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Stress Analysis of Control System

53412

(None)

Pollock, R. G.; Asplund, E. M.; Tom, G. E.
Consolidated Vultee Aircraft Corp., Fort Worth Div., Texas
USAF Contr. No. W535-ac-22352

R-FZS-36-250

(None)

June '47 Unclass. U.S. English 40 diagrs

Analysis is made of the control system of the XB-36 bomber. This analysis is an addendum to the stress analysis previously given for the YB-36 and B-36A bombers. Attention has been given to the control column, aileron controls, elevator controls, elevator trim tab system, rudder controls and brake pedal system, rudder control system and rudder trim tab system. A summary of the margins of safety is included.

Copies of this report obtainable from CADO (1)

Structures (7) Control surfaces - Stress analysis
Stress Analysis of Specific Aircraft (6) (25399.4); XB-36 (99409)

USAF C.N. W535-ac-22352

2406

MODEL XB-36

REPORT FZS-36-250

DATE June 11, 1947

TITLE

STRESS ANALYSIS OF CONTROL SYSTEM

SUBMITTED UNDER

Contract W535-ac-22352

PREPARED BY: R. S. Pollock
E. M. Asplund
D. E. Tom

GROUP: STRUCTURES

REFERENCE:

CHECKED BY: O. N. Thompson

APPROVED BY: M. B. Robbins
Hubert Clay

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INTRODUCTION

This addendum is written to incorporate the analysis of the XB-36 Control System. The operation of the control system and the design conditions are the same for the XB-36 as previously shown for the YB-36 and B-36A in C.V.A.C. Report FZS-36-150, Stress Analysis of Control System; however, there are minor differences in the construction of some of the components that will be analzyed in this addendum.

CONTROL COLUMN

THE CONTROL COLUMN DESIGN LOADS FOR THE XB-36 ARE THE SAME AS THOSE SHOWN FOR THE YB-36 & B-36A ON PAGES 4, 5 & 6 OF FZS-36-150.

AILERON SYSTEM IN CONTROL COLUMN

THE AILERON SYSTEM IN THE CONTROL COLUMN OF THE XB-36 IS IDENTICAL TO THAT OF THE YB-36 & B-36A. SINCE THE LOADINGS ARE ALSO THE SAME, THE ANALYSIS FOR THIS REGION SHOULD BE REFERRED TO PAGES 6 THROUGH 12 OF FZS-36-150.

ELEVATOR SYSTEM IN CONTROL COLUMN

THE ELEVATOR SYSTEM IN THE CONTROL COLUMN OF THE XB-36 IS THE SAME AS THAT FOR THE YB-36 & B-36A EXCEPT THAT THE COLUMN IS ONE INCH SHORTER AND THE ELEVATOR CABLE IS ATTACHED TO A HORN ON THE TORQUE TUBE (REF. 36C003) INSTEAD OF THE PUSH-PULL TUBE (REF. 36C4739)

ALL COMPONENTS SHOWN IN FZS-36-150 WHICH WILL HAVE DIFFERENT STRESSES DUE TO THESE CHANGES ARE ANALYZED IN THIS ADDENDUM.

THIS ADDENDUM WILL ALSO ANALYZE ANY NEW PARTS WHICH ARE ADDED AS A RESULT OF THIS CHANGE.

ALL COMPONENTS OF THE ELEVATOR SYSTEM IN THE COLUMN WHICH ARE ANALYZED IN FZS-36-150 WHICH DO NOT APPEAR IN THIS ADDENDUM ARE EITHER NOT USED ON THE XB-36 OR THE STRESSES INVOLVED HAVE NOT BEEN ALTERED BY THE ABOVE CHANGES.

BENDING MOMENT DUE TO FORE & AFT LOADS

AT TOP OF BASE CASTING:

$= 450 \times 23.25$ (REF. FZS-36-150 WITH COLUMN 1 IN. SHORTER.)

$= 10{,}500$ IN. LBS

AT ℄ OF TORQUE TUBE:

$= 450 \times 33.5$

$= 15{,}080$ IN. LBS.

BENDING MOMENT DUE TO SIDE LOAD

AT TOP OF BASE CASTING:

$= 150 \times 23.25$

$= 3490$ IN. LBS.

AT ℄ TORQUE TUBE:

$= 150 \times 33.5$

$= 5025$ IN. LBS.

TORSION DUE TO SIDE LOAD

$T = 705$ IN. LBS.

(REF. FZS-36-150, PG. 13)

THE COLUMN IS CRITICAL IN COMBINED BENDING ABOUT BOTH AXES AND TORSION ON A SECTION AT THE TOP OF THE BASE CASTING.

$B.M._{X-X} = 10500$ IN. LBS.

$B.M._{Y-Y} = 3490$ IN. LBS.

TORQUE $= 705$ IN. LBS.

SECTION PROPERTIES

$I_{X-X} = .4679$ IN.^{4} (REF. FZS-36-150, PAGE 17)

$I_{Y-Y} = 1.5825$ IN.^{4} (" , PG. 17)

$Y = .999$ IN. (" " , PG. 18)

$X = 2.185$ IN. (" " , PG. 18)

STRESSES AND MARGIN OF SAFETY

COLUMN AT TOP OF BASE CASTING:

$$f_b = \frac{(3490 \times 2.185)}{1.5826} + \frac{(10{,}500 \times .999)}{.4679}$$

$$= 4820 + 22{,}400 = 27{,}220 \text{ P.S.I.}$$

$f_s = 987$ P.S.I. (REF. FZS-36-150, PAGE 18)

$F_{cy} = 32{,}000$ P.S.I. (REF. FZS-36-150 PAGE 18)

$F_{sy} = 17{,}000$ P.S.I. (REF. FZS-36-150 PAGE 18)

$R_b = \frac{27{,}200}{32{,}000} = .850$ $R_s = .0580$ (REF. FZS-36-150 PAGE 18)

$$\underline{M.S.} = \frac{1}{.850 + .0580} - 1 = \underline{+.10}$$

BASE-CONTROL COLUMN (36C054)

THE CASTING WILL BE CHECKED AT SECTION A-A (REF. FZS-36-150, PAGE 19)

$B.M._{x-x} = 450 \times 26.5 = 11{,}920$ IN. LBS.
$B.M._{y-y} = 150 \times 26.5 = 3980$ IN. LBS.
$T = 705$ (REF. PAGE 3)
$I_{x-x} = 2.218$ IN.^{4}, $I_{y-y} = 7.82$ IN.^{4} (REF. FZS-36-150, PAGE 19)

CONTROL COLUMN

BASE CASTING (CONT.)

$V = 1.1095$ IN., $X = 2.297$ IN., (REF. FZS-36-150, PAGE 19)

$$f_b = \frac{3980 \times 2297}{7.82} + \frac{11920 \times 1.095}{2.218}$$

$$= 1,170 + 5,900 = 7,070 \text{ P.S.I.}$$

$f_s = 254$ P.S.I. (REF FZS-36-150, PAGE 19)

$F_c = 16,000$ P.S.I. (REF FZS-36-150, PAGE 19)

$F_{ST} = 18,000$ P.S.I. (REF FZS-36-150, PAGE 19)

$R_b = \frac{7,070}{16\,000} = .442$, $R_s = .014$ (REF FZS-36-150, P. 14)

