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NRC - CISTI
J. H. PARKIN
BRANCH
ANALY 70 JUN 8 1995
ANNEXE
J. H. PARKIN
CNRC - ICIST

STRESS REPORT

7/0510/3

GENERAL A/C
ANALYSIS FOR
SYMMETRIC
LOADING CASES

Classification cancelled / Changed to ~~UNCLASSIFIED~~

AVRS

By authority of

Date

30 Sept 62

Signature

DBB

Unit / Rank / Appointment

AVRS

~~CONFIDENTIAL~~

AVRO AIRCRAFT LIMITED
MALTON ONTARIO

TECHNICAL DEPARTMENT

REPORT NO 7/0510/3

SHEET NO 1

AIRCRAFT:

C 105

General Aircraft Analysis

PREPARED BY

DATE

R. N. Shearly

Sept 1956

CHECKED BY

DATE

SEPT 56

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SUMMARY

The purpose of this analysis is to join the component parts of the complete aircraft (wing, beam, tank, center fuselage, rear fuselage and stiff fin) together by means of the border or closed circuit redundancies and statically determinate reactions.

The results of this analysis are:

- a) the border or closed circuit redundancies to general aircraft load matrix, F_{PA} ;
- b) the displacement matrix for the general aircraft analysis loading points, Z_{AB} ;
- c) the stress to general aircraft load matrix for each component, S_{1A}^*



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REPORT NO 7/0510/3

SHEET NO 2

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General Aircraft Analysis

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R.N. Shearly

June 1956

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NOTATION

Indices:

* *
i, k stress points of the individual analyses,

* *
a, b load points including border or closed circuit redundancies
of the individual analyses.

The symbol * stands for W, B, T, C and R for wing, beam, tank,
center fuselage and rear fuselage respectively.

U, V fictitious stress points of the general aircraft analysis,

P, Q, R border or closed circuit redundancies of the general
aircraft analysis,

A, B load points of the general aircraft analysis.

See Table I for the relationship between.

* *
a, b and U, V

* * *
a, b, c and P, Q, R

* *
a, b and A, B

Matrices:

C_{UV} Elastic Influence Coefficients (symmetric) to be made up of
 Z_{ab}^* matrices of the individual component analyses,

K_{UF} fictitious stress to border or closed circuit redundant
group matrix,

T_{UA} statically determinate fictitious stress to ^{general aircraft} load matrix,

S_{iU}^* stress to fictitious stress matrix for particular component,



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REPORT NO. 7/0510/1

SHEET NO. 3

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General Aircraft Analysis

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δ_{uv} unit matrix (Kronecker Delta).

The lower case letter indices of the above matrices have the range and are defined as in the particular component analysis. The capital letter indices of the above matrices have the range and are defined as follows:

1) general aircraft analysis loading point indices

A, B = 1, 2, 3 88

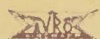
2) fictitious stress point indices

U, V = 1, 2, 3 119

3) border or closed circuit redundant group indices

P, Q, R = 1, 2, 3 14

Indices of the same group are interchangeable, the first index denoting the row, the second index the column of the matrix.



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METHOD

The general aircraft analysis for symmetrical loading cases is performed in the following way. First, the complete aircraft is thought to be divided into components as shown in fig. 1. The components considered are wing, beam, tank, center fuselage, rear fuselage and stiff fin. Initially the beam is thought to be cut free from the wing at the transport joint rib and attached to the tank which in turn is attached to the center fuselage which is attached to the rear fuselage which is supported by an imaginary foundation at two pick up points per side. The wing is considered to be supported by the imaginary foundation at the same two pick up points per side. To establish compatibility of the components the border or closed circuit redundancies are applied as shown in fig. 1. The stiff fin is the medium for applying the effects of redundancies 13 and 14 (see fig. 1) to the rear fuselage.

