13

ARROW 1 A/C 25203 71/PERF/2 ISS.4

PROGRAMMING FOR PERFORMANCE DATA FROM ARROW 1 AIRCRAFT 25203(PHASE II) FLIGHT TESTS

I.WILKINSON
R.WAECHTER

SEPT.1958

AVRO AIRCRAFT LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: ARROW 1 A/C 25203

REPORT NO: 71/PERF/2 Iss.4

FILE NO:

NO. OF SHEETS 28

TITLE: PROGRAMMING FOR PERFORMANCE DATA FROM ARROW 1 AIRCRAFT 25203 (PHASE II) FLIGHT TESTS

PREPARED BY I. Wilkinson DATE Sept. 1958

R. Wachter
R.C. Rose.

RECOMMENDED FOR APPROVAL DATE Sept. 1958

APPROVED F/L RCAF DATE Sept 58

APPROVED FOR RELEASE DATE Sept. 58.

AVRO AIRCRAFT LIMITED
MALTON – ONTARIO

TECHNICAL DEPARTMENT

REPORT NO.	71/PERF/2 Iss.4
SHEET NO.	1
PREPARED BY	DATE
I. Wilkinson	Sept. 1958
CHECKED BY	DATE
R. Waechter	Sept. 1958

AIRCRAFT: ARROW 1 A/C 25203

PERFORMANCE FLIGHT TESTS

PROGRAMMING FOR PERFORMANCE DATA FROM ARROW 1 AIRCRAFT 25203 (PHASE II) FLIGHT TESTS

SUMMARY:-

This report outlines the Avro computing program to be used during the initial R.C.A.F. Performance Evaluation of Arrow 1 Aircraft 25203 commencing in mid September 1958. Flight test data will be transformed to punch cards and fed into the I.B.M. 704 Digital Computer giving results requiring no further computations. All anticipated performance parameters will be calculated, including total air miles covered in a particular manoeuvre or over a complete flight. The computer's operations are based on the applicable formulae shown in the input - output summary of sheets 8 to 16, incorporating charts I to VII.

In general I.B.M. 704 computer output will be presented graphically versus time except when specifically requested to be tabulated or to be cross plotted. Graphical presentation will be made with 4 outputs versus time on one graph and therefore the input - output summary presented herein is grouped such that each successive 4 outputs are related and will appear on one graph. Coding of output data is presented in Appendix I to this report.

Programming is arranged such that data from all manoeuvres including steady levels, are analysed similarly i.e. all input data must be tabulated versus time; meaning that for steady levels, all points are calculated and the stablilized point is determined after plotting final computed results. Partly for convenience and partly by necessity all output data will be given at the mean time interval.

Mainly for the case of accelerated and decelerated levels an energy term, E/W, is output from the computer as well as the final required answer of drag or thrust minus drag. This energy term combines A.S.I., altitude and temperature readings into a single unit which should show a smooth variation with time. Therefore, if the final required answer is "scattered", it is hoped to interject a smoothing process into the energy term such that a relatively smooth answer will result.

It should be noted that presently available instruments measure airspeed in m.p.h. and pressure in "Hg" and the applicable formulae have been derived for units of knots and psi. respectively. It is therefore required to convert these values to consistent units before applying them to the formulae herein.

All parameters will be recorded by an auto - observer operating at either of two speeds i.e. 1 frame per 4 seconds or at 1 frame per 1 or $\frac{1}{2}$ seconds; with the following exceptions; ambient total temperature, normal acceleration, elevator angle and airbrake angle. These latter measurements are recorded on a continuous trace oscillograph, but only the first three of these are fed into the computer.

REFERENCES

I.D.M. - 2863/20/J	Input Order for Performance Program 71/PERF/2 Iss.4
71/FAR/29	Arrow 1, Phase 2 Instrumentation
R.F.T. 5059	Arrow 1, Phase 2 Testing
71/FAR/33 -	Preparations for Phase 2 Performance Testing

AVRO AIRCRAFT LIMITED
MALTON – ONTARIO

TECHNICAL DEPARTMENT

REPORT NO.	71/PERF/2 Iss. 4
SHEET NO.	3
PREPARED BY	I. Wilkinson
DATE	Sept. 1958
CHECKED BY	R. Waechter
DATE	Sept. 1958

AIRCRAFT: ARROW 1 A/C 25203

PERFORMANCE FLIGHT TESTS

SYMBOLS

ASIR – Airspeed indicator reading

A_A – Axially projected area of aft divergent section of ejector

A_B – Effective by-pass area near exit

A_C – Axially projected area of convergent section of ejector

A_F – Axially projected area of forward divergent section of ejector

A_{10} – Primary jet nozzle area

a_L – Longitudinal acceleration

a_n – Normal acceleration

B – Sonic Mach number function (depends on position error)

C_L – Aircraft lift coefficient

C_{LW} – Aircraft lift coefficient neglecting thrust effect (i.e. based on weight only)

C_D – Aircraft drag coefficient

C_g – Gross thrust coefficient

D – Aircraft drag

D_S – Spillage drag

E – Total aircraft energy

F_G – Installed engine gross thrust

F_N – Installed engine net thrust

$f_{1,2,3}$ – Functions of Mach number

G – Quantity of fuel consumed

g – Gravitational acceleration

H – Altitude

SYMBOLS (Cont'd)

H_p – Pressure altitude

K_1 – Fuel density at 0 °C

K_2 – Decrease in fuel density per degree increase in T_F

K_t – Temperature correction factor to C_g

L – Aircraft Aerodynamic lift

M – Mach number

M_B – By-pass Mach number

$\overline{M_i}$ – M_i at which M = 1.00

ΔM_{PEC} – Static position error correction to M_i

ΔM_{PECP} – Total head position error correction to M_{iP}

m – Inlet mass flow

m_i – Actual inlet air weight flow

m_o – Nominal or capture air weight flow

N_1 – Low pressure compressor RPM

N_2 – High pressure compressor RPM

P – Total pressure (capital P)

P_B – By-pass total pressure

P_{th} – Inlet throat total pressure

p – Static pressure (small p)

p_A – Ejector manifolded wall static pressure (divergent section aft)

p_B – By-pass static pressure near exit

SYMBOLS (Cont'd)

P_C – Ejector manifolded wall static pressure (convergent section)

P_F – Ejector manifolded wall static pressure (divergent section fwd.)

Q – Fuel flow

R – Gas constant or range

R_{01} – Free stream ram pressure ratio

R/C_1 – Actual rate of climb

R/C_2 – Rate of climb correction (speed method)

R/C_3 – Rate of climb correction (accelerometer method)

$R/C/\sqrt{\theta}$ – Non-dimensional steady state rate of climb

S – Gross wing area

T – Time

T – Ambient temperature

T_B – By-pass total temperature near exit

T_F – Fuel temperature

V – True airspeed

W – Aircraft weight

W_a – Primary engine air weight flow

W_B – By-pass air weight flow

W_o – Initial aircraft all up weight before flight

X_G – Basic or primary engine gross thrust

X_N – Basic or primary engine net thrust

X_1 – Pressure thrust (by-pass)

SYMBOLS (Cont'd)

X_2 – Pressure thrust (convergent section)

X_3 – Pressure thrust (divergent section fwd.)

X_4 – Pressure thrust (divergent section aft.)

α (alpha) – Angle of attack

γ (gamma) – Ratio of specific heats

δ (delta) – Pressure ratio

η (M) – eta (M) – ratio of the total head pressure behind to that in front of normal shock at Mach number M if $M > 1$, and $\eta(M) = 1$ for $M < 1$.

θ (theta) – Temperature ratio

μ (mu) – Mass flow ratio

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT No.	OUTPUT All outputs denoted * are to be mean between successive runs. Remaining are meaned during computations.
i	Flight No., Run No. & Frame No.		i	Flight No. Run No. & Frame N
ii	Initial Time, hrs;min;sec.		ii	Time Base (± .0001 Min.) or ± .01 secs. *
iii	Time Interval Per Frame			
1)	A.S.I.R. (M.P.H.)	V_i (knots)	1 a)	M *
2)	H_R	H_i (feet)		

meaned ning outputs ns.	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
me No. *) s. *	Time Base = Frame No. - Initial Frame No. x Time Interval Per Frame	
	Determine M from M_{ip} using Charts 1A & 1B	Note: 1MPH = .8684 Knots
	i.e. $M_{ip} + \Delta M_{PECP} = M_i$ Chart 1A	Total head position error correction
	and $M_i + \Delta M_{PEC} = M$ Chart 1B	Static position error correction

Determine M_i using the following formulae

$$\eta(M)\left[1+0.2M_{ip}^2\right]^{3.5} = \left\{\eta(M_{S.L.})\left[1+\left(\frac{V_i}{1481}\right)^2\right]^{3.5} - 1\right\} \times \left(\frac{P_{S.L}}{P_i}\right) + 1$$

This equation contains two unknowns when M>1, i.e. M & M_{ip}. For small supersonic ΔM_{PEC}, it can be assumed $M = M_{ip}$. For large supersonic ΔM_{PEC}, successive approximations are required, but the second should suffice. Normally, supersonic $\Delta M_{PEC} \approx 0$.

