REPORT NUMBER 144

MARCH 1965

FUSELAGE STRUCTURAL ANALYSIS
Volume IV
ENGINE INLET, THRUST SPOILER, PITCH FAN LOUVERS

XV-5A

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XV-5A

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL ELECTRIC

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REPORT NUMBER 144

FUSELAGE STRUCTURAL ANALYSIS

VOLUME IV

ENGINE INLET, THRUST SPOILER, PITCH FAN LOUVERS

XV-5A Lift Fan
Flight Research Aircraft Program

Contract No. DA 44-177-TC-715

March 1965

ADVANCED ENGINE AND TECHNOLOGY DEPARTMENT
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

CONTENTS

1.0 INTRODUCTION

The structural analyses of the engine air inlet, the thrust spoiler installation, and the pitch fan louver installation of the U.S. Army XV-5A Lift Fan Research Aircraft are presented in this report.

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2.0 ENGINE AIR INLET

The engine air inlet installation provides the ducting for inlet air to the turbo jet engines, ducting for cooling air and provides the faired cover for the accessory and hydraulic compartments.

The engine inlet is constructed of Fiberglas, 181 cloth with polyester resin, per MIL-R-7575. The external skins are made up of three plys of 181 cloth reinforced along the attachment edges by eight additional layers. The inlet duct cylinders are of four ply construction.

The inlet installation is attached to the aircraft fuselage structure at the canted bulkhead aft of the cockpit, at two intermediate sub-frames, the engine forward support structure frame and along the lower edges to the fuselage upper longerons.

Critical design pressure loads are shown and the critical skin panel is analyized for this loading. The attachments are investigated and shown to be adequate for inlet loading.

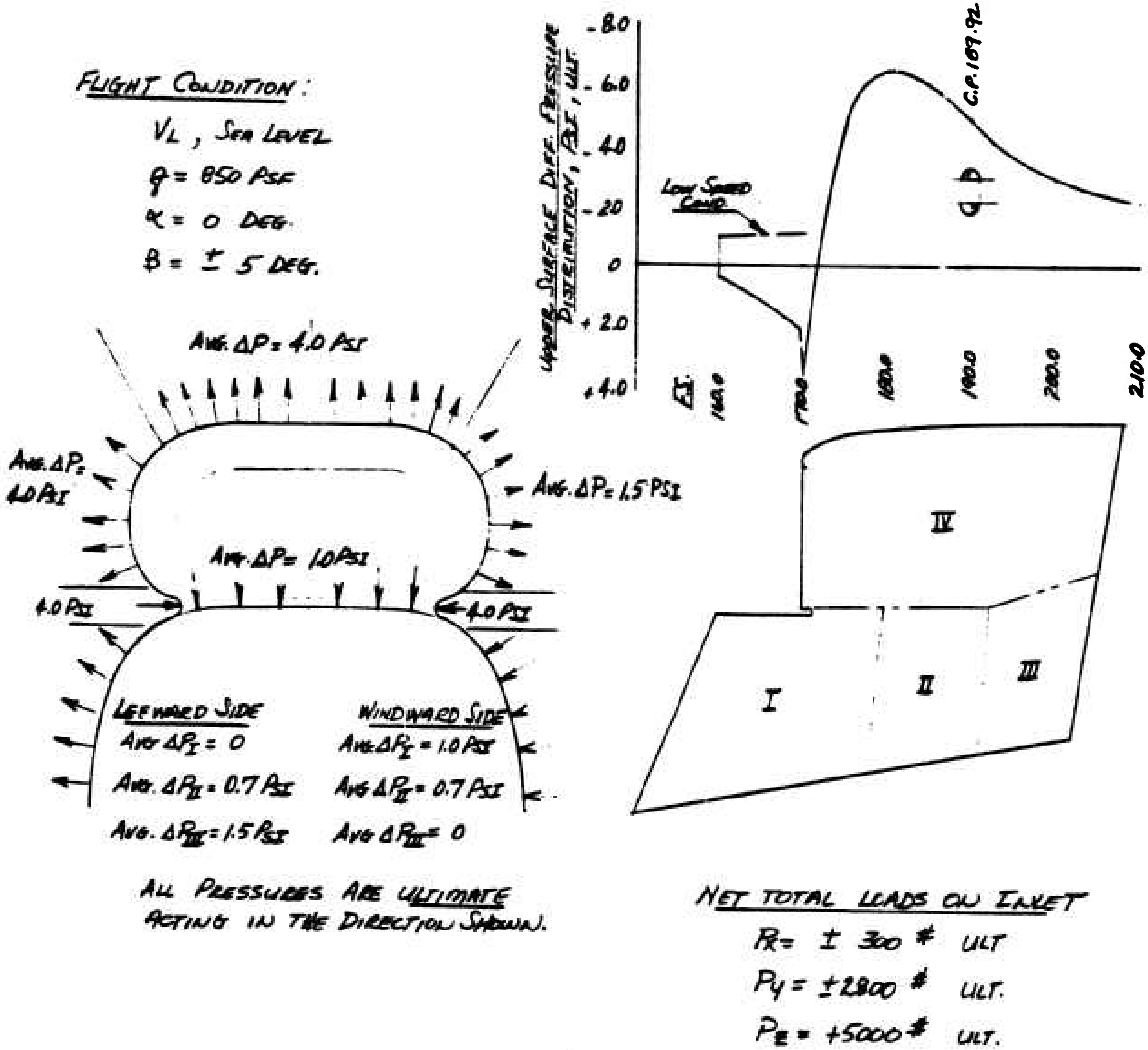
Material allowables for 181 cloth, polyester resin, Fiberglas are taken from MIL-HNDBK-17 and MIL-R-7575 and are shown below:

F_{t_u} = 40,000 psi

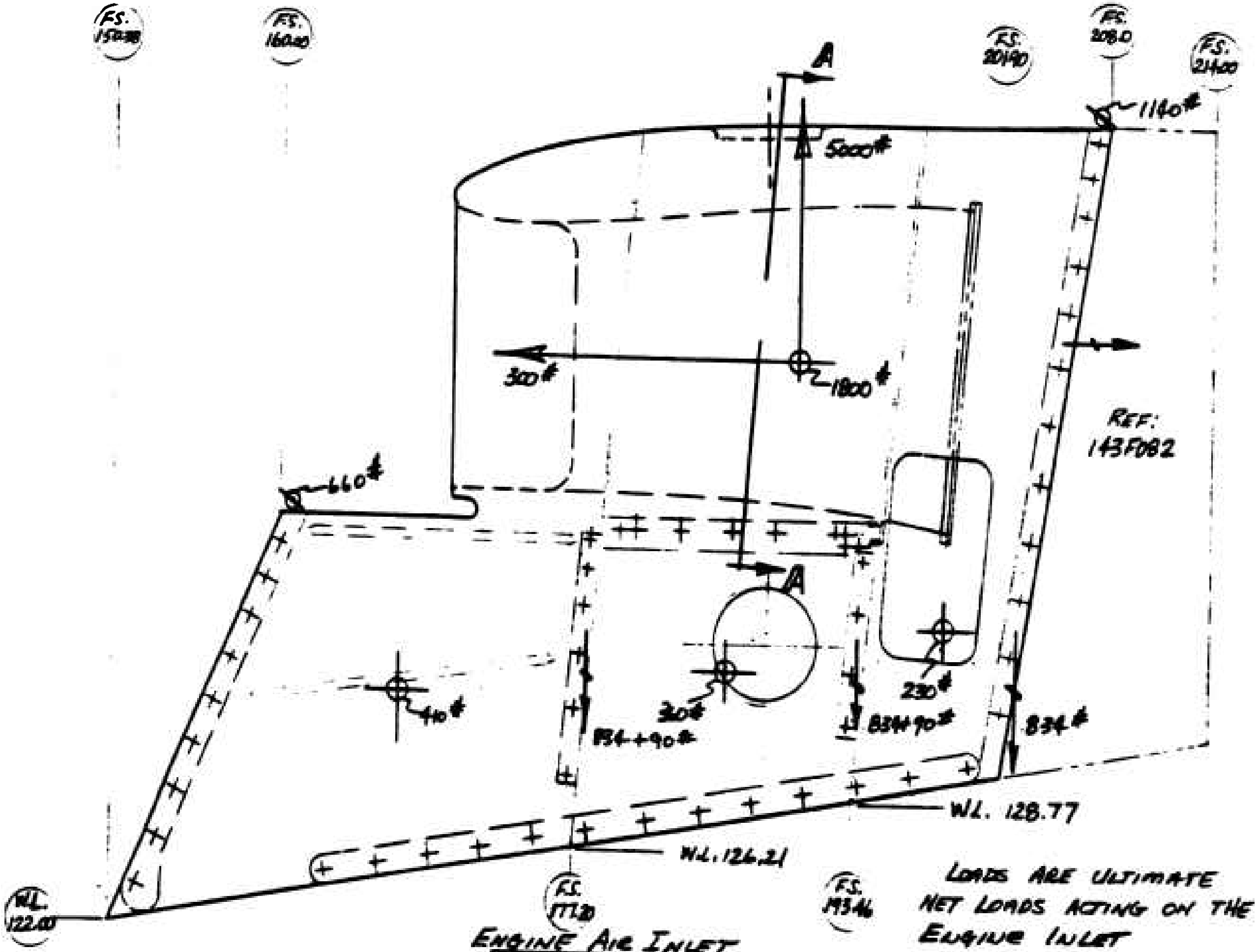
F_{c_u} = 35,000 psi

F_{s_u} = 9,000 to 20,000 psi

E = $2.5\ (10)^6$ psi



INLET LOADS & PRESSURE DISTRIBUTION

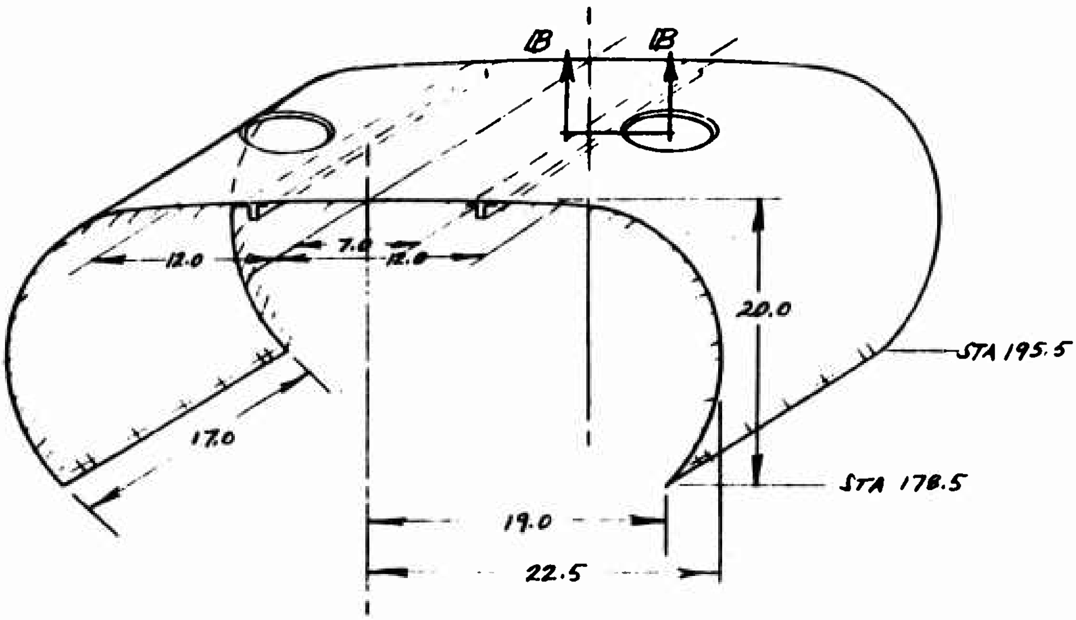


LOADS ARE ULTIMATE
NET LOADS ACTING ON THE
ENGINE INLET

ENGINE AIR INLET
INSTALLATION
DWG NO. 163P006

OUTSIDE UPPER SKIN PANEL

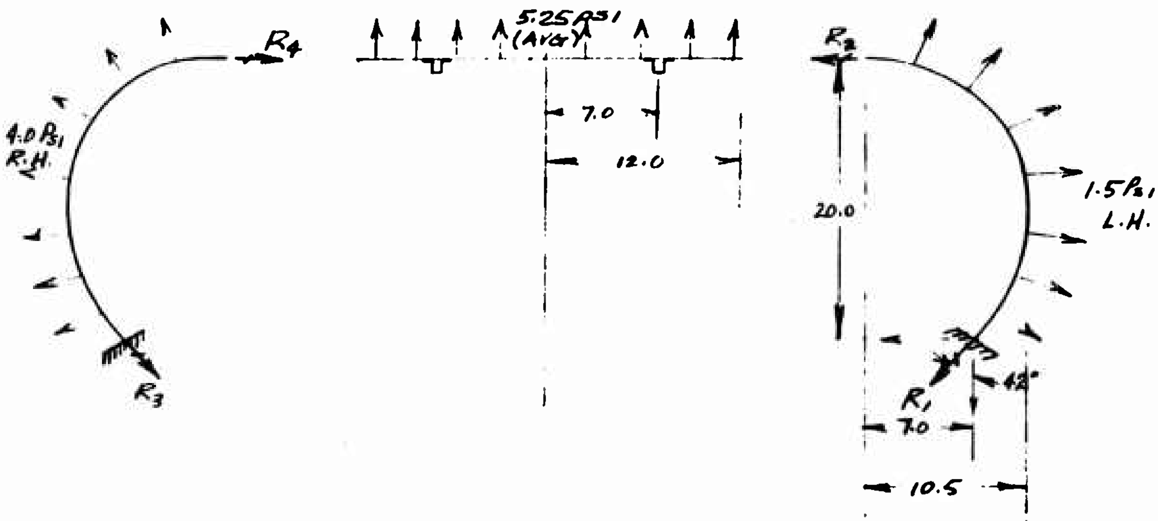
SECTION A-A



THE ABOVE SKETCH REPRESENTS AN AVERAGE CROSS-SECTION OF THE OUTER SKIN PANEL BETWEEN THE TWO INLET TRANSVERSE BULKHEADS. THE PANEL IS DIVIDED INTO THREE SEGMENTS FOR ANALYSIS PURPOSES AS SHOWN ON THE FOLLOWING PAGES. THE END PANELS ARE ESSENTIALLY CYLINDRICAL SEGMENTS AND ARE ANALYZED AS SUCH. THE UPPER PANEL IS A FLAT MEMBRANE PARTIALLY SUPPORTED BY TWO HAT SECTION BEAMS LOCATED APPROXIMATELY SEVEN INCHES EITHER SIDE OF THE CENTER-LINE.

THE MEMBRANE SUPPORT IS PROVIDED ON THE LONG SIDES BY THE BULKHEADS AND ON THE SHORT SIDES BY THE CYLINDRICAL END SEGMENTS. THE AVERAGE UPPER SURFACE PRESSURE OF 5.25 psi ULT IS APPORTIONED TO THE BEAMS AND TO THE MEMBRANE ACCORDING TO THE BEAM ALLOWABLE BENDING STRENGTH WHICH IS EQUIVALENT TO 2.11 psi. THE REMAINING 3.14 psi PRESSURE IS APPLIED TO THE MEMBRANE AND MAXIMUM SKIN STRESSES AND PANEL DEFLECTION ARE CALCULATED. BECAUSE THE END SEGMENTS PROVIDE LESS RIGID PANEL SUPPORT THAN THE BULKHEADS A FICTICIOUS MEMBRANE LENGTH IS USED WHICH ALLOWS A SHORT END REACTION APPROXIMATELY EQUAL TO THE AVERAGE END SEGMENT REACTIONS. THE MAJOR PORTION OF THE MEMBRANE LOADING IS THEN REACTED

AT THE TWO BULKHEADS. THE MEMBRANE MAXIMUM DEFLECTION IS CALCULATED ON THIS BASIS AND IS SHOWN TO BE COMPATIBLE WITH THE MAXIMUM ALLOWABLE BEAM DEFLECTION.



R_{z_3} = 7.0(4.0) = 28.0 #/IN

R_3 = $\frac{28.0}{\cos 42°}$ = 37.68 #/IN

R_{x_3} = 37.68 SIN 42° = 25.21 #/IN

R_4 = 4.0(20.0) - 25.21 = 54.79 #/IN

$f_{t_{MAX}}$ = $\frac{54.79}{.030}$ = 1826 PSI

R_{z_1} = 7.0(1.5) = 10.50 #/IN

R_1 = $\frac{10.5}{\cos 42°}$ = 14.13 #/IN

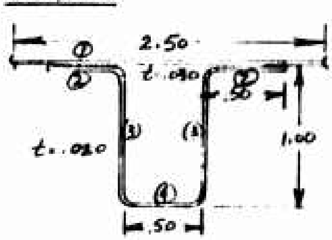
R_{x_1} = 14.13 SIN 42° = 9.45 #/IN

R_2 = 1.5(20.0) - 9.45 = 20.55 #/IN

$f_{t_{MAX}}$ = $\frac{20.55}{.030}$ = 685 PSI

AVG. MEMBRANE END REACTION = $\frac{54.79 + 20.55}{2}$ = 37.68 #/IN

BEAMS:



ITEM	A	y	Ay	Ay²	I₀
1	.075	.015	.00112	.00002	-
2	.020	.040	.00080	.00003	-
3	.038	.530	.02014	.01067	.00294
4	.010	1.020	.01020	.01040	-
Σ	.143		.03226	.02112	.00294

BEAMS: CONT.

$\bar{y} = \frac{.03226}{.143} = .2256 = C_t$

$C_c = 1.0300 - .2256 = .8044$ IN.

$I = .02112 - (.2256)(.03226) + .00294 = .0168 \text{ IN}^4$

$M_a = \frac{1.25 F_c I}{C_c} = \frac{1.25(35,000)(.0168)}{.8044} = 914$ "# $[F_b = 1.25 F_c]$

$M_{MAX} = \frac{w\ell^2}{8}$ WHERE $w = pd$ AND $d = 12.0$ IN

$p_a = \frac{8 M_a}{12 \ell^2} = \frac{8(914)}{12(17)^2} = 2.11$ psi

$\delta_{MAX} = \frac{5 w \ell^4}{384 EI} = \frac{5(2.11)(12.00)(17)^4}{384(2.5)(10)^6(.0168)} = \frac{10.574}{16.128} = .656$ IN.

MEMBRANE: [REF SECHLER & DUNN, "AIRPLANE STRUCTURAL ANALYSIS & DESIGN"]

$p = 5.25 - 2.11 = 3.14$ psi

$a = 24$ (ASSUME = 65)

$b = 17$

$t = .030$

$a/b = 3.82$

$n_1 = .070$, DEFL @ CENTER

$n_S = .025$, f_t SHORT SIDE

$n_L = .240$, f_t LONG SIDE

$f_t = n\left[p^2 E \frac{a^2}{t^2}\right]^{1/3}$

$= n\left[3.14^2 (2.5)(10)^6 \left(\frac{65^2}{.030^2}\right)\right]^{1/3} = n\left[115.60(10)^{12}\right]^{1/3}$

$= n\left[4.87(10)^4\right] = n(48,700)$ psi

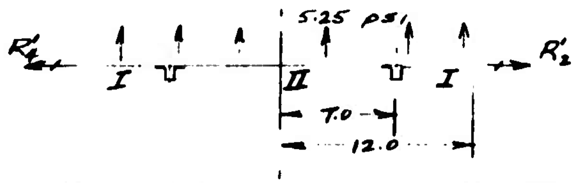
f_t SHT. SIDE $= .025(48,700) = 1218$ psi $= 36.5$ #/IN

f_t LONG SIDE $= .240(48,700) = 11,688$ psi

$\delta_{CENT.} = n_1 a \left[\frac{pa}{Et}\right]^{1/3} = .070(65)\left[\frac{3.14(65)}{2.5(10)^6(.030)}\right]^{1/3}$

$= 4.55\left[.00271\right]^{1/3} = 4.55(.140) = .637$ IN.

MEMBRANE: CONT.
UPPER PANEL LOAD IS APPLIED TO THE BEAMS BY MEMBRANE ACTION OF THE SKIN PANELS.



$R_{AVG} = 37.68$ #/IN – ASSUME PANEL LENGTH TO APPROXIMATE THIS END LOADING.

PANELS I & II

$p = 5.25$ psi [ULT]
$a_I = 5.0$ (ASSUME = 100)
$a_{II} = 14.0$ (ASSUME = 100)
$b = 17.0$
$t = .030$

$a/b = 5.88$
$\eta_1 = .05$
$\eta_5 = .014$
$\eta_6 = .18$
$\eta_7 = .06$

$$f_t = \eta \left[p^2 E \frac{a^2}{t^2} \right]^{1/3}$$

$$= \eta \left[(5.25)^2 (2.5)(10)^6 \left(\frac{100^2}{.030^2} \right) \right]^{1/3} = \eta \left[765.55 (10)^{12} \right]^{1/3}$$

$$= \eta \, (91{,}500)$$

$f_{t\ SHT.\ SIDE} = .014\,(91{,}500) = 1281$ psi $=$ **38.43 #/IN** [ULT.]

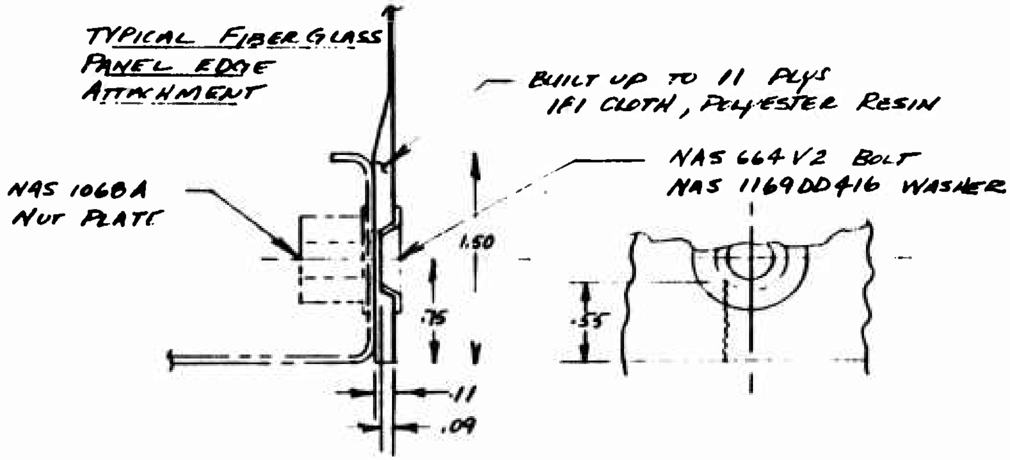
$f_{t\ LONG\ SIDE} = .18\,(91{,}500) =$ **16,470 psi** $=$ **494.10 #/IN** [ULT.]

