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AIRCRAFT: Arrow 2

Addendum I to Periodic
REPORT NO. Performance Report No. 1

FILE NO:

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Date 27 Sept 58

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AVRO ARROW 2 - ZOOM CEILINGS



PREPARED BY Performance Group DATE April 1958

CHECKED BY DATE

SUPERVISED BY R.G. Rose [Signature] DATE

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AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

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REPORT NO. Add. 1 to Report No. 13

SHEET NO. i

AIRCRAFT:		PREPARED BY	DATE
Arrow 2		Performance Group	April 1958
Zoom Ceilings		CHECKED BY	DATE

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REPORT NO. Add. I to Report No.13

SHEET NO. 1

AIRCRAFT:	Arrow 2	Zoom Ceilings	PREPARED BY	DATE
			Performance Group	April 1958
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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 maximum 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.



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REPORT NO. Add. 1 to Report No. 13
SHEET NO. 2

AIRCRAFT: Arrow 2	Zoom Ceilings	PREPARED BY	DATE
		Performance Group	April 1958
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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 numbers 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	20°, 10°
		limit	30°, 20°, 10°
1.5	52,000	1.25	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.



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SHEET NO. 3

AIRCRAFT:	Zoom Ceilings	PREPARED BY	DATE
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From an examination of Figs. 1 to 4 it was found that, in every case, a 10° 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 lg 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 lg 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 be increased to roughly 67,000 ft. with the Mach number falling to 1.1.

Thus 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 1.38M and slowing down to the afterburner flame out limit at 1.2M.

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, pl0.

SECRET

ARROW 3 ZOOM PERFORMANCE

REF ID: A67128

INITIAL CONDITIONS

$M = 1.5$ $H_p = 50,000$ ft.

FINAL $M = 1.0$

FINAL 65
PRESSURE
HEIGHT

$H_p \times 10^{-3}$
- Ft. 50

TIME - SECONDS

AVERAGE G OF LIMIT
CASES

80° - CLIMB
ANGLE

LOAD FACTOR ($n = 3.5$) TO ACHIEVE ANGLE OF CLIMB

INITIAL CONDITIONS

$M = 1.5$ $H_p = 50,000$ ft.

FINAL $M = 1.2$

FINAL 60
PRESSURE
HEIGHT

$H_p \times 10^{-3}$
- Ft. 55

TIME - SECONDS

AVERAGE G OF LIMIT
CASES

80° - CLIMB
ANGLE

LOAD FACTOR ($n = 3.0$) TO ACHIEVE ANGLE OF CLIMB

N.W. AF 58

ARROW 2 ZOOM PERFORMANCE

12/PERF/18

INITIAL CONDITIONS

M=1.5 HP=52,000 F

FINAL M=1.4

FINAL
PRESSURE
HEIGHT
HPx10⁻³
FT.

60

55

TIME - SECONDS

AVERAGE OF LIMIT
CASES

50

10

1.5

2.0

2.5

3.0

LOAD FACTOR ($\eta \cdot g^0$) TO ACHIEVE ANGLE
OF CLIMB

Fig 1(a) (iii)