where

$$\eta(M) = \left[\frac{1}{\left(\frac{M^2+5}{6M^2}\right)^{1.4}\left(\frac{7M^2-1}{6}\right)}\right]^{2.5} \quad \text{for } M>1$$

and $\eta(M) = 1$ for $M \leq 1$

Hence it must be determined whether $M > 1$

or $V_i > 1481\sqrt{\left[B\frac{P_i}{P_{S.L.}}+1\right]^{2/7}-1}$ where $B = \left[(1+0.2\bar{M}_i^2)^{3.5}-1\right]$ @ $M = 1$ (see Chart 1B)

$\eta(M_{S.L.})$ substitutes $\frac{V_i}{660}$ for M in the above equation for $\eta(M)$

and $\eta(M_{S.L.}) = 1$ for $V_i \leq 660$

$$\frac{P_i}{P_{S.L.}} = (1 - 0.00000687\, H_i)^{5.2603} \quad \text{for } H_i \leq 36{,}089$$

$$= 0.2234\, e^{-0.0000481(H_i-36{,}089)} \quad \text{for } H_i > 36{,}089$$

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT (All outputs denoted * are to be meaned between successive runs. Remaining output are meaned during computations.)	
			1(b)	Hp *
			1(c)	R_{o_1} *
3)	Ambient Total Temperature T_R °C	T_1 °C	1(d)	T °K *
			2(a)	R (N.A.M.) *
			2(b)	$(R/C)_1$ (fpm)
			2(c)	$(R/C)_2$ (fpm)
			2(d)	$\frac{R/C}{\sqrt{\theta}}$

TESTS

CHARTS FOR I.B.M. 704 COMPUTOR

SHEET NO. 9 REPORT NO. 71/PERF/2 ISS.4

DATE June 1958 PREP. BY R.WAECHTER

...e meaned ...ining outputs ...ons.	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
	$p_{(P.S.I.)} = \dfrac{1 + 0.2M^2}{1.4M\Delta M_{PEC} + 1 + 0.2M^2} \left(\dfrac{P_i}{P_{S.L.}}\right) \times 14.7$	for $M \leq 1$ — derived from English Electric Co. Aero TN. A_E 67 Equations 12 & 13
	$= \dfrac{(7M^2 - 1)M}{7(2M^2-1)\Delta M_{PEC} + M(7M^2 - 1)} \times \left(\dfrac{P_i}{P_{S.L.}}\right) \times 14.7$	for $M > 1$ — derived from English Electric Co. Aero TN. A_E 67 Equations 12 & 13
	$H_p = 145,447 \left[1 - \left(\dfrac{p}{14.7}\right)^{0.1903}\right]$	for $p \geq 3.2831$
	$= 60,820 - 47,907 \log_{10} p$	for $p < 3,2831$
	$R_{o_1} = (1 + 0.2M^2)^{3.5}$	
	$T = \dfrac{T_i + 273}{(1+0.2KM^2)}$	K = constant, initially assume = 0.95
	$R = \Sigma\left[0.650(M\sqrt{T})_{MEAN}\, \Delta T_{MINS}\right]$	
	$(R/C)_1 = \dfrac{\Delta H_p \text{ (feet)}}{\Delta T \text{ (mins)}} \times \left[\dfrac{T^oK_{MEAN}}{288.16 - .00198\, H_{p_{MEAN}}}\right]$	
	$(R/C)_2 = \dfrac{67.2\,\Delta(M^2T)}{\Delta T \text{ (mins)}}$	
	$\dfrac{R/C}{\sqrt{\theta}} = \dfrac{(R/C)_1 + (R/C)_2}{\left(\sqrt{T/288}\right)_{MEAN}}$	

2

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I.F

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT All outputs denoted * are to be meaned between successive runs. Remaining outputs are meaned during computations.	
6)	A/C Starting Weight	W_o (lbs.)		
7)	Port Engine Fuel T_{FR} °C @ flow sensor	T_F (°C)		
8)	Port Engine Gals Gone G_{PE_R} (counts)	G_{PE} (gals)		
9)	Stbd. Engine Gals Gone G_{SE_R} (counts)	G_{SE} (gals)		
10)	Port A/B Gals Gone G_{PA_R} (counts)	G_{PA} (gals)	3a)	W *
11)	Stbd. A/B Gals Gone G_{SA_R} (counts)	G_{SA} (gals)		
12)	Normal Acceleration a_{nR}	a_{ni} ('g' units)	3b)	a_n
13)	Long. Acceleration a_{LR}	a_{Li} ('g' units)	3c)	a_L
			3d)	C_{L_W}
			4a)	α
			4b)	${C_{L_W}}^2$
			4c)	a_n W/p
			4d)	$(R/C)_3$

...meaned ...g outputs	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
	$W = W_o - [G_{PE} + G_{SE} + G_{PA} + G_{SA}][K_1 - K_2\ T_F\ ^oC]$ where K_1 = lbs. per gallon @ 0^oC, initially assume = 7.8 K_2 = decrease in lbs per gallon per degree increase in T_F ^oC initially assume = .007	{change when necessary, {depending on hydrometer checks
	$a_n = [(a_{ni})_M - \cos\theta]\cos\alpha + [(a_{Li})_M - \sin\theta]\sin\alpha + \cos\theta$ $a_L = [(a_{Li})_M - \sin\theta]\cos\alpha - [(a_{ni})_M - \cos\theta]\sin\alpha$	Inputs relative to A/C datum and outputs relative to flight path. Subscript 'M' denotes mean value for successive points
	$\theta = \sin^{-1}\left[\frac{(R/C)_1}{3945(M\sqrt{T})_{MEAN}}\right]$ α is obtained from chart II knowing C_{L_W} and M where $C_{L_W} = \frac{1}{0.7S}\left(\frac{a_n W}{p\ M^2}\right)_{MEAN}$ S = 176,400 square inches i.e. $\alpha = f_1(M) + C_{L_W} f_2(M) + (a_n - 1) f_3(M)$	Note: Successive approximations are required to determine C_{L_W} & a_n. i.e. First approximation should use a_{ni} for a_n in the equation for C_{L_W}
	derived above	Output α can be compared to cockpit readings of angle of attack vane position.
	$(R/C)_3$ fpm = $3945\ a_L\ (M\sqrt{T})_{MEAN}$	$(R/C)_3$ is equivalent to $(R/C)_2$ except that it is obtained by the accelerometer method. It is hoped to obtain a comparison of methods

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT (All outputs denoted * are to be meaned between successive runs. Remaining output are meaned during computations.)	
12)	Port Engine Intake Total P_{2P_R} ("H_g)	P_{2P} (psi)	5a)	$\frac{Q_{PE}}{P_{2P}\sqrt{T_1}}$
			5b)	$\frac{Q_{PA}}{P_{2P}\sqrt{T_1}}$
13)	Stbd. Engine Intake Total P_{2S_R} ("H_g)	P_{2S} (psi)	5c)	$\frac{Q_{SE}}{P_{2S}\sqrt{T_1}}$
			5d)	$\frac{Q_{SA}}{P_{2S}\sqrt{T_1}}$
14)	Port H.P. rpm N_{2P_R}	N_{2P_i} (%)	6a)	$N_{2P}/\sqrt{T_1}$ *
15)	Stbd. H.P. rpm N_{2S_R}	N_{2S_i} (%)	6b)	$N_{2S}/\sqrt{T_1}$ *
			6c)	$N_{2P}/\sqrt{\theta}$ *
			6d)	$N_{2S}/\sqrt{\theta}$ *
			7a)	$N_2/\sqrt{\theta}$ (average) *
			7b)	V^{δ}/Q (N.A.M.P.P.)
			7c)	P_{2P}/P_1 *
			7d)	P_{2S}/P_1 *
16)	Port Turb. Discharge P_{7P_R} ("Hg)	P_{7P} (psi)	8a)	$(P_7/P_2)_P$ *
17)	Stbd.Turb. Discharge P_{7S_R} ("Hg)	P_{7S} (psi)	8b)	$(P_7/P_2)_S$ *
18)	Port Turb. Discharge T_{7P_R}	T_{7P} (°C)	8c)	$T_{7P}+273/T_1$ *
19)	Stbd.Turb. Discharge T_{7S_R}	T_{7S} (°C)	8d)	$T_{7S}+273/T_1$ *

TESTS HARTS FOR I.B.M. 704 COMPUTOR	SHEET NO. 11 DATE June 1958	REPORT NO. 71/PERF/2 Iss. 4 PREP. BY R. WAECHTER

...e meaned ...ing outputs ...ns?	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
	$Q_{PE} = \frac{60}{\Delta T_{MIN}} \left[K_1 - K_2 T_F {}^\circ C\right] \Delta G_{P.E}$ K_1 & K_2 are defined previously Q_{PA}, Q_{SE}, Q_{SA} derived similarly $T_1 = T\,{}^\circ K\,(1 + .2M^2)_{MEAN}$ P_2 obtained at mean interval	Note: 1 "H_g = .4912 psi
	$N_2 = N_{2i} \times .8731$ for P-5 engines $\theta = \frac{T^\circ K}{288}$	
	$N_2 = \frac{N_{2P} + N_{2S}}{2}$ $V = 38.95(M\sqrt{T})_M$, $\delta = p/14.7$, $Q = Q_{PE} + Q_{SE} + Q_{PA} + Q_{SA}$ $P_1 = R_{o_1}\,p$ (psi)	