Next each of the components is analysed separately, see reports 7/0510/4, /5, /7, /8, /9 and /10 with the redundancies considered to be applied loads. From these analyses are obtained the following matrices for each component:

- * S_{1a} stress to unit load
- * Z_{ab} displacement to unit load

For convenience a portion of report Gen/1020/336 is reproduced here with one slight change - the indices associated with the general aircraft analysis are capitalized to avoid misunderstanding.

"In order to combine the partial problems for final solution, a unified index and notation system is introduced for the whole structure.

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SHEET NO. 3

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DATE

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June 1956

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COMPUTATION PROGRAM PART I Establishing the C_{UV} , Z_{UP} , T_{UA} , S_{IU}^* Matrices.

The following matrices are available from the individual component analyses

Component	Report No.	Matrix
Wing	7/0510/7	$\begin{matrix} W \\ S_{ia} \end{matrix}$ and $\begin{matrix} W \\ Z_{ab} \end{matrix}$
Beam	7/0510/1	$\begin{matrix} B \\ S_{ia} \end{matrix}$ and $\begin{matrix} B \\ Z_{ab} \end{matrix}$
Tank	7/0510/8	$\begin{matrix} T \\ S_{ia} \end{matrix}$ and $\begin{matrix} T \\ Z_{ab} \end{matrix}$
Center Fuselage	7/0510/9	$\begin{matrix} C \\ S_{ia} \end{matrix}$ and $\begin{matrix} C \\ Z_{ab} \end{matrix}$
Rear Fuselage	7/0510/12	$\begin{matrix} R \\ S_{ia} \end{matrix}$ and $\begin{matrix} R \\ Z_{ab} \end{matrix}$
Wing webs	7/0510/15	$\begin{matrix} W \\ S_{ia} \end{matrix}$ continued

Table I gives the relationship between indices of the general aircraft analysis and those of the individual component analyses..

C_{UV} Matrix

In theory the C_{UV} matrix can be formed directly from the known Z_{ab}^* matrices. Unfortunately in practice this is not true because due to small unavoidable computational errors the Z_{ab}^* matrices are not exactly symmetrical. To overcome this difficulty the following procedure is advised for wing, center fuselage and rear fuselage displacement to unit load matrices $\begin{matrix} W \\ Z_{ab} \end{matrix}$, $\begin{matrix} C \\ Z_{ab} \end{matrix}$ and $\begin{matrix} R \\ Z_{ab} \end{matrix}$ resp.. Add to the Z_{ab}^* matrix of the particular component its transpose matrix and divide the resulting matrix by two. In this manner the Z_{ab}^* matrix is made exactly symmetrical. After this is done the C_{UV} matrix is made up as follows:

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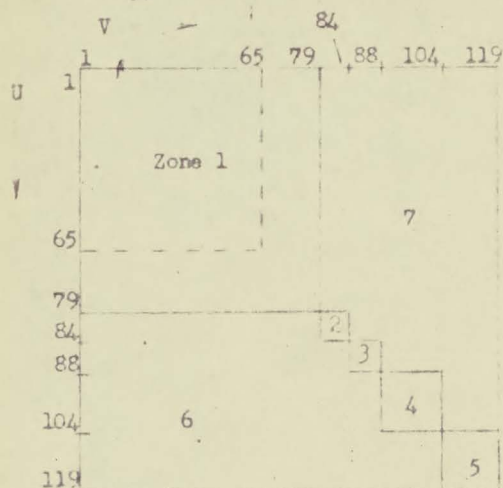
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Stage (a)

Key to the C_{UV} Matrix

Non zero elements

Zone 1	6241	
2	21	see section
3	16	entitled,
4	256	"Established
5	225	Matrices"
6	0	
7	0	

Total 6759

Elements Total 14161

For zone 1, the elements of the C_{UV} matrix consist of the elements of the exactly symmetrical Z_{ab} matrix of the wing rounded off to 6 decimal places. The indices of the IBM numbering system correspond to those of the numbering system of the general aircraft analysis. The check row and column will have to be recalculated.

