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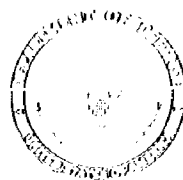
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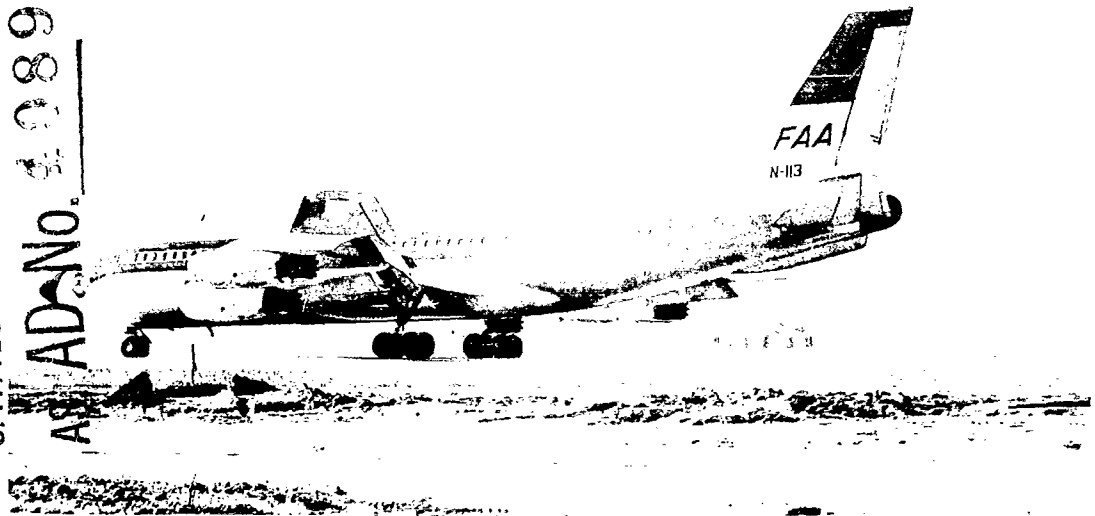
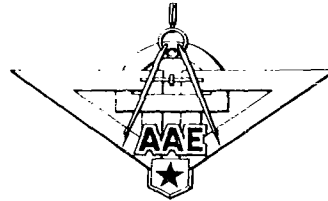
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FINAL REPORT, CONTRACT FAA ARDS-437

DEVELOPMENT OF MODEL 3500 ARRESTING GEAR
AND CONTINUED DEVELOPMENT OF SPRING HOOK
FOR COMMERCIAL AIRCRAFT

M-788
PART II
January 1963

Prepared for

FEDERAL AVIATION AGENCY
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

By

ALL AMERICAN ENGINEERING COMPANY
WILMINGTON, DELAWARE

408964

FINAL REPORT, CONTRACT FAA ARDS-437

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AND CONTINUED DEVELOPMENT OF SPRING HOOK
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PART II

This report has been prepared by All American Engineering Company for the Systems Research and Development Service, Federal Aviation Agency, under Contract No. FAA ARDS-437. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA.

ALL AMERICAN ENGINEERING COMPANY
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INTRODUCTION

Part II of this report is the presentation of the results and interpretation of strain data accumulated on the hook equipped Boeing 720-027, N-113 during the Model 3500 Arresting Gear tests at NAFEC, Atlantic City, New Jersey.

The instrumentation used to gather the data used herein is described in Part I of this report.

Calculations on the applied nose landing gear loads and cross-wind fuselage stresses are included.

Nose landing gear deflections were recorded but not tabularized or utilized in the calculations of loads.

DISCUSSION AND DESCRIPTION

The FAA Boeing 720 Dynamic arresting gear test was conducted from October 19, 1962 to October 30, 1962 at the National Aviation Facility Experimental Center test site at Atlantic City, New Jersey.

Stress instrumentation used during the test were strain gages to obtain fuselage bending and cap stresses along with the tail hook shank stresses. Strain gage location and significance is described on pages 12 and 13 . Figure 2 on page 14 shows the gage locations.

A metalurgical study was made of the hook shank which was yielded during the arrestment tests. Specimens were obtained from the yielded area and from a similar area of low stress. The stress-strain curves drawn for these specimens showed that strain-hardening took place. The increase in the yield strength is due to high loads which are a combination of bending, tension, and hook dynamic behavior. By raising the elastic limits, the fatigue strength of the deformed section increases for a given number of load cycles, but ultimately reduces its fatigue life.

The engaging velocities experienced were 78.4 to 135.6 knots and gross weights of 135,000, 175,000, and 220,000 pounds were used. Off center shots were 40 ft. at the lower gross weight and 20, 40, and 60 ft. for the maximum gross weight. One test run for the 175,000 pound gross weight with an engaging velocity of 96.4 knots and 10 ft. off center was conducted. Engaging velocities, aircraft runout, distance from center-line, hook loads, hook angles, and aircraft configuration for the actual gross weights can be found on page 15 .

Total combined effect of keel beam stresses obtained during arrestment and deadload stresses for the 135,000, 175,000, and 220,000 pound gross weight conditions are tabulated on pages 23 to 25 . The deadload stresses are calculated on page 25 .

An analysis for the nose gear load and an example calculation using run 25 for the Boeing 720 airplane during arrestment are on pages 26 to 35 . Also a free body diagram of the forces acting on the aircraft for this condition is on page 36 . Justification for using run 25 as an example is explained on page 37 .

The cross wind stresses in the fuselage at balance station 887 due to cantilever action are small, reference page 39 .

Two curves were plotted on pages 42 and 43 of hook load vs stress for strain gage 7, the steel hook attachment fitting, forward of production station 960. It is to be noted that for high hook loads, the stresses are starting to exceed the limits from static test load condition III (Reference: b.). Since the material is steel, these stresses are well below the limit design stress.

All the other gages on the fuselage which were read and summarized on Page 2 have low stresses. The stresses (Gage S17 and S18) on the hook shank have no general trend of hook load vs stress because of the dynamic effect during arrestment. These stresses are well under the design limit stress.

The appendix consists of two parts:

- (1) Appendix C, Interpretation of the data obtained from the Boeing 720 and 707 hooks tested at Swarthmore College, Pennsylvania.
- (2) Appendix D, Strain gage data reduced during the NAFEC tests.

SUMMARY

The fuselage stresses, fuselage accelerations and engine accelerations obtained on the FAA Boeing 727-027, N-113 during arrestments into the Model 3500 Arresting Gear at speeds through 135.6 knots and gross weights through 220,000 pounds ~~were~~ within safe working levels.

A summary of stresses as obtained by strain measurement are shown on pages 5 through 9.

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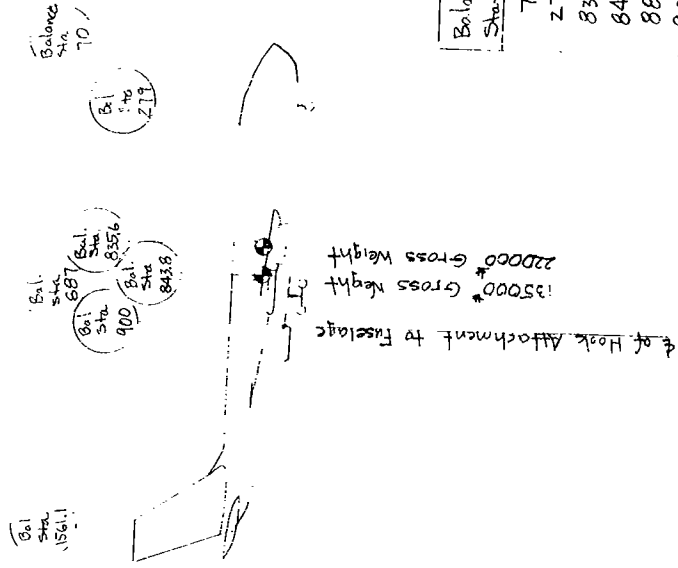
Summary of Accelerations (g's)

REPORT NO.

Summary of Accelerations							Engaging Velocity knots	Gross Wt lbs	Distance From ft
# Project Run No.	Ax	Azy	Azz	AEx	AEy				
1	.31	small	—	—	—		80.8	135000	on E
2	1.08	small	—	—	—		120.8	"	"
3	.82	small	—	—	—		106.5	"	"
4	.91	.12	—	—	—		119.2	"	"
5	N.R	N.R	—	—	—		128.2	"	"
6	1.07	small	—	—	—		135.6	"	"
7	.37	.26	—	—	—		78.4	"	40
8	.62	small	—	—	—		100.1	"	"
9	.81	.44	—	—	—		116.2	"	"
10	1.03	.41	—	—			130.2	"	"
11	.46	small	—	.46	.36		85.5	220000	on E
12	.64	.14	—	.91	.12		101.1	"	"
13	.77	.23	—	.56	.30		114.7	"	"
14	.88	.22	—	.70	.30		123.0	"	"
15	.91	.15	—	.65	.58		129.8	"	"
16	.36	.15	—	.47	.37		78.5	"	20
17	.60	.23	—	.58	.30		104.2	"	"
18	.77	.19	—	.64	.22		121.0	"	"
19	.45	.15	—	.46	.22		79.5	"	40
20	.57	.15	—	.47	.30		102.4	"	"
21	.87	.37	—	.93	.44		127.4	"	"
22	.57	.11	—	.65	.22		94	"	60
23	.60	.37	—	.93	.37		106.8	"	"
24	.70	—	.34	1.03	.37		115.4	"	"
25	.85	—	.40	1.12	.44		126.0	"	"
26	.84	—	.16	.84	.29		116.0	"	40
27	.88	—	.40	.93	.45		123.2	"	20
28	.86	—	.47	1.21	.87		96.4	175000	10
10a	1.2	.40	—	1.30	.60	Braking	Hard Braking		
10a	.7	.40	—	.90	.60		Normal Landing		
Bal Sta = 610	Ax = Fwd. Acceleration on Fuselage C								
Bal Sta = 1306	Azy = Lateral Acceleration on Fuselage								
Bal Sta = 1302	Azz = Vertical Acceleration on Fuselage								
Lateral Sta = 552	AEx = Fwd. Acceleration on Outboard Engine								
Lateral Sta = 552	AEy = Lateral Acceleration on Outboard Engine								

Location of Subject Material

Fig 1



* Production Station = Balance Station + 60

Strain Gage Data

Gage	Gage Location	Limit Stress Design Cond.	Significance
S-7(s)	Stl. fitting, bottom of body	142,000 psi Cond IIIA	Max. bending + axial stress body of stl. fitting
S-8	Existing stiffener Sta 960	26,400 psi Cond. IIIA	Distribution of vertical loads from bld. 960 to tank walls
S-9	Existing stiffener sta 960	< 26,400 psi cond. IIIA	Same as above
S-10	Top of alum. beam fwd of end vert. hole	43,300 psi cond. IIIA	Max. bend. in alum. beam
S-11	Keel, at sta. 920	16,100 psi cond. IIIA	Monitor keel load build-up; should be half of max. load
S-12	Tension strap	42,900 psi cond IIIA	Avg. tensile stress in strap
S-13	4 tee flange at sta 865	0 All cond's	Indicate load remaining in floor at sta 865.
S-14	Skin in floor aft of load transfer section sta 865	0 All cond's	Indicate load remaining in floor at sta 865.
S-15	Keel at sta 865	32,200 psi Cond IIIA	Should have large % of aft loading
S-16 } S-17 }	Upper hook shank 4 1/2" from hole	64,000 psi 99,000 psi	S16+S17 = Axial stress (hook load) S16-S17 = Bend stress

* Ref. b.

Strain Gauge Data - Cont'd

S-18(3)	Hook pt. above weld - one side only	163 000 psi	Max. surface (Upper Side) stress
S-19	Tension strap, sta 930 33" up	—	Distribution of load into tank walls from 930 blkd.
S-21	Stringer, aft face of sta 960; $\frac{1}{2}$ at W.L. 185	7700 psi cond IIIA	Comp. stress in stringer. Distributed load to shear panels & then to tank walls
S-22	Peripheral angle, Bottom of sta 960, 45° from vert.	—	Side load distributed into sta 960 blkd.
S-23	Forged side member blkd. sta 960, 85° from vert.	—	Same as above
S-26	On vert. web of $\frac{1}{2}$ T	—	Determine stress distribution fwd of hook attach. fitting (sta 960)
S-27	On vert. web of $\frac{1}{2}$ T	—	Same as above
S-28	On vert. web of keel beam	—	Same as above
S-29	On vert. web of keel beam	—	Same as above
S-30	On vert. web of keel beam	—	Determine stress distribution between sta 930 & 960
S-31	Near $\frac{1}{2}$ of airplane on extreme fiber of hat section at 1" up	—	Determine stress distribution aft of hook attach. fitting (sta 960)
S-32	On vert. web of keel beam	—	Same as above
S-33	On vert. web of keel beam	—	Determine stress distribution between sta 930 & 960
S-34	Upper flange + floor beam ^{sta 1030}	—	Indicate stress due to hook shank hitting bottom of fuselage.
S-35	Lower flange floor beam ^{sta 1030}	—	Same as above



