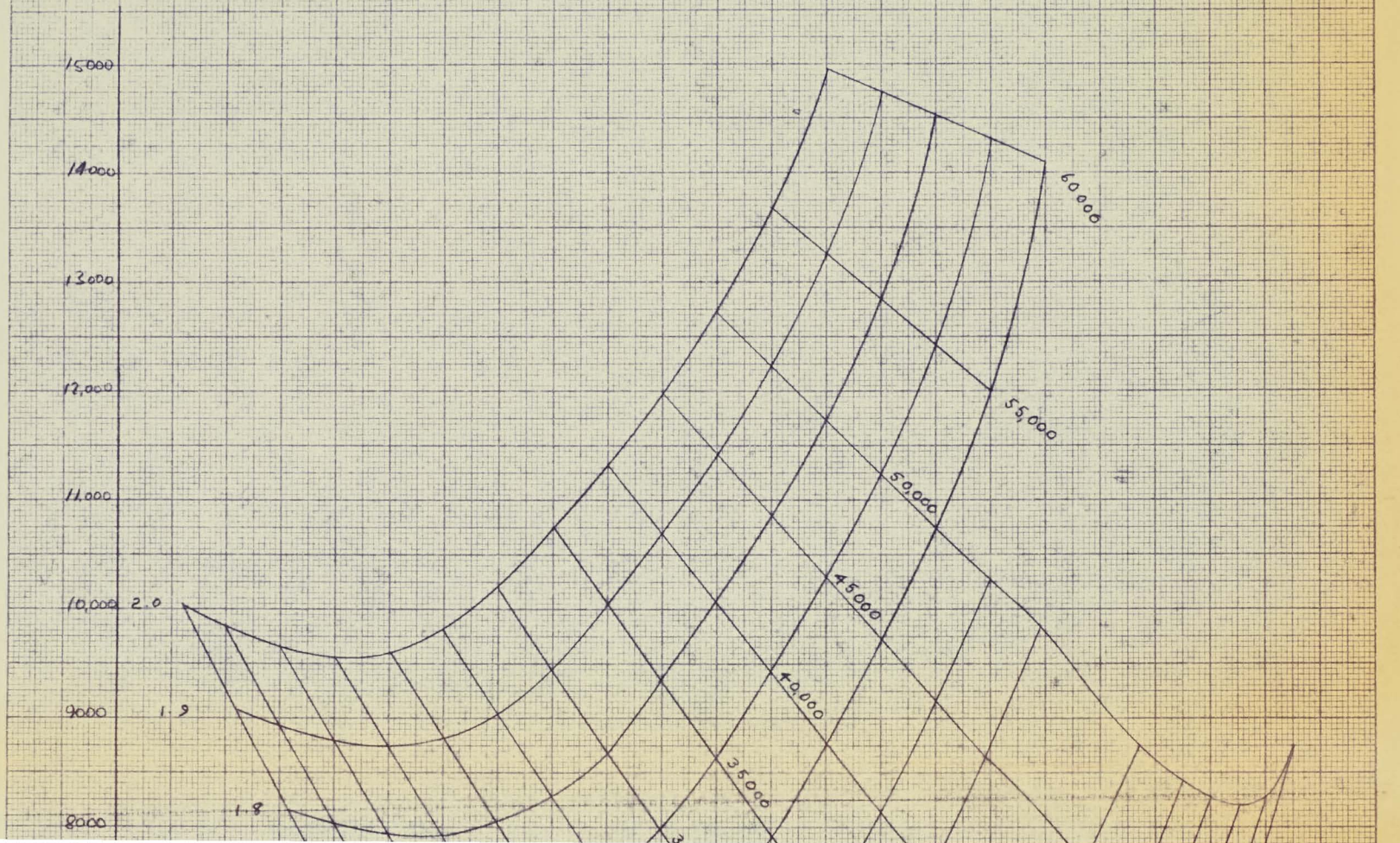


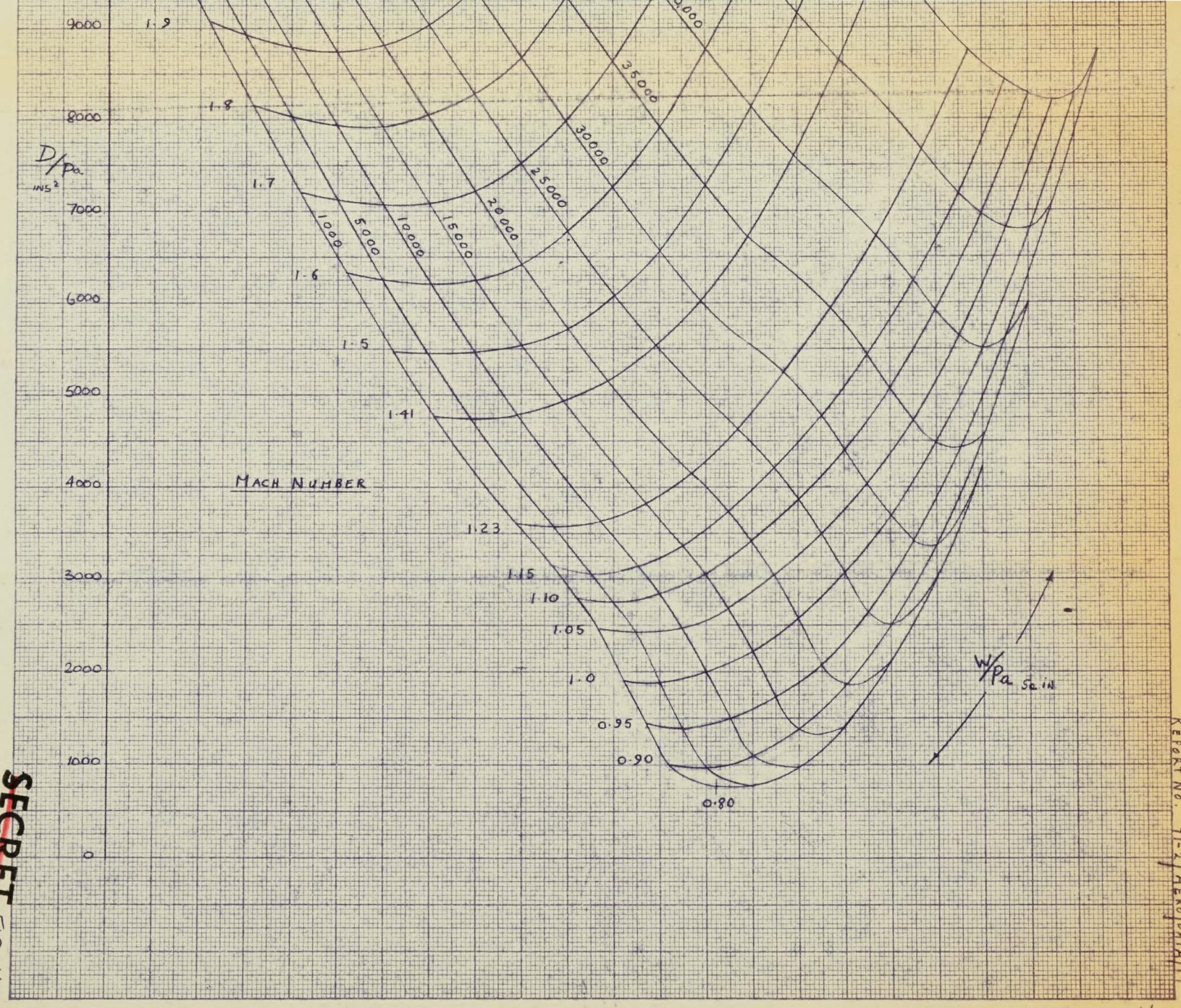
ARROW

REVISED D/Pa – W/Pa & M. OCTOBER/58

NO AILERON DEFLECTION

C.G. AT 29.5% M.A.C.



