

QCX
Avro
CF105
R-7-0500-3
ANALYST



TECHNICAL REPORT



A. V. ROE CANADA LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

ANALYZED

AIRCRAFT:

REPORT NO. 7/0500/3

FILE NO:

NO OF SHEETS:

TITLE: INVESTIGATION OF THERMAL STRESSES
IN WING STRUCTURE

~~CONFIDENTIAL~~

Classification cancelled / Changed to UNCLASS

By authority of

AVRS

Date

30 Sept 66

Signature

[Signature]

Unit / Rank / Appointment

AVRS F

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DATE

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DATE

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DATE

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

FORM 1384

15867862

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

REPORT NO.

3/10-00/3

SHEET

12

DATE _____

17 SEP 1954

PREPARED BY

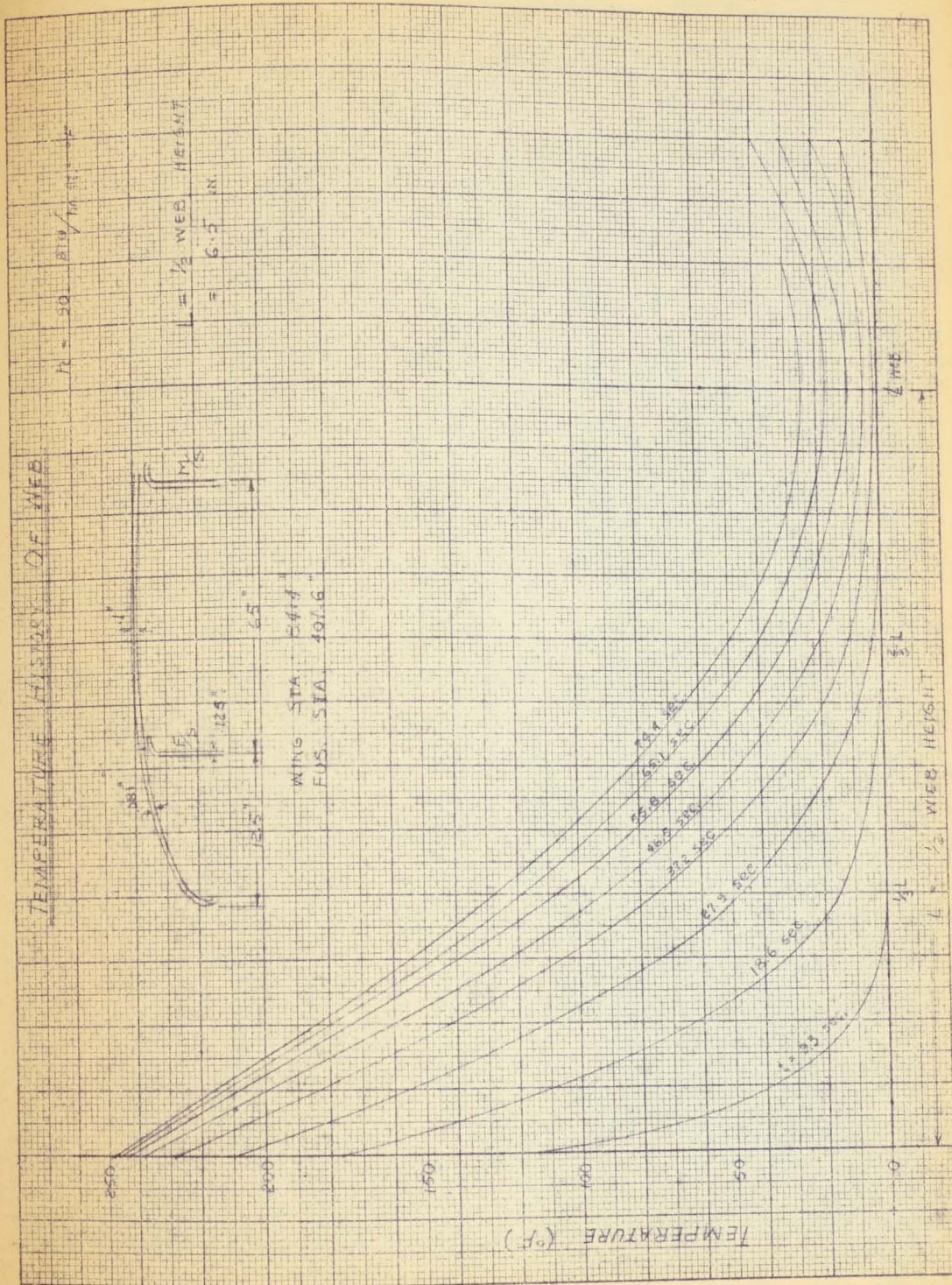
2004-158

AIRCRAFT

WEIGHT

C. G. POSITION

[illegible]





AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT:

WING

REPORT NO. 7/0500/3

SHEET NO. 6

PREPARED BY

DATE

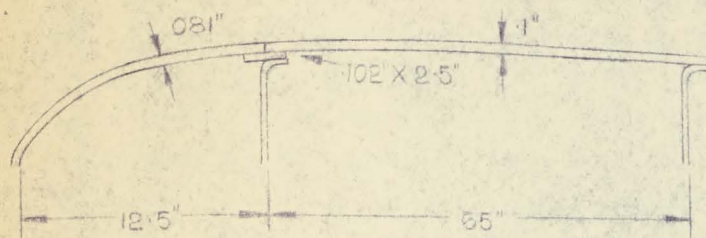
A COMINSKY

20 SEP, 54

CHECKED BY

DATE

F/S CAP



$$\text{CAP AREA} = \frac{1}{2} \times 65 \times 1 + 2.25 \times .081 + .102 \times 2.5$$

$$= 3.25 + .506 + .255$$

$$= 4.011 \text{ SQ IN.}$$

$$\text{CAP VOL/IN.} = 4.011 \text{ CU. IN.}$$

$$\text{CAP WT/IN.} = 4.011 \times \frac{1}{12 \times 144} \times 163 = .378 \text{ LB./IN.}$$

HEAT TRANSFER AT SURFACE

$$Q = h A (T_1 - T_2) t$$

$$h = 90 \text{ BTU/hr ft}^2 \text{ } ^\circ\text{F}$$

$$A = \frac{1}{2} (65 + 12.5) 1.0 = 38.75 \text{ SQ IN./IN.}$$

$$= 269 \text{ SQ FT/IN.}$$

$$Q = 90 \times 269 (T_1 - T_2) t$$

$$= 24.21 (T_1 - T_2) t \text{ BTU/IN.}$$



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT:

WING

REPORT NO. 7/0500/3

SHEET NO. 7

PREPARED BY

DATE

A. COMINSKY

20 SEP. 54

CHECKED BY

DATE

F/S CAP

HEAT STORAGE $Q = CPV(T_1 - T_2)$

$$PV = 378 \text{ LB./IN.}$$

$$C = 28 \text{ BTU/LB. } ^\circ\text{F}$$

$$Q = 28 \times 378 (T_1 - T_2)$$

$$= 106 (T_1 - T_2) \text{ BTU/IN}$$

DIFF EQU'N OF HEAT TRANSFER FROM BOUNDARY LAYER
AIR TO WING SKIN

$$\frac{dT_2}{dt} + \beta T_2 = \beta T_1$$

WHERE

T_1 = TEMP OF BOUNDARY LAYER

T_2 = INITIAL TEMP OF SKIN

$$\beta = \frac{h}{CPd}$$

$$\text{SOL'N } T = T_2 + (T_1 - T_2)(1 - e^{-\beta t})$$

$$\beta = \frac{92}{28 \times 163 \times \frac{1}{12}} = 236.4 \text{ HR}^{-1}$$

$$= \frac{1}{15.81} \text{ SEC}^{-1}$$

$$T_1 = 250^\circ\text{F}$$

$$T_2 = 0^\circ\text{F}$$



AVRO AIRCRAFT LIMITED
MALTON, ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 7/0500/3

SHEET No. 8

AIRCRAFT:

WING

PREPARED BY

DATE

A COMINSKY

20 SEP 54

CHECKED BY

DATE

SKIN TEMPERATURE RISE

①	②	③	④		
$t(\text{sec})$	$t(\text{hrs})$	At	e^{-At}	$1-e^{-At}$	$(T-T_a)(1-e^{-At})$
0	0	0	1.0000	0	0
9.3	.002583	.61062	.5431	.4569	114.23
18.6	.005170	1.22219	.2947	.7053	176.33
27.9	.007755	1.83210	.1601	.8399	209.98
37.2	.01034	2.44438	.0669	.9331	228.28
46.5	.01292	3.05429	.0472	.9528	238.20
55.8	.01550	3.66420	.0256	.9744	243.60
65.1	.01810	4.27881	.0139	.9861	246.53
74.4	.02065	4.88166	.0076	.9924	248.10
83.7	.02328	5.50332	.0046	.9954	248.85
93.0	.02581	6.10148	.0023	.9977	249.43
102.3	.02840	6.71378			
111.6	.03100	7.32840			
120.9	.03359	7.94068			
130.2	.03620	8.55768			
139.5	.03878	9.16759			
148.8	.04130	9.78332			
158.1	.0440	10.40160			
167.4	.0465	10.99260			

①
3600



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 7/0500/3

SHEET NO. 10

AIRCRAFT.

WING

PREPARED BY

DATE

A. COMINSKY

24 SEP. 54

CHECKED BY

DATE

TIME t (sec)

TEMP DIFF

[REF. SHT 3]

37.2

228.28 - 1.06 = 227.22 °F

46.5

238.20 - 4.41 = 233.79 °F

55.8

243.60 - 9.84 = 233.76 °F

65.1

246.53 - 16.78 = 229.75 °F

DETERMINATION OF TAV FOR $t = 46.5 \text{ sec}$

$$\begin{aligned} \text{AREA OF 1 FLANGE} &= \frac{1}{2} \times 6.5 \times 1 + 6.25 \times .081 \\ &= 3.25 + .506 = 3.756 \text{ SQ IN.} \end{aligned}$$

$$\text{AREA OF } \frac{1}{2} \text{ WEB} = 6.5 \times .125 = .8125 \text{ SQ IN.}$$

TEMP OF FLANGE = 238.20 °F

$$\text{TAV} = \frac{\int T dA}{\sum A}$$

$$\text{FLANGE} \quad \int T dA = 238.20 \times 3.756 = 894.7$$

$$\begin{aligned} \text{WEB} \quad \int T dA &= .125 \times \frac{w}{12} [(y_0 + y_n) + 4(y_1 + \dots + y_{n-1}) + 2(y_2 + \dots + y_{n-2})] \\ \text{WHERE } w &= \frac{1}{12} \quad \& \quad n = 12 \quad (\text{SIMPSON'S RULE}) \end{aligned}$$

$$y_0 = 238.20$$

$$y_1 = 200.0$$

$$y_2 = 160.0$$

$$y_{12} = \frac{4.41}{242.61}$$

$$y_3 = 123.5$$

$$y_4 = 92.0$$

$$y_5 = 65.4$$

$$y_6 = 47.2$$

$$y_7 = 32.0$$

$$y_8 = 20.0$$

$$y_9 = 12.5$$

$$y_{10} = 8.0$$

$$y_{11} = 5.8$$

$$327.2$$

$$440.2$$

$$\int T dA = .125 \times \frac{6.5}{12} \times \frac{1}{3} [242.61 + 4 \times 440.2 + 2 \times 327.2]$$

$$= \frac{.125 \times 6.5}{36} \times 2657.21 = 60.0$$



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MALTON, ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 7/0500/3

SHEET NO. 11

AIRCRAFT:

WING

PREPARED BY

DATE

A COMINSKY

21 SEP

CHECKED BY

DATE

THERMAL STRESSES IN WEB

$$TAV = \frac{894.7 + 60.0}{3.756 + .8125} = \frac{954.7}{4.5685} = 208.97^{\circ}F$$

$$THERMAL STRESS = E \alpha (T_i - TAV)$$

WHERE E = YOUNG'S MOD

α = COEFFICIENT OF EXPANSION

$$= .0000257/^{\circ}C$$

$$OR .0000143/^{\circ}F$$

FLANGE

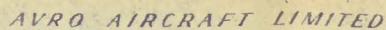
$$\sigma = -10^7 \times .0000143 \quad \begin{matrix} 29.23 \\ (238.20 - 208.97) \end{matrix}$$

$$= -4180 \text{ psi}$$

WEB

$$\sigma = -10^7 \times .0000143 \quad \begin{matrix} -204.56 \\ (4.41 - 208.97) \end{matrix}$$

$$= 29,230 \text{ psi}$$



TECHNICAL DEPT. (AIRFRAME)

REPORT NO.