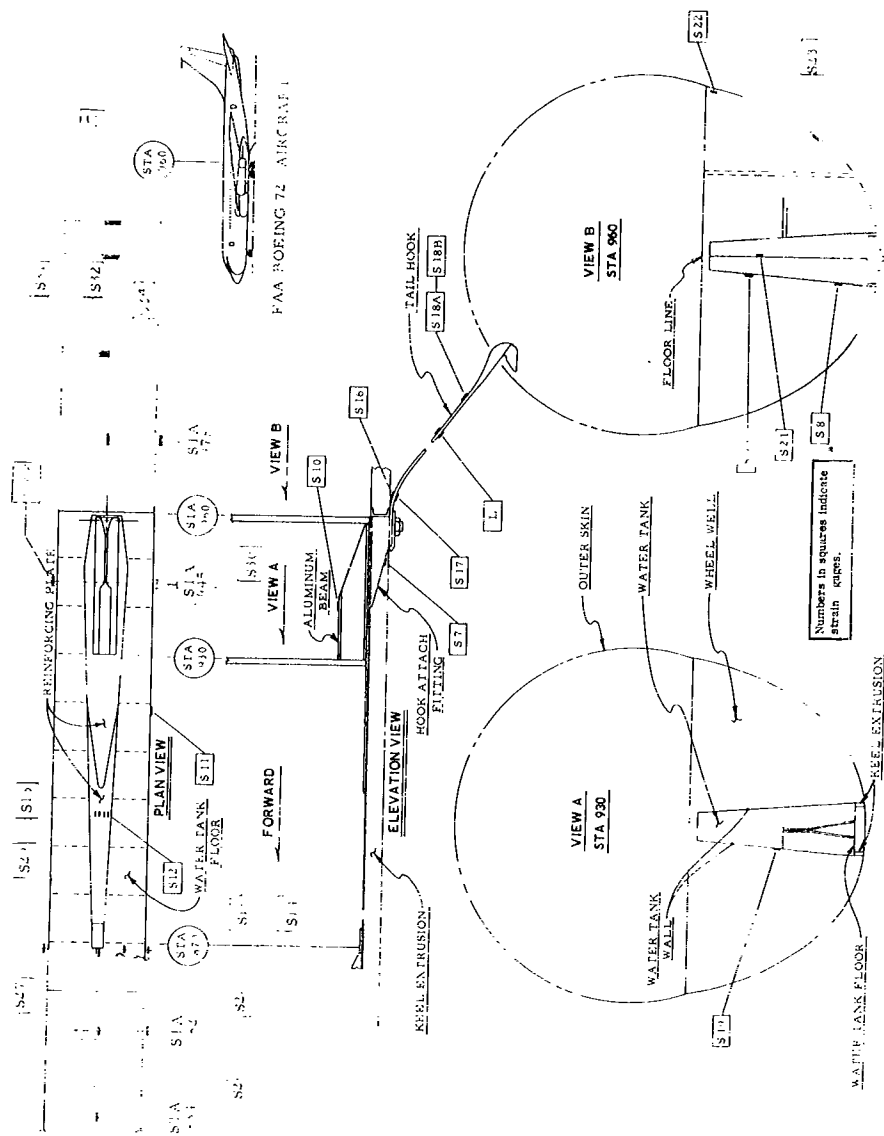


Figure 2 Strain Gage Locations
MODEL 3530 A/G TESTS AT NAPEC, ATLANTIC CITY, NEW JERSEY

Tabulated Load Data

Project 12th	Peak Hydraulic Load at Peak Hydraulic Angle	Hook Load at Max. Velocity Angle	Actual Aircraft Weight	Aircraft Run out Distance	Aircraft Configuration		
Fun	Dynamic Hydraulic Load (lbs)	Hook Load (lbs)	Max. Velocity Angle (Deg.)	Actual Aircraft Weight (lbs)	Aircraft Run out Distance (ft.)	Aircraft Configuration	
1	46,000	66,200	1.4	6.1	41,000	80.8	30° flap, C.G. 22% MAC, stabilizer trim 2 units nose up
2	N.R.	N.R.	N.R.	3.5	N.R.	120.8	"
3	72,000	96,300	4.3	5.0	56,200	106.5	"
4	84,500	118,000	.9	6.2	68,500	119.2	"
5	N.R.	N.R.	N.R.	N.R.	128.2	136,045	"
6	77,100	135,000	.5	4.1	71,200	135.6	"
7	43,000	51,500	1.4	12.5	10,300	78.2	"
8	68,800	75,900	4.0	10.3	50,600	100.1	"
9	83,000	102,700	1.8	13.0	56,600	116.2	"
10	102,900	132,000	.5	13.4	40,200	130.2	"
* 10a	Braking						"
11	52,400	83,900	.5	3.0	20,800	85.5	30° flap, C.G. 19.8%, stabilizer trim 2 units nose up
12	70,300	113,900	1.0	4.5	62,900	101.1	"
13	41,000	50,900	.5	5.9	75,700	114.7	"
14	102,300	162,000	.5	4.6	92,500	123.0	"
15	107,800	189,000	.9	4.1	91,400	129.8	"
16	43,100	68,400	1.4	9.5	19,100	78.5	"
17	73,400	122,800	0	8.6	21,500	104.2	"
18	101,000	152,900	1.2	8.6	72,000	121.0	"
19	56,400	68,900	1.8	13.0	10,300	79.5	"
20	70,200	102,800	.56	14.6	41,400	102.4	"

* Purpose of run was to measure engine accelerations by use of mix, brake & reverse thrust.

Tabulated Load Data - Cont'd

Project Run No.	Peak Dynamic Hook Load (lbs.)	Hook Angle (Deg.)	Hook Max. Angle (Deg.)	Hook Load Engaging Velocity (knots)	Actual Aircraft Weight (lbs.)	Aircraft Runout (ft)	Distance From d	Aircraft Configuration
21	102,800	2.0	12.4	67,600	177.4	220,850	40	30° flap, C.G. 19.8%, stabilizer 2 units nose up
22	81,100	.9	12.7	14,300	94.0	220,100	60	" " " " " "
23	82,600	.5	13.6	12,700	106.8	220,000	60	" " " " " "
24	93,400	0	13.6	85,400	115.4	219,590	60	" " " " " "
25	113,000	0	17.6	14,500	126.0	220,400	60	" " " " " "
26	95,500	0	13.0	67,000	116.0	219,600	40	" " " " " "
27	114,300	1.7	9.6	66,100	123.2	220,000	20	" " " " " "
28	47,700	1.6	7.7	31,800	96.4	174,000	10	" " " " " "

* At approx. 500 ft from pendant, full brake & reverse thrust applied

KEEL BEAM STRESSES

Oscillograph Data

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MODEL NO.

DATE NOV 2 1962

135K to 175K LOAD *

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DU PONT AIRPORT .. WILMINGTON, DELAWARE

MODEL NO.

DATE Nov 1, 1962

175^L to 220^L Lead *

REPORT NO

		K	R _c	F _L K/R _c	ΔD	C _D	E ^{x10}	S
1	S7	2910	.51	1836	-	-	29.0	-
2	S8	2869	1.86	1550	-	-	10.5	-
3	S9		.44	6530	-	-	10.5	-
4	S10		1.64	1750	.01	18	10.3	185
5	S11		1.64	1750	-.04	76		-720
6	S12		1.86	1572	-.05	80		-825
7	S13		1.45	1980	-.07	146		-1440
8	S14		1.74	1650	-.06	19		-1020
9	S15	2869	.69	3285	-	-		-
10			.62				10.3	
11	S17	2057	.63	3265			28.5	
12	S18						28.5	
13	S19	2869	1.42	2100	.03	60	10.3	618
14	S21	2896	1.36	2130	-	-	10.7	-
15	S22	2869	.34	3450	-	-	10.3	-
16	S23		1.10	2616	-	-		-
17	S26		1.56	1840	.01	18		185
18	S27		1.50	1910	.03	57		588
19	S34		.49	5860	-	-		-
20	S28		1.27	2260	.03	67		670
21	S29	2869	1.5-	1910	.03	57		588
22	S30	2816	.29	4980	-	-		-
23	S31		.46	6300	-	-		-
24	S32		1.78	1625	-	-		-
25	S33		1.60	1810	.03	54		555
26	S35	2896	.58	5000	-	-	10.3	-

* INCREASED G.W. PRODUCED BY WATER BALLAST
IN CONTAINERS ON FUSELAGE FLOOR BETWEEN
NOSE WHEEL AND AFT LANDING GEAR.

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MODEL NO.

REPORT NO.

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Dead Load Stresses in Keel Beams

Section Modulus [Ref. C.]

Product Steel	Distance Static	Inertia Keel Beams	Distance to Keel Beams	E_y Calculated
#34	874	15230.2 in ⁴	98.2 in	1610 in ³
#60	900	116700	104.3	1130
#12	918	30000	117.9	1330

$$\text{Gross Weight} = 135,022^{\#}$$

$$I = 125,000^{\text{in}^4} \text{ [Ref. p. 20]}$$

In E_y use 1330 since smallest section modulus.

$$(\text{bending stress}) = \frac{135,022 \times 12}{1130} = -10,500 \text{ psi}$$

To be conservative, add this stress to all the strain gage readings obtained for the keel beams with sign of dead load stress to be of same sign as the stresses read from the oscillographs during arrestment; see pages 23 to 25.

$$\text{Gross Weight} = 220,000^{\#}$$

Add algebraically the strain gage readings from pages 18 and 19. To be conservative add this increase in stress for the gage under consideration to the 10,500 psi stress regardless of sign. This now

gives the dead load stresses for 220,000[#] gross weight.
Next add these stresses to stresses obtained during
arrestment as explained above for 135,000[#] gross weight,
See pages 23 to 25.

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DATE _____

Stresses @ Keel Beam

REPORT NO. _____

Project Run No.	Engaging Velocity	Distance from #	Gross Weight	S-28 # Sta 852	Dead Load Stress	Total * Stress	S-32 # Sta 978	Dead Load Stress	Total * Stress
	knots	ft.	lbs	psi	psi	psi	psi	psi	psi
1	80.8	on #	135000	N.R.	+10500	—	N.R.	-10500	—
2	120.5	"		6860		17360	-2430		-12930
3	106.5	"		5680		16130	-2420		-12920
4	119.2	"		6100		16600	-1160		-11660
5	128.2	"		8480		18180	-2320		-12820
6	135.6	"		3420		13920	-2190		-12690
7	78.4	40		2200		12720	0		-12520
8	100.1	"		N.R.		—	N.R.		—
9	116.2	"		7200		17700	-2850		-13350
10	130.2	"	135000	9570	+10500	28610	-2560	-10500	13060
11	95.5	on #	220000	2570	+11370	13940	-3430	-11672	-15102
12	101.1	"		7010		18330	-3320		-14992
13	114.7	"		8900		20270	-8600		-20272
14	123.0	"		11650		-3020	-2650		-14322
15	129.8	"		11650		23020	-1492		-13164
16	78.5	20		5350		16720	-3540		-15212
17	104.2	"		8500		19870	-3700		-15372
18	121.0	"		9600		20770	-4870		-16542
19	79.5	40		5550		16920	-3480		-15152
20	102.4	"		2440		14210	-2610		-14282
21	127.4	"		6630		18060	-6580		-18252
22	94.0	60		5900		17270	-4700		-16372
23	106.5	"		5970		20340	-6080		-17152
24	115.4	"		8820		20190	-5420		-17092
25	126.0	"		10450		21820	3380		-15052
26	116.0	40		9900		21270	-5420		-17092
27	123.2	20	220000	8250	+11370	19620	-5420		-17092
28	76.4	10	175000	2360	+12060	14420	-2540	-11672	-14212
*	Conservative	see p 21 & 22							
#	Ref. Pa. 59								

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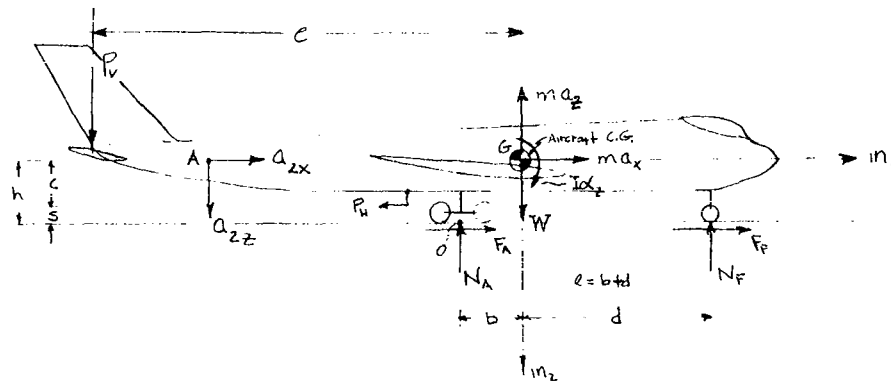
DATE _____

Stresses @ Keel Beam

REPORT NO. _____

Project Run No.	Engaging Velocity	Distance From £	Gross Weight	S-15 # Sta. 865	Dead Load Stress	Total Stress *	S-29 # Sta. 870	Dead Load Stress	Total Stress *
	knots	ft.	lbs.	psi	psi	psi	psi	psi	psi
1	80.8	20 ft	135000	5600	+10500	16100	N.R.	+10500	—
2	120.8	"	↑	—	↑	—	4470	↑	14170
3	106.5	"	↑	5480	↑	15980	4870	↑	15370
4	119.2	"	↑	6610	↑	17190	5510	↑	16010
5	128.2	"	↑	7310	↑	17890	7080	↑	17580
6	135.6	"	↑	9500	↑	20000	6840	↑	17340
7	78.4	40	↑	3310	↑	13870	1960	↑	12460
8	100.1	"	↑	17300	↑	17800	N.R.	↑	—
9	116.2	"	↓	7000	↓	17500	6500	↓	17000
10	130.2	"	135000	8050	+10500	18550	7450	+10500	17950
11	85.5	20 ft	230000	17700	+21172	38872	2250	+11832	14132
12	101.1	"	↑	1350	↑	28522	6350	↑	18232
13	114.7	"	↑	8020	↑	29192	8680	↑	20562
14	123.0	"	↑	11400	↑	32572	9690	↑	21572
15	129.8	"	↑	10600	↑	31772	10150	↑	22032
16	78.5	20	↑	6450	↑	27622	0	↑	11882
17	104.2	"	↑	9200	↑	30372	8950	↑	20832
18	121.0	"	↑	9500	↑	30672	6660	↑	18542
19	79.5	40	↑	6330	↑	27502	0	↑	11882
20	102.4	"	↑	8810	↑	29982	2840	↑	14722
21	127.4	"	↑	12000	↑	33172	10650	↑	22532
22	94.0	60	↑	6520	↑	27692	8860	↑	20742
23	105.8	"	↑	9260	↑	30432	6520	↑	18402
24	115.4	"	↑	9950	↑	31122	8890	↑	20772
25	126.0	"	↑	10300	↑	31472	11850	↑	23732
26	116.0	40	↑	9950	↑	31122	8890	↓	20772
27	123.2	20	220,000	6630	↓	27802	7700	+11882	19582
28	96.4	(1)	175000	3315	+21172	24487	0	+12470	12470
*	Conservative	see pg. 21 & 22							
#	Ref. B. 59								