$f_{s\ LONG\ SIDE} = .06\,(91{,}500) =$ **5490 psi**

MAX. MEMBRANE STRESS 16,470 psi

$M.S. = \frac{35{,}000}{16470} - 1 =$ HIGH

INLET ATTACHMENTS:



SHEAR-OUT

$A = 2(.55)(.11) = .121$

$P_{S_a} = .121(9000^*) = 1089^\# /$ FASTENER * MIN. SHEAR ALLOW.

BEARING:

$A = .45(.09) = .041$

$P_{BR_a} = .041(35{,}000^{**}) = 1435^\# /$FASTENER $^{**}(F_c)$

ASSUME P_x ($300^\#$ ULT) REACTED BY FASTENERS INTO 143F082
ATTACHMENTS NOT CRITICAL

ASSUME P_y, SEGMENT IV, ($1800^\#$ ULT) REACTED BY FASTENERS ACROSS TOP SURFACE AT F.S. 160.0 & F.S. 208.0. INDUCED M_x MOMENT REACTED BY FASTENERS INTO BLKHDS AT F.S. 177.20 & F.S. 193.46 AS SHEAR COUPLES.

$R_{y_{208.0}} = 1140^\#$; 4 FASTENERS @ F.S. 208.0 NOT CRITICAL
$M_{X_{W.L.135.0}} \cong 9000''^\#$; EQUIVALENT TO APPROX. $180^\#$/SIDE.

P_y LOADS ON SEGMENTS I, II & III REACTED BY PANEL EDGE ATTACHMENTS. ATTACHMENTS NOT CRITICAL

INLET ATTACHMENTS: CONT.

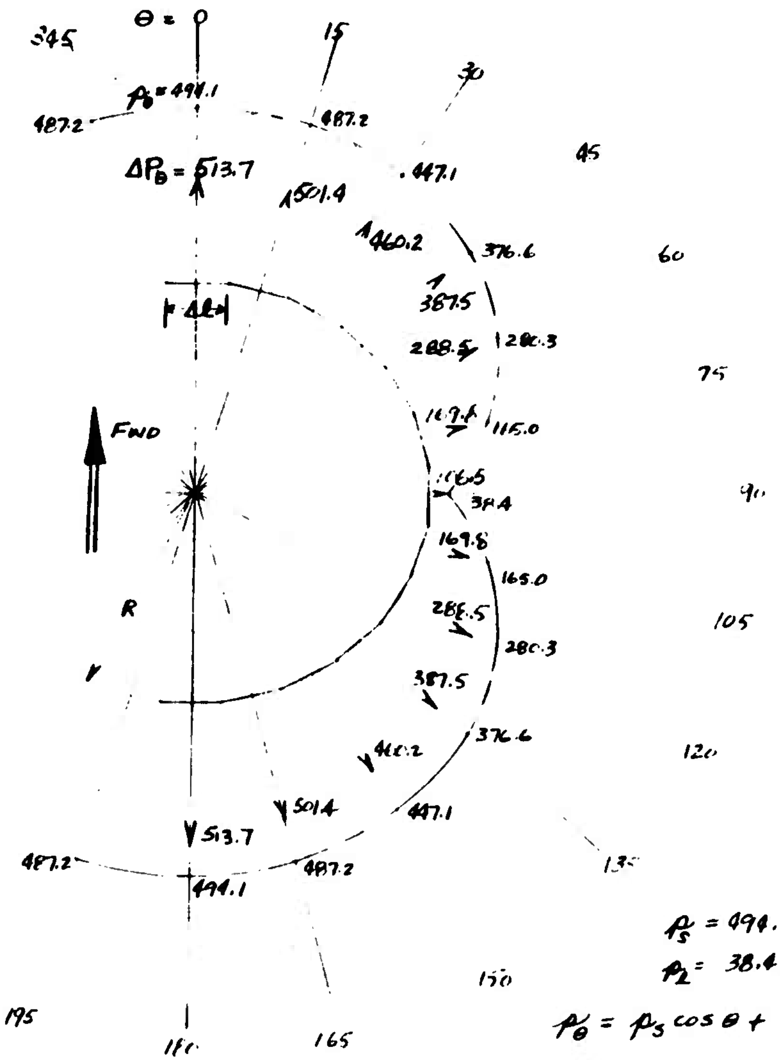
ASSUME P_3 (5000# ULT) REACTED BY FASTENERS INTO BLKHDS AT STAS. 177.20, 193.46 AND 143F082 FRAME.
EQUAL REACTIONS EQUAL 834 # / FRAME SIDE
TWO SHEAR FASTENERS AT EACH FRAME ARE SUFFICIENT

ATTACHMENTS NOT CRITICAL

TOP COOLING AIR INLET:

IN ORDER TO REDUCE THE EFFECT OF RE-INGESTION ON COOLING AIR SUPPLIED TO THE ELECTRICAL, HYDRAULIC AND ENGINE COMPARTMENTS AN ALTERNATE INLET IS PROVIDED ON THE UPPER SURFACE OF THE ENGINE AIR INLET. THE UPPER INLET IS LOCATED IN THE AREA OF HIGH PRESSURE LOADING ON THE SKIN AND IS THEREFORE FRAMED WITH A RING CAPABLE OF TRANSFERRING SKIN MEMBRANE STRESSES.

TOP COOLING AIR INLET RING LOADS:



$p_s = 494.1$ #/in [FWD & AFT LONG SIDE]

$p_l = 38.4$ #/in [SHORT SIDE SIDES]

$p_\theta = p_s \cos\theta + p_l \sin\theta$ #/in

$\Delta l = \frac{\pi R}{12}$; $R = 4.00$; $\Delta l = 1.047$ in

$$\Delta P_\theta = \Delta l \left[\frac{p_{\theta-15} + 2p_\theta + p_{\theta+15}}{4} \right] \# = .2618 \left[p_{\theta-15} + 2p_\theta + p_{\theta+15} \right] \#$$

INLET RING BENDING MOMENTS

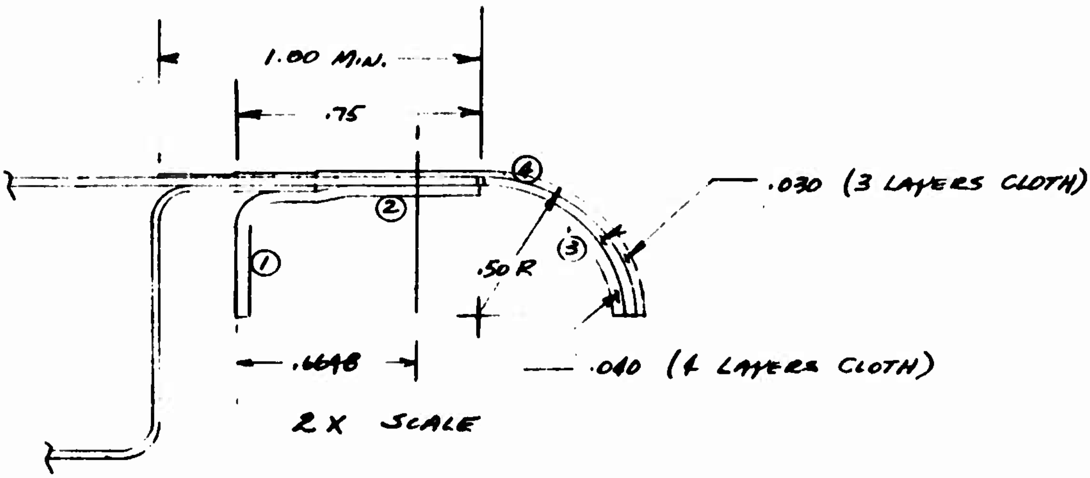
θ	BENDING MOMENT													ΣM_θ
	P_0 513.7	P_{15} 501.4	P_{30} 460.2	P_{45} 387.5	P_{60} 288.5	P_{75} 169.8	P_{90} 106.5	P_{105} 169.8	P_{120} 288.5	P_{135} 387.5	P_{150} 460.2	P_{165} 501.4	P_{180} 513.7	
0	-493	-221	-37	78	104	68	38	41	29	-31	-92	-140	-164	-820
15	-226	-481	-202	-31	58	61	43	61	69	39	-37	-100	-144	-890
30	-41	-221	-442	-170	-23	34	38	68	104	93	46	-40	-103	-657
45	103	-40	-202	-372	-127	-14	21	61	115	140	110	50	-41	-196
60	185	100	-37	-170	-277	-75	-8	34	104	155	166	120	51	+348
75	205	180	92	-31	-127	-163	-47	-14	58	140	184	180	123	+780
90	185	201	166	78	-23	-75	-102	-75	-23	78	166	201	185	+962
105	123	180	184	140	58	-14	-47	-163	-127	-31	92	180	205	+780
120	51	120	166	155	104	34	-8	-75	-277	-170	-37	100	185	+348
135	-41	50	110	140	115	61	21	-14	-127	-372	-202	-40	103	-196
150	-103	-40	46	93	104	68	38	34	-23	-170	-442	-221	-41	-657
165	-144	-100	-37	39	69	61	43	61	53	-31	-202	-481	-226	-890
180	-164	-140	-92	-31	29	41	38	65	104	78	-37	-221	-493	-820

$M_P = C_m R \Delta P$

$M_{MAX} = -890$ IN-LB [ULT] COMP INSIDE

$M_{MAX} = +962$ IN-LB [ULT] TENS INSIDE

SECTION B - B:



2X SCALE

INLET RING BENDING:

ASSUME CONSERVATIVELY THAT THE .040 CHANNEL & .030 TOP SPLICE CARRY TOTAL RING BENDING MOMENTS

ITEM	A	x	Ax	Ax²	Io
1	.0164	.020	.00033	---	---
2	.0280	.390	.01092	.00426	.0011
3	.0282	1.026	.02893	.02968	.0005
4	.0437	.850	.03714	.03157	.0043
	.1163		.07732	.06551	.0059

$$\bar{x} = \frac{.07732}{.1163} = .6648 = C_{OUTSIDE}\ ;\ C_{INSIDE} = .6152$$

$$I = .06551 - .6648(.07732) + .0059 = .0200\ IN^4$$

$M = -890$ IN-LB TENS. OUTSIDE

$$f_{b_t} = \frac{890(.6648)}{.0200} = 29{,}580\ PSI$$

$$F_{b_t} = 40{,}000\ PSI$$

$$M.S._t = \frac{40{,}000}{29{,}580} - 1 = \underline{\underline{+.35}}$$

INLET RING BENDING: CONT.

$M = +962$ IN-LB COMP. OUTSIDE

$f_{bc} = \frac{962(.6648)}{.0200} = 31,980$ psi

$F_{bc} = 35,000$ psi

$M.S._c = \frac{35,000}{31,980} - 1 = +.09$

SKIN SPLICE TO CHANNEL:

$P_{sa} = .175(1.00)(9000) = 6750$ #/IN

$P_{max} = 494.1$ #/IN

NOT CRITICAL

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3.0 THRUST SPOILER INSTALLATION (Drawing 143P069)

The thrust spoilers consist of a pair of doors located aft of the tailpipe nozzles and supported by the fairing structure below the fuselage box structure. The tailpipe exhaust impinges on the doors when they are extended. The doors are operated by a single hydraulic actuator located on the airplane centerline. The actuator drives a rod which is connected to the door support links. Longitudinal movement of rod and door supports joint causes the doors to pivot about the door hinges located at the forward end. The rod/door supports joint motion is guided by a track. An idler link at the actuator/rod joint reacts vertical loads so that the guide track is not loaded.

The spoilers are designed for operation under the following condition:

100 kts., hot day, 2500 ft., 9200 lbs. gross weight, full flaps, 98.6% RPM

Ultimate load per spoiler = 1553 lbs.