7/9500/3

SHEET

1-4

DATE _____

22 SEP 54

PREPARED BY

A COMINSFO

AIRCRAFT

WEIGHT

C. G. POSITION

6	7	8	9	10	11	12	13	14	15	16	17	18	19
5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th
1-57.40	1-68.88	1-80.40	1-91.84	1-103.32	1-114.80	1-126.28	1-137.76						
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
04321	06642	08963	11284	13605	15926	18247	20568						
21605	2716	31756	35757	39331	42595	45617	48441						
05556	09166	1258	17613	21682	25656	29275	32629						
01235	04116	07682	1015	13604	16673	20585	24358						
WEB TEMPERATURE													
1-57.40	1-68.88	1-80.40	1-91.84	1-103.32	1-114.80	1-126.28	1-137.76						
21016	22218	23118	23710	24110	24318	24517	24710						
11414	13017	14518	15310	16018	16710	17311	17718						
4515	6015	7314	8417	9418	10318	11211	11916						
1117	2111	314	419	5215	6213	7119	8111						
216	318	419	515	617	717	810	916						

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

AIRCRAFT
A. U. W.

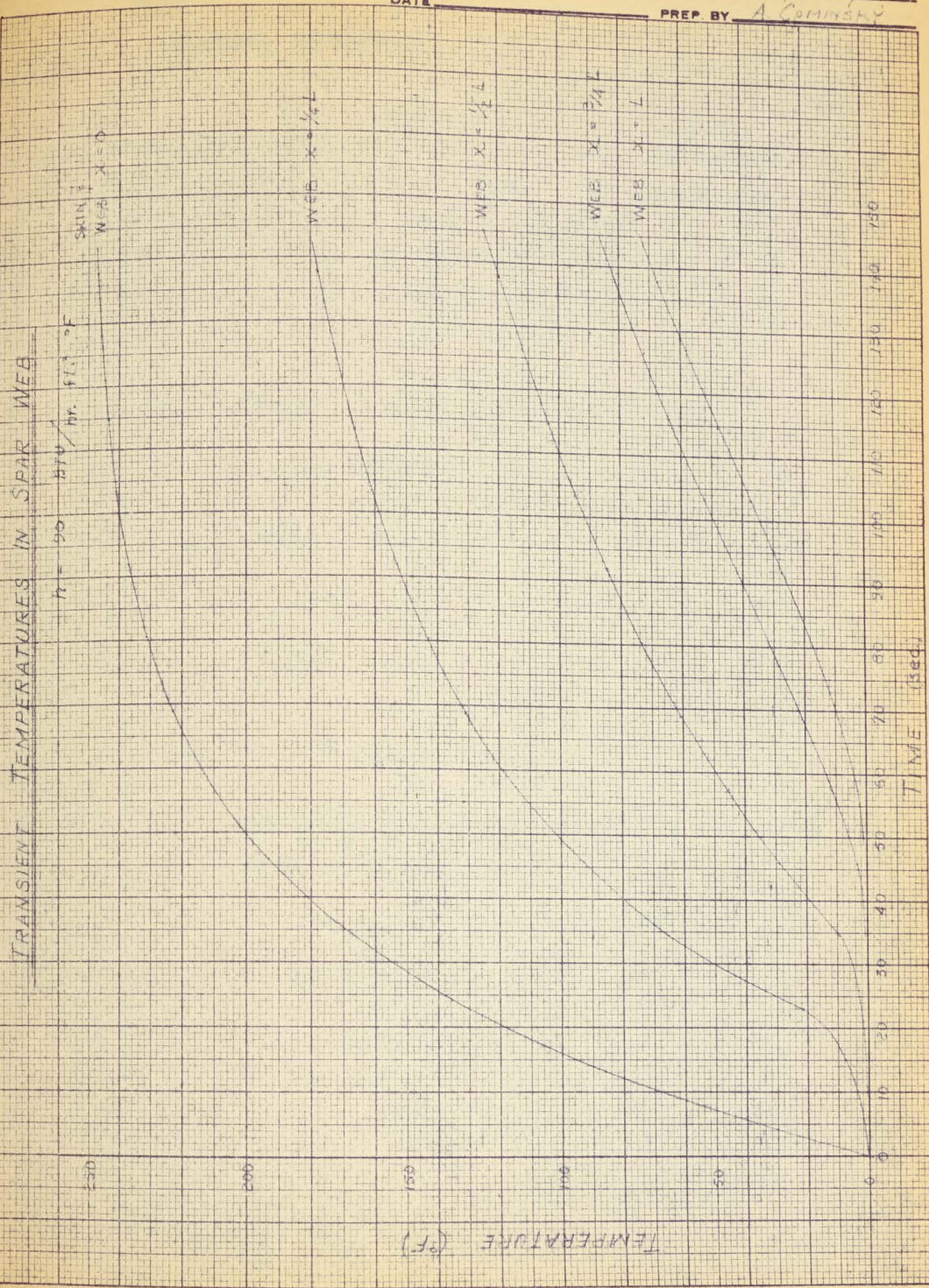
COMPONENT

SHEET NO. 1-6

REPORT NO. 2/0500/3

DATE

PREP BY A. COMINSKY



FORM 1746



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT: C105

WING
INVEST. OF THERMAL
STRESSES

REPORT No. 7/0500/3

SHEET No. 2-1

PREPARED BY

DATE

E. KOSKO

20 SEP, 54

CHECKED BY

DATE

EFFECT OF THERMAL RESISTANCE BETWEEN SKIN & WEB

ASSUMED = IDEAL CONDUCTION IN SKIN (NO TEMP GRADIENT IN SKIN)

SKIN THICKNESS = 0.2 IN WEB THICKNESS = 0.166 IN

GOOD THERMAL B ND OVER WEB THICKNESS $h = 1000 \text{ BTU/hr ft}^2 \text{ } ^\circ\text{F}$
(OR POOR THERMAL B ND OVER FLANGED ATTACHMENT)

HEATING OF SKIN $T_{\text{skin}} - T_{\text{in}} = (T_{\text{ex}} - T_{\text{in}})(1 - e^{-\beta})$

$T_{\text{in}} = 0^\circ\text{F}$ $T_{\text{ex}} = 250^\circ\text{F}$

$n = 90 \text{ BTU/hr ft}^2 \text{ } ^\circ\text{F}$

$$\beta = \frac{h}{p q d} = \frac{90 \times 12}{48.7 \times 0.2} = 118 \text{ hr}^{-1} = 0.0323 \text{ sec}^{-1} = \frac{1}{30.5 \text{ sec}}$$

HEATING OF WEB WITH CONVECTIVE TRANSFER AT BOUNDARY

$z = 135''$

$k/h = 96/1000 = 0.096 \text{ ft}^2 = 1.185 \text{ in}$

I (SHT) $\Delta x = 1.125''$, $r = \frac{1}{6}$ $\Delta t = \frac{(1.125)^2}{6 \times 0.0867} = 2.5 \text{ sec}$

IN WEB $T_{x,n+1} = \frac{1}{6} (T_{x-\Delta x,n} + T_{x+\Delta x,n}) + \frac{2}{3} T_{x,n}$

$$x = 0 \quad s = \Delta x \cdot \frac{h}{k} = \frac{1.125}{1.185} = 1.0$$

$$T_{0,n+1} = \frac{1}{3} (T_{0,n} + T_{1,n} - T_{\text{skin}})$$

II (SHT) $\Delta n = 2.25$, $r = \frac{1}{6}$ $\Delta t = \frac{(2.25)^2}{6 \times 0.0867} = 10 \text{ sec}$

IN WEB AS ABOVE

$$n = 0, \quad s = \frac{4.85}{1.125} = 2.0$$

$$T_{0,n+1} = \frac{1}{3} (T_{1,n} + 2T_{\text{skin}})$$

$S = 2.0$



AVRO AIRCRAFT LIMITED
TECHNICAL DEPT. (AIRFRAME)