$$\text{M.S.} = \frac{1}{.442 + .014} - 1 = \underline{+1.19}$$

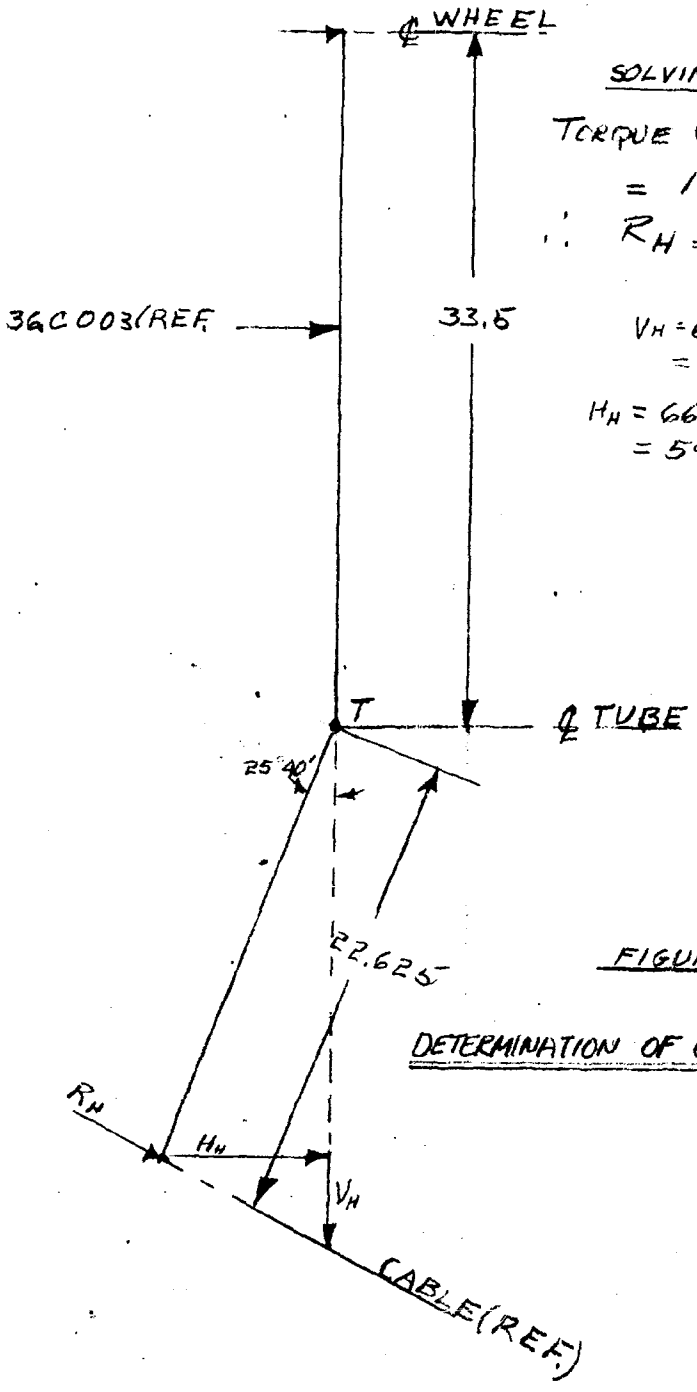
TORQUE TUBE

LOADS IN VERTICAL PLANE

1. SIDE LOAD ON CONTROL COLUMN

MOMENT AT COLUMN BASE = 5025 "# (REF P. 3)

2. VERT. COMPONENT OF CONTROL HORN LOAD
= 288# (REF. P. 6)



SOLVING FOR R_H

TORQUE @ ℄ TUBE FROM WHEEL
= 15,080 "# (REF. PG. 2)

$\therefore R_H = \frac{15080}{22.625} = 665\#$

$V_H = 665 \sin 25°40'$
$= 288\#$

$H_H = 665 \cos 25°40'$
$= 599\#$

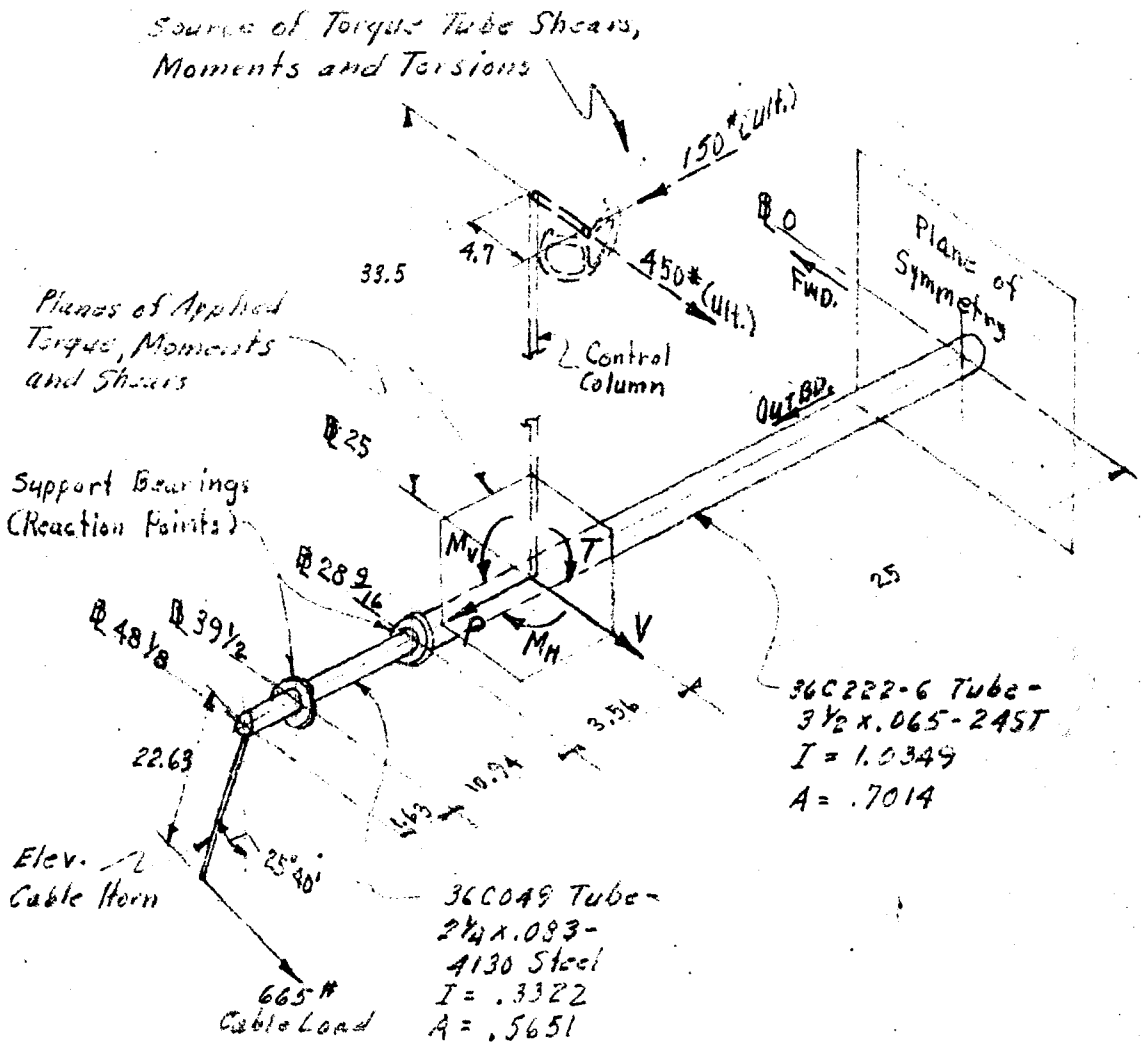
FIGURE 1

DETERMINATION OF CONTROL HORN LOADS

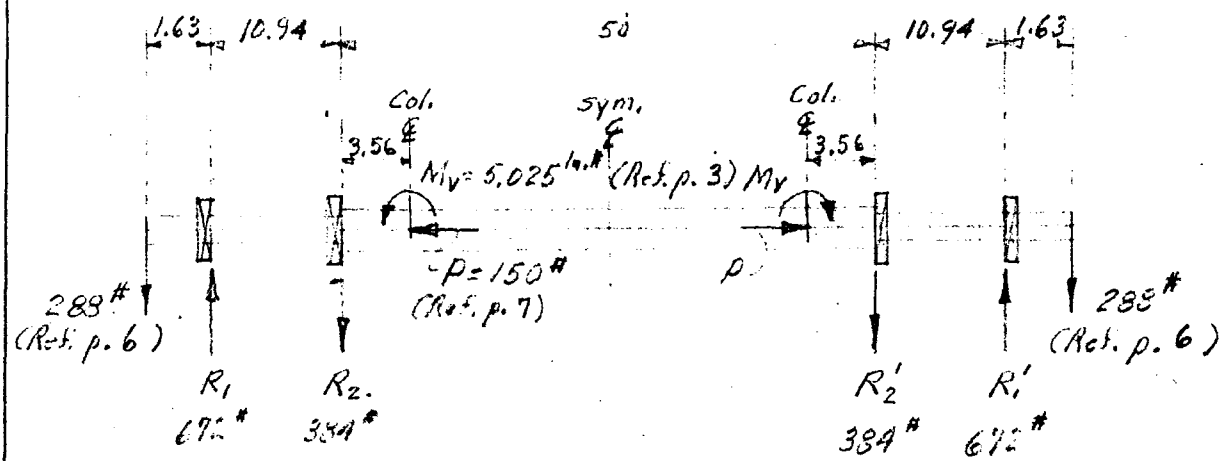
SCHEMATIC SKETCH OF TORQUE TUBE & APPLIED LOADS

As the torque tube, and loading, are symmetrical about the plane of symmetry of the airplane only the L.H. is shown.

Loads Ref. FTS-36-150.
Dimensions Ref. 36C004.