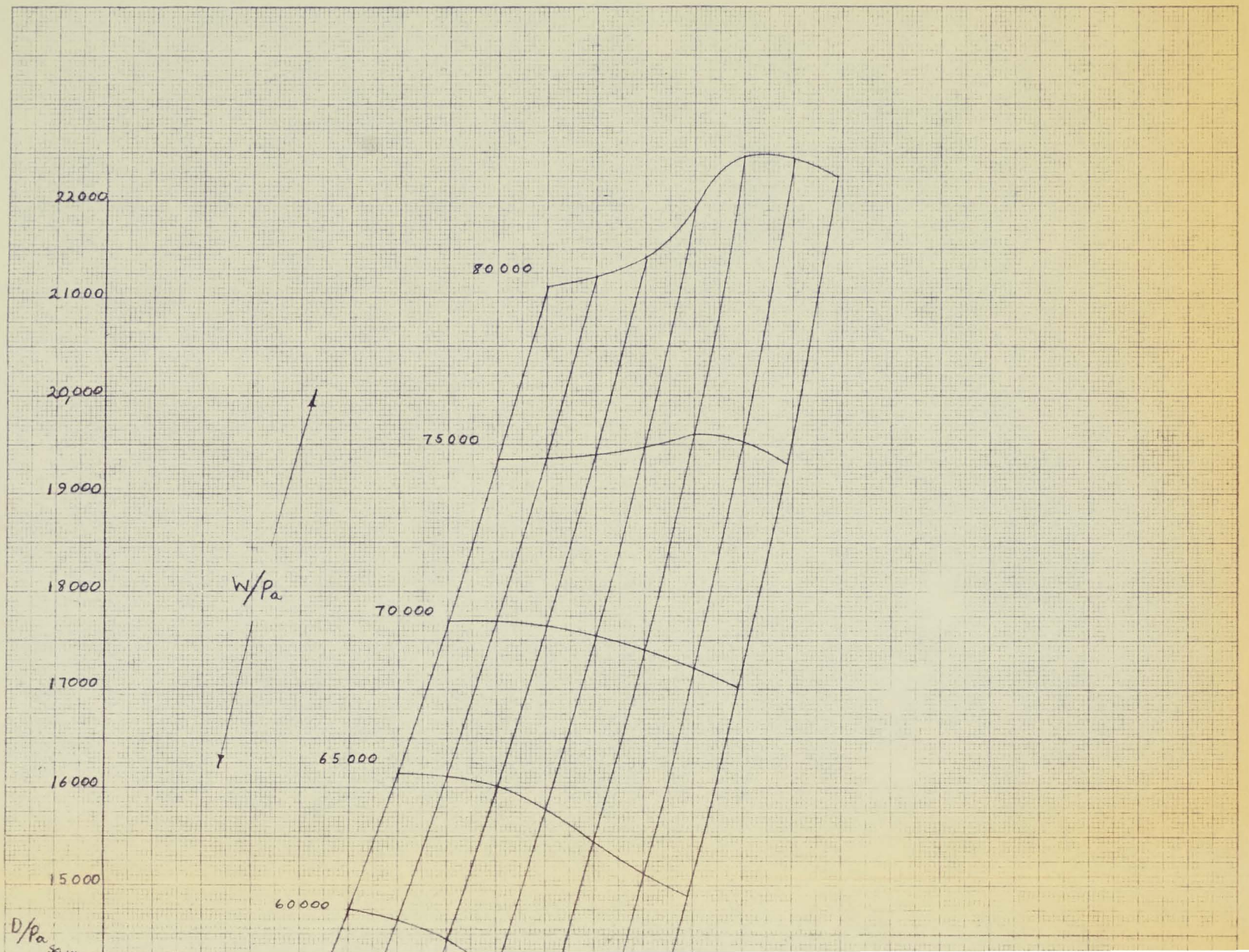


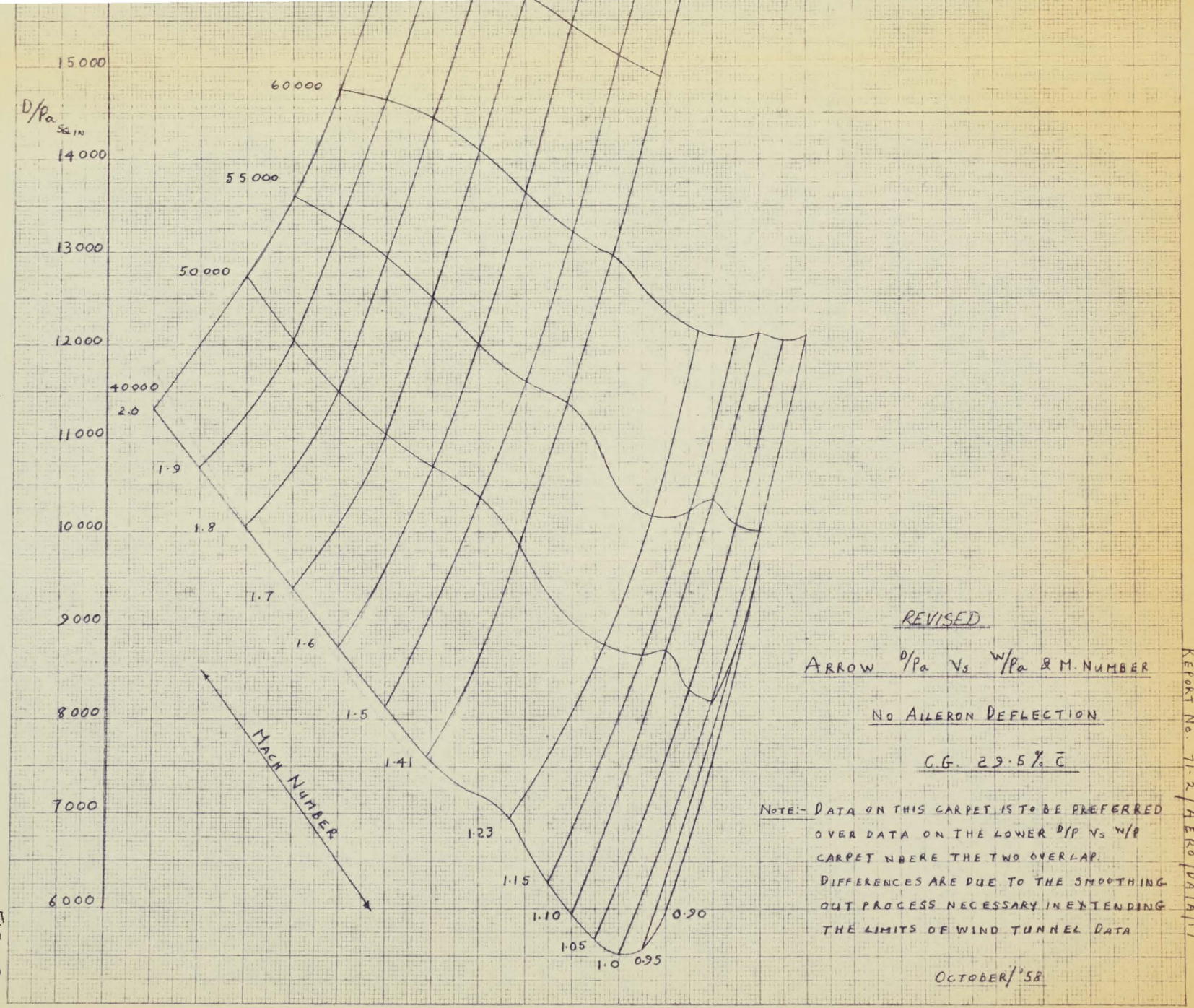
SECRET

FIG. 11.

REPORT NO. 71-2/AERO/DATA/17

Oct/58





REVISED

ARROW D/P_a Vs W/P_a & M. NUMBER

NO AILERON DEFLECTION

C.G. 29·5% $\bar{C}$

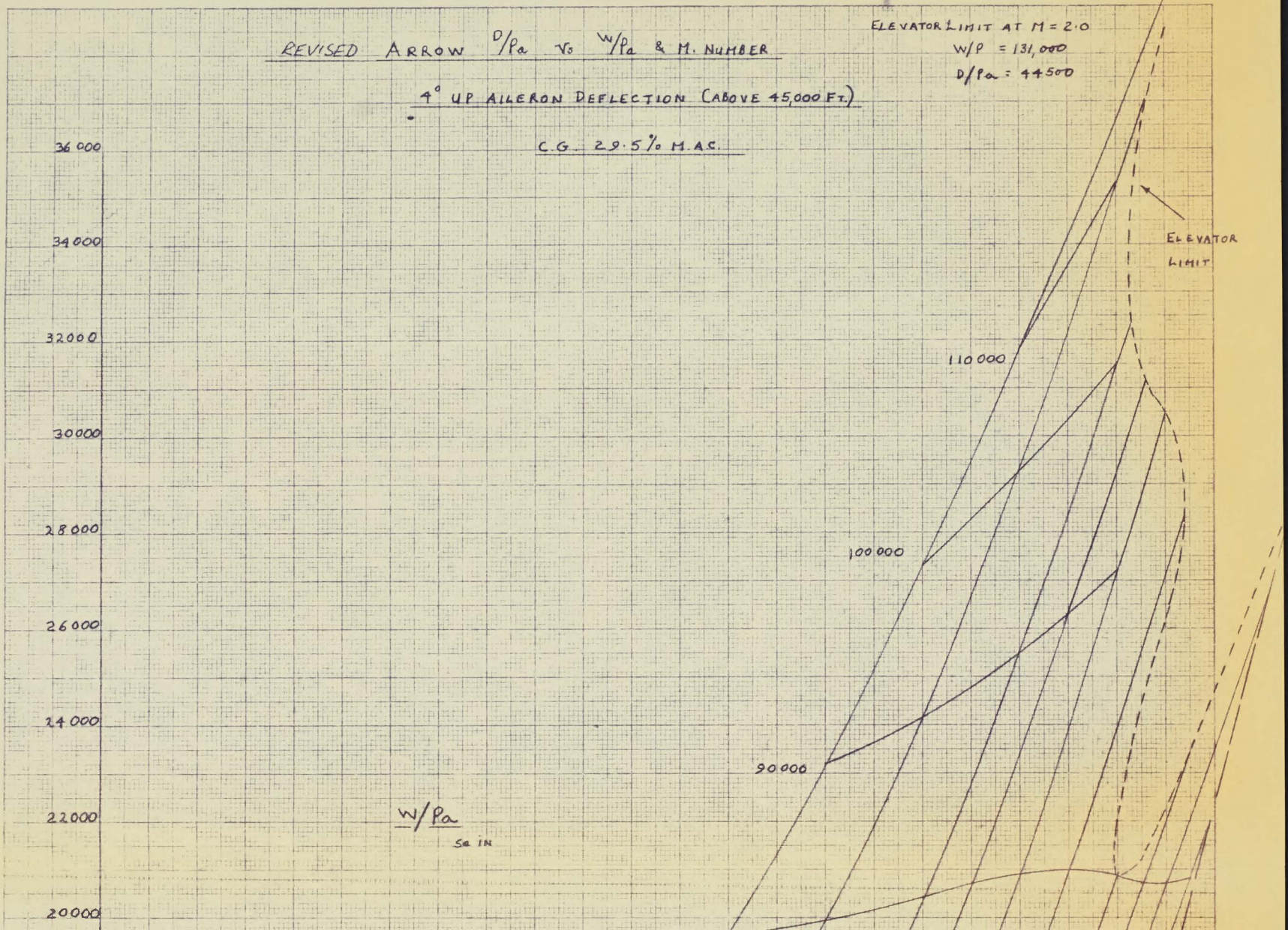
NOTE:- DATA ON THIS CARPET IS TO BE PREFERRED OVER DATA ON THE LOWER D/P Vs W/P CARPET WHERE THE TWO OVERLAP. DIFFERENCES ARE DUE TO THE SMOOTHING OUT PROCESS NECESSARY IN EXTENDING THE LIMITS OF WIND TUNNEL DATA