REPORT NO. 7/0500/3

SHEET 2-3

DATE _____

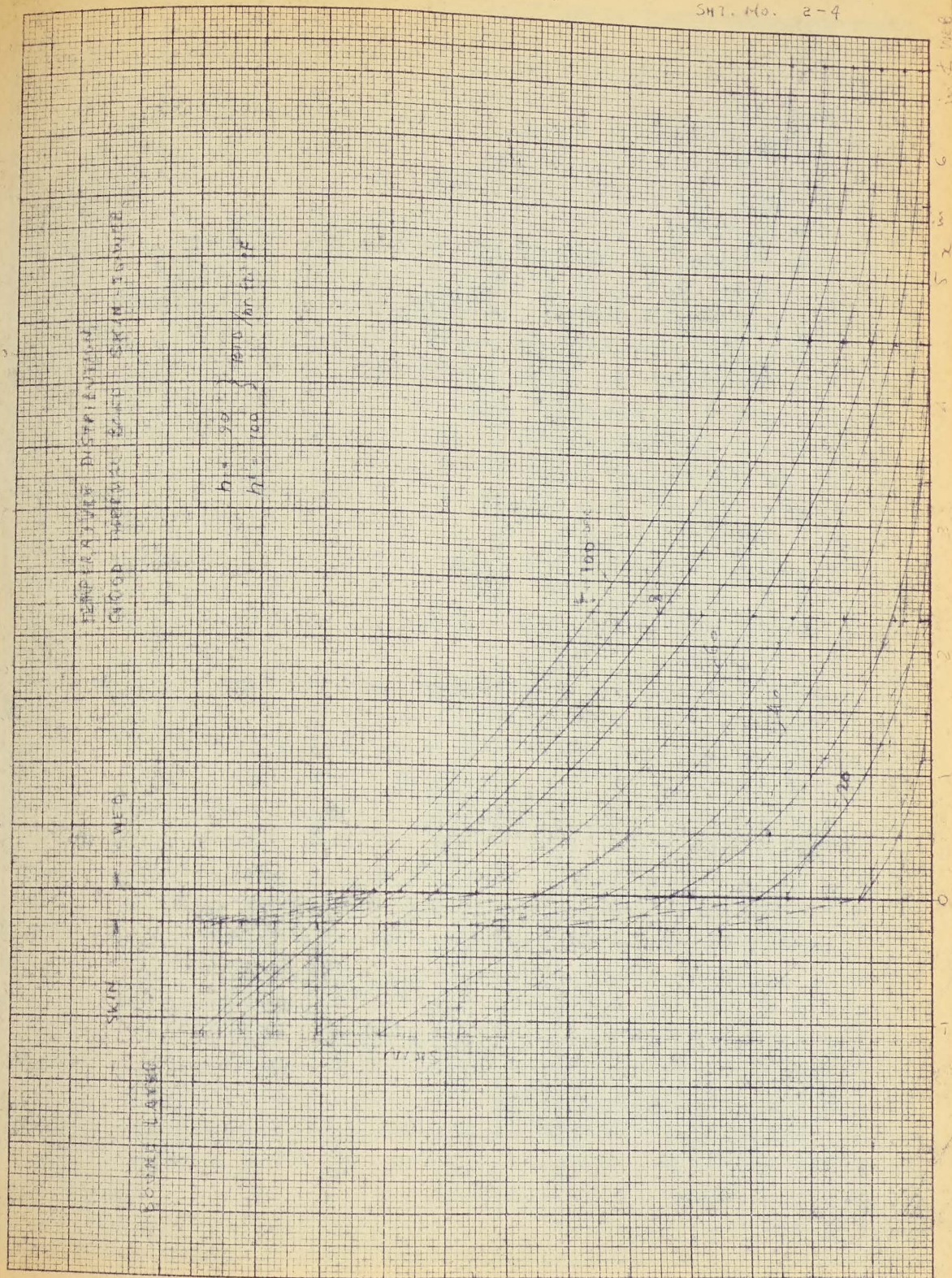
AIRCRAFT

WEIGHT

C. G. POSITION

PREPARED BY -

[illegible]





AVRO AIRCRAFT LIMITED
MALTON, ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 70500/3

SHEET NO. 2-8

AIRCRAFT:

WING

PREPARED BY

DATE

A COMINSKY

27 SEP, 54

CHECKED BY

DATE

TEMPERATURE OF BOUNDARY LAYER = 250 °F - T_a

INITIAL TEMPERATURE OF WING SKIN = 0 °F

MATERIAL 75 ST

SURFACE TRANSFER COEFFICIENT $h = 90 \text{ BTU/hr.ft}^2 \text{ °F}$

THERMAL DIFFUSIVITY $\alpha = 0.084 \text{ IN}^2/\text{sec}$

SPECIFIC HEAT $C = 0.28 \text{ BTU/LB °F}$

DENSITY OF MATERIAL $\rho = 163 \text{ LB/FT}^3$

HEAT TRANSFER BETWEEN SKIN & WEB $h' = 100 \text{ BTU/hr.ft}^2 \text{ °F}$
(POOR BOND)

THERMAL CONDUCTIVITY $K = k c \rho$

$$= 0.084 \times 28 \times 163$$

$$= 0.0222 \text{ BTU/sec in. °F}$$

$$= 0.0222 \times 3600 \times 12 \text{ BTU/hr.ft}^2 \text{ °F}$$

$$= 95.9 \text{ BTU/hr.ft}^2 \text{ °F}$$

$$h' = \frac{100}{144 \times 3600} = 0.00193 \text{ BTU/sec.in}^2 \text{ °F}$$

$$\text{LET } r = \frac{1}{8}$$

$$\Delta t = \frac{r^2 \Delta x^2}{K} = \frac{1}{8} \times \frac{1.125^2}{0.0222} = 2.24 \text{ sec}$$

$$S = \frac{\Delta x h'}{K} = \frac{1.125 \times 0.00193}{0.0222} = 0.978$$

$$\text{LET } r = \frac{1}{3}$$

$$\Delta t = \frac{1}{3} \times \frac{1.125^2}{0.0222} = 4.48 \text{ sec}$$

$$S = \frac{1.125 \times 0.00193}{0.0222} = 0.978$$

$$\frac{1}{2+5} = \frac{1}{2.0978} = 476 > 333$$



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 7/0000/3

SHEET No. 2-9

AIRCRAFT:

WING

PREPARED BY

DATE

A. COMINSKY

27 SEP 54

CHECKED BY

DATE

EQUATION OF HEAT TRANSFER FROM BOUNDARY LAYER
AIR TO SKIN

$$T = T_2 + (T_1 - T_2)(1 - e^{-\beta t})$$

$$\beta = \frac{h}{C_p d} = \frac{90}{28 \times 153 \times \frac{804}{12}}$$

$$= 118.0 \text{ HR}^{-1}$$

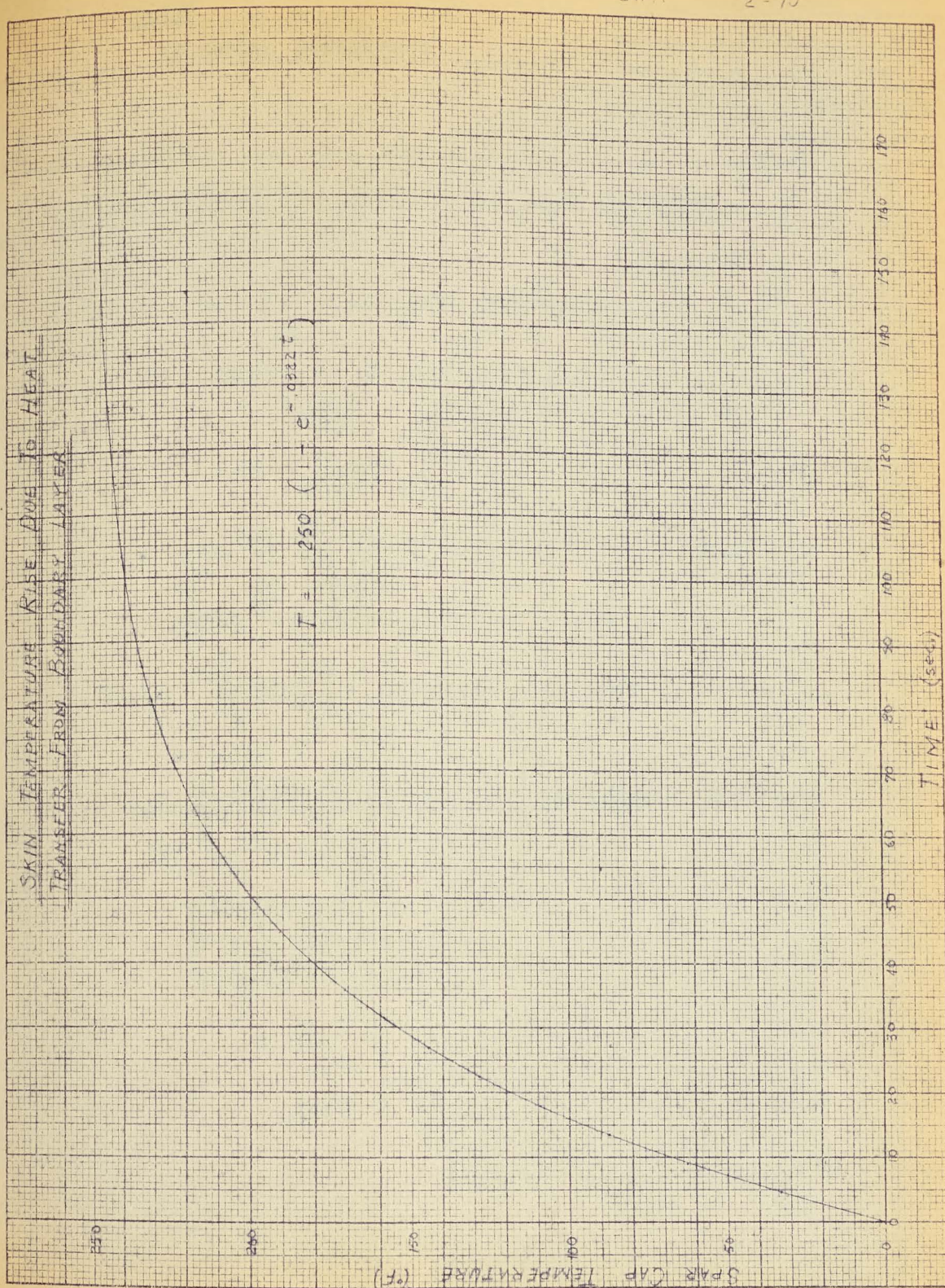
$$= 0.322 \text{ sec}^{-1}$$

$$T_1 = 250^\circ\text{F}$$

$$T_2 = 0^\circ\text{F}$$

	1	2	3	4	5
	t sec	βt	$e^{-\beta t}$	$1 - e^{-\beta t}$	$(T_1 - T_2)(1 - e^{-\beta t})$
1	4.48	.443	.6657	.3343	33.6
2	8.96	.885	.4194	.5806	62.7
3	13.44	1.328	.2687	.7313	87.8
4	17.92	1.770	.1616	.8384	109.6
5	22.40	2.213	.1062	.8938	128.5
6	26.88	2.655	.0709	.9291	144.8
7	31.36	3.098	.0464	.9536	158.9
8	35.84	3.540	.0284	.9716	171.2
9	40.32	3.983	.0173	.9827	181.9
10	44.80	4.426	.0104	.9896	190.9
11	49.28	4.868	.0066	.9934	198.4
12	53.76	5.311	.0042	.9958	205.7
13	58.24	5.753	.0028	.9972	211.7
14	62.72	6.196	.0017	.9983	216.8
15	67.20	6.638	.0010	.9990	221.3
16	71.68	7.081	.0005	.9995	225.1
17	76.16	7.524	.0002	.9998	228.5
18	80.64	7.966	.0001	.9999	231.4

REPT. NO. 7/0500/3
SHT. 2-10





AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

REPORT NO.

7/0500/3

SHEET

2412

DATE _____

28 SEP 54

PREPARED BY -

A COMMERCIAL

AIRCRAFT

WEIGHT

C. G. POSITION

[illegible]

AIRCRAFT
A. U. W.

