UNCLASSIFIED CONFIDENTIAL

A V ROE CANADA LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: Arrow I

REPORT NO: 70/SIMUL/14

FILE NO:

NO OF SHEETS: 60

TITLE:

GENERAL INTRODUCTION TO THE ARROW FLIGHT SIMULATOR

PREPARED BY: REGISTERED PROFESSIONAL ENGINEER D. J. FOSTER PROVINCE OF ONTARIO — DATE: May 1958

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INTRODUCTION

The Arrow Flight Simulator has been designed to provide a replica of the aircraft's performance over the range of flight conditions between take off and Mach 2.5 and up to altitudes of 80,000'. All known significant cross-coupling effects have been included and the variation of aerodynamic derivatives with Mach No., Altitude and incidence have been allowed for.

In conjunction with the cockpit and control system simulation, it can be used familiarize pilots with the performance of the aircraft, especially from the point of view of instrument display. Alternatively, it may be used in conjunction with a simulation of the radar system to investigate fire control problems. Two ways in which the simulator has already been used were to check out the suitability of the control system for the aircraft, by linking the computer to the B-1 rig, and to check the behaviour of the controls and damping system installed in the first aircraft, by linking the simulator to the aircraft control surfaces and providing an auxiliary instrument panel inside the cockpit.

EQUATIONS OF MOTION

In the course of simulation, the six equations of motion are formulated, specifically the lift, drag, sideforce, rolling moment, yawing moment and pitching moment equations. Of these, the first two equations are in the wind axes system, and the remaining four in the body axes system. Once the lift and drag forces have been obtained, they are resolved into their components in the body axes system. This has been done because, although the body axes system is more suitable for simulation, people in general are more familiar with the concepts of lift and drag than of normal force and axial force.

The principal problem to be overcome in mechanizing the force and moment equations was that some of the aerodynamic derivatives were functions of three variables:- Mach Number, Altitude and Incidence. By examining the variations, it was concluded that an acceptable approximation would be to separate the variables, and take sums and multiples of functions of each of the three variables.

LIFT COEFFICIENT

$CL = CL_{\alpha E} (\alpha - \alpha o_E) + CL_{\delta eE} . \delta e$

where $CL_{\alpha E} = CL_{\alpha R} (1 - f_1 g_1)$

$\alpha oE = \alpha oR (1 - f_2 g_2)$

$CL_{\delta eE} = CL_{\delta eR} (1 - f_3 g_3)$

$CL_{\alpha R}$, $f_1 \alpha oR$, f_2, $CL_{\delta eR}$, f_3 are Mach Functions.

g_1, g_2, g_3, are Altitude Functions.

Drag Coefficient

$CD = CD_o + C(CL + E)^2 + G . CL . \delta e + H . \delta e^2$

where CD_o, C, E, G, and H are Mach Functions

Sideforce Coefficient

$CY = CY_{\beta E} . \beta + CY_{\delta rE} . \delta r$

where $CY_{\beta E} = CY_{\beta R} + CY_{\beta \alpha} . \alpha - (f_{20} + f_{21} . \alpha) . g_{20}$

$CY_{\delta rE} = CY_{\delta rR} . (1 - f_{19} . g_{19})$

$CY_{\beta R}$, $CY_{\beta \alpha}$, f_{20}, f_{21}, $CY_{\delta rR}$, f_{19} are Mach Functions

g_{20}, g_{19} are Altitude Functions

Pitching Moment Coefficient

$CM = CM_{oE} + (c.g - a.c)\, CL\alpha_E . (\alpha - \alpha_{oE}) + CM_{\delta eE} . \delta e + CMq . \frac{q.c}{2v} + CM\dot{\alpha} . \frac{\dot{\alpha}.c}{2v}$

where $CM_{oE} = CM_{oR} . (1 - f_9 . g_9)$

$CM\delta_{eE} = CM_{\delta eR} . (1 - f_{10} . g_{10})$

CM_{oR}, f_9, $CM_{\delta eR}$, f_{10}, CM_q, $CM_{\dot{\alpha}}$, (c.g - a.c) are Mach Functions

g_9, g_{10}, are Altitude Functions

Yawing Moment Coefficient

$$Cn = Cn_{\beta E}\cdot\beta + Cn_{\delta rE}\cdot\delta r + Cn_{\delta aE}\cdot\delta a + Cn_p \frac{pb}{2v} + Cn_r\cdot \frac{rb}{2v}$$

where $Cn_{\beta E} = Cn_{\beta R} + Cn_{\beta\alpha}\cdot\alpha + l(f_{20} + f_{21}\cdot\alpha)\, g_{20}$

$Cn_{\delta rE} = (Cn_{\delta rR} + \alpha . Cn_{\delta r\alpha})\ (1-f_{22}g_{22})$

$Cn_{\delta aE} = (Cn_{\delta aR} + \alpha Cn_{\delta a\alpha})\ (1-f_{23}g_{23})$

where $Cn_{\beta R}$, $Cn_{\beta\alpha}$, l, f_{20}, f_{21}, $Cn_{\delta r}$, $Cn_{\delta r\alpha}$, $Cn_{\delta a}$, $Cn_{\delta a\alpha}$, f_{23} are Mach Functions

g_{20}, g_{22}, g_{23} are Altitude Functions

Rolling Moment Coefficient

$$Cl = Cl_{\beta E}\cdot\beta + Cl_{\delta rE}\cdot\delta r + Cl_{\delta aE}\cdot\delta a + Cl_{pE}\cdot \frac{pb}{2v}$$

where $Cl_{\beta E} = Cl_{\beta E} = Cl_{\beta R} + \alpha . Cl_{\beta\alpha}\cdot\ -Z(f_{20} + f_{21}\cdot\alpha)\cdot g_{20}$

$Cl_{\delta aE} = Cl_{\delta aR}(1-f_{23}g_{23})$

$Cl_{\delta rE} = Cl_{\delta rR}(1-f_{24}g_{24})$

$Cl_{pE} = Cl_{pR}\ (1-f_{26}g_{26})$

$Cl_{\beta R}$, Cl_{β} , f_{20}, f_{21}, $Cl_{\delta aR}$, f_{24}, $Cl_{\delta rR}$, Cl_{pR}, f_{23}, f_{26} are Mach Functions

g_{20}, g_{23}, g_{24}, g_{26} are Altitude Functions

Although the derivatives were generated in the way just described, when it came to mechanizing the equations of motion in the computer, it was not always convenient to use the derivative values. One reason was that the derivatives might not be correctly scaled. Another was that the computer had to generate forces and moments rather than just derivatives, so in some cases the Mach Number times the derivative was scaled. Scaling was necessary because the functions of Mach No. and altitude were obtained from tapped potentiometers, and a value of greater than 1.0 could never be obtained, but for reasons of accuracy a value of as near 1.0 as possible was desireable.

(a) Aircraft

Provision has been made in the computer for inserting aerodynamic derivates pertinent to the centre of gravity being located at either 29% or 31% of the mean aerodynamic chord. Due to the difficulties involved in scaling the equations of motion, the same physicaly constants for the aircraft inertias have been used for either centre of gravity position.

Wing Area	S	1225 ft^2
Wing Span	b	50 ft
Wing Mean Aerodynaic Chord	$\bar{c}$	30.22 ft
Weight	W	55,000 lb.
Mass	M	1710 slugs
Moment of inertia in roll	I_x	75,200 slug ft^2
Moment of inertia in pitch	I_y	389,000 slug ft^2
Moment of inertia in yaw	I_z	453,000 slug ft^2
Product of inertia (yaw-roll coupling)	I_{xz}	11,200 slug ft^2

(b) Atmospheric (Sea Level)

Speed of sound	a_o	1116 ft/sec
Density	ρ_o	.00238 $slugs/ft^3$
Pressure	P_o	2116 lb/ft^2
Ratio of Specific heats	γ	1.40

Normal

$$\dot{\alpha} = \frac{p\beta}{57.3} + q + \frac{57.3}{v}\left\{ g \cos\theta \cos\phi - \frac{\dot{v}\alpha}{57.3} + \frac{\Sigma Fz}{M} \right\}$$

Axial

$$\dot{v} = \frac{v\alpha}{(57.3)^2}(-q + \dot{\alpha}) - \frac{g \sin\theta}{57.3} + \frac{T}{M}\cos i + \frac{\Sigma Fx}{M}$$

Sideslip

$$\dot{\beta} = \frac{\alpha p}{57.3} - r + \frac{57.3}{v}\left(\frac{-\dot{v}\beta}{57.3}\right) + g \cos\theta \sin\phi + \frac{\Sigma Fy}{M}$$

Roll

$$\dot{p} = \frac{Ixz}{Ix}\left(\dot{r} + \frac{pq}{57.3}\right) + \frac{57.3}{Ix}\Sigma L$$

Yaw

$$\dot{r} = \frac{Ixz}{Iz}\dot{p} + \frac{Ix - Iy}{Iz}\frac{pq}{57.3} + \frac{57.3}{Iz}\Sigma N$$

Pitch

$$\dot{q} = \frac{Iz - Ix}{Iy}\frac{rp}{57.3} - \frac{Ixz}{Iy}\cdot\frac{p^2}{57.3} + \frac{57.3eT}{Iy} + \frac{57.3}{Iy}\cdot\Sigma M$$

In the above equations, all angles and angular rates are in degrees.

Because of the nonlinear character of the equations of motion, particularly when the speed and altitude are variable, a large number of multiplications were required. These multi plications were performed by using servos and ganged potentiometers. In general, the multiplications could be separated into two distinct types.

(1) The multiplication of two quantities which occured as voltages in the computer.

(2) The multiplication of two quantities, one of which occured as a voltage in the computer and the other was a function of a voltage in the computer.

For the first type, a servo motor was driven by one variable such that its angular rotation from a reference position was proportional to the variable. By exciting one of the ganged potentiometers with the second variable and driving the wiper by the servo motor, a voltage was picked off which was proportional to the product of the two quantities.

The second type of multiplication may be most easily seen if we first consider how the function of a variable was generated. As before, the servo motor was positioned such that its rotation fbom some reference position was proportional to the applied variable.

The wiper moved around a potentiometer as the servo motor rotated, but the potentiometer had thirteen tap points, each of which was taken to a printed circuit card. On this card were three bars, one carrying a positive reference voltage, one carrying the negative of this reference voltage and the third grounded. By connecting each of the thirteen taps of the potentiometer to one of the three bus bars through an appropriate resistor any arbitrary function of the variable driving the servo motor could be obtained. The wiper would pick off the value of the function appropriate to the input variable. If the reference voltage were now replaced by a second variable, then the wiper would pick off a voltage proportional to the product of this second variable and the function of the variable driving the servo.

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TECHNICAL DEPARTMENT

AIRCRAFT: ARROW SIMULATOR.	DETAILS OF MACH & ALTITUDE FUNCTION CARDS.	REPORT NO 70/SIM/14. SHEET NO 10	
		PREPARED BY: D. J. Foster	DATE: April 58
		CHECKED BY	DATE

Card No.	Derivative or Function	Scale Factor	Load Resistor	Input	Output
1	Mach Follow-up	.4	1.0	-100v	40M
2	$CL_{\alpha R}$	10/57.3	1.0	$-2(\alpha-\alpha_o)$	-20CL
3	$CL_{\alpha R}f1$	40/57.3	4.0	$+2(\alpha-\alpha_o)g_1$	-20CL
4	$CL_{\delta e}$	40/57.3	4.0	$+2\delta e''$	+40CL
5	$CL_{\delta e}f_3$	40/57.3	4.0	$-2\delta e''.g_3$	40CL
6	CD_o+CE^2	20	10.0	+100v	$200C_D$
7	C	2	0.5	$50CL^2$	$200C_D$
8	C.E	40	5.0	50CL(+&-)	$200C_D$
9	.G	-200	2.0	$2CL.\delta e$	$200C_D$
10	H	10,000	4.0	$4\delta e^2/50$	$200C_D$
11					
12	f11	-0.2	5.0	100v	$20f_{11}$
13	CM_o	20.2	4.0	-100v	$-p_o\dot{q}/16pM^2$
14	CM_of_9	50.5	5.0	$+50.g_9$	$-p_o\dot{q}/16pM^2$
15-2	(a.c-c.g)/$\bar{c}$	5.05	0.4	$40CL(\alpha)$	$-p_o\dot{q}/16pM^2$
16.2	$CM_{\delta e}$	-2.2	0.5	$2\delta e'$	$-p_o\dot{q}/16pM^2$
17-2	$CM_{\delta e}f_{10}$	-8.8	2.0	$-2\delta e'g_{10}$	$-p_o\dot{q}/16pM^2$
18	CM_q	-.1907M	1.0	$-a\rho q/a_o\rho_o$	$\dot{q}/10$
19	$CM_{\dot{\alpha}}$	1.907M/5	2.0	$a\rho\dot{\alpha}/a_o\rho_o$	$\dot{q}/10$
20-1	$CY_{\beta R}$	-1.58	1.0	$2\beta M^2p/p_o$	Y/10,000
21	$CY_{\beta VR}$	-1.58	1.0	$2\beta M^2p/p_o$	-YV/10,000
22	$CY_{\alpha\beta}$	.632	1.0	$5\alpha\beta M^2p/57.3p_o$	-YV/10,000
23	f20	-3.95	1.0	$-2\beta M^2p/p_o$	$ETL/4000g_{20}$
24	f21	-1.58	1.0	$5\alpha\beta M^2p/57.3p_o$	$ETL/4000g_{20}$
25	$CY_{\delta r}$	7.90	1.0	$2\delta rM^2p/p_o$	Y/2000

AIRCRAFT		REPORT NO 70/SIM/14	
		SHEET NO. 11	
		PREPARED BY	DATE
Arrow Simulator	Details of Mach and Altitude Function cards	D. J. Foster	April '58
		CHECKED BY	DATE

Card No	Derivative of Function	Scale Factor	Load Resistor	Input	Output
26	$CY_{\delta r}f_{19}$	7.90	1.0	$-2\delta r M^2 p . g_{12}/p_o$	Y/2000
27-2	$Cn_{\beta R}$	18.0	1.8	$2\beta M^2 p/p_o$	$\dot{r}/10$
28-1	$Cn_{\alpha\beta}$	2.00	0.5	$-5\alpha\beta M^2 p/57.3 p_o$	$\dot{r}/10$
29-2	$Cn_{\delta r}$	-20.0	2.0	$-2\delta r' M^2 p/p_o$	$\dot{r}/10$
30-0	$Cn_{\delta r \alpha}$	25.0	5.0	$-2\delta r M^2 p/p_o$	$-57.3\dot{r}/20\alpha$
31	f22	0.5	1.0	$-2\delta r M^2 p g_{22}/p_o$	$\delta r' M^2 p/p_o$
32	$Cn_{\delta aR}$	-50.0	5.0	$-2\delta a' M^2 p/p_o$	$\dot{r}/10$
33	Mach Follow-up	.4	1.0M	-100v	40M
34	$Cn_{\alpha\delta a}$	10.0 125	2.0	$-2\delta'_A M^2 \frac{p}{p_o}$	$57.3\dot{r}''/2\alpha 10$
35	f23	.25	1.0	$-2\delta_A g23 M^2 p/p_o$	$-1/2\delta_A g23\ 23 M^2 p/p_o$
36-2	Cn_r.M	2.243	5.0	$-a\rho/a_o\rho_o . r$	$\dot{r}/10$
37-1	Cn_p.M	8.97	5.0	$a\rho/a_o\rho_o . p/4 (+\&-)$	$\dot{r}/10$
38					
39	Cl_{β}	-7.537	0.5	$-2\beta M^2 p/p_o$	$\dot{p}/40$
40	$Cl_{\alpha\beta}$	-1.2059	0.2	$-\frac{5\alpha\beta}{57.3} M^2 p/p_o$	$\dot{p}/40$
41	$Cl_{\delta rR}$	75.37	5.0	$2\delta r M^2 p/p_o$	$\dot{p}/40$
42	$Cl_{\delta r}.f24$	75.37	5.0	$-2\delta r . M^2 p/p_o g24$	$\dot{p}/40$
43	$Cl_{\delta a}$	-7.537	0.5	$-2\delta_A' M^2 p/p_o$	$\dot{p}/40$
44-2	Elastic tail moment arm	.05059	4.0	E.T.L. $/10^3$	$\dot{r}/10$
45	Cl_{pR}.M	-1.080	0.4	$-a\rho/a_o\rho_o . \frac{p}{4}$	$\dot{p}/40$
46	M.$Cl_{pR} . f_{26}$	-1.080	0.4	$a\rho/a_o\rho_o . p/4 g_{26}$	$\dot{p}/40$
47	Ch_{oE}	12.990	5.0	-100v	$-H_E/2,000$
48	$.Ch_{\delta E}$	-25.98	0.2	$-2\delta_e$	$-H_E/2,000$
49	$Ch_{\alpha E}$	-64.95	0.5	2α	$-H_E/2,000$
50	Ch_{oA}	10.794	2.5	-100v	$-H_A$ Port/1,000

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SHEET NO.	12
PREPARED BY	D. J. Foster
DATE	April '58
CHECKED BY	
DATE	

AIRCRAFT: Arrow Simulator

Details of Mach and Altitude Function Cards

Card No	Derivative or Function	Scale Factor	Load Resistor	Input	Output
51	$Ch_{\delta A}$	-21.588	0.1	$-2\delta_A$	-HA/1,000
52	$Ch_{\alpha A}$	-21.588	0.1	2α	-HA/1,000
53	Ch_{β}	93.78	0.2	$2\beta M^2 p/p_o$	HR/500
54	$Ch_{\delta R}$	93.78	0.1	$-2\delta_R M^2 p/p_o$	HR/500
55	M	0.4	1.0	20M	$8M^2$
56	M	0.4	1.0	$8M^2$	$3.2M^3$
57	$f(M)/M^2.P_o$	1/4,000	1.0	$40M^2 P/P_o$	qc/100
58	α_o	0.2	10.0	100v (+&-)	$2\alpha_o$
59	αf_2	0.4	10.0	$-50g_2$	$2\alpha_o$
60	$CM_{\delta e}{}^2$	.00630	2.0	$-4\delta c^2/50$	$1/16\ q' \frac{p_o}{p} \cdot \frac{1}{M^2}$
61	$Ch_{\delta A}$	-43.176	5.0	-100v	-HA/1,000
62	Ch_{α}	-35.866	0.25	-57.3p/v	-HA/1,000
63-1 64	$CY_{\alpha\beta}$	-72.6	2.0	$\frac{5\times\beta}{57.3} M^2 \frac{p}{P_o}$	-FY/10,000
65	Altitude Follow-up	1/80,000	1.0M	-100v	h/3,200
66	g_1	1	1.0	$-2(\alpha-\alpha_o)$	$-2(\alpha-\alpha_o)\ g_1$
67	g_3	1	1.0	$2\delta e''$	$2\delta e''\ g_3$
68	g_9	1	1.0	-100v	$-100\ g_9$
69	g_{10}	1	1.0	$K_1 CM_{\delta e} + K_2 CM_{\delta e}{}^2$	Input. g_{10}
70	g_{19}	1	1.0	$2\delta r\ M^2 p/p_o$	Input. g_{19}
71	g_{20}	1	1.0	$K\beta(f_{20}+f_{21}\alpha)$	-E.T.L./1,000
72	g_{22}	1	1.0	$2\delta r M^2 p/p_o$	Input. g_{22}
73	g_{23}	1	1.0	$2\delta A\ M^2 p/p_o$	Input. g_{23}
74	g_{24}	1	1.0	$2\delta r M^2 P/P_o$	Input. g_{24}
75	g_{26}	1	1.0	$-a\rho/a_o\rho_o\ p/4$	Input. g_{26}

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AIRCRAFT		PREPARED BY	DATE
Arrow Simulator	Details of Mach and Altitude Function Cards	D. J. Foster	April '58
		CHECKED BY	DATE

Card No	Derivative or Function	Scale Factor	Load Resistor	Input	Output
76	g_{30}	1/20,000	5.0	-100	TM/1,000
77	g_{31}	1/10,000	2.0	20M	TM/1,000
78	g_{32}	-1/8,000	1.0	$8M^2(-\lambda+)$	TM/1,000
79	g_{33}	1/100,000	10.0	-100	$T_{AB}/10,000$
80	g_{34}	-1/100,00	2.0	$20M(-\lambda+)$	$T_{AB}/10,000$
81	g_{35}	1/80,000	1.0	$8M^2$	$T_{AB}/10,000$
82	g_{36}	-1/32,000	1.0	$-3.2M^3$	$T_{AB}/10,000$
83					
84	a	500	1.0	-V/50	-10M
85	$\sqrt{\sigma}$	1.0	1.0	V/50	$V\sqrt{\sigma}/50$
86	$a\rho/a_o\rho_o$	1.0	1.0	-p/4	Input . $a\rho/a_o\rho_o$
86	$a\rho/a_o\rho_o$	1.0	1.0	q	Input . $a\rho/a_o\rho_o$
88					
89	$a\rho/a_o\rho_o$	1.0	1.0	$\dot{\alpha}$	Input . $a\rho/a_o\rho_o$
90	$a\rho/a_o\rho_o$	1.0	1.0	$p\alpha$	Input . $a\rho/a_o\rho_o$
91	$a\rho/a_o\rho_o$	1.0	1.0	r	Input $a\rho/a_o\rho_o$ (replacing 81)
92	g_2	1.0	1.0	100	$100g_2$
93	P/P_o	1.0	1.0	$-8M^2$	$-8M^2\ P/P_o$
94					
95					
96					

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator
WEIGHT	55,000 lb.
C. G. POSITION	.29c
REPORT NO.	70/Sim./14
SHEET	2.1
DATE	Feb. '58
PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	1	2	3	4	5	6	7	8	9
Function	Followup	$CL_{\alpha}R$	$CL_{\alpha}Rf1$	$CL_{\delta e}R$	$CL_{\delta e}f3$	$CD_0+C_E^2$	C	C x E	G.
Mach No. / Associated Card.									
0		2.40	0	.773	0	.009075	.342	-.00506	-.0035
.5		2.54	.060	.773	.055	.009075	.342	-.00506	-.00345
.7		2.73	.168	.773	.135	.00925	.325	-.0083	-.00345
.9		3.05	.418	.848	.385	.00940	.320	-.010	-.00293
1.0		3.27	.740	.756	.490	.01680	.310	-.0156	-.00225
1.05		3.18	.847	.670	.490	.0200	.305	-.0116	-.0020
1.10		3.27	.985	.659	.570	.0221	.285	-.0036	-.00238
1.15		3.28	1.126	.596	.565	.0226	.280	-.0016	-.00175
1.20		3.16	1.160	.476	.465	.0230	.25	-.0008	-.00172
1.40		2.74	1.082	.304	.335	.0233	.380	-.0050	-.0013
1.70		2.46	1.108	.172	.220	.0223	.390	.002	-.0016
2.00		2.03	1.025	.138	.195	.0231	.475	-.0018	-.00125
2.50		1.37	.780	.120	.195	.0231	.475	-.0018	-.00125

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT - - Arrow Simulator

WEIGHT - - 55,000 lb.