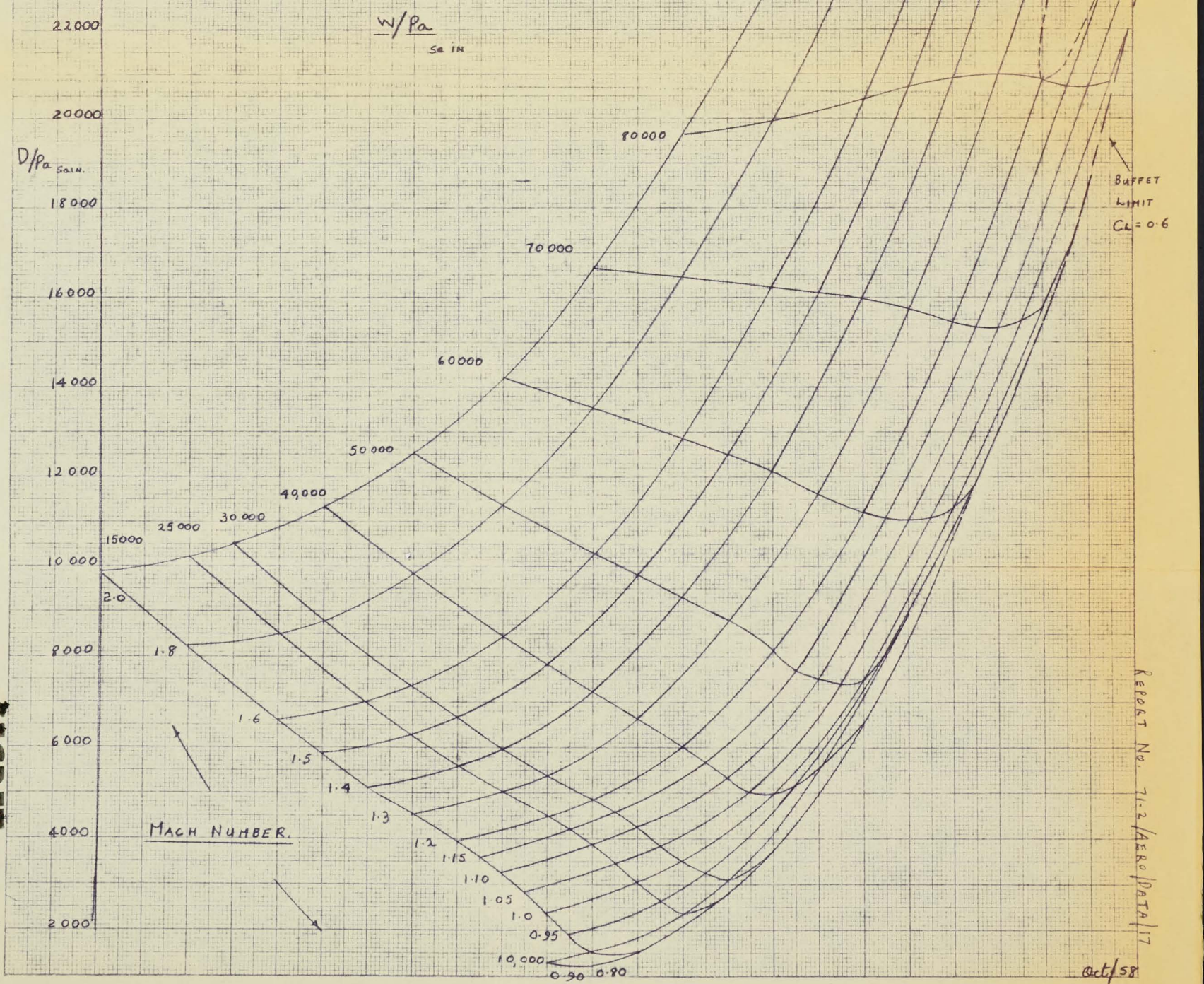
OCTOBER/'58

REPORT No. 71-2/AERO/DATA/17

SECRET

FIG 12





SECRET

FIG 13

REPORT No. 71·2/AERO/DATA/17

Oct/58

SECTION 3 PROPULSION DATA

Introduction

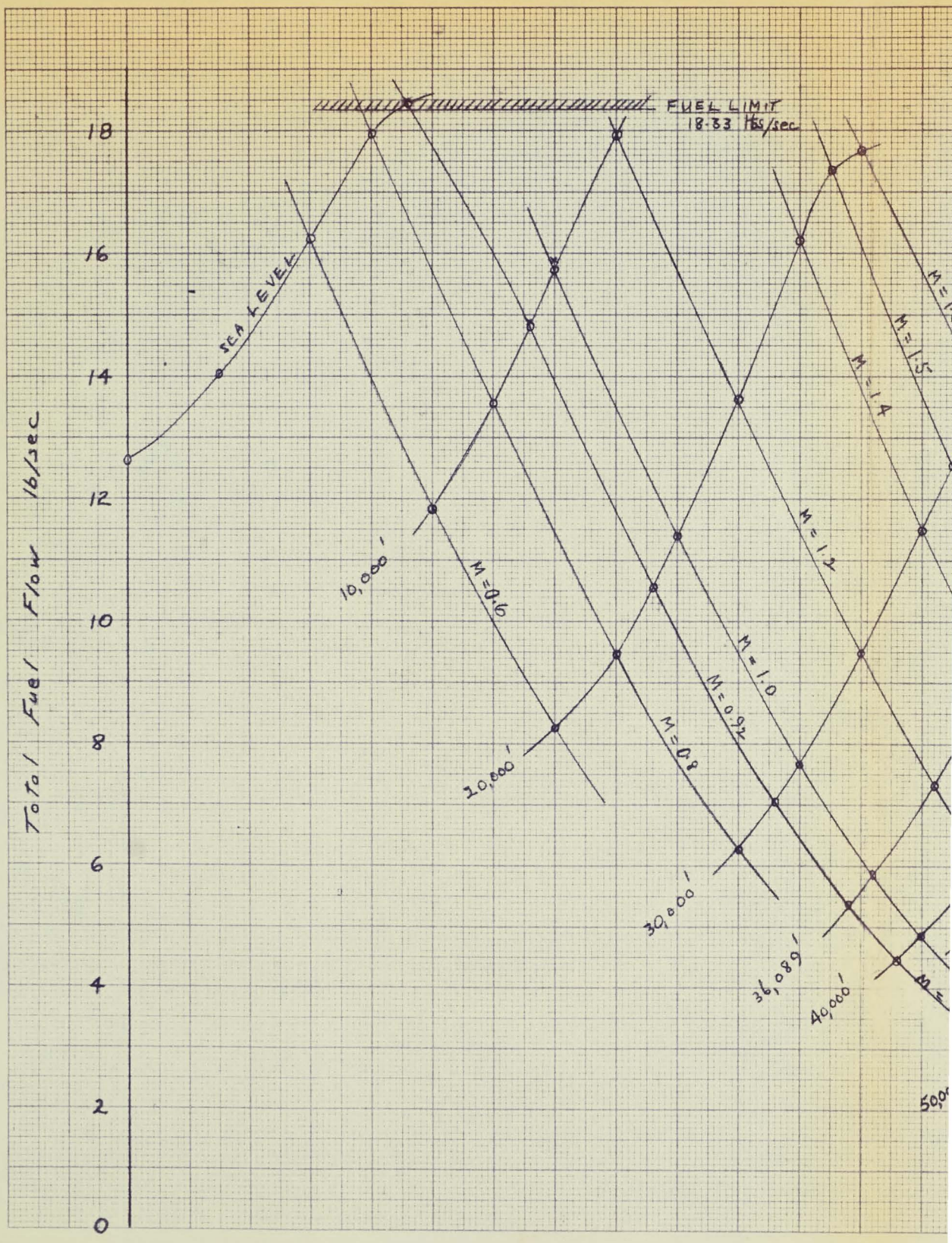
The changes within the Arrow 2/Iroquois propulsion system between publication of P.P.R. 14 and P.P.R. 15 are:- (a) A decrease in maximum high pressure rotor speed from 8150 to 8050 r.p.m. but with identical rotor swallowing capacity. (b) The introduction of a high pressure rotor control rather than a low pressure rotor control such that at free stream total temperatures greater than 288°K there is a drop in low pressure rotor speeds. Thus above M = 1.278 above the tropopause there is a drop in engine swallowing capacity. (c) A reduction in the variable restrictor flow area in the closed position to give small improvements in subsonic performance and significant improvements in distortion levels.

