





AVRO AIRCRAFT LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

UNCLASSIFIED

AIRCRAFT: ARROW 2

REPORT NO: 72/PERF/12 (EXTRACT)

FILE NO:

NO. OF SHEETS: 8

TITLE:

Classification cancelled/changed to \_\_\_\_\_ (date) \_\_\_\_\_  
by authority of \_\_\_\_\_  
Signature \_\_\_\_\_

27.51 X 10<sup>6</sup>  
51.14 X 10<sup>6</sup>  
88.9 X 10<sup>6</sup>

ARROW 2 - CONDITIONS FOR BRAKE SPECIFICATION

Classification cancelled/changed to \_\_\_\_\_ (date) \_\_\_\_\_  
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PREPARED BY *P. Hollenbery* DATE \_\_\_\_\_  
Performance Group

CHECKED BY \_\_\_\_\_ DATE \_\_\_\_\_

SUPERVISED BY *R. G. Rose* DATE *June 1958*  
Senior Aerodynamicist

June 1958

APPROVED BY *[Signature]* DATE *June 1958*  
Chief of Performance Evaluation

ISSUE NO.	REVISION NO.	REVISED BY	APPROVED BY	DATE	REMARKS

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MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 72/PERT/12 (EXTRACT)

SHEET NO. \_\_\_\_\_

AIRCRAFT:  
ARROW 2

CONDITIONS FOR BRAKE  
SPECIFICATION

PREPARED BY	DATE
Performance Group	June 1958
CHECKED BY	DATE

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SECRET

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**TECHNICAL DEPARTMENT**

REPORT NO. 72/PERF/12 (EXTRACT)

SHEET NO. 1

AIRCRAFT:

ARROW 2

CONDITIONS FOR BRAKE  
SPECIFICATION

PREPARED BY

DATE

Performance Group

June 1958

CHECKED BY

DATE

S E C R E T

ARROW 2 - CONDITIONS FOR BRAKE SPECIFICATION

This report has been drawn up as the result of R.C.A.F. letter ref. S36-38-105-8-2 (APO-1) dated May 9th. 1958.

The report contains details of the method used and the assumptions made for calculating Arrow 2 brake energy capacity, as required by MIL-W-50130 para. 3.3.1.1.2.1.

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MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 72/PERF/12 (EXTRACT)

SHEET No. 2

AIRCRAFT:

ARROW 2

CONDITIONS FOR BRAKE  
SPECIFICATION

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June 1958

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S E C R E T

ARROW 2

CONDITIONS FOR BRAKE SPECIFICATION

The following cases are covered in the brake specification:-

(1) 45 STOP CASE

Landing weight (W) = 55,000 lb., Touchdown speed ( $V_{TD}$ ) = 165 kts.

(normal  $V_{TD}$ )

Braking force coefficient,  $\mu = 0.4$  constant, 24 ft. diameter parachute.

(2) 5 STOP CASE

W = 55,000 lb.  $V_{TD} = 165$  kts. (normal  $V_{TD}$ )

$\mu = 0.4$  constant, No Parachute.

(3) 1 STOP CASE

W = 64,600 lb.  $V_{TD} = 210$  kts. (overspeed  $V_{TD}$ )

$\mu = 0.4$  constant, No Parachute.

80

75

The above cases are for determining energy only, not distance.

Brakes are applied and parachute is assumed fully open 4 seconds after T.D.

The undercarriage is assumed to be fully compressed at T.D., the A/C having 3° Tail clearance giving an angle of attack ( $\alpha$ ) = 11°.



AVRO AIRCRAFT LIMITED  
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 72/PERF/12 (EXTRACT)

SHEET NO. 3

AIRCRAFT: ARROW 2	CONDITIONS FOR BRAKE SPECIFICATION	PREPARED BY	DATE
		Performance Group	June 1958
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SECRET

The nosewheel was assumed to be down 1 1/2 seconds after touchdown.

Air Brakes were extended throughout the landing run.

Fig. (1) shows the variation of drag coefficient ( $C_D$ ) with lift coefficient ( $C_L$ ) during landing. The curve is taken from N.A.E. low speed tunnel tests and includes ground effect.

The rolling  $C_L$ (nosewheel down) was assumed constant at 0.174 giving  $C_D = 0.065$ .