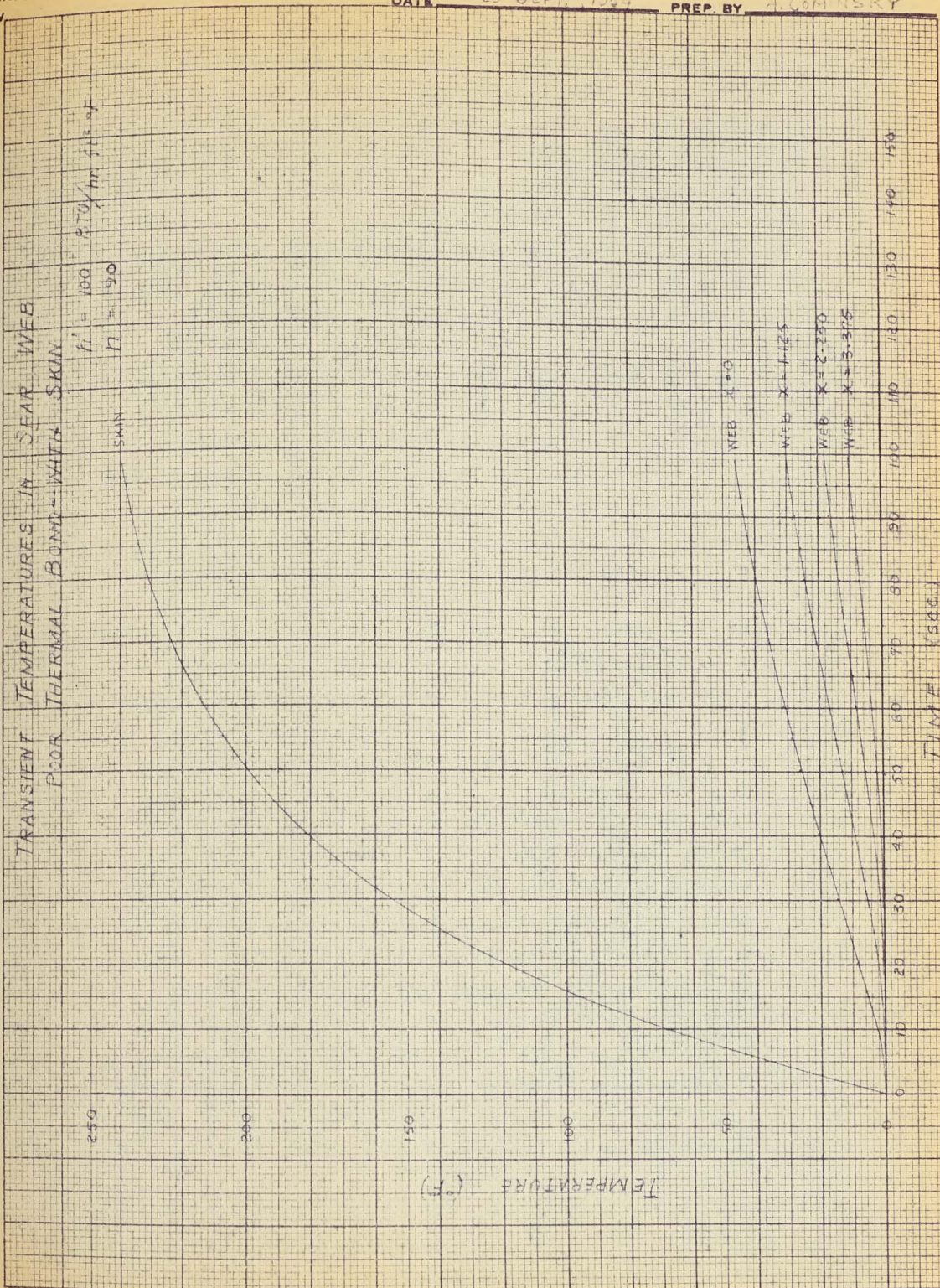
COMPONENT

SHEET No. 2-13

REPORT No. 7/0500/2

DATE 29 SEPT. 1954

PREP. BY A. GOMINSKY





AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 7/0500/3

SHEET NO. 2-15

AIRCRAFT:

WING

PREPARED BY

DATE

A. COMINSKY

29 SEP 54

CHECKED BY

DATE

TIME t(sec)

TEMP DIFF

85.34

234.0 - 7 = 233.3 °F

90.36

236.3 - 8 = 235.5 °F

95.38

238.4 - 1.4 = 237.0 °F

DETERMINATION OF TAV FOR t = 95.38 sec

AREA OF 1 FLANGE = 7.636 SQ IN
AREA OF $\frac{1}{2}$ WEB = 85 SQ IN } REF SHT. 1-13
TEMP OF FLANGE = 238.4 °F

FLANGE $\int T dA = 238.4 \times 7.636 = 1820.4$

WEB $\int T dA = 125 \frac{w}{3} [(y_0 + y_n) + 4(y_1 + \dots + y_{n-1}) + 2(y_2 + \dots + y_{n-2})]$

WHERE $w = \frac{L}{10} = 675$ IN. & $n = 10$

$y_0 = 238.4$	$y_1 = 34.0$	$y_2 = 26.5$
$y_n = 1.4$	$y_3 = 19.6$	$y_4 = 14.0$
239.8	$y_5 = 10.0$	$y_6 = 7.0$
	$y_7 = 4.8$	$y_8 = 3.5$
	$y_9 = 2.0$	51.0
	70.4	

$\int T dA = 125 \times \frac{675}{3} [239.8 + 1 \times 70.4 + 2 \times 51.0]$
 $= 125 \times 225 [238.4] = 1750$

$\therefore TAV = \frac{1820.4 + 17.5}{8.486} = \frac{1837.9}{8.486} = 216.4 °F$

THERMAL STRESSES

FLANGE $\sigma = -10^7 \times 0.000143 (238.4 - 216.4) = 3150$ psi

WEB $\sigma = -10^7 \times 0.000143 (1.4 - 216.4) = 30750$ psi



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 7/0500/3

SHEET NO. 3-1

AIRCRAFT:

WING

PREPARED BY

DATE

A. COMINSKY

30 SEP. 54

CHECKED BY

DATE

EFFECT OF EXCELLENT THERMAL BOND BETWEEN SKIN & WEB

$$[h' = 5000 \text{ BTU/hr.ft}^2 \text{ } ^\circ\text{F}]$$

TEMPERATURE OF BOUNDARY LAYER = 250°F

INITIAL TEMP. OF WING SKIN = 0°F

MATERIAL 75 ST

SURFACE TRANSFER COEFF. $h = 90 \text{ BTU/hr.ft}^2 \text{ } ^\circ\text{F}$

THERMAL DIFFUSIVITY $K = .084 \text{ IN}^2/\text{sec}$

SPECIFIC HEAT $C = .28 \text{ BTU/LB } ^\circ\text{F}$

DENSITY OF MATERIAL $P = 163 \text{ LB/FT}^3$

HEAT TRANSFER BETWEEN SKIN & WEB $h' = 5000 \text{ BTU/hr.ft}^2 \text{ } ^\circ\text{F}$

THERMAL CONDUCTIVITY $K = KC/P = .00222 \text{ BTU/sec.in. } ^\circ\text{F}$

(SHT 2-2)

OR $95.9 \text{ BTU/hr.ft}^2 \text{ } ^\circ\text{F}$

$$h' = \frac{5000}{144 \times 3600} = .00965 \text{ BTU/sec.in}^2 \text{ } ^\circ\text{F}$$

$$\text{LET } r = \frac{1}{6}$$

$$\Delta t = \frac{r \Delta x^2}{K} = \frac{1}{6} \times \frac{(1.125)^2}{.084} = 2.51 \text{ sec.}$$

$$S = \frac{\Delta x h'}{K} = \frac{1.125 \times .00965}{.00222} = 4.90$$

$$\text{LET } r = \frac{1}{3}$$

$$\Delta t = \frac{1}{3} \times \frac{(1.125)^2}{.084} = 5.02 \text{ sec.}$$

$$S = \frac{\Delta x h'}{K} = 4.90$$



57/0550/

15

30 SEP, 54

A. COMINSKY

C. G. POSITION

[illegible]

AIRCRAFT
A. U. W.

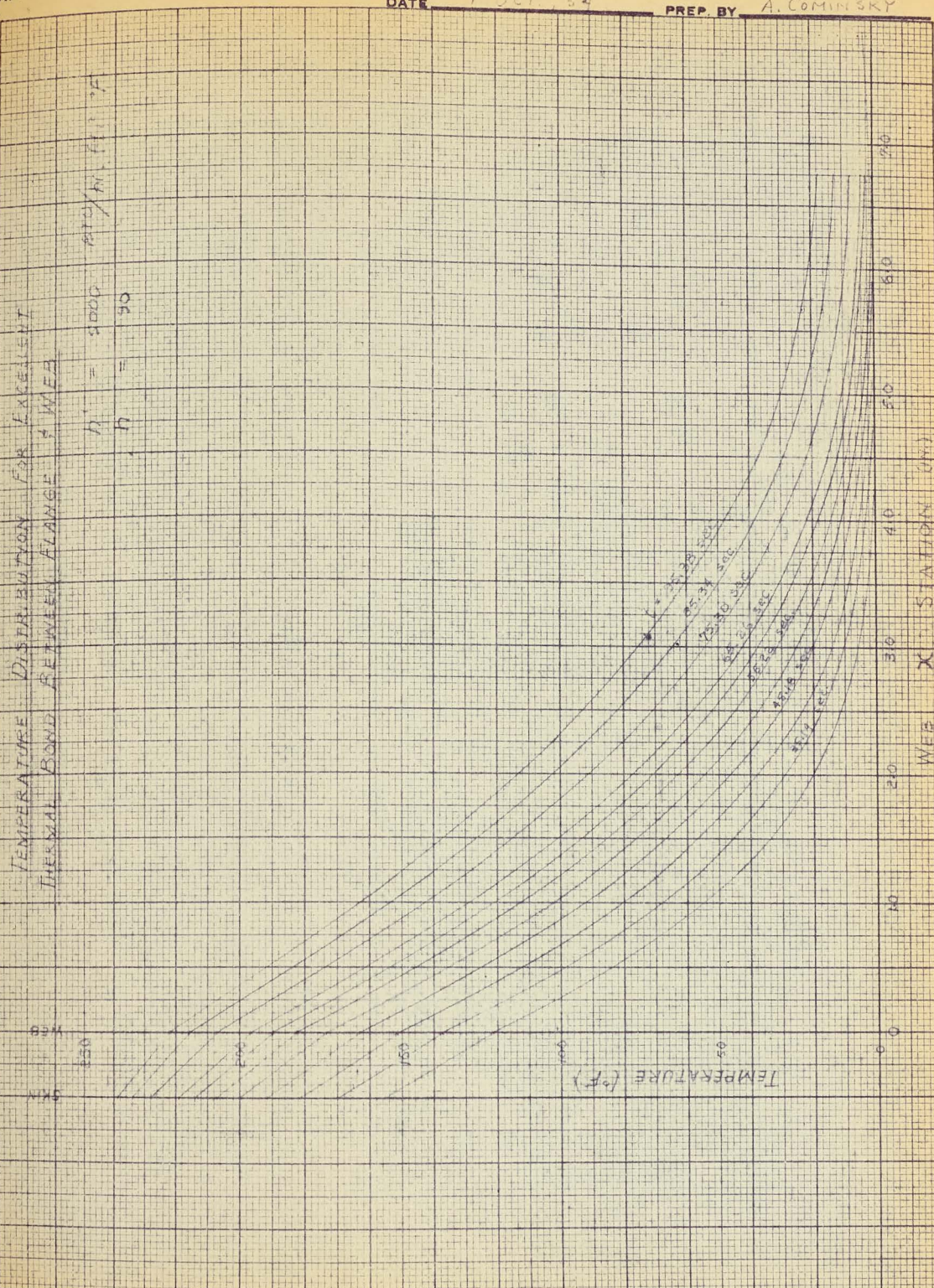
COMPONENT

SHEET No. 2-1

REPORT No. 7/0500/3

DATE 1 OCT. 54

PREP BY A. COMINSKY



AIRCRAFT
A. U. W.