Both reports contain identical intake and ejector geometry, afterburner fuel schedule, and afterburner efficiency.

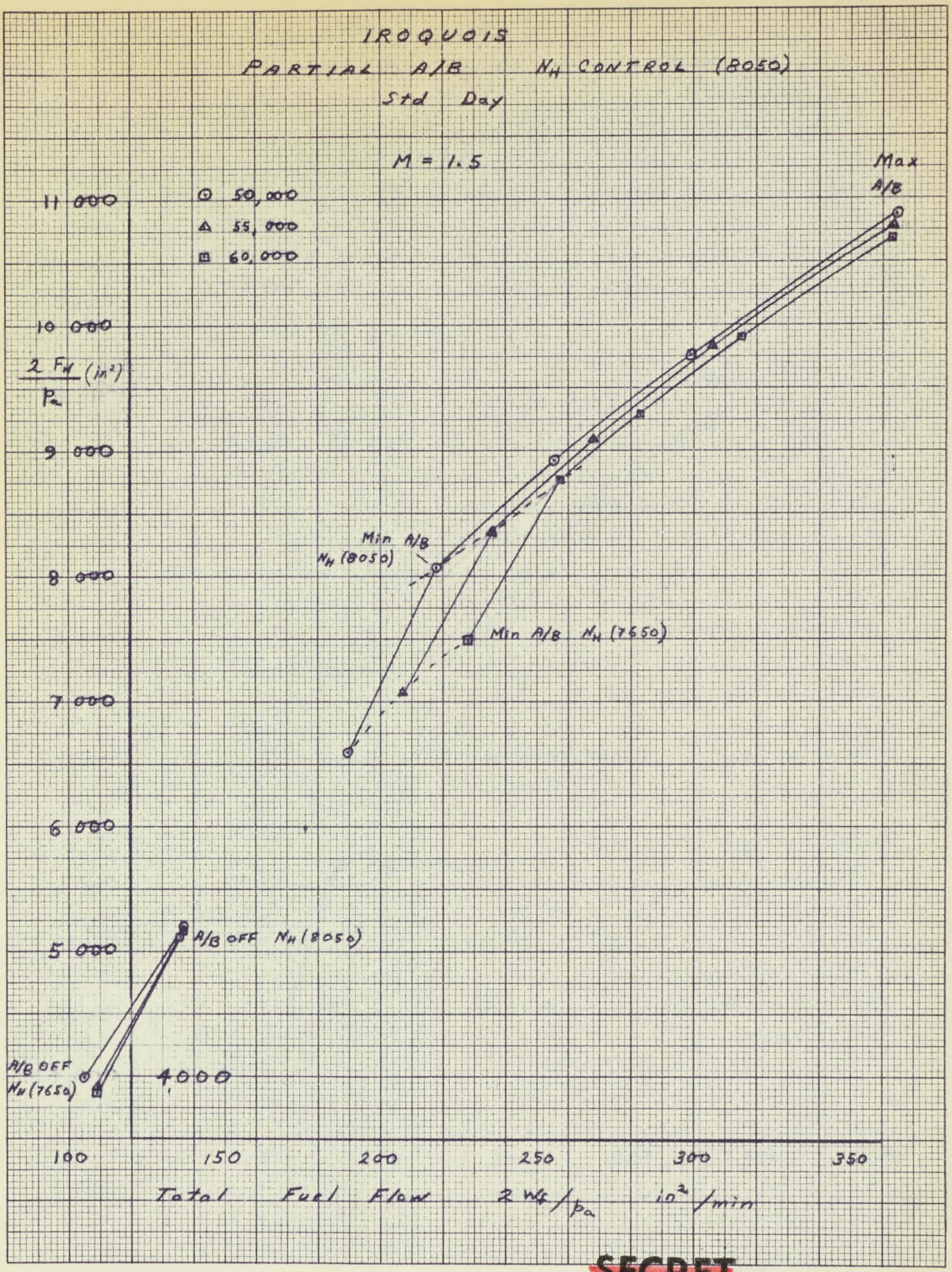
Prepared by Internal Aero. Group - Nov. 1958.

C B Mc Carter.

SECRET


FUEL LIMIT
18.33 lbs/sec
Total Fuel Flow lb/sec
0
2
4
6
8
10
12
14
16
18
SEA LEVEL
10,000'
20,000'
30,000'
36,089'
40,000'
M=0.6
M=0.8
M=0.92
M=1.0
M=1.2
M=1.4
M=1.5