C. G. POSITION - .29c

REPORT NO. - 70/Sim./14

SHEET - - 2.2

DATE - - Feb. '58

PREPARED BY - D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	10	11	12	13	14	15	16	17	18
Function	H		f_{11}	CM_o	CM_{of9}	ac-cg/$\bar{c}$	$CM_{\delta e}$	$CM_{\delta e}f_{10}$	CM_q
Associated Card. / Mach No.									$M.CM_q$
0	.0000345		-2.0	.0094	0	.08191	-.2646	0	-1.15
.5	.0000345		-2.0	.0098	-.00083	.08191	-.2746	-.0056	-1.25
.7	.0000375		-2.0	.0120	-.002	.08191	-.3047	-.0169	-1.52
.9	.0000525		-1.93	.0174	-.006	.0970	-.4255	-.0561	-2.95
1.0	.0000755		-1.79	.0248	-.0109	.1266	-.4241	-.0735	-2.25
1.05	.0000690		-1.70	.0264	-.0117	.1535	-.4046	-.0793	-3.00
1.10	.0000610		-1.63	.0274	-.0114	.1595	-.3629	-.0800	-3.25
1.15	.0000627		-1.57	.0246	-.0107	.175	-.3113	-.0729	-2.57
1.20	.000058		-1.54	.0219	-.0107	.179	-.2769	-.0651	-2.30
1.40	.0000575		-1.59	.0177	-.0115	.180	-.1940	-.0441	-0.75
1.70	.0000475		-2.06	.0122	-.0094	.176	-.1085	-.0249	-0.68
2.00	.0000390		-2.06	.0086	-.0073	.162	-.0928	-.0225	-0.675
2.50	.0000390		-1.08	.0034	-.0036	.1465	-.0796	-.0225	-0.670

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.3
C. G. POSITION	.29$\bar{c}$	DATE	Feb. '58
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	19	20	21	22	23	24	25	26	
Derivative Function	$CM_{\dot{\alpha}}$	$CY_{\beta R}$	$CY_{\beta RV}$	$CY_{\beta \alpha V}$	f20	f21	$CY_{\delta r}$	$CY_{\delta r} f_{19}$	
M \ Associated Card	$M.CM_{\dot{\alpha}}$								
0	.17	-.3449	-.220	0	0	0	.092	0	
.5	.19	-.3518	-.245	0	-.005	0	.092	.0092	
.7	.24	-.3736	-.292	.225	-.017	.012	.092	.019	
.9	.44	-.4085	-.305	.225	-.032	.018	.096	.031	
1.0	.77	-.4246	-.310	0	-.049	0	.095	.039	
1.05	1.25	-.4246	-.317	.075	-.068	.027	.080	.045	
1.10	1.49	-.4441	-.326	.275	-.098	.088	.079	.065	
1.15	1.27	-.4206	-.336	.440	-.109	.145	.083	.079	
1.20	0.92	-.4401	-.359	.750	-.118	.201	.083	.070	
1.40	0.19	-.4332	-.325	.750	-.147	.316	.053	.038	
1.70	0.16	-.4120	-.246	.473	-.110	.222	.096	.083	
2.00	0.16	-.3759	-.220	.440	-.122	.229	.056	.052	
2.50	0.16	-.3300	-.180	.238	-.190	.254	.029	.039	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

REPORT NO. 70/Sim./14

SHEET 2.4

DATE D. J. Foster

AIRCRAFT Arrow Simulator

WEIGHT 55,000 lb.

C. G. POSITION $.29\bar{c}$

PREPARED BY

	1	2	3	4	5	6
Card No.	27	28	29	30	31	32
Derivative Function	$Cn_{\beta R}$	$Cn_{\beta\alpha}$	$Cn_{\delta r}$	$Cn_{\delta r\alpha}$	f22	$Cn_{\delta aR}$
M						
0	.02584	-.0657	-.0412	.0286	0	-.0110
.5	.02690	-.0657	-.0413	.0316	.11	-.0110
.7	.02738	-.1410	-.0419	.0330	.26	-.0110
.9	.02993	-.1770	-.0416	.0295	.40	-.0117
1.0	.04099	-.2173	-.0404	.0198	.52	-.0135
1.05	.05524	-.3071	-.0398	.0240	.61	-.0123
1.10	.04822	-.1963	-.0399	.0300	.78	-.0113
1.15	.03366	-.2197	-.0394	.0328	1.00	-.0118
1.20	.03954	-.2268	-.0386	.0319	1.05	-.0122
1.40	.03386	-.2346	-.0332	.0230	1.02	-.0074
1.70	.01614	-.3116	-.0226	.0256	.98	-.0055
2.00	.01073	-.1156	-.0178	.0230	1.25	-.0050
2.50	.00516	-.0636	-.0173	.0252	1.71	-.0043

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.5
C. G. POSITION	$.29\bar{c}$	DATE	February 1958
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	33	34	35	36	37	38	39	40	
Derivative Function	Mach Followup	$Cn_{\delta a \alpha}$	f23	Cn_r	Cn_p		$Cl_{\beta R}$	$Cl_{\beta\alpha}$	
M									
0	0	.0425	0	-.107	-.0480		-.0150	-.550	
.5	0.50	.0412	.20	-.107	-.0480		-.0135	-.556	
.7	0.70	.0400	.366	-.107	-.0492		-.0100	-.561	
.9	0.90	.0570	.663	-.183	-.0780		-.0150	-.565	
1.0	1.00	.0850	.688	-.233	.1020		-.0280	-.575	
1.05	1.05	.0810	.792	-.181	.0855		-.0505	-.565	
1.10	1.10	.0785	.901	-.136	.0583		-.0515	-.765	
1.15	1.15	.0810	1.002	-.119	.0300		-.0450	-.730	
1.20	1.20	.0930	1.108	-.114	.0083		-.0645	-.765	
1.40	1.40	.0640	1.529	-.104	-.0160		-.0630	-.285	
1.70	1.70	.0470	2.368	-.099	-.0073		-.0725	-.115	
2.00	2.00	.0460	2.804	-.097	.0062		-.0575	-.195	
2.50	2.50	.0460	3.888	-.096	.0062		-.0530	-.350	

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AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.6
C. G. POSITION	.29$\bar{c}$	DATE	February 1958
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	41	42	43	44	45	46	47	48	
Derivative Function	$CL_{\delta r}$	$CL_{\delta r}f_{24}$	$Cl_{\delta a}$	1	Cl_{pR}	$Cl_p.f_{26}$	$Ch_{\theta,e}$	$Ch_{\delta e}$	
Associated Card / M					$-M.Cl_p$	$-M.Cl_p f_{26}$			
0	.00748	.00337	-.0860	16.264	-.17	-.012	.0050	-.0115	
.5	.00808	.00374	-.0869	16.264	-.17	-.015	.0050	-.0115	
.7	.00877	.00491	-.0899	16.264	-.185	-.025	.002	-.0120	
.9	.00955	.00649	-.0970	16.476	-.238	-.064	-.002	-.0200	
1.0	.0100	.00720	-.0940	16.914	-.345	-.122	-.008	-.0329	
1.05	.01032	.00826	-.0888	17.355	-.425	-.166	.006	-.0333	
1.10	.01083	.01040	-.0825	18.336	-.495	-.223	.020	-.0326	
1.15	.01139	.01287	-.0755	17.865	-.445	-.218	.017	-.0315	
1.20	.01137	.01330	-.0688	17.934	-.400	-.205	.032	-.0305	
1.40	.00927	.01130	-.0440	19.514	-.352	-.228	.042	-.0262	
1.70	.00735	.00985	-.0340	18.935	-.350	-.274	.038	-.0201	
2.00	.00601	.00962	-.02640	18.974	-.350	-.320	.027	-.0153	
2.50	.00393	.00668	-.0135	18.974	-.350	-.372	.016	-.0107	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.7
C. G. POSITION	$.29\bar{c}$	DATE	Feb. '58
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	49	50	51	52	53	54	55	56	
Derivative Function	$Ch_{\alpha, e}$	$Ch_{e,a}$	$Ch_{\delta a}$	$Ch_{\alpha, a}$	$Ch_{\beta, r}$	$Ch_{\delta r}$	M	M	
M									
0	-.0028	-.003	-.0072	-.0049	.0025	-.0055	0	0	
.5	-.0028	-.003	-.0072	-.0049	.0025	-.0055	.50	.50	
.7	-.0031	-.002	-.0080	-.0058	.0025	-.0060	.70	.70	
.9	-.0028	-.003	-.0099	-.0088	.00245	-.0075	.90	.90	
1.0	-.0030	-.012	-.0178	-.0151	.00284	-.0088	1.00	1.00	
1.05	-.0120	.009	-.0230	-.0182	.00431	-.0098	1.05	1.05	
1.10	-.0130	.024	-.0194	-.0156	.00848	-.0104	1.10	1.10	
1.15	-.0136	.035	-.0194	-.0215	.00536	-.0104	1.15	1.15	
1.20	-.0128	.048	-.0185	-.0207	.00648	-.0100	1.20	1.20	
1.40	-.0134	.027	-.0179	-.0206	.00572	-.0104	1.40	1.40	
1.70	-.0132	.020	-.0176	-.0204	.00152	-.0160	1.70	1.70	
2.00	-.0124	.005	-.0154	-.0165	.00277	-.0090	2.00	2.00	
2.50	-.0116	-.010	-.0132	-.0125	.00380	-.0075	2.50	2.50	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT - Arrow Simulator

WEIGHT - 55,000 lb.

C. G. POSITION - $.29\bar{c}$

REPORT NO. - 70/Sim./14

SHEET - 2.8

DATE - February 1958

PREPARED BY - D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	57	58	59	60	61	62	63		
Derivative Function	$f(M)p_o/M^2$	α_o	$\alpha_o f_2$	$CM_{\delta e}{}^2$	$Ch_{\delta a}$	$Ch_{\alpha, a}$	$CY_{\beta\alpha}$		
M									
0	1480.	.05	0	0	-.0072	-.0049	-.00172		
.5	1560.	.10	.04	.000040	-.0072	-.0049	-.00172		
.7	1671.9	.25	.096	.000076	-.0080	-.0058	-.00229		
.9	1806.1	.30	.168	.000128	-.0099	-.0088	-.00401		
1.0	1889.6	.50	.235	.000100	-.0178	-.0151	-.00688		
1.05	1936.	.37	.395	.000072	-.0230	-.0182	-.00516		
1.10	1981.2	.47	.498	.000072	-.0194	-.0156	-.00573		
1.15	2024.	.36	.548	.000052	-.0194	-.0215	-.00458		
1.20	2068.5	.24	.540	.000046	-.0185	-.0207	-.00458		
1.40	2212.6	.63	1.010	.000017	-.0179	-.0206	.00172		
1.70	2360.6	.19	1.084	-.000005	-.0176	-.0204	-.00115		
2.00	2455.1	-.43	1.052	0	-.0154	-.0165	-.00229		
2.50	2548.3	-.15	.968	0	-.0132	-.0125	-.00229		
				NOTE:-					
				PER $(\text{DEGREE})^2$					

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.9
C. G. POSITION	.29$\bar{c}$	DATE	February 1958
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	65	66	67	68	69	70	71	72	
Function	Altitude Pot	g_1	g_3	g_9	g_{10}	g_{19}	g_{20}	g_{22}	
ASSOCIATED MACH. CARD / ALTITUDE		CL_α	$CL_{\delta e}$	CM_o	$CM_{\delta e}$	$CY_{\delta r}$	$(f_{20}+f_{21})$	$CN_{\delta r}$	
0		1.000	1.000	1.00	1.00	1.00	1.00	1.00	
5,000'		.905	.907	.381	.856	.884	.855	.678	
10,000'		.805	.814	.759	.725	.786	.738	.530	
15,000'		.710	.722	.647	.615	.697	.647	.462	
20,000'		.616	.632	.544	.515	.611	.575	.445	
25,000'		.535	.546	.458	.425	.534	.499	.398	
30,000'		.465	.462	.385	.347	.459	.420	.316	
35,000'		.396	.388	.319	.281	.388	.351	.256	
40,000'		.322	.325	.260	.227	.320	.298	.223	
50,000'		.212	.218	.178	.145	.214	.209	.151	
60,000'		.135	.142	.118	.083	.136	.136	.102	
70,000'		.070	.089	.072	.035	.070	.070	.072	
80,000'		.025	.046	.034	.009	.025	.025	.047	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.10
C. G. POSITION	$.29\bar{c}$	DATE	February 1958
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	73	74	75	76	77	78	79	80	
Function	g_{23}; g_{25}	g_{24}	g_{26}	g_{30}	g_{31}	g_{32}	g_{33}	g_{34}	
ASSOCIATED MACH CARD / ALTITUDE	$Cl_{\delta a}$; $Cn_{\delta a}$	$Cl_{\delta r}$	Cl_p	Mil Thrust	Mil Thrust	Mil Thrust	A/B Thrust	A/B Thrust	
0	1.00	1.00	1.00	12,988.	1732.5	2544.3	18,475.	4004.8	
5,000'	.842	.810	.871	10,590.	4080.	3540.	17,730.	-3600.	
10,000'	.711	.685	.770	8,180	6380.	4560.	17,150.	-10,280.	
15,000'	.599	.608	.685	5,965.	8617.6	5593.1	16,848.	-19,251.	
20,000'	.505	.548	.609	5320.	6280.	3670.	17,240.	-26,809.	
25,000'	.419	.477	.544	4675.3	4711.3	2009.3	24,024.	-53,016.	
30,000'	.344	.403	.482	4000.	3050.	780	32,205.	-71,860.	
35,000'	.286	.352	.420	3346.8	1595.3	-340.1	26,028.	-57,026.	
40,000'	.237	.304	.361	2300.	2550.	220.	25,094.	-56,346.	
50,000'	.1575	.222	.257	-200	3840.	1090.	8172.1	-15,987.	
60,000'	.1015	.167	.175	-711.1	3390.4	1114.9	7533.0	-13078.	
70,000'	.072	.112	.053	-440.7	2101.1	690.95	4318.3	-7496.8	
80,000'	.047	.057	0	-257.5	1228.1	403.8	2434.9	-4227.3	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator	REPORT NO.	70/Sim./14
WEIGHT	55,000 lb.	SHEET	2.11
C. G. POSITION	$.29\bar{c}$	DATE	February 1958
		PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	81	82	83	84	85	86	87	88	
Function	g_{35}	g_{36}		a		$\frac{ap}{a_0p_0}$	$\frac{ap}{a_0p_0}$	$\frac{ap}{a_0p_0}$	
REMARKS / ALTITUDE	AB Thrust	A/B Thrust				input p	input q	input r	
0	15,501.	-10,149		1/1,116		1.00	1.00	1.00	
5,000'	24,400.	-11,290		1/1097		.8473	.8473	.8473	
10,000'	31,700.	-13,500		1/1077		.7122	.7122	.7122	
15,000'	38,018.	-14,757		1/1057		.5957	.5957	.5957	
20,000'	42,069.	-14,631		1/1037		.4952	.4952	.4952	
25,000'	63,761.	-19,853		1/1017		.4081	.4081	.4081	
30,000'	72,142.	-20,132		1/995		.3336	.3336	.3336	
35,000'	56,358.	-15,115		1/972		.2665	.2665	.2665	
40,000'	53,763.	-14,334		1/972		.2134	.2134	.2134	
50,000'	18,294.	-5242.1		1/972		.1324	.1324	.1324	
60,000'	12,040.	-3158		1/972		.0819	.0819	.0819	
70,000'	6901.8	-1810.3		1/972		.0505	.0505	.0505	
80,000'	3891.8	-1020.8		1/972		.0300	.0300	.0300	

AVRO AIRCRAFT LIMITED

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT	Arrow Simulator
WEIGHT	55,000 lb.
C. G. POSITION	$.29\bar{c}$
REPORT NO.	70/Sim./14
SHEET	2.12
DATE	February 1958
PREPARED BY	D. J. Foster

	1	2	3	4	5	6	7	8	9
Card No.	89	90	91	92	93	94	95	96	
Function	$a\rho/a_0\rho_0$	$a\rho/a_0\rho_0$		ϑ_2	p/p_0				
REMARKS / ALTITUDE	Input $\dot{\alpha}$	Input αp		MACH CARD α_0					
0	1.00	1.00		1.00	1.0				
5,000'	.8473	.8473		.891	.832				
10,000'	.7122	.7122		.783	.688				
15,000'	.5957	.5957		.673	.564				
20,000'	.4952	.4952		.572	.460				
25,000'	.4081	.4081		.491	.371				
30,000'	.3336	.3336		.422	.297				
35,000'	.2665	.2665		.360	.235				
40,000'	.2134	.2134		.301	.185				
50,000'	.1324	.1324		.210	.115				
60,000'	.0819	.0819		.143	.0708				
70,000'	.0505	.0505		.093	.044				
80,000'	.0300	.0300		.052	.028				

AIRCRAFT:		PREPARED BY	DATE
	Arrow Flight Simulator	D. J. Foster	Feb. '58
		CHECKED BY	DATE

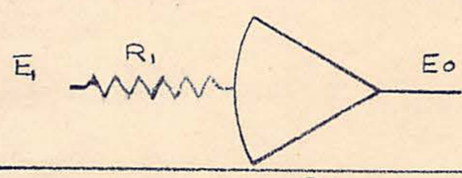
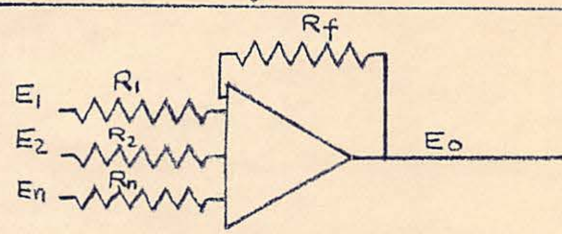
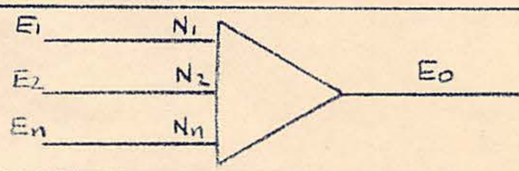
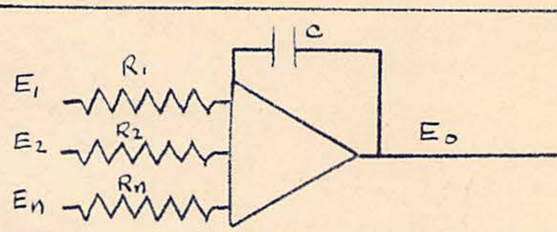
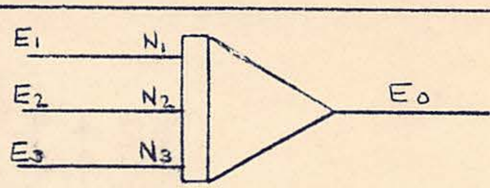
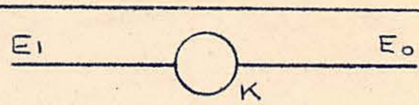
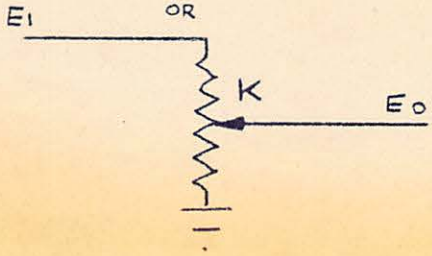
List of Circuit Diagrams

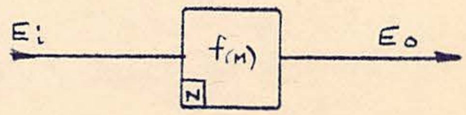
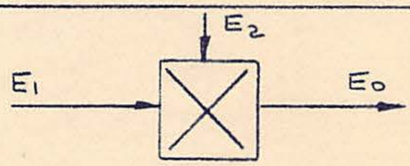
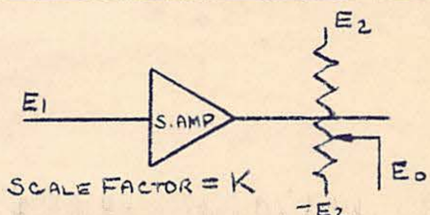
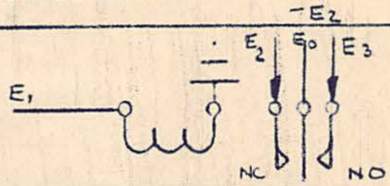
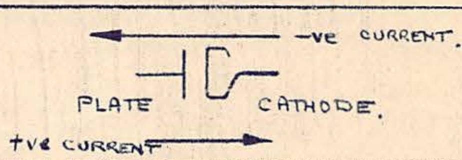
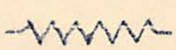
Note:-

Since the circuit diagrams were drawn, there have been a number of minor modifications made, but these do not invalidate the general schemes outlined for the mechanization of the equations.