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT (All outputs denoted * are to be meaned between successive runs. Remaining outputs are meaned during computations.)	
			9 a)	X_{NP}/p *
			9 b)	X_{NS}/p *
20)	Port L.P. rpm N_{1P_R}	N_{1P} (%)		
21)	Stbd. L.P. rpm N_{1S_R}	N_{1S} (%)		
			9 c)	$\frac{Q_P}{X_{NP}\sqrt{\theta}}$
			9 d)	$\frac{Q_S}{X_{NS}\sqrt{\theta}}$

ESTS

HARTS FOR I.B.M. 704 COMPUTOR

SHEET NO. 12 | REPORT NO. 71/PERF/2 ISS.4
DATE June 1958 | PREP. BY R.WAECHTER

be meaned ing outputs ns.	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS

*

$$\frac{X_N}{p} \text{ (port or stbd)} = \frac{X_G}{p} - \frac{W_a V}{g\,p}$$

*

where

$$\frac{X_G}{p} = \left[1.258\,\frac{P_7}{p} - 1\right] C_g K_D A_{10} \times K_t \quad \text{for} \quad \frac{P_7}{p} \geqslant 1.852$$

$$= 8.06 \left[\left(\frac{P_7}{p}\right)^{.248} - 1\right] C_g K_D A_{10} K_t \quad \text{for} \quad \frac{P_7}{p} < 1.852$$

A_{10} = 509.5 sq.in A/B off (Average for port and
= 939.0 sq.in A/B on (stbd. engines, see 70/PERF/1 APP.II Iss. 2

C_g & K_t from Chart III knowing $\frac{P_7}{p}$, T_7 & P_7 for A/B off

C_g from Chart IV knowing $\frac{P_7}{p}$ for A/B on $\sim K_t$ & $K_D = 1$

Remarks: Require A/B on or off (Q_{PA} & Q_{SA}) signals to differentiate A_{10} and C_g for A/B on and off

$$\frac{W_a V}{g\,p} = \frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}} \times \frac{P_2}{p} \times \frac{2.36\,M}{\sqrt{1+.2M^2}} \left(1 + \%\Delta \frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}}\right)$$

where $\frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}}$ is obtained from P.W.A. Curve No. Inst. 27739 (1a test rev. 4-18-58)

Knowing $$N_1/\sqrt{\theta_{t_2}} = \frac{\%\,N_1 \times 6778}{\sqrt{T_1/16.98}}$$

and $\%\Delta \frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}}$ also obtained from P.W.A. Curve No. Inst. 27739

knowing $$\frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}} \times \frac{\delta_{t_2}}{(\theta_{t_2})^{1.24}} = \frac{W_a\sqrt{\theta_{t_2}}}{\delta_{t_2}} \times \frac{P_2}{T_1^{1.24}} \times 76.2$$

$Q_P = Q_{PE} + Q_{PA}$ derived previously

$Q_S = Q_{SE} + Q_{SA}$ derived previously

$\theta = T/288$

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I.

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT (All outputs denoted * are to be meaned between successive runs. Remaining outputs are meaned during computations.)		
22)	Port by-pass total P_{BPR} ("Hg)	P_{BB} (psi)			
23)	Port by-pass static p_{BPR} ("Hg)	p_{BP} (psi)	10 a)	M_{BP}	*
24)	Stbd by-pass total P_{BSR} ("Hg)	P_{BS} (psi)			
25)	Stbd by-pass static p_{BSR} ("Hg)	p_{BS} (psi)	10 b)	M_{BS}	*
26)	Port by-pass total T_{BPR}	T_{BP} (°C)	10 c)	W_{BP} (lbs/sec)	
27)	Stbd. by-pass total T_{BSR}	T_{BS} (°C)	10 d)	W_{BS} (lbs/sec)	
			11 a)	$\frac{(m\ V)_{BP}}{p}$ (lbs)	
			b)	$\frac{(m\ V)_{BS}}{p}$ (lbs)	
			11 c)	$\frac{X_{1P}}{p}$ (lbs)	*
			11 d)	$\frac{X_{1S}}{p}$ (lbs)	*
28)	Port ejector manifolded wall statics (convergent section) p_{CPR} ("Hg)	p_{CP} (psi)	12 a)	$\frac{X_{2P}}{p}$ (lbs)	*
29)	Stbd. ejector manifolded wall statics (convergent section) p_{CSR} ("Hg)	p_{CS} (psi)	12 b)	$\frac{X_{2S}}{p}$ (lbs)	*
30)	Port ejector manifolded wall statics (divergent section, fwd) p_{FPR} ("Hg)	p_{FP} (psi)	12 c)	$\frac{X_{3P}}{p}$ (lbs)	*
31)	Stbd. ejector manifolded wall statics (divergent section, fwd) p_{FSR} ("Hg)	p_{FS} (psi)	12 d)	$\frac{X_{3S}}{p}$ (lbs)	*

TESTS

CHARTS F... 104 ... [illegible]

SHEET NO. 13 — REPORT NO. 71/PERF/2 ISS. 4

DATE JULY 1958 — PREP. BY R. WAECHTER

...be meaned ...ning outputs ...ons.	APPLICABLE FORMULAE, EQUATION, OR CHART	REMARKS

Note: 1 "H_g = .4912 psi

$$M_{BP} = \sqrt{5\left[\left(\frac{P_{BP}}{p_{BP}}\right)^{.286} - 1\right]}$$

$$M_{BS} = \sqrt{5\left[\left(\frac{P_{BS}}{p_{BS}}\right)^{.286} - 1\right]}$$

$$W_{BP} = \sqrt{\frac{1.4\,g}{R}}\; M_{BP}\, A_{BP}\left[\frac{P_{BP}}{\sqrt{T_{BP}+273}}\left(\frac{p_{BP}}{P_{BP}}\right)^{.286}\right]_{MEAN}$$

$$W_{BS} = \sqrt{\frac{1.4\,g}{R}}\; M_{BS}\, A_{BS}\left[\frac{P_{BS}}{\sqrt{T_{BS}+273}}\left(\frac{p_{BS}}{P_{BS}}\right)^{.286}\right]_{MEAN}$$

$A_{BP} = A_{BS}$ = effective by-pass area in plane of nozzle open ≈ .90x468 = 421$^{\square}$"

R = 96.02

g = 32.2

$$\frac{(m\,V)_{BP}}{p} = \frac{W_{BP}\, M_{BP}}{p_{MEAN}}\sqrt{\frac{\gamma R}{g}} \times \sqrt{(T_{BP}+273)}_{MEAN}$$

similar to $(m\ V)_{BP}$ above

$$\frac{X_{1P}}{p} = \left(\frac{p_{BP}}{p} - 1\right) A_{BP}$$

$$\frac{X_{1S}}{p} = \left(\frac{p_{BS}}{p} - 1\right) A_{BS}$$

$$\frac{X_{2P}}{p} = \left(1 - \frac{p_{CP}}{p}\right) A_{CP}$$

$A_{CP} = A_{CS}$ = axial projection of convergent section = 645$^{\square}$"

$$\frac{X_{2S}}{p} = \left(1 - \frac{p_{CS}}{p}\right) A_{CS}$$

$$\frac{X_{3P}}{p} = \left(\frac{p_{FP}}{p} - 1\right) A_{FP}$$

$A_{FP} = A_{FS}$ = ½ axial projection of divergent section = 287$^{\square}$"

$$\frac{X_{3S}}{p} = \left(\frac{p_{FS}}{p} - 1\right) A_{FS}$$

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT	All outputs denoted * are to be meaned between successive runs. Remaining outputs are meaned during computations.	
32)	Port ejector manifolded wall statics (divergent section, aft) P_{APR} ("H_g)	P_{AP} (psi)	13 a)	$\frac{X_{4P}}{p}$ (lbs)	*
33)	Stbd. ejector manifolded wall statics (divergent section, aft) P_{ASR} ("H_g)	P_{AS} (psi)	13 b)	$\frac{X_{4S}}{p}$ (lbs)	*
			13 c)	$\frac{F_{NP}}{p}$	
			13 d)	$\frac{F_{NS}}{p}$	

be meaned ... ining outputs ... ions.	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
*	$\frac{X_{4P}}{p} = \left(\frac{P_{AP}}{p} - 1\right) A_{AP}$	$A_{AP} = A_{AS} = \frac{1}{2}$ axial projection of divergent section = 287°"
*	$\frac{X_{4S}}{p} = \left(\frac{P_{AS}}{p} - 1\right) A_{AS}$	
	$\frac{F_{NP}}{p} = \frac{F_{GP}}{p} - \frac{m_pV}{p} - D_{SP}/_p$	
	where $\frac{F_{GP}}{p} = \left(\frac{X_{GP}}{p}\right)_{\substack{A/B\ off\\ mean}} + \frac{(mV)_{BP}}{p} + \frac{X_{1P}}{p} + \frac{X_{3P}}{p} + \frac{X_{4P}}{p}$ for A/B off	
	$= \left(\frac{X_{GP}}{p}\right)_{\substack{A/B\ on\\ mean}} + \frac{(mV)_{BP}}{p} + \frac{X_{1P}}{p} + \frac{X_{2P}}{p} + \frac{X_{3P}}{p} + \frac{X_{4P}}{p}$ for A/B on	
	and $\frac{m_pV}{p} = \left(\frac{W_{aP}V}{g\ p}\right)_{mean} + \frac{W_{BP}M}{P_{mean}}\sqrt{\frac{\gamma RT}{g}}$	Note: $\left(\frac{X_{GP}}{p}\right)_{\substack{A/B\ on\ or\ off\\ mean}}$ and $\left(\frac{W_{aP}V}{gp}\right)_{mean}$ are obtained from calculations for output 9.a).
	$D_{SP}/_p = 4130\ C_{D_{SP}} M^2$	
	where $C_{D_{SP}} = \frac{\partial C_{D_S}}{\partial(m_i/m_o)}\left[\frac{W_{aP}+W_{BP}+3}{1003\ \frac{p_m M}{\sqrt{T}}} - \frac{.308(1+.2M^2)^3}{M}\left(\frac{P_{th}}{P_1}\right)\right]$	see report 70/PERF/1 App. II. for derivation of this spillage drag coefficient formula.
	$\frac{\partial C_{D_S}}{\partial(m_i/m_o)}$ From Chart V	
	$\frac{P_{th}}{P_1}$ From Chart VI	
	W_{aP} derived in 15a) output calcs.	
	Similar to $F_{NP}/_p$ above	