TORQUE TUBE LOADING DIAGRAM IN VERTICAL PLANE



$M_1 = -288(1.63) = -470^{in.\#}$

$M_2 = M_3 = M_2'$

$L_1 = L_3 = 10.94$

$L_2 = 50$ $\qquad a = 3.56 \quad b = 46.44$

$I_1 = I_3 = .3322^{in.^4}$ $(E_s = 29 \times 10^6)$

$I_2 = 1.0349^{in.^4}$ $(E_a = 10.5 \times 10^6)$ $\left\{ E_s/E_a = 2.76 \right.$

$$\frac{M_1 L_1}{2.76 I_1} + \frac{2 M_2 L_1}{2.76 I_1} + \frac{2 M_2 L_2}{I_2} + \frac{M_3 L_2}{I_2}$$

$$= \frac{M_V}{I_2}\left[\left(\frac{3b^2}{L_2} - L_2\right) - \left(\frac{3a^2}{L_2} - L_2\right)\right]$$

$$\frac{(-470)\,10.94}{2.76(.3322)} + \frac{2(10.94)M_2}{2.76(.3322)} + \frac{2(50)M_2}{1.0349} + \frac{50 M_2}{1.0349}$$

$$= \frac{5.025}{1.0349}\left[\left(\frac{3(46.44)^2}{50} - 50\right) - \left(\frac{3(3.56)^2}{50} - 50\right)\right]$$

$$-5,600 + 23.8\,M_2 + 96.6\,M_2 + 42.3\,M_2$$
$$= 4,850\left[(129.1-50)-(.76-50)\right]$$

$$168.7\,M_2 = 631,100$$

$$M_2 = 3,742 \text{ in.\#}$$

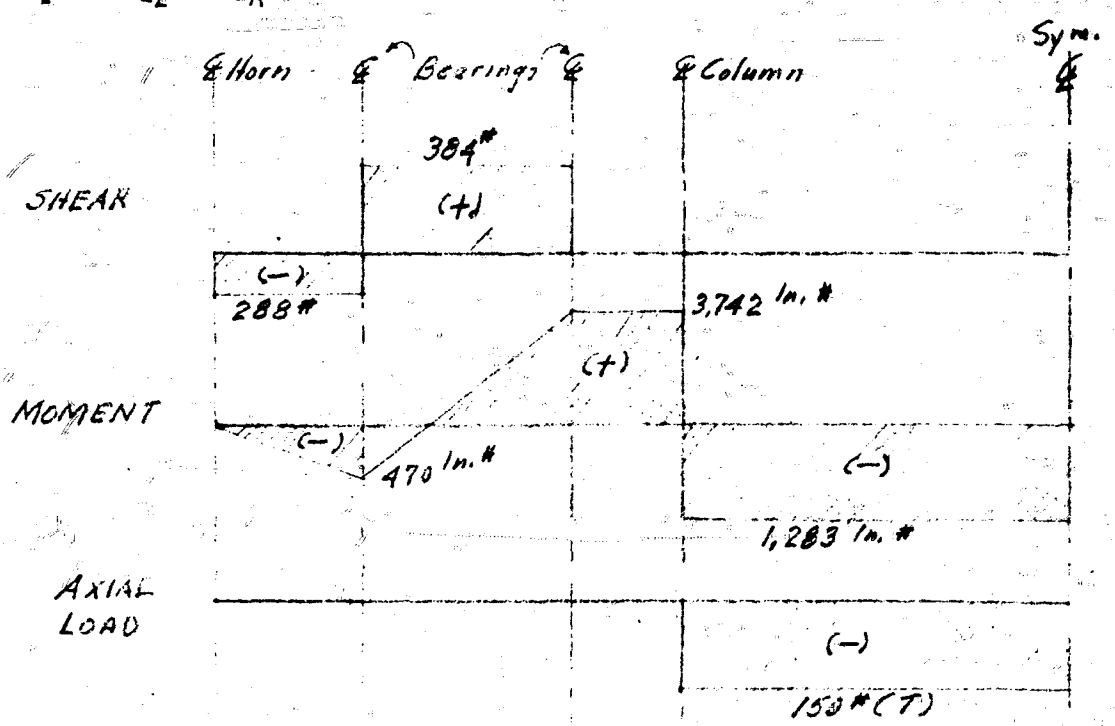
$$R_{1_L} = 298^{\#} \text{ (Up)}$$

$$R_{1_R} = R_{2_L} = (470 + 3,742) \div 10.94 = 384^{\#} \text{ } (R_{1_R} \text{ Up} - R_{2_L} \text{ Dwn.})$$

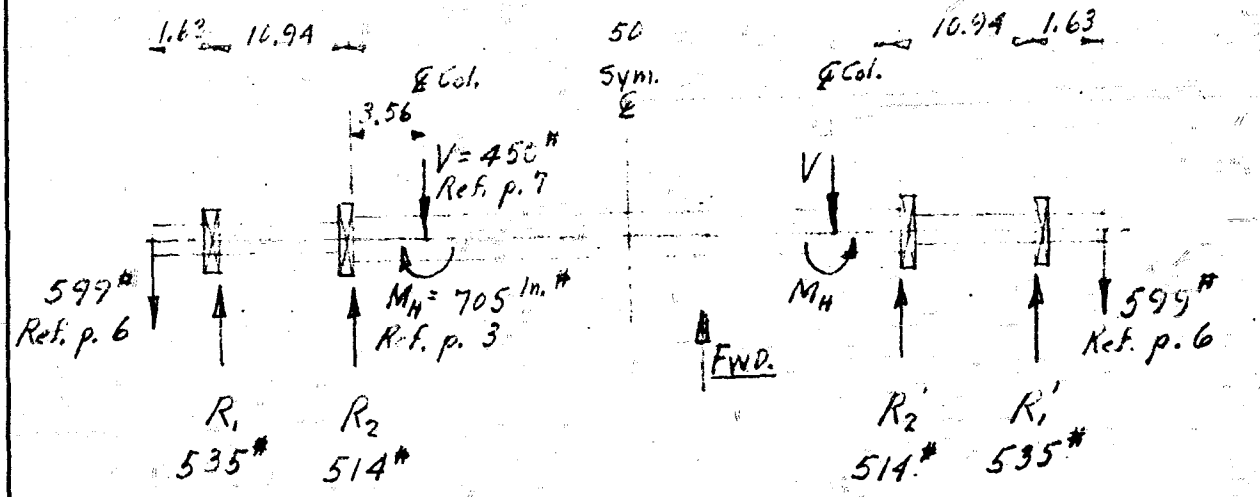
$$R_{2_R} = 0$$

$$R_1 = R_{1_L} + R_{1_R} = 298 + 384 = 682^{\#} \text{ (Up)}$$

$$R_2 = R_{2_L} + R_{2_R} = 384 + 0 = 384^{\#} \text{ (Dwn.)}$$



TORQUE TUBE LOADING DIAGRAM IN HORIZONTAL PLANE



$M_1 = -599(1.63) = -975$ in.#

$M_2 = M_3 = M_2'$

$L_1 = L_3 = 10.94$

$L_2 = 50$ $\quad a = 3.56 \quad b = 46.44$

$I_1 = I_3 = .3322$ in.^{4} $\quad (E_s = 29 \times 10^6)$ $\quad \left\{ E_s/E_a = 2.76 \right.$

$I_2 = 1.0349$ in.^{4} $\quad (E_a = 10.5 \times 10^6)$

$$\frac{M_1 L_1}{2.76\, I_1} + \frac{2 M_2 L_1}{2.76\, I_1} + \frac{2 M_2 L_2}{I_2} + \frac{M_3 L_2}{I_2}$$

$$= \frac{M_H}{I_2}\left[\left(\frac{3a^2}{L_2} - L_2\right) - \left(\frac{3b^2}{L_2} - L_2\right)\right] - \frac{V}{I_2 L_2}\left[b(L_2^2 - b^2) + a(L_2^2 - a^2)\right]$$

$$\frac{-975(10.94)}{2.76(.3322)} + \frac{2(10.94)M_2}{2.76(.3322)} + \frac{2(50)M_2}{1.0349} + \frac{50\, M_2}{1.0349}$$

$$= \frac{705}{1.0349}\left[\left(\frac{3(3.56)^2}{50} - 50\right) - \left(\frac{3(46.44)^2}{50} - 50\right)\right] - \frac{450}{1.0349(50)}\left[46.44(50^2 - 46.44^2)\right.$$

$+ 3.56(50^2 - 3.56^2)\Big]$

$-11,6[illegible] + 23.8 M_2 + 96.6 M_2 + 48.3 M_2$

$= 681[(-49.2) - (79.2)] - 8.7[16,000 + 7,860]$

$168.7 M_2 = -283,680$

$M_2 = -1,680$ In.#

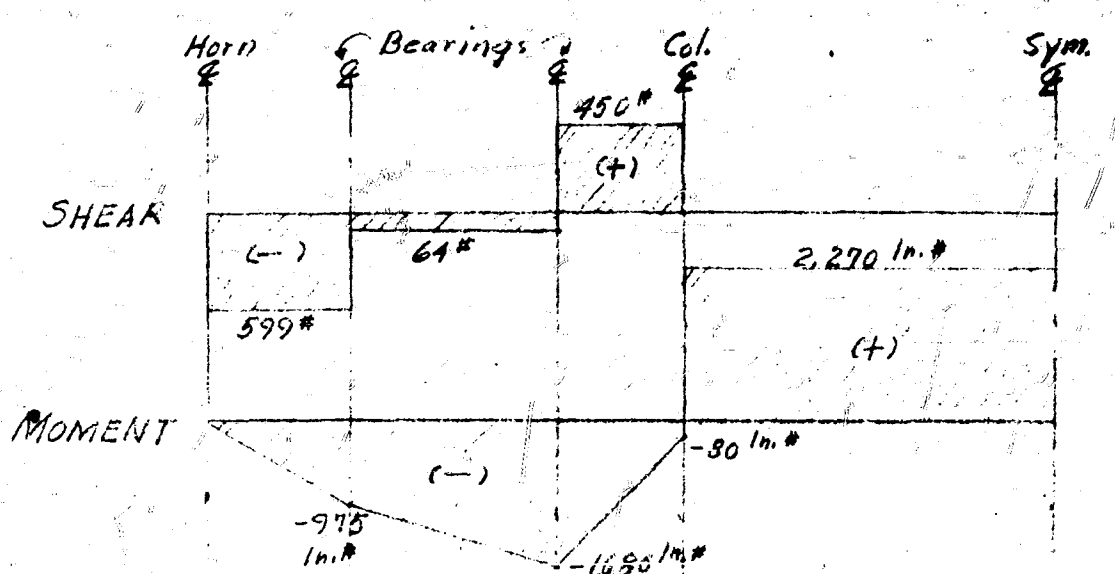
$R_{1L} = 599^{\#}$ (Fwd.)