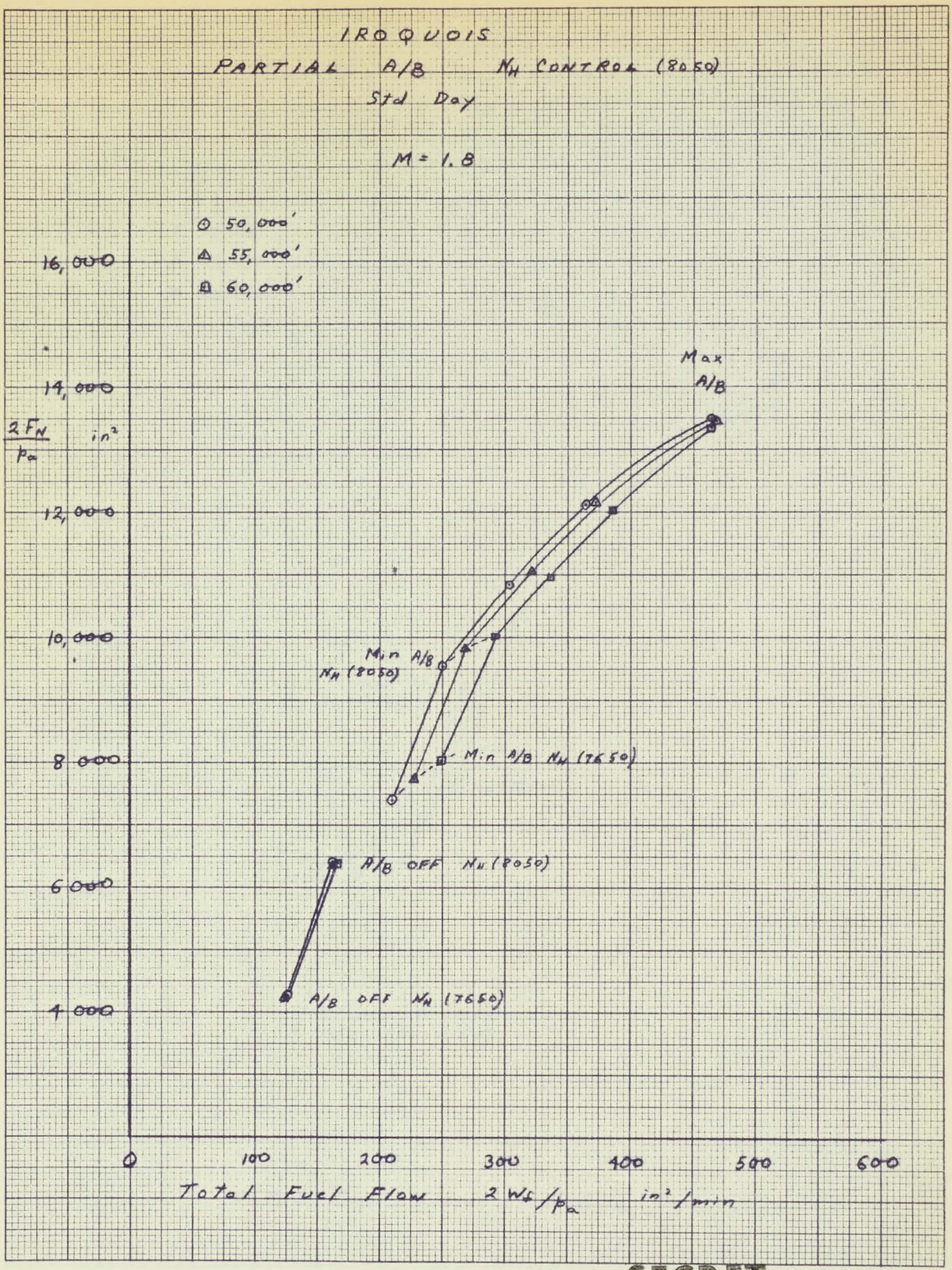
Ref: 72/AT Aero/133



SECRET

FIG 16

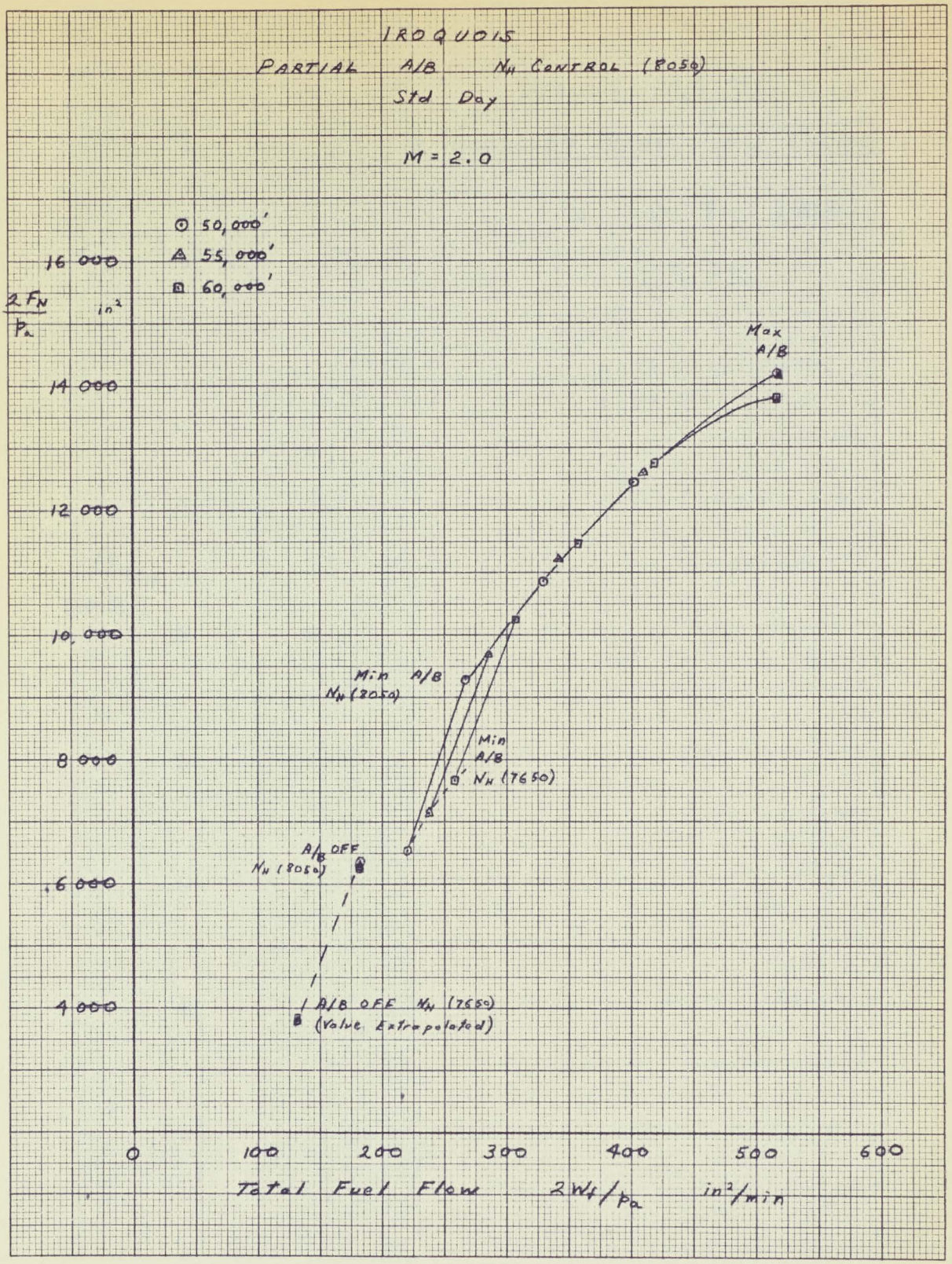
Ref: 72/Int Aero/133



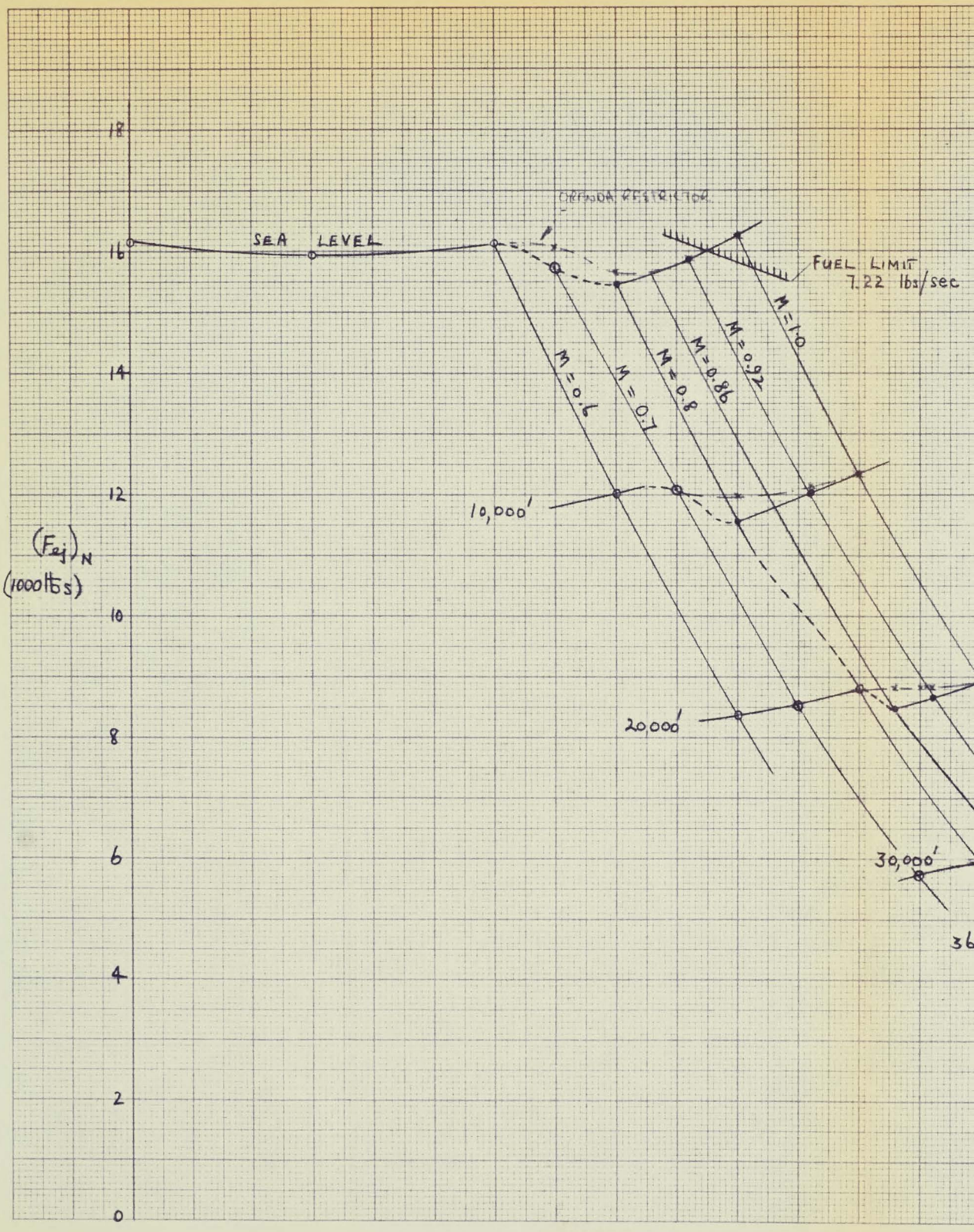
SECRET

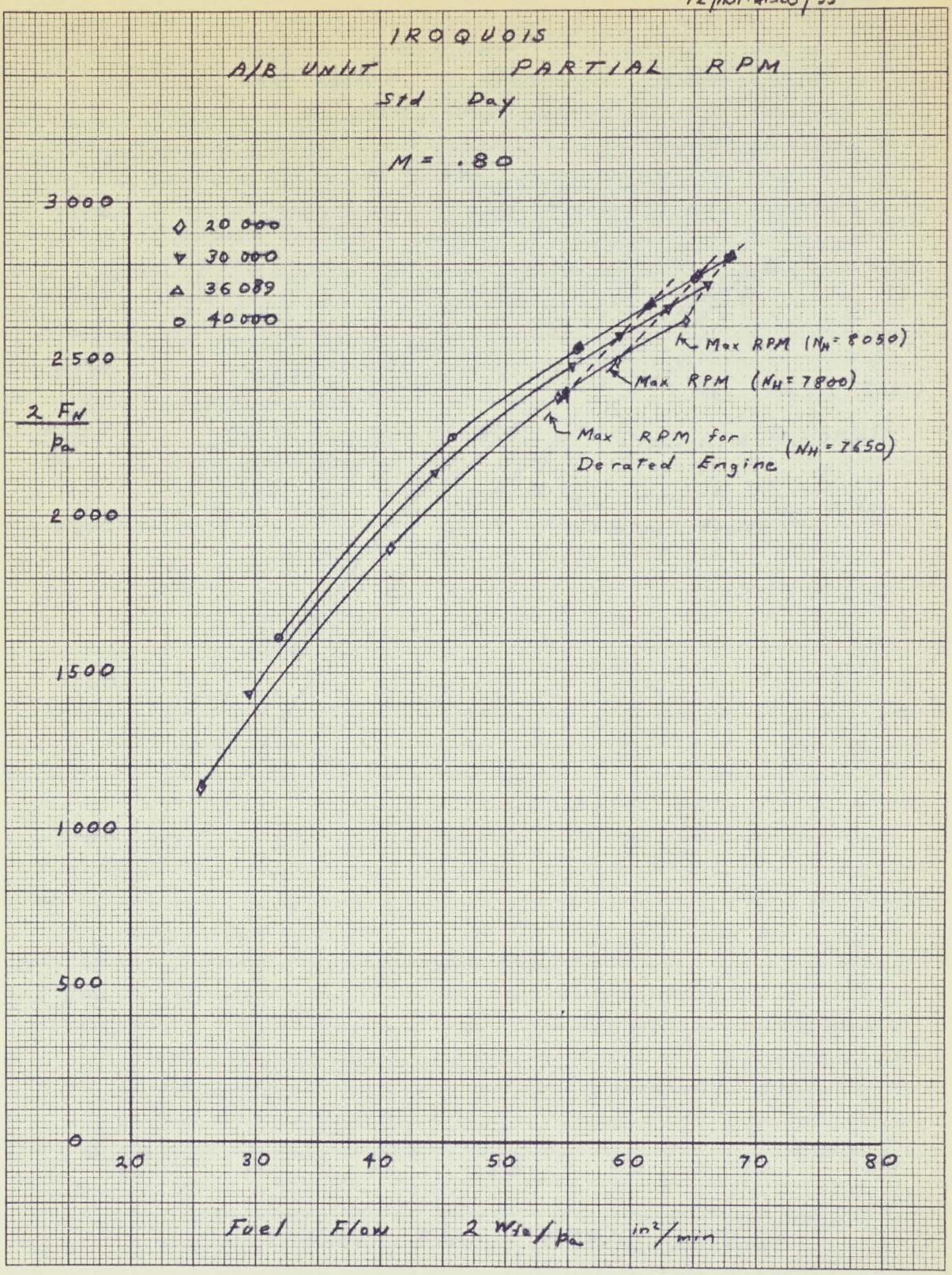
FIG. 17.

Ref: 72/Int Aero/33