Load is normal to the deflected plane and c.p. is at the center of area.

Unsymmetrical loading due to differential engine RPM of ± 0.5% if ± 40 lbs.

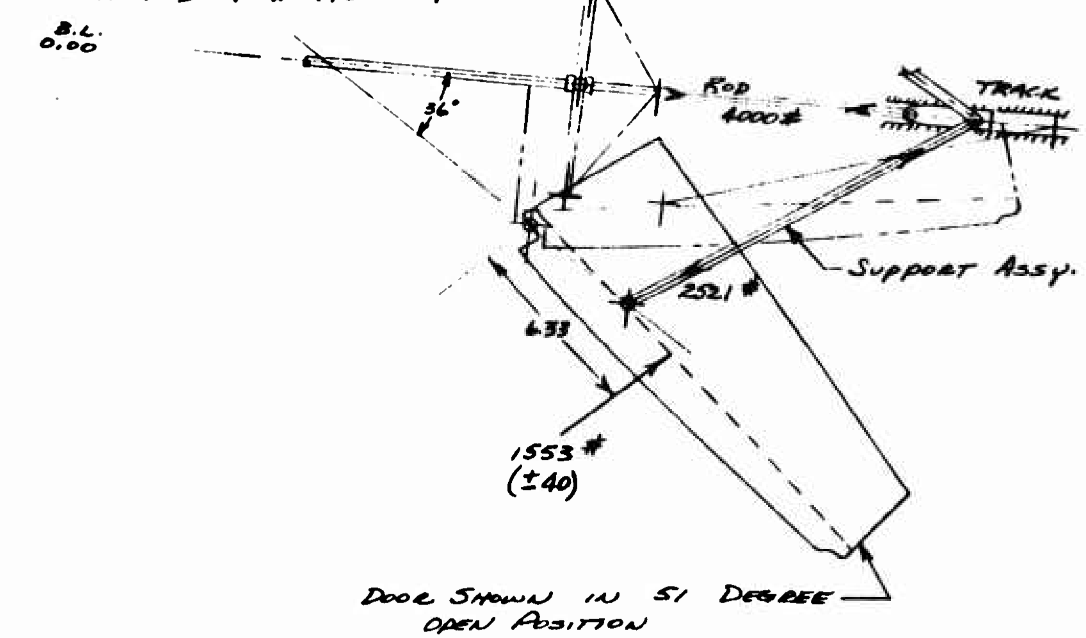
Design temperature for links and operating mechanism = 300°F

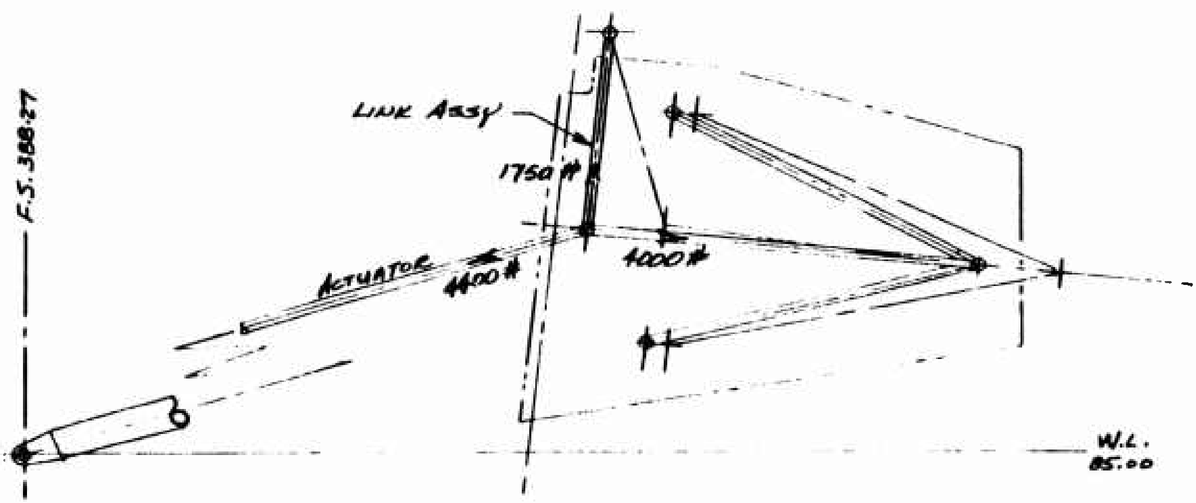
Materials used in the construction of the thrust spoilers are 19-9 DL and A-286 steel alloys.

Material properties used in stress analysis are shown below. (Reference: MIL-HNDBK-5, AMS55525A and Allegheny Ludlum Data Sheets)

Property	R.T. Mat'l Allowable KSI		300°F Mat'l Allowable KSI		1200°F Mat'l Allowable KSI	
	19-9DL	A-286	19-9DL	A-286	19-9DL	A-286
F_{tu}	95	140	86.4	139	51.3	99
F_{ty}	45		39.6	94	24.3	87.5
F_{cy}	45		41.4		31.05	
F_{su}	60		50.4		33.6	
F_{bru} e/D = 2.0	225		184.5		144.0	
E	29,000	29,000	27,260	28,000	1[illegible],560	22,000

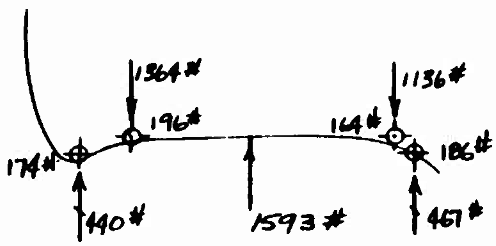
MECHANISM GEOMETRY:
REF: DWG # 143P069

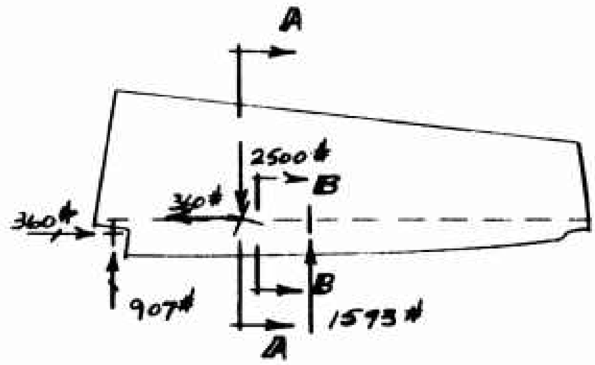




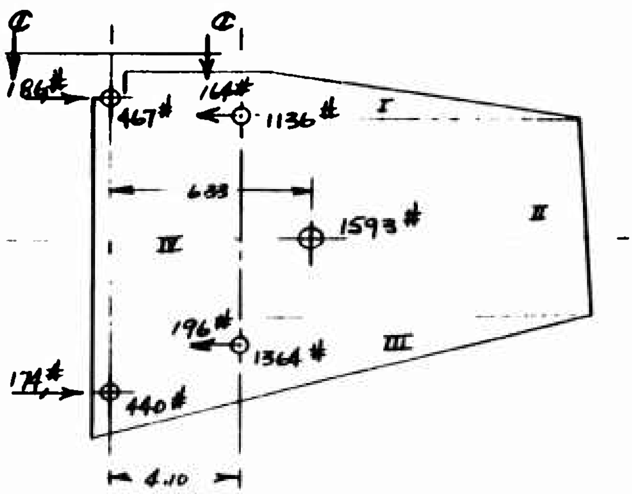
Door Free Body:

51 Degree Open Position





Seg.	A	x	z	Ax	Az
I	9.84	7.35	4.87	72.32	47.92
II	74.53	9.19	.73	684.93	54.41
III	15.65	7.52	-3.78	117.68	-59.16
	100.02			874.93	43.17
IV	54.78	1.91	-.67	104.95	-36.70
Tot.	154.80			979.88	6.47



Total Surface:

$$\bar{x} = \frac{979.88}{154.80} = 6.33 \text{ in.}$$

$$\bar{z} = \frac{6.47}{154.80} = .04 \text{ in.}$$

$$p = \frac{1593}{154.80} = 10.29 \text{ psi}$$

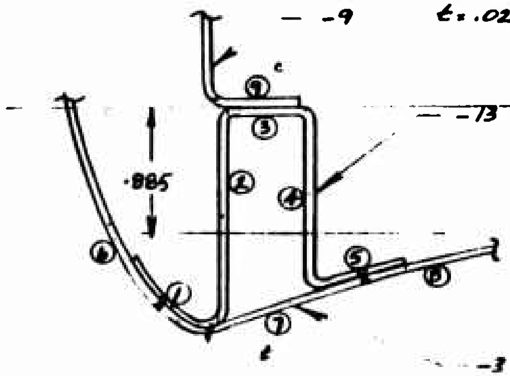
Area Outboard (Aft) of A-A:

$$\bar{x} = \frac{874.93}{100.02} = 8.75 \text{ in.}$$

$$d = 8.75 - 4.10 = 4.65 \text{ in}$$

$$M_{A\text{-}A} = 4.65(100.02)(10.29) = 4786 \text{ in·lb}$$

SECTION A-A @ SUPPORT LINK HINGE, LOWER BEAM:



ELEM.	A	y	Ay	Ay^2	I_o
1	.0200	1.40	.0280	.0392	
2	.0375	.75	.0281	.0211	.0070
3	.0125	.012	.0002	—	
4	.0312	.62	.0193	.0120	.0041
5	.0150	1.18	.0177	.0209	
* 6	.0500	.80	.0400	.0320	.0166
7	.0250	1.40	.0350	.0490	
8	.0250	1.10	.0275	.0302	
9	.0100	-.01	-.0001	—	
	.2262		.1957	.2044	.0277

$\bar{y} = \frac{.1957}{.2262} = .865$

$C_c = .865 + .020 = .885$

$C_t = 1.600 - .885 = .715$

$I = .2044 - (.865)(.1957) + .0277$
$= .0628 \text{ IN}^4$

$* \quad F_{cc} = KE\left(\frac{t}{b}\right)^2 = 3.64\,(16.56)(10)^6\left(\frac{.025}{1.00}\right) = 42{,}200 \text{ PSI}$

$M = \frac{1364}{2500}(4786) = 2611 \text{ IN-LB}$

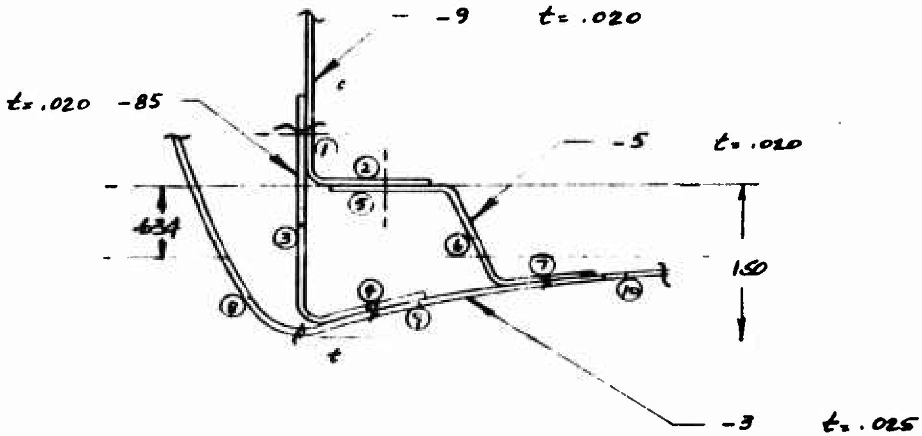
$f_{bc_u} = \frac{2611\,(.885)}{.0628} = 36{,}795 \text{ PSI ULT} = 24{,}530 \text{ PSI LIMIT}$