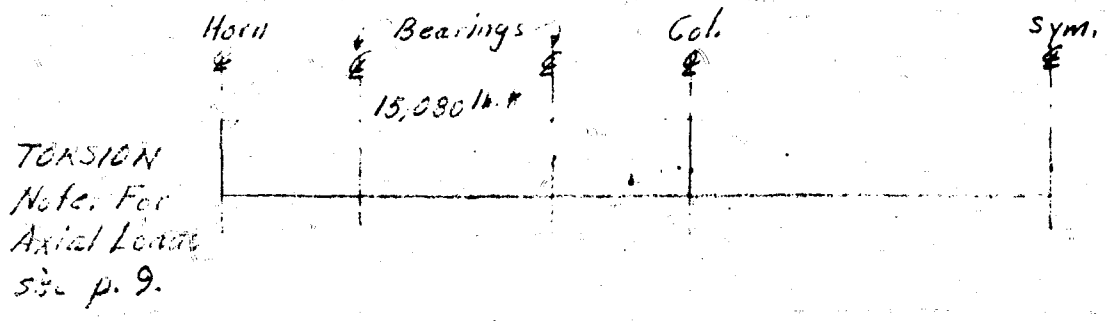
$R_{1R} = R_{2L} = (1,680 - 975) \div 10.94 = 64^{\#}$ (R_{1R} Aft $- R_{2L}$ Fwd.)

$R_{2R} = 450^{\#}$ (Fwd.)

$R_1 = R_{1L} + R_{1R} = 599 - 64 = 535^{\#}$ (Fwd.)

$R_2 = R_{2L} + R_{2R} = 64 + 450 = 514^{\#}$ (Fwd.)





TORSION
Note: For Axial Loads see p. 9.

OUTBOARD TORQUE TUBE (2 1/4 x .093 STEEL)

The critical bending moment occurs at the inboard support bearing.

$$\text{Resultant Moment} = \sqrt{1{,}690^2 + 3{,}742^2} = 4{,}100 \text{ in.\#}$$

$$T = 15{,}080 \text{ in.\#}$$

Tube Properties

$$I = .3322 \qquad Y = \frac{D}{2} = 1.125$$

$$A_{(enclosed)} = \pi\, 2.167^2/4 = 3.70 \text{ sq. in.}$$

$$f_{s_T} = \frac{T}{2At} = \frac{15{,}080}{2(3.7)(.093)} = 24{,}500 \text{ \#/in.}^2$$

$$f_b = \frac{MY}{I} = \frac{4{,}100\,(1.125)}{.3322} = 13{,}900 \text{ \#/in.}^2$$

$$f_{s_{max.}} = \sqrt{24{,}500^2 + \left(\frac{13{,}900}{2}\right)^2} = 25{,}450 \text{ \#/in.}^2$$

$$f_{n_{max.}} = \frac{13{,}900}{2} + 25{,}450 = 32{,}400 \text{ \#/in.}^2$$

For $D/t = 2.25/.093 = 27.2$ and H.T. 180,000 #/in.^{2}

Bending Modulus of Rupture = 202,000 #/in.^{2} (ANC-5)

Torsional Modulus of Rupture = 110,000 #/in.² (ANC-5)

$$K_B = \frac{32\,400}{202,000} = .15$$

$$K_T = \frac{25,450}{110,000} = .231$$

$$M.S. = \frac{1}{\sqrt{K_B^2 + K_T^2}} - 1$$

$$= \frac{1}{\sqrt{.15^2 + .231^2}} - 1 = \boxed{+2.61}$$

The critical normal shear occurs just outboard of the outboard support bearing. This shear, on a VQ/I basis, will be combined with the torsional shear, at the N.A. of the tube.

f_{S_T} = 24,500 #/in.² (Ref. p. 12)

Tube Properties: O.D. = 2.25 I.D. = 2.167

$$\bar{y}_{(\frac{1}{2}\text{ tube})} = \frac{4(1.125^3 - 1.084^3)}{3\pi(1.125^2 - 1.084^2)} = .612$$

$$Q_{(\frac{1}{2}\text{ tubes})} = \frac{A\bar{y}}{2} = \frac{.5651(.612)}{2} = .173 \text{ in.}^3$$

Resultant Normal Shear $= \sqrt{288^2 + 599^2} = 665^{\#}$

$$f_S = \frac{V_R Q}{2It} = \frac{665(.173)}{2(.332).083} = 2,090 \text{ \#/in.}^2$$

$f_{s_{max}} = f_s + f_{s_T} = 2,090 + 24,500 = 26,590$ #/in.²

$F_{su} = 105,000$ #/in.² (Ref. ANC-5)

$M.S. = \frac{105,000}{26,590} - 1 =$ | + 2.95

CENTER TORQUE TUBE (3½ x .065 - 24ST)

The critical bending moment on this tube occurs between the control columns.

Resultant Moment $= \sqrt{1,283^2 + 2,270^2} = 2,618$ in.#

Axial Load = 150# (T)

Tube Properties

$I = 1.0349$ in.⁴
$A = .7014$ in.²
$y = 1.75$ in.

$f_c = \frac{My}{I} - \frac{P}{A} = \frac{2,618(1.75)}{1.0349} - \frac{150}{.7014} = 4,216$ #/in.² (C)

$f_t = \frac{My}{I} + \frac{P}{A} = 4,430 + 214 = 4,634$ #/in.² (t)

M.S. = | + Large

ELEVATOR CABLE CONTROL HORN (36C018)

The critical bending moment occurs 2.19 in. below the ℄ of the torque tube. Cable load = 665# (Ref. p. 7)

$M = 665 \times 20.44 = 13,600$ in.#

CONTROL HORN

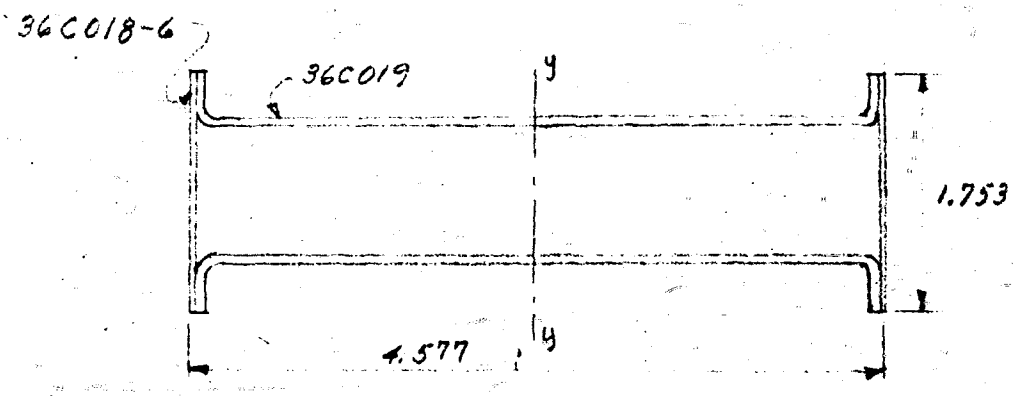


FIG. 4 - SECTION THRU HORN

$I_{y-y} = 1.20 \text{ in.}^4$

$$f_b = \frac{My}{I_y} = \frac{13,600\,(2.29)}{1.20} = 26,000 \text{ \#/in.}^2$$

$F_{ccr} = K_c E (t/b)^2$ (Ref. ANC-5 p. 1-32)

$E = 10.3 \times 10^6$ $K = 3.6$ (Ref. ANC-5 p. 1-33)

$t = .032$ $b = .625$

$$F_{ccr} = 3.6\,(10.3)\,10^6\,(.032/.625)^2 = 96,800 \text{ \#/in.}^2$$

$F_{cy} = 57,000$ \#/in.^{2} (For 24ST81 Sheet)

$$M.S. = \frac{57,000}{26,000} - 1 = \boxed{+1.19}$$

AILERON CONTROL SYSTEM

THE AILERON CONTROL SYSTEM OF THE XB-36 IS IDENTICAL TO THAT OF THE YB-36 & B-36A. SINCE THE LOADINGS ARE ALSO THE SAME, THE ANALYSIS FOR THIS REGION SHOULD BE REFERRED TO PAGES 73 THROUGH 96 OF FZS-36-150

ELEVATOR CONTROL SYSTEM

THE ELEVATOR CONTROL SYSTEM OF THE XB-36 IS IDENTICAL TO THAT OF THE YB-36 & B-36A. SINCE THE LOADINGS ARE ALSO THE SAME, THE ANALYSIS FOR THIS REGION SHOULD BE REFERRED TO PAGES 37 THROUGH 47 OF FZS-36-150.