For zones 2, 3, 4 and 5 the elements and check sums are shown in the section entitled, "Established Matrices".



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General Aircraft Analysis

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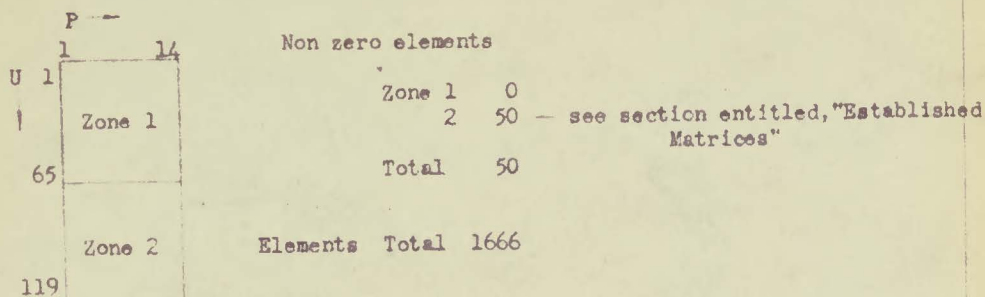
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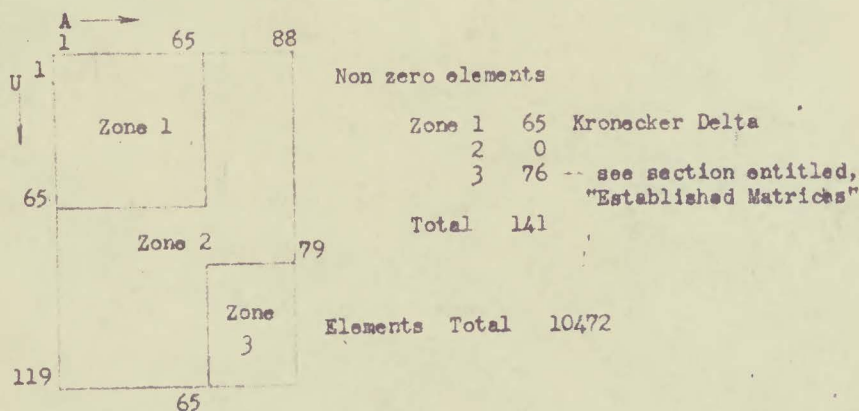
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Key to the K_{UP} Matrix



Key to the T_{UA} Matrix



Since the load point index system $\bar{A}$, $\bar{B}$ as defined in report 7/0510/13 has already been issued to the stress office and considerable work has been done using this index system, it will be the official load point system. The index system A, B as used in this report up to this sheet



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SHEET NO. 11 (a)

AIRCRAFT:

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R.N. Shearly

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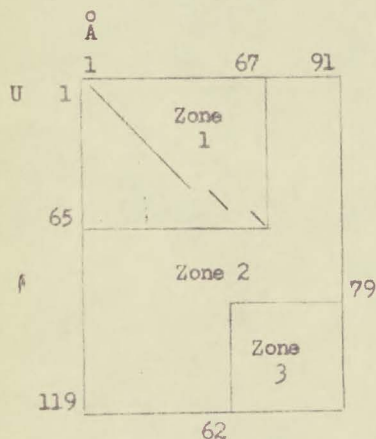
Oct. 1956

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DATE

has been used for numerical convenience. However to reduce the possibility of error and additional work in the future the matrix T_{UA}^0 will be recoded to T_{UA}^0 and the following sheets in this report will use the load point indices $\overset{0}{A}, \overset{0}{B}$.

Key to the T_{UA}^0 matrix



Non zero elements

Zone 1	65	see note below
2	0	
3	76	see section entitled, "Established Matrices"
Total	141	

Elements Total 10829

In zone 1 the elements T_{UA}^0 are equal to unity for $U = \overset{0}{A} = 1$ to 57 inclusive

and for	(i)	$U = 58$	$\overset{0}{A} = 59$
	(ii)	59	60
	(iii)	60	61
	(iv)	61	62
	(v)	62	64
	(vi)	63	65
	(vii)	64	66
	(viii)	65	67

all others are equal zero.