The rolling coefficient of friction was taken to be .03 constant

The parachute drag coefficient was 0.47 based on an area of 452 sq.ft. (i.e. 24 ft. diam.).

Fig. (2) shows the idling thrust variation with speed.

During the ground run 0.9 of the weight of the aircraft is assumed to be taken by the main U/C.



AVRO AIRCRAFT LIMITED  
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 72/PERF/12 (EXTRACT)

SHEET NO. 4

AIRCRAFT:

ARROW 2

CONDITIONS FOR BRAKE  
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PREPARED BY

DATE

Performance Group

June 1958

CHECKED BY

DATE

S E C R E T

METHOD OF CALCULATION

The calculations were carried out in two parts:-

(1) Taking increments of time from  $V_{TD}$  to  $V_{BRAKE}$  (a total time of 4 seconds).

(2) Taking increments of velocity from  $V_{BRAKE}$  to  $V = 0$ .

FOR (1) the Drag Equation used was:-

$$C_{D_{TOTAL}} = C_{D_0} + C_{D_{U/C}} + C_{D_{DIVE}} + C_{D_i} + C_{D_{ROLLING}}$$

$$= [0.057 + 0.269 C_L^2] + \frac{0.02}{q s} (W-L)$$

FOR (2) the Drag Equation used was:-

$$C_{D_{TOTAL}} = C_{D_0} + C_{D_{U/C}} + C_{D_{DIVE}} + C_{D_i} + C_{D_{BRAKES}} + C_{D_{CHUTE}} \text{ (if used)}$$

$$+ C_{D_{ROLLING}}$$

$$= .009 + .032 + .016 + .269 C_L^2 + \frac{W}{q s} (0.9 \mu + .003)$$

$$- C_L(0.9 \mu + .003) + .1736 \text{ (if drag chute is used)}$$

$$= [0.057 + 0.269 C_L^2] - C_L(0.9 \mu + .003) + 0.687 \frac{W}{V^2} (0.9 \mu + .003)$$

$$+ 0.1736 \text{ (if drag chute is used)}$$



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MALTON, ONTARIO

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REPORT No. 72/PERF/12 (EXTRACT)

SHEET No.

PREPARED BY

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AIRCRAFT:

ARROW 2

CONDITIONS FOR BRAKE  
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Performance Group

June 1958

CHECKED BY

DATE

S E C R E T

METHOD OF CALCULATION (Continued)

FOR (1) the calculation stages are:-

- (1)  $V$  ft/sec. Starting at  $V_{TD}$ .
- (2)  $C_L$  Assuming 1.0 g.
- (3)  $C_D$  from fig. (1)
- (4)  $q S$
- (5)  $D = (3) \times (4)$
- (6)  $2 F_n$  from fig. (2)
- (7) Lift = (2)  $\times$  (4)
- (8) Rolling Drag = .03 (W-L)
- (9) Total Drag = (5) + (8) - (6)
- (10)  $a = g/W \times (-9)$
- (11)  $\Delta t$  secs. (Chosen increments)
- (12)  $\Delta V = (10) \times (11)$  Hence obtain  $V_{BRAKE}$

FOR (2) the calculation stages are:-

- (1)  $V$  ft/sec. (Chosen increments)
- (2)  $v^2$
- (3)  $(0.9 \mu + .003)$
- (4)  $C_L(0.9 \mu + .003)$
- (5)  $(3) \times \frac{.687 W}{v^2}$



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MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 72/PERF/12 (EXTRACT)

SHEET No. 6

AIRCRAFT:

ARROW 2

CONDITIONS FOR BRAKE  
SPECIFICATION

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DATE

Performance Group

June 1958

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S E C R E T

METHOD OF CALCULATION (Continued)

(6) (5) - (4)

(7) q S

(8) (6) x (7) = Brake Force

(9)  $2 F_n$  from fig.(2)

(10)  $.065 \times (7) [ + 0.1736 \times (7) \text{ (if drag chute used)} ]$

(11) (8) + (10) - (9)