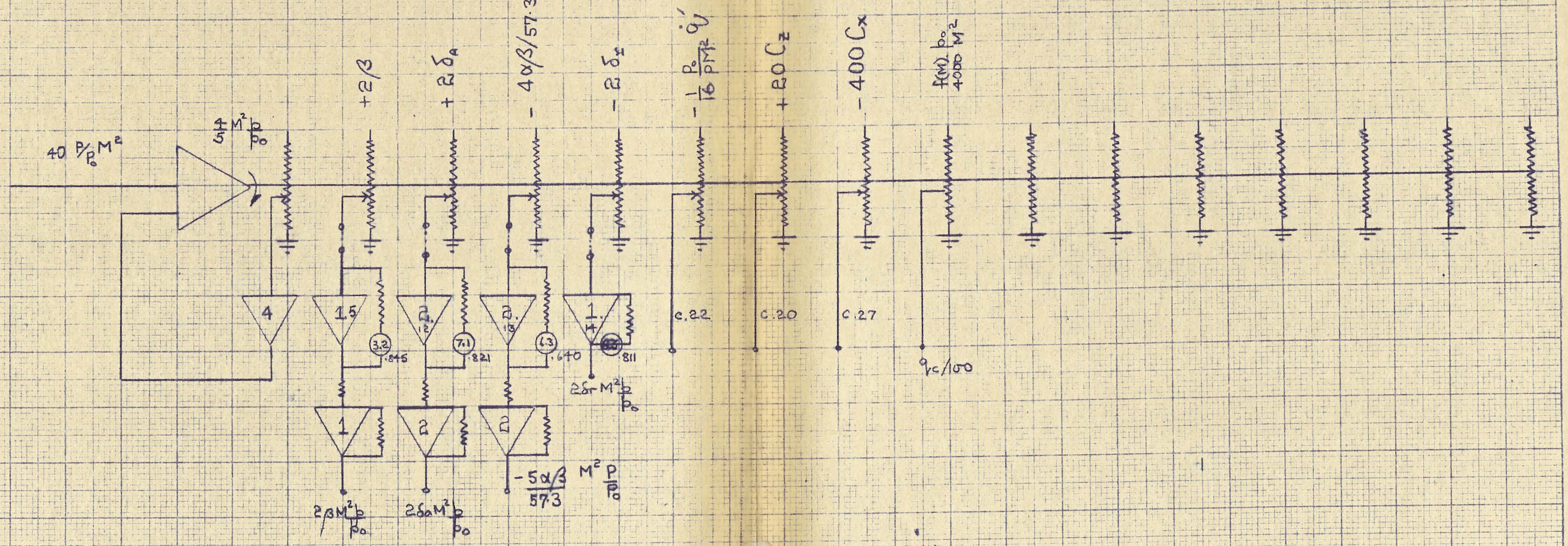
Sheet No.	Title
3.1	Lift Equation
3.2	Drag Equation
3.3	Sideslip Equation
3.4	Pitch Equation
3.5	Roll Equation
3.6	Yaw Equation
3.7	Altitude Equation
3.8	Thrust Computation
3.9	Reeves Servo Utilisation
3.10	$M^2 p/p_o$ Servo Utilisation
3.11	High incidence effects on pitching moment coefficient
3.12	High incidence effects on sideslip derivatives
3.13	Ground Reaction Circuit
3.14	Ground Effect on Pitching moment coefficient
3.15	Undercarriage switching circuits
3.16	Rudder rate limiting circuit (due to hinge moments)
3.17	Function Generator Utilisation
3.18	Euler angle resolution circuit
3.19	Rate of turn and compass heading
3.20	Aircraft display circuit
3.21	Fixed gain pitch damper circuit
3.22	Fixed gain roll damper circuit
3.23	Fixed gain yaw damper circuit
3.24	Variable gain yaw damper circuit
3.25	Ay monitor circuit

EXPLANATION OF SYMBOLS USED IN CIRCUIT DIAGRAMS

SYMBOL	MEANING
	High Gain Amplifier. $Eo = -10^7 \frac{E1}{R1}$
	Summing amplifier. Adds to together several inputs and multiplies by a constant. $Eo = -Rf \frac{E_1}{R_1} + \frac{E_2}{R_2} + \dots + \frac{En}{Rn}$
	Same as above $Eo = -(N_1E_1 + N_2E_2 + \dots\dots NnEn)$
	Integrating amplifier. Adds together several inputs and integrates them w.r. to time $Eo = -\frac{1}{c}\int \frac{E_1}{R_1} + \frac{E_2}{R_2} + \frac{En}{Rn} .dt$
	Same as above $-Eo = \int N_1E_1 + N_2E_2 + N_3E_3 .\ dt$
 OR 	Potentiometer $Eo = K.Ei \quad 0 < K < 1$

SYMBOL	MEANING
	Tapped potentiometer with wiper driven off servo shaft. $E_o = E_i . f(M)$ N denotes the function number.
	Multiplier $E_o = E_1 . E_2 \div K$ (sometimes a servo multiplier, sometimes an electronic multiplier
	Servo Multiplier $E_o = K . E_1 . E_2$
	Relay $E_o = E_2 \quad , \quad E_1 \leqslant 0$ $E_o = E_3 \quad , \quad E_1 \geqslant 0$
	Diode
	Resistor
	Ground

$M^2 p/p_0$ SERVO UTILISATION.



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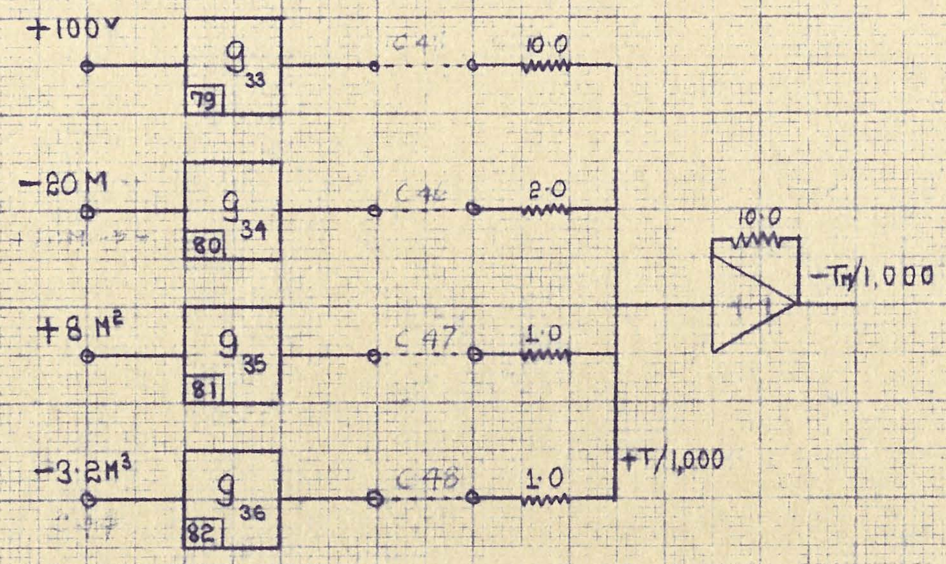
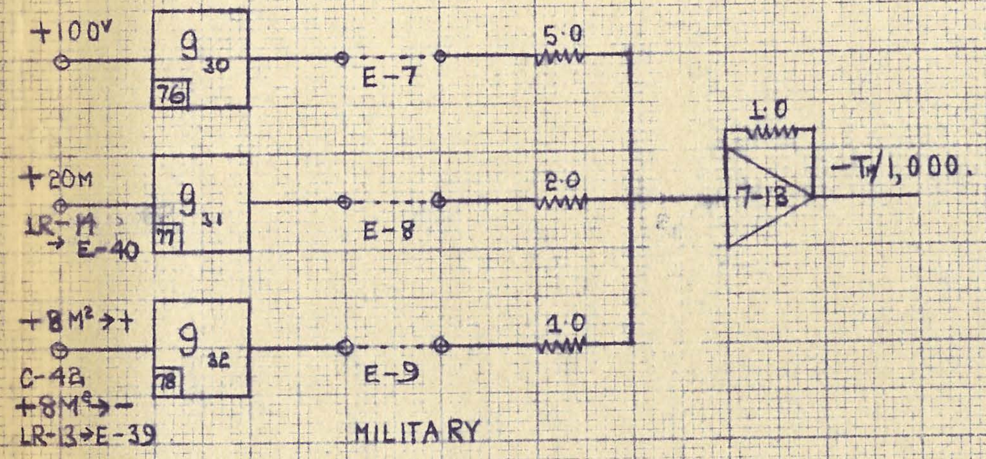
THRUST COMPUTATION

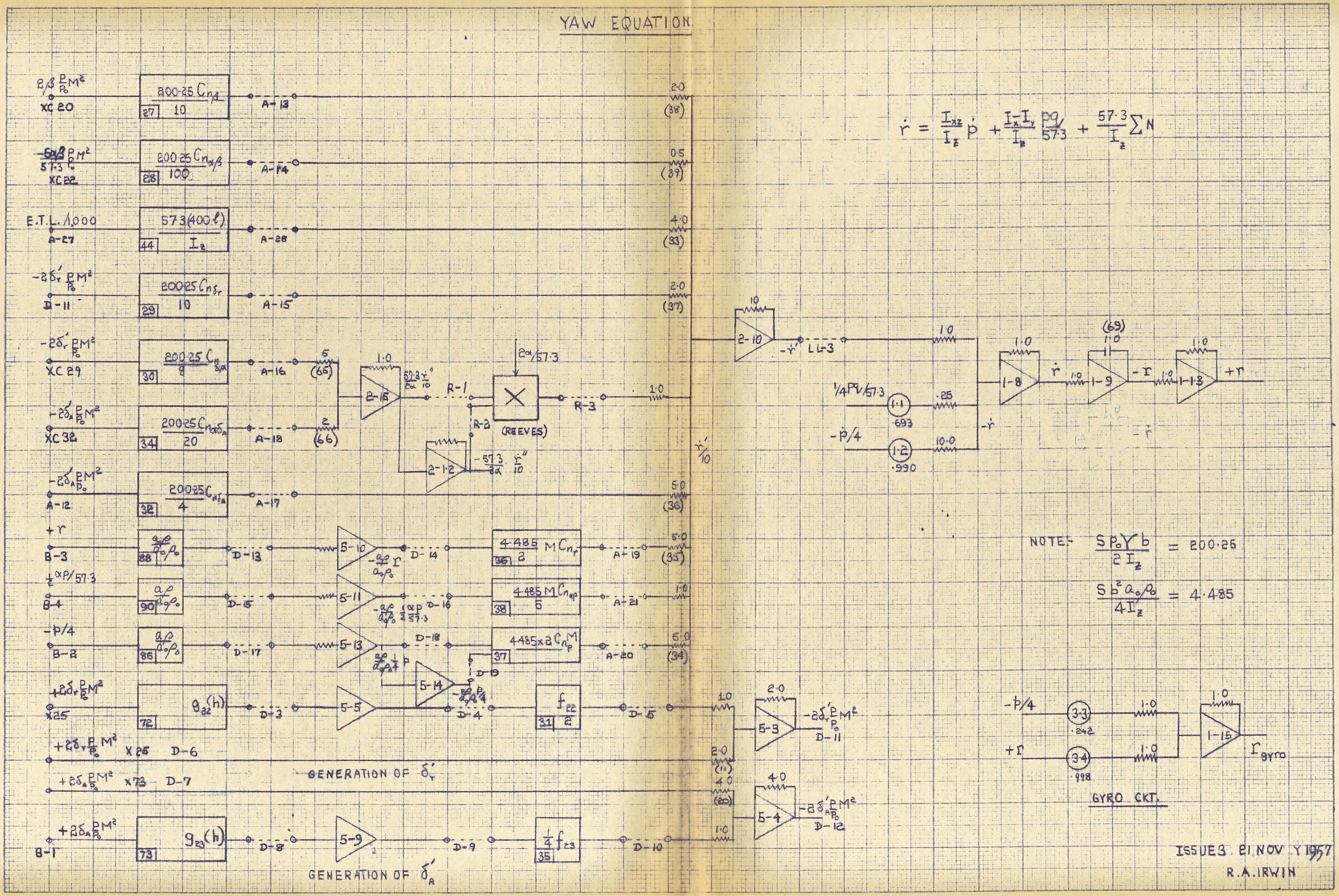


AFTERBURNER



MILITARY

ISSUE 1 R.A. IRWIN 8 DEC 57



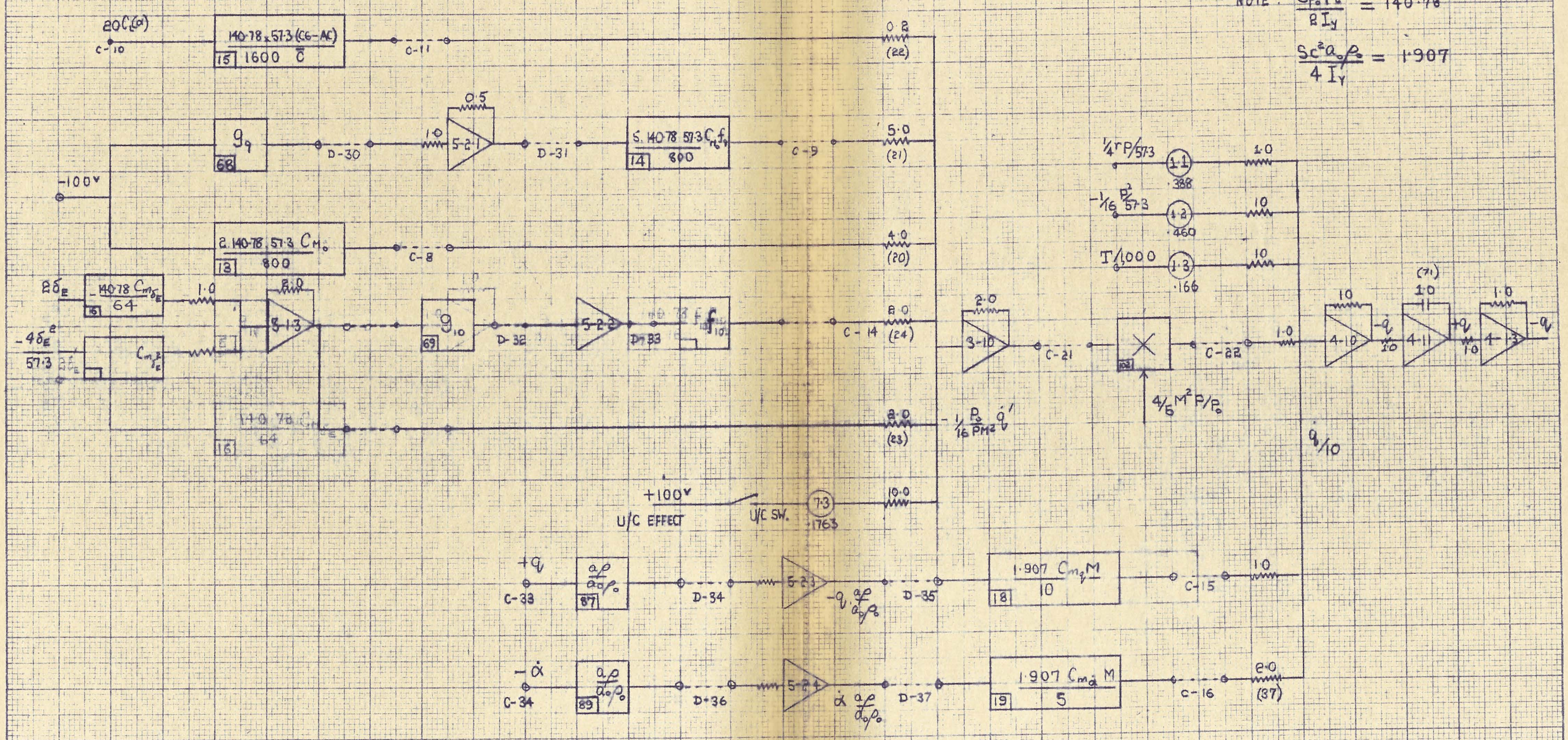
YAW EQUATION.
ṙ = (I_xz / I_z) ṗ + ((I_x − I_y) / I_z)(pq / 57.3) + (57.3 / I_z) ΣN
(REEVES)
GENERATION OF δ′_r
GENERATION OF δ′_A
NOTE:- S P₀ V b / 2 I_z = 200.25
S b² a₀ ρ₀ / 4 I′_z = 4.485
GYRO CKT.
r_gyro
ISSUE 3 21 NOV 1957
R.A. IRWIN

PITCH EQUATION

$$\dot{q} = \frac{I_z - I_x}{I_Y}\frac{rp}{57 \cdot 3} - \frac{I_{xz}}{I_Y}\frac{p^2}{57 \cdot 3} + \frac{57 \cdot 3\, eT}{I_Y} + \frac{57 \cdot 3 \sum M}{I_Y}$$

NOTE :- $\frac{S\rho_0 Y_C}{8 I_Y} = 140 \cdot 78$

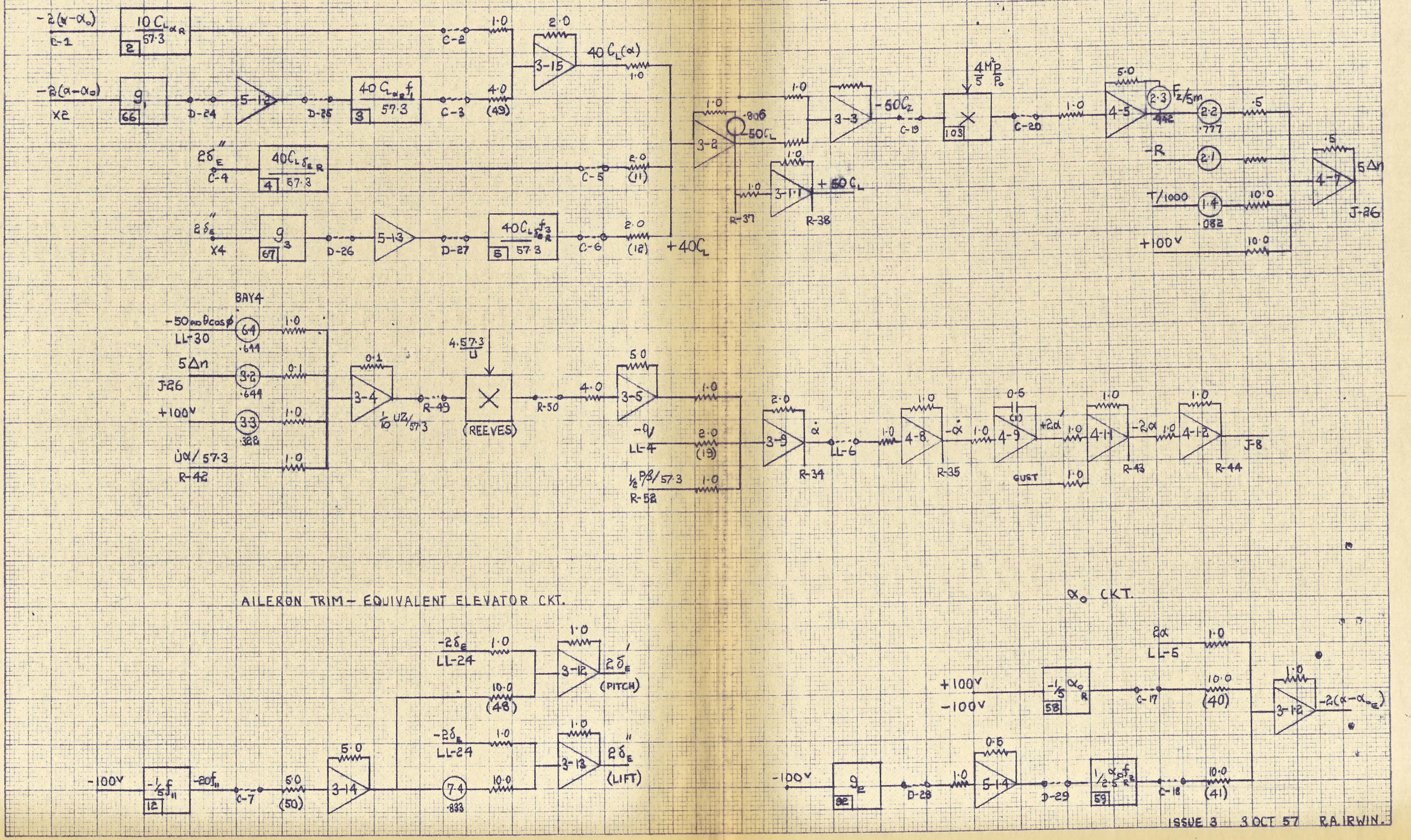
$\frac{Sc^2 a_0 \rho_0}{4 I_Y} = 1 \cdot 907$



ISSUE B 16 SEPT 1957
R.A. IRWIN.