ELEVATOR TRIM TAB SYSTEM

THE ELEVATOR TRIM TAB SYSTEM FOR THE XB-36 IS IDENTICAL TO THE TRIM TAB SYSTEM FOR THE YB-36 AND B-36A EXCEPT FOR THE TORQUE TUBES AND THE SPROCKETS IN THE PEDESTAL. THERE ARE THREE TUBES INSTEAD OF TWO. THE SMALL SPROCKETS ARE THE SAME SIZE. THE DIAMETER OF THE LARGE SPROCKET IS 2.630 IN. (REF. 36C2230)

LOAD IN CHAIN = 620 # ULT. (REF. FZS-36-150, P. 52)

LOAD IN CABLE $= \dfrac{620 \times 1.315}{1.21} = 675$ # ULT.

TORSION IN LOWER SHAFT = 675 X 1.21 = 816 "#

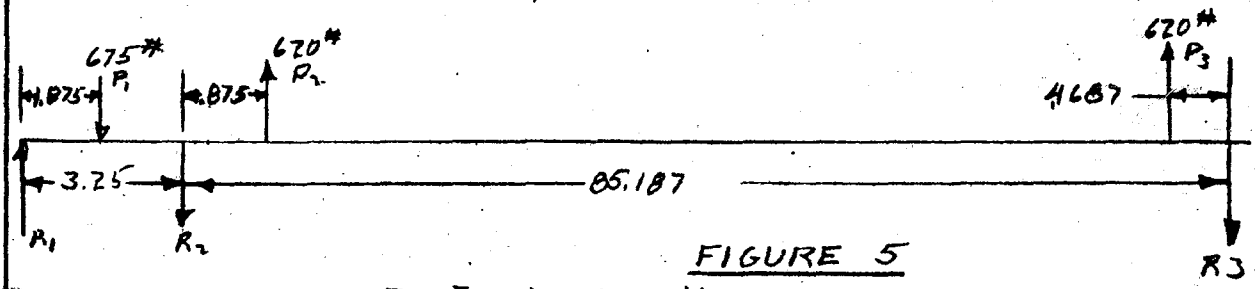


FIGURE 5

$M_1L_1 = 0$, $M_3L_2 = 0$ $I_1 = I_2$, $Y_A = Y_B = Y_C$.

$$M_1L_1 + 2M_2L_1 + 2M_2L_2 + M_3L_2 = K_1 + K_2 + \frac{6E}{L_1}(Y_A - Y_B) + \frac{6E}{L_2}(Y_C - Y_B)$$

$$2M_2(L_1 + L_2) = \frac{P_1A_1(L_1^2 - A_1^2)}{L_1} + \frac{P_2B_2(L_2^2 - B_2^2)}{L_2} + \frac{P_3B_3(L_2^2 - B_3^2)}{L_2}$$

$$2M_2(88.43 = \frac{-675 \times 1.875(\overline{3.25}^2 - \overline{1.875}^2)}{3.25} + \frac{620 \times 84.72(\overline{85.18}^2 - \overline{84.31}^2)}{85.18} + \frac{620 \times .4687(\overline{85.18}^2 - .4687^2)}{85.18}$$

$$M_2 = \frac{120460}{176.86} = 680 \text{ IN. LBS.}$$

ELEVATOR TRIM TAB SYSTEM

LOWER TUBE

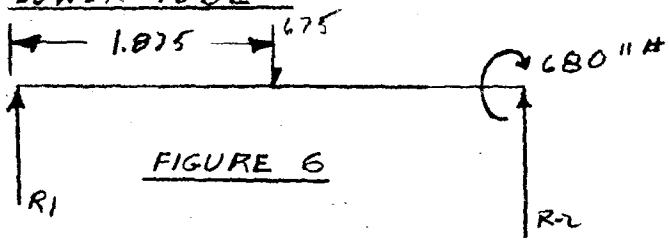


FIGURE 6

$675 \times 1.375 - 680 - 3.25 R_1 = 0$

$R_1 = 76.7$ LBS. UP.

$$R_2 = \frac{675 \times 1.875 + 680}{3.25}$$

$R_2 = 599$ LBS. UP.

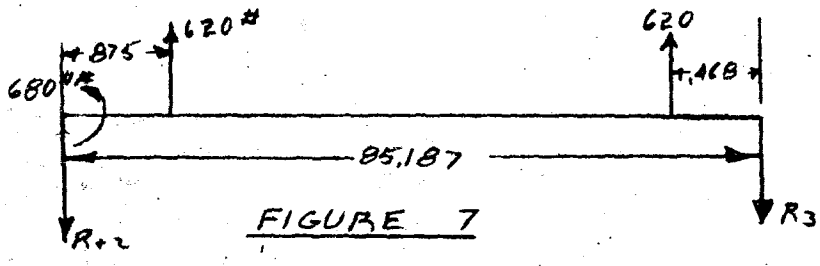


FIGURE 7

$$R_{+2} = \frac{620(84.31 - .468) - 680}{85.187}$$

$R_{+2} = 608$ LBS DOWN.

$$R_3 = \frac{680 + 620(.875 + 84.72)}{85.187}$$

$R_3 = 632$ DOWN.

THE LOWER TUBE CONSISTS OF A 7/8 O.D X .049 24ST TUBE BETWEEN THE SPROCKETS (36C22234) WITH A STEEL TUBE (36C22228-17 ATTACHED TO THE R.H. END AND TWO STEEL TUBES (36C22280 AND 36C22228-16) ATTACHED TO THE L.H. END.

ELEVATOR TRIM TAB SYSTEM

LOWER TUBE

THE TUBE (36C22280) WILL TAKE ALL OF THE TORSION DUE TO THE SPROCKETS. THIS TUBE AND 36C22280-16 WILL TAKE ALL OF THE BENDING.

BENDING AND TORSION ON STEEL TUBES

$I = .012$, $y = .375$, $J = .024$, $D/t = .75/.114 = 6.57$

$L/D = .875/.750 = 1.17$ $F_{tu} = 95{,}000$ P.S.I.

$B.M. = 599 \times 1.875 = 1122$ IN. LBS.

$$f_b = \frac{1122 \times .375}{.012} = 35{,}000 \text{ P.S.I}$$

$$f_s = \frac{Tc}{J} = \frac{816 \times .375}{.024} = 12{,}750 \text{ P.S.I.}$$

$F_b = 129{,}000$ P.S.I. (REF. ANC-5, FIG. 4-20)

$F_{sy} = .86 \times 95{,}000 = 81{,}600$ P.S.I. (REF. ANC-5, FIG. 4-22)

$$R_B = \frac{35{,}000}{129{,}000} = .272 \quad R_S = \frac{12{,}750}{81{,}600} = .156$$

$$\underline{M.S.} = \frac{1}{.272 + .156} - 1 = \underline{+1.33}$$

BENDING AND TORSION ON ALUMINUM TUBE

$O.D = .875$, $t = .049$ $I = .011$, $D/t = 17.9$, $J = .022$

$B.M. = 290$ IN. LBS.

$$f_b = \frac{290 \times .4375}{.011} = 11{,}500 \text{ P.S.I.}$$

ELEVATOR TRIM TAB SYSTEM

$$f_s = \frac{Tc}{J} = \frac{816 \times 4375}{.022} = 16{,}200 \text{ P.S.I.}$$

$F_b = 68{,}000$ P.S.I. (REF. ANC-5, FIG. 5-8)

$F_{ST} = 33{,}000$ P.S.I. (REF. ANC-5, FIG. 5-9)

$$R_b = \frac{11{,}500}{68{,}000} = .17 \quad R_s = \frac{16200}{33{,}000} = .492$$

$$\underline{M.S.} = \frac{1}{.17 + .492} - 1 = \underline{+.51}$$

Rudder Controls and Brake Pedal System

The rudder control and brake pedal system on the XB-36 is similar to that of the YB-36 and B-36A. By comparison of Figure R-1, Report Number FZS-36-150 and Figure B of this report, it can be seen that a cable runaround system is used on the XB-36, while a push and pull bar replaces the runaround system on the YB-36 and B-36A. Also, a quadrant (36C040) is used on the XB-36 instead of the segment (36C4525) installed on the YB-36 and B-36A airplanes. Also A-frame rudder and brake pedal shaft supports are fabricated from drawn 24ST aluminum alloy and extruded angles. (36C067)

The rudder servo control system on the XB-36 airplane is also similar to that on the YB-36 and B-36A, except the rudder servo control quadrants (36C1746), the bellcranks (36C1721), and the torque tube (36C1723).