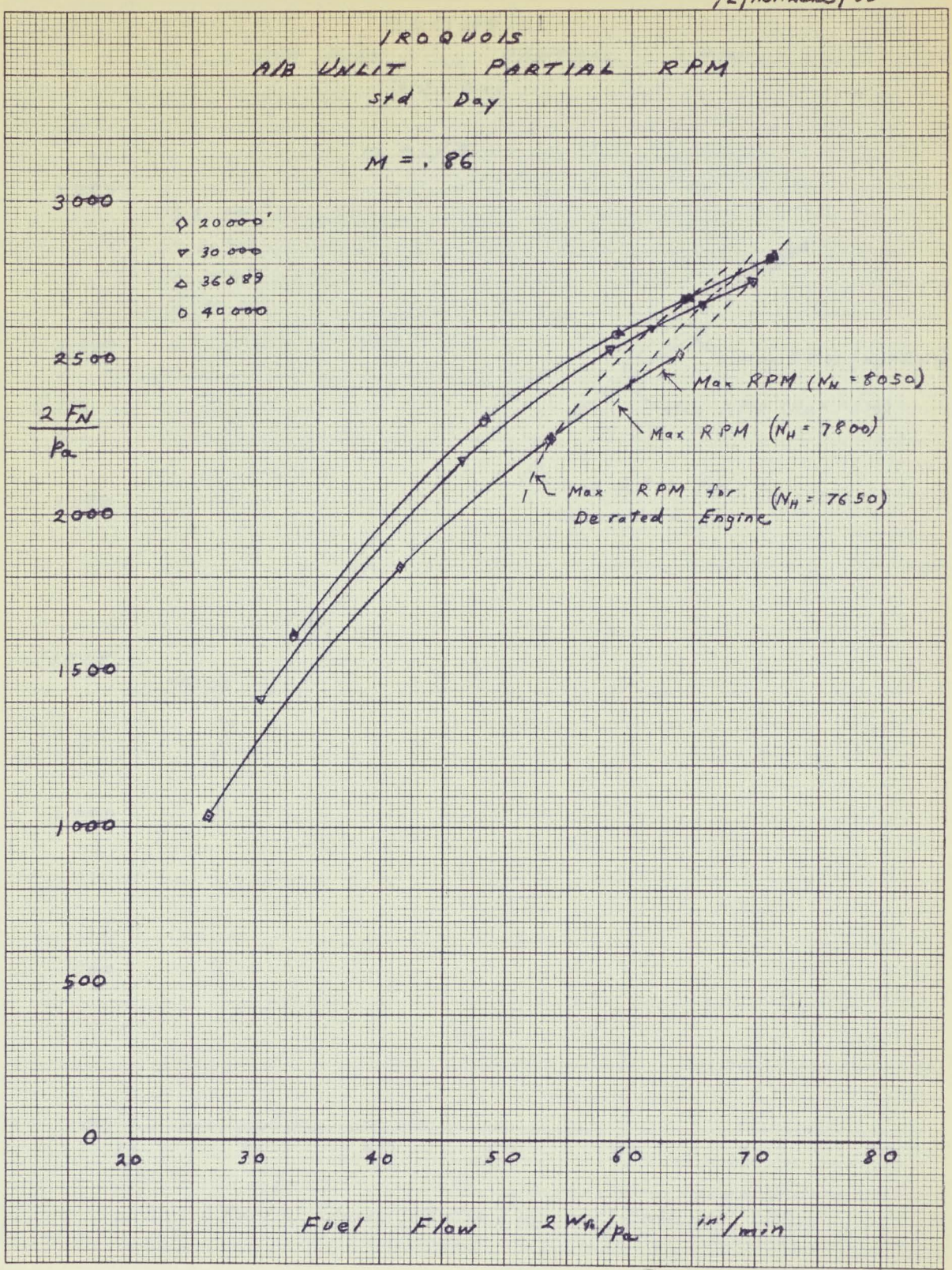
SECRET FIG. 18.


SEA LEVEL
OVERSPEED RESTRICTOR
FUEL LIMIT
7.22 lbs/sec
M=1.0
M=0.92
M=0.86
M=0.8
M=0.7
M=0.6
10,000'
20,000'
30,000'
$(F_{ej})_N$
(1000 lbs)
18
16
14
12
10
8
6
4
2
0



SECRET

FIG 21.



SECRET

FIG. 22.