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Stage (b)

*

S_{1U} Matrix

The elements of the S_{1U}^* matrix are the elements of the S_{1a}^* matrix of the individual component analyses rounded off to 5 decimal places.

For wing ($* = W$) no recoding necessary. Check sums to be recalculated.

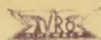
For beam ($* = B$)

> see section entitled, "Established Matrices"

For tank ($* = T$)

For center fuselage ($* = C$) the S_{1U}^* matrix will be added to the section

For rear fuselage ($* = R$) entitled, "Established Matrices", at a later date.



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REPORT NO 7/0510/3

SHEET NO 13

AIRCRAFT:

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General Aircraft Analysis

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COMPUTATION PROGRAM PART 2

A) Established Matrices:

C_{UV} Elastic Influence Coefficients (symmetric)
 K_{UP} Fictitious stress to border or closed circuit redundancies
 T_{UA} Statically determinate fictitious stress to load
 S_{1U} Stress to fictitious stress for wing
 B_{1U} beam
 T_{1U} tank
 C_{1U} center fuselage
 R_{1U} rear fuselage

with indices

$\lambda, \beta = 1, 2, \dots 91$
 $U, V = 1, 2, \dots 119$
 $P, Q, R = 1, 2, \dots 14$
 (webs included)
 for wing $\lambda, k = 1, 2, \dots 132, 201, 202, \dots 282$ excluding 279 and 281
 for beam $1, k = 1, 2, \dots 4$
 for tank $1, k = 1, 2, \dots 30$
 for c/fus. $1, k = 101, 102, \dots 143, 201, 202, \dots 243, 301, 302, \dots 343, 401, 402, \dots 434$ excluding 427
 for r.fus. $1, k = 1, 2, \dots 51$



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B) Elementary Operations:

Transpose to A_{iP} is A_{Pi}

Matrix product of A_{Ak} and B_{ki} is C_{Ai} , denoted as

$$A_{Ak} B_{ki} = C_{Ai}$$

Inverse to D_{PQ} is D_{QP}^{-1}

C) Checks to be printed:

Inversion Error $D_{PR} D_{RQ}^{-1} - \delta_{PQ}$

Symmetry of D_{PQ}

Symmetry of Z_{AB}

D) Results to be printed: (Punched cards to be retained for future use)

Border or closed circuit redundancies to general aircraft unit loads

F_{PA}^0

Displacement to general aircraft unit loads

Z_{AB}

Component stresses to general aircraft unit loads

S_{iA}^*

E) Operations: (Operations 1 - 10 identical with operations 1 - 10 of Report Gen/1090/334, Type Program No. 1)

Stage (a)

1) Multiply $H_{UP} = C_{UV} K_{VP}$

2) Multiply $D_{PQ} = K_{PU} H_{UQ}$ print

3) Invert $D_{PQ} \rightarrow D_{QP}^{-1}$

4) Perform $D_{PR} D_{RQ}^{-1} - \delta_{PQ}$ print



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AIRCRAFT

C 105

General Aircraft Analysis

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DATE

R.N. Shearly

June 1956

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REFERENCES

- Avro report; Gen/1090/334 Type Programs April 1955; Alex. Grzedzielski
- Avro report Gen/1090/336 Theory of Multi-Spar and Multi-Rib Wing Structures
June 1955; Alex. Grzedzielski
- Avro report 7/0510/14 E/S Beam Analysis May 1956; R.N. Shearly
- Avro report 7/0510/7 Wing Analysis June 1955; V.F. Gardener, R.N. Shearly,
D.L. Turner.
- Avro report 7/0510/2 Tank 3 Analysis March 1955; Alex. Grzedzielski and
W. Roberts.
- Avro report 7/0510/9 Center Fuselage Analysis Dec. 1955; E. Augustine,
V.F. Gardener and C. Burrell
- Avro report 7/0510/12 Rear Fuselage Analysis Sept. 1956; J. Andrews,
E. Augustine, C. Burrell and C. Gundersen
- Avro report 7/0510/13 Load System of General Stress Analysis of the
Aircraft May 1956; Alex. Grzedzielski and R.N. Shearly
- Avro report 7/0510/15 Wing Web Shear Flows ; C. Burrell and
C. Gundersen