NOSE GEAR LOAD



W = Gross Weight
 m = Mass of Airplane
 I = Mass Moment of Inertia about airplane C.G.
 α_z = Pitching Angular Acceleration
 $\dot{\alpha}_z$ = Pitching Angular Velocity
 in_1, in_2 = Unit vectors fixed at airplane C.G.
 a_x = Acceleration along in_1 direction
 a_z = Acceleration along in_2 direction
 F_A, F_F = Frictional Forces of aft wheels & nose wheels respectively
 N_A, N_F = Aft wheels normal load & nose gear load
 P_H = Hook Load
 P_V = Vertical load on horizontal tail. *

Assumptions

1. Assume rigid body

* Ref. a.

$$\phi^A = \phi^{A/0} + \phi^C$$



ϕ is small angle

$$a_{zx} n_1 + a_{zz} n_2 = (\Gamma_{0A} w_z^2 \cos \phi + \Gamma_{0A} x_z \sin \phi) n_1 + (\Gamma_{0A} w_z^2 \sin \phi - \Gamma_{0A} x_z \cos \phi) n_2 + a n_1$$

$$\text{Note: } \cos \phi \approx 1 \quad \sin \phi \approx \phi$$

$$(a_{zx} - \Gamma_{0A} w_z^2 - \Gamma_{0A} x_z \phi - a) n_1 + (a_{zz} - \Gamma_{0A} w_z^2 \phi + \Gamma_{0A} x_z) n_2 = 0$$

Then

$$\Gamma_{0A} w_z^2 \phi + \Gamma_{0A} x_z \phi^2 - a_{zx} \phi + a \phi = 0$$

$$-\Gamma_{0A} w_z^2 \phi + \Gamma_{0A} x_z + a_{zz} = 0$$

$$\Gamma_{0A} (\phi^2 + 1) x_z + \phi (a - a_{zx}) + a_{zz} = 0$$

$$x_z = -\frac{1}{\Gamma_{0A}} \left[\frac{\phi (a - a_{zx}) + a_{zz}}{(1 + \phi^2)} \right]$$

$$\phi^2 \approx 0$$

$$x_z = -\frac{1}{\Gamma_{0A}} \left[\phi (a - a_{zx}) + a_{zz} \right]$$

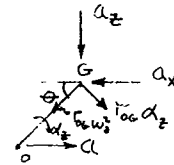
Lets find a

$$\phi^G = \phi^{G/O} + \phi^O$$

$$w_z^2 \approx 0 \text{ small}$$

$$a_x = -\Gamma_{OG} \alpha_z \cos \theta - a$$

$$a = -(\Gamma_{OG} \alpha_z \cos \theta + a_x)$$



Place a into a_z in above eq

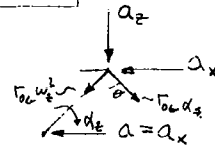
$$\alpha_z = -\frac{1}{\Gamma_{OA}} \left[\phi (-\Gamma_{OG} \alpha_z \cos \theta - a_x - a_{zx}) + a_{zz} \right]$$

$$\alpha_z (\Gamma_{OA} - \Gamma_{OG} \phi \cos \theta) = -[-\phi (a_x + a_{zx}) + a_{zz}]$$

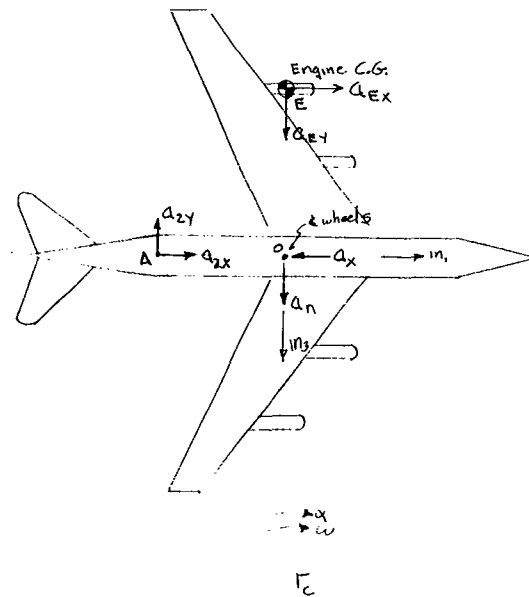
$$\Gamma_{OG} \cdot \phi \cdot \cos \theta \approx 0 \text{ small} \quad \text{there fore } a = -a_x$$

$$\alpha_z = -\frac{1}{\Gamma_{OA}} [-\phi (a_x + a_{zx}) + a_{zz}] \quad \text{--- (1)}$$

$$w_z^2 \approx 0 \text{ small}$$



$$a_z = \Gamma_{OG} \cdot \alpha_z \cdot \cos \theta \quad \text{--- (1a)}$$



$$a^E = \dot{\Gamma}^{E/O} + a^O$$

$$a_{Ex} m_1 + a_{Ey} m_3 = \Gamma_{OE} \omega_y^2 m_3 + \Gamma_{OE} \alpha_y m_1 - a_x m_1 + a_n m_3$$

$$(a_{Ex} - \Gamma_{OE} \alpha_y + a_x) m_1 + (a_{Ey} - \Gamma_{OE} \omega_y^2 - a_n) m_3 = 0 \quad \text{----- (1)}$$

$$\Phi^A = \Phi^{A/0} + \Phi^0$$

$$a_{zx} n_1 - a_{zy} n_3 = \Gamma_{0A} \omega_y^2 n_1 - \Gamma_{0A} \alpha_y n_3 + a_n n_3 - a_x n_1$$

$$(a_{zx} - \Gamma_{0A} \omega_y^2 + a_x) n_1 + (-a_{zy} + \Gamma_{0A} \alpha_y - a_n) n_3 = 0 \quad \dots \quad (3)$$

From eq (2) & (3)

$$\alpha_y = \frac{a_{Ex} + a_x}{\Gamma_{0E}}$$

$$a_n = \Gamma_{0A} \alpha_y - a_{zy}$$

$$\text{Then } a_n = \frac{\Gamma_{0A}}{\Gamma_{0E}} (a_{Ex} + a_x) - a_{zy} \quad \dots \quad (4)$$

Also from eq (2) & (3)

$$\omega_y^2 \Gamma_{0E} = a_{Ey} - a_n$$

$$\& \quad \omega_y^2 \Gamma_{0A} = a_{zx} + a_x$$

Eliminate ω_y^2

$$\frac{\Gamma_{0E}}{\Gamma_{0A}} (a_{zx} + a_x) = a_{Ey} - a_n$$

$$a_{zx} = \frac{\Gamma_{0A}}{\Gamma_{0E}} (a_{Ey} - a_n) - a_x \quad \dots \quad (5)$$

$$\Sigma F_{ix} = 0 \quad [\text{See fig. on pg. 27}]$$

$$F_A + F_F = P_H - m a_x$$

$$\Sigma F_{iz} = 0$$

$$N_F + N_A = W + P_V - m a_z$$

$$\Sigma M_{CG} = 0$$

$$I \alpha_z - N_F \cdot d + N_A b - (F_A + F_F) h + P_H \cdot c - P_V \cdot e = 0$$

Place N_A & $(F_A + F_F)$ into this eq.

$$I \alpha_z - N_F \cdot d + (W + P_V - m a_z - N_F) b - (P_H - m a_x) h + P_H c - P_V e = 0$$

$$N_F (b + d) = I \alpha_z + W b + P_V b - m a_z b - P_H h + m a_x h + P_H c - P_V e$$

$$l = b + d$$

$$N_F = \frac{1}{l} [I \alpha_z + P_H (c - h) + m a_x h + W b + P_V (b - e) - m a_z b]$$

$$\text{with } (c - h) = -s$$

$$N_F = \frac{1}{l} [I \alpha_z - P_H s + m a_x h + W b - P_V (e - b) - m a_z b]$$

where $e > b$

$$a_z = r \alpha_z \cos \theta \quad [\text{See pg. 29}]$$

Component	* Mass	* Balance Arm of Component	* C.G. #	* L = (Bal. Arm. - C.G.)	* L ²	* L ³	* I = Σ m L ²
Structure	60267	1870	1031	835.6	675	5.62	31.60
Engines	18770	582	606.0	"	27.6	2.30	5.29
Equip. (Fixed)	20005	623	723.9	"	111.7	9.29	2.10
Crew	850	264	193.4	"	642.2	53.60	347.00
Fuel	1117	34.7	799.4	"	36.2	3.02	9.10
Equip. (Load)	1065	325	775.7	"	36.9	3.07	9.40
Payload	117,911	3660	905.6	"	70.0	5.82	54.0
							I = 310,300 slugs-ft ²
* Obtained from aircraft log.							
≠ Ref e.							

Example Calculation

Run 25 Engaging Velocity = 126.0 knots 60 ft of centerline

$$a_{zz} = .40 \cdot 32.2 = -12.9 \text{ ft/sec}^2$$

$$a_{Ex} = 1.12 \cdot 32.2 = -36 \text{ ft/sec}^2$$

$$a_{Ey} = .44 \cdot 32.2 = 14.1 \text{ ft/sec}^2$$

$$a_x = .85 \cdot 32.2 = 27.4 \text{ ft/sec}^2$$

$$P_H = 183,800^*$$

$$P_V = 7750^*$$

$$W = 220,000^*$$

$$m = \frac{220,000}{32.2} = 6.850 \text{ slugs}$$

$$I = 316,800 \text{ slugs-ft}^2 \text{ [Ref. Pg. 33]}$$

$$S = 3.5 \text{ ft}$$

$$h = 9.58 \text{ ft}$$

$$e = 60.39 \text{ ft}$$

$$l = 50.67 \text{ ft}$$

$$b = 4.29 \text{ ft}$$

$$r_{0A} = (35^2 + 9.58^2)^{1/2} = 36.5 \text{ ft}$$

$$r_{0b} = (9.58^2 + 4.29^2)^{1/2} = 10.5 \text{ ft}$$

$$r_{0E} = 46.0 \text{ ft}$$

$$\phi = \arctan \frac{9.58}{35} = \arctan .274$$

$$\theta = \arctan \frac{4.29}{9.58} = \arctan .447 = 66.8^\circ$$

a_{zy} was not measured for this run.

Use $a_{zy} = .37 \cdot 32.2 = -11.9 \text{ ft/sec}^2$ which is a_{zy} measured for.

Run 21 (Vel = 127.4 knots, 40' off centerline). Run 21 being similar to

Run 25.

From eq (4)

$$a_n = \frac{36.5}{46.0} (-36 + 28.2) + 11.9 = \underline{\underline{+5.7 \text{ ft/sec}^2}}$$

From eq (5)

$$a_{zx} = \frac{36.5}{46.0} (14.1 - 5.7) - 28.2 = \underline{\underline{-21.5 \text{ ft/sec}^2}}$$

From eq ①

$$\alpha_z = \frac{-1}{36.5} [-274(28.2 - 21.5) - 12.9]$$

$$\alpha_z = \frac{-1}{36.5} (-1.85 - 12.9) = +.403 \text{ rad/sec}^2$$

$$a_z = r_{OG} \alpha_z \cdot \cos \theta \quad [\text{Ref. eq (1a)}]$$

$$a_z = 10.5 \cdot .403 \cdot \cos 66.8^\circ = 1.67 \text{ ft/sec}^2$$

From Eq. ⑥

$$N_F = \frac{1}{50.67} [316,800(.403) - 183,800 \cdot 35 + 6850 \cdot 27.4 \cdot 9.58 \\ + 220,000 \cdot 4.29 + 7750(60.39 - 4.47) - 6850 \cdot 1.67 \cdot 4.29]$$

$$N_F = \frac{1}{50.67} [128,000 - 641,000 + 1,800,000 + 940,000 \\ - 435,000 - 49,000]$$

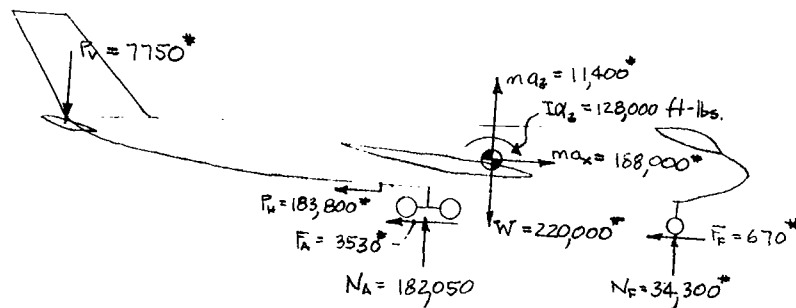
$$N_F = \frac{1}{50.67} \times 1,743,000 = \underline{\underline{34,300^*}}$$

See free body diagram of forces acting on airplane, page

Russo

36

Free body diagram of forces acting on airplane during arrestment for run 25.



$$\mu (\text{coeff. of friction}) = \frac{m a_x - P_H}{(N_A + N_F)} = \frac{188,000 - 183,800}{216,350} = .0195$$

$$F_A = .0195 \cdot 182,050 = 3530* \text{ or } 382* / \text{tire}$$

$$F_F = .0195 \cdot 34,300 = 670*$$

The justification for using run 25 as an example calculation is as follows.

If neglecting the friction forces which are small in comparison to P_H & $m a_x$, we then obtain $P_H = m a_x$ from summing horizontal forces.

Revising eq. (2) we get

$$N_F = \frac{1}{L} [I X_z - P_H S + P_H h + W b - P_V (e-b) - m a_z b]$$

$$N_F = \frac{1}{L} [I X_z + W b + P_H c - P_V (e-b) - m a_z b]$$

where $c > b$

N_F depends largely on W , P_H , & P_V . At higher speeds P_H is maximum & at larger gross weights P_V is smallest in magnitude.

Therefore the nose gear load, N_F , is maximum at higher speeds & maximum gross weights.

It is to be noted that P_V (vertical load on horizontal tail) is known for the 220,000# gross weight [see ref. a] with a velocity of 130 knots and would be difficult

to adjust for other speeds and gross weights.

The net acceleration at pt. A (see p. 27) was measured only for some of the 220,000 lb. gross weight runs.