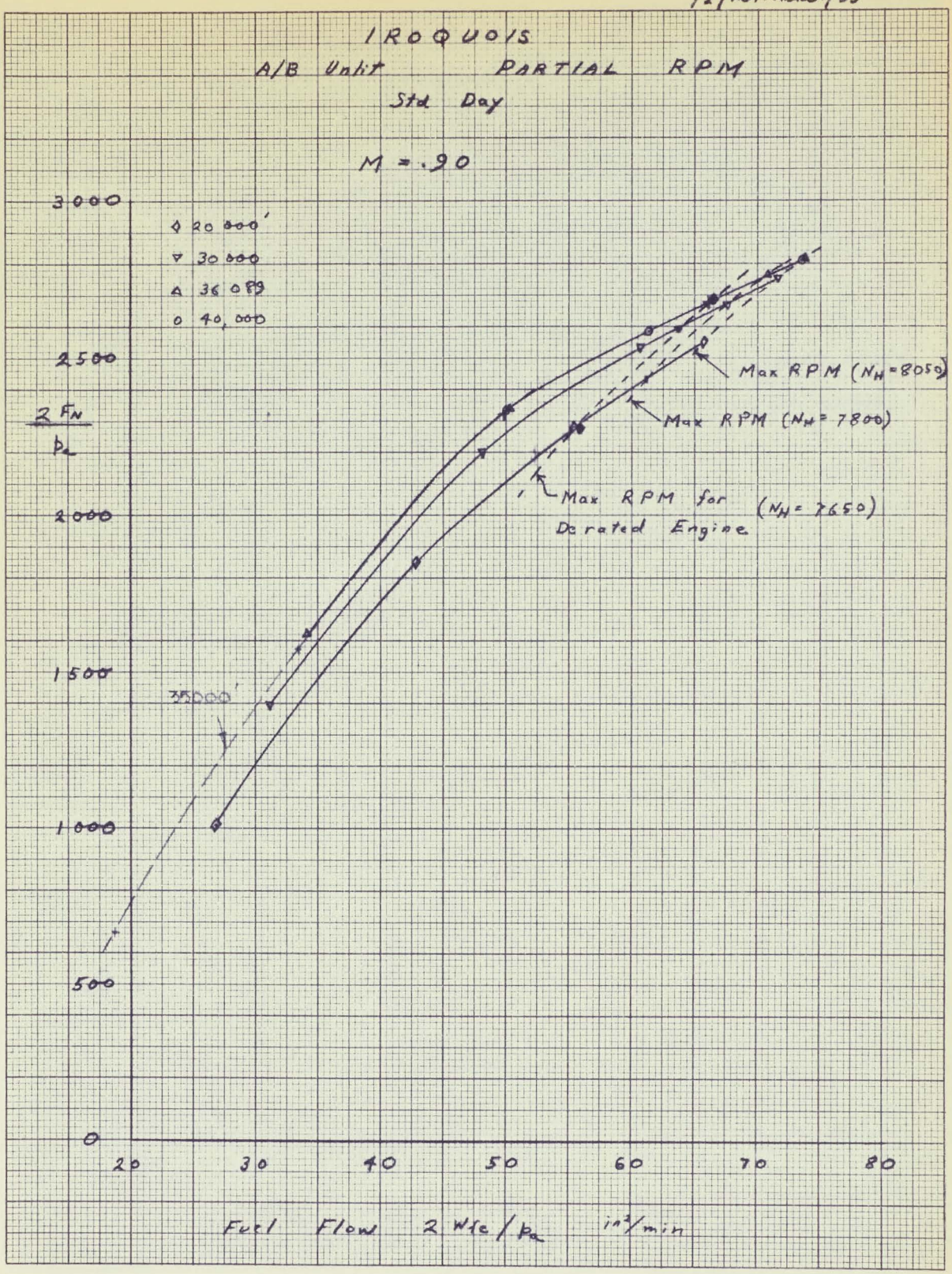
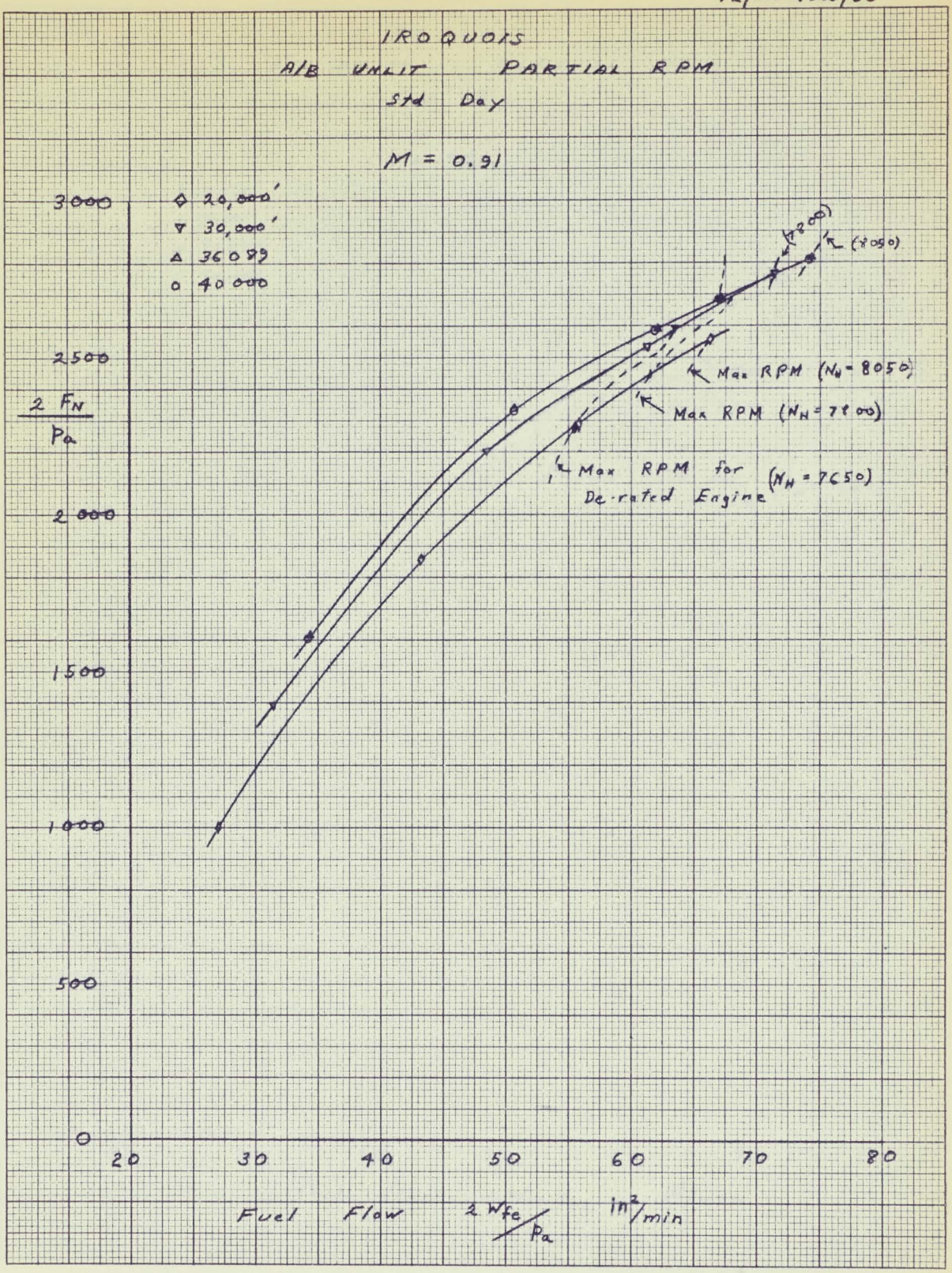


FIG 23. 19.

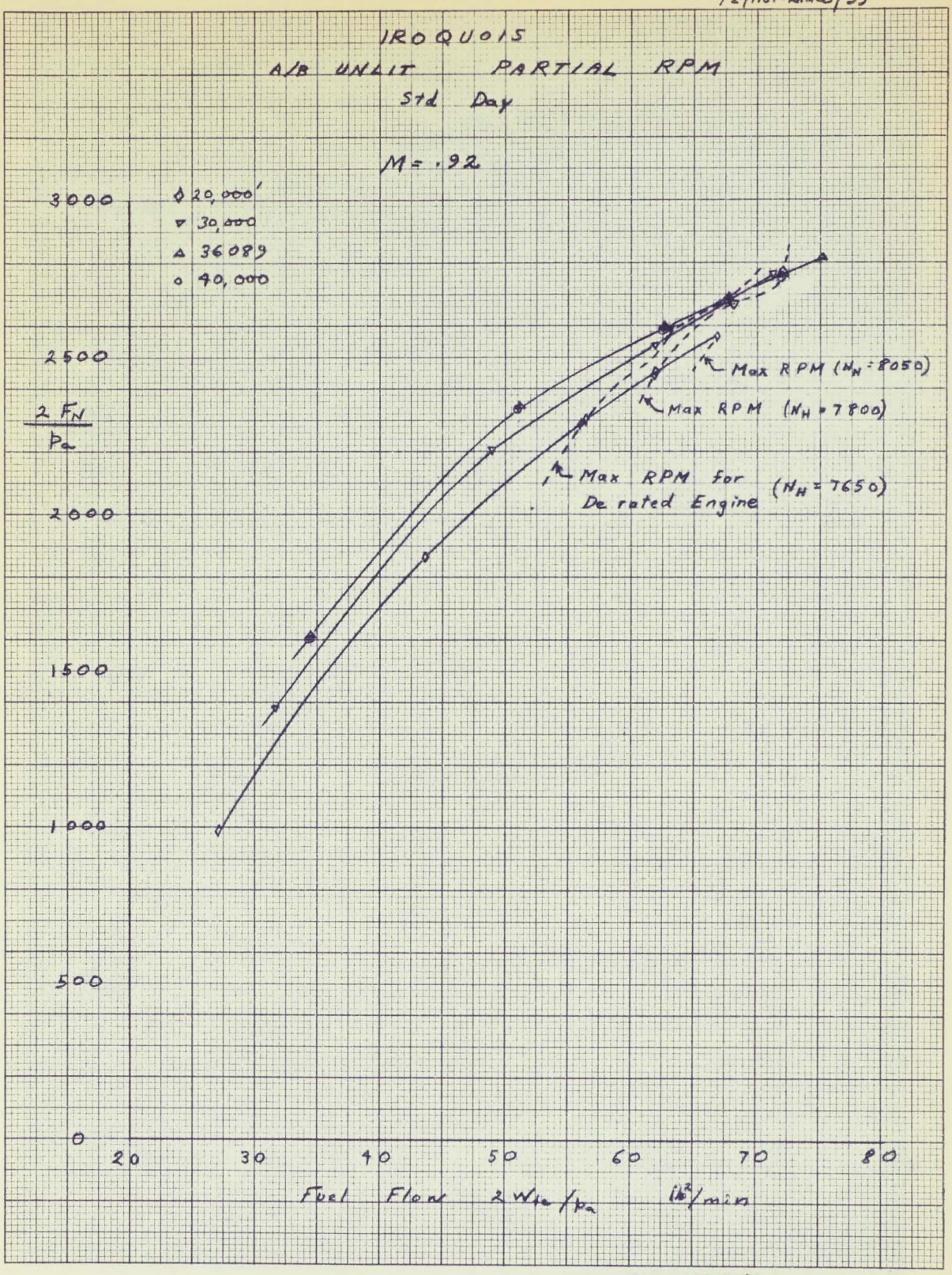


Note: Orenda Restrictor rates some points

SECRET FIG 24.