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR

INPUT		CORR.	OUTPUT
No.	AS READ	FOR INST. ERROR	All outputs denoted * are to be meaned between successive runs. Remaining outpu are meaned during computations.
			14 a) $\frac{Q_P}{F_{NP}\sqrt{\theta}}$
			14 b) $\frac{Q_S}{F_{NS}\sqrt{\theta}}$
			14 c) $(F_G/X_G)_P$
			14 d) $(F_G/X_G)_S$
			15 a) μ_P
			15 b) μ_S

...o be meaned ...aining outputs ...tions.	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
	$Q_P = Q_{PE} + Q_{PA}$ derived previously $Q_S = Q_{SE} + Q_S$ derived previously $\theta = T_{mean}/288$ $\left(F_G/X_G\right)_P = \dfrac{F_{GP}/p}{X_{GP}/p}$ for A/B on $= \dfrac{F_{GP}/p}{X_{GP}/p} \times \dfrac{X_G}{X_{iG}}$ for A/B off where X_G/X_{iG} is obtained from Chart VII Similar to $\left(F_G/X_G\right)_P$ above	
	$\mu_P = \dfrac{W_{BP}}{W_{10P}} \sqrt{\dfrac{T_{BP} + 273}{T_{10P}}}$ where $W_{10P} = W_{aP}$ for A/B off $= W_{aP} + \dfrac{Q_{PA}}{3600}$ for A/B on $W_{aP} = \left(\dfrac{W_{aP}V}{g\ \ p}\right)_{mean} \times \dfrac{p_{mean}}{M} \sqrt{\dfrac{g}{\gamma RT}}$ $\sqrt{T_{10P}}\ (^\circ K) = \sqrt{T_{7P} + 273}$ for A/B off $= \left[\dfrac{.717\ X_{GP}}{W_{aP} + \dfrac{Q_{PA}}{3600}}\right] \times \left[\dfrac{.0009\ \dfrac{X_{GP}}{p} + 0.8}{.00219\ \dfrac{X_{GP}}{p} - .02}\right]$ Similar to μ_P above	Assume engine fuel offsets airbleed and leakage see 9 a) output calcs. for $\left(\dfrac{W_{aP}V}{g\ \ p}\right)$ for A/B on

ARROW I - PERFORMANCE FLIGHT TESTS

INPUT - OUTPUT SUMMARY AND APPLICABLE FORMULAE OR CHARTS FOR I.

INPUT No.	INPUT AS READ	CORR. FOR INST. ERROR	OUTPUT No.	OUTPUT (All outputs denoted * are to be meaned between successive runs. Remaining outputs are meaned during computations.)	
			15 c)	$\frac{P_{1OP}}{p}$	*
			15 d)	$\frac{P_{1OS}}{p}$	*
			16 a)	$\frac{m_{iP}}{m_o}$	
			16 b)	$\frac{m_{iS}}{m_o}$	
			16 c)	$\frac{E}{W}$	*
			16 d)	D/p	
			17 a)	C_D	
			17 b)	L/p	
			17 c)	C_L	
			17 d)	$C_L{}^2$	
			18 a)	$\Sigma \Delta \frac{E}{W}$	
			18 b)	$\frac{N_{1P}}{\sqrt{\theta_{t_2}}}$	
			18 c)	$\frac{N_{1S}}{\sqrt{\theta_{t_2}}}$	
			18 d)	T_1	

TESTS

HARTS FOR I.B.M. 704 COMPUTOR

SHEET NO. 16 REPORT NO. 71/PERF/2 ISS.4

DATE JULY 1958 PREP. BY R.WAECHTER

e meaned ing outputs	APPLICABLE FORMULAE, OPERATION OR CHART	REMARKS
	$\frac{P_{10P}}{p} = .96 \frac{P_{7P}}{p}$ for A/B off	
	$= \frac{C_g}{.967} \times \frac{P_{7P}}{p} - \frac{C_g}{1.208} + 0.8$ for A/B on	See 70/PERF/1 App. II for derivation.
	Similar to $\frac{P_{10P}}{p}$ above	
	$m_o = .1003 \frac{pM}{\sqrt{T}}$	
	$m_{iP} = (W_{aP})_{mean} + W_{BP} + 3$ where W_{aP} is derived in 15 a) output calcs. W_{BP} = output 10 c)	Constant 3 assumed = overboard cooler air flow
	Similar to m_{iP}/m_o above	
	$\frac{E}{W} = 67.3\, M^2\, T + Hp$	
	$D/p = \left(\frac{F_{NP}}{p} + \frac{F_{NS}}{p}\right) \cos(\alpha - 2.58^\circ) - \frac{W}{p}_{MEAN} \times \frac{1}{(65.8 M\sqrt{T})_{MEAN}} \times \frac{\Delta \frac{E}{W}}{\Delta T (secs.)}$	
	$C_D = D/p \times \frac{1}{123{,}480\, M^2}$	
	$L/p = a_n \left(\frac{W}{p}\right) - \left(\frac{F_{NP}}{p} + \frac{F_{NS}}{p}\right) \sin(\alpha - 2.58^\circ)$	where 2.58° = angle of thrust axis relative to fuselage datum
	$C_L = \frac{L/p}{\frac{\gamma M^2 S}{2}}$ where $\gamma = 1.4$, $S = 176{,}400$ sq.inches	
	$\Delta \frac{E}{W} = 65.8\, (M\sqrt{T}\, a_L)_{MEAN} \times \Delta T (secs.) + \Delta H_p$	This relative specific energy term may be compared to the absolute specific energy term 16 c) as far as slope and scatter is concerned
	See calculations opposite inputs 20 & 21	
	$T_1\ ^\circ K = T\,(1 - .2\, M^2)$	

Chart IA (nose probe pilot correction) of

ΔM_{PECP} versus M_{iP} where $M_{iP} + \Delta M_{PECP} = M_i$

will be inserted when flight results become available.

Initially ΔM_{PECP} is assumed zero, until flight results

prove otherwise.