$f_{bt_u} = \frac{2611\,(.715)}{.0628} = 29{,}727 \text{ PSI ULT} = 19{,}818 \text{ PSI LIMIT}$

$M.S._c = \frac{31{,}050}{24{,}530} - 1 = +.26$

$M.S._t = \frac{24{,}300}{19{,}818} - 1 = +.23$

SECTION B-B, LOWER BEAM



ELEM	A	y	Ay	Ay²	I₀
1	.010	-.25	-.0025	.0006	
2	.015	-.01	-.0001	—	
3	.038	.40	.0152	.0061	.0114
4	.016	1.30	.0208	.0270	
5	.016	.01	.0002	—	
6	.022	.55	.0121	.0066	.0022
7	.012	1.00	.0120	.0120	
8	.051	.52	.0265	.0138	.0166
9	.040	1.25	.0500	.0625	
10	.025	.85	.0212	.0181	
	.245		.1554	.1467	.0302

$\bar{y} = \frac{.1554}{.245} = .634$

$c_c = .634 + .50 = 1.134$

$c_t = 1.500 - .634 = .866$

$I = .1467 - (.634)(.1554) + .0302$

$= .0784 \text{ IN}^4$

$M = \frac{1364}{2500}(4786) = 2611 \text{ IN-LB}$

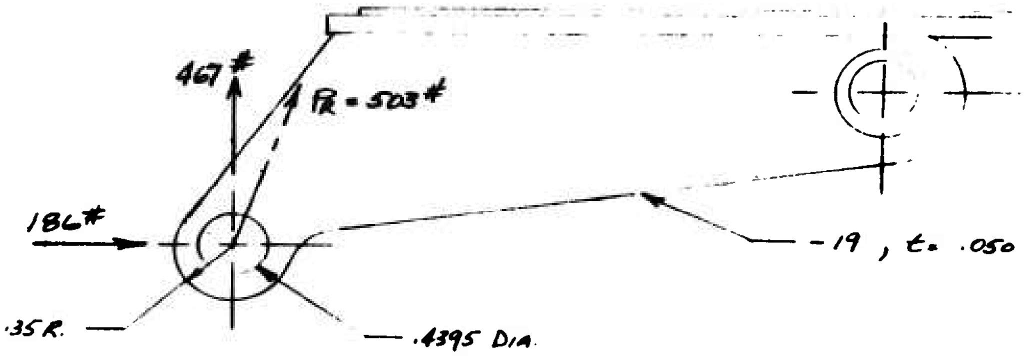
$f_{bc_u} = \frac{2611\ (1.134)}{.0784} = 37{,}767 \text{ PSI ULT} = 25{,}178 \text{ PSI LIMIT}$

$f_{bt_u} = \frac{2611(.866)}{.0784} = 28{,}840 \text{ PSI ULT} = 19{,}227 \text{ PSI LIMIT}$

$M.S._c = \frac{31{,}050}{25{,}178} - 1 = +.23$

$M.S._t = \frac{24{,}300}{19{,}227} - 1 = +.26$

DOOR HINGE LUGS:
VIEW C - C



TOTAL LUG THICKNESS IS MADE UP OF -19 DOUBLER & -11 CHANNEL , t= .025

t_{TOT} = .075 PER LUG , TWO LUGS PER HINGE.

SHEAR TEAR OUT: (ASSUME ACTING @ MIN. SHEAR-OUT AREA)

$P_S = 503\#$

$A_{S_{MIN}} = 4(.32 - .2197)(.075) = .0300 \text{ IN}^2$

$f_S = \frac{503}{.0300} = 16{,}766$ PSI ULT

$F_{SU_{1200°F}} = 33{,}600$ PSI

$M.S. = \frac{33{,}600}{16{,}766} - 1 = 1.00$

BEARING:

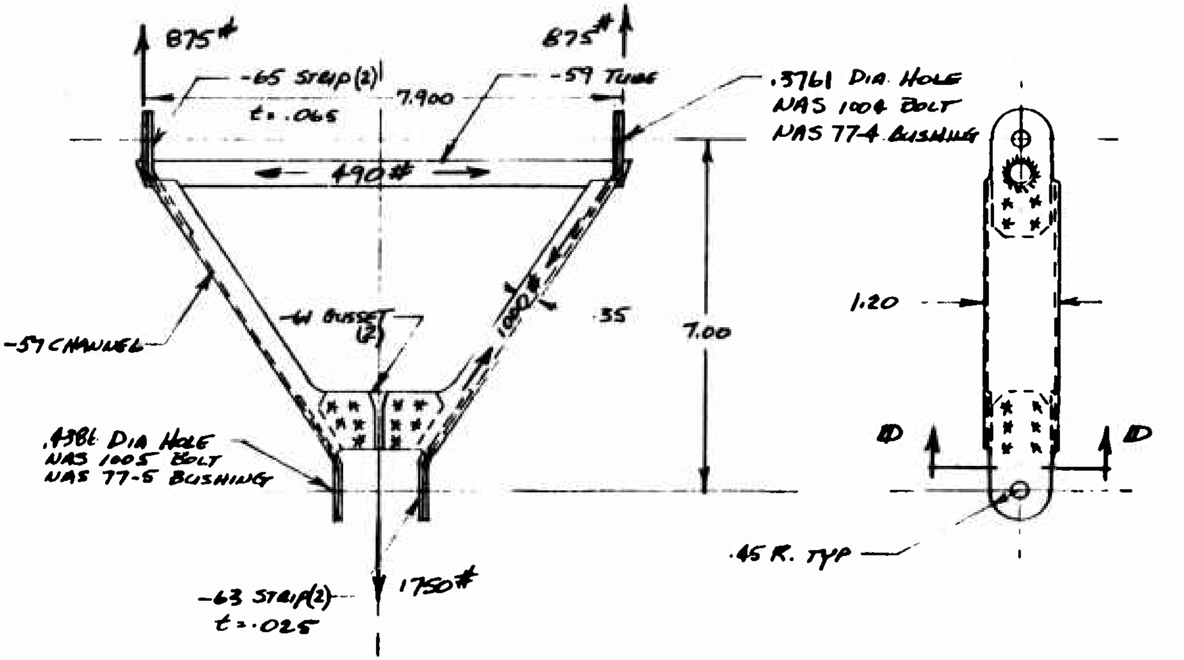
$P_{BR} = 503\#$

$A_{BR_{MIN}} = 2(.4385)(.075) = .066 \text{ IN}^2$

$f_{BRU} = \frac{503}{.066} = 7621$ PSI

NOT CRITICAL

IDLER LINK :



-59 TUBE :

1/2 DIA X .025 , $I = .0011$ IN^4 , $L' = 7.90$ (PINNED ENDS)
MATL: A-286 $E_{300} = 28(10)^6$ PSI

$P_c = 490$# ULT.

$$P_{CR} = \frac{\pi^2 E I}{(L')^2} = \frac{\pi^2 (28)(10)^6 (.0011)}{(7.90)^2} = 4865\#$$

TUBE NOT CRITICAL

-57 CHANNEL : LOWER LUG , NET TENSION SECTION

MATL: .025 19-9 DL (2 THICKNESSES)

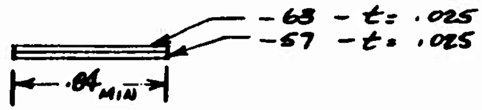
$A_{t_{MIN.}} = (.050)(.84 - .439) = .020$ IN^2

$F_{tu_{300}} = 86{,}400$, $P_{t_a} = .020(86{,}400) = 1732$#

$P_t = 875$# ULT. TENSION NOT CRITICAL

IDLER LINK:

LOWER LUG, SECTION D-D, COMPRESSION ALLOWABLE



$F_{CR} = KE\left(\frac{t}{b}\right)^2$ WHERE $K = 1.00$, $a/b = 1.00$, ENDS PINNED, SIDES FREE

& $E_{300} = 18.56(10)^6$ PSI

$F_{CR} = 18.56(10)^6\left(\frac{.025}{.84}\right)^2 = 16,370$ PSI

$P_{CR} = (.050)(.84)(16,370) = 687$ #/LUG

SHEAR TEAR-OUT: LOWER LUG

$P_S = 875$ #/LUG

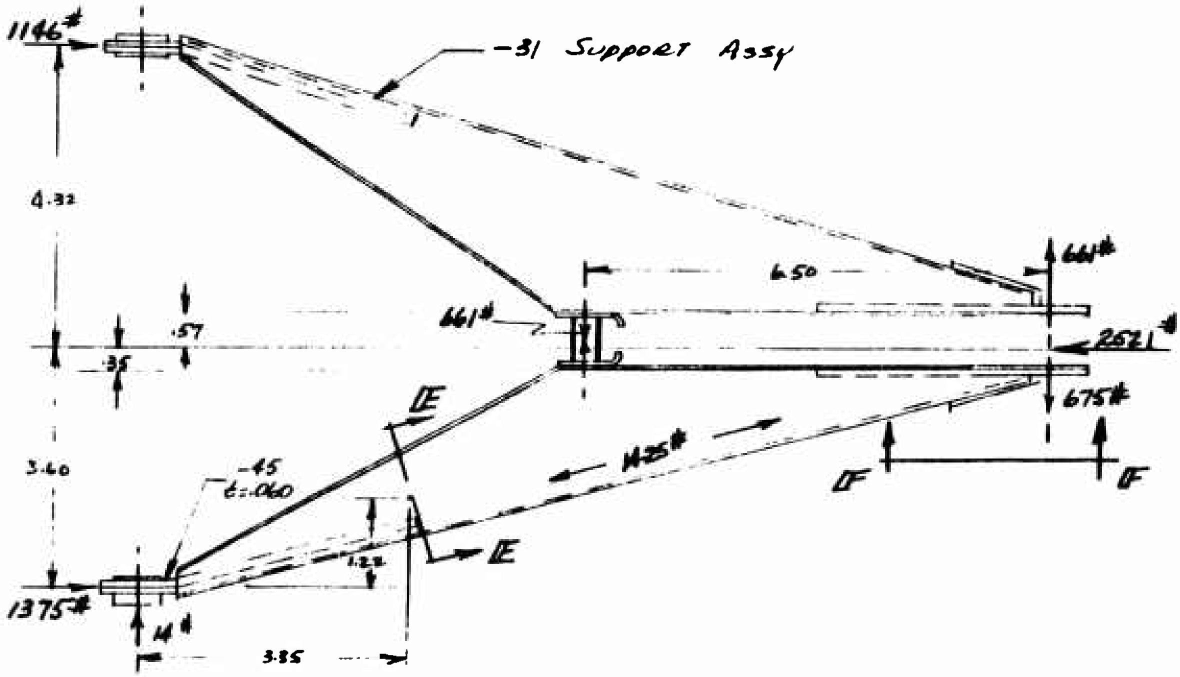
$A_S = 2(.42 - .2193)(.050) = .020 \text{ IN}^2$

$f_S = \frac{875}{.020} = 43,750$ PSI

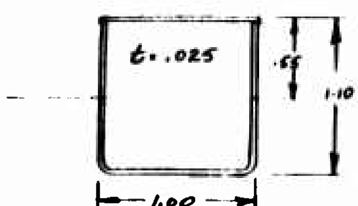
$F_{SU\,300°} = 50,400$ PSI

$M.S. = \frac{50,400}{43,750} - 1 = \underline{+.15}$

DOOR SUPPORT LINKS:



SECTION E-E



$C_t = C_c = .55$ IN.