COMPONENT

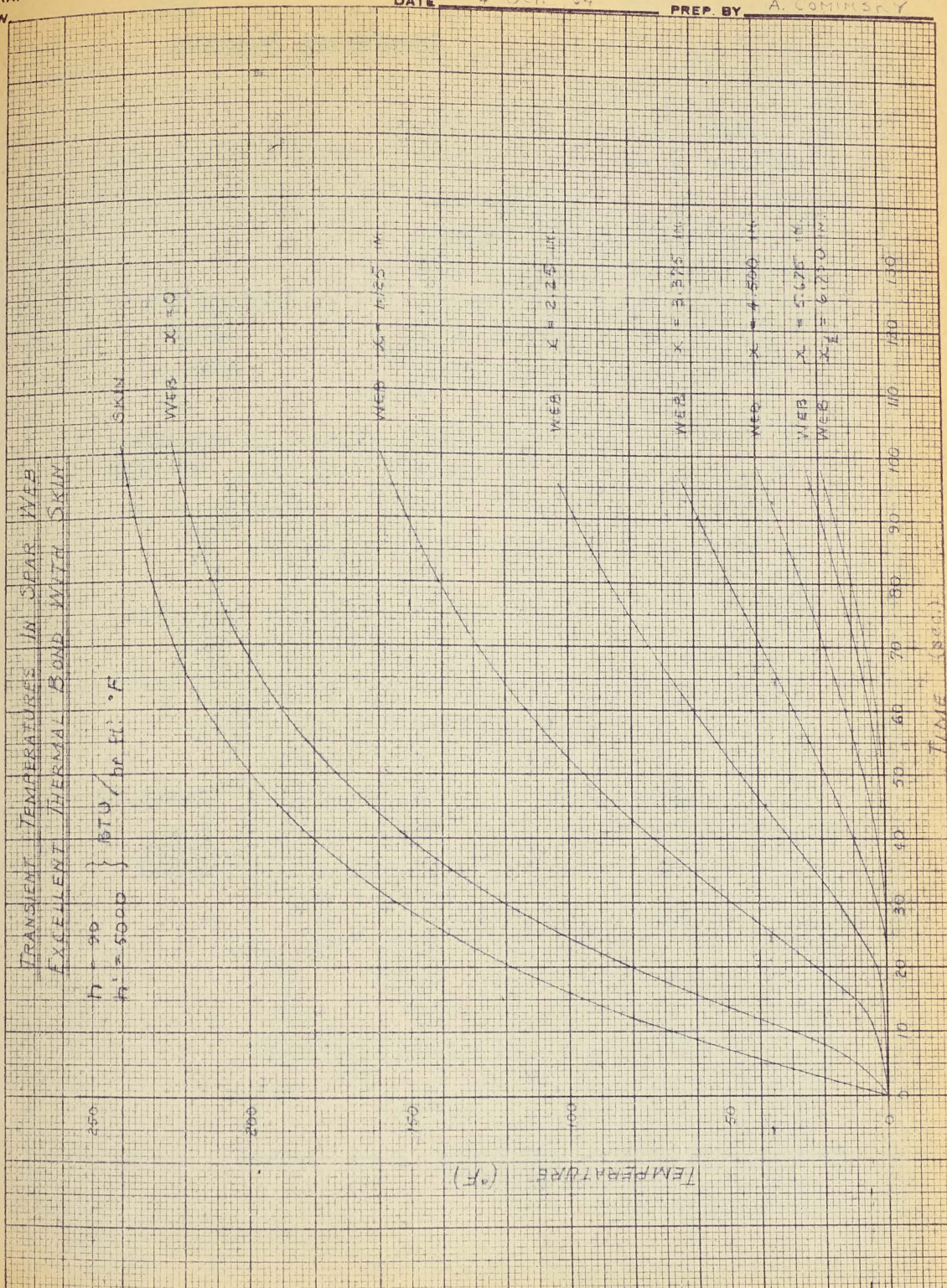
SHEET No. 2-5

DATE 4 OCT 54

REPORT No. 7/0500/3

PREP BY A. COMINSKY

K₀M 10 X 10 TO THE 1/2 INCH 359-12
KEUFFEL & ESSER CO. MADE IN U.S.A.



ALRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 7/0500/3

SHEET NO. 3-5

AIRCRAFT:

WING

PREPARED BY

DATE

A COMINSKY

4 OCT, 54

CHECKED BY

DATE

TIME t (sec)

TEMP DIFF

75.30

228.0 - 75 = 220.5 °F

80.32

231.0 - 97 = 221.3 °F

85.34

234.0 - 122 = 221.8 °F

90.36

236.3 - 149 = 221.4 °F

95.38

238.4 - 173 = 220.6 °F

DETERMINATION OF TAV FOR t = 85.34 sec

AREA OF 1 FLANGE = 7.636 SQ IN.

AREA OF 1 WEB = .85 SQ IN.

SHT 1-7

TEMP OF SKIN = 234.0 °F

FLANGE $Jt_{dA} = 234.0 °F \times 7.636 = 1786.8$ WEB $Jt_{dA} = 125 \times \frac{W}{3} \left[\left(\frac{y_0}{2} - y_0 \right) + 4(y_1 + y_2 + y_{n-1}) + 2(y_n + y_{n-2}) \right]$ WHERE $W = \frac{L}{10} = 8.675$ & $n = 10$ $y_0 = 234.0$ $y_1 = 172.6$ $y_2 = 134.0$ $y_{10} = 12.2$ $y_9 = 106.0$ $y_8 = 78.1$

246.2

 $y_6 = 56.0$ $y_5 = 39.4$ $y_7 = 27.2$ $y_4 = 19.7$ $y_3 = 14.2$

271.2

376.0

WEB $Jt_{dA} = 125 \times \frac{6.75}{3} \left[246.2 + 4 \times 376.0 + 2 \times 271.2 \right]$ $= 125 \times 2.25 \times 2276.6 = 64.50$ $\therefore TAV = \frac{1786.8}{8.498} + \frac{64.5}{8.498} = 1851.3 = 218.1 °F$

THERMAL STRESSES

FLANGE $\sigma = -10 \times 0.000143 \left(234.0 - 218.1 \right) = 2280 \text{ psi}$ WEB $\sigma = -10 \times 0.000143 \left(12.2 - 218.1 \right) = 29500 \text{ psi}$



AVRO AIRCRAFT LIMITED
MALTON ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT:

WING

REPORT NO. 7/0500/3

SHEET NO. 4-2

PREPARED BY

DATE

A COMINSKY

4 OCT 54

CHECKED BY

DATE

HEAT TRANSFER FROM BOUNDARY LAYER AIR TO WING SKIN

$$T = T_2 + (T_1 - T_2)(1 - e^{-\beta t})$$

$$\beta = \frac{h}{40} = \frac{28.163 \times 204}{12} = 51.5 \text{ HR}^{-1}$$

$$= 0.143 \text{ sec}^{-1}$$

$$T_1 = 250^\circ\text{F} \quad T_2 = 0$$

	1	2	3	4	5
	t (sec)	βt	$e^{-\beta t}$	$1 - e^{-\beta t}$	$(T_1 - T_2)(1 - e^{-\beta t})$ °F
1	11.5	1.645	.9483	.1517	37.9
2	23.0	3.289	.7197	.2803	70.4
3	34.5	4.934	.6105	.3895	97.4
4	46.0	6.578	.5180	.4820	120.5
5	57.5	8.223	.4394	.5606	140.2
6	69.0	9.867	.3728	.6272	156.8
7	80.5	11.512	.3162	.6838	171.0
8	92.0	13.156	.2682	.7317	182.9
9	103.5	14.801	.2277	.7723	193.1
10	115.0	16.445	.1931	.8069	201.7
11	126.5	18.090	.1638	.8362	209.1
12	138.0	19.734	.1390	.8610	215.3
13	149.5	21.379	.1179	.8821	220.5
14	161.0	23.023	.1001	.8999	225.0
15	172.5	24.668	.0849	.9151	228.8
16	184.0	26.312	.0721	.9279	232.0
17	195.5	27.957	.0610	.9389	234.7
18	207.0	29.601	.0519	.9481	237.0
19	218.5	31.246	.0440	.9560	239.0
20	230.0	32.890	.0373	.9627	240.7
21	241.5	34.535	.0317	.9683	242.1
22	253.0	36.179	.0270	.9730	243.3



77505

5 OCT 5

C. G. POSITION

[illegible]

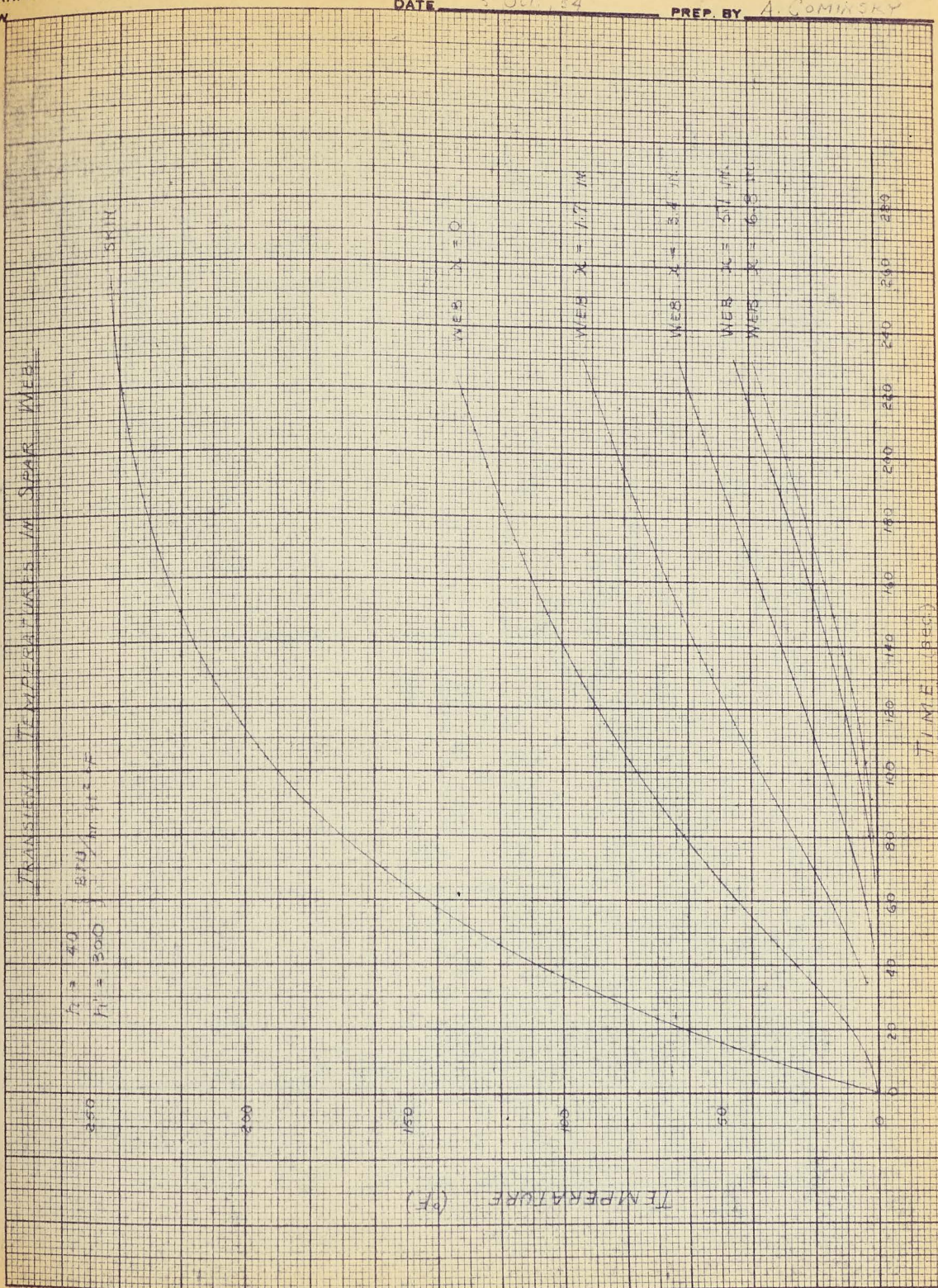
AIRCRAFT
A. U. W.

