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The reports cover the Arrow 2 i.e. the Iroquois powered Mark 2 (Arrows 206 and later)

The notes added or text high-lighted in blue are my own.

There will be more information like this added as time permits.

AVRO

Classification cancelled / changed to ....Uncl
By authority of.. AVRO Arrow Declassif.
Date.. 28 Jul 87
Signature .... Co-
Unit / Rank / Appointment .... DSIS 3 ....

TE

S E C R E T

AIRCRAFT: ARROW 2

REPORT NO: Periodic Perfor Report No. 15

FILE NO: 72/PERF/36

NO. OF SHEETS 49

ANAL

TITLE:

[redacted]

PERFORMANCE OF THE ARROW 2

 5657

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 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 altitiude mission -subsonic combat	589	+35	+15
2	Subsonic high altitiude mission -supersonic combat	506	+35	+15
3	Supersonic (1.5M) high altitude mission - supersonic (1.5M) combat	358	+25	+10
3A	Supersonic (1.8M) high altitude mission - supersonic (1.8M) combat	338	+25	+10
4	Combat Air Patrol - Supersonic combat	620	+35	+15
5	Subsonic low level mission (10,000') - subsonic combat	396	+26	+10
6	Ferry Mission (no armament) ventral tank carried throughout	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.	70,747
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) Maximun thrust, A/B unlit Kts.630

50,000 ft.(i) Maximum thrust, A/B lit Kts.1147*

*(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 ft/min. 18,600

50,000 ft. (i) Maximum thrust, A/B lit at 1.8 M ft/min. 10,330

* That's 8.4 miles per minute!

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. 4.8

MANOEVERABILITY

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 (135 mph)

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 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	60.5	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	46,853
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. Ehdurance 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

TABLE 4 - ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITIONS	DIST. N.M	TIME MIN.	FUEL LBS.	A/C WEIGHT LBS.
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	1.1	815	66,398
Climb @ .92 M to 35,OOO' Max thrust, A/B lit	12.2	1.5	1,840	64,558
Acc. to 1.5M @ 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 maxe endurance speed at S.L.	-	5.0	825	44,556
Total	716.0	97.74	21,613	

Fuel density 7.8 lb/gallon

*1336 lb missiles fired at comba

TABLE 4A - ARROW 2 WITH IROQUOIS SERIES 2 ENGINES

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

CONDITIONS	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	1.1	815	66,398
Climb @ 0.92 M to 35,000' max thrust A/B lit	12.2	1.5	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 to 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
Total	676**	90.6	21,613	

Fuel density 7.8 lb/gallon.

*1336 lb. missiles fired at combat.

** That's 2771 gal. for an average of 0.25 mpg.!

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	-	0.5	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. Trust, A/B Unlit	43.5	5.0	2,100	67,350
Cruise Climb to 40,000' at M = .905	1451	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

** That's 3271 gal. for an average of 0.53 miles/per gallon!

SECTION 2 DRAG DATA

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

Basically the estimated data of Periocdic 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.

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 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.

AVRO AIRCRAFT L1M1TED

MALTON - ONTARIO REPORT NO. Add. 1 to Report No .13

TECHNICAL DEPARTMENT

AIRCRAFT: Arrow 2 Zoom Ceilings PREPARED BY DATE

Performance Group April 1958

ARROW 2 - ZOOM CEILINGS

(ADDENDUM I TO PERIODIC PERFORMANCE REPORT No.13)

SUMMARY

An investigation has been made to ascertain the gain in altitude which could be achieved by the Arrow 2 when zoom climb tactics are employed.

It was found that for all supersonic initial speeds within the flight envelope, the maximum altitudes reached during a zoom represented a considerable increase over the 1 g power limited ceiling, the maximum increment being approximately 12,000 ft.

The altitude which can be reached in a zoom is limited by afterburner flame out and elevator trim limits for high supersonic initial Mach numbers, and by afterburner flame out only for low supersonic initial Mach numbers.

INVESTIGATION DETAILS

This investigation was undertaken to ascertain the zoom ceilings of the Arrow 2 for the half full internal fuel weight of 55,600 lb. (ref. Report 7-0400-34 Issue 16 dated Feb. 1st. 1958). Several zoom cases were considered to determine the optimum initial load factor and angle of climb, for the greatest gain in altitude from various initial Mach number and altitudes. The load factors given were not held constant throughout the zoom, but were merely held until the angle of climb had reached the required value; the load factor was then reduced to approximately 1.0

The cases examined were :-

Initial Mach No.	Initial Height ft.	Load Factor	Climb Angle
2.0	57,000	1.5	30°,20°,10°
		2.0	30°,20°,10°
		limit	30°,20°,10°
2.0	52,000	1.5	30°,20°,10°
		2.0	30°,20°,10°
		2.5	30°,20°,10°
		limit	30°,20°,10°
1.8	60,000	1.25	30°,20°,10°
		1.5	30°,20°,10°
		limit	30°,20°,10°
1.8	55,000	1.5	30°,20°,10°
		2.0	30°,20°,10°
		limit	30°,20°,10°
1.5	57,000	1.25	30°,20°,10°
		limit	30°,20°,10°
1.5	52,000	1.25	30°,20°,10°
		1.5	30°,20°,10°
		limit	30°,20°,10°

All these calculations were carried out on the analogue computer and detail machine results are given in-Report 72/Comp.A/9.

The detail results have been cross plotted and are presented in Figs. 1 to 4, which show altitude vs initial load factor, for the various angles of climb. Time taken is also indicated. These curves are included in order that any tactical analysis involving zoom climbs might be more readily carried out.

From an examination of Figs. 1 to 4 it was found that, in every case, a 10o climb angle gave the maximum zoom height increment, and in general, close to the minimum time taken to reach a given height.

The results of Figs. 1 to 4 have been extrapolated to obtain the final zoom performance picture presented in Fig. 5. Here it can be seen that, starting with an initial Mach number of 2.0 at the 1g power limited ceiling of 58,000 ft. the Arrow 2 can be zoomed, with an initial 1.5 g load factor, to an altitude of 70,000 ft, and 1.65 M. At this altitude, afterburner flame-out occurs.

For a starting Mach number of 1.5 at the 1g power limited ceiling of 57,500 ft., the Arrow can be zoomed with an initial 1.25 g load factor to an afterburner flame out altitude of 62,000 ft. and 1.3M. With no flame out limitation this zoom ceiling could bc increased to roughly 67,000 ft. with the Mach number falling to 1.1.

The afterburner flame out limitations restrict the zoom ceiling capabilities of the Arrow 2 at low supersonic Mach number; whilst at high supersonic Mach numbers, the zoom performance is limited by both afterburner flame out and elevator trim limitations.

With present afterburner flame out limitations, the aircraft could maintain an altitude of 65,000 ft. for 2.43 minutes, starting at 1.79 M and finishing at 1.43 M.

For an initial zoom from 1.5M at 57,500 ft., the Arrow 2 could maintain 60,000 ft. for 0.97 minute, starting at 1.38 M and slowing down to the afterburner flame out limit at 1.2 M.

It should be noted that no extension of zooms has been carried out after flame out. i.e. with engines giving maximum thrust, A/B unlit. All detail calculations in fact were carried out on the assumption of full afterburner power at all altitudes. The flame out data used were derived from EM S-8, Issue 2, p10.

Iroquois Performance Graph

Return