INITIAL CONDITIONS

M=9.0 HP=52,000 F

FINAL M=1.4

FINAL TO
PRESSURE
HEIGHT
HPx10⁻³
F

65

TIME - SECONDS

AVERAGE OF
LIMIT CASES

60

0

1.5

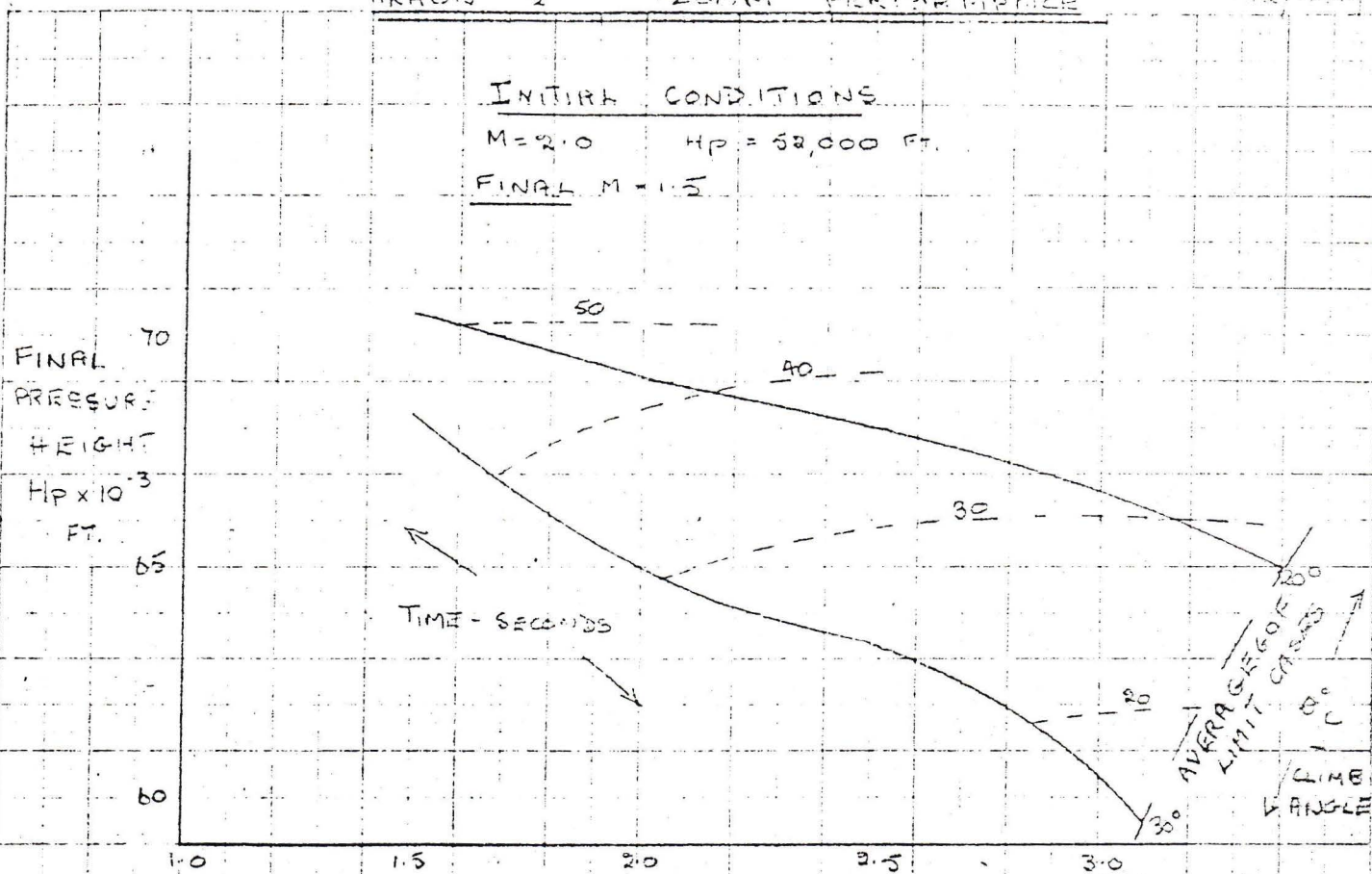
2.0

2.5

3.0

LOAD FACTOR ($\eta \cdot g^0$) TO ACHIEVE ANGLE

Fig 1(b) (i)



