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Calculations of Motions and Loads Resulting From Gust Disturbances Acting Upon Aircraft in Coupled Flight

Prepared in Connection with

Phase I of Air Force Project MX-1016

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INTRODUCTION

This report presents the results of step-by-step solutions of the equations of motion derived in Reference 2 for the two forms of attachment under consideration.

The first method, single-joint attachment, contains three degrees of freedom, namely, a motion of the bomber accompanied by a roll and a pitch of the fighter relative to the bomber. The second method, two-joint attachment, prevents pitching motion of the fighter relative to the bomber, thereby removing one degree of freedom and simplifying the amount of labor required for solution of the equations.

From the resultant oscillations so determined. the wing tip loads are calculated, using the equations given in Reference 2 , and the loads form the basis for the structural modifications necessary as shown in Reference 3 , and therefore, the feasibility of the coupling scheme.

SUMMARY

A. Single-Joint Attachment:

1. The resultant oscillations have been calculated for a symmetrical gust disturbance giving rise to pitching motion of the bomber and the fighter, and roll of the fighter relative to the bomber. Detailed calculations are shown in Table I and the time history of the acceleration, velocities, and displacements plotted in Figure 3 . The wing tip shear loads accompanying this disturbed motion is given in Figure 3.

2. Similar calculations have been made for an anti-symmetrical gust disturbance, causing roll of the bomber and rolling and pitching of the fighter relative to the bomber. The results of these calculations are shown in Table II , and plotted in Figure 4 The wing tip shear loads associated with this form of disturbance are plotted against time in Figure 4.

3. The yawing motion has been calculated for a side gust disturbance acting on the bomber tail, causing yawing of the combination, and yawing of the fighter relative to the bomber. Results are given in Table III, and the motion plotted in Figure 5 . Wing tip loads are plotted in Figure 5.

B. Two-Joint Attachment:

1. The resultant oscillations have been calculated for a symmetrical gust disturbance giving rise to pitching motion of the combination, and roll of the fighter relative to the bomber. Detailed calculations are shown in Table IV and the time history of the displacements, velocities, and accelerations plotted in Figure 6. The wing tip shear loads and torsional moments referred to the fighter center of gravity position that accompany this disturbed motion is given in Figure 6.

2. Similar calculations have been made for an anti-symmetrical gust disturbance, causing roll of the combination and roll of the fighter relative to the bomber. The results of this calculation is presented in Table V, and plotted in Figure 7. The wing tip shear loads, and torsional moment, referred to the fighter center of gravity position, associated with this form of disturbance are plotted against time in Figure 7.

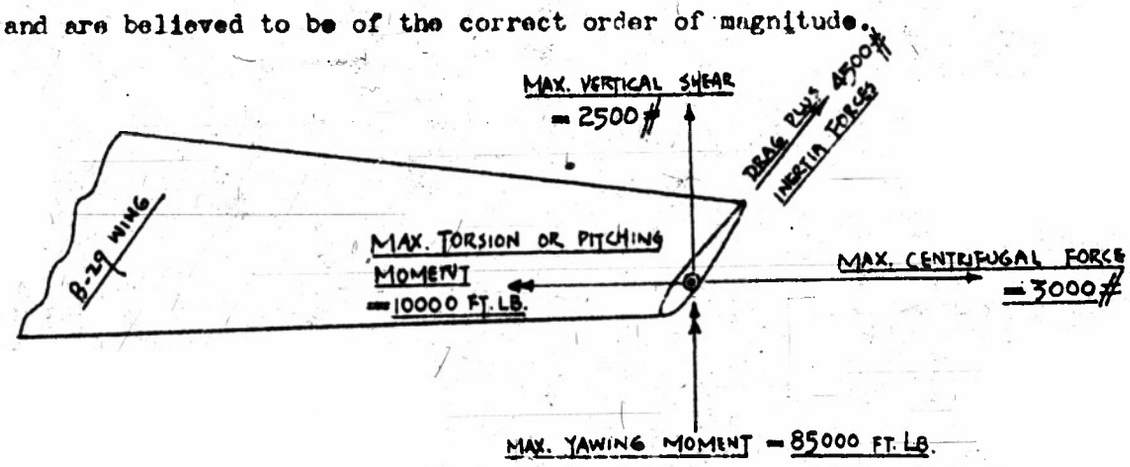
3. The yawing motion has been calculated for a side gust disturbance acting on the bomber tail, causing yawing of the combination only since the fighter is locked to the bomber for yaw. The results of an analytical solution are plotted in Figure 8 and the wing tip loads associated with this disturbance in Figure 9.