Chart I A

POSITION ERROR

ARROW - 1

M_i VS. ΔM_{PEC}

ESTIMATE BASED ON PRELIMINARY FLIGHT TRIALS

$M_i + \Delta M_{PEC} = M$

$B = .7336$

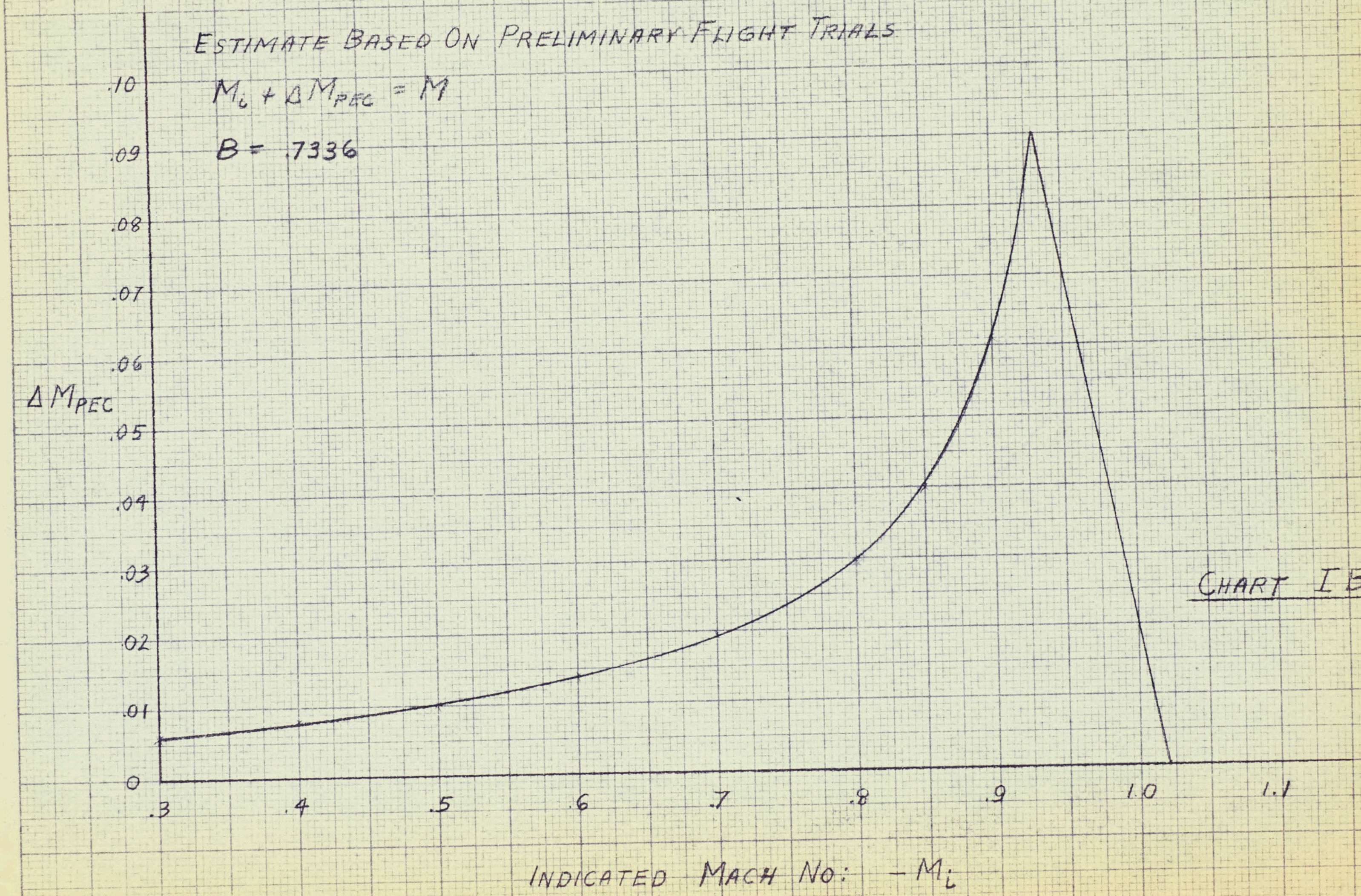


CHART IB

REF.
REP. No. P/AERO DATA/93.

FOR EXACT VALUES
SEE REP. No. 72/STAB/35.

PREDICTION OF THE ANGLE OF ATTACK FROM FLIGHT DATA.

$$\alpha = f_1(M) + \frac{a_n W}{\frac{1}{2}\rho S V^2} f_2(M) + (a_n - 1) f_3(M).$$

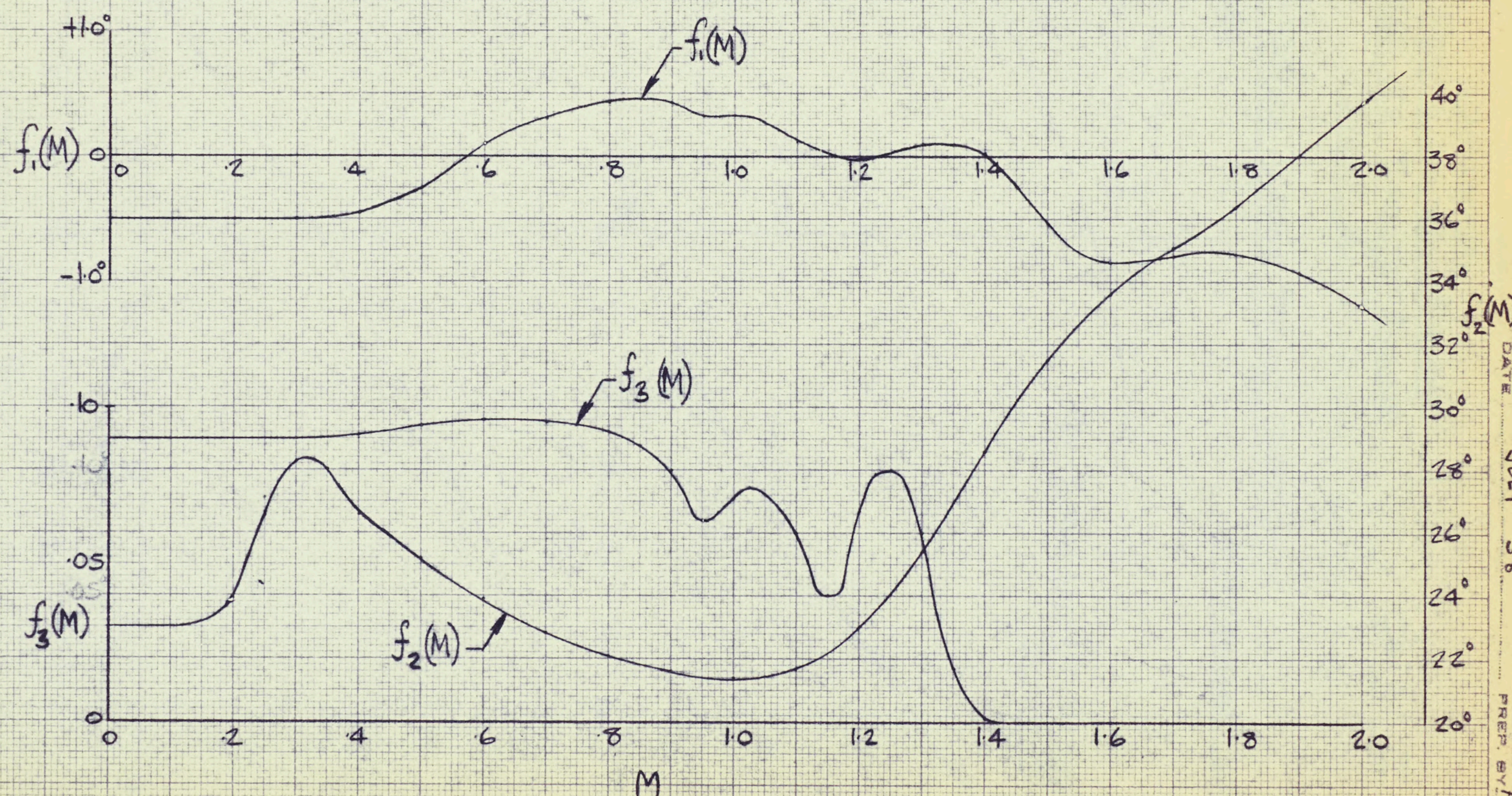


CHART II.

CONFIDENTIAL

PRATT & WHITNEY AIRCRAFT

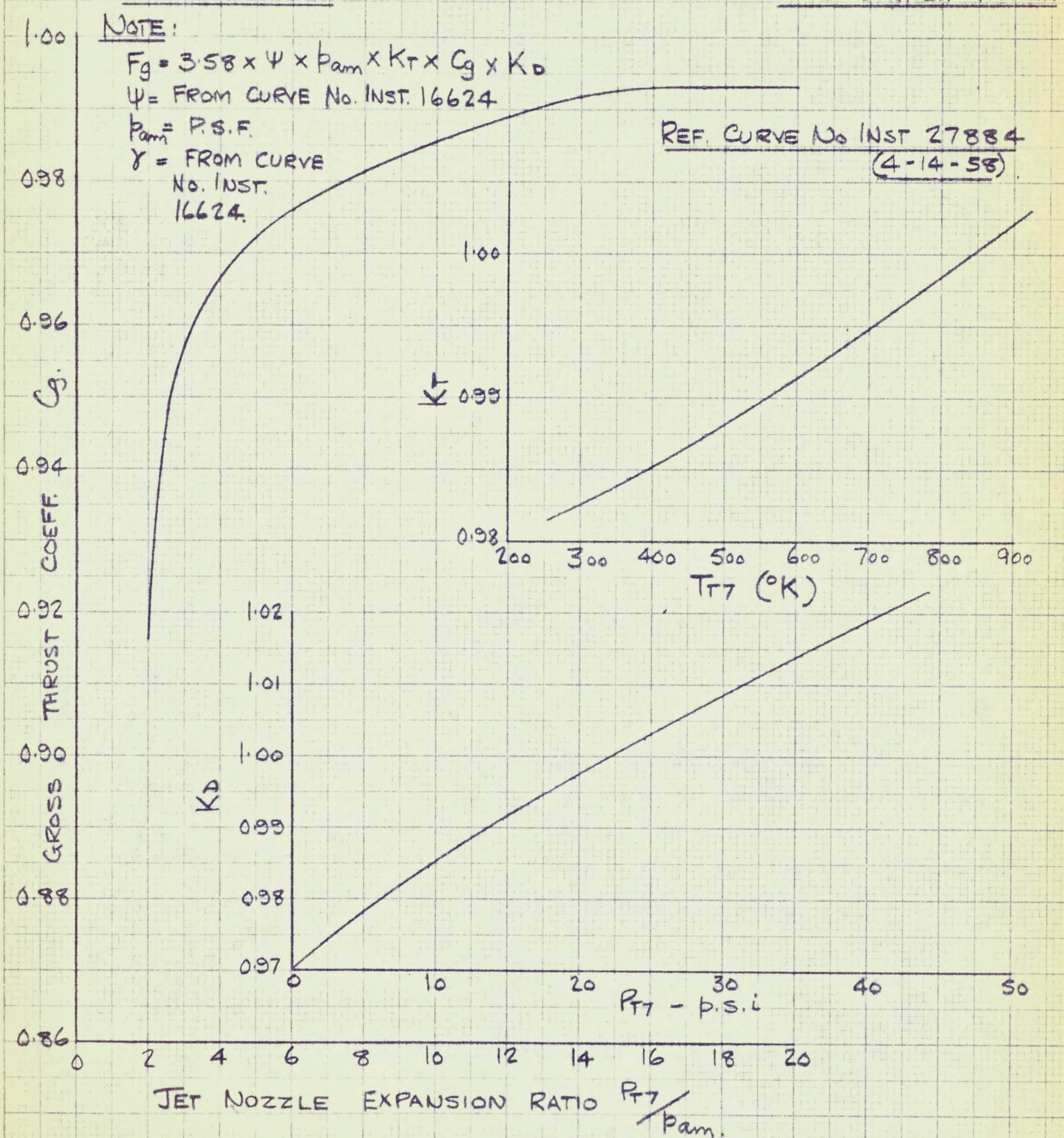
JT-4A-25 TURBOJET ENGINE

(J75-P-5)

CHART III

JET NOZZLE GROSS THRUST COEFFICIENT

NOZZLE CLOSED AFTERBURNER NOT LIT



SHEET NO. 21 REPORT NO. 71/PERF/2 ISS.4

DATE FEB. 25, 1958 REF. NO. J.W.