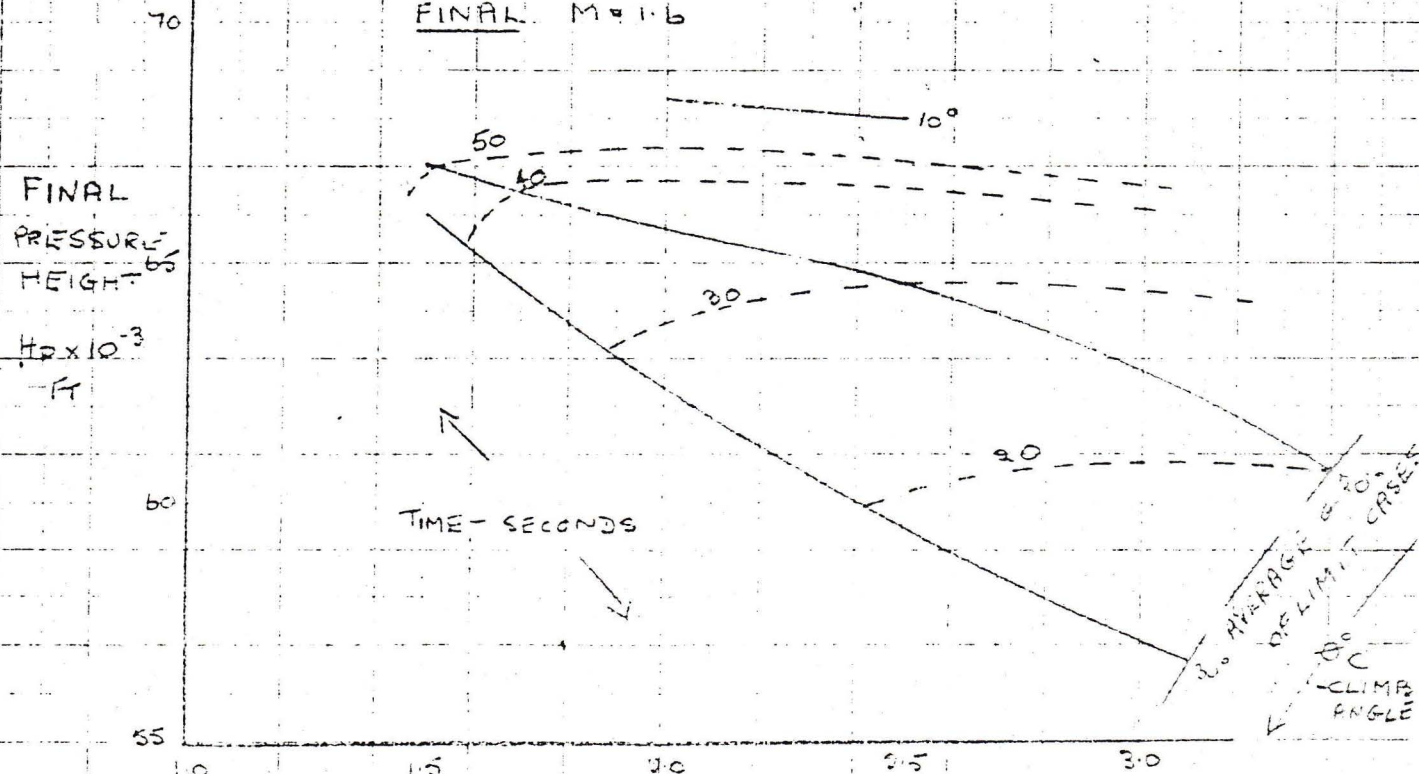
LOAD FACTOR ($n - g$) TO ACHIEVE ANGLE OF CLIMB

FIG 1(b)(ii)

INITIAL CONDITIONS

$M = 2.0$ $H_p = 52,000$ FT.