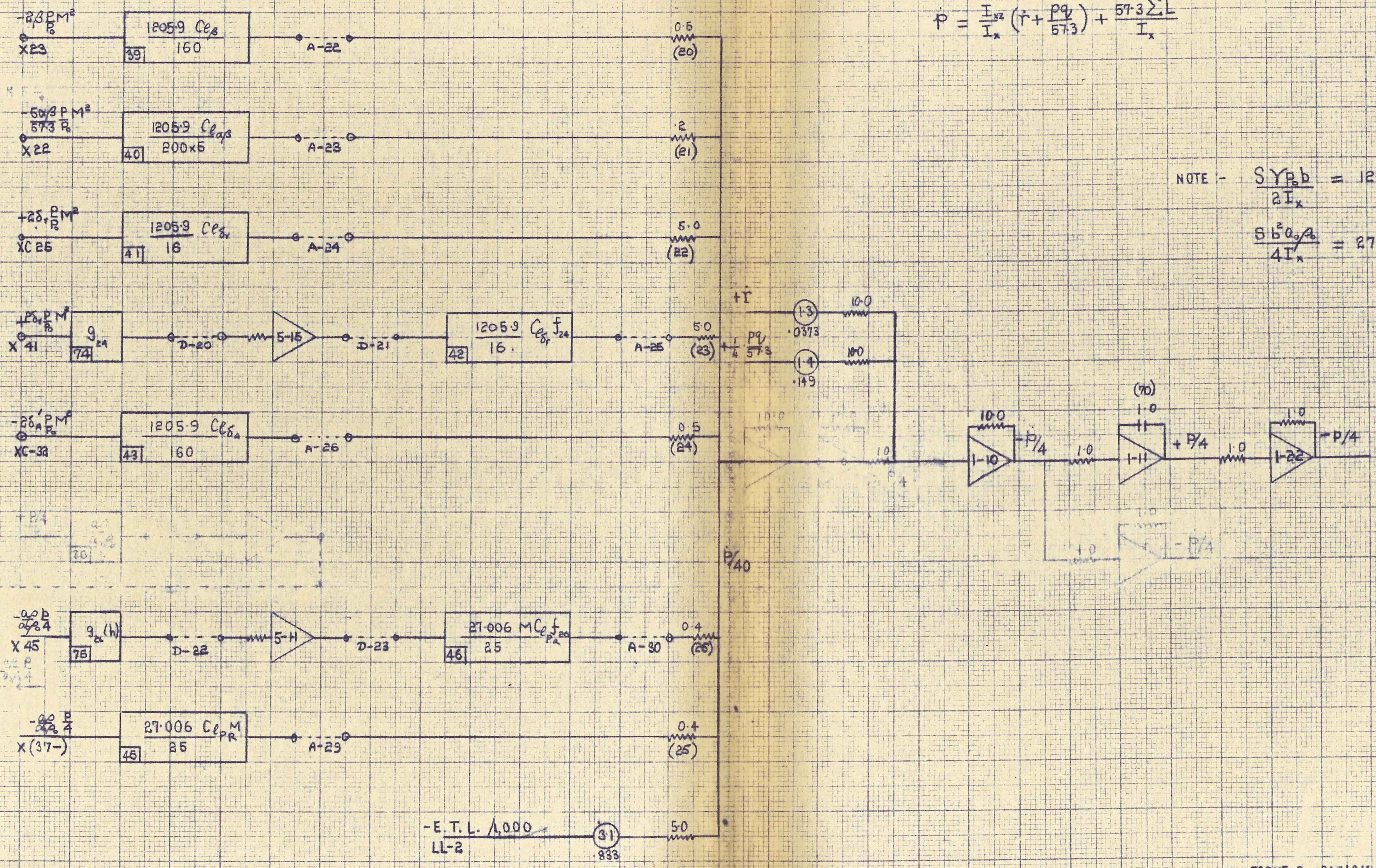
LIFT EQUATION

$$\dot{\alpha} = -\frac{P\beta}{57.3} + q + \frac{57.3}{U}\left[(g\cos\theta\cos\phi) - \dot{u}\alpha + \sum F_z/m\right] \qquad \Delta n = -\sum F_z/mg - 1$$



ROLL EQUATION

$$\dot{P} = \frac{I_{xz}}{I_x}\left(\dot{r} + \frac{pq}{57.3}\right) + \frac{57.3\,\Sigma L}{I_x}$$



NOTE :- $\frac{S\,\gamma P_0 b}{2 I_x} = 1205.9$

$\frac{S\,b^2 a_0/P_0}{4 I_x'} = 27.006$

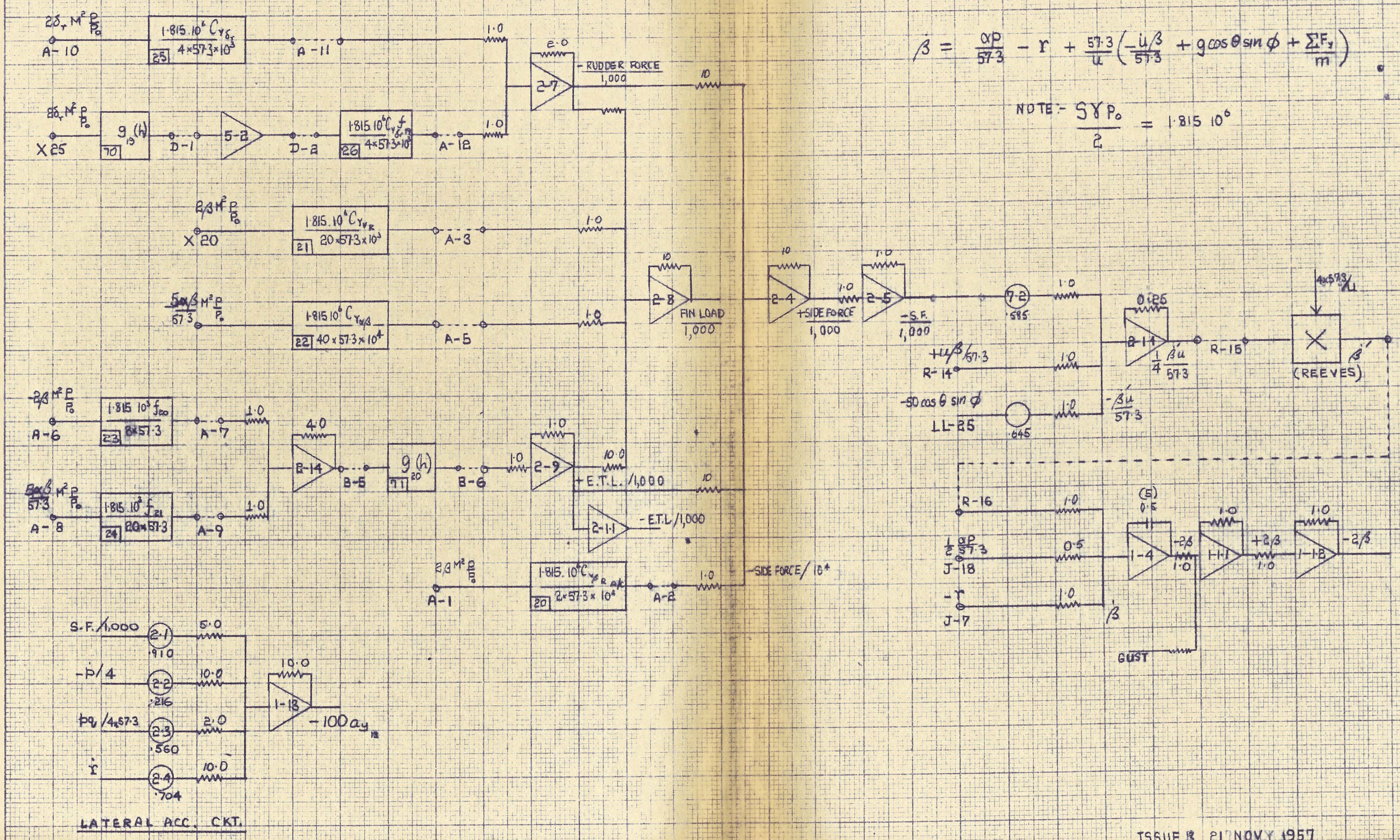
ISSUE 3 21 NOV 1957

R.A. IRWIN.

SIDESLIP EQUATION

$$\beta = \frac{\alpha p}{57 \cdot 3} - r + \frac{57 \cdot 3}{u}\left(\frac{-\dot{u}\beta}{57 \cdot 3} + g\cos\theta\sin\phi + \frac{\Sigma F_y}{m}\right)$$

NOTE :- $\frac{S \gamma P_o}{2} = 1 \cdot 815\ 10^6$

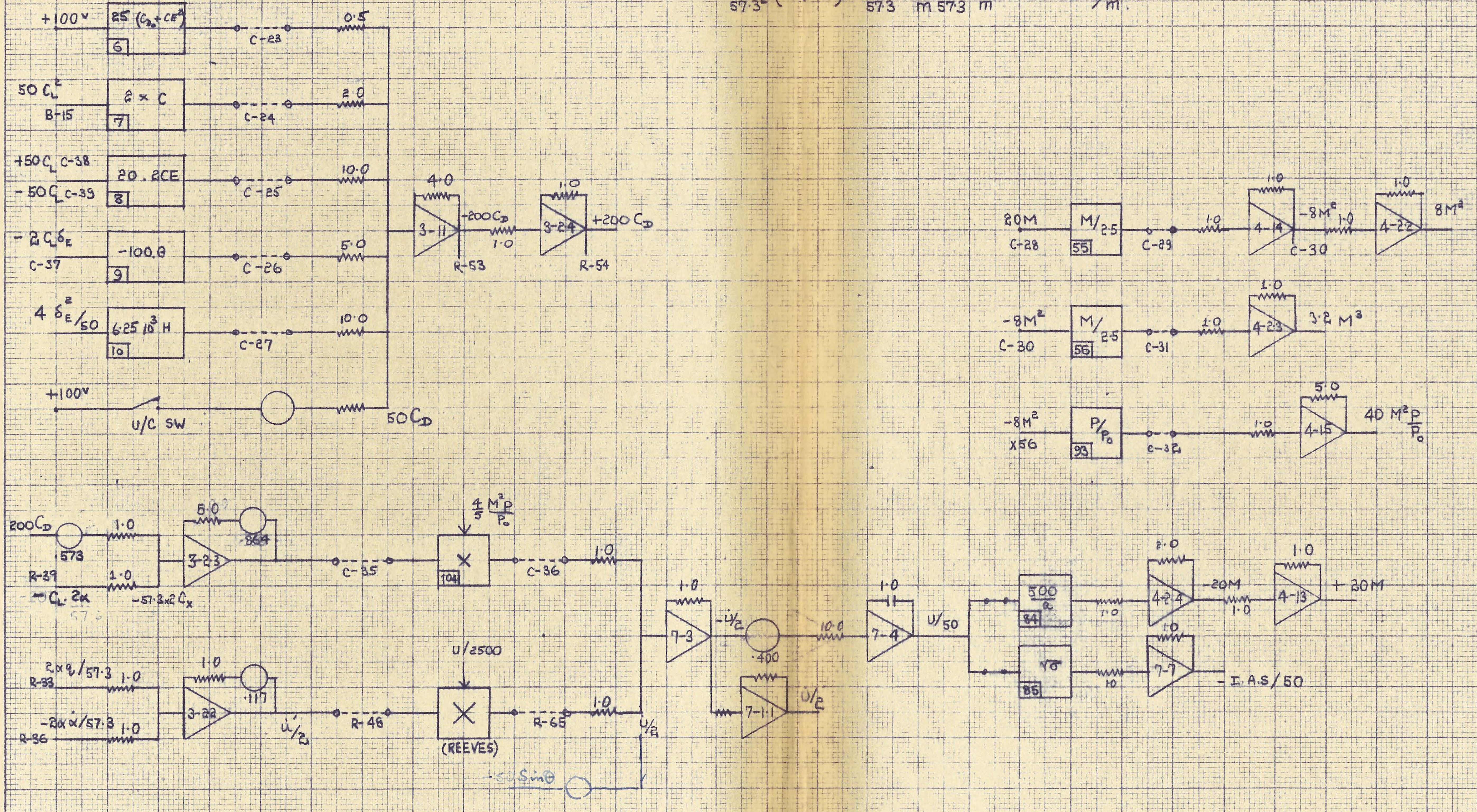


ISSUE 3 21 NOV. 1957

R. A. IRWIN

DRAG EQUATION

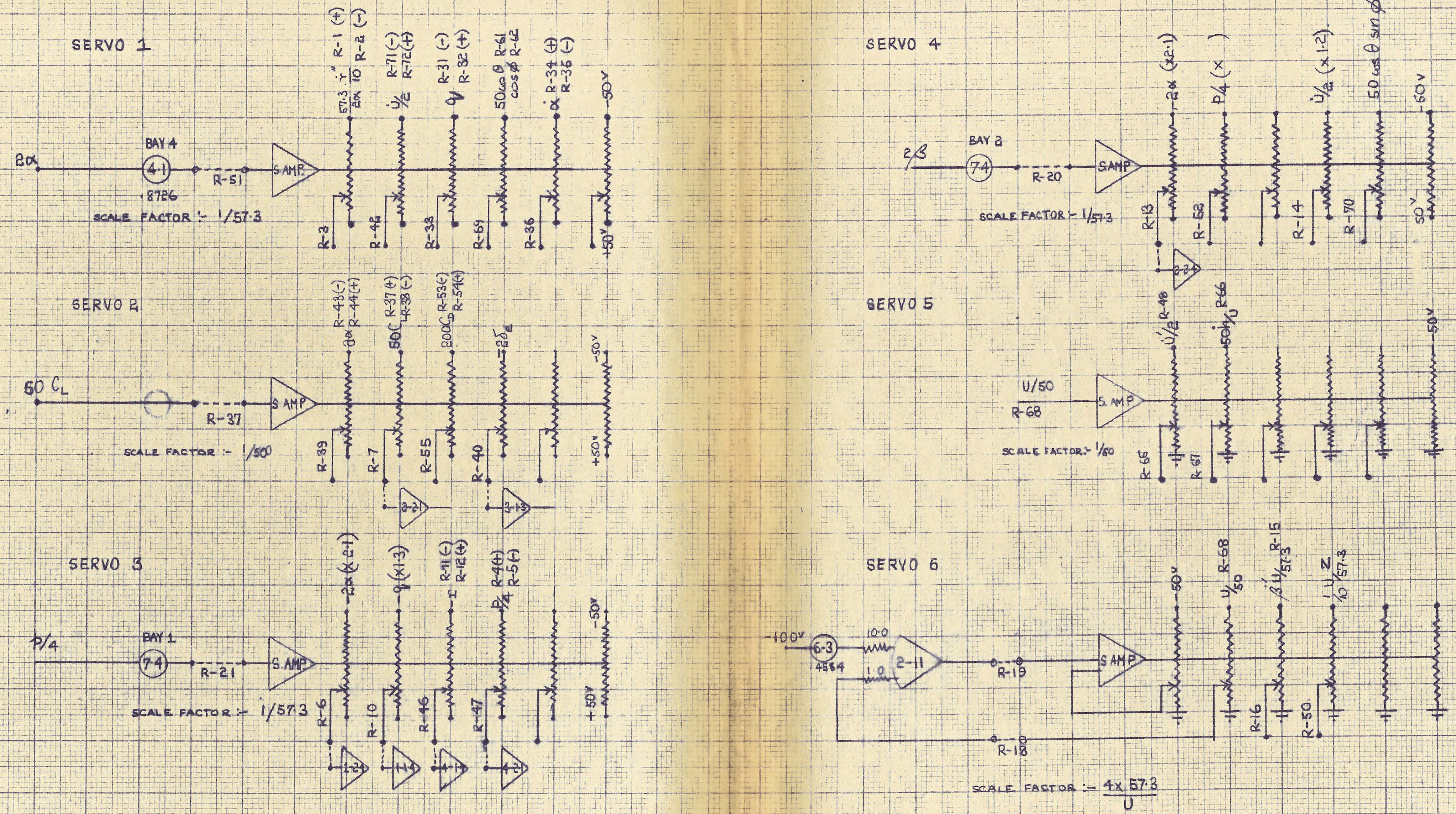
$$\dot{u} = \frac{U\alpha}{57.3^2}\left(-Q+\dot{\alpha}\right) - \frac{g\theta}{57.3} - \frac{R\theta}{m\,57.3} - \frac{T}{m}\cos i + \sum F_x/m.$$



ISSUE 3 19 SEPT 1957

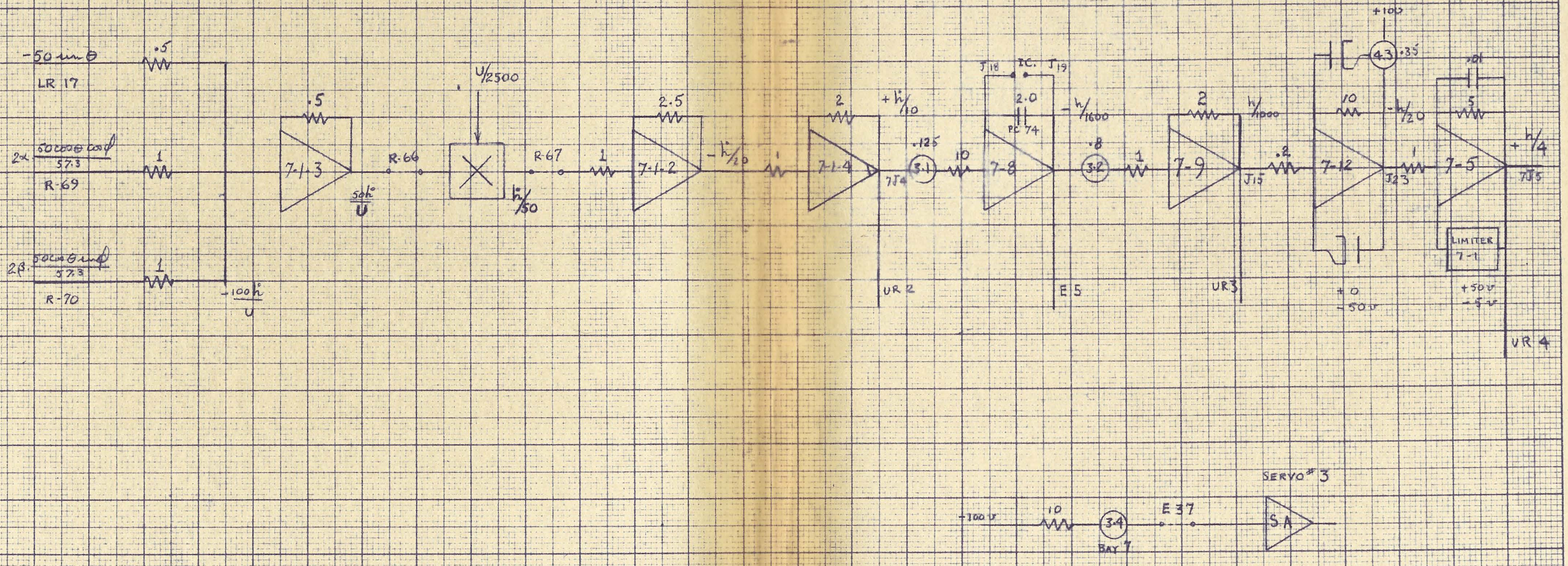
R.A. IRWIN.