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AIRCRAFT:

C-105

GENERAL AIRCRAFT
ANALYSIS

REPORT NO. 7/0510/3

SHEET NO. 20

PREPARED BY

R.H. FEARIN

DATE

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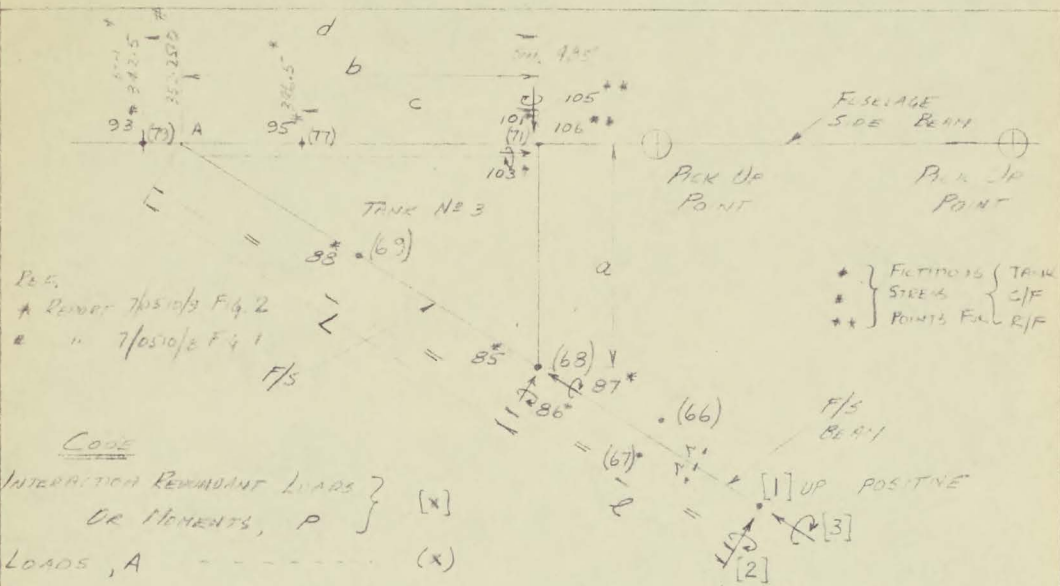
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(b) & (d)

THE EXPERIMENTS (b) & (d) WILL BE CONSIDERED TOGETHER. FOR THE COMPOUND STRUCTURES AS SHOWN BELOW



THE LOAD AT INTERSECTION OF F/S & FUSELAGE SIDE BEAM, POINT A IN ABOVE DIAGRAM, IS DISTRIBUTED TO LOAD POINTS 77 & 79 AS FOLLOWS:

$$Q_{77} = \frac{d-b}{d-c} Q_A = \alpha Q_A$$

$$Q_{79} = \frac{b-c}{d-c} Q_A = \beta Q_A$$

$$\alpha + \beta = 1$$

FIGURE 2

THE FICTITIOUS STRESSES IN TANK 3 STRUCTURE, CENTER FUSELAGE STRUCTURE & REAR FUSELAGE STRUCTURE,

S_u^T , S_u^C & S_u^R RESP. ARE AS GIVEN IN THE FOLLOWING:

TECHNICAL DEPARTMENT (Aircraft)

REPORT NO.

7/0510/3

SHEET NO.