FINAL $M = 1.6$

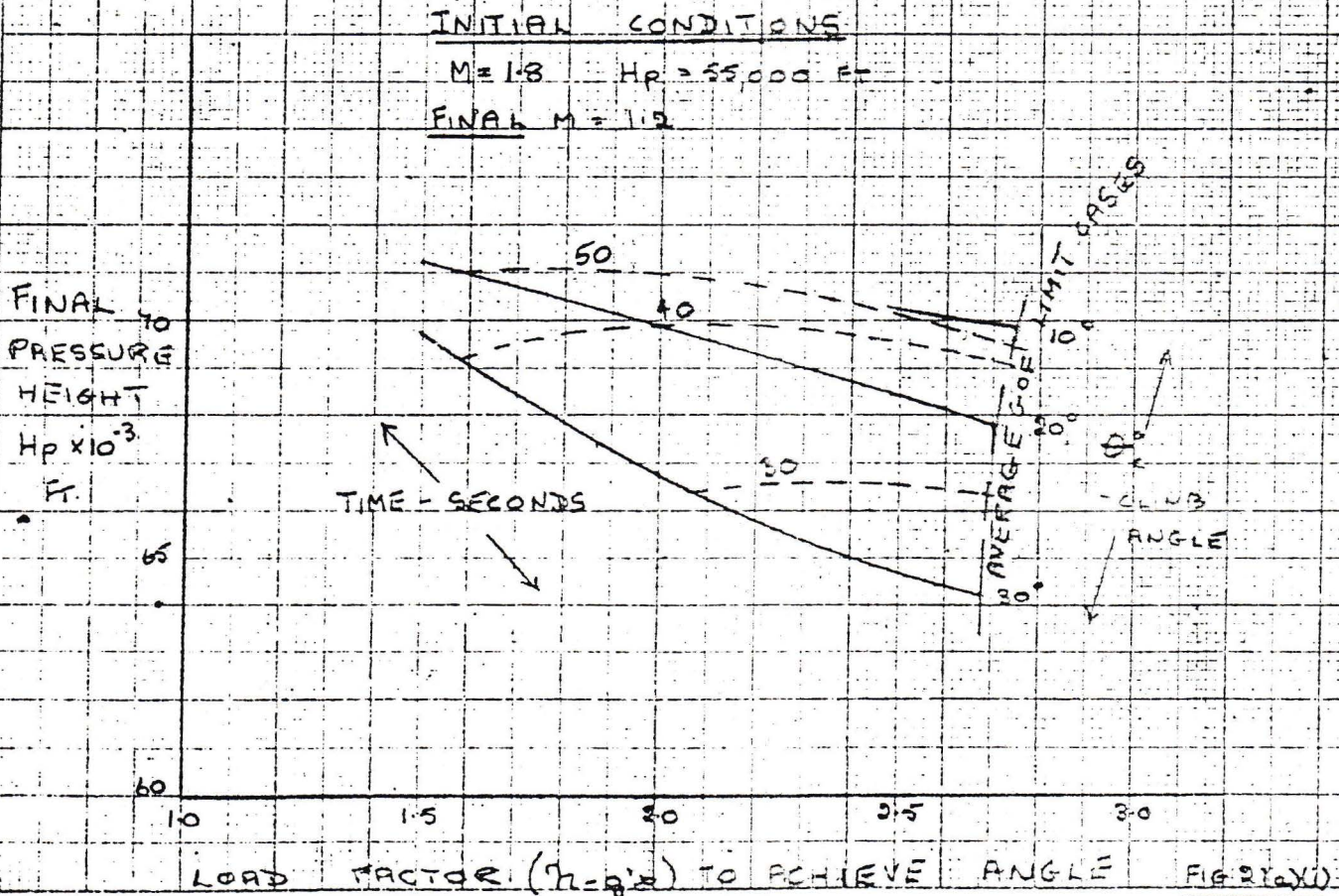