COMPONENT

SHEET NO. 4-5
DATE 5 OCT 84

REPORT NO. 7/0300/3
PREP. BY A. COMINSKY

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

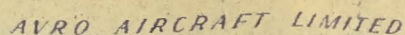


TEMPERATURE VARIATION OF SKIN & WEB

$$h = 40$$

HEAT TRANSFER FROM SKIN TO WEB

$$T_2 = 2\pi \sqrt{\frac{m}{k}}$$
[illegible]



REPORT NO.

SHEET

DATE _____

PREPARED BY -

AIRCRAFT

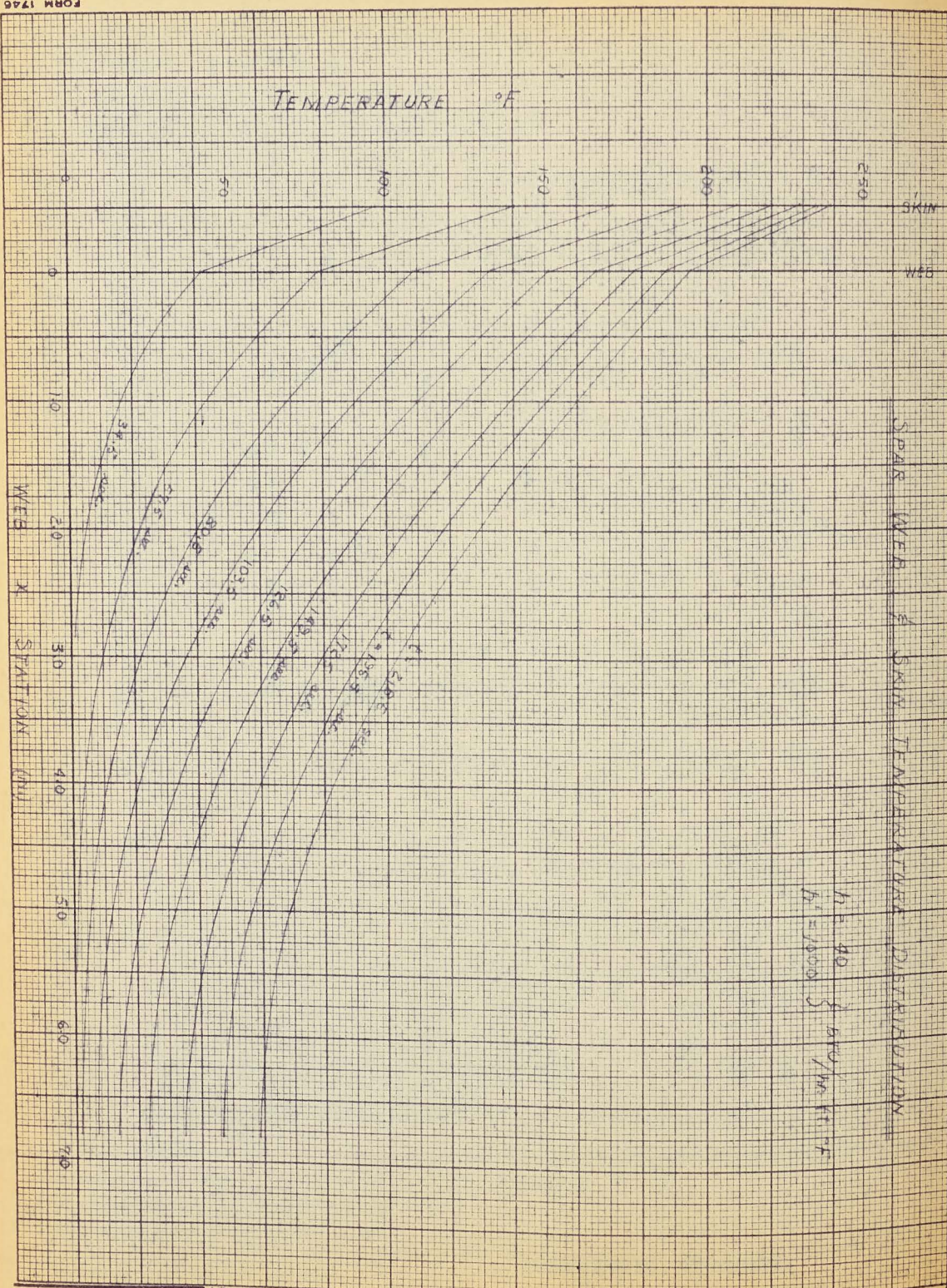
WEIGHT

C. G. POSITION

[illegible]

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MADE IN U.S.A.

FORM 1746



AIRCRAFT A.U.W. COMPONENT WING SHEET NO. 4-12 DATE 5 OCT 54 REPORT NO. 7/0500/3 PREP. BY A. COMINSKY



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT:

WING

REPORT NO. 70500/3

SHEET NO. 1-3

PREPARED BY

DATE

A. C. MINSKY 13 DEC 54

CHECKED BY

DATE

HEAT TRANSFER FROM BOUNDARY LAYER AIR TO
WING SKIN WHEN THE TEMPERATURE OF THE BOUNDARY
LAYER AIR INCREASES PARABOLICALLY

SINCE QUANTITY OF HEAT TRANSFERRED = HEAT ABSORBED

$$Q = h(T - T_b)A \Delta t = C_p A \Delta T$$

$$\frac{dT}{dt} = \frac{h}{C_p A} (T - T_b) = -\beta (T - T_b)$$

$$\text{BUT } T_b = \alpha t^2$$

$$\therefore \frac{dT}{dt} = -\beta (T - \alpha t^2)$$

$$\boxed{\frac{dT}{dt} + \beta T = +\beta \alpha t^2}$$

THIS EQUATION IS A LINEAR EQUATION OF 1ST ORDER

INTEGRATING FACTOR IS $e^{+\beta t}$

MULTIPLYING THE EQUATION THROUGH BY THE INTEGRATING
FACTOR IT BECOMES

$$e^{+\beta t} \frac{dT}{dt} + \beta e^{+\beta t} T = +\beta \alpha t^2 e^{+\beta t}$$

$$\frac{d(Te^{+\beta t})}{dt} = +\beta \alpha t^2 e^{+\beta t}$$

$$Te^{+\beta t} = +\beta \alpha \int t^2 e^{+\beta t} dt$$

$$= \beta \alpha \left[\frac{t^2 e^{+\beta t}}{\beta} - \frac{2}{\beta} \int t e^{+\beta t} dt \right]$$

$$= \alpha \left[t^2 e^{+\beta t} - \frac{2}{\beta} e^{+\beta t} (\beta t - 1) \right] + C$$

$$= \alpha t^2 e^{+\beta t} - \frac{2 \alpha t e^{+\beta t}}{\beta} + \frac{2 \alpha e^{+\beta t}}{\beta^2} + C$$



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT:

REPORT NO. 7/0500/3

SHEET NO. 5-7

PREPARED BY

DATE

A. COMINSKY

15 OCT. 54

CHECKED BY

DATE

HEAT TRANSFER FROM SKIN TO WEB

$$T_{\text{int},0} = T_{\text{a},0} [1 - (H_5)_{2r}] + T_{\text{h},2r} + T_{\text{h},2rs}$$

FOR REF 3 $\delta = 0.113$ (SHT. 4-1)

$$T_{\text{int},0} = T_{\text{a},0} \times 0.33 + T_{\text{h},0} \times 0.667 + T_{\text{a},0} \times 0.0033$$

(REF. SHT. 4-3)

HEAT TRANSFER THRO WEB BY CONDUCTION

$$T_{\text{int},0} = \frac{1}{3} [T_{\text{a},0} + T_{\text{h},0} + T_{\text{h},2r}]$$

TEMPERATURE VARIATION OF SKIN & WEB

[300 SEC ACCELERATION]

$n=40$ } STUW 1-8 IF
 $n=300$ }

HEAT TRANSFER FROM SKIN TO WEB $T_{in} = 0.325 T_a + 60.67 T_{in} + 2.053 T$

HEAT TRANSFER THRU WEB $T_{web} = \frac{1}{3} [T_a + 4 T_{in} + T_{in}]$

	1	2	3	4	5	6	7	8	9
t (sec)	11.5	23.0	34.5	46.0	57.5	69.0	80.5	92.0	103.5
T (SKIN)	02	15	45	110	208	348	530	763	1053
x=0	0	01	05	14	33	66	118	178	246
x=17 (IN)	0	0	0	02	05	17	37	65	109
x=34 (IN)	0	0	0	0	01	02	05	11	20
x=51 (IN)	0	0	0	0	0	0	01	02	04
x=68 (IN)	0	0	0	0	0	0	0	0	0
t (sec)	230.0	241.5	253.0	264.5	276.0	287.5	299.0	300	311.5
T (SKIN)	83.74	94.49	105.95	118.13	131.02	144.63	158.94	176.3	193.8
x=0	30.08	33.95	40.92	46.68	52.61	58.83	65.73	73.34	81.77
x=17 (IN)	15.18	17.46	20.67	23.91	27.32	31.30	35.53	40.0	44.5
x=34 (IN)	7.11	8.52	10.04	12.06	14.15	16.43	19.07	21.8	24.7
x=51 (IN)	3.49	4.32	5.27	6.49	7.82	9.31	10.92	12.5	13.0
x=68 (IN)	2.47	3.15	3.96	4.90	5.94	7.20	8.61	10.0	10.3

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

REPORT NO. 1705043

SHEET 11

DATE - 1957 OCT 31

PREPARED BY - A. EDWARDS

AIRCRAFT : _____

WEIGHT

C. G. POSITION _____

8	9	10	11	12	13	14	15	16	17	18	19
820	03.5	15.0	26.3	38.4	46.5	61.0	71.3	184.0	195.5	207.0	218.5
763	7.53	13.38	16.02	20.68	27.97	33.90	40.50	47.77	55.73	64.36	73.71
1.78	5.65	3.74	5.07	6.68	8.50	10.81	13.32	16.22	19.42	23.00	26.96
43	19	21	1.76	2.46	3.22	4.36	5.60	7.04	8.72	10.69	12.77
31	10	34	54	82	118	164	220	289	3.71	4.68	5.81
100	04	22	16	85	43	61	87	1.20	4.68	2.13	2.75
0	01	03	06	12	21	36	53	75	1.05	1.43	1.90
300	11.0	32.30	324.5	348.0	357.5	361.0	380.5	392.0	403.5		
160.2	73.99	125.33	185.19	103.49	210.56	216.53	221.61	225.91	229.56		
65.33	75.73	81.0	87.86	94.63	100.75	106.57	111.97				
28.3	40.52	45.47	50.56	55.65	60.95	65.83	70.79				
19.80	25.17	25.22	28.68	32.23	36.00	39.92	43.91				
01.13	13.04	5.16	17.81	20.09	22.90	25.90	28.13				
8.71	16.35	18.14	14.15	16.33	18.56	21.23	24.46				

K
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AIRCRAFT
A. U. W.