CONFIDENTIAL

PRATT & WHITNEY AIRCRAFT

JT4 A - 20, -23 & 26 TURBOJET ENGINES

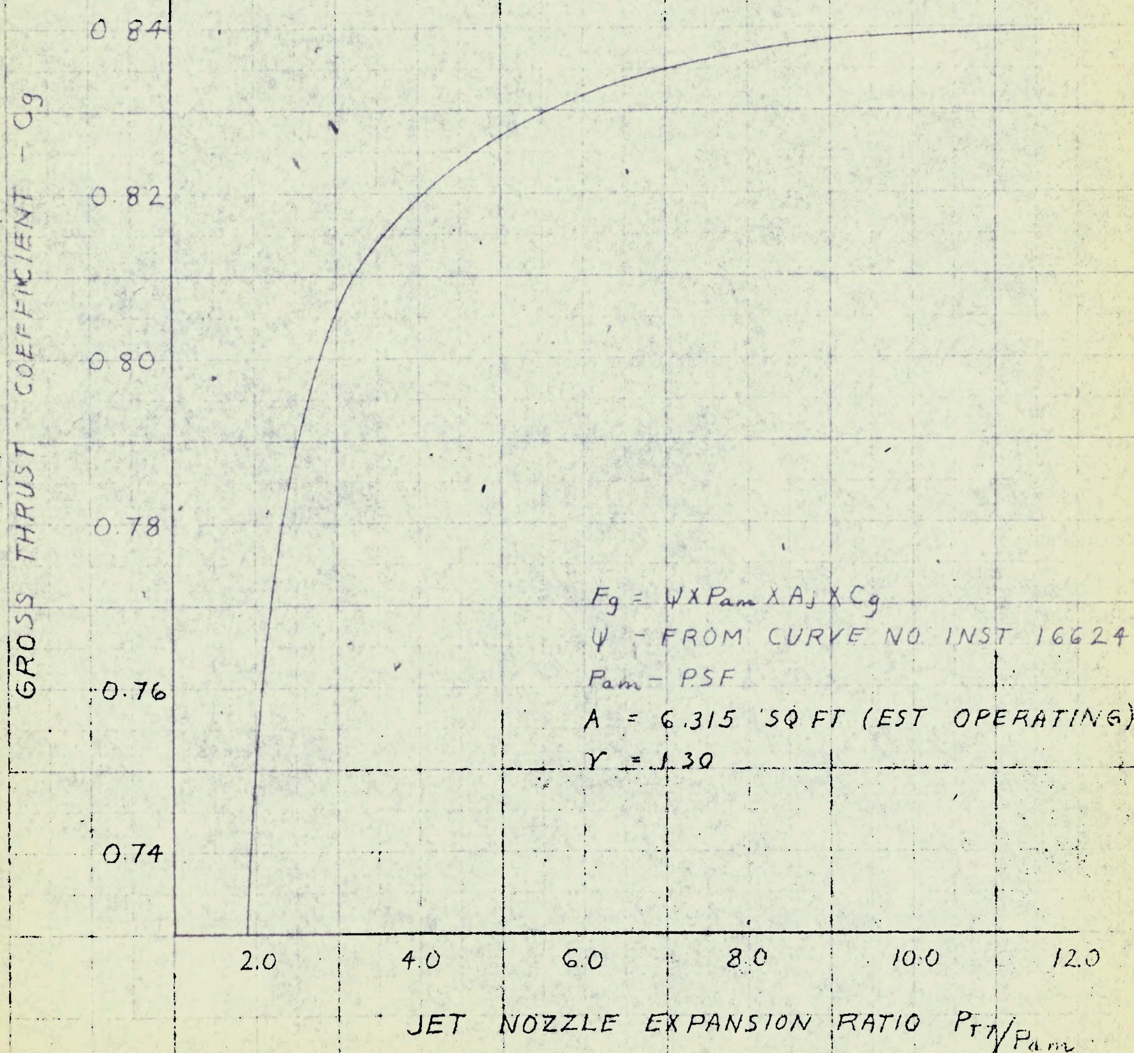
(-YJ-75-P-1, -3 & -11)

JET NOZZLE GROSS THRUST COEFFICIENT

AFTERBURNER LIT

REF: CURVE NO. INST. 18151 FILE - JT4 GAS TURB.
4-18-57 SPEC - PERF AND CORR. FACTOR CURVES BOOK.