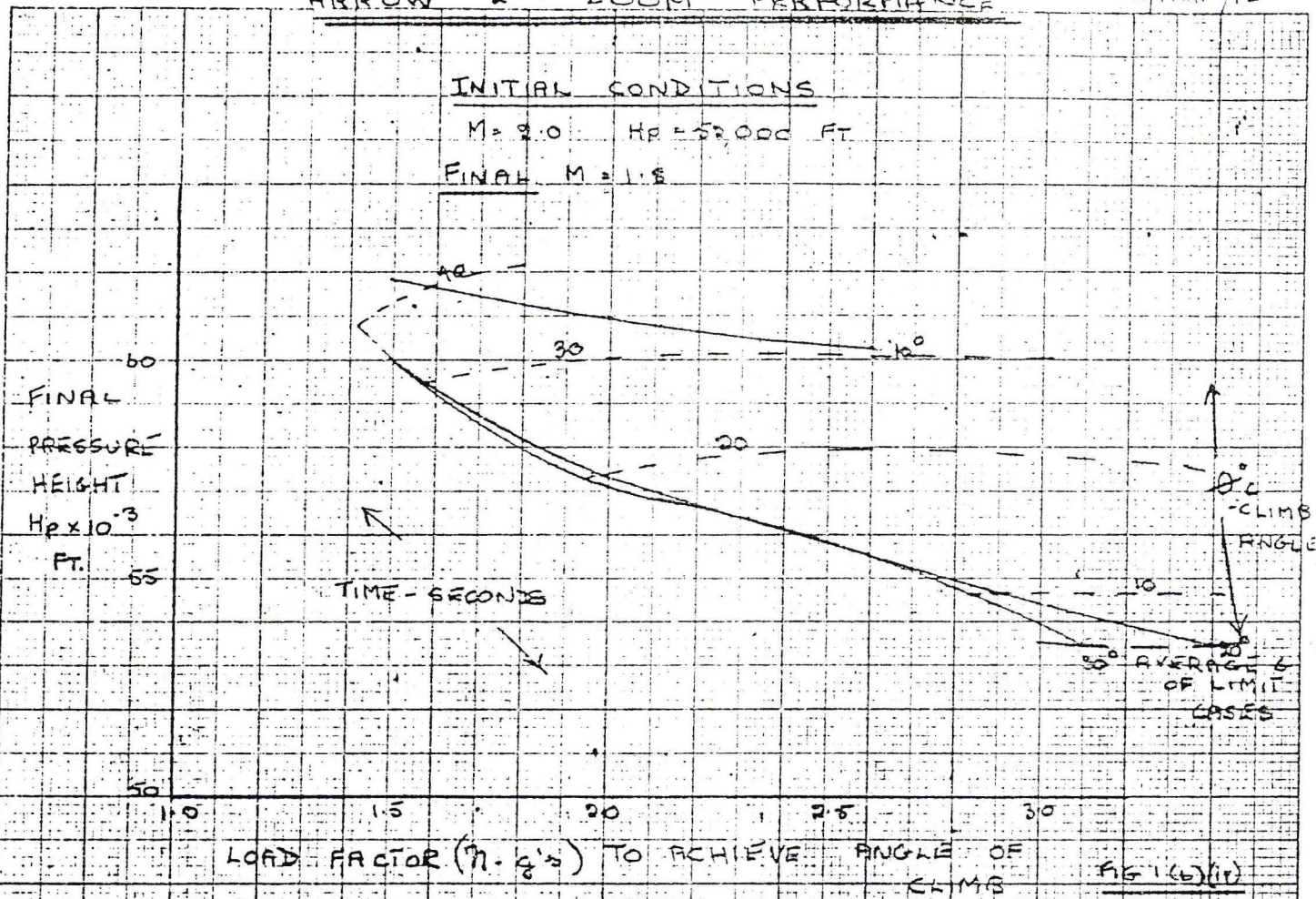