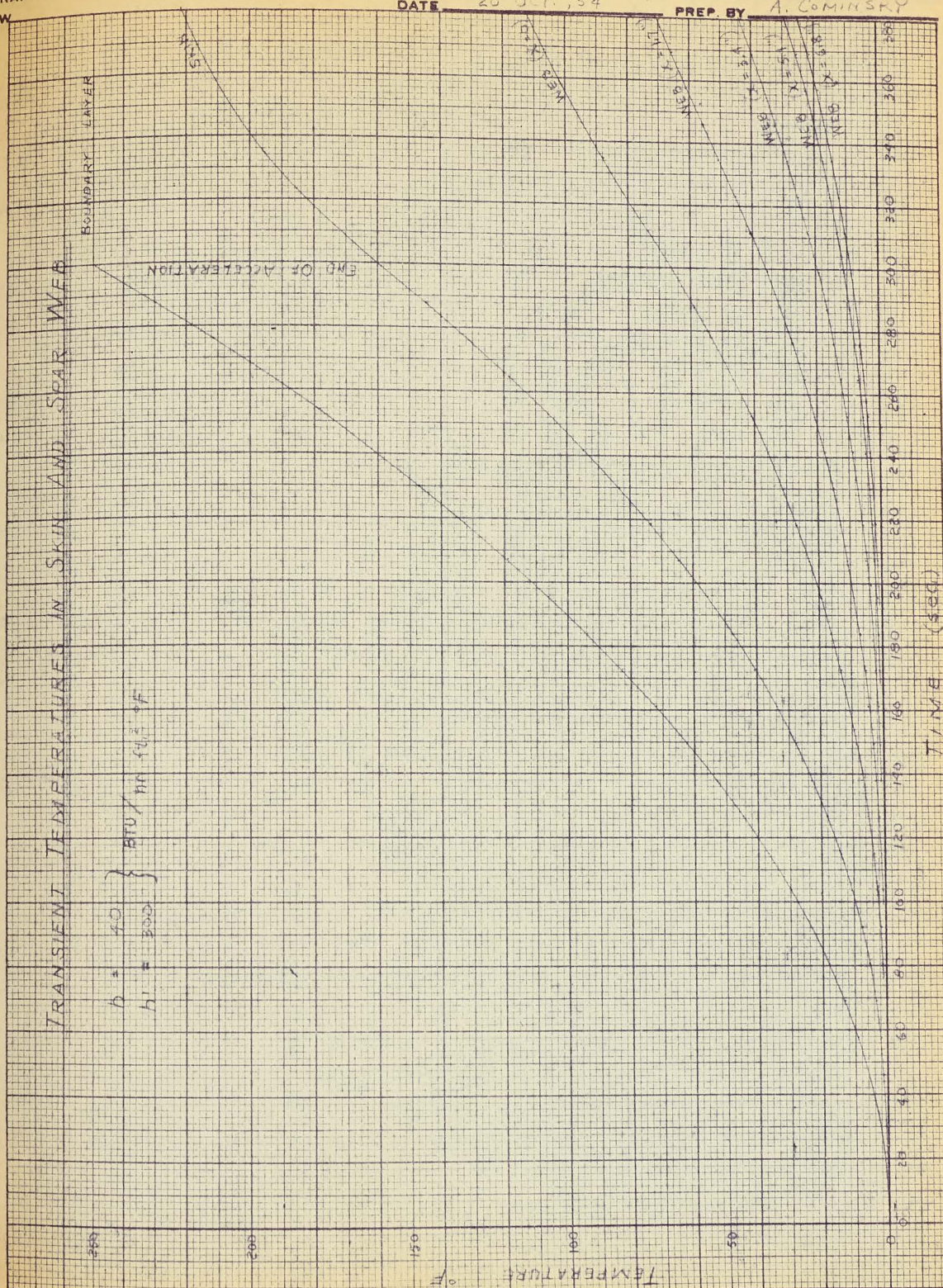
COMPONENT

SHEET NO. 3-7

REPORT No. 7/0500/3

DATE 20 OCT. , 54

PREP. BY A. COMINSKY



FORM 1748



AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 7/0500/3

SHEET No. 5-11

AIRCRAFT:

PREPARED BY

DATE

A. COMINSKY

21 OCT. 50

CHECKED BY

DATE

THE FOLLOWING WORK WILL BE DONE TO DETERMINE THE TRANSCIENT TEMPERATURES IN SKIN & WEB FOR THE SAME CONSTANTS AS THOSE GIVEN ON QIT No. 5-11 WITH THE IMPORTANT EXCEPTION $h = 1000 \text{ BTU/HR}^2 \text{ F}$

$$1 = \frac{1000}{1713500} = 0.000583 \text{ BTU/HR}^2 \text{ F}$$

$$2 = 3 \times 2 \times 10^{-5} = 6 \times 10^{-5} \text{ BTU/HR}^2 \text{ F}$$

$$3 = \frac{1000}{1713500} = 0.000583$$

[REF SET. 21 OCT. 50]

THE HEATING UP OF THE BOUNDARY LAYER AND THE TRANSFER OF HEAT FROM THE BOUNDARY LAYER TO THE WING SKIN WILL BE THE SAME AS PREVIOUSLY. SEE QIT No. 5-11 5-5 5-5 G.

HEAT TRANSFER FROM SKIN TO WEB

$$T_{web} = \frac{8}{50} T_o + \frac{1}{50} T_{in} \quad [\text{FOR LARGE VALUES OF } S]$$

$$\frac{8}{50} = \frac{1440}{1440} = 1.000 \quad \frac{1}{50} = \frac{1}{1440} = 0.000694$$

$$T_{web} = 1.000 T_o + 0.000694 T_{in}$$

HEAT TRANSFER THRO WEB BY CONDUCTION

$$T_{web} = \frac{1}{3} [T_{skin} + T_{in} + T_{out}]$$

AIRCRAFT
A.U.W.

COMPONENT

SHEET No. 5-13

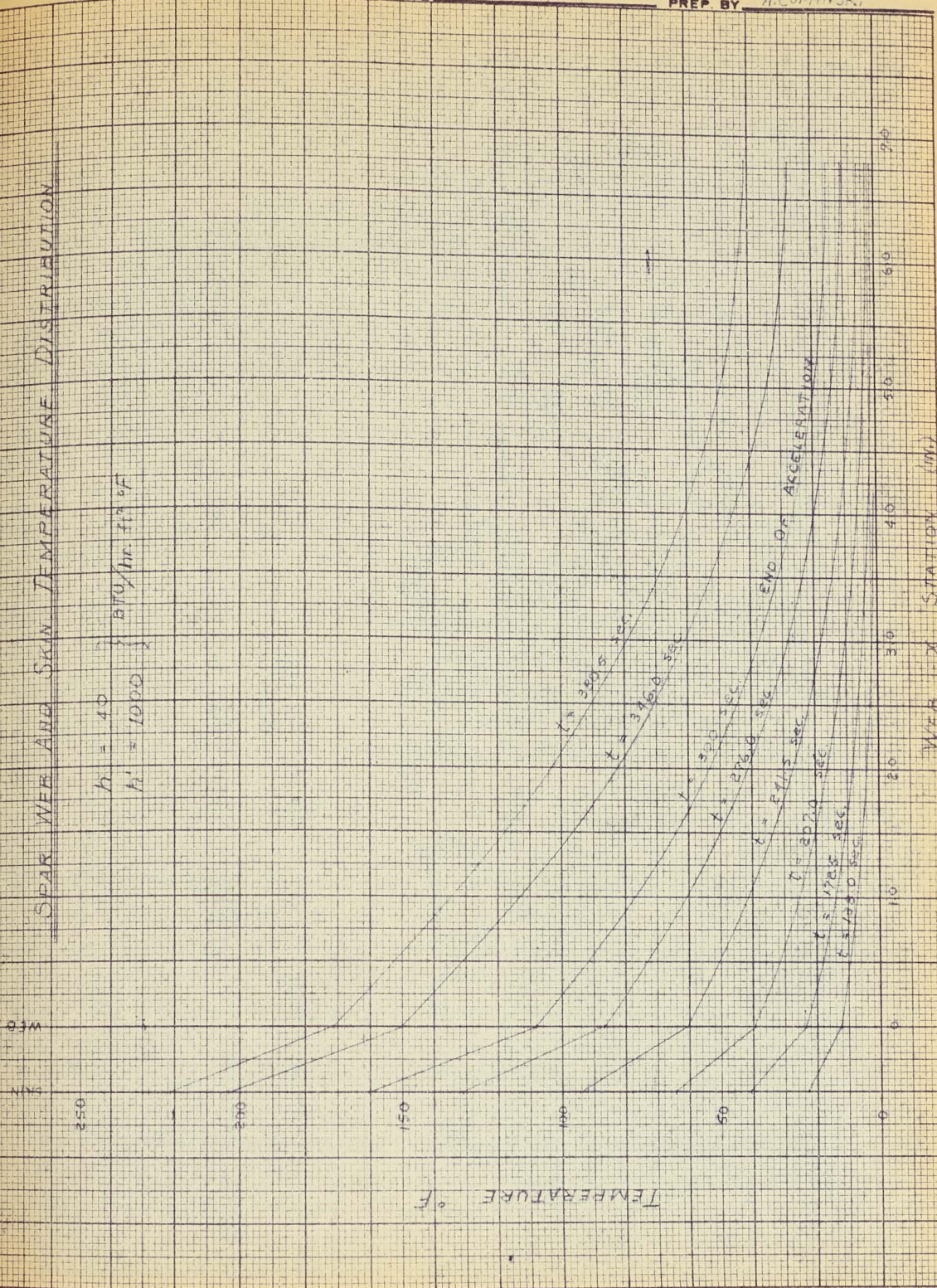
REPORT No. 7/0500/3

DATE 22 OCT, 54

PREP BY A. COMINSKY

SEAR WEB AND SKIN TEMPERATURE DISTRIBUTION

$h = 40$
 $h' = 1000$ } BTU/hr. $ft^2 \cdot ^\circ F$



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AIRCRAFT
A. U. W.