CHART IV



22 DEC. 1957

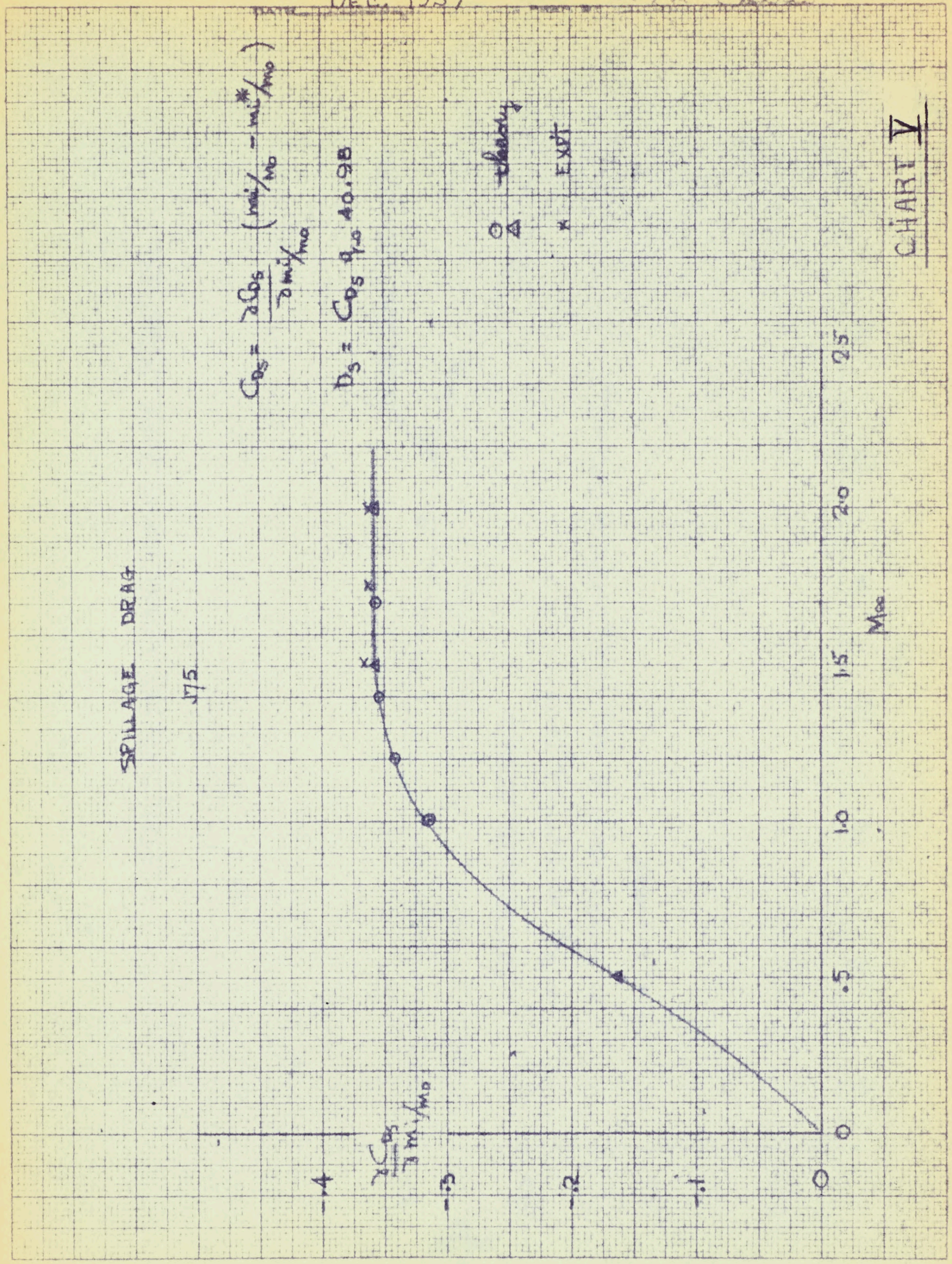


CHART V

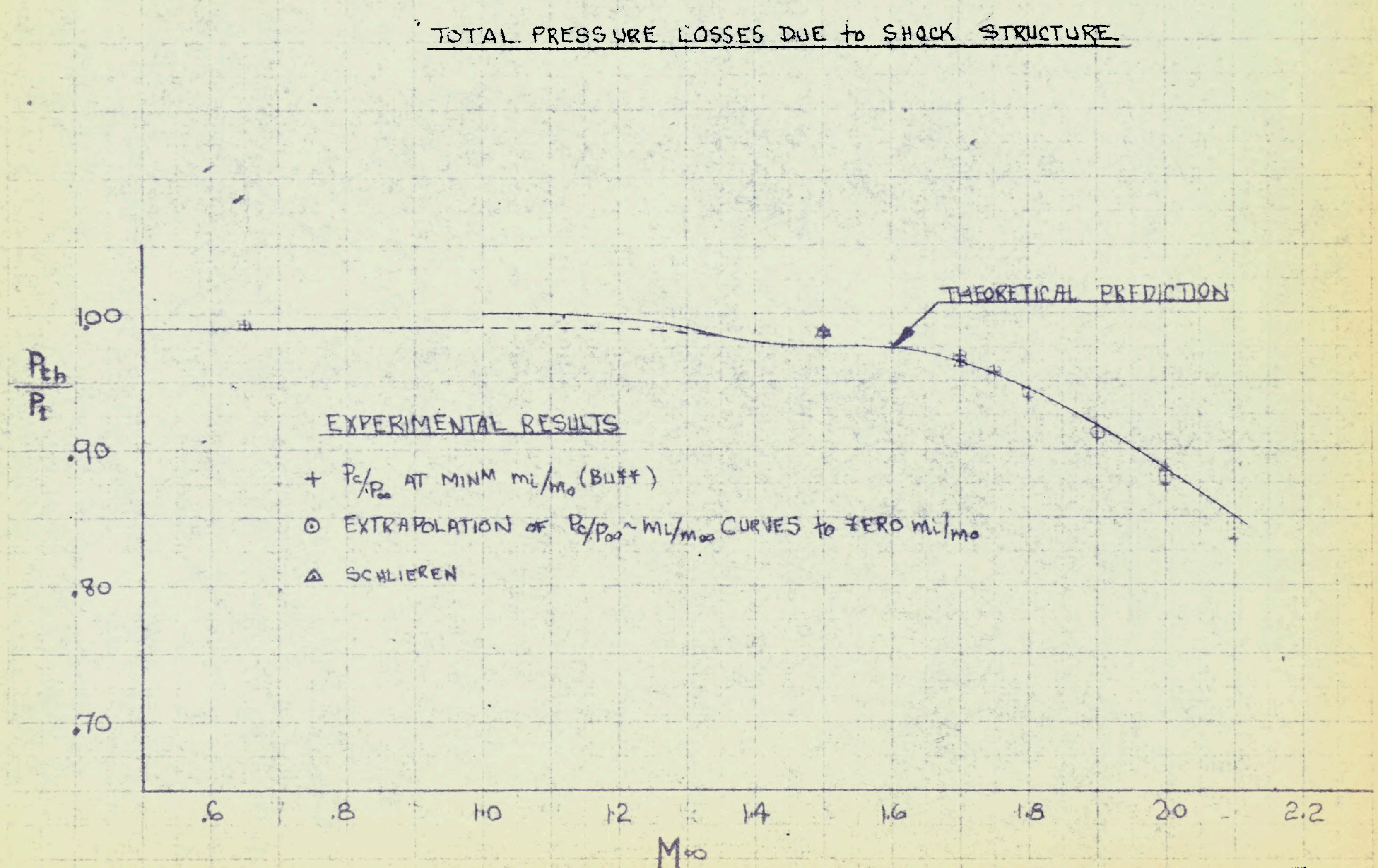
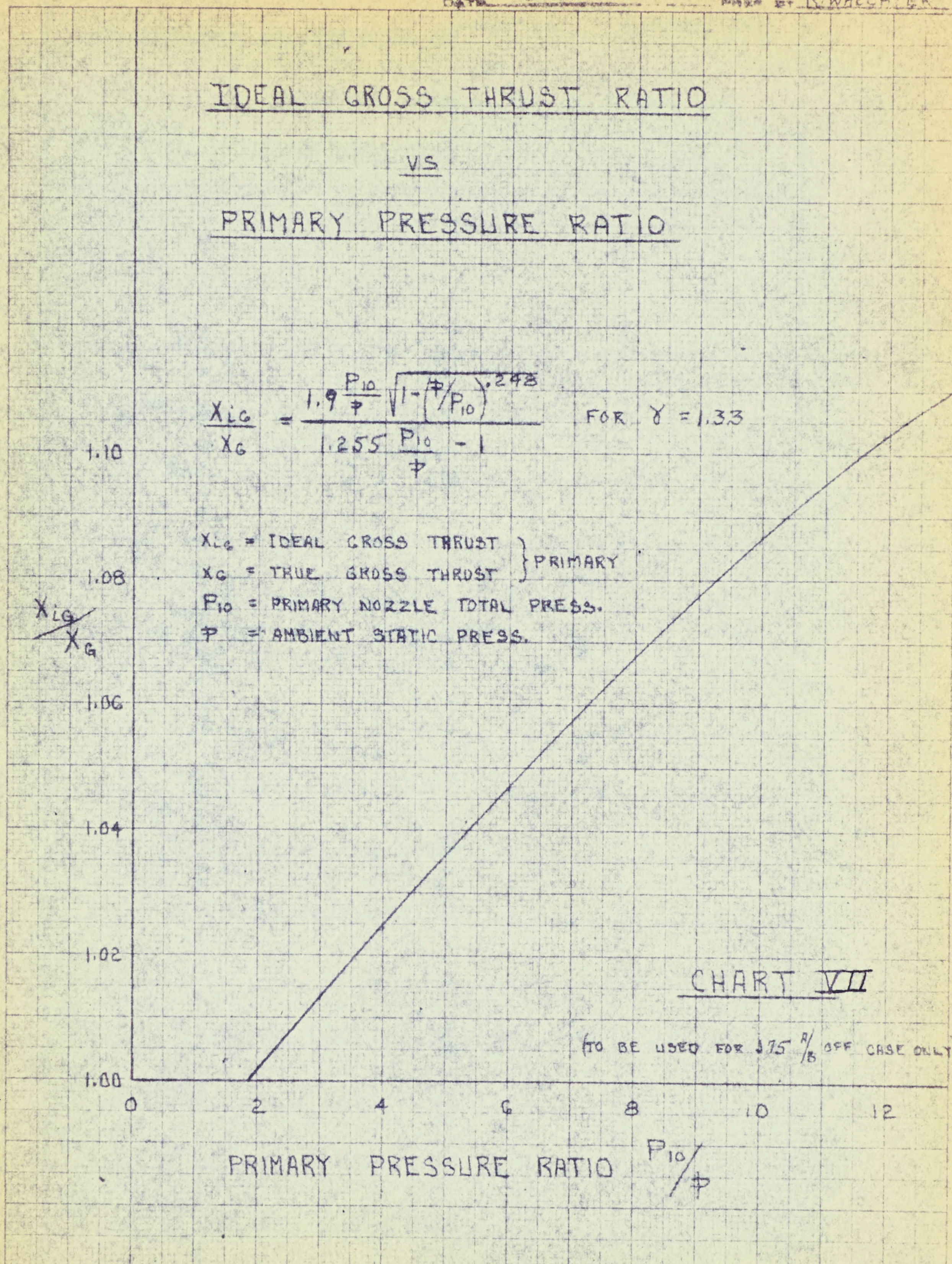

TOTAL PRESSURE LOSSES DUE to SHOCK STRUCTURE
THEORETICAL PREDICTION
EXPERIMENTAL RESULTS
+ Pc/P∞ AT MINM mi/mo (BUFF)
⊙ EXTRAPOLATION OF Pc/P∞ ~ mi/m∞ CURVES to ZERO mi/mo
△ SCHLIEREN
Pth/Pt
1.00
.90
.80
.70
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
M∞

CHART VI


IDEAL GROSS THRUST RATIO
VS
PRIMARY PRESSURE RATIO
$$\frac{X_{iG}}{X_G} = \frac{1.9\,\frac{P_{10}}{p}\sqrt{1-\left(p/P_{10}\right)^{.248}}}{1.255\,\frac{P_{10}}{p}-1}$$
FOR $\gamma = 1.33$
X_{iG} = IDEAL GROSS THRUST } PRIMARY
X_G = TRUE GROSS THRUST } PRIMARY
P_{10} = PRIMARY NOZZLE TOTAL PRESS.
p = AMBIENT STATIC PRESS.
X_{iG}/X_G
1.00
1.02
1.04
1.06
1.08
1.10
0
2
4
6
8
10
12
PRIMARY PRESSURE RATIO P_{10}/p
CHART VII
(TO BE USED FOR 175 A/B OFF CASE ONLY)