CROSS WIND STRESSES

Cross Wind Stress in Fuselage @ Balance Sta 887

$$D = C_D A \frac{\rho V^2}{2}$$

D = Drag force
 C_D = Coefficient of drag
 A = Projected area
 ρ = Density or mass/volume
 V = Wind Velocity

Assume $V = 20$ mi/hr and acting 90° to aircraft.

$$V = \frac{20 \times 5280}{3600} = 29.4 \text{ ft/sec}$$

$$\rho = \frac{\gamma}{g} = \frac{.0763}{32.2} = .00237 \text{ slugs/ft}^3 \quad \text{where } \gamma = \text{specific weight}$$

Vertical Tail

$$\text{with } \frac{b}{h} = \frac{15}{24.5} < 1 \quad C_D = 1.17 \text{ [Ref. d]}$$

$$A = 15 \times 24.5 = 368 \text{ ft}^2$$

$$(\text{Drag})_{VT} = 1.17 \times 368 \times \frac{.00237 \times 29.4^2}{2} = 443^{\#}$$

Fuselage

$$\text{with } \frac{b}{h} = \frac{62.5}{14.25/2} = 8.9 \quad C_D = .75 \text{ [Ref. d]}$$

$$A = 62.5 \times 7.1 = 444 \text{ ft}^2$$

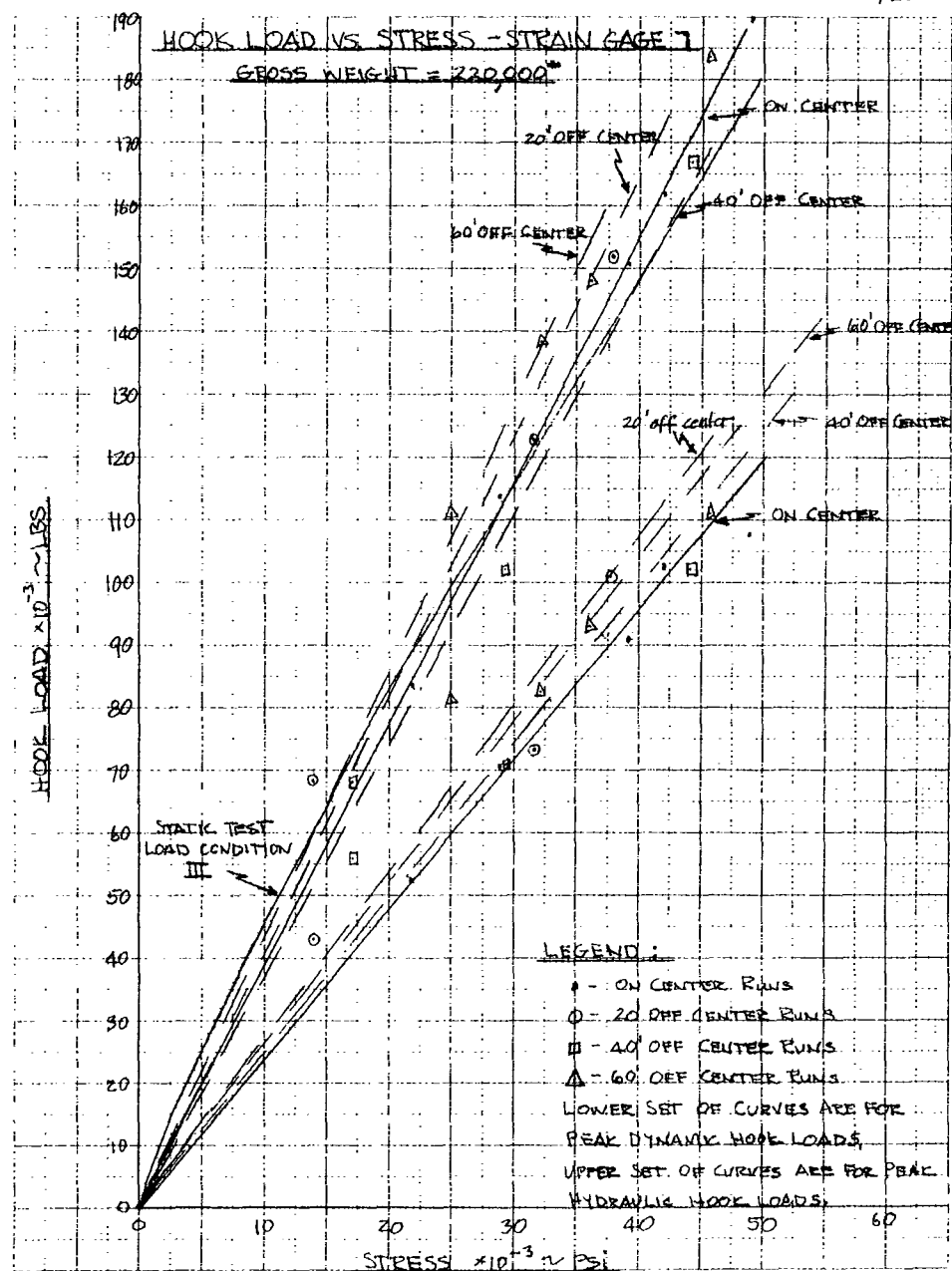
$$(\text{Drag})_F = .75 \times 444 \times \frac{.00237 \times 29.4^2}{2} = 342^{\#}$$

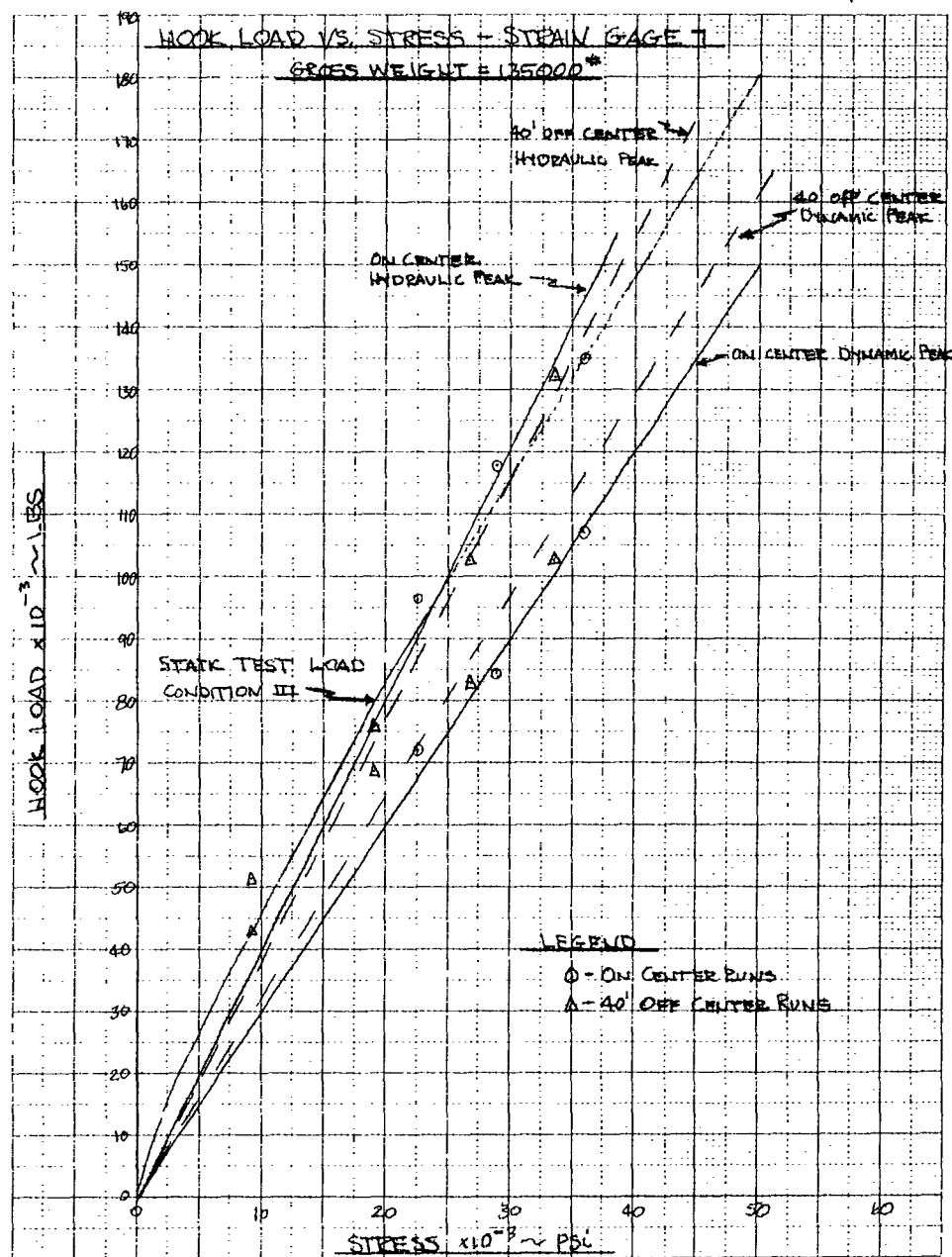
Moment at Bal. Sta 887

$$M = 443.55 + 342 \cdot \frac{62.5}{3} = \underline{\underline{31,550 \text{ ft-lbs}}}$$

Z_y (about lateral axis) = 1130 in^3 at Balance Sta 900 [Ref. Pg. 21]

If we assume $\frac{1}{10}$ of 1130 in^3 for Z_z (about vertical axis) the stress value would be $\frac{31,550}{113} = 279 \text{ psi}$ which is low.





43a

REFERENCES

- a. Phone call from M. C. Wardle (All American Engineering Co.) to Richard Sliff (FAA test pilot) at Boeing Aircraft Co., Seattle, Washington.
- b. "Prototype Arresting Hook Installation Design for FAA-Boeing 720 Aircraft," All American Engineering Report M-635B
- c. Telegram from Boeing Aircraft Co., Seattle, Washington to John Clarkson (All American Engineering Co.), Reference No. 6-7776-226.
- d. Aero Dynamic Drag, Book by Sighard F. Hoerner
- e. Verbal conversation between John Clarkson (All American Engineering Company) and Dean Crimm (FAA weights engineer).

APPENDIX

Appendix CBoeing 720 and 707 hooks tested at
Swarthmore College, Pennsylvania

The purpose of this part of the report is to interpret the findings of the Boeing 720 and 707 hooks tested at Swarthmore College, Pennsylvania on July 24, 1962.

Erroneous strain gage readings were obtained from the Boeing 707 hook because the strain gages slipped. Readings were obtained for the Boeing 720 hook and are presented on page 47.

Both hooks were pulled to destruction and recorded on page 56.

LOADS CRITERIA

ARRESTING HOOK ASSEMBLIES, BOEING 707 AND 720 AIRCRAFT

S. O. 1734, Task 440

1. GENERAL

- 1.1 Scope - This criteria defines the load and load parameters which will govern the design and analysis of the arresting hook assemblies to be used on the Boeing 707 and 720 aircraft.
- 1.2 Description of Assemblies - Each arresting hook assembly will be of the Sheaffer spring hook type consisting of a flat plate shank welded to a hook point. A replaceable light metal shoe will be bolted to the hook point to complete the assembly.

One hook assembly shall be designed to meet the arresting load requirements of the Boeing 707 aircraft, and the other hook assembly shall be designed to meet the arresting load requirements of the Boeing 720 aircraft.

The Boeing 707 hook assembly shall be readily adaptable to installation on the Boeing 720 aircraft. However, a weak link shall be incorporated as part of the installation in order to preclude the possibility of inadvertently applying to the 720 aircraft an arresting load exceeding the structural capability of the reinforced hard point. This will be accomplished by removing material from the 707 hook shank and the process will thus be an irreversible one.

The Boeing 720 hook assembly shall not be capable of installation on the Boeing 707 aircraft.

- 1.3 Requirements - References 5.1, 5.2, and 5.3 define all specifications for the assemblies. Structural requirements resulting from these are stated in the following sections.

2. LOADS

- 2.1 Limit Loads - Limit loads are defined as the maximum arresting loads to which the assemblies will normally be subjected. The limit loads will be different for the two assemblies, as noted below.

Boeing 707 A/C
350,000#

Boeing 720 A/C
225,000#

- 2.2 Yield Loads - Defined as the loads at which yielding of the assemblies can be expected to occur. Obtained by multiplying limit loads by a yield load factor (paragraph 3).

3. LOAD FACTOR AND LOAD CYCLES

The factor listed below will be used to obtain the yield load as noted in paragraph 2, 2.

- 3.1 Yield Load Factor, YLF = 1.15.
- 3.2 Number of Load Cycles - Each hook assembly shall have the structural capability of being cycled from zero load to limit load and back to zero load for a total of one hundred (100) cycles.

4. MARGIN OF SAFETY

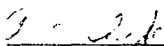
Margins of safety shall be computed for critically loaded sections as follows:

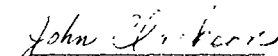
$$M. S._{yield} = \left[(F_{t_y} / (YLF)(Limit Load Stress)) \right] - 1$$

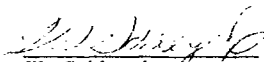
5. REFERENCES

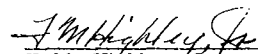
- 5.1 AAE Sales Order 1485, dated 18 June 1962.
- 5.2 Addendum A to Sales Order Nos. 1470 thru 1485 dated 18 June 1962.
- 5.3 Initial Plan - Mod. 3500 Follow-On Work, Inter-Office reference (Program Planning) EPP-1, J. N. Eustis, dated 19 June 1962.

6. APPROVAL

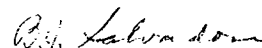

B. R. Sheaffer


J. Clarkson

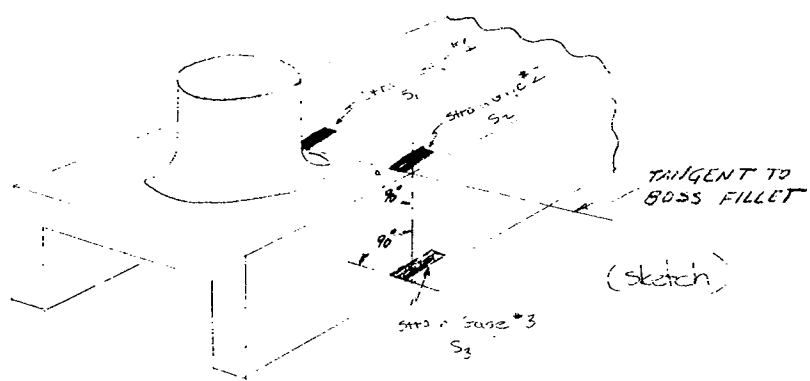

W. Schlegel


F. M. Highley, Jr.


M. C. Wardle


B. J. Salvadori

25 June 1962

Strain Gage LocationsBozma 12.2 HookHook Shank

MODEL NO.