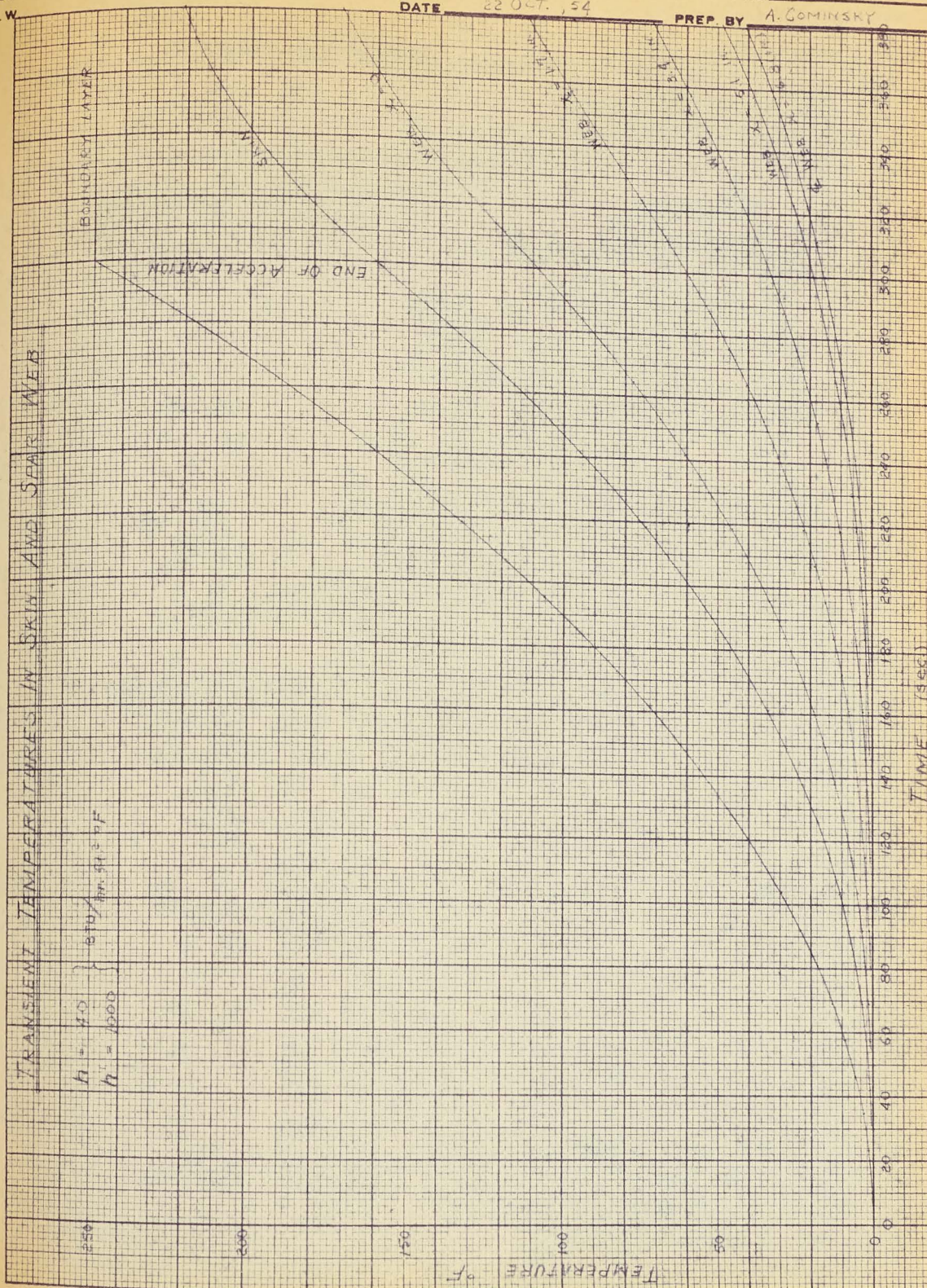
COMPONENT

SHEET No. 5-14

REPORT No. 7/0500/3

DATE 22 OCT. 54

PREP BY A. GOMINSKY





AVRO AIRCRAFT LIMITED
MALTON, ONTARIO

TECHNICAL DEPARTMENT

REPORT No. 7/0500/3

SHEET No. 6-2

AIRCRAFT:

1

WING

PREPARED BY

DATE

A. COMINSKY

23 OCT 54

CHECKED BY

DATE

VARIAION OF T_a

$$T_a = 250 \left(\frac{t}{34.5} \right)^2 = 0.210 t^2$$

[FOR $t = 0 \rightarrow 34.5$]

$$t \text{ (sec)} = \frac{t^2}{0.210 t^2}$$

$$0 = 0$$

$$11.5 = 132.25$$

$$23.0 = 529$$

$$34.5 = 1190.25$$

HEAT TRANSFER FROM BOUNDARY LAYER AIR TO WING SKIN

$$T = \frac{h}{2k} \left[\frac{1}{3} t^3 - 2 \frac{1}{2} t^2 + 2 \left(1 - e^{-at} \right) \right]$$

$$h = \frac{h}{C \cdot d} = 0.43 \text{ sec}^{-1} \quad (\text{SH. 4-2})$$

$$a = \frac{250}{(34.5)^2} = 0.210$$

$$\frac{A}{2k} = \frac{210}{0.002048} = 102538$$

$$T = 210 t^2 - 29.369 t + 2053.8 (1 - e^{-at})$$

	1	2	3	4	5	6	7	8
	t	t^2	$\frac{1}{3} t^3$	$(1 - e^{-at})$	$2053.8 - e^{-at}$	$29.369 t$	$210 t^2$	T
	sec	sec ²						
1	11.5	132.25	1645	1517	311.58	337.70	2777	11.57
2	23.0	529.0	3285	2903	575.63	675.51	11109	11.28
3	34.5	1190.25	4934	3895	800.00	1013.27	25995	36.88
4								
REF								6-6-0

AIRCRAFT
A. U. W.

COMPONENT *WING*

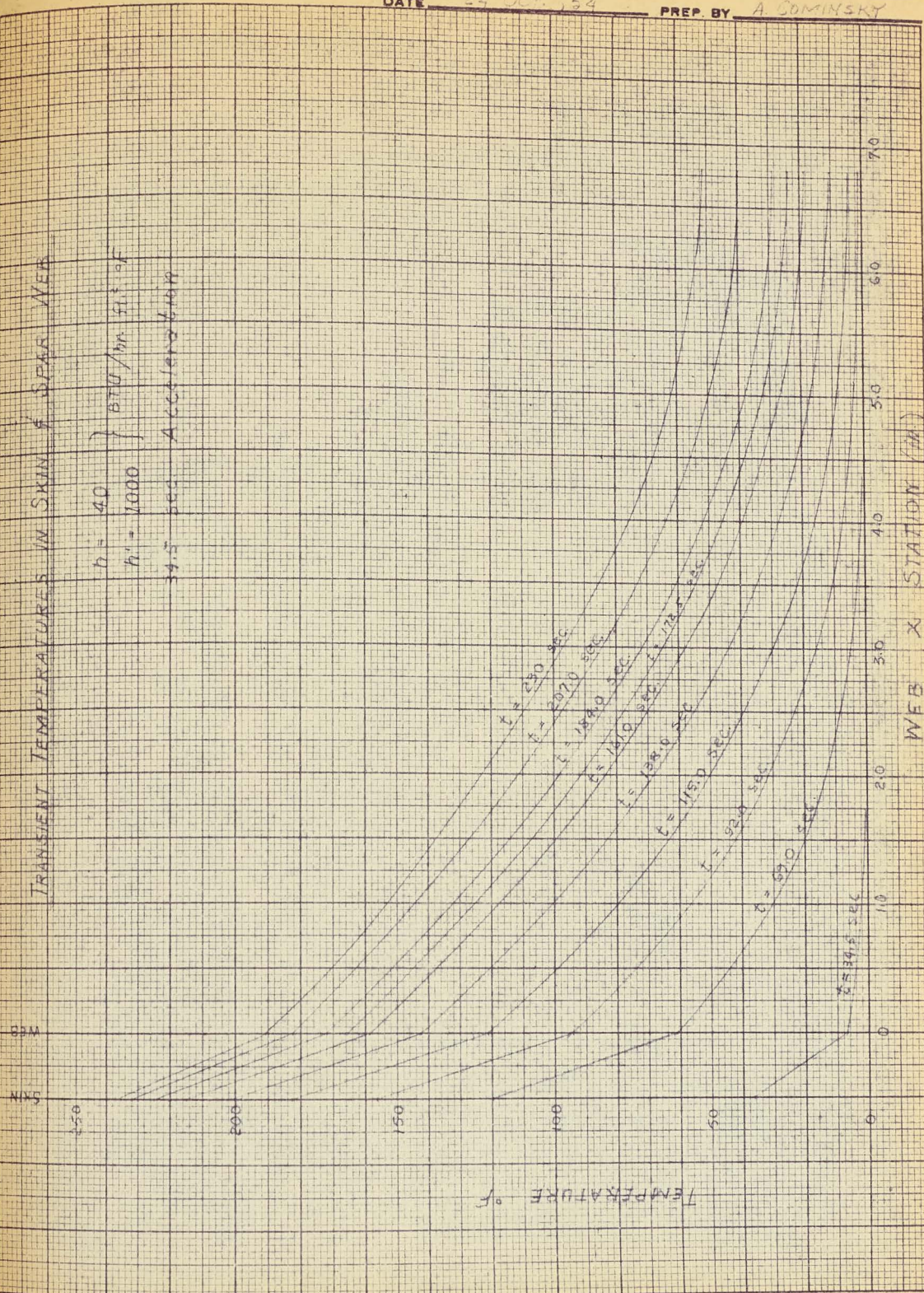
SHEET No. *6-2*

REPORT No. *7/3520/3*

DATE *24 Oct. 54*

PREP BY *A. DOMINSKY*

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AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT NO. 110900/F

SHEET NO. 7-1

AIRCRAFT:

105

WING

TRANSIENT TEMPS.

PREPARED BY

E. KOSKO

CHECKED BY

DATE

1 FEB 55

DATE

THICKNESS CHANGED TO 3/16 IN
ACCELERATION FROM 14-55 TO 14-22 IN 34.5 SEC

INITIAL TEMP OF WING SKIN = 0°F

FINAL TEMP OF BOUNDARY LAYER = 250°F

SURFACE TRANSFER COEFF $h = 40 \text{ BTU/hr ft}^2 \text{ } ^\circ\text{F}$

SKIN TO WEB $k = 300 \text{ BTU/hr ft } ^\circ\text{F}$

THERMAL CONDUCTIVITY (SKIN & WEB) $k = 0.0222 \text{ BTU/sec in } ^\circ\text{F}$

VOLUMETRIC HEAT CAPACITY $\rho c_p = 28 \times 10^3 = 456 \text{ BTU/ft}^3 \text{ } ^\circ\text{F}$

THERMAL DIFFUSIVITY $\alpha = \frac{k}{\rho c_p} = \frac{0.0222}{28 \times 10^3} = 0.000793 \text{ ft}^2/\text{sec}$

$$Biot = \frac{hL}{k} = \frac{200}{300} = 0.667 \text{ } ^\circ\text{F/ft}$$

TAKE $A_0 = 1 \text{ in}$ $r = \frac{1}{2}$

$$A_0 = \frac{200}{k} \times \frac{1}{2} = \frac{100}{0.0222} = 4500 \text{ } ^\circ\text{F/ft}$$

$$Biot = \frac{hL}{k} = \frac{200}{300} = 0.667$$

$$ACCELERATION = \frac{(1450 - 800)}{34.5} = \frac{650}{34.5} = 18.84 \text{ ft/sec}^2$$

CHANGE OF AMBIENT TEMPERATURE

PROPORTIONAL TO THE SQUARE OF THE SPEED

FROM 14-55 AT 14-55

TO 14-22 AT 14-22

$$T_a = T_{a_0} + (T_{a_1} - T_{a_0}) \left(\frac{V_1}{V_0} \right)^2$$

$$= 250 + \frac{1}{400} (250 - 0)$$

$$= 0.250$$

$\frac{V_1}{V_0}$	$\frac{h_1}{h_0}$	T_1 (°F)
0	0	0
11.8	1.35	17.8
25.0	0.25	0.25
34.5	1.90-2.6	250

REPORT NO. 78-1042

SHEET 4

DATE _____

PREPARED BY -

AIRCRAFT -

WEIGHT - - - - -

C. G. POSITION _____

[illegible]

REPT. 7/0500/3

SPT. 7-5

S. Kosho