C. Tabulation of Maximum Wing Tip Loads

	Single-Joint Attachment		Two-Joint Attachment			
	Shear Load	Occuring Seconds After Start	Shear Load	Time	Torsional M	Time
Disturbance	#	Sec.	#	Sec.	ft.-lbs.	Sec.
Pitch	- 255	0.2	408	.18	- 2528	0.18
Roll	1854	2.0	612	.10	2710	2.94
Yaw	Spanwise 2000	0.25	Spanwise 36	1.00	--	--
	Chordwise 2200*	0.30	Chordwise 2986*	0.30	--	--

* Includes 1000# Drag Force of F-64 Airplane

From the results of the calculations made in this report, the following preliminary design loads are recommended for the purpose of stressing the wing structures. These design loads in round numbers are ultimate (Factor of 1.5 included) and are believed to be of the correct order of magnitude.



For single-joint attachment, the pitching moment is null and the yawing moment is reduced to two-thirds of the value shown above.

LIST OF SYMBOLS AND COEFFICIENTS

The standard definitions and symbols used in aerodynamics have been retained in this report. The XYZ axes with origin at the center of gravity of the bomber are a set of orthogonal axes fixed to the body of the bomber; the xyz axes with origin at the center of gravity of the fighter, fixed to the body of the fighters.

m = mass of the fighter airplane, slugs

I = Polar moments of inertia, slug - ft.^{2}

Subscripts with capital letters refer to the bomber
lower-case letters to the fighter

k = radius of gyration, ft.

R = Bomber wing - semi-span, ft.

r = Fighter wing - semi-span, ft.

a_i = Distance from flapping axis of the fighter to the lift vector of the fighter wing, ft.

A = Distance from bomber pitching axis (c.g.) to the fighter pitching axis (the joint hinge), ft.

c = Distance from fighter pitch axis (hinge) to c.g. of fighter, ft.

d = Distance from MACenter of the fighter wing to fighter c.g., ft.

l_t = tail length of the fighter, ft.

ϕ = roll angle of the bomber wing-plane from horizontal plane of the space axes, rad.

β = flap angle of the fighter wing-plane from the bomber wing-plane, rad. (relative coordinate)

θ = pitch angle of the bomber wing-plane from the horizontal plane of the space axes, rad.

α = pitch angle of the fighter wing-plane from the horizontal plane of the space axes, rad.

ψ = yaw angle of the bomber wing from the vertical plane XZ of the space axes, rad.

γ = relative yaw angle of the fighter from the bomber, rad.

ΣL_w = Summation of incremental fighter wing lift caused by disturbed motion, lbs.

ΣL_t = Summation of incremental fighter tail lifts caused by disturbed motion, lbs.

L_o = External rolling disturbance on combination, ft. lbs.

L_1 = External rolling disturbance on fighter about hinge, ft. lbs.

M_{α_1} = External pitching disturbance due to anti-symmetric gust on fighter, ft. lbs.

M_o^1 = External pitching disturbance on combination, ft. lbs.

M_o = External pitching disturbance on bomber, ft. lbs.

M_2 = External pitching disturbance due to symmetric gust on fighter, ft. lbs.

L_2 = External rolling disturbance on fighter, ft. lbs. occurring with pitch motion.

N_o = External yawing disturbance on combination, ft. lbs.

N_1 = External yawing disturbance on fighter, ft. lbs.