REPORT NO

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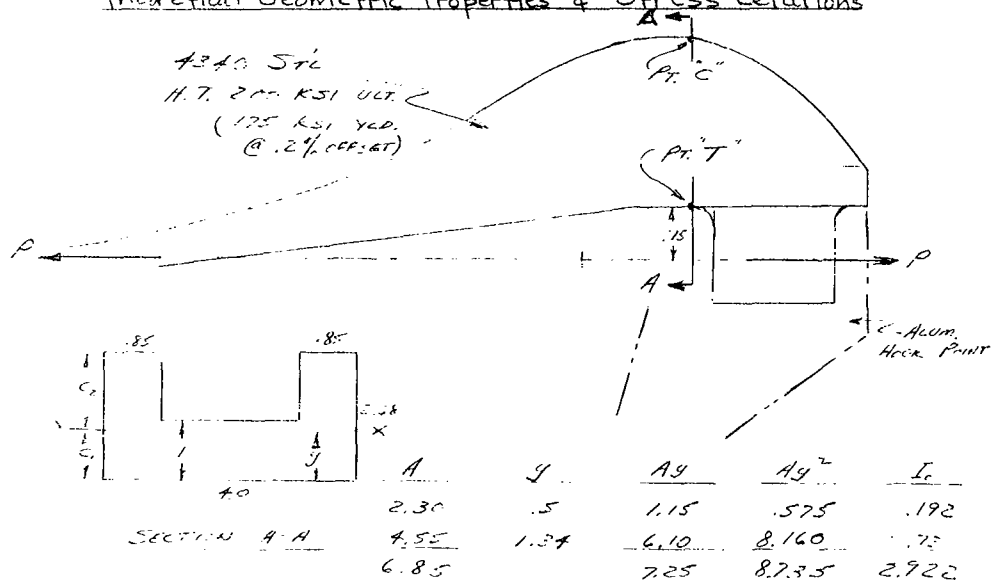
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(1734-440)

50

BOWING 720 TAIL HOOD
(DWG 7253)

Theoretical Geometric Properties & Stress Relations



$$\bar{y} = \frac{7.25}{6.85} = 1.06 = C_1 \quad C_2 = 2.68 - 1.06 = 1.62$$

$$I_x = 2.922 + 8.735 - (6.85)(1.06)^2 = 3.797 \text{ in}^4$$

$$C = 75 + 1.06 = 1.81$$

4340 STEEL

(a) STRESS: ACCORDING TO STRAIGHT BEAM THEORY ---

$$f_c = \frac{P}{A} + \frac{P C C_1}{I} = \frac{P}{6.85} + \frac{P \times 1.81 \times 1.06}{3.797} = P(1.46 + .48) = 1.94 P$$

$$f_t = \frac{P}{A} - \frac{P C C_2}{I} = \frac{P}{6.85} - \frac{P \times 1.81 \times 1.62}{3.797} = P(1.46 - .733) = .727 P$$

(b) STRESS: ACCORDING TO INSTRUMENTATION ---

$$E = \frac{\text{STRESS}}{\text{STRAIN}} = 29 \times 10^6 \text{ PSI (FOR 4340 STEEL)}$$

$$f_t = f_c = 29 \times 10^6 (\text{STRAIN})$$

UFP
4/6/62

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STRESSES AT SECTION A-A
(REF PG 50 (a) & (b))

APPLIED LOAD	INSTRUMENT. CALC.						STR. BEAM THEORY CALC.	
	GAGE #1		GAGE #2		GAGE #3		f_c	f_t
	STRAIN	f_c	STRAIN	f_c	STRAIN	f_c		
	K. PSI IN/IN (1)	KSI (2)	K. PSI IN/IN (4)	KSI (5)	K. PSI IN/IN (6)	KSI (7)	KSI (8)	KSI (9)
0	0	0	0	0	0	0	0	0
25	270	7.8	540	15.7	457	13.5	15.7	14.7
50	1108	32.1	1067	31.0	885	25.7	31.3	29.4
75	1950	56.5	1607	46.6	1297	37.6	47.0	44.0
100	2775	80.4	2137	61.9	1690	49.0	62.6	58.7
125	3600	104.2	2670	77.5	2083	60.5	78.3	73.5
150	4325	126.2	3175	92.7	2473	71.7	94.0	88.0
175	5220	151.5	3717	107.7	2863	83.1	109.8	103.0
200	6028	175.0	4250	123.2	3243	94.4	125.0	117.5
225	6795	197.0	4770	138.5	3612	103.9	141.0	132.0

NOTES:

②, ④, & ⑥ - AVERAGE TOTAL STRAINS FROM TEST
DATA SHEET, PAGE 49.

③, ⑤ & ⑦ - CALCULATED STRESS ACCORDING TO ②, ④ & ⑥
AND $E = 29 \times 10^6$ PSI (SEE PG. 50, ITEM (a)).

⑧ & ⑨ - CALCULATED STRESS ACCORDING TO STRAIN AT
BEAM THEORY BASED ON GEOMETRICAL GEOMETRICAL
PROPERTIES OF SECTION (SEE PG. 50, ITEM (a)).

⑧ IS COMPARABLE TO ③, & ⑨ IS COMPARABLE TO ⑦.

⑩ - ⑤ VALUES FROM 1 AT 25 KIPS. INCREASING TO .981 AT 225 KIPS.
THIS APPROXIMATES THE "STRAIGHT" BEAM THEORY.

⑪ - ⑦ VARIES FROM .795 AT 25 KIPS. TO .787 AT 225 KIPS.
THIS MORE CLOSELY APPROXIMATES THE "CURVED" BEAM THEORY.

NOTICE THAT PT. "T" IS ON THE "STRAIGHT" PORTION OF THE
BEAM & PT. "C" IS ON THE "CURVED" PORTION.

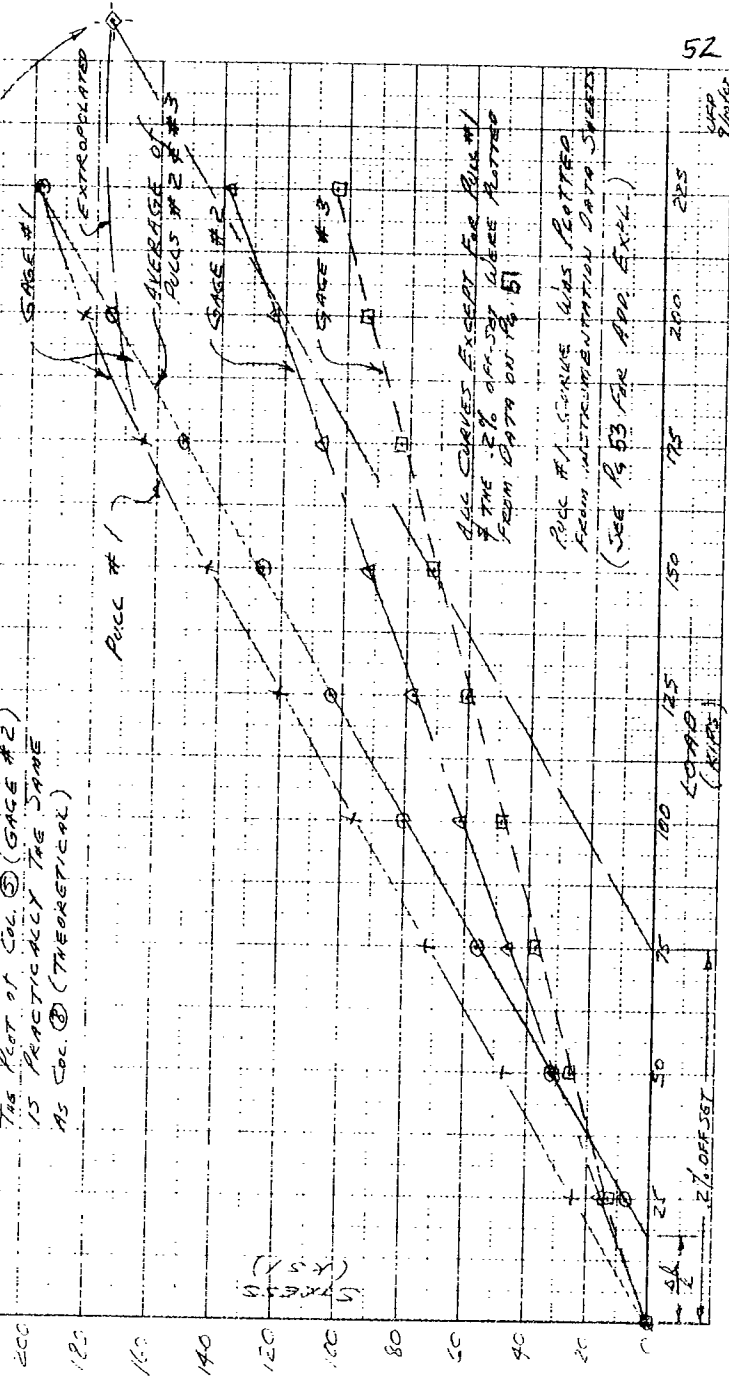


720 HOOK

LOAD VS STRESS
AT SECT A-A

200 KSI MATL. YLD. @ 2%
AND 5 YIELD KSI

NOTE: (FROM PG. 51)
THE PLOT OF COL. ⑤ (GAGE #2)
IS PRACTICALLY THE SAME
AS COL. ③ (THEORETICAL)



UFP
9/11/62

53

INTERPRETATION OF CURVES ON PG 52

- (1) ALL TEST PULLS (EXCEPT PULL #1 ON GAGE #1) WERE MADE WITHIN THE PROPORTIONAL LIMIT OF THE MATERIAL.
- (2) PULL #1 ON GAGE #1 INDICATES THAT THE PROPORTIONAL LIMIT WAS EXCEEDED. SUCCEEDING PULLS ON THE SAME GAGE, HOWEVER, SHOW A LINEAR RELATIONSHIP, INDICATING THAT THESE SUCCEEDING PULLS WERE MADE WITHIN THE PROPORTIONAL LIMIT OF THE MATERIAL, WHICH WAS PROBABLY WORK-HARDENED BY THE FIRST PULL.
- (3) THE CURVE OF PULL #1 ON GAGE #1 ABOVE THE PLOTTED POINT AT 165 KSI IS FICTITIOUS SINCE THE PROPORTIONAL LIMIT HAS BEEN EXCEEDED.
- (4) THE OFFSET $\frac{\Delta L}{L} = .057\%$ CALCULATED AS FOLLOWS:
 - (a) FROM CURVE ON PG 52: $\frac{\Delta L}{L} = 17.5 \text{ KIPS}$
 - (b) FROM DATA SHEET PG 49 FOR GAGE #1, PULLS #2, #3, THE AVERAGE STRAIN INCREMENT FOR EACH 25 KIPS LOADING INCREMENT IS $816 \mu\text{in./in.}$.
THEREFORE $\frac{816}{25} = \frac{X}{17.5}$; $X = 570 \mu\text{in./in.}$
 $570 \mu\text{in./in.} = .00057 \text{ in./in.} = .057\% \text{ in./in.}$
- (5) THE EXTRAPOLATED PORTION OF THE CURVE FOR PULL #1 WAS ARRIVED AT AS FOLLOWS:
 - (a) BY KNOWING THE MATE. YLD. = 176 KSI @ .2% OFFSET FOR 200 KSI ULT H.T. ALLOY STL. (REF. ANGLE'S), DETERMINE THE EQUIVALENT LOAD FOR EACH PARTICULAR GAGE #1 READINGS. FROM DATA SHEET, PG 49, IT IS FOUND THAT AN APPROX. 75 KIPS LOAD PRODUCES A $2070 \mu\text{in./in.}$ STRAIN ($\approx .2\%$).
 - (b) DRAW A LINE THRU THIS POINT (AT 75 KIPS) PARALLEL TO THE STRAIGHT PORTION OF THE CURVE FOR PULL #1. WHERE THIS LINE INTERSECTS 176 KSI, DETERMINE THE .2% OFFSET YLD. POINT ON THE CURVE.
 - (c) REFERRING TO A TYPICAL "STRESS VS STRAIN" CURVE, FARE BETWEEN THE UPPER EXTREMITY OF THE

LFP
8/1/52

54.

STRAIGHT PORTION OF THE CURVE σ_{ϵ} Pull #1 /
is YLD (Y. LOCATED IN STEP 1). KEEP IN MIND
THAT THE YLD PT. IS THE TIGHTEST POINT OF
THE EXTRAPOLATED CURVE.

* STRAIGHT LEARN THEORY IS CURVED LEARN THEORY.

TO ALL KINDS OF THE DATA ON 1/3/51 THE
HOMOPHONY OF THE DESIGN IN THE CURVED LEARN
THEORY IS NOT THE SAME. THAT IS TO SAY THAT
SINCE THE YLD IS NOT THE TIGHTEST POINT ANYMORE
BUT THE LEARNED LEARN FROM CH.

$$\frac{\sigma}{\epsilon} = \frac{K}{\epsilon}$$

THEY ARE NOT THE SAME. ϵ_{YLD} IS APPLIED
TO THE BENDING STRESS ($\frac{K \epsilon}{\epsilon}$) AS FOR A TYPICAL
CURVED LEARN.

* STRESS CONCENTRATION.