LOAD FACTOR ($n - g$) TO ACHIEVE ANGLE OF CLIMB

FIG 1(b)(iii)

ARROW 2 ZOOM PERFORMANCE

72/PREF/18



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INITIAL CONDITIONS

M = 1.8

Hp = 55,000 Ft

FINAL M = 1.4

FINAL 70

PRESSURE
HEIGHTHp x 10⁻³

Ft 65

TIME - SECONDS

60

1.0

1.5

2.0

2.5

3.0

LOAD FACTOR (n-g's) TO ACHIEVE ANGLE FIG 2(a)(ii)
OF CLIMB

INITIAL CONDITIONS

M = 1.8

Hp = 55,000 Ft.

FINAL M = 1.5

FINAL

PRESSURE 65

HEIGHT

Hp x 10⁻³

Ft

60

TIME - SECONDS

1.0

1.5

2.0

2.5

3.0

LOAD FACTOR (n-g's) TO ACHIEVE ANGLE FIG 2(a)(iii)

ARROW 2 ZOOM PERFORMANCE

Sheet 1

REPORT NO. 19 APR 15

INITIAL CONDITIONS

$M = 1.8$

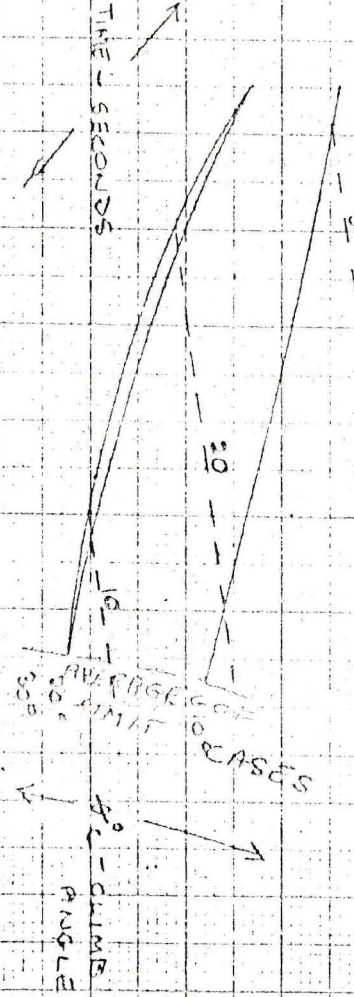
$H_P = 55,000 \text{ Ft}$

FINAL $M = 1.6$

FINAL 65
PRESSURE
HEIGHT

$H_P \times 10^{-3}$
Ft

TIME - SECONDS



LOAD FACTOR ($n \cdot g$'s) TO ACHIEVE ANGLE OF CLIMB FILE 210XIV

INITIAL CONDITIONS

$M = 1.5$

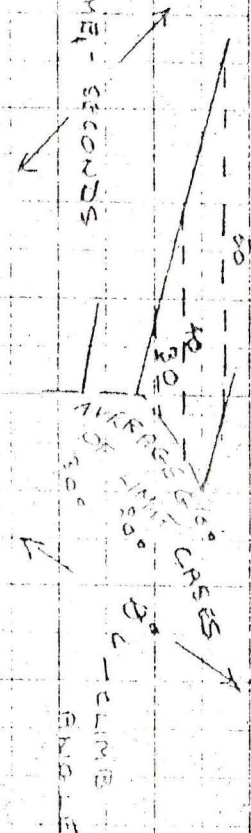
$H_P = 57,000 \text{ Ft}$

FINAL $M = 1.3$

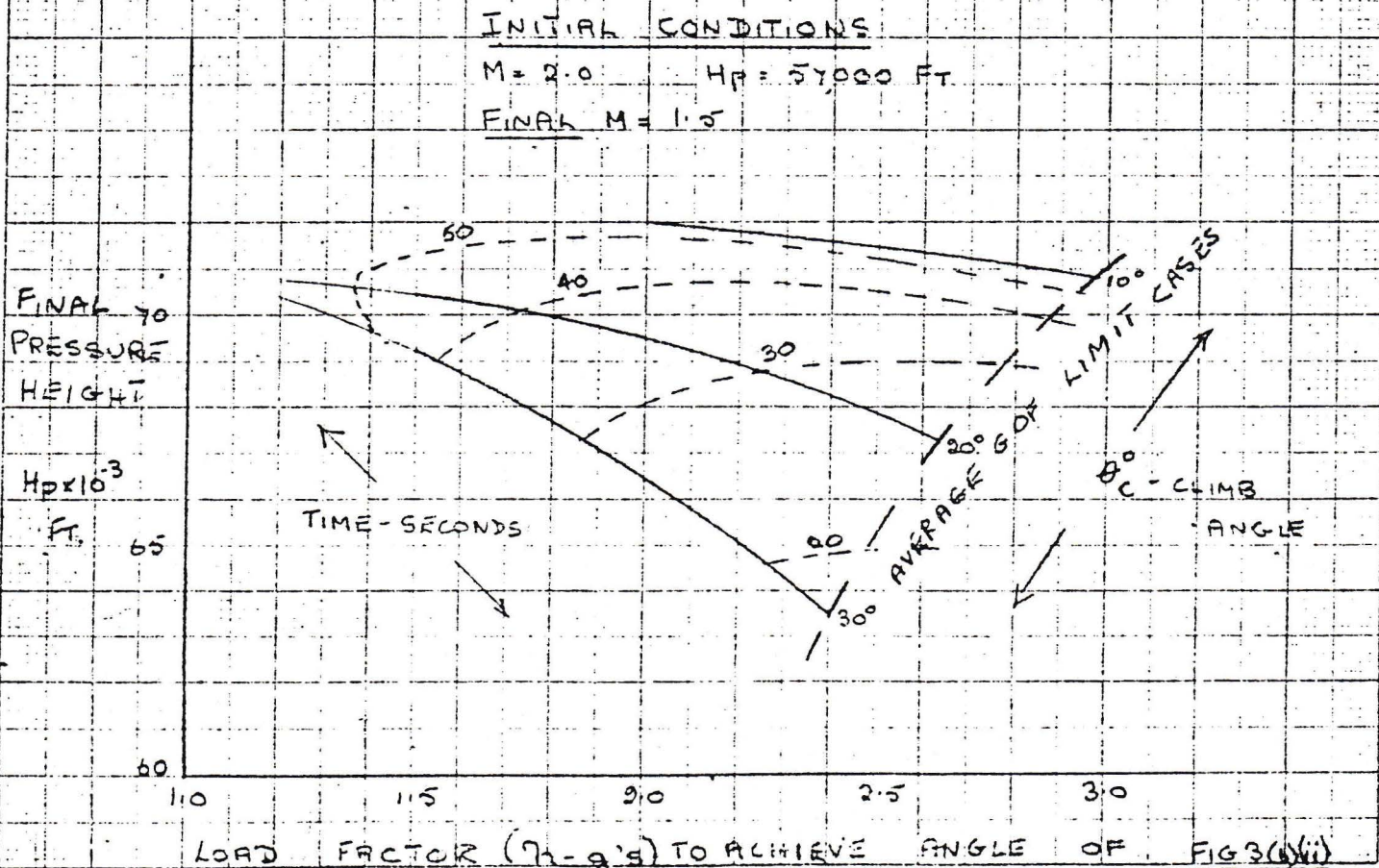
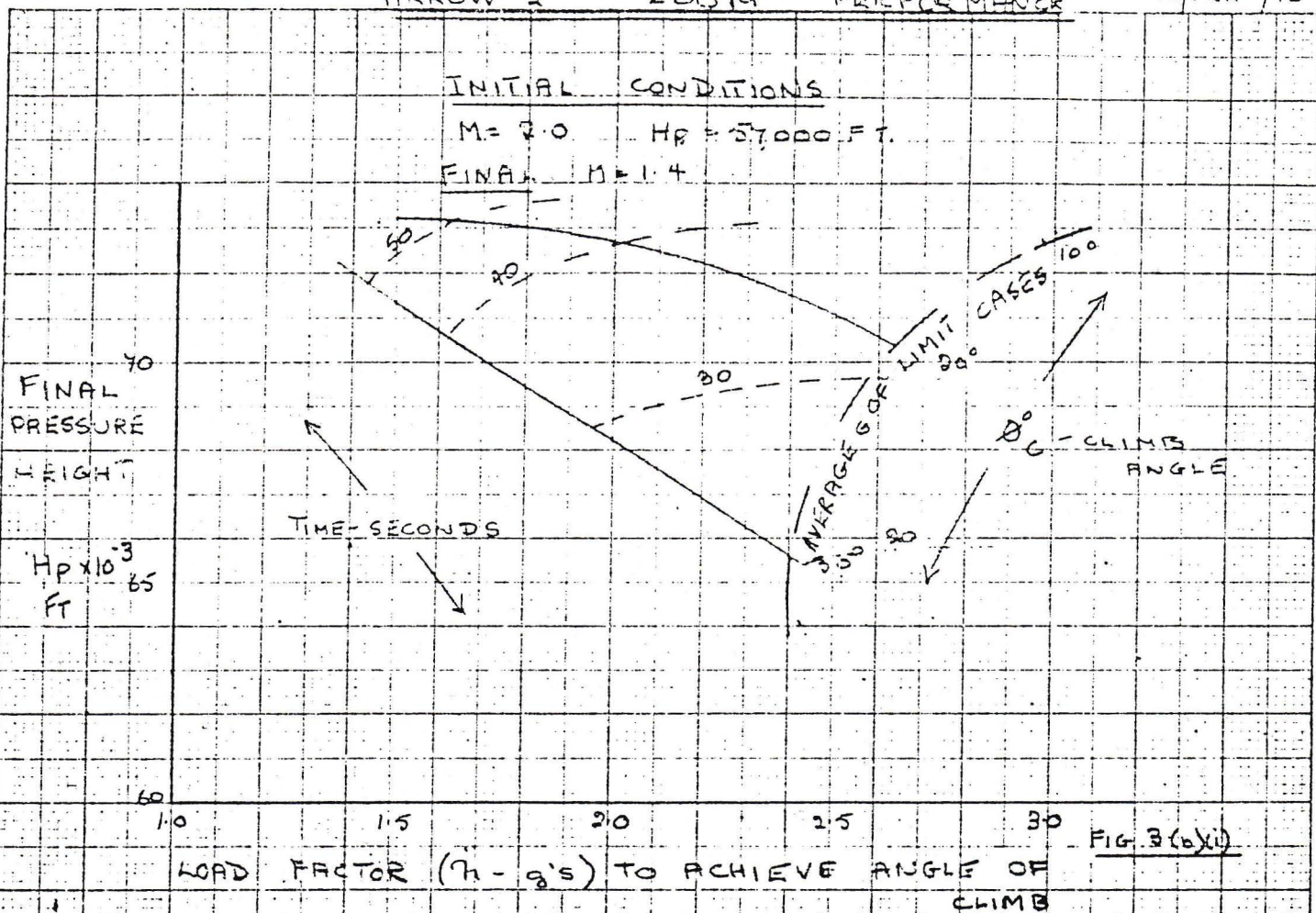
FINAL
PRESSURE
HEIGHT

$H_P \times 10^{-3}$
Ft

TIME - SECONDS



LOAD FACTOR ($n \cdot g$'s) TO ACHIEVE ANGLE



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REPORT NO.