M_{F_α} = Fighter fuselage pitching moment due to angle of attack change, ft. lbs./rad.

S = Fighter wing-area, ft.^{2}

V = Level flight speed, ft./sec.

q = Dynamic pressure, lbs./sq. ft.

δ = Control deflection, rad. (NACA convention of signs)

k = Auto-pilot rate control ratio

K = Auto-pilot displacement control ratio

Subscripts:

w - wing t - tail

e - elevator f - flap

a - ailerons

Subscripts $\dot{\theta}$, $\ddot{\theta}$, β, $\dot{\beta}$, α, $\dot{\alpha}$ etc denote partial differntiation with respect to the variables, as $L_{\dot{\phi}}$, $L_{\dot{\beta}}$ etc., etc. $= \frac{\partial L}{\partial \dot{\phi}}$, $\frac{\partial L}{\partial \dot{\beta}}$ etc., etc.

Positive direction for angles, velocities and accelerations, and distances of the forces are indicated in Fig. 1 which shows schematically the two proposed methods of coupling considered.

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LIST OF REFERENCES

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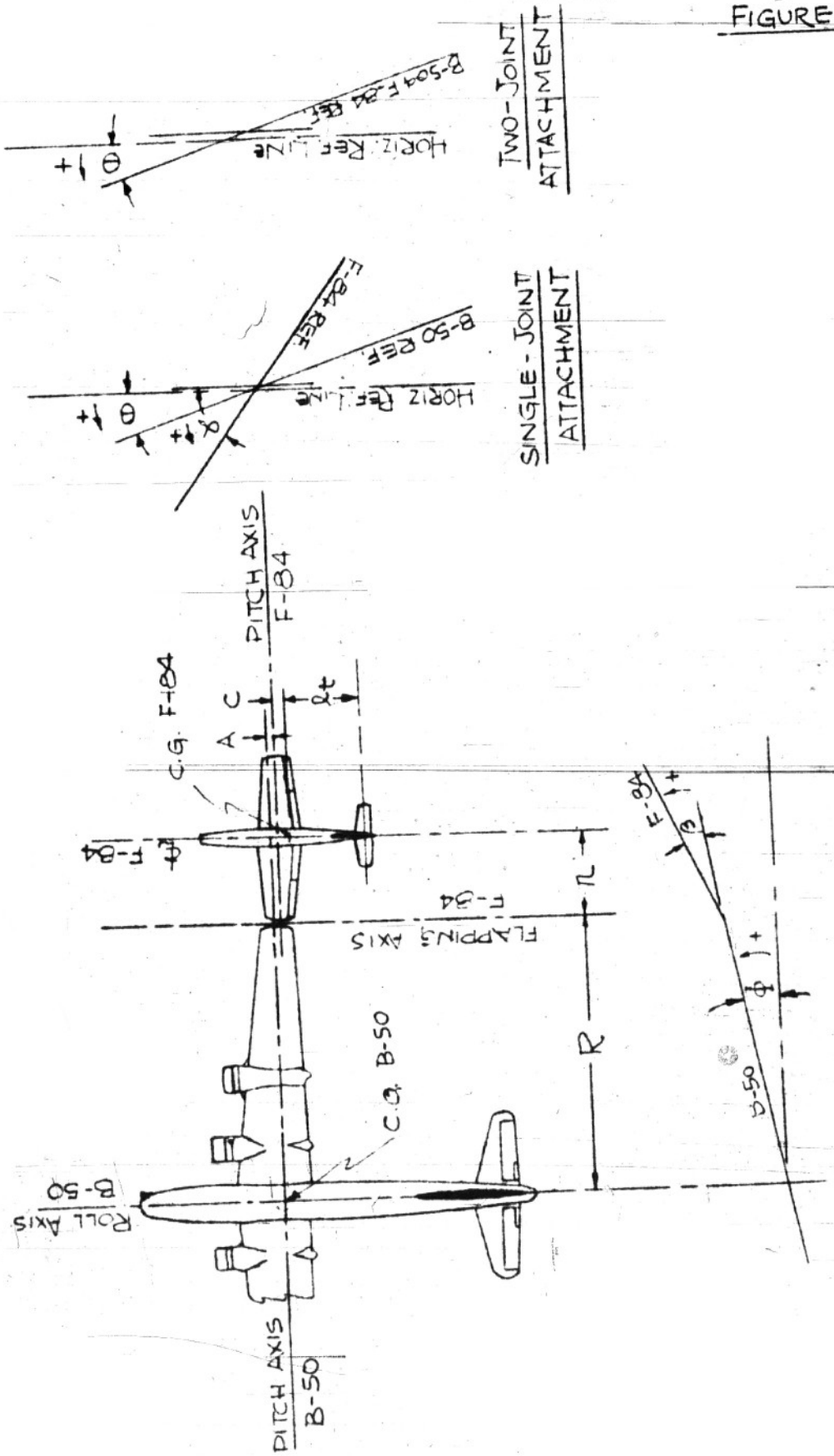
2. Lu, H.R., Helfman, S. and Cangelosi, J.: Theoretical Investigation of the Dynamic Stability of Bomber-Fighter Coupled Flight. Republic Aviation Corporation Report No. EDR-F-905-102, July 10, 1949