AT THE INTERSECTION OF THE HOMO. POINT ϵ_{YLD}
THE SLOPE FROM EQUATION OF GAGE #1 IS A
STRESS CONCENTRATION. IT IS THE SLOPE OF THE
THE SLOPE DIFFERENTIAL BETWEEN THE CURVES FOR
GAGE #1 & GAGE #2. THE SLOPE OF THE STRAIGHT
PORTION OF THE CURVE FOR PULL #1 ON GAGE #1 IS

$$C_1 = \frac{\sigma_{YLD}}{\epsilon_{YLD}} = \frac{K}{\epsilon_{YLD}} \quad (\text{SAME AS STR. LEARN})$$

& THE SLOPE OF THE CURVE FOR GAGE #2 IS

$$C_2 = \frac{\sigma_{YLD}}{\epsilon_{YLD}} = \frac{K}{\epsilon_{YLD}}$$

THE STRESS CONCENTRATION FACTOR K_2 IS
THE RATIO OF THE SLOPES OR

$$K_2 = \frac{C_1}{C_2} = 1.596$$

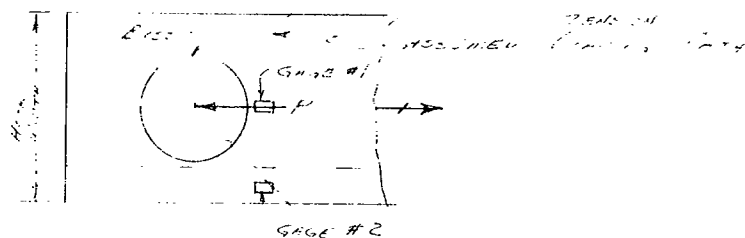
* SEE NOTE ON STRESS EFFECT IN Pg 53

UFP
9/10/62

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* METHOD OF LOADING EFFECT

DUE TO A "FANNING OUT" EFFECT OF LOAD WHICH IS APPLIED TO THE BOSS, PERHAPS ALL THE LOAD DOES NOT GO THRU THE LOCATION AT GAGE #2. IF THIS IS TRUE, IT MAY ONLY BE COINCIDENTAL THAT THE GAGE READINGS (CAL ⑤ of Pg 51) AGREES WITH THE THEORETICAL CALCULATION (CAL ② of Pg 51), COINCIDENTAL TO THE DEGREE THAT PERHAPS A TOTAL STRESS INCREASE DUE TO A CURVED BEAM FINGER MAY BE COUNTERED BY A STRESS DECREASE AT THIS POINT BECAUSE OF IT A REDUCED AMOUNT OF THE TOTAL LOAD PASSES THRU THIS POINT RESULTING IN THE CALCATED OVERALL FEMUR (L₁) APPROXIMATELY EQUAL TO UNITY BETWEEN ⑤ & ② of Pg. 5.



- ALTHOUGH WHAT HAS BEEN SAID ABOVE IS TRUE IN GENERAL, IT IS FELT THAT THIS "FANNING EFFECT" IS NEGLIGIBLE IN THE SPECIFIC CASE OF THE 720 & 707 HICK DESIGNS, BECAUSE:
- (1) THE BOSS DIAMETER IS LARGE IN COMPARISON WITH THE HICK JUNCTION.
 - (2) THE BEELINESS OF THE HICK DESIGN CREATES THE S.D. PROVIDES ADDITIONAL LOAD PATHS TO DISTRIBUTE THE APPLIED LOAD P MORE UNIFORMLY TO GAGE #2.

THIS COMMENT ON "METHOD OF LOADING EFFECT" IS MENTIONED SO THE RESULTS DERIVED FROM THIS TEST ARE NOT INDISCRIMINATELY USED FOR OTHER DESIGNS.

* SEE Pg. 54

OFF
9/2/62

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(TEST HOOKS)

THEORETICAL CALCULATIONS AT DESIGN LOAD

FOR 707 HOOKS

(SEE PG 50 FOR SECT. DATA)

121 HOOK 1340 STL FWD 200 KSI F_y 176 KSI @ .02%
(7253) $P = 225$ LBS # (1.417)

$$f_t = K_s \left(\frac{P}{A} + \frac{PEI}{I} \right) = 1.55 \left(\frac{225}{0.52} + \frac{225 \times 14.81 \times 1.55}{5.977} \right)$$

$$= 1.55 (20,240 + 12,400) = 219,000 \text{ PSI (24,000 PSI)}$$

SAME
STABILITY

NOTE: ACTUAL TEST SPECIMEN H. = 14.81"

$F_{cy} = 185 \text{ KSI @ .02\%}$, $f_t = 176 \text{ KSI @ .02\%}$

REL. TO. WARPING (REF. TESTING DATA)

111 HOOK 1110 STL TEST SPECIMEN H. = 14.81" $F_{wd} = 275 \text{ KSI}$
(7253) $F_{cy} = 227 @ .02\%$, $f_t = 206 @ .02\%$ - 111 HOOK

$P = 350$ LBS # (1.417) - 111 HOOK

$$f_t = \frac{350}{0.52} \times 1.55 = 351 \text{ PSI (24,000 PSI)}$$

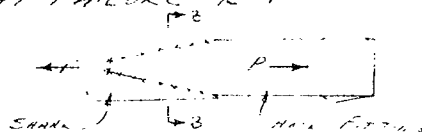
NOTE: TENSILE PROPERTIES AT $F_{wd} = 275 \text{ KSI}$

101720 - PULLED TO DESTROYED AT 350 KSI
AFTER 10 CYCLES @ 225 KSI

$$ULT. FACTOR = \frac{350}{219} = 1.59$$

101707 - PULLED TO DESTROYED AT 484 KSI
AFTER 100 CYCLES @ 350 KSI

$$ULT. FACTOR = \frac{484}{350} = 1.38$$

[illegible]

725 --
 $f_c = \frac{358}{175} = 205 \text{ psi}$
 then $\phi f_c = 0.75 \times 205 = 154 \text{ psi}$

$$f_c = \frac{f_{cr}}{1.75} = 277 \text{ ksi}$$

$$f_{cr} = \text{MATERIALEVAL} = 275 \text{ ksi} \quad \phi_{cr}$$

The first half of the book contains the chapters on
 "Foundations of Mathematical Logic" and "The
 Mathematical Language".

A. H. IS NOT A STRAIGHT LINE AT THE POINT OF THE 1ST ORDER KINK BECAUSE THE BENDING SURFACE A. H. IS NOT SYMMETRICAL ABOUT THE BENDING AXIS & THEREFORE THEORETICALLY - SHOULD NOT BE CONSIDERED.

UFR
7/18/62

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DEVELOPMENTAL CALCULATIONS LEADING TO THE DESIGN OF THE TEST HOOKS WERE DONE IN ROUGH FORM & ARE NOT IN A METHODOICAL ORDER DUE TO NUMEROUS DESIGN & MATERIAL CHANGES. ALTHOUGH THESE CALCULATIONS ARE NOT IN REPORT FORM, THEY ARE ON FILE IN THE AAE, STRESS DEPT. THESE CALCULATIONS WERE PROVED TO BE TRUE BY THE SUCCEEDING TESTS.

THE FINAL DESIGN ANALYSIS IS IN GOOD FORM IN AAE STRESS FILES. KNOWLEDGE GAINED FROM THE TEST RESULTS WAS USED IN ANALYZING THE FINAL DESIGN.

PERTINENT DRAWING LIST

	ASSEM. DWG. ↓	SHANK DWG. ↓	HOOK FITTING DWG. ↓
FILE TEST:			
720 Hook →	7251-1	7252	7253
707 Hook →	7275-1	7277	7276
FINAL DESIGN:			
720 Hook →	7251-2	7252	7260
707 Hook →	7275-2	7277	7262

Note:

(a) DIFFERENCES BETWEEN 720 & 707 DESIGN:

1. MATERIAL --

720 - A516 STEEL $F_u = 20 \text{ KSI}$ & $F_y = 10 \text{ KSI}$

707 - MILD STEEL $F_u = 27 \text{ KSI}$ & $F_y = 24 \text{ KSI}$

2. SHANK WIDTH AT A/C ATTACHMENT --

720 - 11" WIDE

707 - 10" WIDE

(b) DIFFERENCE BETWEEN TEST HOOK & FINAL DESIGN:

1. HOOK FITTING THREAT LENGTH --

FINAL DESIGN IS $\frac{1}{4}$ " LONGER THAN

TEST HOOK (INSIGNIFICANT STRESS WISE)

Appendix D

Strain gage data reduced during the NAFEC test. Total stress in the aircraft members monitored does not include deadload stress but rather arrested landing stress

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE 10-19-62

* Run #1 (80.8 knots)

REPORT NO. _____

Gage No.	$K \times 10^4$ in/in	D_R = R_c	$F_z \times 10^4$ = K/D_R	ΔD = $D_z - D_j$	$G \times 10^4$ = $F_z \times \Delta D$	E $\times 10^{-4}$	S psi = $E \times G$		
S7	2910	1.55	1880	.23	433	29.0	12600		
S8	2869	.18		0		10.5	0		
S9	"	.08		0		10.5	0		
S10	"	1.52	1885	-.20	377	10.3	-3900		
S11	"	1.65	1740	.30	522	"	5400		
S12	"	1.82	1578	.20	316	"	3260		
S13	2896	—		.35		"	—		
S14	"	1.70	1700	.20	340	"	2460		
S15	2869	.53	5420	.10	542	"	5600		
S16	2057	—				28.5	—		
S17	2057	.10	20570	-17	3500	28.5	-100000		
S18	1029	NR	—	—	—	28.5	—		
S19	2869								
S21	2896								
S22	2869								
S23	"								
S26	"								
S27	"								
S28	"								
S29	"								
S30	2896								
S31	"								
S32	"								
S33	2869								
* Estimated from Run #2 - Re's for Run #1 Missing									

NO RECORD

MODEL NO. _____

REPORT NO. _____

Gage No.	$K \times 10^{10}$ in/in	D_R $= R_c$	F_z $= \frac{K}{D_R} \times 10^{10}$	ΔD $= D_z - D_i$	E $= F_z / \Delta D$	E $\times 10^{-6}$	S_{psi} $= E \times G$
S7	2910	.55	1875	.55	1030	29	29900
S8	2869	.18	15950	.10	1595	10.5	16750
S9	"	.08	35900	0	0	10.5	0
S10	"	.52	1885	.65	1225	10.3	12600
S11	"	.65	1740	.5	870	"	8550
S12	"	—	—	.42	—	"	—
S13	2896	—	—	.67	—	"	—
S14	"	.17	1700	.3	510	"	5250
S15	2869	.53	5420	small	—	"	—
S16	2057	—	—	small	—	28.5	—
S17	2057	.10	20600	-.18	3710	"	-106000
S18	1029	.45	2290	-.93	2130	"	-61000
S19	2869	.14	2040	.15	-307	10.3	3160
S21	2896	.13	2200	-.07	154	10.7	-1650
S22	2869	.33	8680	0	0	10.3	0
S23	"	.88	3240	.08	259	"	2660
S26	"	.52	1890	.30	568	"	5830
S27	"	.49	1920	±.25	538	"	±5520
S28	"	.29	2220	.30	665	"	6860
S29	"	.45	1970	.22	433	"	4470
S30	2896	.26	11100	0	0	"	0
S31	"	.36	8050	.12	765	"	-10000
S32	"	.37	7850	±.03	235	"	-2430
S33	2869	.37	7720	0	0	"	0

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO.

DATE OCT 20 1962

RUN #3

(106.5 kts)

REPORT NO.

	GAGE NO	K IN/IN	R _c = DR	F ₂ = K/DR	AD DYN HYD	E = 10 ⁶ F ₂ (AD)	E = 10 ⁴ E PSI	S = E E PSI
1	S7	2910	1.57	1850	.31 .42	777	29.0	22500
2	S8	2869	.15	19120	0 .03	573	10.5	6020
3	S9	2869	.08	35900	0 0	0	10.5	0
4	S10	2869	1.62	1770	.35 .47	832	10.3	8560
5	S11	2869	1.64	1750	.35 .4	700	10.3	7210
6	S12	2869	1.82	1578	.3 .38	600	10.3	6180
7	S13	2896	—	—	.5 .58	—	10.3	—
8	S14	2896	1.75	1650	.22 .25	412	10.3	4240
9	S15	2869	.54	5320	.10 .10	532	10.5	5480
10	S16	2057	—	—	0 0	0	28.5	0
11	S17	2057	1.41	1460	-2.60	3790	28.5	10800*
12	S18	1029	N.R.	—	—	—	28.5	—

AD

S19	2869	1.4	2040	.6				
S21	2896	.3	2200	.07			2.7	1.50
S22	2869	.33	8680				10.3	
S23		.88	3240	.07				2230
S26		.52	1870	.16				3520
S27		1.49	1920	.25				4140
S28		1.29	2220	.25				5680+
S29		1.45	1970	.24				4870-
S30	2896	.26	11100					+
S31		.36	8050	.18				6700
S32		.37	7850	.03				1420-
S33	2869	.37	7720	.03				2400+

*

The max. stress was estimated because it was beyond the trace ran off oscillograph paper.

DATE Oct 20 1962

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DU PONT AIRPORT .. WILMINGTON, DELAWARE

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MODEL NO. _____

REPORT NO. _____

	GAGE NO	K	RC	F ₂ K/DR	AD DYN	AD HYD	E ₁₀₀ ⁴ F ₂ (AD)	E ₁₀₀ ⁴ PSI	S EE
1	97	2910	1.57	1850		.52	962	29.0	28900
2	98	2869	1.5	1920		—	—	10.5	—
3	99		1.08	35900		—	—	10.5	—
4	S10		1.63	1770		.48	850	10.3	8750
5	S11	"	1.64	1750		.51	882	10.3	9080
6	S12	"	1.82	1578		.30	472	10.3	4860
7	S13	2896	—	—		.70	—	10.3	—
8	S14	2896	1.73	1670		.30	501	10.3	5160
9	S15	2869	.53	5420		.12	650	10.3	6690
10	S16	2057	—	—		—	—	28.5	—
11	S17	2057	1.42	1455		-3.0	4365	28.5	-24000 *
12	S18	1029	N.R.	—		—	—	28.5	—

				ΔD		
S19	2869	1.4	2040	-0.5		10.3 -1170
S21	2816	1.3	2200	.07		10.7 1650
S22	2869	.33	8680	0		10.3 0
S23	"	.81	3530	0		" 0
S26	"	1.55	1850	.19		" 3640
S27	"	1.49	1920	.34		" 6720
S28	"	1.32	2170	.27		" 6100
S29	"	1.50	1910	.28		" 5510
S30	2896	.26	1100	0		" 0
S31	"	.36	8050	.05		" 4170
S32	"	1.80	.610	-.07		" -1160
S33	2869	1.60	.790	.17		" 3140

* The max. stress was estimated because at this instant the trace ran off oscillograph paper.

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MODEL NO.

REPORT NO.