$I = 2\frac{(1.05)^3(.025)}{12} + 2(1.00)(.025)(.54)^2 = .0194 \text{ IN}^4$

$A = 2(1.05 + 1.00)(.025) = .1025 \text{ IN}^2$

$M_{c.c} = 1.22(1375) - 3.35(14) = 1631$ IN-LB

$f_b = \frac{1631(.55)}{.0194} = 46{,}240$ PSI ULT $=$ 30,827 PSI LIMIT

$f_c = \frac{1425}{.1025} = 13{,}902$ PSI ULT $=$ 9268 PSI LIMIT

DOOR SUPPORT LINKS:

SECTION E-E

$\Sigma f_c = 60{,}142$ psi ULT $= 40{,}095$ psi LIMIT

$F_{cc} = KE\left(\frac{t}{b}\right)^2 = 3.64(27.26)(10)^6\left(\frac{.025}{.95}\right)^2 = 68{,}664$ psi

$F_{cy} = 41{,}400$ psi @ 300°F

$M.S._c = \frac{41{,}400}{40{,}095} - 1 =$ **+.03**

-45 LUG ATTACHMENT TO SUPPORT

THE 1425# ULT SUPPORT LOAD IS TRANSFERED TO THE -45 LUG THROUGH 10 SPOT WELDS PER MIL-W-6858 @ .5 SPACING.

$t_{MIN} = .025$

$P_{sa_{.025}} = 425$ #/SPOT FOR MATL F_{tu} 90-150 KSI [REF: MIL-HDBK-5] WHICH IS APPLICABLE TO 19-9 DL @ R.T.

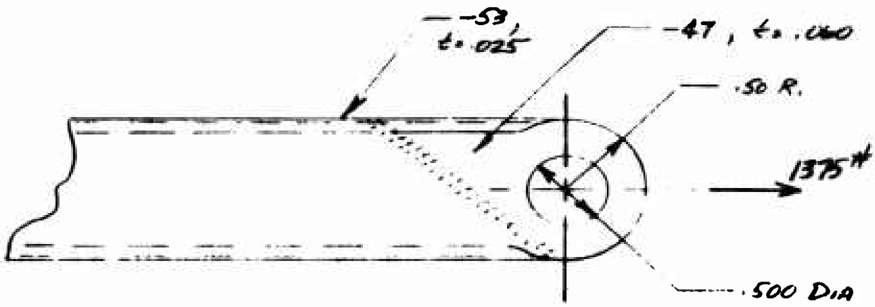
$P_{sa_{1200°F}} = \frac{51.3}{95.0}(425) = 230$ #/SPOT

$\Sigma P_{sa} = 10(230) = 2300$ # ULT

$M.S. = \frac{2300}{1425} - 1 =$ **+.61**

DOOR SUPPORT LINK LUG:

VIEW F-F



SHEAR TEAR OUT:

$P_S = 1375\#$ ULT.

$A_{S_{MIN}} = 2(.47 - .251)(.085) = .037 \; IN^2$

$f_{S_u} = \frac{1375}{.037} = 37{,}162 \; PSI$

$F_{S_u \; 300°F} = 50{,}400 \; PSI$

$M.S. = \frac{50{,}400}{37{,}162} - 1 = +.36$

LUG BEARING NOT CRITICAL

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4.0 PITCH FAN INLET LOUVER INSTALLATION

The pitch fan inlet louver installation (Ref. Dwg. 143P010) consists of two independently operated sets of four louvers, one set on each side of the aircraft centerline, at the inlet to the pitch fan. The louvers are designed for flight operations in two positions only. Fully closed they provide a faired upper surface over the pitch fan and fully open they allow inlet air to enter the pitch fan and guide the flow of the inlet air.

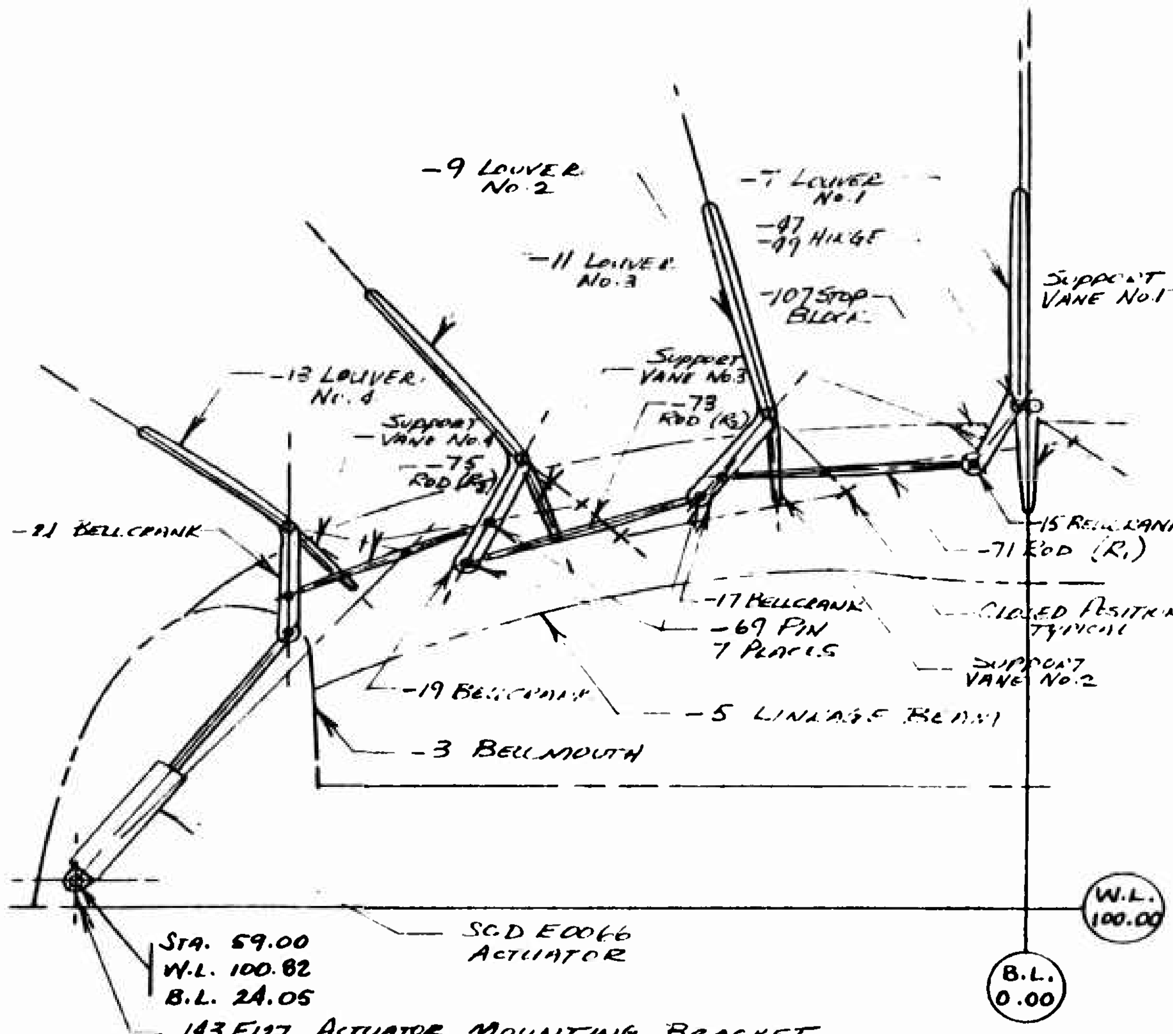
The louvers are attached to the inlet through the louver support vanes, which are integral parts of the inlet, by means of full length piano hinges. Louver actuation is accomplished through a series of push rods between the louver bellcranks by a single electrical actuator for each set of four louvers. The actuator (Ref. Dwg. SCDE0066) is designed to preload the louver system against the centerline bellcrank stop throughout the range of relieving louver loads and is load limited to preclude overloading of the mechanism.

A sketch of the installation of one set of the louvers is shown in Figure 1.

The louver installation is designed to withstand normal pressure loading in the closed position for any conventional flight condition. Critical design loads occur in the open position at maximum design speeds of ; 125 knots fan power on and 180 knots fan power off with the aircraft in a $\pm$ 15 degree sideslip flight condition. These loads, in terms of louver hinge moments are shown in the accompanying pages.

Because of the similarity of components which make up the separate louvers and mechanism units, stress analysis and margins of safety are shown for the critical component only.

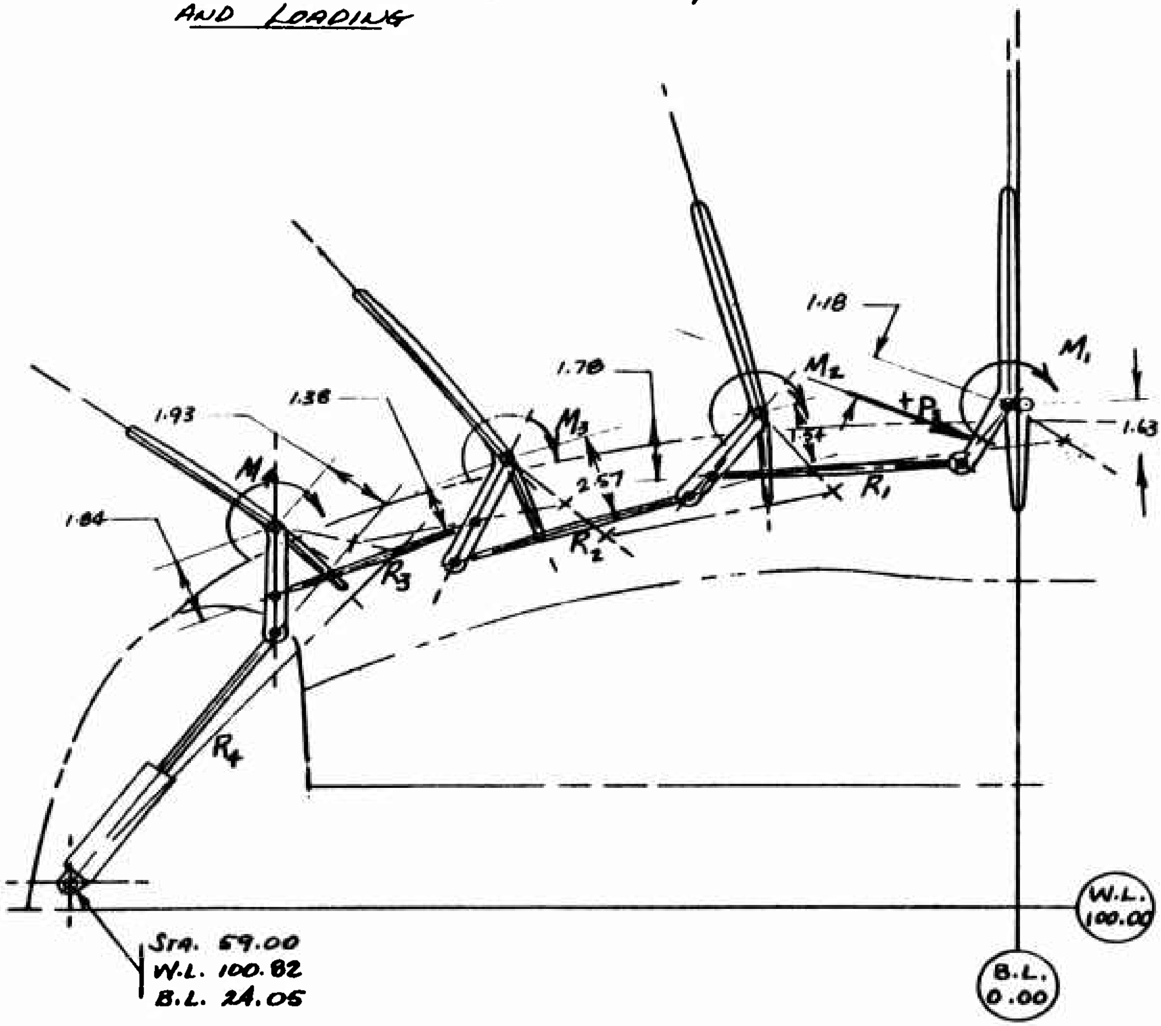
PITCH FAN INLET LOUVER INSTALLATION
REF: DWG 143 P010