REEVES SERVOS

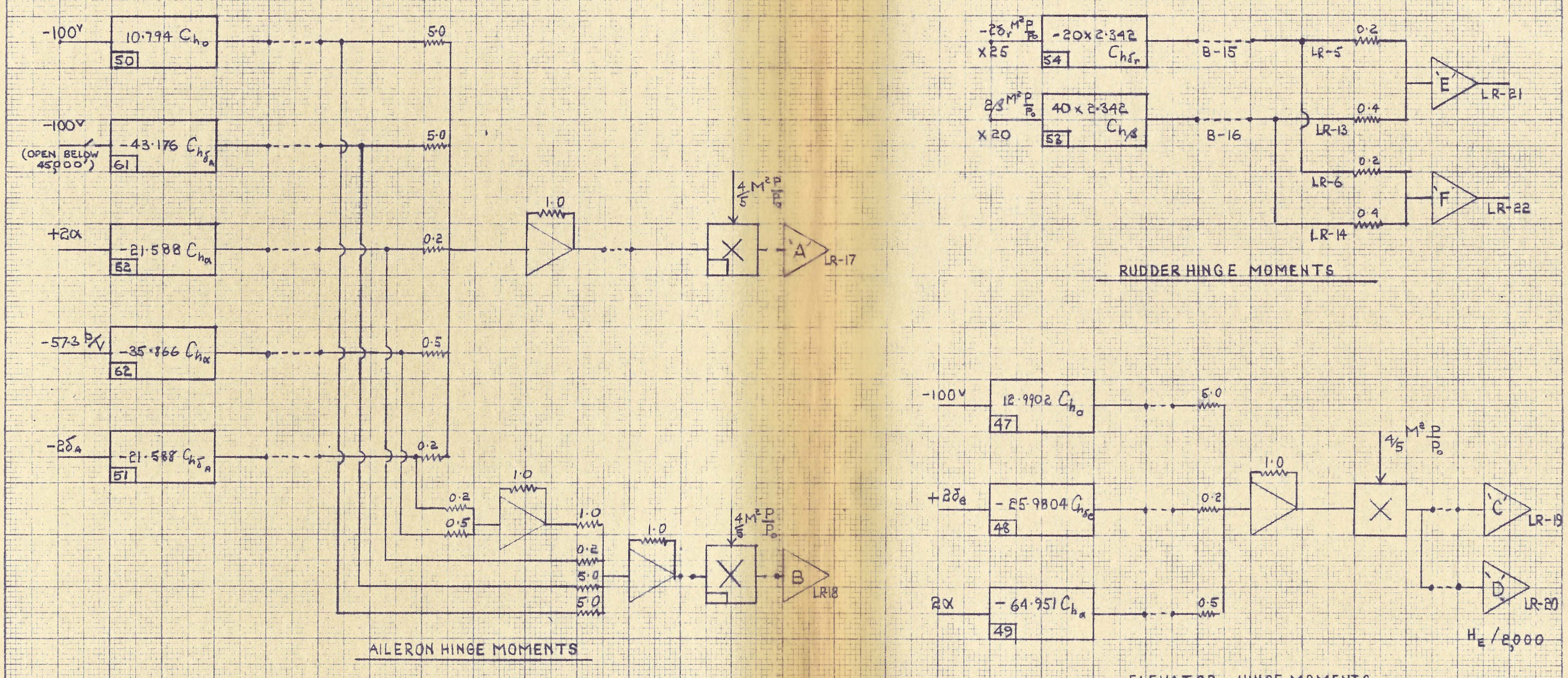


ALTITUDE EQUATION

$$\dot{h} = -U\{\alpha \cos\theta \cos\phi + \beta \cos\theta \sin\phi - \sin\theta\}$$



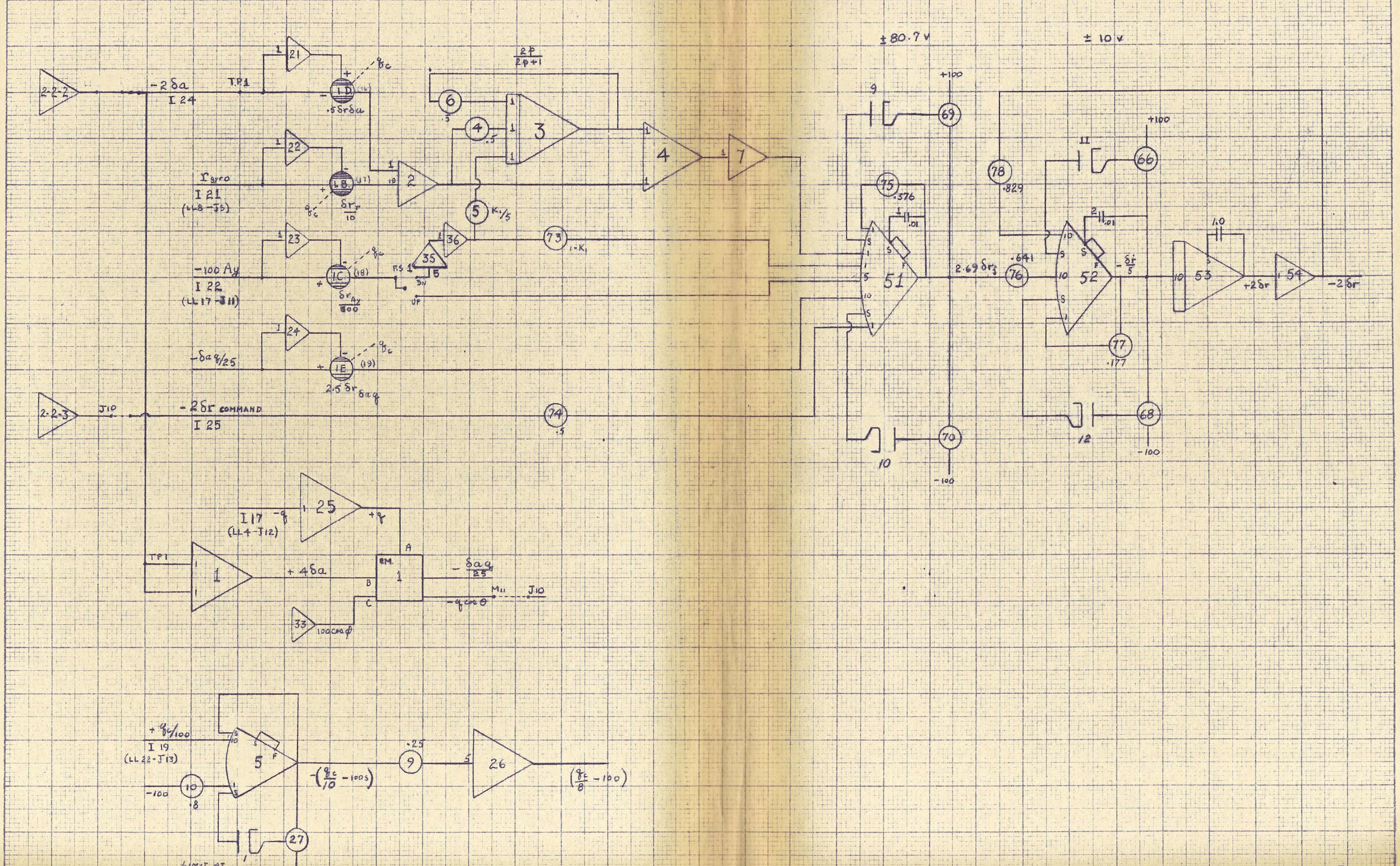
FUNCTION GENERATOR.



ISSUE 1 23 OCT 1957

R.A. IRWIN.

VARIABLE GAIN YAW DAMPER CIRCUIT

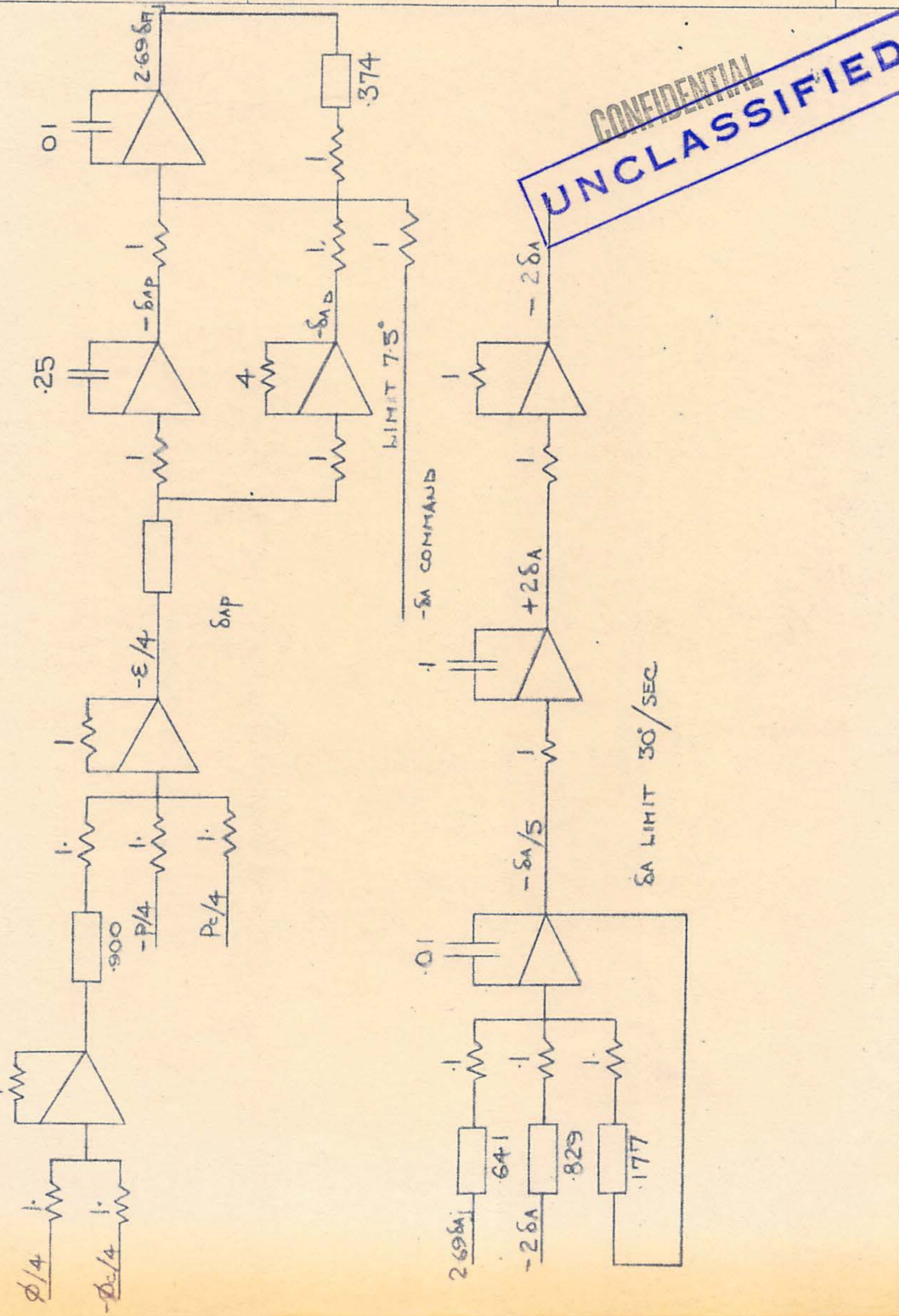


Issue 1, Dec. 18, 1957 K.N.B.

AVRO AIRCRAFT LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: C-105 ROLL DAMPER		REPORT NO.	
		SHEET NO.	
		PREPARED BY	DATE
		N W	AUG 30/57
		CHECKED BY	DATE

CONFIDENTIAL
UNCLASSIFIED



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FORM 1319A

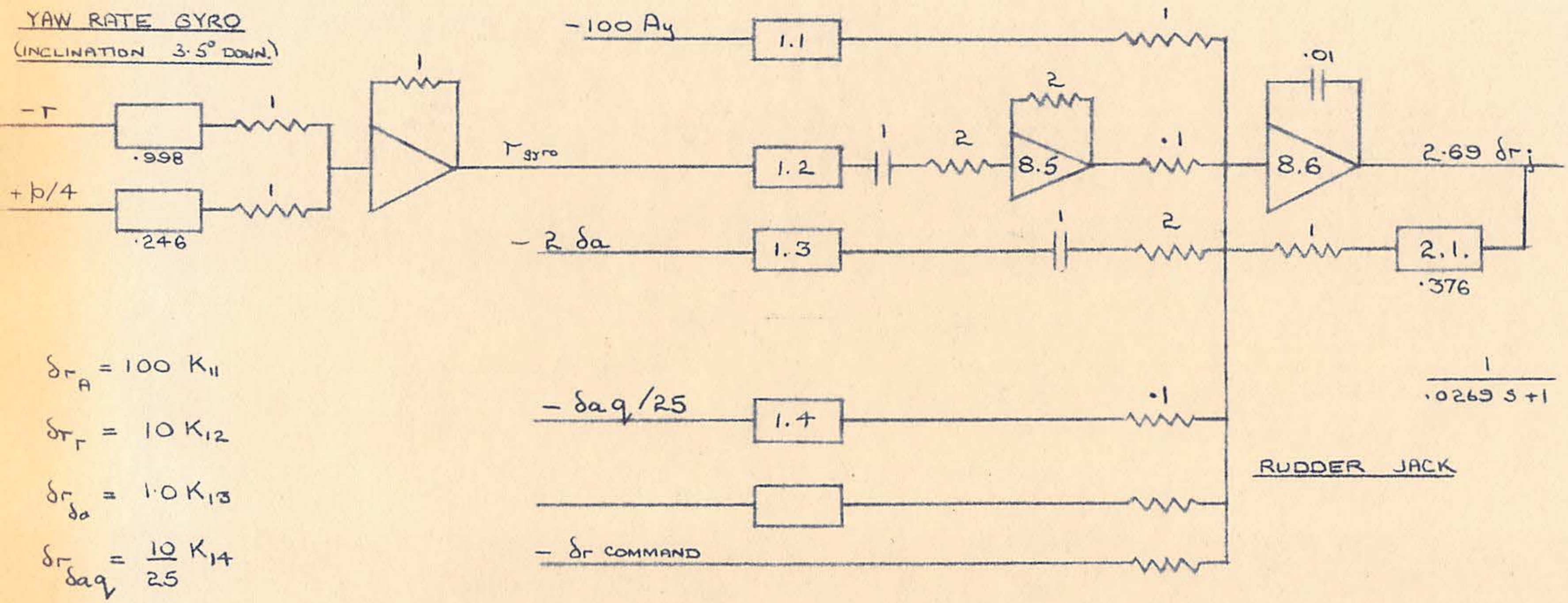
AVRO AIRCRAFT LIMITED
MALTON . ONTARIO

TECHNICAL DEPARTMENT

AIRCRAFT: C-105

RUDDER CONTROL CIRCUIT

REPORT NO.
SHEET NO.
PREPARED BY | DATE
TRACED D. J FOSTER | AUG 30 1957
CHECKED BY | DATE

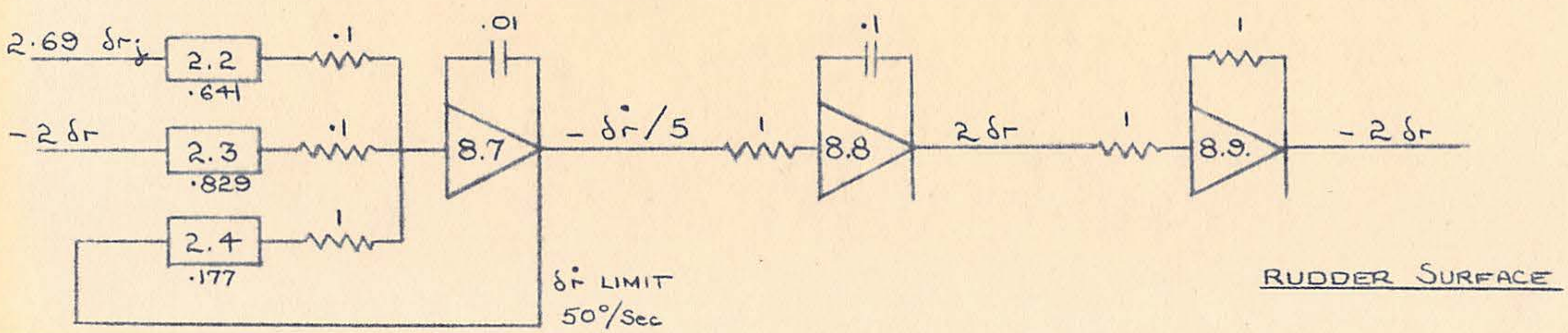


$\delta r_A = 100\ K_{11}$

$\delta r_r = 10\ K_{12}$

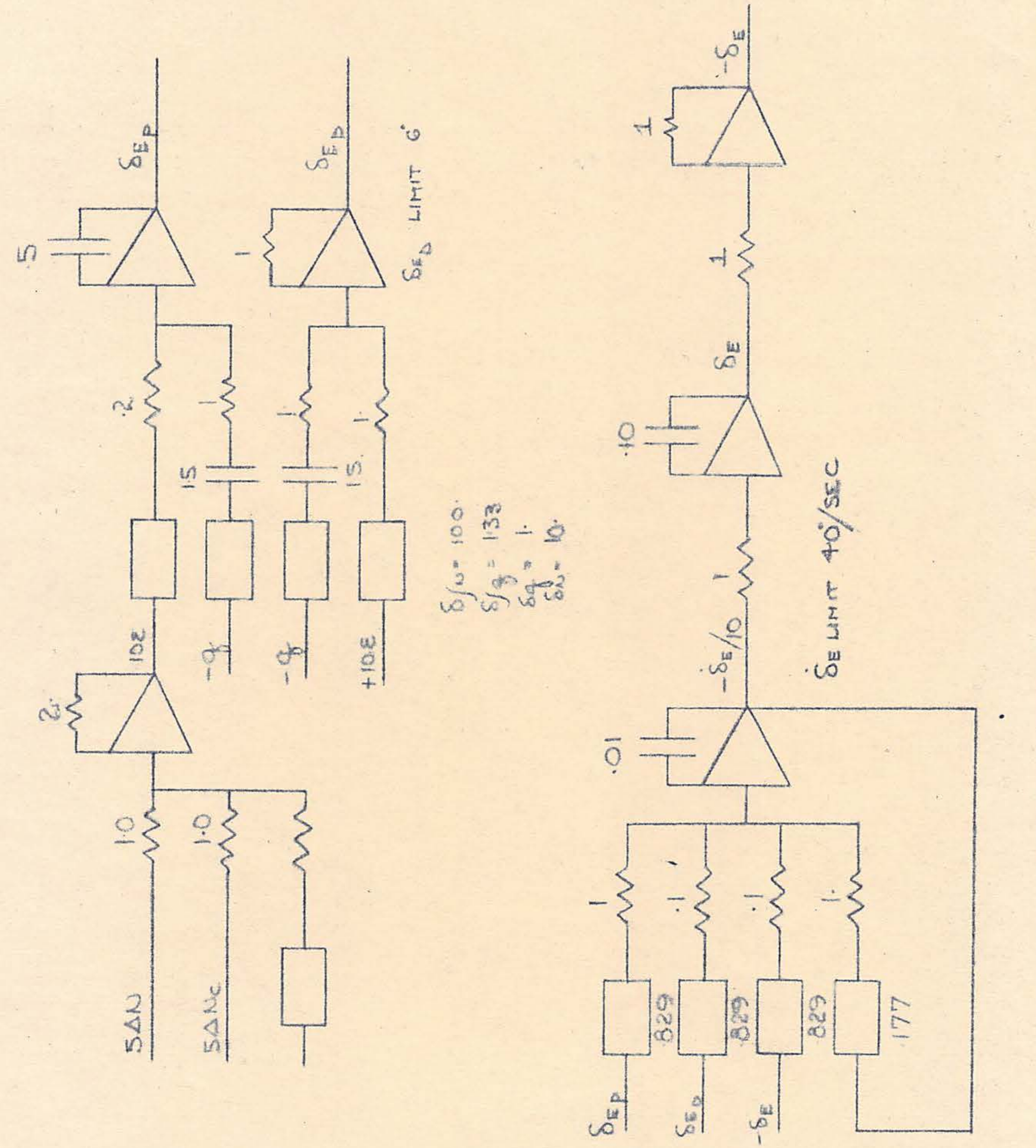
$\delta r_{\delta a} = 1{\cdot}0\ K_{13}$

$\delta r_{\delta aq} = \frac{10}{25}\ K_{14}$



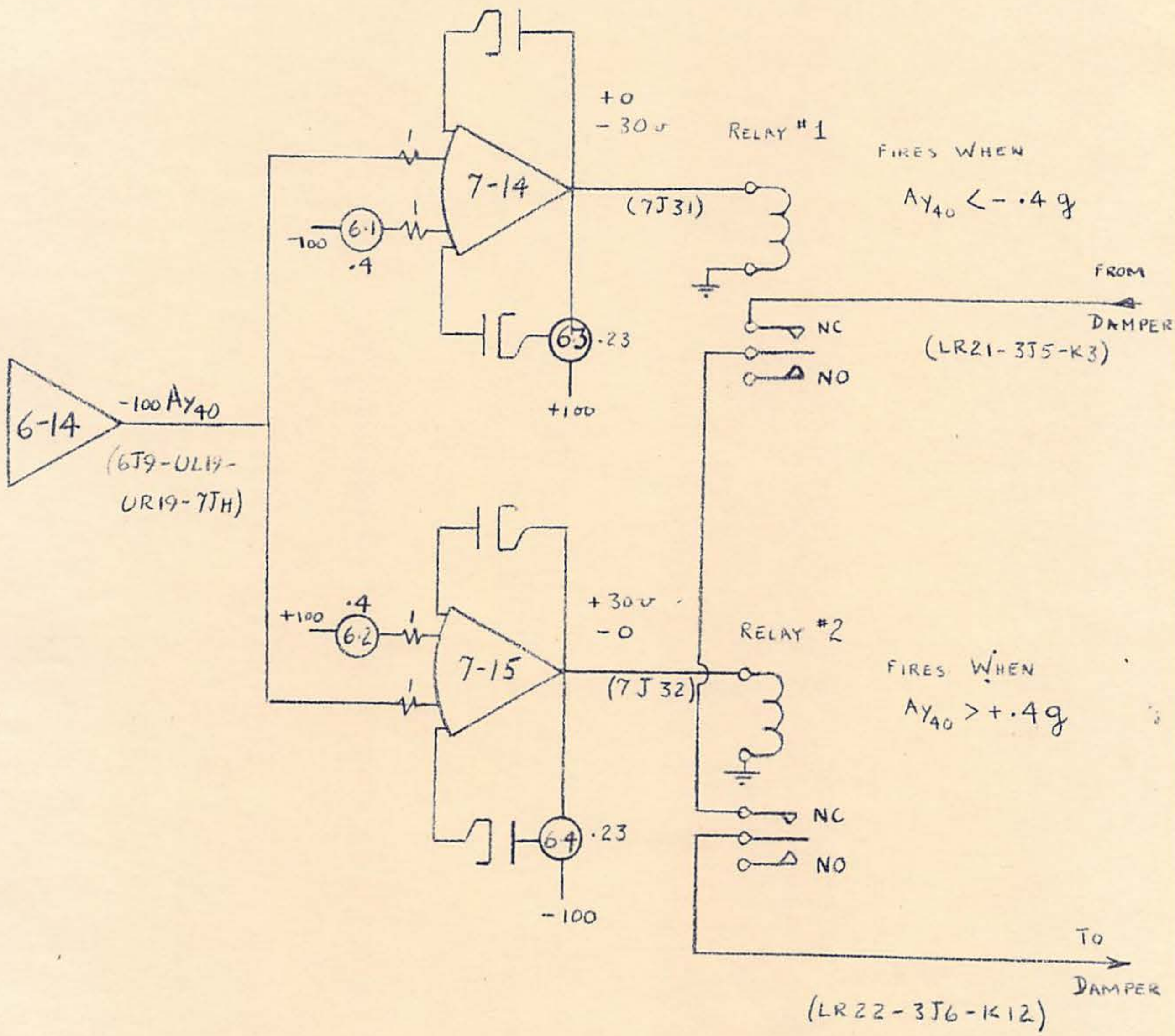
AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

REPORT NO.		
SHEET NO.		
AIRCRAFT: C-105 PITCH DAMPER	PREPARED BY: N.W.	DATE: AUG 30, 1957
	CHECKED BY:	DATE:



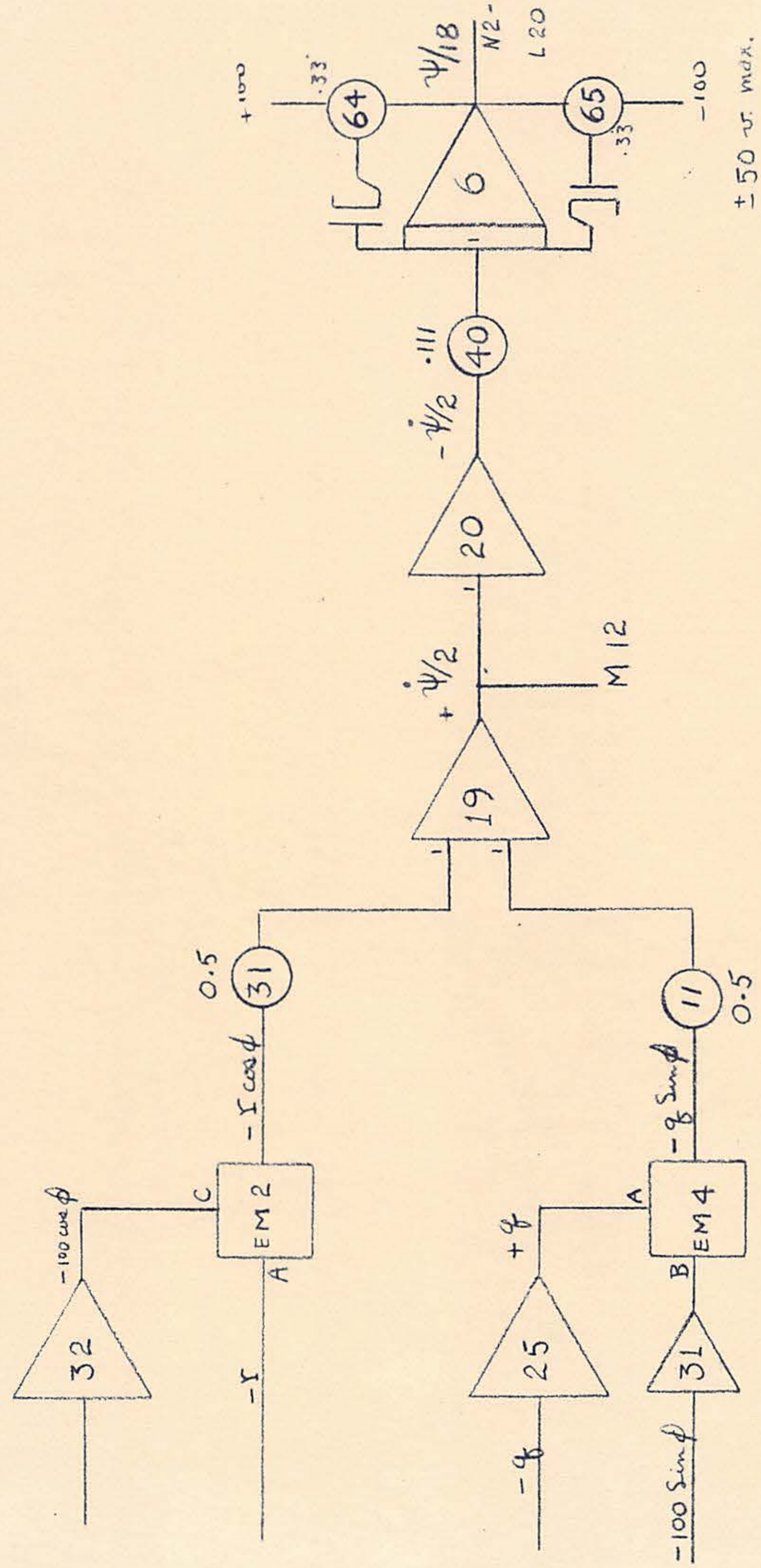
AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT		REPORT NO	
C-105	Ay MONITOR	SHEET NO	
		PREPARED BY: K. Y. Brown	DATE: Jan 14/58
		CHECKED BY	DATE



AVRO AIRCRAFT LIMITED
MALTON ONTARIO
TECHNICAL DEPARTMENT

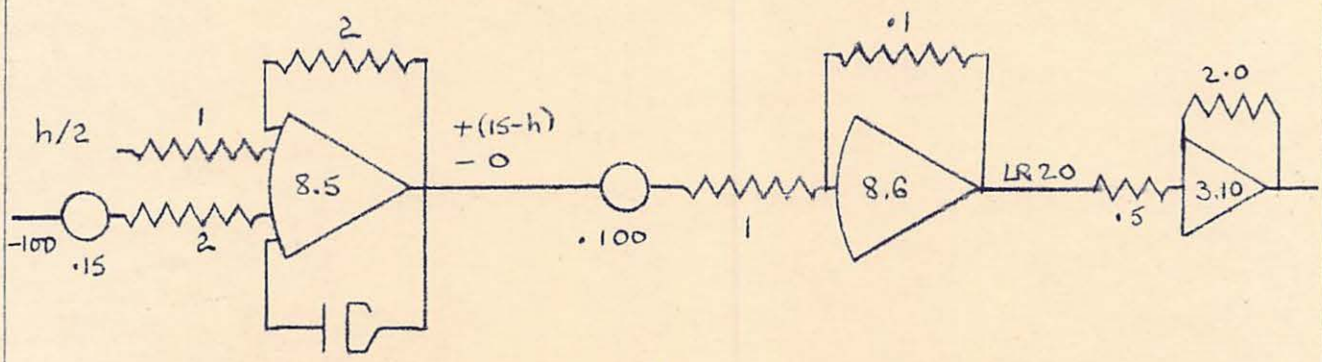
AIRCRAFT		REPORT NO	
C - 105	Rate of Turn and Compass Heading	SHEET NO	
		PREPARED BY: K. H. Braun	DATE: Jan 14/58
		CHECKED BY	DATE

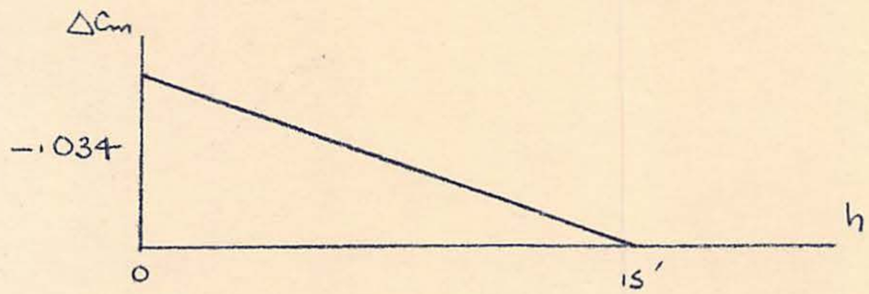


AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO.	
		SHEET No	
		PREPARED BY	DATE
C105	SIMULATOR.	D. J. Foster	Jan 57
		CHECKED BY	DATE

GROUND EFFECT ON PITCHING MOMENT





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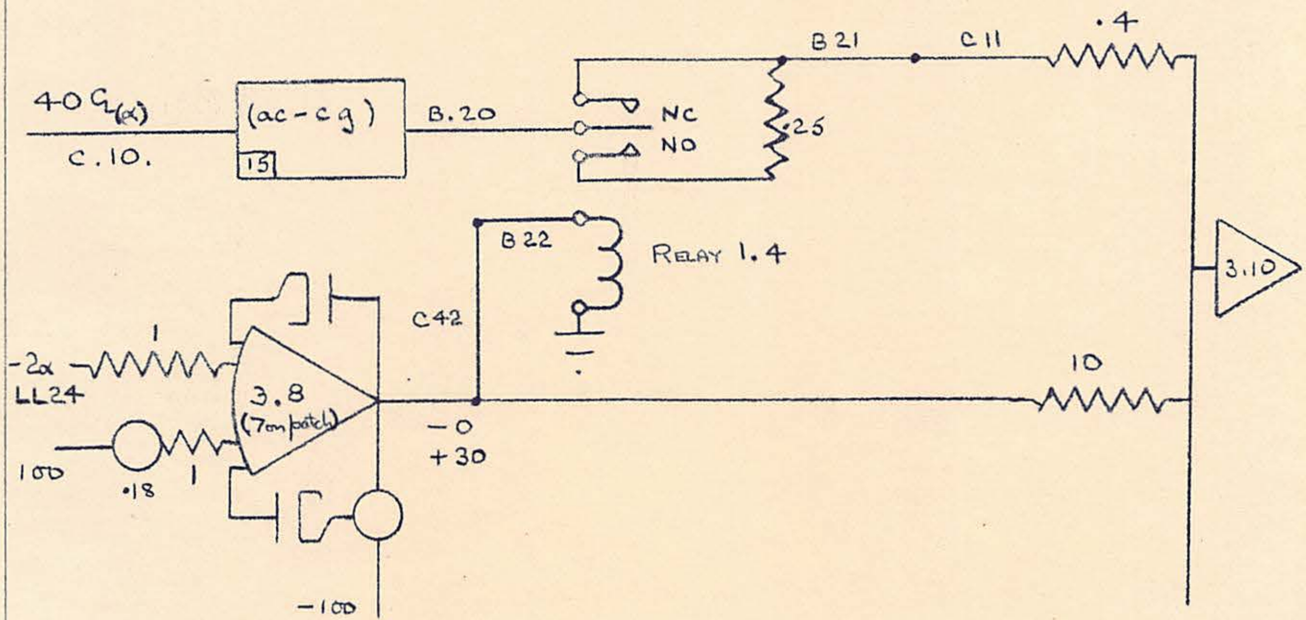
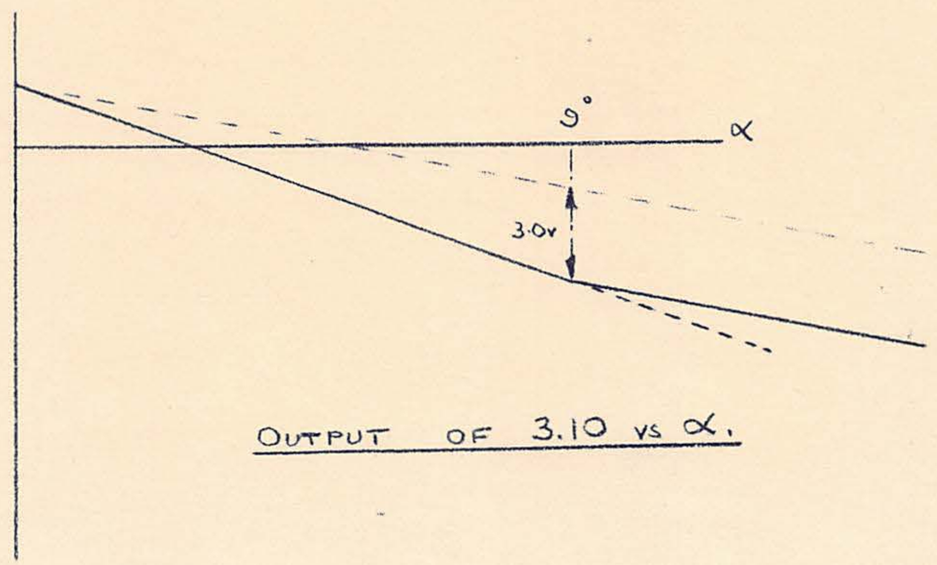
MALTON · ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO.	
C-105	SIMULATOR.	SHEET NO.	
		PREPARED BY: D. J. Foster	DATE: Jan 57.
		CHECKED BY	DATE

HIGH INCIDENCE EFFECTS ON PITCHING MOMENT.

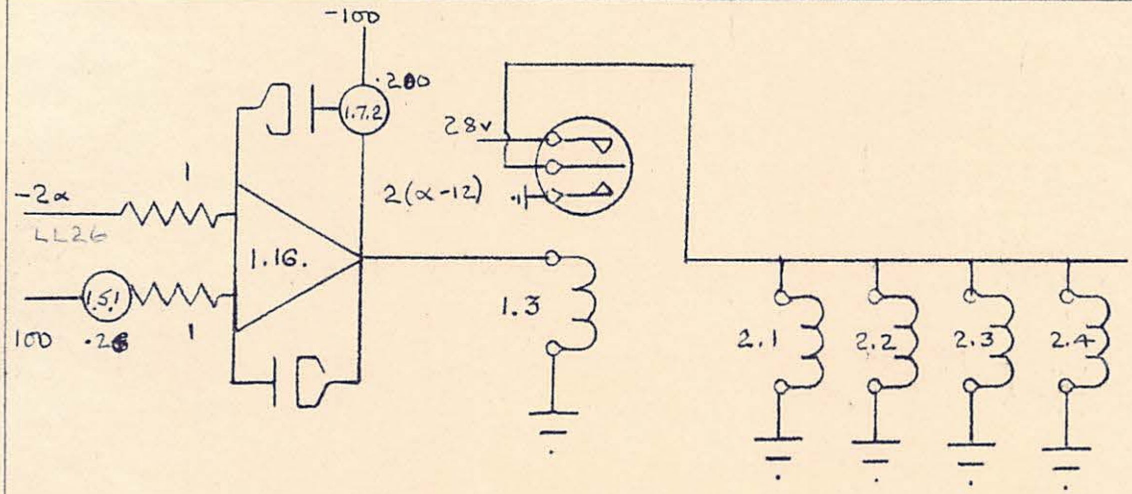


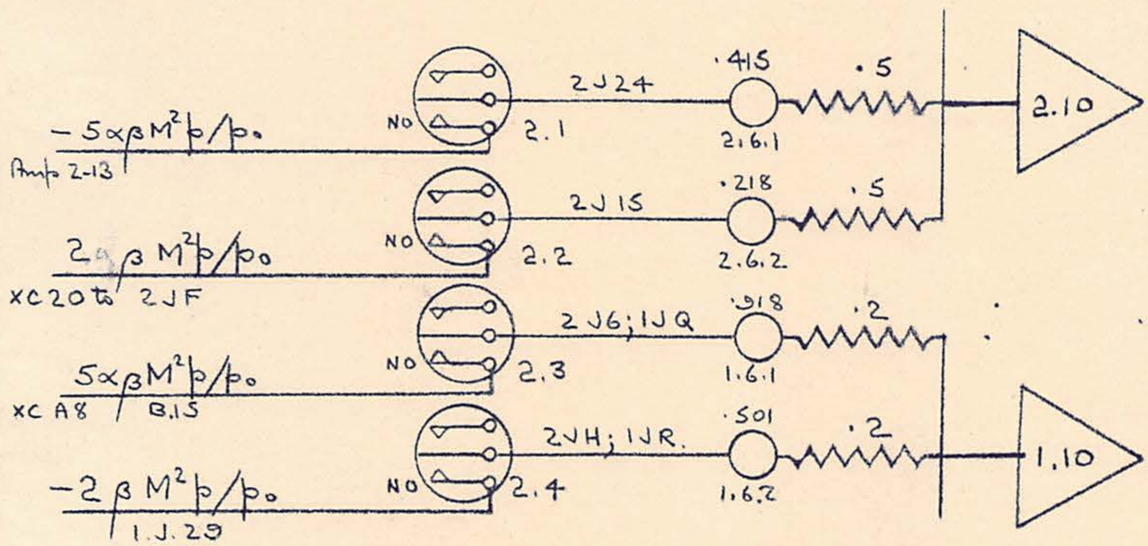


OUTPUT OF 3.10 vs α.

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: C-105	HIGH INCIDENCE EFFECTS. ON C_{n_β}; C_{l_β}.	REPORT NO.	
		SHEET NO.	
		PREPARED BY: D.J. Foster	DATE: Jan 5
		CHECKED BY:	DATE:





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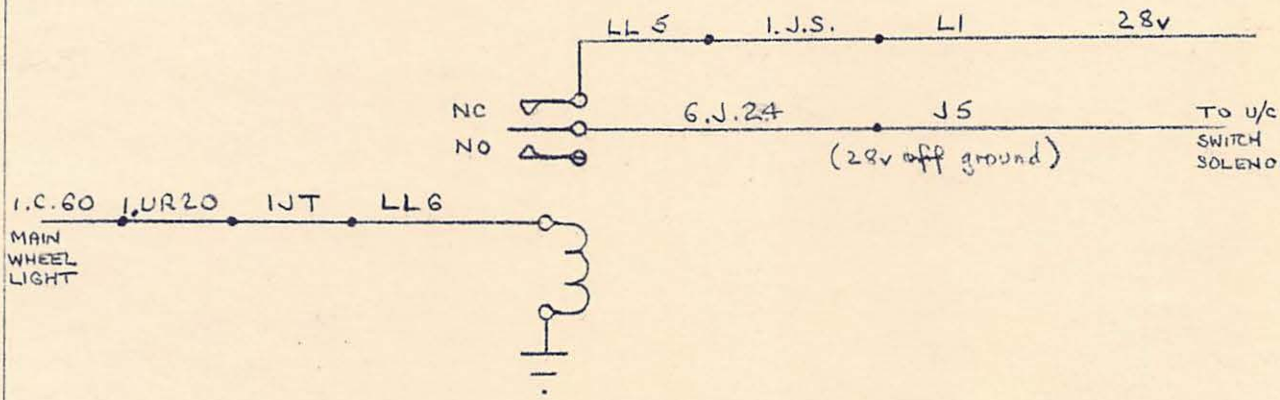
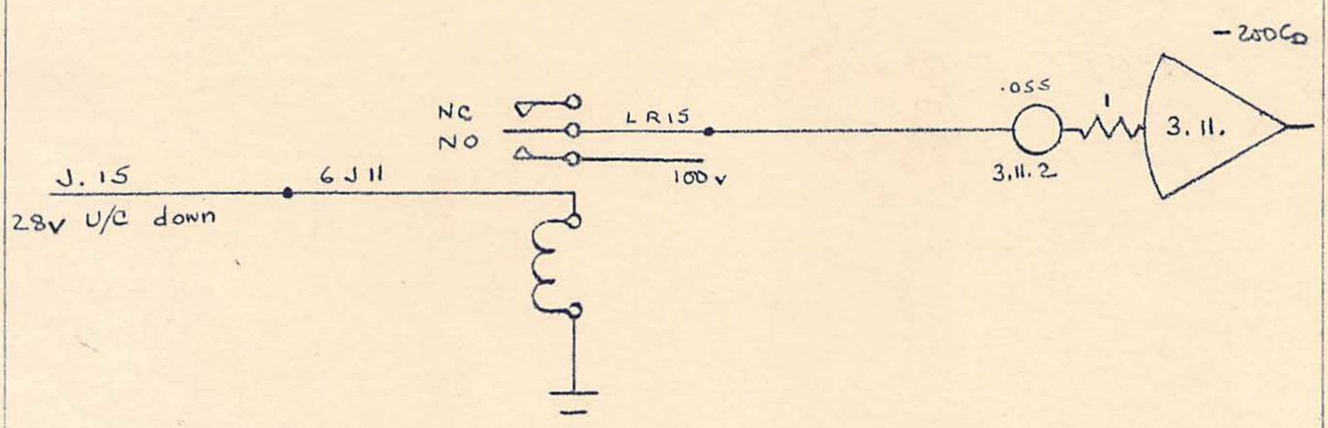
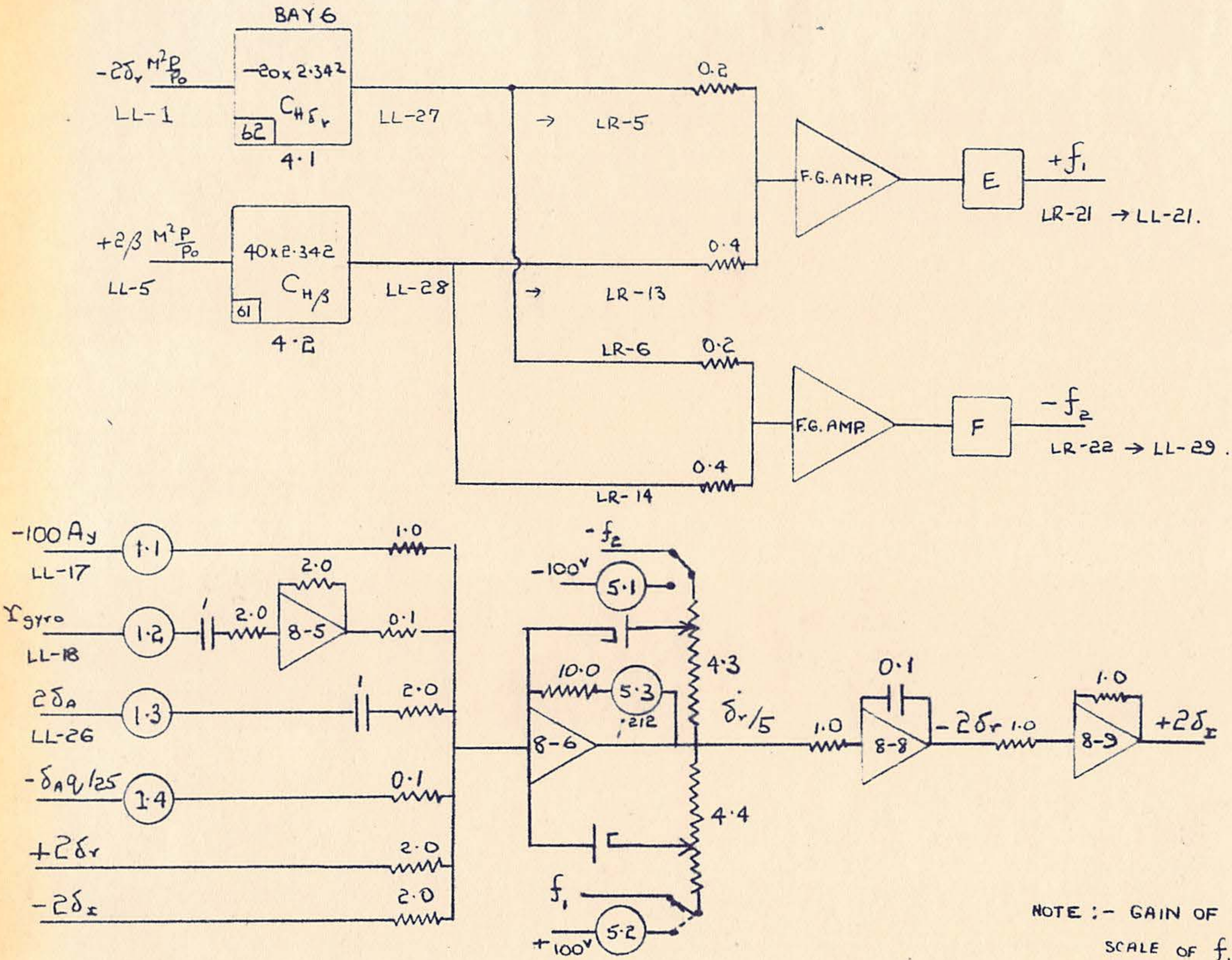
AIRCRAFT		REPORT No. / SHEET No.	
C-105	SIMULATOR.	PREPARED BY: D. J. Foster	DATE: Jan 57.
		CHECKED BY	DATE

CIRCUIT TO FREE UNDERCARRIAGE SWITCH IN THE AIR.