	GAGE NO	K	RC	F ₂ K/DR	AD	F ₂ (AD)	E ¹⁰ PSI	S E
1	57	2910	1.58	1850	.58	1072	29	31100
2	58	2869	.12	23900	.02	478	10.5	5030
3	59	2869	1.08	17500	-.02	-350	10.5	-3680
4	510	2869	1.64	1770	-.75	-1330	10.3	-13700
5	511	2869	1.65	1850	.60	1110	10.3	11420
6	512	2869	1.80	1595	.48	766	10.3	7900
7	513	2896	NO RC	—	.81	—	10.3	—
8	514	2896	1.72	1685	.32	538	10.3	5550
9	515	2869	.53	5420	.14	755	10.3	7390
10	516	DELETED	7 A	1.00 K	READING	SUBSTITUTED		
11	517	2057	1.42	1445	-3.20	4640	28.5	-13200
12	518	1029	NO RC	—	—	—	28.5	NR.
13	519	2869	1.43	2010	.07	141	10.3	4451
14	521	2896	1.34	2160	.06	129.5	10.7	1385
15	522	2869	.33	8680	0	0	10.3	0
16	523	"	.81	3530	.07	247		12540
17	526	"	1.54	1850	.22	406		4180
18	527	"	1.49	1920	.32	616		6350
19	528	"	1.32	2170	.38	823		8480
20	529	"	1.50	1910	.36	688		7080
21	530	2896	.26	11100	.04	444		4570
22	531	"	.36	8050	.06	483		4980
23	532	"	1.80	1610	-.14	225		-2320
24	533	2869	1.60	1790	.14	251	10.3	2590

* The max. stress was estimated because at this instant the trace ran off oscillograph paper.

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MODEL NO. _____

DATE OCT 20 1962

RUN # 6 (135.6 KNOTS)

REPORT NO.

	GR NO	K	Dr = RC	Fz = K/OR	ΔD	$E \cdot 10^4$ Fz(ΔD)	$E \cdot 10^4$ $\times 10^{-4}$	S
1	57	2910	1.58	1850	.67	1240	29.0	36000
2	58	2869	1.82	1575	.35	352	10.5	±3700
3	59	2869	.42	6680	0	0	10.5	0
4	510	2869	1.64	1770	-.77	-1362	10.3	-14020
5	511	2869	1.65	1850	.58	1072		11030
6	512	2869	1.8	1595	.55	876		9300
7	513	2896	1.45	1995	.58	1158		11920
8	514	2876	1.72	1685	.38	641		6620
9	515	2869	.53	5420	.17	920	10.3	9500
10	516	DELE			-	-	28.5	-
11	517	2057	1.4	1445	-3.4	4920	28.5	-4000*
12	518	1029	NO RC		NR	-	28.5	-
13	519	2869	1.42	2020	.10	202	10.3	2080
14	521	2896	1.32	2170	.09	195	10.7	2090
15	522	2869	.33	8700	.02	173	10.3	1780
16	523	↑	.82	3510	.12	422		4340
17	526	↓	1.54	1862	.3	560		5760
18	527		1.5	1915	.17	325		3350
19	528	↓	1.3	2210	.15	332		3420
20	529	2869	1.47	1951	.34	664		6840
21	530	2896	.27	10720	.07	752		7750
22	531	↓	.37	7840	-.14	-1095		-11300
23	532	2896	1.77	1635	-.13	213		-2190
24	533	2869	1.58	1815	.18	327	10.3	3370

* The max. stress was estimated because at this instant the trace ran off oscillograph paper.

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DU PONT AIRPORT -- WILMINGTON, DELAWARE

MODEL NO.

DATE OCT 21 1962

RUN #7 (78.4 KNOTS)

REPORT NO.

[illegible]

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE OCT 21 1962 RUN # 8 (100.1 KNOTS)

REPORT NO. _____

	G	K	DR = RC	F ₂ = K/DR	ΔD	$\frac{G \times 10^6}{F_2(ΔD)}$	$\frac{E-L}{\times 10^6}$	S		
1	S7	2810	1.6	1850	.36	6660	29	19320		
2	S8	2869	1.87	1575	.2	3150	10.5	3310		
3	S9	2869	.43	6680	0	0	10.5	0		
4	S10	2869	1.69	1770	-.44	-778	10.3	-8030		
5	S11	2869	1.68	1850	.35	647		6680		
6	S12	2869	1.82	1595	.28	446		4610		
7	S13	2896	1.48	1995	.4	797		8220		
8	S14	2896	1.75	1685	.22	387		3990		
9	S15	2869	.54	5420	.31	1680	10.3	17300		
10	S16		HOOK							
11	S17	2057	1.42	1445	-2.5		28.5	-11250	*	
12	S18		N.R.							
13	S19	2869								
14	S21	2896								
15	S22	2869								
16	S23									
17	S24									
18	S27									
19	S28									
20	S29	2869								
21	S30	2896								
22	S31	2896								
23	S32	2896								
24	S33	2869								

NO RECORD

* The max. stress was estimated because at this instant the trace ran off oscillograph paper.

DATE 10-21-62

DU PONT AIRPORT -- WILMINGTON, DELAWARE

Run #9 (116.2 Lts)

REPORT NO.

G	K	D_2 = R_c	F_2 = F_{AD}	AD	$E \cdot 10^4$ = $F_2(AD)$	$E \cdot 10^4$ Psi	S
S7	2910	1.6	1850	.5	924	29	26800
S8	2869	1.86	1575	.25	394	10.5	4130
S9	"	.45	6390	0	0	10.5	0
S10	"	1.65	1770	-.57	1010	10.3	-10400
S11	"	1.65	1850	.46	852	"	8460
S12	"	1.82	1595	.42	670	"	6900
S13	2896	1.45	1995	.5	995	"	10280
S14	"	1.75	1685	.3	505	"	5200
S15	2869	.85	3390	.2	678	"	7000
S16	2057	Hook	—	—	—	—	—
S17	"	1.4	1445	-2.75	3880	23.5	-113500 *
S18	1029	N.R.	—	—	—	—	—
S19	2869	1.45	1980	.07	139	10.3	1415
S21	2896	1.34	2140	-.11	-235	10.7	-2510
S22	2869	.34	8450	0	0	10.3	0
S23	"	.83	3450	.04	138	"	1420
S26	"	1.57	1815	.23	417	"	4300
S27	"	1.51	1900	.35	665	"	6850
S28	"	1.31	2190	.32	700	"	7200
S29	"	1.52	1890	.32	632	"	6500
S30	2896	.27	10600	.06	635	"	6550
S31	"	.37	7850	-.12	-930	"	-9550
S32	"	1.78	1615	-.17	-276	"	-2850
S33	2869	1.60	1795	.24	430	"	4450

* The max. stress was estimated because the trace ran off oscillograph.

	G	K	D_R = RC	F_2 = K/D_R	ΔD	$E \times 10^6$ $F_2 (\Delta D)$	E $\times 10^{-6}$	S
1	S7	2910	1.56	1870	.62	1160	29	33,500
2	S8	2869	1.83	1560	.34	530	10.5	5550
3	S9	A	.42	2800	.01	68	10.5	711
4	S10		1.63	1760	-.59	1040	10.3	-10,700
5	S11		1.60	1792	.42	752	A	7750
6	S12	2809	1.78	1610	.49	790		8100
7	S13	2876	1.42	2040	.60	1220		12,500
8	S14	2870	1.71	1700	.35	594		6100
9	S15	2869	.88	3250	.24	780	10.3	8050
10	-							
11	S17	2057	.62	3340	-1.62	-5410	28.5	-155,000
12	S18	1029	N.R.					
13	S19	2829	1.45	1980	.12	238	10.3	2450
14	S21	2876	1.35	2130	.08	171	10.7	1750
15	S22	2869	.32	8950	0	0	10.3	0
16	S23	A	.95	3010	.08	242	A	2500
17	S26		1.58	1810	.25	452		4650
18	S27		1.50	1910	.40	762		7850
19	S34		.45	6410	.05	320		3300
20	S28		1.30	2200	.42	922		9510
21	S29	2869	1.50	1910	.38	725		7450
22	S30	2870	.25	11600	.11	1160		12000
23	S31	2890	.36	8010	-.02	160		-1650
24	S32	2940	1.75	1660	-.15	249	10.3	-2,500
25	S33	2801	1.60	1790	.22	374	10.3	4050
26	S35	2869	.59	4800	0		10.3	0

G	$K \cdot 10^6$	R_c	F_2	ΔD	G	$F \cdot 10^6$	S_{ps}
S7	2910	1.58		-0.08		29	-4350
S8	2869	1.83		.10		12.5	1640
S9		.42		.04		10.3	2860
S10		1.63		.13			2350
S11		1.66		-.47			-3580
S12		1.80		-.43			-7120
S13	2896	1.45		-.52			-12000
S14	2896	1.72		-.23			-4050
S15	2869	.93		-.20		10.3	-6700
S17	2057	.63		0		28.5	0
S15	Not hooked	Up					—
S19	2869	1.40	2050	-.01		10.3	-202
S21	2896	1.35	2130	.02		10.7	1135
S22	2869	.32	2450	.02		10.3	1840
S23		.80	3580	.02			7212
S26		1.45	1970	-.16			-1595
S27		1.56	1910	-.39			-7492
S34		.50	5720	-.01			-593
S28		1.30	2200	-.36			-3170
S29	2869	1.48	1910	-.33			-7482
S30	2896	.23	11600	-.02			2790
S31	"	.35	8010	-.13			-10722
S32	"	1.80	1610	-.41			-6310
S33	2869	1.60	1790	-.35			-4890
S35	2869	.53	5470	+.06		10.3	3380

DATE _____

DU PONT AIRPORT -- WILMINGTON, DELAWARE

Run # 11

REPORT NO. _____

G	K ₁₀	R _c	F ₂	AD	E	E ₁₀	S ₁₀
S7	2710	1.56	1870	.4		29	21700
S8	2861	1.92	1860	.12		10	1970
S9	"	.42	6300	0		10	0
S10	"	1.62	1760	-1.45		17	-8200
S11	"	1.65	1730	.33		"	6780
S12	"	1.77	1520	.33		"	5510
S13	2876	1.42	2040	.42		"	3820
S14	"	1.70	1700	.55		"	1270
S15	2229	.87	3250	.63		10	7700
S17	2057	.63	3340	-1.1		23	-10500
S18	1929	.62	1600	-1.12		23	-5370
S19	2869	1.4		0			0
S21	2896	1.32		0			0
S22	2861	.33		0			0
S23	"	.80		0			0
S26	"	1.45		.09			1840
S27	"	1.58		-1.15			-2960
S31	"	.54		0			0
S28	"	1.26		+1.1			2570
S29	2861	1.45		+1.1			2250
S30	2896	.25		0			0
S31	"	.35		0			0
S32	"	1.72		-1.20			-3430
S33	2869	1.58		.13			2400
S35	2869	.58		0			0

DATE OCT 24 62

ALL-AMERICAN ENGINEERING CO.

DU PONT AIRPORT - WILMINGTON, DELAWARE

(101.1 KNOTS) RUN #12

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MODEL NO. _____

REPORT NO. _____

	G	K	Rc	F ₂	AD	E ^{*10⁶}	E ^{*10⁴}	S
1	57		1.57	1870	.53	992	29	28800
2	58		1.82	1560	.18	281	10.5	2950
3	59		.42	6800	0		10.5	0
4	510		1.63	1760	-.60	-1055	10.3	-10900
5	511	2869	1.64	1750	.47	823	↑	8500
6	512		1.77	1610	.38	612	↑	6320
7	513		1.44	2040	.48	980	↑	10100
8	514		1.70	1700	.30	510	↑	5250
9	515		.87	3250	.22	715	↓	7350
10							10.3	
11	517		.62	3340	-.92	-3070	28.5	-87500
12	518	1029	.47	2200	-.75	-1650	28.5	-46100
13	519	2869	1.40	2040	+0.5	163	10.3	1690
14	521	2869	1.35	2130	0	0	10.7	0
15	522	2869	.35	8950	0	0	10.3	0
16	523	2869	.5	5740	0	0	↑	0
17	526	2869	1.52	1890	+0.2	278	↑	2870
18	527	2869	1.58	1910	+0.39	745	↑	7680
19	534	2869	.5	5740	+0.2	115	↑	1290
20	528	2869	1.25	2270	.3	680	↑	7010
21	529	2869	1.45	1930	+0.3	613	↑	6350
22	530	2876	.39	7450	0	0	↑	0
23	531	2896	.32	8010	-.15	-120	↑	-1240
24	532	2896	1.75	1660	-.2	-332	↑	-3320
25	533	2869	1.58	1790	+0.2	-215	↑	+2220
26	535	2869	.58	4800	-.01	-48	10.3	-496

	G	K-10 ⁶	D _R = R _c	F ₂ = K/D _R	ΔD	G × 10 ⁶ = F ₂ (ΔD)	E × 10 ⁶	S D ₁
1	S7		1.55	1870	.72			39200
2	S8		1.82	1560	.18			2950
3	S9		.42	6800	0			0
4	S10		1.62	1760	-.83			-15100
5	S11		1.63	1750	.60			10900
6	S12		1.78	1610	.55			9150
7	S13		1.42	2040	.42			8850
8	S14		1.68	1700	.41			7200
9	S15		.87	3250	.24			8020
10	—							
11	S17		.62	3340	-.88	-2930	28.5	-83500
12	S18		.47	2200	-.95	-2090	26.5	-59500
13	S19	2867	1.42	2020	.08	162	10.3	1670
14	S21	2896	1.3	2310	.02	462	10.7	4620
15	S22	2869	.48	5980	0	0	10.3	0
16	S23	2869	.58	4950	0	0	↑	0
17	S26	2869	1.51	1890	.28	528		5450
18	S27	↑	1.58	1910	.45	860		8880
19	S34		.60	4780	.02	95.8		990
20	S28	↓	1.25	2270	.38	863		8900
21	S29	2869	1.50	1910	.39	745		8680
22	S30	2896	.80	3730	.09	337		3470
23	S31	2896	.70	4260	-.32	1362		-14050
24	S32	2896	.74	4040	-.19	835		-8600
25	S33	2869	1.58	1815	+.19	345	↓	3550
26	S35	2869	.8	3590	0	0	10.3	0

[illegible]