VIEW LOOKING FORWARD, L.H. SIDE

FIGURE I

INLET LOUVER LINKAGE GEOMETRY AND LOADING



VIEW LOOKING FORWARD, L.H. SIDE

FIGURE II

MECHANISM UNIT LOADS: ACTUATOR LOADED: LOUVERS OPEN

PUSH ROD AND ¢ CRANK STOP LOADS FOR A ONE POUND TENSION LOAD IN THE ACTUATOR, NO OTHER LOADS APPLIED. LOUVERS OPEN. + INDICATES TENSION.

$$R_4 = +1.00\#$$

$$R_3 = \frac{1.93}{1.84} R_4 = +1.05\#$$

$$R_2 = \frac{1.38}{2.57} R_3 = +.56\#$$

$$R_1 = \frac{1.54}{1.78} R_2 = +.48\#$$

$$P_S = \frac{1.63}{1.18} R_1 = +.66\#$$

FOR A COMPRESSION LOAD IN THE ACTUATOR THE PUSH ROD LOADS ABOVE WOULD BE MINUS (COMPRESSION) AND THE STOP LOAD, P_S, BECOMES ZERO.

LOUVERS LOADED:

FOR POSITIVE LOUVER HINGE MOMENTS REACTIONS ARE SUPPLIED BY BOTH THE ¢ CRANK STOP AND THE ACTUATOR. PRELIMINARY ANALYSIS SHOWED THE FOLLOWING DIVISION OF LOAD TO THESE REACTIONS TO BE REPRESENTATIVE OF THE DISTRIBUTION DUE TO FLEXIBILITY OF THE LINKAGE MECHANISM. NEGATIVE HINGE MOMENTS ARE REACTED BY THE ACTUATOR ALONE.

HINGE MOMENT	NO. OF EQUAL SPRINGS TO		LOAD RATIO	
	ACTUATOR	STOP	ACTUATOR	STOP
$+M_1$	4	1	1/5 (.20)	4/5 (.80)
$+M_2$	3	2	2/5 (.40)	3/5 (.60)
$+M_3$	2	3	3/5 (.60)	2/5 (.40)
$+M_4$	1	4	4/5 (.80)	1/5 (.20)
$-M_{1-4}$			ALL	

MECHANISM UNIT LOADS: LOUVERS FULL OPEN & LOADED HINGE MOMENTS EQUAL ONE INCH POUND, NO OTHER LOADS.

R \ M	$+M_1$	$+M_2$	$+M_3$	$+M_4$	$-M_1$	$-M_2$	$-M_3$	$-M_4$
R_1	−.12	+.34	+.14	+.05	+.61	0	0	0
R_2	−.14	−.26	+.16	+.06	+.70	+.65	0	0
R_3	−.26	−.48	−.43	+.11	+1.30	+1.21	+.72	0
R_4	−.25	−.46	−.41	−.41	+1.24	+1.15	+.69	+.52
P_S	+.68	+.47	+.19	+.07	—	—	—	—

INLET LOUVER LOADS:

THE FOLLOWING TABLE SHOWS MAXIMUM ESTIMATED HINGE MOMENTS APPLIED TO THE LOUVERS FOR TWO CRITICAL FLIGHT CONDITIONS WITH THE LOUVERS IN THE FULLY OPEN POSITION. POSITIVE HINGE MOMENTS TEND TO OPEN THE LOUVERS.

HINGE MOMENT	LIMIT HINGE MOMENT, INCH POUNDS PER LOUVER.			
	FAN POWER ON, V = 125 K.		FAN POWER OFF, V = 180 K.	
	$\beta = +15$	$\beta = -15$	$\beta = +15$	$\beta = -15$
M_1	− 125	+ 125	− 170	+ 170
M_2	− 75	+ 75	− 150	+ 150
M_3	− 60	+ 60	− 120	+ 120
M_4	− 30	+ 30	− 60	+ 60

MECHANISM LOADS: LIMIT

FLIGHT COND. IV, FAN POWER OFF, V = 180 K., β = +15 DEG.

THIS CONDITION APPLIES CRITICAL NEGATIVE HINGE MOMENTS (CLOSING MOMENTS) WHICH INCREASE TENSION LOADS IN THE PUSH RODS & IN THE ACTUATOR

LOAD	M_1 = -170	M_2 = -150	M_3 = -120	M_4 = -60	ACTUATOR LOAD		TOTAL LOAD ACTUATOR	
					+200 #	+300 #	+200 #	+300 #
R_1	+103.7	0	0	0	+96.0	+144.0	+103.7	+103.7
R_2	+119.0	+97.5	0	0	+112.0	+168.0	+216.5	+216.5
R_3	+221.0	+181.5	+86.4	0	+210.0	+315.0	+488.9	+488.9
R_4(ACT.)	+210.8	+172.5	+82.8	+31.2	+200.0	+300.0	+497.3*	+497.3*
P_5	—	—	—	—	—	—	0	0

* ACTUATOR LOAD IS HIGHER THAN MAXIMUM ACTUATOR OPERATING LOAD OF 300#, WHICH MEANS THAT THE ACTUATOR COULD NOT OPERATE THE LOUVERS IN THIS CONDITION. ACTUATOR ULT. STATIC LOAD IS ± 1000#, HOWEVER, SO IT WOULD MAINTAIN LOUVER POSITION.

FLIGHT COND. V, FAN POWER OFF, V = 180 K., β = -15 DEG.

THIS CONDITION APPLIES CRITICAL POSITIVE HINGE MOMENTS (OPENING MOMENTS) WHICH TEND TO RELIEVE PRE-TENSION LOADS IN THE PUSH RODS AND IN THE ACTUATOR. NOTE THAT THE ACTUATOR PRELOAD IS NOT REVERSED IN ANY LINKAGE COMPONENT AT A MINIMUM ACTUATOR PRELOAD OF 200#.

LOAD	M_1 = +170	M_2 = +150	M_3 = +120	M_4 = +60	ACTUATOR LOAD		TOTAL LOAD ACTUATOR	
					+200 #	+300 #	+200 #	+300 #
R_1	-20.4	+51.0	+16.8	+3.0	+96.0	+144.0	+146.4	+194.4
R_2	-23.8	-39.0	+19.2	+3.6	+112.0	+168.0	+72.0	+128.0
R_3	-44.2	-72.0	-51.6	+6.6	+210.0	+315.0	+48.8	+153.8
R_4(ACT.)	-42.5	-69.0	-49.2	-24.6	+200.0	+300.0	+14.7	+114.7
P_5	+115.6	+70.5	+22.8	+4.2	+132.0	+198.0	+345.1	+411.1

MECHANISM UNIT LOADS, LOUVERS OPEN & LOADED:
℄ CRANK STOP UNLOADED

R \ M	+M_1	+M_2	+M_3	+M_4
R_1	−.61	0	0	0
R_2	−.70	−.65	0	0
R_3	−1.30	−1.21	−.72	0
R_4	−1.24	−1.15	−.69	−.52
R_5	0	0	0	0

MECHANISM LOADS: LIMIT

FLIGHT COND VI, FAN POWER OFF, V=180K., β= −15 DEG.

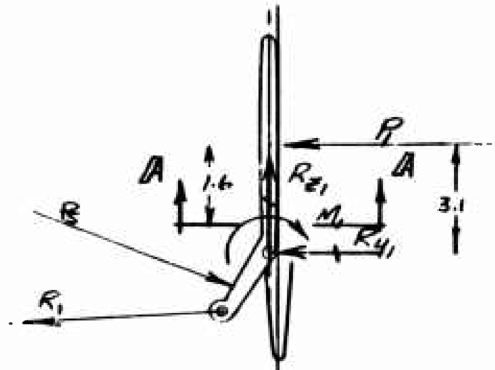
THIS CONDITION APPLIES CRITICAL POSITIVE HINGE MOMENTS (OPENING MOMENTS) WHEN THE LOUVERS ARE OPEN BUT NOT AGAINST THE ℄ CRANK STOP. THIS APPLIES CRITICAL COMPRESSION LOADS IN THE PUSH-RODS AND ACTUATOR.

LOAD	M_1 = +170	M_2 = +150	M_3 = +120	M_4 = +60	ACTUATOR LOAD −200#	ACTUATOR LOAD −300#	TOTAL LOAD ACTUATOR 200#	TOTAL LOAD ACTUATOR 300#
R_1	−103.7	0	0	0	− 96.0	− 144.0	−103.7	−103.7
R_2	−119.0	− 97.5	0	0	− 112.0	− 168.0	−216.5	− 216.5
R_3	−221.0	− 181.5	− 86.4	0	− 210.0	− 315.0	−488.9	− 488.9
R_4(ACT.)	−210.8	− 172.5	− 82.8	− 31.2	− 200.0	− 300.0	−497.3*	− 497.3*
R_5	0	0	0	0	0	0	0	0

* ACTUATOR LOAD EXCEEDS MAXIMUM ACTUATOR OPERATING LOAD OF 300#, WHICH MEANS THE ACTUATOR COULD NOT OPERATE THE LOUVERS IN THIS CONDITION. STATIC ACTUATOR CAPABILITY OF ± 1000 # ASSURES THAT THE ACTUATOR WILL MAINTAIN THIS LOUVER POSITION.

No. 1 (CENTER LINE) LOUVER

-7 LOUVER, -15 BELLCRANK

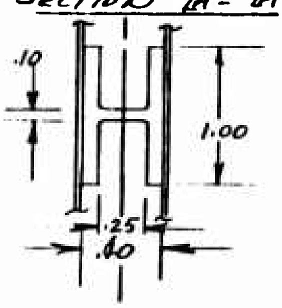


LIMIT LOADS:

CONDITION	M_1	R_1	P_3	P_1	R_{Y_1}	R_{Z_1}
IV, $\beta = +15$ FULL OPEN	-170	+103.7	0	+ 54.8	-157.8	+ 6.5
V, $\beta = -15$ AGAINST STOP	+170	+194.4	+411.1	- 54.8	+240.8	-172.0
VI, $\beta = -15$ NOT AGAINST STOP	+170	-103.7	0	- 54.8	+157.8	- 6.5

CRITICAL LOUVER BENDING & TORSION:

SECTION A - A



$M_{ULT} = 1.5\,(1.6)\,(54.8) = 131.5$ IN-LB

$I = 2(.075)(.163)^2 + .10\frac{(.25)^3}{12} = .0041$ IN⁴

$f_b = \frac{131.5\,(.20)}{.0041} = 6415$ psi ULT.

MATL: 7075-T651, $F_{tu} = 77{,}000$ psi.