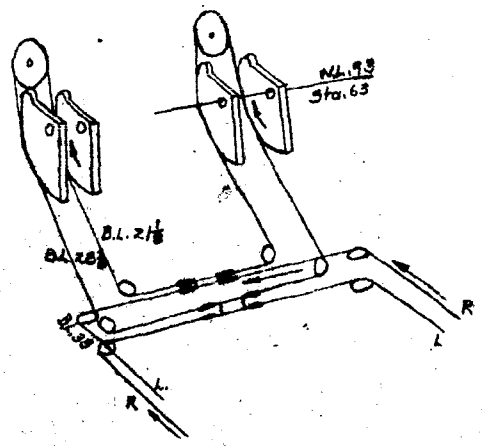


Figure 8

Diagram of Rudder Control System

Ref. 36C006

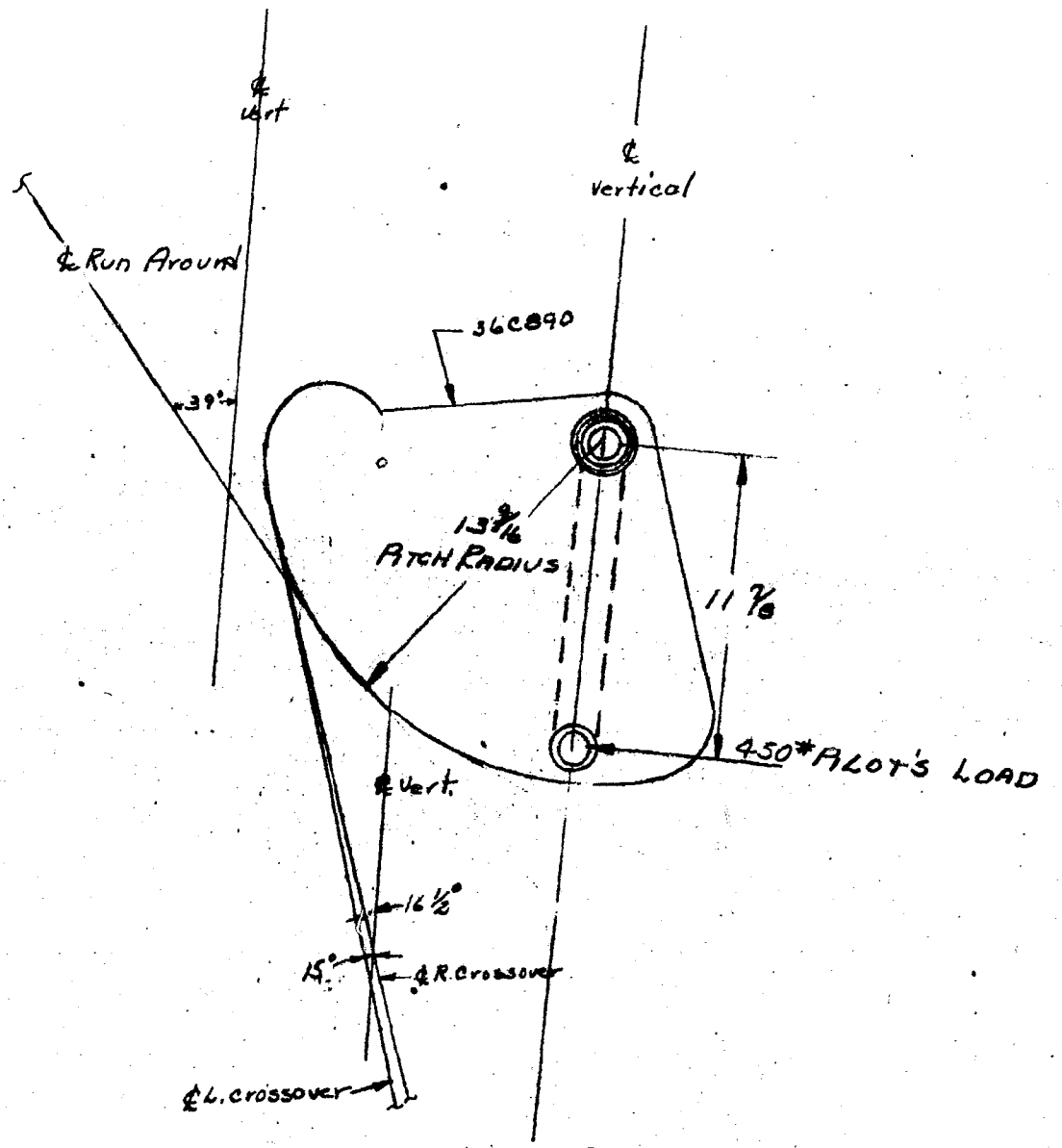


Figure 9
RUDDER PEDAL SEGMENT
NEUTRAL POSITION

Rudder and Brake Pedal System

Rudder Pedal Assembly (Ref. 36C006)

The pedal assembly consists of two pedals (Ref. 36C030) and segments (Ref. 36C040) mounted on a shaft (Ref. 36C076) which is supported by three A-frames (Ref. 36C067).

Figure 8 shows a sketch of the control system and Figure 9 shows the direction in which the cable loads act.

Load in the crossover cable

$$= \frac{450(11.875)}{13.563}$$

$$= 394^{\#}$$

Check .032-24ST ALC. web of quadrant for bearing due to AN25 bolt attaching cable to quadrant

$P = 394^{\#}$

$A = .313(.032) \times 2$

$= .02 \text{ in}^2$

$f_{br} = \frac{394}{.02}$

$= 19{,}700 \ \#/\text{in}^2$

$F_{br} = 114{,}000 \ \#/\text{in}^2$ (Structures Bulletin B-4)

$M.S. = \frac{114{,}000}{19{,}700} - 1 =$ +4.78

Resultant load applied to the rudder & brake pedal shaft

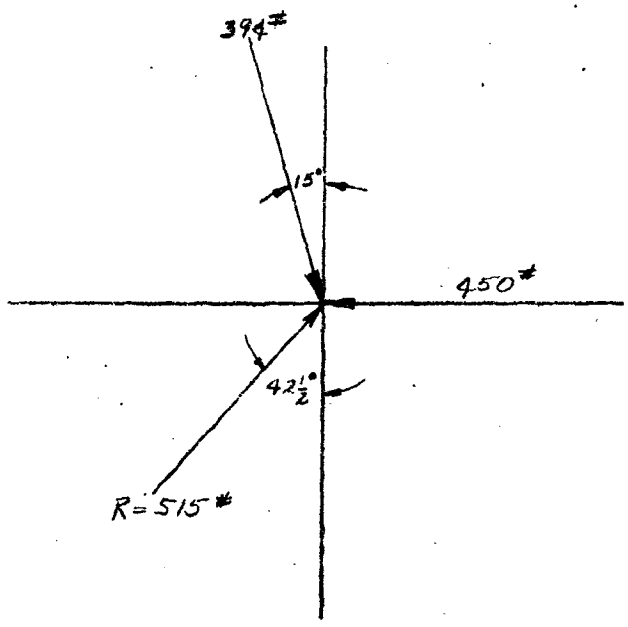


Figure 10

$$\Sigma F_H = 0 = 450 - 394 \sin 15^\circ$$
$$= 450 - 394(.259)$$
$$= 450 - 102$$
$$= 348^{\#}$$

$$\Sigma F_V = 0 = 394 \cos 15^\circ$$
$$= 394(.965)$$
$$= 380^{\#}$$

$$R = \sqrt{(348)^2 + (380)^2}$$
$$= 515^{\#} \text{ at angle} = \tan^{-1}\frac{348}{380}$$
$$= 42\tfrac{1}{2}^\circ \text{ measured from vertical}$$

This resultant load is considerably smaller than the one applied to the rudder pedal control shaft on the YB-36 and B-36A airplanes and

PREPARED BY Tom
CHECKED BY Thompson
REVISED BY

Consolidated Vultee Aircraft Corporation
FORT WORTH DIVISION
FORT WORTH, TEXAS

REPORT NO. FZS-31-250
MODEL XB-36
DATE 5/15/47

Rudder and Brake Pedal System

since the XB-36 shaft is shorter, it is unnecessary to check the XB-36 shaft (36C076) for failure.