	G	K	R _c	F ₂	ΔD	E	F	S
1	S7	2915	1.52	1920	.25	480	29	13900
2	S8	"	1.76		.15		10.7	2620
3	S9		.65		0		10.3	0
4	S10		1.58		-.38		"	-7100
5	S11		1.60		.36			6620
6	S12		1.62		.28			5100
7	S13	221	1.33		.37			8000
8	S14		1.63		.20			3600
9	S15	220	.87		.19		10.3	+6450
10	S16	2357	.62	3330	-.95	2160	28.5	-1500
11	S17	1029	.46	2240	-.95	2130	28.5	-6000
12	S18	221	1.40		.05		10.3	1055
13	S21	2512	1.30		0		10.7	0
14	S22	2267	.62		0		10.3	0
15	S23		.79		.05			2000
16	S24		1.40		.10			2120
17	S27		1.55		.17			3240
18	S31		.62	4230	.05	332	2.3	1100
19	S25		1.22		.22		"	+5350
20	S29				0		"	+ 0
21	S30	2396	.92		.03			+975
22	S31	"	.89	3220	-.30	1230	14.7	+12700
23	S32	"	1.70		-.20			-3540
24	S33	2569	1.55		.15			+2880
25	S35	"	.82	3490	-.04	140	10.3	-1440

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE Oct 20 1946

Run #17 (104.2 46) 2. 6. 1946

REPORT NO. _____

G	K	R _c	F ₂	ΔD	E	E	S		
S7	2910	1.77		.57		29	31600		
S8	2920	1.76		.19		27	3320		
S9	"	1.4		C		10.7	0		
S10	"	1.25		-.65		21.3	12100		
S11	"	1.65		.50		"	9200		
S12	"	1.62		.45		"	8220		
S13	2890	1.38		.50		"	10400		
S14	"	1.64		.33		"	6000		
S15	2880	.67		.27		"	9000		
S16	2057	.62		-.90		28.5	-25200		
S18	1129	.46		1.22		28.5	-76000		
S19	2880	1.35		.12		10.3	2580		
S20	2870	1.30		.07		10.7	1650		
S22	2861	.60		C		10.7	0		
S23	"	.77		C		"	0		
S26	"	1.40		.25		"	5300		
S27	"	1.52		.38		"	7400		
S24	2861	.60		.12		10.3	990		
S28	"	1.22		.35		"	8500		
S29	"	.50		.15		"	-150		
S30	2850	.90		+10		"	+3410		
S31	2896	.30		-.35		"	-11900		
S32	2850	1.70		-.21		"	-3700		
S33	2850	.60		+18		"	+1000		
S35	2850	.52		.05		10.3	1800		

MODEL NO. _____

REPORT NO. _____

G	K	R _c	F ₂	ΔD	E	E	S
S7	2911	1.52		.08		29	37700
S8	2401	1.76		.20		11.7	3500
S9		.65		0		10.7	0
S10		1.58		-.80		10.3	-15000
S11		1.66		.57			16500
S12		1.62		.50			9150
S13	2321	1.39		.63			13500
S14		1.66		.40			7200
S15		.85		.27			9500
S17	2051	.62		-.15		28.2	-45000
S18	1029	.46		-.92		28.1	-50000
S19	2861	1.51		.06		1.3	1710
S21	2596	1.30		.05			170
S22	2821	.62		0			0
S23	"	.77		0			0
S26	"	1.43		.17			3580
S27		1.53		.27			2251
S34		.50		-.08			-4180
S29		1.23		+ .40			+9600
S25		.49		+ .11			+ 500
S30	2401	.90		+ .10			+ 3320
S31		.88		-.50			- 10000
S32		1.72		-.28			- 4870
S33	2469	1.55		+ .20			+ 3520
S35		.85		.06			2150

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE 2-27-78

102.4 LBS

REPORT NO. _____

G	K	R _E	F ₂	ΔC	E	E	S		
17	2115					29	29400		
18	2451	170		.17		15.7	2170		
19		1.15		0		15.7	C		
20				-1.15		15.7	-11950		
S11		1.5		.5			1260		
S12		1.5		.42			7500		
S13		1.5		.52			11200		
S14		1.5		.52			5720		
S15		1.5		.52			2510		
S16	200	1.1		-1.05		1.1	-10400		
S17	100	1.1		-1.05		1.1	-5100		
S18	200	1.1		-1.05		1.1	-10400		
S19	200	1.1		-1.05		1.1	-10400		
S20	200	1.1		-1.05		1.1	-10400		
S21	200	1.1		-1.05		1.1	-10400		
S22	200	1.1		-1.05		1.1	-10400		
S23	200	1.1		-1.05		1.1	-10400		
S24	200	1.1		-1.05		1.1	-10400		
S25	200	1.1		-1.05		1.1	-10400		
S26	200	1.1		-1.05		1.1	-10400		
S27	200	1.1		-1.05		1.1	-10400		
S28	200	1.1		-1.05		1.1	-10400		
S29	200	1.1		-1.05		1.1	-10400		
S30	200	1.1		-1.05		1.1	-10400		
S31	200	1.1		-1.05		1.1	-10400		
S32	200	1.1		-1.05		1.1	-10400		
S33	200	1.1		-1.05		1.1	-10400		
S34	200	1.1		-1.05		1.1	-10400		
S35	200	1.1		-1.05		1.1	-10400		
S36	200	1.1		-1.05		1.1	-10400		
S37	200	1.1		-1.05		1.1	-10400		
S38	200	1.1		-1.05		1.1	-10400		
S39	200	1.1		-1.05		1.1	-10400		
S40	200	1.1		-1.05		1.1	-10400		
S41	200	1.1		-1.05		1.1	-10400		
S42	200	1.1		-1.05		1.1	-10400		
S43	200	1.1		-1.05		1.1	-10400		
S44	200	1.1		-1.05		1.1	-10400		
S45	200	1.1		-1.05		1.1	-10400		
S46	200	1.1		-1.05		1.1	-10400		
S47	200	1.1		-1.05		1.1	-10400		
S48	200	1.1		-1.05		1.1	-10400		
S49	200	1.1		-1.05		1.1	-10400		
S50	200	1.1		-1.05		1.1	-10400		

MODEL NO. _____

REPORT NO. _____

G	K	R	F ₂	AD	E	F	S
S7	2910	1.22		.45		2.9	25000
-	2869	1.5		.15		10.7	2560
		1.5		0		10.7	0
S10		1.5		-.32		10.3	-9450
S11		1.60		.35			7030
S12		1.65		.50			5360
S13	2896	1.45		.4			8530
S14		1.67		.22			3930
S15		1.67		.1			6520
S18	2057	N.G.	2.30			28.5	---
	1.29	.23		-.65		24.5	-1050
S1	2869	.4		.05		10.3	1057
S2	2896	.30		.05		10.7	1150
S6	2869	.32				10.3	0
S6		.78		0			0
S22	"	1.42		.18			3760
S27	"	1.55		.28			5350
S34	"	.60		.25			2470
S28	"	.25		.35			5900
S29	"	.50		.15			8860
S30	2896	.91		.08			2630
S31	"	.90		-.26			-8640
S31		1.72		-.27			-4700
S32	2869	1.56		+.12			+2280
S32	"	.83		-.05			-2850

		R_c	ΔC	Σ	$\bar{P}$	$\bar{C}$			
	2115	1.52	.58		29	32250			
	2369	1.4	.16		10.7	3070			
		.5	0			0			
		1.4	-.45		15.4	-5320			
		1.6	.0			1205			
		1.6	.42			7520			
	2216	1.4	.56			11950			
		1.67	.32			5730			
		.67	.27			4260			
	2155	N.G.							
	1027	.33	-.62		29.5	-6750			
	2541	1.40	.15		10.3	3160			
	2594	1.30	-.05		10.7	-112			
	2361	.62	0			0			
		.78	0			0			
		1.42	.27			5620			
		1.35	.39			7440			
		.60	-.07			-3440			
		1.25	.38			8970			
		.50	.11			3520			
	2596	.90	.11			3650			
		.90	-.24			-5770			
		1.72	-.35			-6080			
	2361	1.56	.15			2850			
	"	.83	-.07			-2500			

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE Oct 22 1962

Run #24 (115.4 kts) 60' off Center

REPORT NO. _____

G	K	Rc	F _r	ΔD	C	E	S		
S7	2910	1.2		.65		27	36100		
S8	2869	1.2		.18		1.7	3070		
S9	↑	.65		0		1.7	0		
S10	↑	1.62	1770	-.35	6200	16.5	-6380		
S11	↓	1.62	1792	.55			10150		
S12	2869	1.6	1740	.50			8950		
S13	2896	1.45	2060	.58			12400		
S14	↑	1.68	1720	.37			6630		
S15	2896	.87	3320	.29			9950		
S16		N.G.		N.G.		28.5	1.6		
S18	1029	.33		-.65		23.5	-5700		
S19	2869	1.40		.10		10.3	2110		
S21	2896	1.30		.65		10.7	1192		
S22	2869	.62		0		10.1	0		
S23	2869	.78		0			0		
S26	↑	1.42		.30			6250		
S27	↑	1.55		.32			6100		
S34	↓	.60		.60			2410		
S28	↓	1.27		.38			8820		
S29	2869	.50		.15			8240		
S30	2896	.90		.12			3980		
S31	↑	.90		-.35			-11620		
S32	2896	1.75	1652	-.32	-532		-5420		
S33	2869	1.54	1855	.21	3900		4020		
S35	2869	.32		.05			1200		

S17
deleted

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE OCT 28 1962

P. 1.1 * 0.1 (V = 126.0 kts)

REPORT NO. _____

	G	K	E	F ₂	AD	C	F	S		
1	S ₁	7			+1.82			45600		
2	S ₂				+1			+1700		
3	S ₃			4420	+1.05	-221	10.7	+2360		
4	S ₄				+1.15			2740		
5	S ₅				+1.05			+9150		
6	S ₆				+1.22			3940		
7	S ₇				+1.55			11750		
8	S ₈				+1.4			7180		
9	S ₉				+1.3			10300		
10										
11	S ₁₀	DELETED								
12	S ₁₁	1000	.33		-1.7			-62400		
13	S ₁₂				+1			2110		
14	S ₁₃				+1.02			+478		
15	S ₁₄				0			0		
16	S ₁₅				0			0		
17	S ₁₆				.52			6670		
18	S ₁₇				.5			9530		
19	S ₁₈				.02			938		
20	S ₁₉				.45			10450		
21	S ₂₀				.2			11850		
22	S ₂₁				.1			3320		
23	S ₂₂				.1			3330		
24	S ₂₃				-.2			-3320		
25	S ₂₄				.2			4020		
26	S ₂₅		.33		0			0		

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE Oct 29 1947

RUN #26 (V = 116.0 KNOTS) WET

REPORT NO. _____

	G	K	R _C	F ₂	ΔD	E	E	S	RUNWAY (40' 0" c)
1	57	2910	1.54		.63			3350	
2	58	2869	1.80		+1.1			+1710	
3	59	↑	.65		0			0	
4	510		1.60		+1.5			2740	
5	511	↓	1.60		-.32			-5920	
6	512	2869	1.63		+1.51			1300	
7	513	2816	1.40		+1.58			12400	
8	514	↑	1.69		+1.38			6630	
* 9	515	2576	.87		+1.30			9950	
10	516	1100 K	No R _C					—	
11	517	2910*	.42	6830	-.45			-87700	
# 12	518	1027	.32		-.52			-47700	
13	519	2869	1.42		+1.08			1360	
14	521	2896	1.31		0			0	
15	522	2869	.63		0			0	
16	523	2869	.79		-.05			1870	
17	526	↑	1.43		+1.32			2650	
18	527	↑	.57		+1.45			8580	
* 19	534	↓	.62		0			0	
20	528	↓	1.25		+1.42			9900	
21	529	2869	.50		+1.15			8870	
22	530	2896	.91		+1.1			3900	
23	531	↑	.91		-.28			-9320	
24	532	2896	1.75		-.32			-5420	
25	533	2869	1.58		+1.21			4020	
** 26	535	2869	.81		0			0	

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO.

DATE OCT 29 1962

RUN #27 (V=123.2 Kts) 20' O.C.

REPORT NO.

	G	K	RC	FZ	AD	E	E	S		
1	S7	2910			+0.8			42800		
2	S8	2869			-0.15			-2560		
3	S1	↑			0			0		
4	S10	↑			0.1			1830		
5	S11	↑			-0.35			-6460		
6	S12	2869			+0.5			9200		
7	S13	2896			+0.22			-4700		
8	S14	↑			+0.22			-4880		
9	S15	2896			0.20			6630		
10	S16	HO 3 K		NO	P. C					
11	S17	2910			-0.80			-156000		
12	S18	1029			-0.75			-68800		
13	S19	2869	1.42		+0.15			3110		
14	S21	2896	1.31	2210	+0.06			+1328		
15	S22	2869	.63		0			0		
16	S23	2869	.79		0			0		
17	S26	↑	1.43		+0.3			6250		
18	S27	↑	1.57		.45			8580		
19	S34	↑	.62		0			0		
20	S28	↑	1.25		.35			8250		
21	S29	2869	.50	5750	.13	748		7700		
22	S30	2896	.71		.1			3900		
23	S31	2869	.91		-0.3			-5930		
24	S32	2869	1.75		-0.32			-5420		
25	S33	2869	1.58		+0.15			2870		
26	S35	2869	.81		0			0		

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DU PONT AIRPORT - WILMINGTON, DELAWARE

MODEL NO. _____

DATE OCT 30 1962

RUN # 28 (16.4 kts)

REPORT NO. _____

	G	K	RC	F2	ΔD	ε	E	S		
1	S7				.12			6430		
2	S8				0			0		
3	S9				0			0		
4	S10				+ .22		+	4030		
5	S11				- .2			- 3700		
6	S12				.2			3740		
7	S13				.2			4600		
8	S14				.13			2270		
9	S15				.1			3315		
10	S16				0		NO RC			
11	S17	2910	.70.	4170	-1.0		2.5-	119000		
12	S18				-1.82			- 75300		
13	S19				.05			1040		
14	S21				.02			442		
15	S22				0			0		
16	S23				0			0		
17	S26				0			0		
18	S27				+ .1		+	1910		
19	S34				0			0		
20	S28				.1			5360		
21	S29			Λ				0		
22	S30				-1.02			0		
23	S31				-			0		
24	S32				-1.5		-	3540		
25	S33				+ .1		+	1910		
26	S35				0			0		