3. Stern, M.: Structural Investigation of F-84 and B-50 Wing-Tip to Wing-Tip Coupling Republic Aviation Corporation Report No. EDR-F905-1, July 15, 1949

FIGURE 1



PLANFORM - PROPOSED COUPLING SCHEMES

FIGURE 1

EQUATIONS OF MOTION

A. Single-Joint Attachment:

The derivation of the equations of motion is given in Reference 2 and the results repeated here for the values of the mass and geometric parameters as follows:

I_{y-y} = 1000×10^3 slugs-ft.^{2}

m = 453.4 slugs

A = 3.25 ft.

c = .5912 ft.

r = 18.3 ft.

k_x = 5.61 ft.

I_{y-y} = 18.59×10^3 slugs-ft.^{2}

d = .2217 ft.

I_{x-x} = 1712×10^3 slugs-ft.^{2}

$R + r$ = 90 ft.

I_{z-z} = 2712×10^3 slugs-ft.^{2}

k_z = 8.36 ft.

1. Pitch Disturbance

a) Pitch of B-50:

$$\left[-53.713\, D^2 - (36.377 - 61.412\, k_e)\, D + 61.412\, K_e\right]\beta$$
$$+ \left[1009.58\, D^2 + 713.37\, D + 108.30\right]\theta$$
$$+ \left[1.7423\, D^2 + 7.3613\, D + 8.332\right]\alpha = M_o \times 10^{-3} \quad \ldots\ldots (1)$$

b) Flap of F-84:

$$\left[165.49\,D^2 + (118.49 - 172.9\,k_e - 112.56\,k_a)\,D - (172.9\,K_e + 112.56\,K_a)\right]\beta$$

$$+ \left[-26.966\,D^2 - 417.24\right]\theta$$

$$+ \left[-4.9053\,D^2 - 20.725\,D - 2304\right]\alpha \quad = L_2 \times 10^{-3} \quad \ldots\ldots (2)$$

c) Pitch of F-84:

$$\left[-4.273\,D^2 - (15.389 - 176.97\,k_e)\,D + 176.97\,K_e\right]\beta$$

$$+ \left[.8712\,D^2 + 8.4246\right]\theta$$

$$+ \left[18.753\,D^2 + 21.213\,D + 128.79\right]\alpha \quad = M_2 \times 10^{-3} \quad \ldots\ldots (3)$$