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DATE

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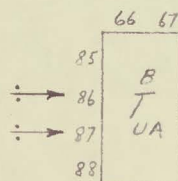
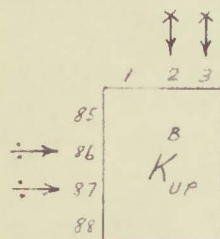
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C-105

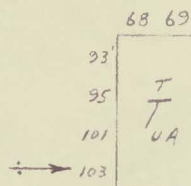
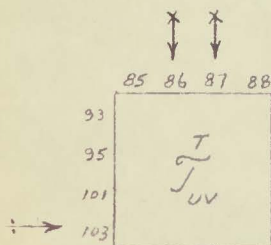
GENERAL AIRCRAFT
ANALYSIS

THE INFORMATION ON THE PREVIOUS PAGES IS APPLICABLE WHEN LOADS AND MOMENTS A, B ; REDUNDANCIES P, Q AND FICTITIOUS STRESSES U, V ARE IN UNITS OF KIPS AND INCH-KIPS.

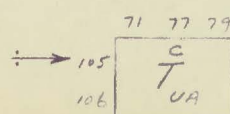
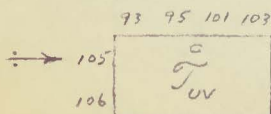
HOWEVER FOR THIS ANALYSIS MOMENTS ARE IN UNITS OF 100 INCH-KIPS. CONSEQUENTLY FOR MOMENTS REDUNDANCIES WHICH ARE MOMENTS AND FICTITIOUS STRESSES WHICH STAND FOR MOMENTS T IN 100 INCH-KIP UNITS THE MATRICES K_{UP} , T_{UA} , T_{UV} , T_{UA} AND T_{UA} MUST BE ALTERED TO SUIT AS SHOWN BELOW.



CODE
COLUMNS MARKED
THUS $\downarrow$ MUST BE
MULTIPLIED BY 100



ROWS MARKED THUS
 $\div \rightarrow$ MUST BE
DIVIDED BY 100



THE NUMERICAL VALUES OF THE ALTERED MATRICES ARE SHOWN ON THE NEXT PAGE.



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TECHNICAL DEPARTMENT

REPORT No. 7/0510/3

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AIRCRAFT:

C-105

GENERAL AIRCRAFT ANALYSIS R.H. SHEARLY

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DATE

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ESTABLISHED MATRICES

THIS SECTION CONSISTS OF:

- 1) DUMMIES OF MATRICES C_{UV} , K_{UP} & T_{UA} & T_{UR}
- 2) ELEMENTS OF C_{UV} MATRIX ZONES 2, 3, 4 & 5
- 3) ELEMENTS OF K_{UP} MATRIX ZONE 2
- 4) ELEMENTS OF T_{UA} MATRIX ZONE 3 & T_{UR} MATRIX ZONE 3
- 5) ELEMENTS OF S_{LU}^B MATRIX
- 6) ELEMENTS OF S_{LU}^T MATRIX

TABLE I

Report No. 7/0510/3

Sheet No. 9

R.N.Snearly June 1956

U	Wing No.	Beam No.	Tank T	C/F C	R/F R	P	Wing No.	Beam No.	Tank T	C/F C	R/F R	A	Gen. Load System (1)	Wing No.	Beam No.	Tank T	C/F C	R/F R
1	1	1				1	66	101	201			1	1	1	1			
2	2	2				2	67	102	202			2	2	2	2			
3	3	3				3	68	103	203			3	3	3	3			
4	4	4				4	69	104		20		4	4	4	4			
5	5	5				5	70	105			3	5	5	5	5			
6	6	6				6	71	106			4	6	6	6	6			
7	7	7				7	72	107			5	7	7	7	7			
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67	73			204					
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74	81							10	
75	80							17	
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78	85							6	
79	84							15	
80	87							4	
81	86							14	
82	88							2	
83	89							1	
84	68								6
85	69								8
86	70								13
87	71								7
88	72								14

(1) Reference Report 7/0510/13

^o A, ^o B of this report identical to

a, b of 7/0510/13

EUFFEL & ESSER CO.
NEW YORK

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REPORT No 7/0510/3

SHEET N^o 33

C-105 GENERAL AIRCRAFT ANALYSIS

COMPUTED P. M. Shandy

DATE JUNE 5/56

CHECKED

DATE _____

SUPERVISED

DATE -

APPROVED.