DRAG INCREMENT DUE TO UNDERCARRIAGE.





NOTE :- GAIN OF 8-6 = 236/5
SCALE OF f_1, f_2 IS $\dot{\delta}_r/2.865$

AVRO AIRCRAFT LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:

RUDDER HINGE MOMENT CKT.

REPORT NO.

SHEET NO.

PREPARED BY: R. A. IRWIN.

DATE: 15th Oct '67

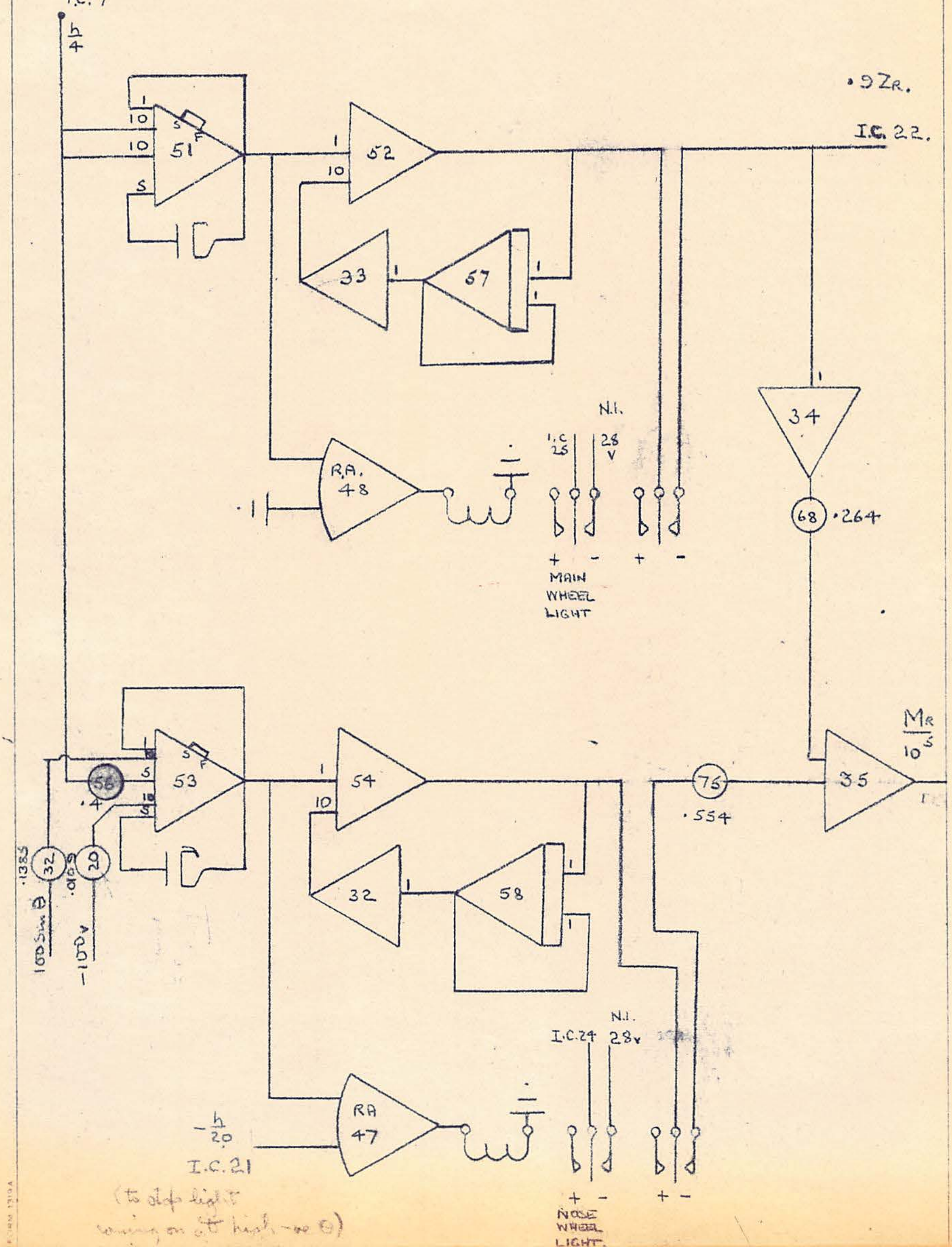
CHECKED BY:

DATE:

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO

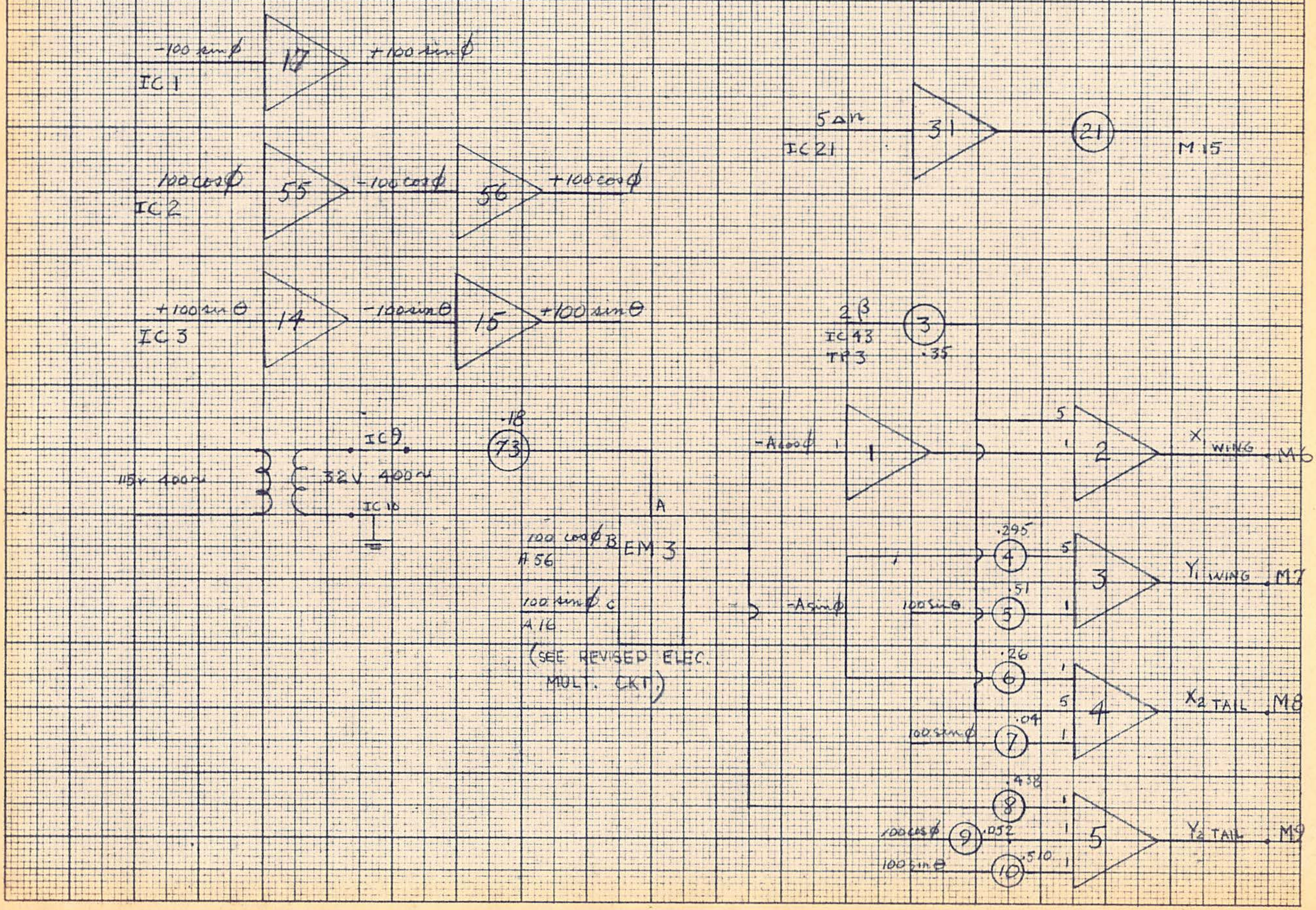
TECHNICAL DEPARTMENT

REPORT No.		
SHEET No.		
AIRCRAFT: ARROW SIMULATOR.	GROUND REACTION	
PREPARED BY	D. J. ~~Foster~~	DATE Jan '58.
CHECKED BY		DATE

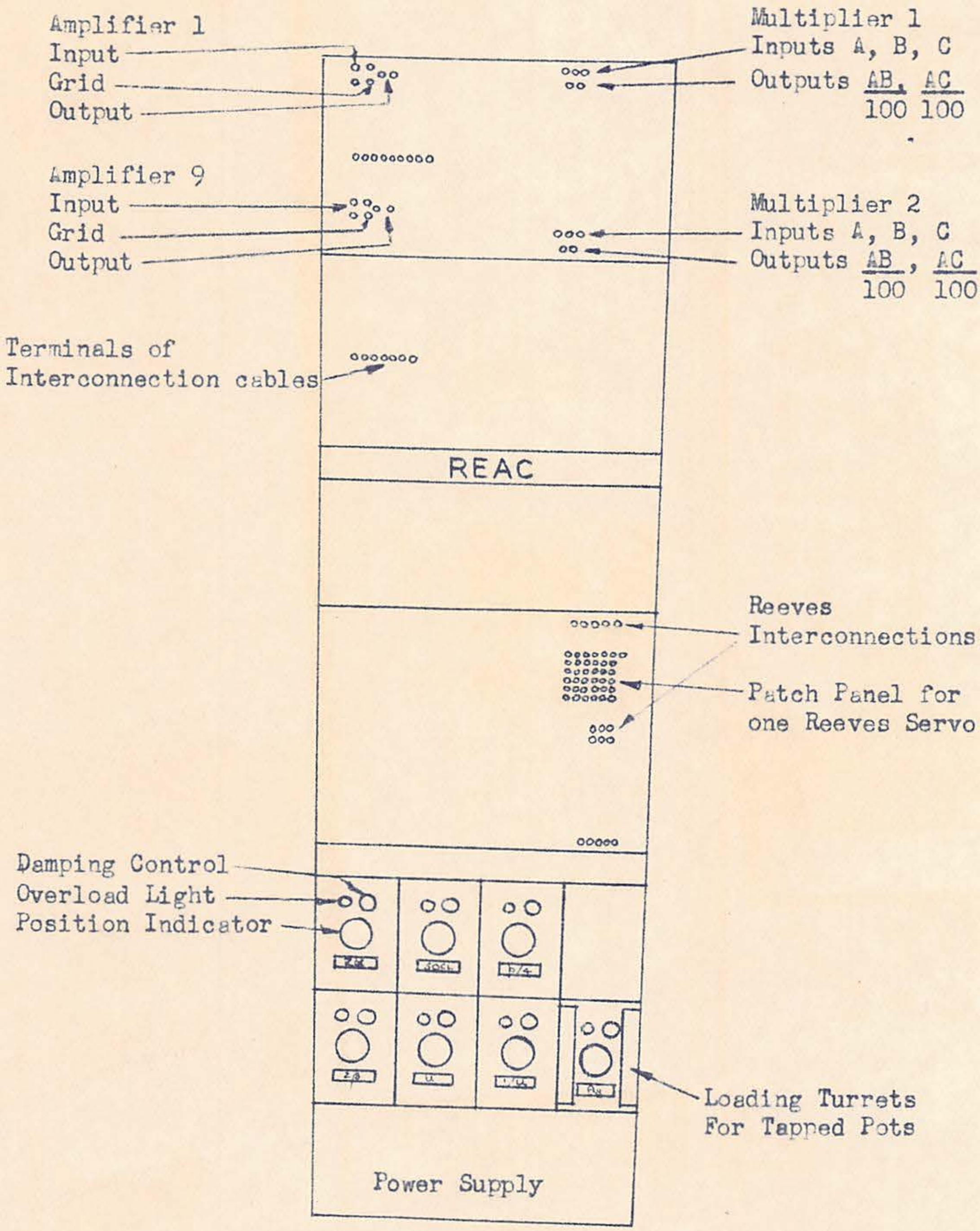


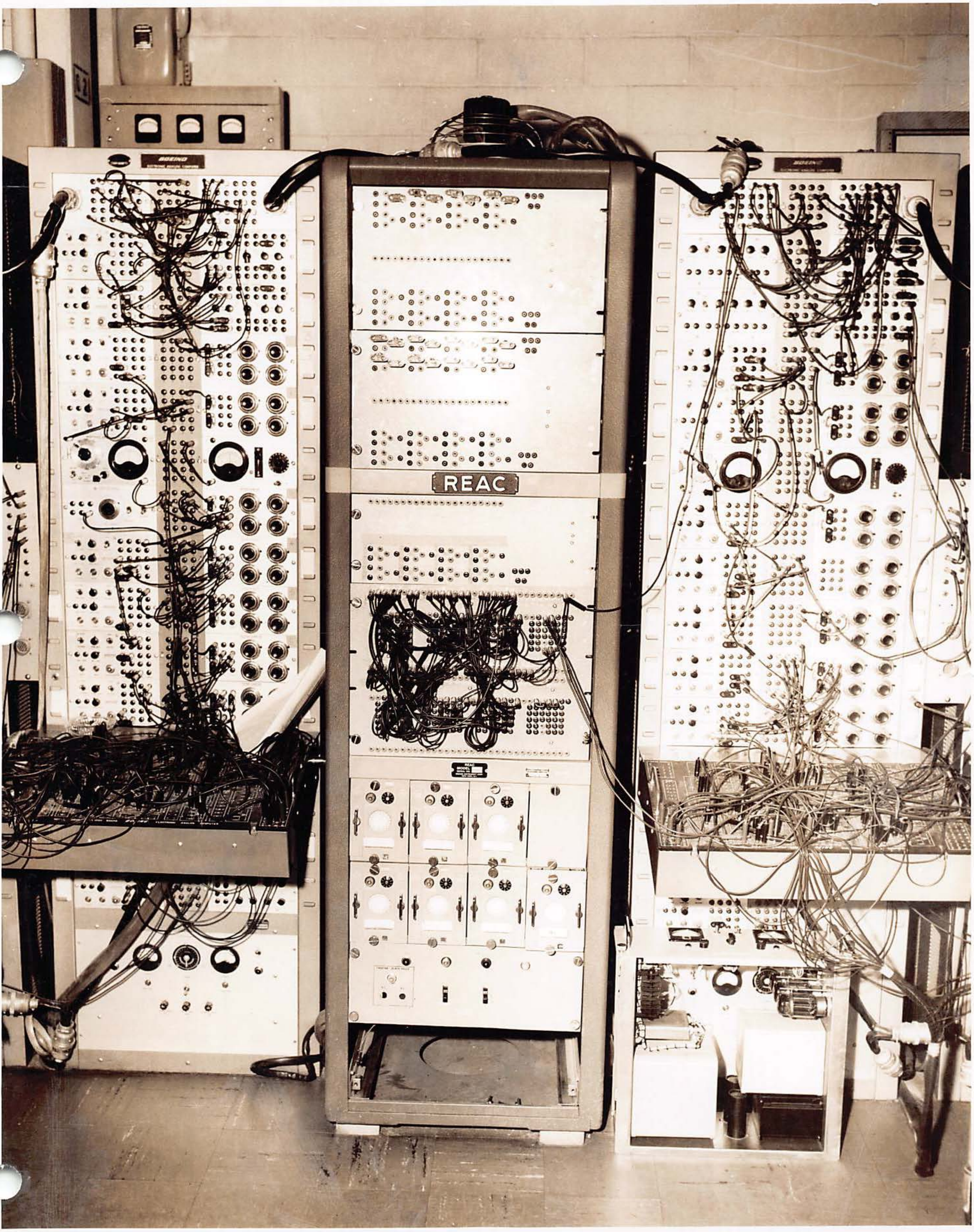
B-1 Rig Instrument Circuit

Issue 2 KNB
Jan 26/58



AIRCRAFT:		PREPARED BY	DATE
Arrow Simulator	Face of Servo Rack	D. J. Foster	
		CHECKED BY	DATE

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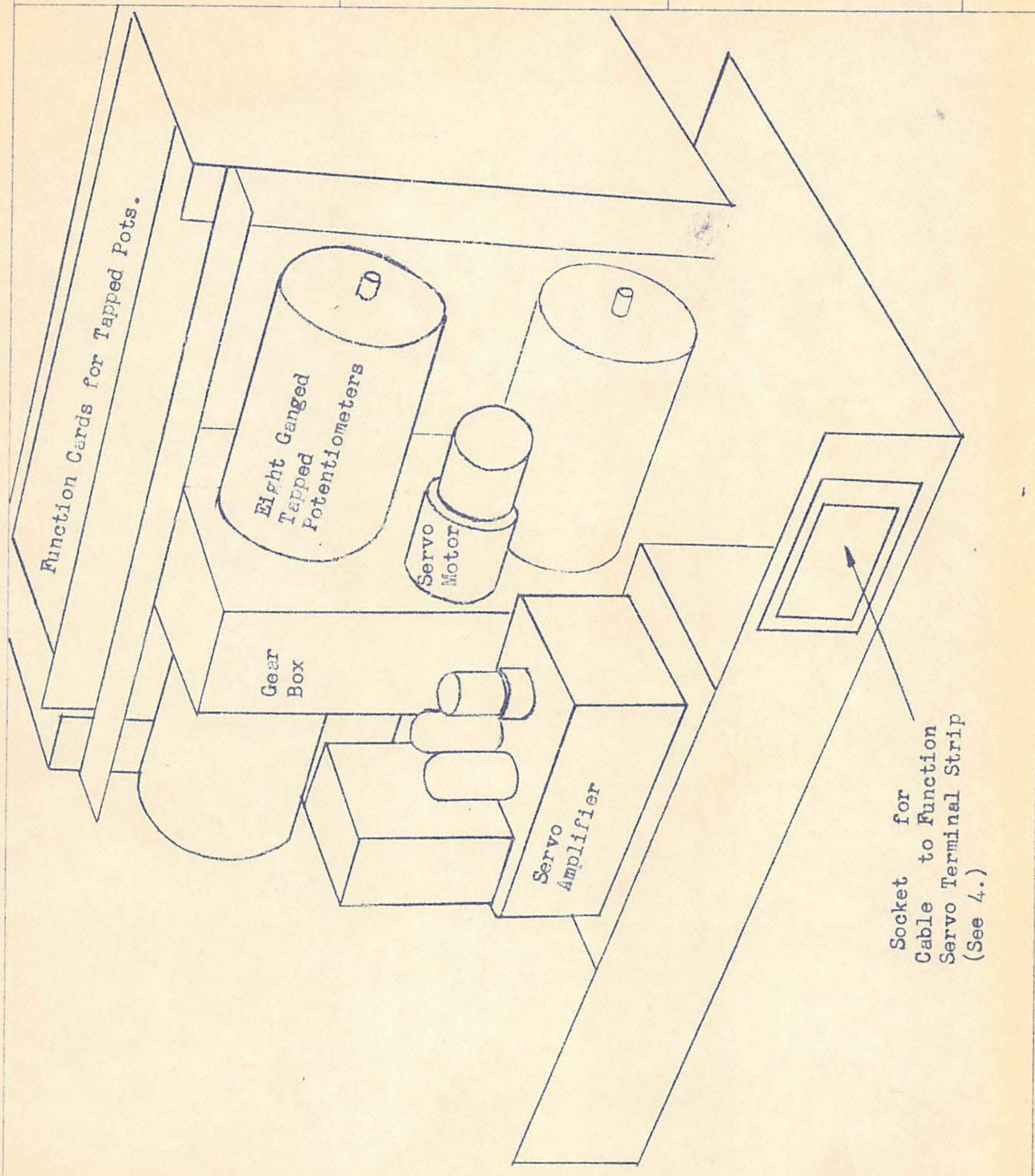
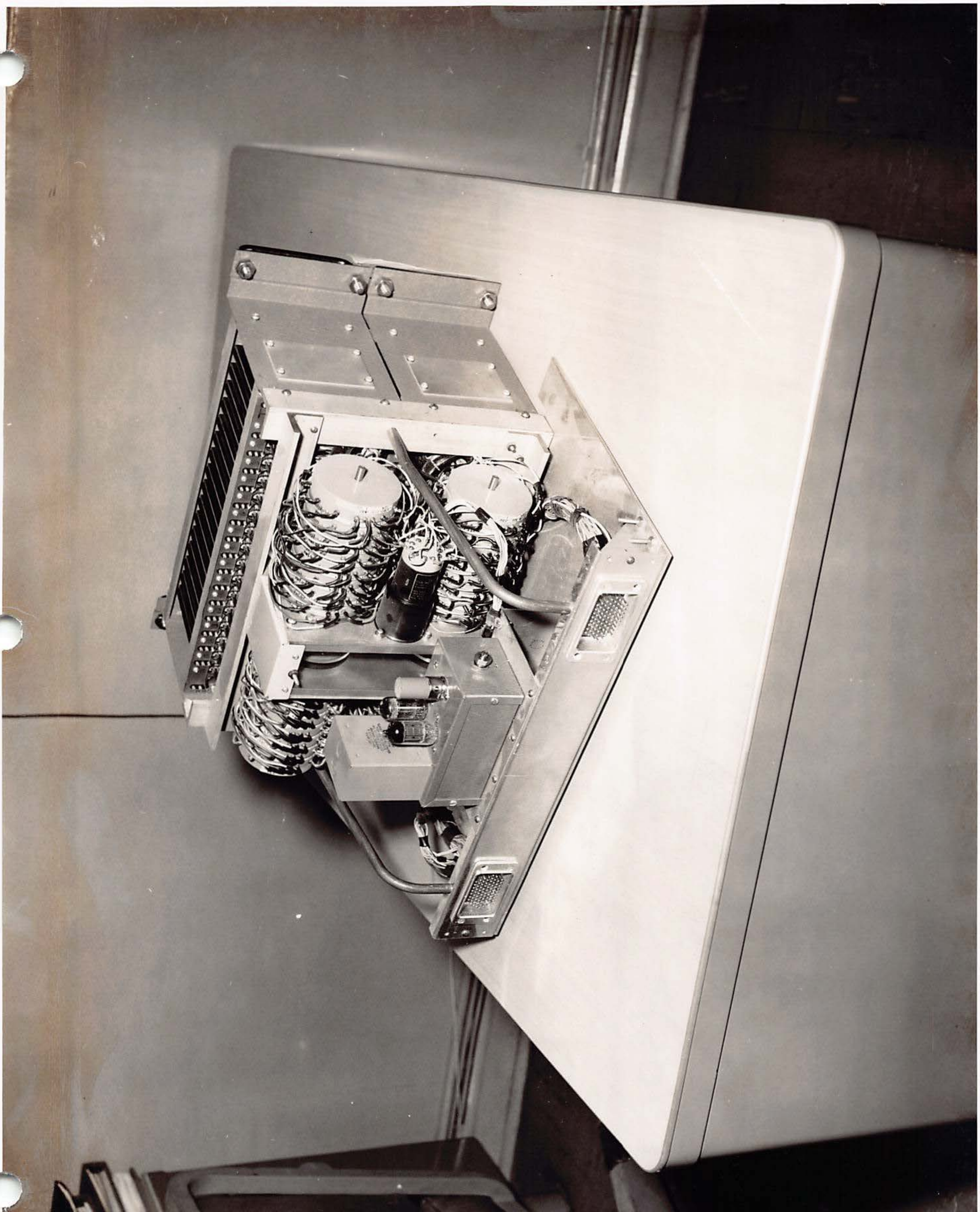
A. V. ROE CANADA LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT		REPORT NO 70/Sim/14	
		SHEET NO 4.1	
		PREPARED BY	DATE
Arrow Simulator	Function Cards Rack	D.J. Foster	May '58
		CHECKED BY	DA