2. Roll Disturbance

a) Roll of B-50:

$$\left[9.056\,D^2 + 8.065\,D\right]\phi$$

$$+ \left[1.516\,D^2 + (1.076 - 1.701\,k_e - .2251\,k_a)\,D - (1.701\,K_e + .2251\,K_a)\right]\beta$$

$$- \left[.2039\,D + 23.08\right]\alpha \quad = L_e \times 10^{-6} + 1.493\,(2\,\dot{\phi}\dot{\beta} + \beta^{\cdot 2}) \quad \ldots\ldots (4)$$

b) Flap of F-84:

$$\left[7.58\,D^2 + 4.503\,D\right]\phi + \left[1.655\,D^2 + (1.185 - 1.729\,k_e - 1.1256\,k_a) - (1.729\,K_e + 1.1256\,K_a)\right]\beta$$

$$- \left[.2071\,D + 23.037\right]\alpha \quad = L_1 \times 10^{-5} - 7.476\,\phi^{\cdot 2}\beta \quad \ldots\ldots (5)$$

c) Pitch of F-84:

$$[21.01\,D^2+74.9\,D]\,\phi$$
$$+\,[4.723\,D^2+(15.39-176.96\,k_e)D-176.96\,K_e]\,\beta$$
$$-\,[18.595\,D^2+21.21\,D+128.76]\,\alpha = M_1\times10^{-3}-24.12\,\phi^2\beta \quad (6)$$

3. Yaw Disturbance

a) Yaw of B-50:

$$[9.957\,D^2+0.532\,D+4.725]\,\psi$$
$$+\,[1.542\,D^2+0.0139\,D+0.2596]\,\gamma = N_0\times10^{-6} \quad (7)$$

b) Yaw of F-84 relative to B-50:

$$[0.768\,D^2+0.0696\,D+0.1298]\,\psi$$
$$+\,[0.1830\,D^2+0.00696\,D+0.1298]\,\gamma = N_1\times10^{-6} \quad (8)$$

B. <u>Two-Joint Attachment</u>

The equations of motion have been derived in Reference 2 for the case of two-joint attachment, and they are repeated below for the same values of mass and geometric parameters considered previously for the single-joint attachment.

1. Pitch Disturbance

a) Pitch of the combination:

$$[1.0506\,D^2 + .76283\,D + 2.1903]\,\theta - [.0623\,D^2 + .06696\,D - .4324\,K]\,\beta = M_o' \times 10^{-6} \quad \text{(9)}$$

b) Flap of the F-84:

$$[1.6571\,D^2 + 1.1841\,D - 10.93\,K]\,\beta - [.3191\,D^2 + .2059\,D + 27.13]\,\theta = L_2 \times 10^{-5} \quad \text{(10)}$$

2. Roll Disturbance

a) Roll of the B-50:

$$[9.093\,D^2 + 7.423\,D]\,\phi + [1.524\,D^2 + .94574\,D - 10.752\,K]\,\beta = L_o \times 10^{-6} + 1.495\,(2\phi\beta + \beta^2)\,\beta \quad \text{(11)}$$

b) Flap of the F-84:

$$[7.576\,D^2 + 4.353\,D]\,\phi + [1.657\,D^2 + 1.184\,D - 10.72\,K]\,\beta = L_1 \times 10^{-5} - 7.476\,\phi^2\beta \quad \text{(12)}$$

3. Yaw Disturbance

a) Yaw of the combination:

$$[10.12\,D^2 + .532\,D + 4.725]\,\psi = N_2 \times 10^{-6} \quad \text{(13)}$$

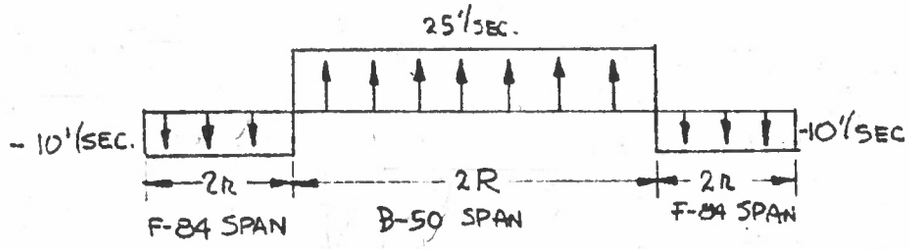
GUST DISTURBANCES

The equations of motion of the two proposed coupling schemes are given in terms of the external disturbing moments, M_θ, L_o, L_1, etc. (Eq. 1 - 13). These external disturbing moments are manifested primarily in two ways; through abrupt or pre-set deflection of the various control surfaces, or through atmospheric gust conditions.