DATE -

K_{UP} MATRIX (ZONE 2)

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GENERAL AIRCRAFT ANALYSIS

T_{4A} MATRIX (ZONE 3)

R. N. Shearly

DATE

OCT. 2/56

CHECKED

Book 9

DATE _____

Oct 2/56

SUPERVI

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REPORT No 7/0510/3

SHEET No 34 (a)

SUPERVISED					DATE			APPROVED			DATE	
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SHEET 5

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74	77	76	79	78	81	80	82	83
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C-105 GENERAL AIRCRAFT ANALYSIS

REPORT
SHEETNº 7/0510/3
35B
S_U MATRIXT
S_U MATRIXU →
80 81 82 83 84 ΣU →
85 86 87 88 Σ

1	3.91304				3.91304
2		4.80890			4.80890
3	4.11617	4.79762	2.05809	2.05809	4.79763
4		4.80890	2.8853	2.8853	4.80890
Σ	4.11617	8.71066	9.61780	1.76956	2.34662

REF. REPORT 7/0510/14 SHEET 2

TABULATED BY R. H. Henry DATE JUNE 12/56
 CHECKED BY T. Smith DATE SEPT '56
 SUPERVISED BY _____ DATE _____
 APPROVED BY _____ DATE _____

1	1.0624	3.0814	1.7302	1.6713	0.7423
2	0.05042	6.5461	4.8042	3.9044	6.9417
3	1.2138	1.9006	5.0058	2.2265	3.4661
4	0.3264	1.12149	5.7699	6.5904	1.00680
5	0.08548	9.6072	2.7920	2.3966	1.08574
6	0.05500	2.03655	1.35134	5.6343	2.76946
7	1.35090	9.0400	1.75300	6.7550	1.17740
8	0.01558	8.9896	4.5581	4.1693	9.2226
9	0.16248	1.3768	4.8449	0.9510	0.8923
10	1.16075	1.23507	2.13840	3.4190	5.9932
11	2.7684	7.3229	1.55007	2.9754	1.70798
12	7.6575	1.53519	3.02906	0.6369	6.6443
13	0.08155	4.0063	7.01330	0.01951	6.71373
14	0.02163	0.01014	0.6294	0.04689	0.01572
15	0.02422	5.7068	3.3409	2.9858	5.8197
16	1.4858	3.7472	6.6479	3.2719	5.6314
17	0.03571	0.05144	0.01575	0.04697	0.02443
18	0.00443	6.7570	5.7560	1.4385	1.10302
19	0.09020	3.4476	7.7422	0.02167	1.23085
20	0.03471	1.0066	0.05652	0.05460	0.02425
21	1.1212	4.6666	0.0453	5.4228	0.00703
22	1.2975	1.24507	0.02163	4.2555	9.7090
23	0.01007	4.57052	2.05170	0.00241	6.64070
24	0.07273	1.6250	1.4396	0.03930	0.05137
25	0.04395	0.00373	2.0068	0.0408	1.3892
26	1.1445	0.03388	1.22244	0.02751	1.11436
27	0.03329	0.7426	0.06594	0.01820	0.02341
28	0.00876	0.06978	0.04348	0.02507	0.09695
29	0.04708	0.02302	6.4604	0.00958	6.1240
30	0.07121	0.02092	5.3947	0.01707	6.0683
Σ	3.95884	16.17637	11.78242	2.12336	

REF. REPORT 7/0510/8 SHEET 104

GENERAL AIRCRAFT ANALYSIS

CUR MATRIX (ZONE 4)