Rudder and Brake Pedal System

Figure 11 shows the applied loads to the shaft. For significance of numbered points on shaft see Figure R-4A of the Rudder Analysis. (Report No. FZS-36-150)

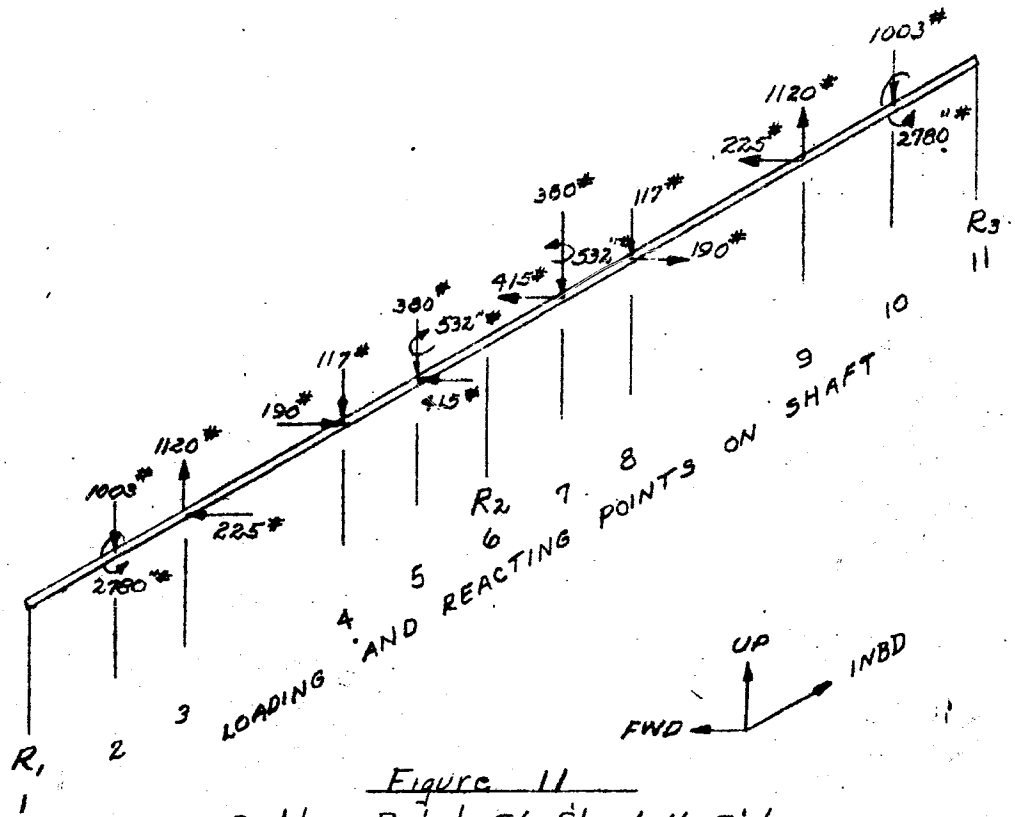


Figure 11
Rudder Pedal Shaft - L.H. Side
Ref. 36C006-21

By comparison of this figure with that of Report No. FZS-36-150, Figure B-5, it is seen that the loads applied to a slightly shorter rudder pedal shaft are the same except for a smaller vertical load on the pedal frame. Thus the YB-36 and B-36A rudder pedal shaft loads will be conservative in checking the A-frame supports on the XB-36.

Rudder and Brake Pedal System

"A"-Frame - Pilot's & Co-Pilot's Rudder Pedal (36C067)

The rudder pedals shaft is supported by three A-frames (36C067). The frames are critical for brake control loads. The frames are made from drawn 24ST ALCLAD and extruded angles (36C067). The applied loads are the same as those shown on Figure B-14, p.153, Report No. FZS-36-150.

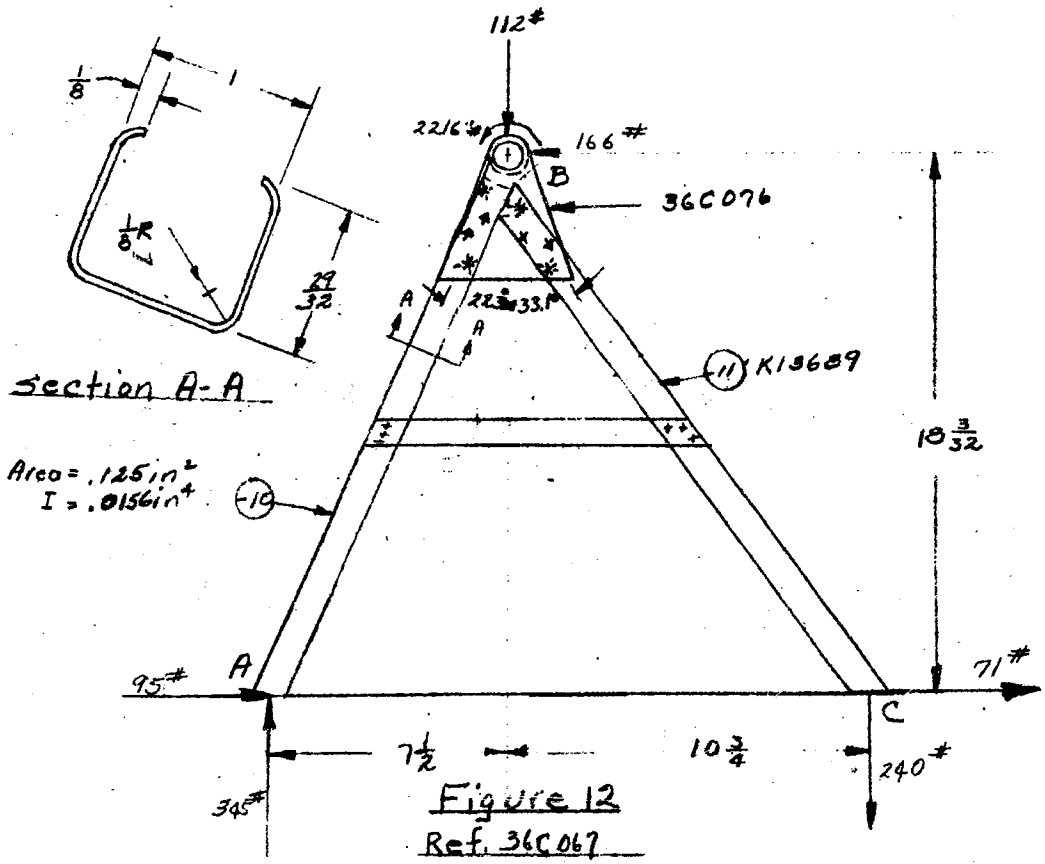


Figure 12
Ref. 36C067

Assume A-Frame to be pin jointed and the torque (2216#) to be reacted as couple forces at A & C.

$$\text{Couple forces} = \frac{2216}{18.25} = 121^{\#}$$

Rudder and Brake Pedal System

Check -10 (Ref page 28) for column failure

$$f_c = \frac{P}{A} + \frac{My}{I}$$

where $P = 295^{\#}$ (Ref. page 28)
$A = .125 \text{ in}^2$ (Ref. page 28)
$M = 121(\sin 22.3)(19.75)$
$= 906 \text{ in-}\#$
$y = .54 \text{ in.}$ (Ref. page 28)
$I = .0154 \text{ in}^4$ (Ref. page 28)

$$f_c = \frac{295}{.125} + \frac{906(.54)}{.0154}$$

$$= 33,760 \ \#/\text{in}^2$$

$$\rho = \sqrt{I/A} = \sqrt{\frac{.0154}{.125}}$$

$$= .354 \text{ in.}$$

$$\frac{L}{\rho} = \frac{18.75}{.354} = 55.8'$$

$F_c \doteq 30,000 \ \#/\text{in}^2$ (C.V.A.C. #1)

$$M.S. = \frac{1}{\frac{2,360}{30,000} + \frac{33760}{65,000}} - 1 = \underline{+.67}$$

Check -11 (Ref. page 23) for tension

-11 is a standard section (K15689) (Ref. 360067)

$$f_t = \frac{P}{A} + \frac{My}{I}$$

where $P = 201^{\#}$
$A = .134 \text{ in}^2$
$M = 121(\sin 31.1^\circ)(20.9)$
$= 1310 \text{ in-}\#$

Rudder and Brake Pedal System

$Y = .4047 \text{ in.}$

$I_{y-y} = .022 \text{ in}^4.$

$$f_t = \frac{201}{.134} + \frac{1310(.4047)}{.022}$$

$$= 1500 + 24{,}100$$

$$= 25600 \ \#/\text{in}^2$$

$F_t = 65{,}000 \ \#/\text{in}^2$ (ANC-5)

$$M.S. = \frac{65{,}000}{25{,}600} - 1 = \underline{+1.54}$$

Rudder and Brake Pedal System

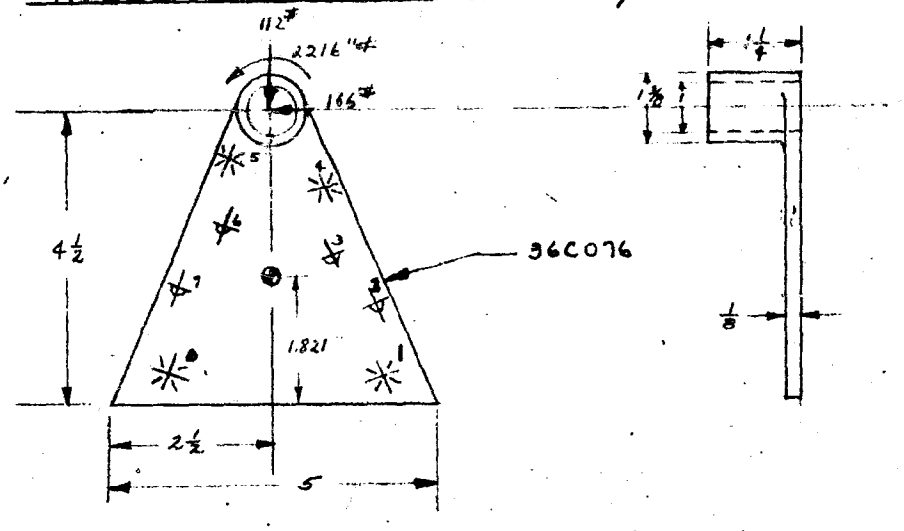


Figure 13 (Ref. Fig. 12)