PROGRAMMING FOR PERFORMANCE DATA FROM ARROW I (A/C 25203) PHASE 2 FLIGHT TESTS

25

TABULATED SUMMARY OF CHARTS I TO VII INCLUSIVE

USE LINEAR INTERPOLATION BETWEEN ALL POINTS

CHART	PARAMETER	1	2	3	4	5	6	7	8	9	10
I_A	M_iP / ΔM_{IECP}	0 / 0	.2 / 0	.4 / 0	.5 / 0	.6 / 0	.7 / 0	.75 / 0	.8 / 0	.85 / 0	.87
I_B	M_i / ΔM_{PEC}	0 / 0	.2 / .0050	.4 / .0077	.5 / .0101	.6 / .0139	.7 / .0192	.75 / .0236	.8 / .0300	.85 / .0402	.87 / .04
II	M / $f_1(M)^o$	0 / -0.50	.1 / -0.50	.2 / -0.50	.3 / -0.50	.4 / -0.45	.5 / -0.25	.6 / +0.10	.7 / +0.31	.8 / +0.44	.9 / +0.4
	$f_2(M)^o$ / $f_3(M)^o$	23.0 / .090	23.0 / .090	23.8 / .090	28.6 / .090	26.7 / .091	25.1 / .094	23.8 / .096	22.8 / .095	22.1 / .092	21.6 / .07
III	P_7/p / C_g	1.0 / 0.800	1.5 / 0.860	2.0 / 0.917	2.5 / 0.947	3.0 / 0.957	3.5 / 0.962	4.0 / 0.967	5.0 / 0.972	6.0 / 0.976	7.0 / 0.97
	P_7(psi) / K_D	0 / 0.970	10 / 0.985	20 / 0.998	30 / 1.009	40 / 1.019	50 / 1.029				
	T_7(°K) / K_T	200 / 0.980	400 / 0.985	600 / 0.991	800 / 0.998	1000 / 1.006					
IV	P_7/p / C_g	1 / 0.600	1.5 / 0.660	2.0 / 0.750	2.5 / 0.789	3.0 / 0.806	3.5 / 0.814	4.0 / 0.819	5.0 / 0.827	6.0 / 0.832	7.0 / 0.83
V	M / $\frac{\partial C_{D_E}}{\partial (m/m_o)}$	0 / 0	.2 / -.055	.4 / -.125	.6 / -.205	.8 / -.272	1.0 / -.317	1.2 / -.342	1.4 / -.354	1.6 / -.358	1.8 / -.35
VI	M / $\frac{P_{th}}{P_1}$	0 / 0.990	.2 / 0.990	.4 / 0.990	.6 / 0.990	.8 / 0.990	1.0 / 0.990	1.2 / 0.990	1.4 / 0.980	1.6 / 0.975	1.8 / 0.9
VII	P_{10}/p / $\frac{X_{IG}}{X_G}$	1.0 / 0.990	2.0 / 1.001	4.0 / 1.025	6.0 / 1.047	8.0 / 1.068	10.0 / 1.087	12.0 / 1.103	14.0 / 1.117		

FORM 1543

ESTS

A. V. ROE CANADA LIMITED

MALTON, ONTARIO

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT - - ARROW 1

WEIGHT - -

C. G. POSITION -

REPORT NO. - 71/PERF/2 ISS.4

SHEET - - 15

DATE - - SEPT. 1958

PREPARED BY - R.WAECHTER

9	10	11	12	13	14	15	16	17	18	19
.85 / 0	.87 / 0	.89 / 0	.91 / 0	.93 / 0		1.02 / 0		1.50 / 0	2.00 / 0	2.50 / 0
.85 / .0402	.87 / .0479	.89 / .0560	.91 / .0689	.93 / .0900		1.02 / 0		1.50 / 0	2.00 / 0	2.50 / 0
.8 / +0.44	.9 / +0.43	1.0 / +0.30	1.1 / +0.15	1.2 / - 0.03	1.3 / +0.09	1.4 / +.03	1.6 / -0.95	1.8 / -0.70	2.0 / -1.20	2.5 / -2.45
2.1 / .092	1.6 / .079	21.3 / .068	21.7 / .068	23.0 / .050	25.4 / .070	28.6 / -.010	33.8 / 0	36.4 / 0	39.7 / 0	48.0 / 0
.0 / 0.976	7.0 / 0.979	8.0 / 0.981	10.0 / 0.985	12.0 / 0.989	14.0 / 0.992	16.0 / 0.993	18.0 / 0.993	20.0 / 0.993		
.0 / 0.832	7.0 / 0.835	8.0 / 0.837	10.0 / 0.839	12.0 / 0.840	14.0 / 0.840	16.0 / 0.840	18.0 / 0.840	20.0 / 0.840		
.6 / -.358	1.8 / -.358	2.0 / -.358	2.5 / -.358							
.6 / 0.975	1.8 / 0.945	2.0 / 0.885	2.5 / 0.735							

APPENDIX I

OUTPUT DATA CODING FROM ARROW 1 PERFORMANCE FLIGHT TESTS

The following data is output from Arrow 1 performance flight tests and subsequent data processing according to report 71/PERF/2 Iss. 4. Coding of output for "I.B.M. print out" is given in units of not more than 3 numbers and/or capital letters. The outputs will appear in the following order, as preferred by the computing department, instead of the order shown in the input - output summary tables.

No.		QUANTITY	CODING	No.		QUANTITY	CODING
1.	a	M	M	4.	a	$(P_7/P_2)_P$	P7P
	b	H_P	HP		b	$(P_7/P_2)_S$	P7S
	c	R_{o_1}	RO1		c	$T_{7P}+273/T_1$	T7P
	d	T	T		d	$T_{7S}+273/T_1$	T7S
2.	a	$N_{2P}/\sqrt{T_1}$	NTP	5.	a	X_{NP}/p	XNP
	b	$N_{2S}/\sqrt{T_1}$	NTS		b	X_{NS}/p	XNS
	c	$N_{2P}/\sqrt{\theta}$	NOP		c	$N_{1P}/\sqrt{\theta_{t2}}$	NIP
	d	$N_{2S}/\sqrt{\theta}$	NOS		d	$N_{1S}/\sqrt{\theta_{t2}}$	N1S
3.	a	$N_2/\sqrt{\theta}$	NOA	6.	a	M_{BP}	MBP
	b	W	W		b	M_{BS}	MBS
	c	P_{2P}/P_1	P2P		c	X_{1P}/p	X1P
	d	P_{2S}/P_1	P2S		d	X_{1S}/p	X1S

AVRO AIRCRAFT LIMITED
MALTON – ONTARIO
TECHNICAL DEPARTMENT

REPORT NO. 71/PERF/2 App.1 Iss.4		SHEET NO. 2	
AIRCRAFT: ARROW 1 A/C 25203	PERFORMANCE FLIGHT TESTS	PREPARED BY: I. Wilkinson	DATE: Sept. 1958
		CHECKED BY: R. Waechter	DATE: Sept. 1958

OUTPUT DATA CODING FROM ARROW 1 PERFORMANCE FLIGHT TESTS (Cont'd)

No.		QUANTITY	CODING	No.		QUANTITY	CODING
7.	a	X_{2P}/p	X2P	11.	a	C_{LW}^2	CW2
	b	X_{2S}/p	X2S		b	α	ALF
	c	X_{3P}/p	X3P		c	$a_n W/p$	NW
	d	X_{3S}/p	X3S		d	$\Sigma \Delta E/W$	SEW
8.	a	X_{4P}/p	X4P	12.	a	L/p	LP
	b	X_{4S}/p	X4S		b	D/p	DP
	c	P_{10P}/p	POP		c	C_D	CD
	d	P_{10S}/p	POS		d	C_L	CL
9.	a	E/W	EW	13.	a	C_L^2	CL2
	b	$(R/C)_1$	RC1		b	$Q_{PE}/P_{2P}\sqrt{T_1}$	QEP
	c	$(R/C)_2$	RC2		c	$Q_{SE}/P_{2S}\sqrt{T_1}$	QES
	d	$R/C/\sqrt{\theta}$	RCO		d	$Q_{PA}/P_{2P}\sqrt{T_1}$	QAP
10.	a	$(R/C)_3$	RC3	14.	a	$Q_{SA}/P_{2S}\sqrt{T_1}$	QAS
	b	a_n	NFP		b	$Q_P/X_{NP}\sqrt{\theta}$	QXP
	c	a_L	XFP		c	$Q_S/X_{NS}\sqrt{\theta}$	QXS
	d	C_{LW}	CW		d	W_{BP}	WBP

OUTPUT DATA CODING FROM ARROW 1 PERFORMANCE FLIGHT TESTS (Cont'd)

No.		QUANTITY	CODING	No.		QUANTITY	CODING
15.	a	W_{BS}	WBS	17.	a	$(F_G/X_G)_S$	FXS
	b	$(mV)_{BP}/p$	MVP		b	μp	UP
	c	$(mV)_{BS}/p$	MVS		c	μ_S	US
	d	F_{NP}/p	FNP		d	m_{ip}/m_o	MMP
16.	a	F_{NS}/p	FNS	18.	a	m_{iS}/m_o	MMS
	b	$Q_P/F_{NP}\sqrt{\theta}$	QFP		b	$V\,\delta_r/Q$	NMP
	c	$Q_S/F_{NS}\sqrt{\theta}$	QFS		c	R	R
	d	$(F_G/X_G)_p$	FXP		d	T_1	T_1