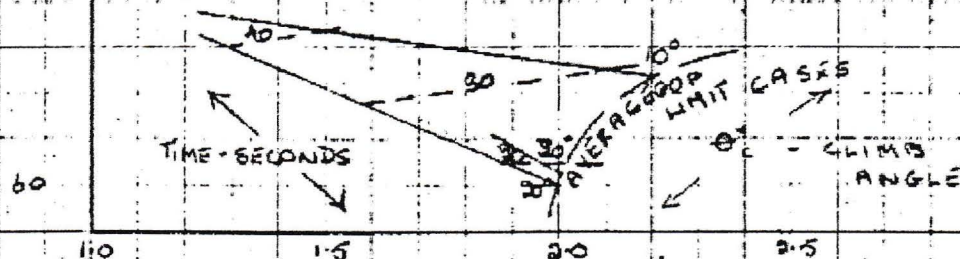
ARROW 2 ZOOM PERFORMANCE

72/PREF/

INITIAL CONDITIONS

M=1.5 HP=57,000 FT

FINAL M=1.2

FINAL
PRESSURE
HEIGHTHP x 10³
FT

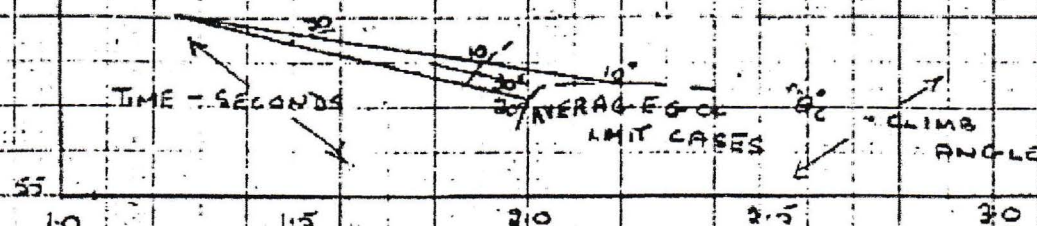
LOAD FACTOR (n-g's) TO ACHIEVE ANGLE OF CLIMB

FIG 3(a)(ii)

INITIAL CONDITIONS

M=1.5 HP=57,000 FT

FINAL M=1.4

FINAL
PRESSURE
HEIGHTHP x 10³
FT

LOAD FACTOR (n-g's) TO ACHIEVE ANGLE OF CLIMB

FIG 3(a)(ii)

NW. APR. '58

INITIAL CONDITIONS $M = 1.8$ $H_p = 60,000 \text{ Ft.}$ FINAL $M = 1.2$ FINAL
PRESSURE
HEIGHT $H_p \times 10^{-3}$
Ft.

TIME - SECONDS

AVERAGE OF
LIMIT CASES θ_c - CLIMB
ANGLE

65

1.0

1.5

2.0

2.5

3.0

FIG 4(a) U)

LOAD FACTOR ($n-g$'s) TO ACHIEVE ANGLE OF
CLIMBINITIAL CONDITIONS $M = 1.8$ $H_p = 60,000 \text{ FT}$ FINAL $M = 1.4$ FINAL
PRESSURE
HEIGHT $H_p \times 10^{-3}$
Ft.AVERAGE OF
LIMIT CASES θ_c - CLIMB
ANGLE

70

65

1.0

1.5

2.0

2.5

3.0

LOAD FACTOR ($n-g$'s) TO ACHIEVE ANGLE FIG 4(a) U)

SECRET

REPORT NO:

72/PERF/18

ARROW 2

ZOOM

PERFORMANCE

INITIAL CONDITIONS

M=2.0 Hp=57,000 FT

FINAL M=1.6

FINAL
PRESSURE
HEIGHT

$H_p \times 10^3$
FT

TIME - SECONDS

AVERAGE OF LIMIT CASES

CLIMB
ANGLE

LOAD FACTOR ($M=2.0$) TO ACHIEVE ANGLE OF CLIMB

Fig. 3(b) (iii)

INITIAL CONDITIONS

M=2.0 Hp=57,000 FT

FINAL M=1.8

FINAL
PRESSURE
HEIGHT

$H_p \times 10^3$
FT

TIME - SECONDS

AVERAGE OF LIMIT CASES

CLIMB
ANGLE

LOAD FACTOR ($M=2.0$) TO ACHIEVE ANGLE OF CLIMB

Fig. 3(b) (iv)

OF CLIMB

N.W. APR. '58