No. 1 (CENTERLINE) LOUVER

LOUVER TORSION:

MAXIMUM TORSIONAL MOMENT IN THE LOUVER BLADE OCCURS AT MID LENGTH AT THE CRANK.

$$M_T = 3.1\left(\frac{54.8}{2}\right)(1.5) = 127.4 \text{ IN-LB (ULT)}$$

$$A = 6.0(.45) = 2.70 \text{ IN}^2$$

$$t = .020 \qquad \text{2024-T4 ALUM.}$$

$$f_s = \frac{127.4}{2(2.70)(.020)} = 1180 \text{ psi}$$

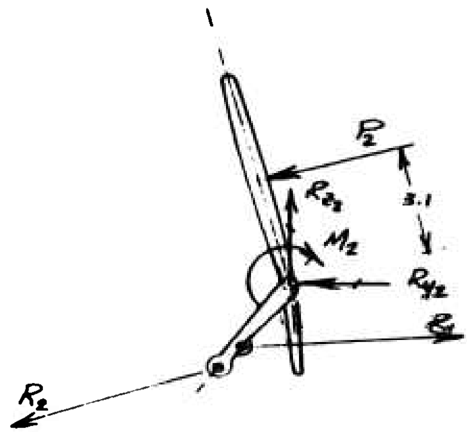
ANGLE OF TWIST:

$$L = 23.0 \text{ IN} \quad ; \quad G = 4.0(10)^6$$

$$\Sigma \frac{ds}{t} = \frac{12}{.020} = 600$$

$$\theta = \frac{127.4(23.0)(600)}{4(7.29)(4.0)(10)^6} = .015 \text{ RAD} = .86 \text{ DEG @ ULT.}$$

No. 2 LOUVER:
-9 LOUVER, -17 BELLCRANK

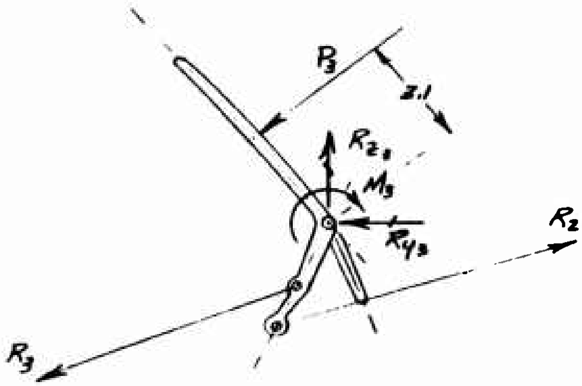


LIMIT LOADS:

CONDITION	M_2	R_1	R_2	P_2	R_{y_2}	R_{z_2}
IV, $\beta = +15$ FULL OPEN	−150	+103.7	+216.5	+ 48.4	−149.5	+ 71.0
V, $\beta = -15$ AGAINST STOP	+150	+194.4	+128.0	− 48.4	+121.0	+ 14.0
VI, $\beta = -15$ NOT AGAINST STOP	+150	−103.7	−216.5	− 48.4	+149.5	− 71.0

NO. 3 LOUVER

-11 LOUVER, -19 BELLCRANK



LIMIT LOADS:

CONDITION	M_3	R_2	R_3	P_3	R_{Y_3}	R_{Z_3}
IV, $\beta = +15$ FULL OPEN	-120	+216.5	+488.9	+ 38.7	- 274.0	+ 138.5
V, $\beta = -15$ AGAINST STOP	+120	+128.0	+153.8	- 38.7	+ 8.0	- 4.5
VI, $\beta = -15$ NOT AGAINST STOP	+120	-216.5	-488.9	- 38.7	+274.0	-138.5

LOUVER HINGE:

CRITICAL HINGE RESULTANT REACTION:

$R_H = 1.5(274.0^2 + 138.5^2)^{1/2} = 460.5$ # (ULT)

ASSUME TOTAL HINGE REACTION AT CRANK

HINGE PIN DIA. = .090

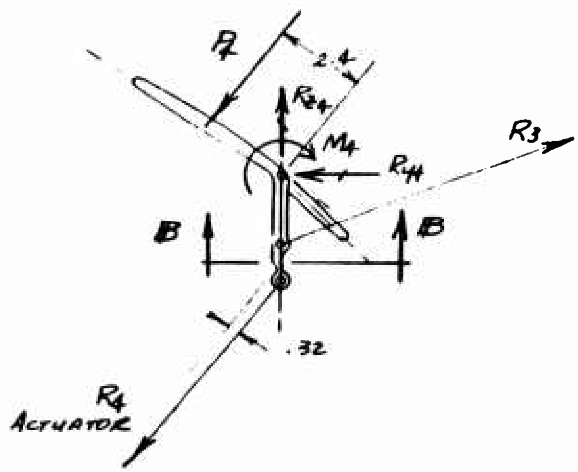
MATL: CORROSION RESISTANT STEEL, $F_{su} = 40{,}000$ PSI MIN

$P_S = 230.3$ # (ULT) PER SHEAR FACE

$A_S = .0064$ IN^2 $\quad f_S = \frac{230.3}{.0064} = 35{,}984$ psi $\quad M.S. = \frac{40{,}000}{35{,}984} - 1 = +.11$

NO. 4 LOUVER:

−13 LOUVER, −21 BELLCRANK

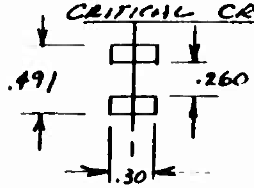


LIMIT LOADS:

CONDITION	M_4	R_3	R_4	P_4	R_{y4}	R_{z4}
IV, β = +15 FULL OPEN	−60	+488.9	+497.3	+25.0	+137.0	+233.0
V, β = −15 AGAINST STOP	+60	+153.8	+114.7	−25.0	+95.0	+19.0
VI, β = −15 NOT AGAINST STOP	+60	−488.9	−497.3	−25.0	−157.0	−233.0

SECTION B-B:

CRITICAL CRANK BENDING:



MATL: 7075-T651, F_{tu} = 77,000 PSI

$I = \frac{.231(.30)^3}{12} = .00051$ IN⁴

$M = .32(497.3)(1.5) = 238.7$ IN-LB (ULT)

$f_{b_t} = \frac{238.7(.15)}{.00057} = 70,205$ psi (ULT)

NO. 4 LOUVER:

SECTION B-B, CONT:

$A = .231\ (.30) = .069\ IN^2$

$P_t = 1.5\ (400) = 600\ \#\ (ULT)$

$f_t = \frac{600}{.069} = 8695\ psi\ (ULT)$

$R_{bt} = \frac{70,205}{1.2\ (77,000)} = .760$ $\qquad R_t = \frac{8695}{77,000} = .113$

$M.S. = \frac{1}{.760+.113} - 1 = \underline{\underline{+.14}}$

CRANK ARM - ACTUATOR ATTACHMENT:

SHEAR TEAR-OUT:

$R_{MIN} = .25$

$D_{MAX} = .194$

$t_{MIN} = .097$

$P = (1.5)\frac{497.3}{2} = 373\ \#\ (ULT)/LUG$

$A_s = 2\ (.25 - .097)(.099) = .030\ IN^4$

$f_s = \frac{373}{.030} = 12,433\ psi\ (ULT)$

$F_s = 46,000\ psi$

NOT CRITICAL

-69 PIN:

$D = .1890$, MATL: 17-4 STL., COND. A

$A_s = 2\ (\frac{.1890^2 \pi}{4}) = .0561\ IN^2$

$P = 1.5\ (497.3) = 746\ \#$

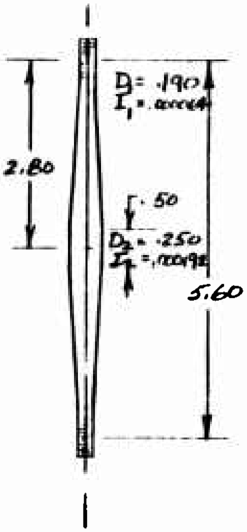
$f_s = \frac{746}{.0561} = 13,300\ psi$ NOT CRITICAL

PUSH RODS:

CRITICAL PUSH ROD IS ROD −75 (R_3)

$P_{C_{MAX}} = 1.5(488.9) = 733.4\ \#$ (ULT.)

REF: "THEORY OF ELASTIC STABILITY", TIMOSHENKO



$\ell = 5.60$ IN. (INCLUDES ROD ENDS)

$c = 1.00$ (PINNED BOTH ENDS)

MATL: 4130 STL., H.T. 125,000 PSI

$E = 29.0(10)^6$ PSI

$a = .50$

$a/\ell = \frac{.50}{5.60} = .089$

$I_1/I_2 = \frac{.000064}{.000192} = .333$

$m = 7.42$

$P_{CR} = 7.42\frac{(29.0)(10)^6(.000192)}{(5.60)^2} = 1317\ \#$

$M.S. = \frac{1317}{733.4} - 1 = +.80$

−107 STOP BLOCK:

MATL: FIBERGLASS CLOTH & 828 DTA RESIN

$F_{tu} = 17,000$ PSI MIN

$F_c = 15,000$ PSI MIN.

$F_{su} = 6,000$ PSI MIN.

REF: MIL-HNDBK-17

MIL-R-9300 EPOXY RESIN

$P_S = 1.5(411.1)\cos 22° = 1.5(411.1)(.9272) = 571.8\ \#$ (ULT)

$A_S = .60(1.00) = .60\ IN^2$

$f_{s_u} = \frac{571.8}{.60} = 954$ PSI

NOT CRITICAL

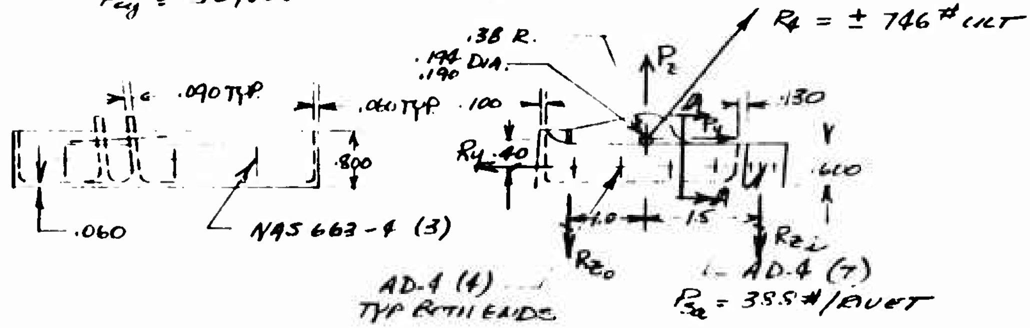
LOUVER ACTUATOR MOUNTING BRACKET

REF: DWG 143F127, 143F003

MAT'L: 2024-T351

F_{tu} = 59,000 psi , $F_{BRU_{2.0}}$ = 118,000 psi , F_{su} = 37,000 psi

F_{ty} = 32,000 "



P_y = 450 # ULT

P_z = 597 # ULT

R_y = 450 # ULT.

R_{z_i} = 167 # ULT.

R_{z_o} = 430 # ULT.

LUG SHEAR OUT:

$A_{s_{MIN}} = 2(.080)(.248) = .040$ IN²/LUG

R_{s_u} = 373 # /SIDE

$f_s = \frac{373}{.040} = 9325$ psi

NOT CRITICAL

LUG BENDING:

ASSUME TRANSFER OF LUG LOAD TO BRACKET SIDES BY LUG BENDING AND LUG AXIAL LOAD ALONE.

$Z_{MIN} = \frac{.080(.59)^2}{6} = .0046$ IN³

$A_{MIN} = .080(.59) = .047$ IN²

$M_{A-A} = 1.25(167) = 209$ IN-LB

$f_{b_e} = \frac{209}{.0046} = 45,434$ psi

$f_t = \frac{225}{.047} = 4788$ psi

$\Sigma f_t = 50,222$ psi

$M.S. = \frac{59,000}{50,222} - 1 =$ +.17