(12)  $V/a = \frac{W}{g} \times \frac{(1)}{(11)}$

(13)  $\Delta V$

(14) (8)<sub>MEAN</sub>

(15) (12)<sub>MEAN</sub>

(16)  $\Delta E_B = (13) \times (14) \times (15)$

(17)  $\Sigma (16) = \text{Brake Energy ft. lb.}$

72/PERF/12

ARROW 2

$C_D - C_L$  DURING GROUND RUN

I.E. INCLUDING GROUND EFFECT

$$C_D = C_{D_0} + C_{Di} + C_{Dj/c} + C_{D_{AIR BRAKES}}$$

REF P/PERF/131

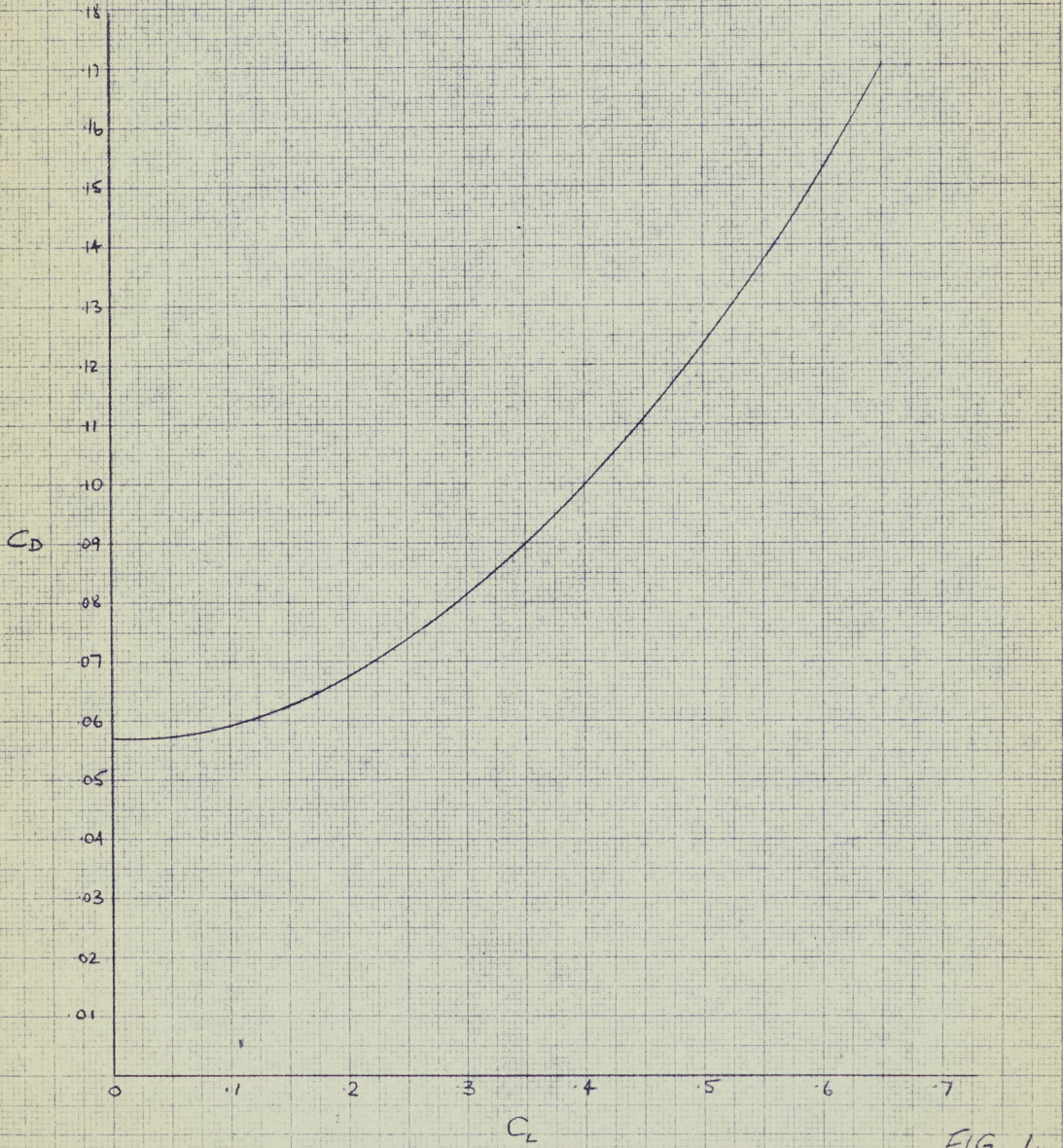


FIG 1.