Front view of Function Card Rack



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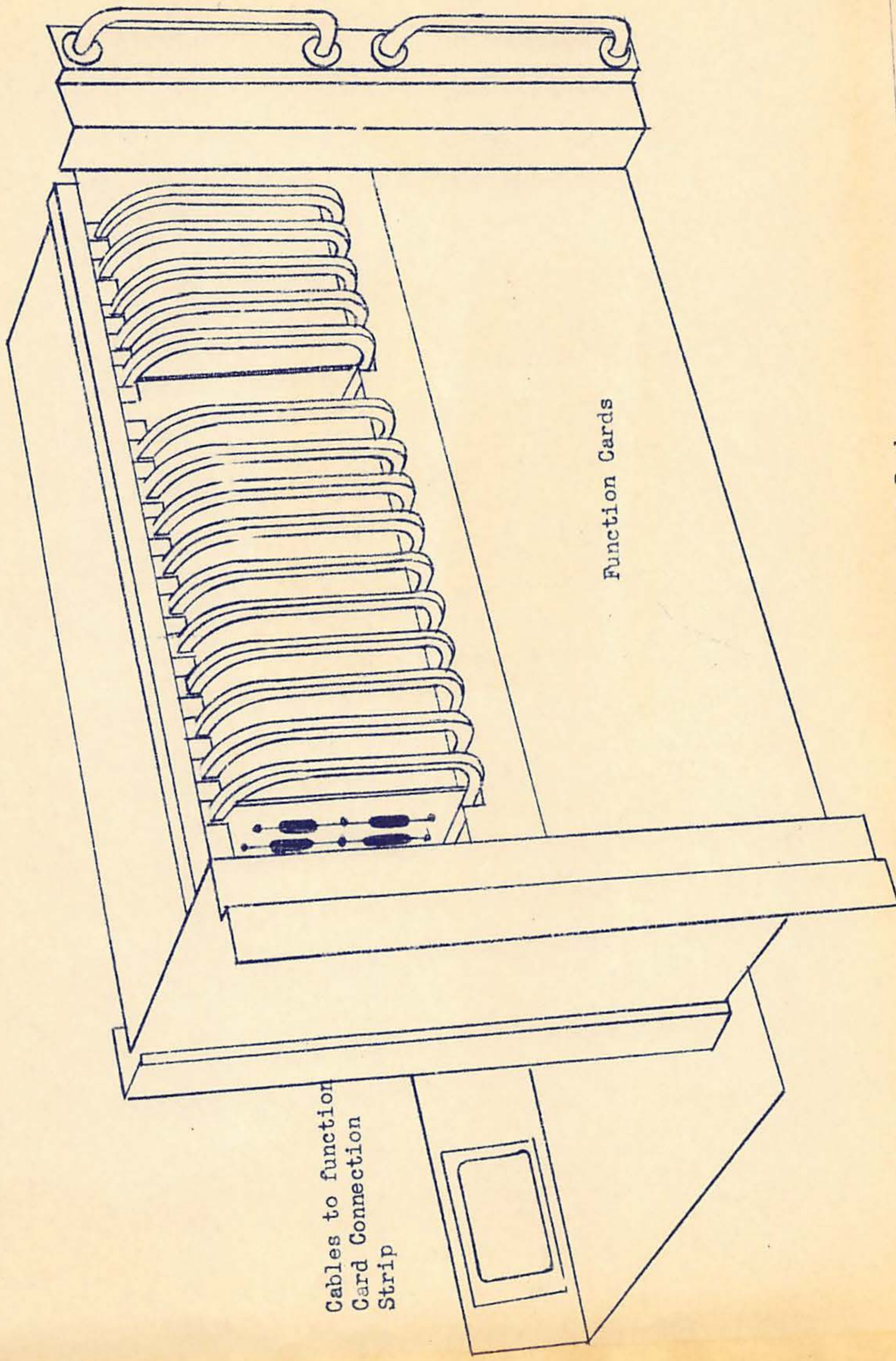
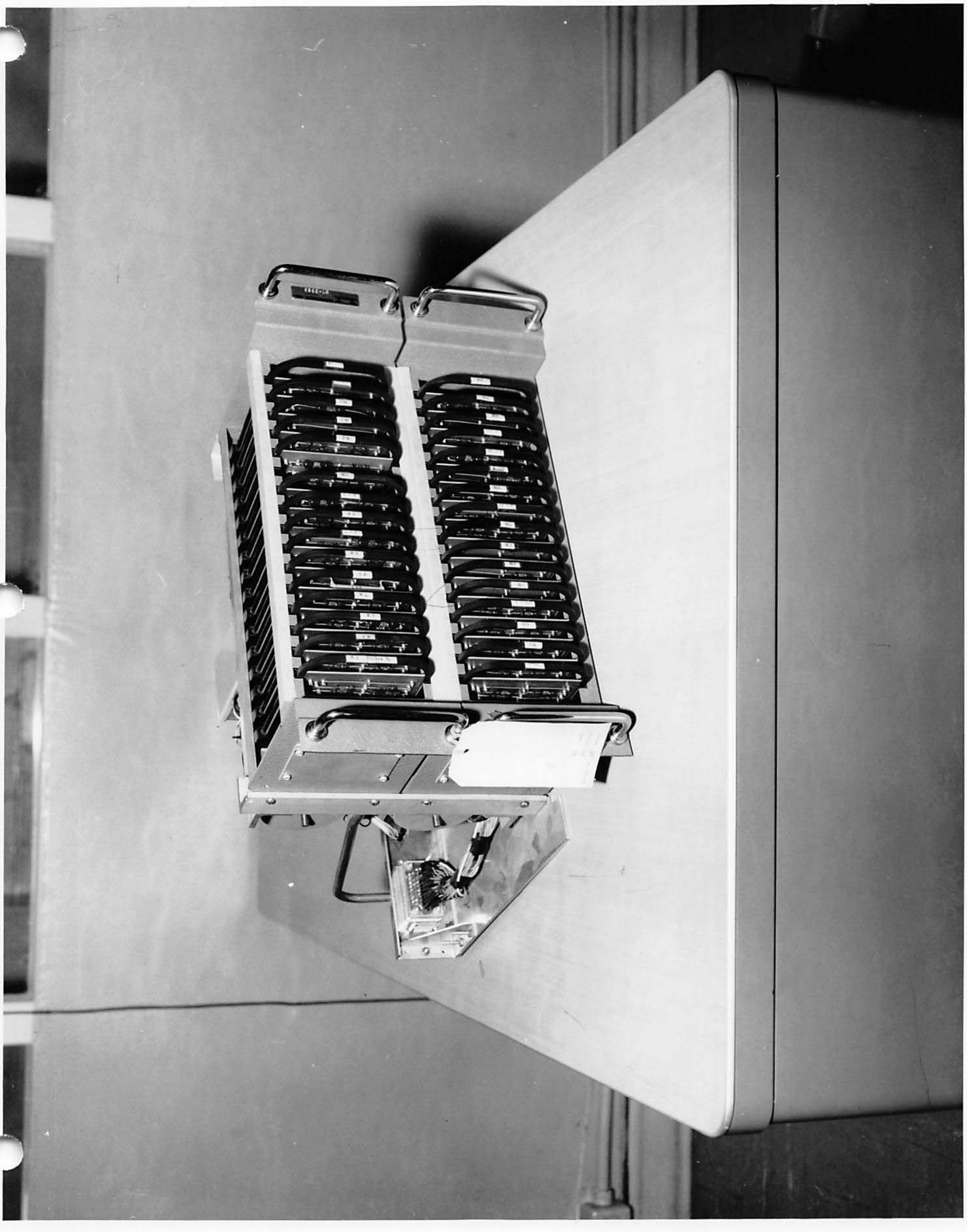
[illegible]8655

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: Arrow Simulator	Function Cards Rack	REPORT NO 70/Sim/14	SHEET NO 4.3
		PREPARED BY D.J. Foster	DATE May '58
		CHECKED BY	DATE



Rear view of Function Card Rack



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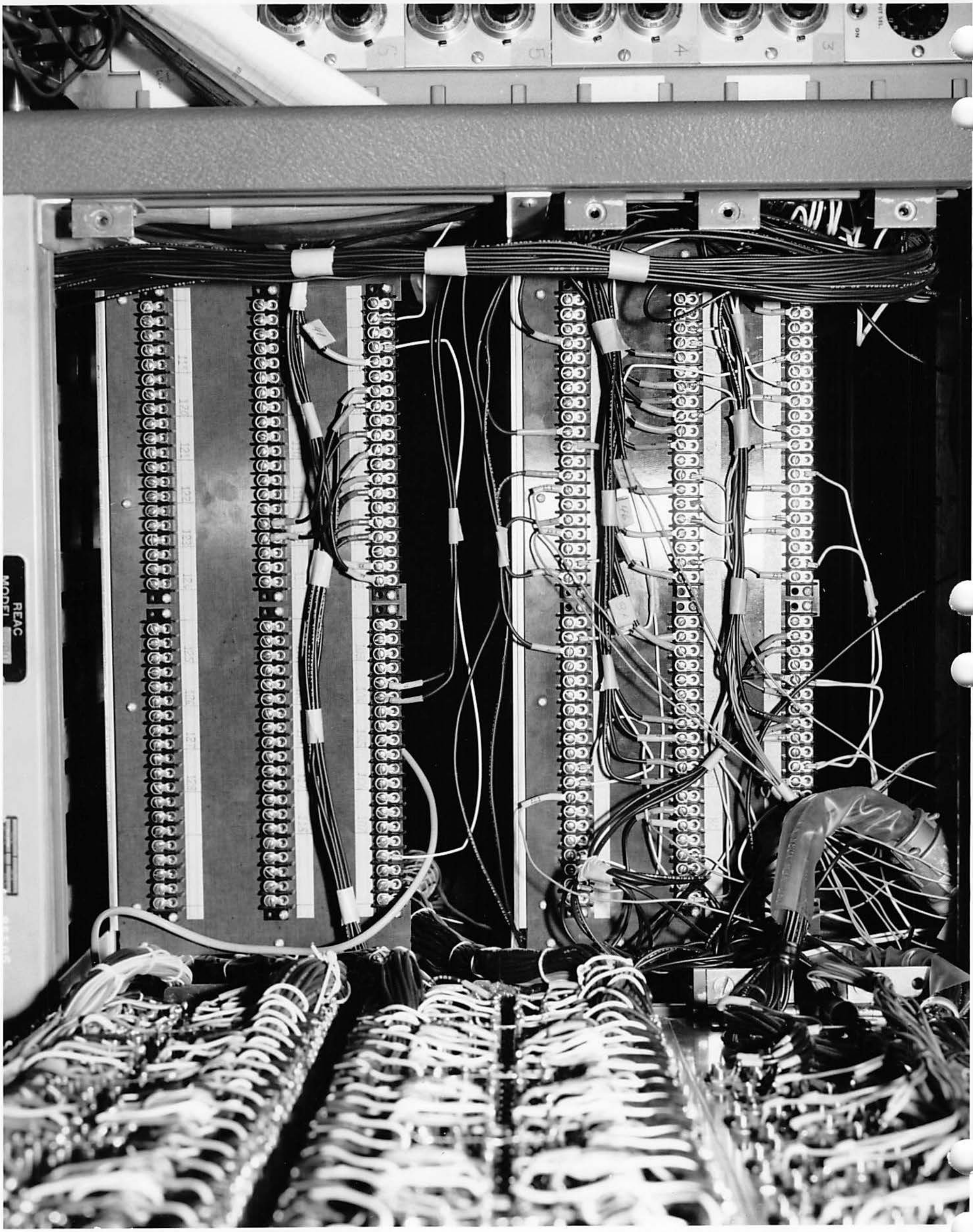
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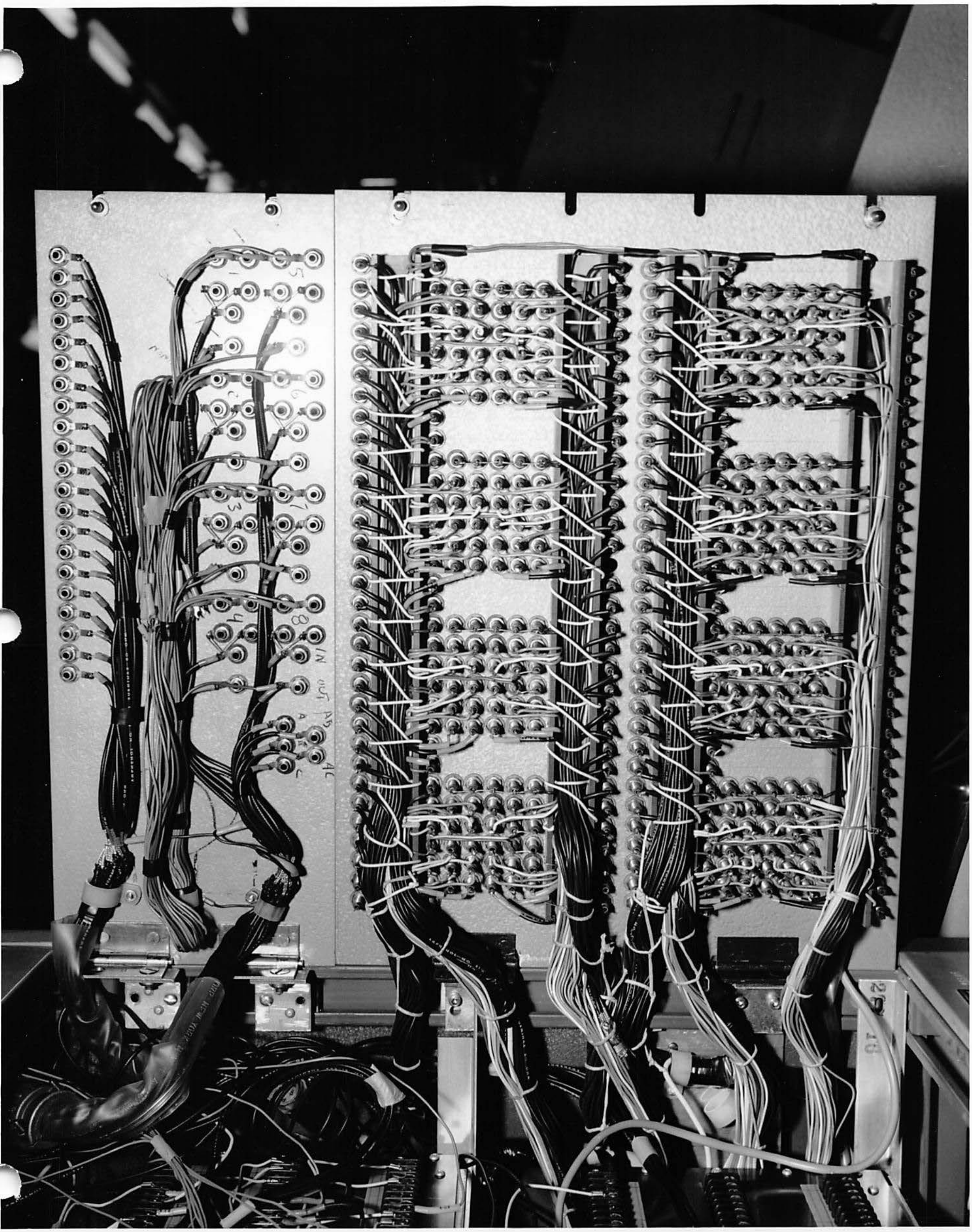

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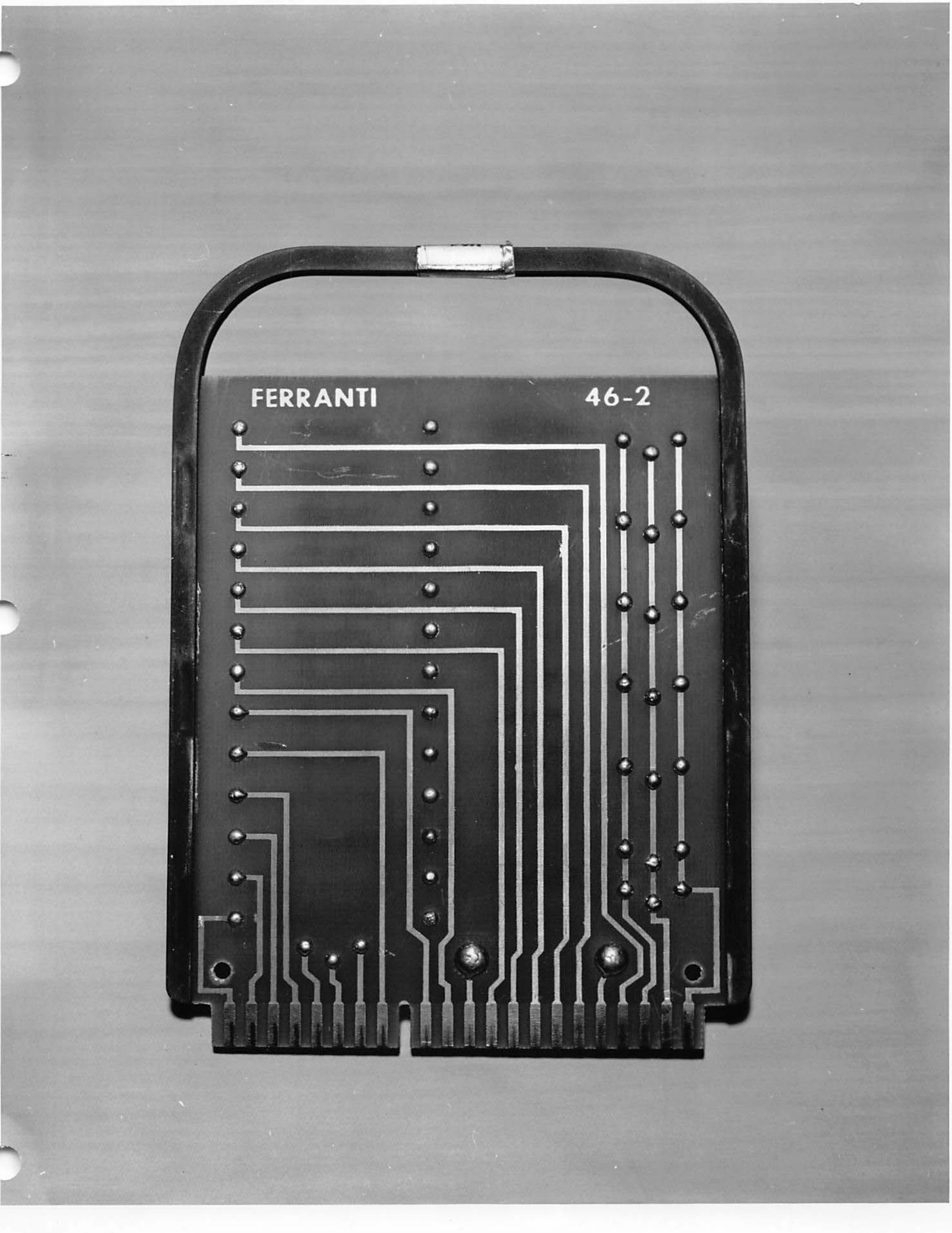
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