IROQUOIS
A/B UNLIT PARTIAL RPM
Std Day

M = .92



SECRET

FIG 25.

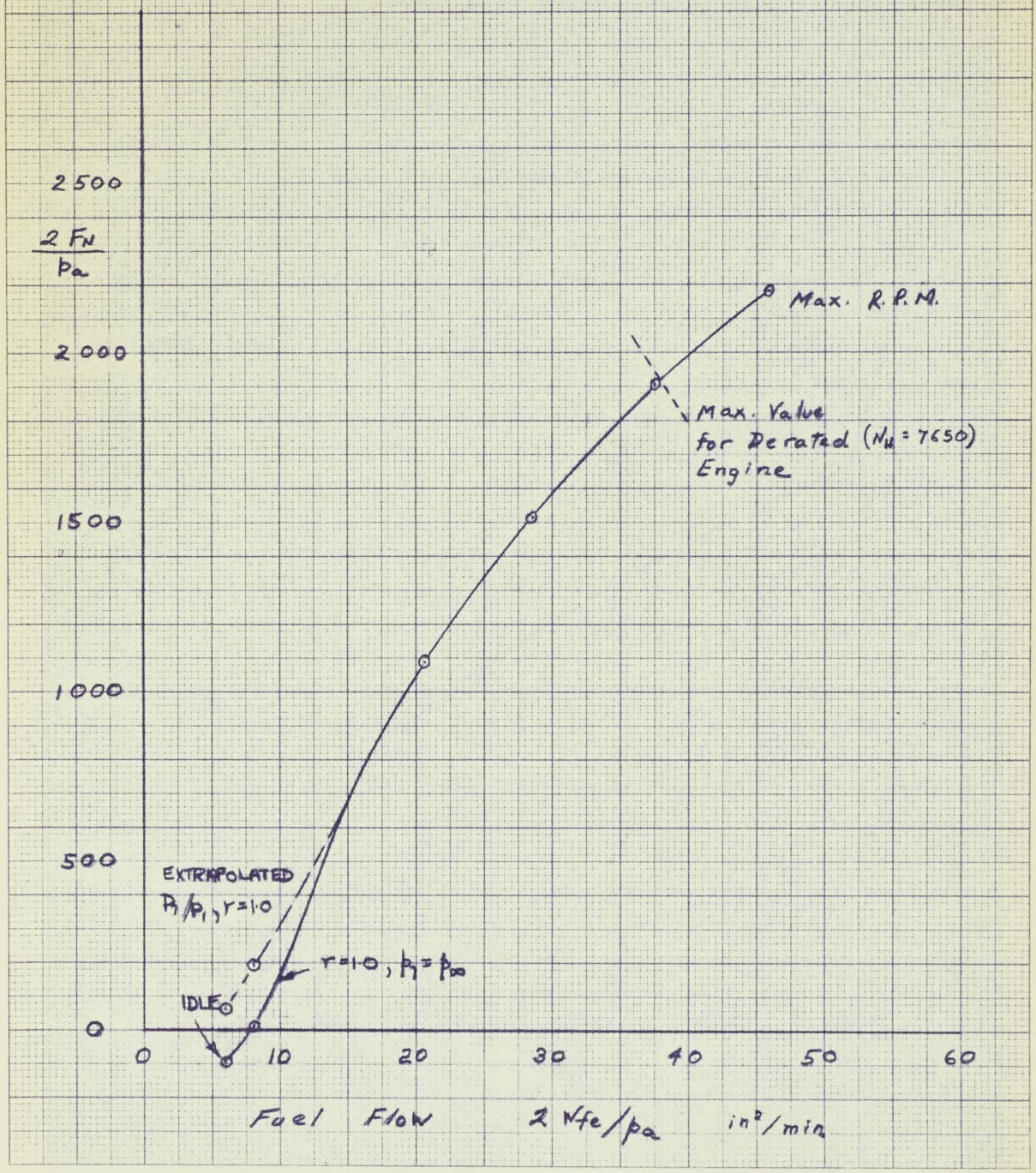
Ref: 72/Dt Aero/33

IROQUOIS

A/B UNLIT PARTIAL R.P.M.

Std. Day

SEA LEVEL M=.40



SECRET

FIG 27

IROQUOIS 2
IDLING
MIN^M DRAG SPEED

THRUST

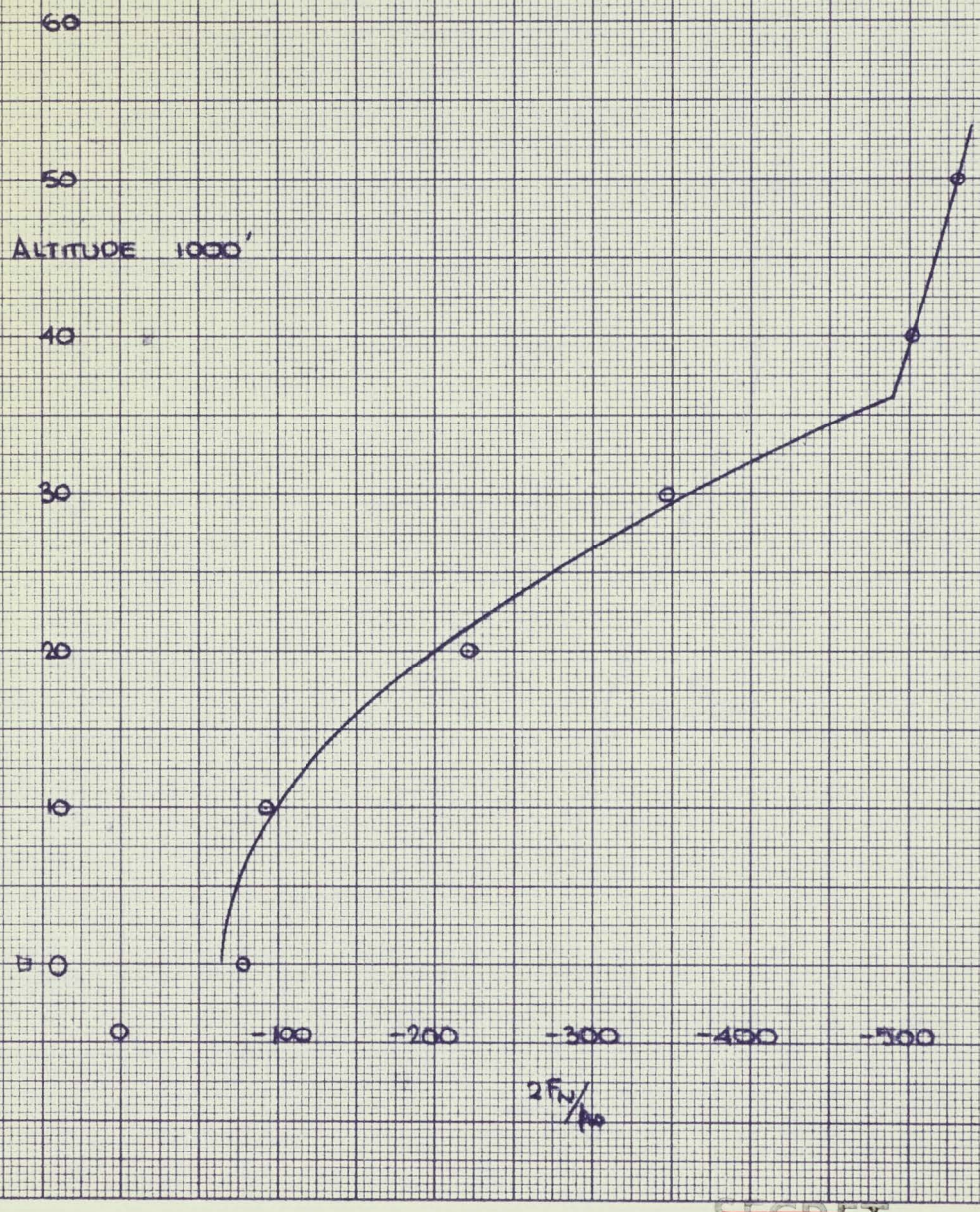


FIG. 28.