PA MAY 58

10 X 10 TO THE CM. 359-14  
NEUFEL & ESSER CO. MADE IN U.S.A.



72/PERF/12

IROQUOIS IDLING THRUST

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S.L. STANDARD DAY

$N_L = 2100$  RPM

NO EJECTOR EFFECT AND  
100% PRESSURE RECOVERY ASSUMED

ONE ENGINE

REF P/PERF/131

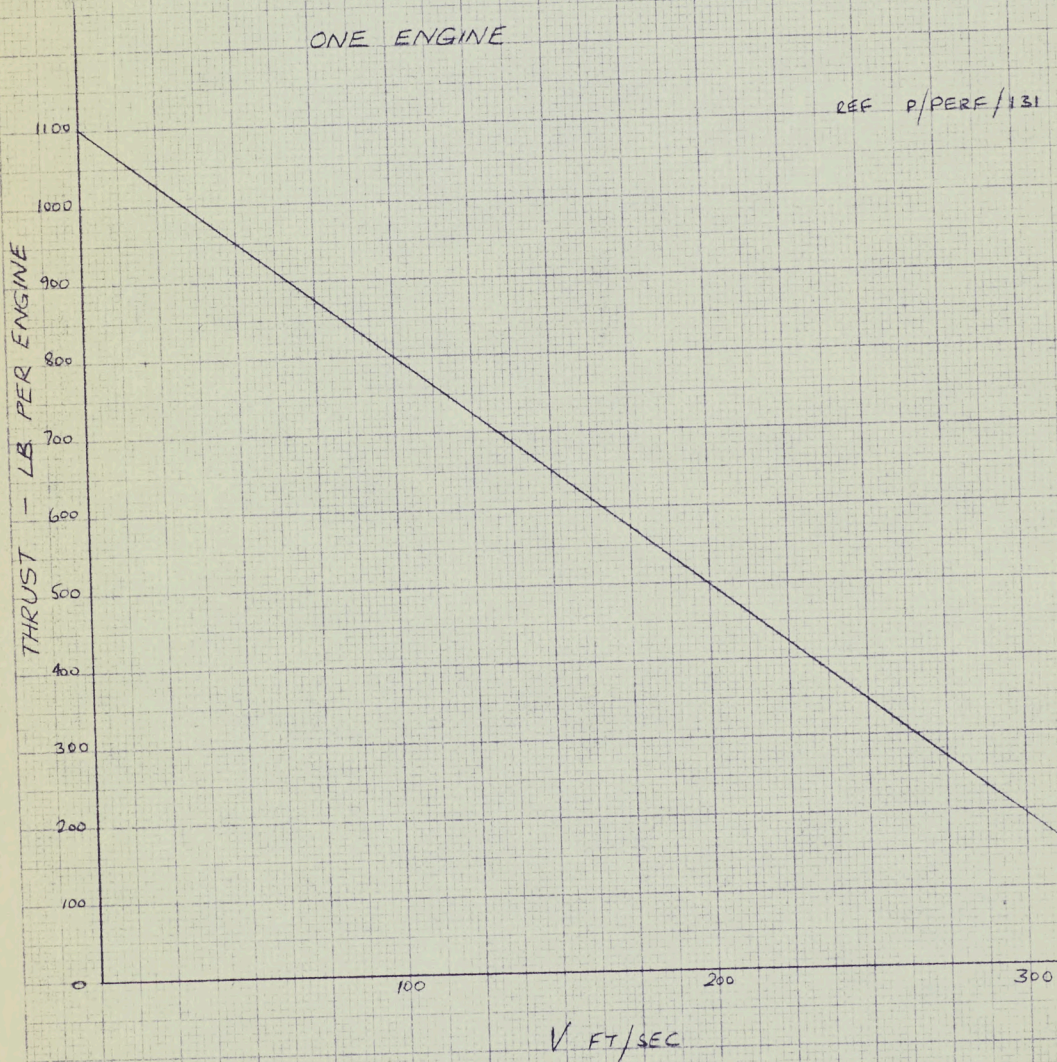


FIG 2

10 X 10 TO THE 1/2 INCH  
KEUFFEL & ESSER CO.  
359-12  
MADE IN U.S.A.

3558  
MADE IN U.S.A.