Check rivets for shear

Rivets. A17ST Casting 24ST

$M = 2.679(166) + 2216$
$= 2661$ in.-#

$d_1 = 2.06$ in.
$K_1 = 1.44$
$\Sigma K = 9.76$
$\Sigma K d^2 = 25.33$ in.²

Rivet no. 1 & 8 are critical in shear.

$$P_{m_{max}} = \frac{2661(1.63)(1.44)}{25.33}$$
$= 247$#

$$P_{m_{max}} = \frac{2661(1.446)(1.44)}{25.33}$$
$= 219$#

$$P_1 = \frac{112(1.44)}{9.76}$$
$= 1.7$#

Rudder and Brake Pedal System

$$R = \sqrt{(247+17)^2 + (219)^2}$$

$$= \sqrt{(254)^2 + (219)^2}$$

$$= 336\#/\text{rivet}$$

Allowable load = 745 #/rivet (ANC-5)

$$M.S. = \frac{745}{336} - 1 = \underline{+1.22}$$

Check AN23 bolt bearing on hub of 36C2309 (Ref. 36C006)

$$\text{Mean Dia.} = \frac{1+1.375}{2} \quad \text{(Ref. p.31)}$$

$$= 1.188 \text{ in.}$$

$$\text{Couple forces due to torque} = \frac{2216}{1.188}$$

$$= 1865\#$$

$$A_{br} = .188(.188) = .0354 \text{ in}^2$$

$$f_{br} = \frac{1865}{.0354} = 52{,}750 \#/\text{in}^2$$

$F_{br} = 83{,}000 \#/\text{in}^2$ for 24ST Aluminum alloy

$$M.S. = \frac{83000}{52750} - 1 = \underline{+.57}$$

Analysis of Rudder Servo Control System

Auto pilot load = 376# (Ref. page 12, Report No. FZS-36-150)
Pilot load = 394# (Ref. page 25)
Total = 770#

The upper rudder quadrant and the lower rudder quadrant are identical (Ref. 36C1723). Assume for unequal distribution of the load that 60% of the load goes into one quadrant and 40% into the other.

Max. load on quadrant = 770(.60) = 462#

Check lug on quadrant for tearout (Ref. 36C1746)

$P = 462^{\#}$

$A = 2(2)(.5 - .312)(.188)$

$= .1412 \text{ in}^2$

$f_s = \frac{462}{.1412}$

$= 3270 \ \#/\text{in}^2$

$F_s = 16{,}000 \ \#/\text{in}^2$ (Structures Bulletin B-4)

$M.S. = \frac{16000}{3270} - 1 =$ **+3.9**

Check bearing of bolt on lug

$P = 462^{\#}$

$A_{br} = .312(.375)$

$= .117 \text{ in}^2$

$f_{br} = \frac{462}{.117}$

$= 3950 \ \#/\text{in}^2$

Analysis of Rudder Servo Control System (Cont.)

$F_{br} = 45000\ \#/in^2$ (Structures Bulletin B-4)

$M.S. = \frac{45000}{3950} - 1 =$ **+10.4**

Bending on lug in not critical because of the short moment arm.

Bellcrank Analysis

The object now is to take loads from the quadrants and beam them on torque tube (36C1723) to find loads applied to the two bell cranks. (36C1721)

Resultant load on bellcrank (36C1721) = 976#.

Moment about center of rotation of bellcrank = 2.75(976)
= 2685 in-#

Load on one arm of bellcrank = $\frac{2685}{4.453}$
= 603#

Load in cable from bellcrank to rudder trim tab = 603#

Check tearout of bolt thru lug of arm (36C1721)

$P = 603\#$

$A = 2(2)(.5-.125)(.192)$
$= .288\ in^2$

$f_s = \frac{603}{.288}$
$= 2090\ \#/in^2$

$F_s = 16000\ \#/in^2$ (Structures Bulletin B-4)

$M.S. = \frac{16000}{2090} - 1 =$ **+6.65**

Analysis of Servo Control System (Cont.)

Check for bearing of bolt on lug

$P = 603^{\#}$

$A = 2(.25)(.192)$

$= .096 \text{ in}^2$

$f_{br} = \frac{603}{.096}$

$= 6300 \ \#/\text{in}^2$

$F_{br} = 45000 \ \#/\text{in}^2$ (Structures Bulletin B-4)

$M.S. = \frac{45000}{6300} - 1 =$ **+6.15**

Check section of bellcrank for bending

Section is located 2.9 in from center of 2 holes in end of arm (Ref. 36C 1721)

$A = .58 \text{ in}^2$

$I = .366 \text{ in}^4$

$f_t = \frac{P}{A} + \frac{MC}{I}$

$= \frac{603}{.58} + \frac{2.9(603)(1.06)}{.366}$

$= 1040 + 5070$

$= 6110 \ \#/\text{in}^2$

$F_t = 15000 \ \#/\text{in}^2$ (Structures Bulletin B-4)

$M.S. = \frac{15000}{6110} - 1 =$ **+1.46**

Analysis of Servo Control System (Cont.)

Check torque tube for bending (36C1642)

$M = 18.163\ (640)$
$= 11,600$ in-#
$Y = 1$ in.
$I = .167$ in.^{4} (ANC-5)

$$f_b = \frac{MY}{I}$$
$$= \frac{11600(1)}{.167}$$
$$= 69500\ \#/in^2$$

Bending Modulus $= 72,000\ \#/in^2$

$$M.S. = \frac{72000}{69500} - 1 = +.035$$

Analysis of Rudder Trim Tab System

The rudder trim tab control system on the XB-36 is identical to the rudder trim tab control system of the YB-36 and B-36A, except for a portion of the system in the pilot's pedestal and the co-pilot's pedestal. In the case of the XB-36, the pilot's and co-pilot's contols in the pedestals are connected by a chain, whereas on the YB-36 and B-36A, there is only one rudder trim tab control system for the pilot and co-pilot.

Check Diamond Roller Chain #89 for tension

Torque applied by pilot = 150 in-#(ult.) (Ref. p. 127 Report No. F25-36-150)

Pitch radius of sproket = .878 in. (Ref. 36C212)

Load applied to chain = $\frac{150}{.878}$ = 171#

Allowable tens. load = 700# (Diamond Catalogue)

M.S. = $\frac{700}{171} - 1$ = **+3.1**

Check bearing on tube due to pin thru sproket

Tube = 3/4 00 x .065 24ST Al. Alloy

Pin dia = .188 in.

Load = $\frac{150}{.75}$ = 200#

$A_{br} = 2(.065)(.188) = .0244 in^2$

$f_{br} = \frac{200}{.0244} = 8180 \#/in^2$

F_{br} = 133,000 (Structures Bulletin B-1)

M.S. = $\frac{133,000}{8180} - 1$ = **+15.3**

— SUMMARY —

MINIMUM MARGINS OF SAFETY

	M.S.	Pg.
I. CONTROL COLUMN		
A. ELEVATOR SYSTEM IN CONTROL COLUMN		
COLUMN	+.10	4
BASE CASTING	+1.19	5
TORQUE TUBE	+2.61	13
HORN	+1.19	15
II. ELEVATOR TRIM TAB SYSTEM		
LOWER TUBE	+.51	20
III. RUDDER CONTROLS AND BRAKE PEDAL SYSTEM		
SEGMENTS	+4.78	24
"A" FRAME	+.57	32
IV. RUDDER SERVO CONTROL SYSTEM		
QUADRANT	+3.9	33
BELLCRANK	+1.46	35
TORQUE TUBE	+.035	36
V. RUDDER TRIM TAB SYSTEM		
CHAIN	+3.1	37

NOTE: REFER TO FZS-36-150 FOR MINIMUM MARGINS OF SAFETY OF PARTS NOT ANALYZED IN THIS REPORT.

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ABSTRACT:

Analysis is made of the control system of the XB-36 bomber. This analysis is an addendum to the stress analysis previously given for the YB-36 and B-36A bombers. Attention has been given to the control column, aileron controls, elevator controls, elevator trim tab system, rudder controls and brake pedal system, rudder control system and rudder trim tab system. A summary of the margins of safety is included.

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