V →

	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
23	461221	241372	172817	173542	114503	115073	066621	067665	029359	031131	00						
24	241372	141516	071002	108144	074160	075325	045575	046458	020960	022727	00						
25	172817	107602	097685	084021	062667	061155	038747	038777	018304	017763	00						
26	173542	109144	084021	089212	061097	063421	038381	040017	018151	020179	00						
27	114503	074160	062667	061097	050627	046250	032492	031102	015720	016568	00						
28	115073	075325	061155	063421	046250	051965	030680	033920	015170	017836	00						
29	066621	045575	038747	038381	032492	030680	026287	021978	013269	012749	00						
30	067665	046458	038777	040017	031102	033920	021978	027934	011788	015739	00						
31	029359	020960	018304	018151	015720	015170	013269	011788	010922	007523	00						
32	031131	022727	017763	020179	016568	017836	012749	015739	007523	014017	00						
33	004377	003864	003473	003471	003159	003060	002856	002589	002637	001987	00						
100	007100	006877	006464	006617	005936	006149	005120	006613	003647	007276	00						
101	000687	000749	000811	000834	000851	000150	000325	001133	000680	001472	00						
102	001168	001665	001803	001852	001887	002107	001853	002517	001512	003264	00						
103	004134	005929	006291	006462	006514	007355	006464	008786	005272	011399	00						
104	001696	002244	002613	002685	002742	003057	002687	003652	002194	004737	00						
Σ	483132	842186	694092	673234	596781	511110	326844	333748	160709	173151	03						

RES. REPORT

7/05/10/3

Sheet 16-1

REPORT NO 7/0510/3 SHEET NO 31

TABULATED BY C. M. L. DATE FEB 13/6

CHECKED BY C. M. L. DATE JAN 1/6

SUPERVISED BY D. T.

APPROVED BY DATE

AIRPORT ANALYSIS

COR. MATRIX (ZONE 4)

34	35	36	37	38	39	100	101	102	103	104	Σ
.115073	.066621	.067665	.029259	.031131	.004977	.007900	.000527	.001168	.004084	.001696	.483132
.075325	.045595	.046458	.020960	.022727	.003854	.006877	.000747	.001665	.005808	.002414	.892186
.061155	.039749	.039799	.018304	.019763	.003498	.006464	.000811	.001803	.006291	.002613	.694092
.063421	.038381	.040017	.018151	.020179	.003471	.006617	.000834	.001852	.006462	.002685	.698204
.046250	.032492	.031102	.015720	.016568	.003159	.005936	.000851	.001887	.006574	.002702	.506781
.051965	.030690	.033920	.015170	.017836	.003060	.006490	.000950	.002107	.007355	.003057	.511110
.030680	.026287	.021978	.013269	.012749	.002856	.005120	.000935	.001853	.006464	.002687	.326844
.033920	.021778	.027934	.011788	.015739	.002589	.006613	.001133	.002517	.008786	.003652	.333748
.015170	.013269	.011788	.010922	.007523	.002637	.003647	.000680	.001512	.005279	.002194	.160709
.017836	.012749	.015739	.007523	.014017	.001987	.007276	.001472	.003264	.011399	.004737	.173151
.003060	.002856	.002589	.002637	.001987	.002574	.001232	.000297	.000653	.002300	.000955	.033001
.006490	.005120	.006613	.003647	.007276	.001232	.008704	.002025	.004495	.015699	.006525	.053122
.000950	.000835	.001133	.000680	.001472	.000297	.002025	.005603	.003079	.006752	.002523	.006793
.002107	.001853	.002517	.001512	.003264	.000653	.004495	.003079	.003681	.012798	.005597	.018147
.007355	.006464	.008786	.005279	.011399	.002300	.015699	.006752	.012798	.110082	.019548	.037063
.003057	.002687	.003652	.002194	.004737	.000955	.006525	.002523	.005597	.019548	.008122	.011361
.511110	.326844	.333748	.160709	.173151	.033001	.053122	.006793	.018147	.037063	.011361	

7/0510/3

SHEET 16-1, 16-2, 16-3 & 16-4