For the numerical calculations performed in this report, it is assumed that the external disturbing moments are functions of various gusts of different intensity and direction. Subsequent calculations will show the effect of various control surface deflection histories upon the resultant oscillations and loads.

A. Pitch Motion

The type of gust assumed for the case of pitch motion is shown in the following sketch:



where the maximum value of the up gust (25'/sec.) is constant along the B-50 span, and the maximum value of the down gust (10'/sec.) is constant along the 2-F-84 wing spans.

The form of the gust assumed is given by the equation

$$\bar{X} = e^{-4.75t}(1-e^{-.5t})$$

and is shown plotted in Figure 2 . The maximum value of $\bar{X}$ is .0368 and occurs at t = 0.2 sec. Therefore, the gust on the bomber is

$$v_{B-50} = \frac{25}{.0368} e^{-4.75t}(1-e^{-.5t}) = 679\,\bar{X} \text{ Ft./sec.}$$

The gust on the fighter is

$$v_{F-84} = -\frac{10}{.0368}\bar{X} = -272\,\bar{X} \text{ FT./SEC.}$$

The corresponding increase in angle of attack of the B-50 and the F-84 is:

$$\Delta\alpha_{B-50} = \frac{v}{V} = \frac{679\,\bar{X}}{440} = 1.542\,\bar{X}$$

$$\Delta\alpha_{F-84} = \frac{v}{V} = -\frac{272}{440}\bar{X} = -.617\,\bar{X}$$

The disturbance moments are:

Combination Pitch (Two-Joint):

$$M_0' = \left(\frac{\partial M}{\partial \alpha}\right)_{B-50}\Delta\alpha_{B-50} + \left(\frac{\partial M}{\partial \alpha}\right)_{F-84}\Delta\alpha_{F-84}$$

$$M_0' = \left[-.93478\times10^{6}\times1.542 + (-.05296\times10^{-6})\times(-.617)\right]\bar{X}$$

(pg. , Ref. 2.)

$$M_0' = -1.3761\times10^{6}\,\bar{X} \text{ FT-LBS.}$$

Bomber Pitch (Single-Joint):

$$M_0 = \left(\frac{\partial M}{\partial \alpha}\right)_{B-50}\Delta\alpha_{B-50}$$

$$M_0 = -1.4414\times10^{6}\,\bar{X} \text{ FT.-LBS.}$$

Fighter Pitch (Single-Joint):

$$M_2 = q S c \frac{\partial C_m}{\partial C_L} \frac{dC_L}{d\alpha} \Delta\alpha_{F-84}$$

$$M_2 = (103.5)(260)(7.39)(-.06)(5.286)(-.617\,X)$$

$$M_2 = 38.82 \times 10^3\, X \text{ FT-LBS.}$$

Fighter-Flapping (Single-Joint):

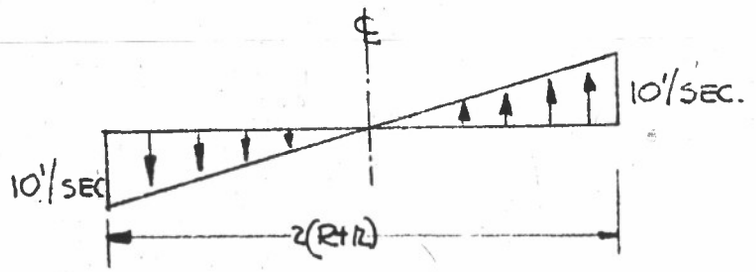
$$L_2 = \left(\frac{dC_L}{d\alpha}\right)_{F-84} q S\, Q_w \cdot \Delta\alpha_{F-84}$$

$$L_2 = (5.286)(103.5)(260)(17.95)(-.617\,X)$$

$$L_2 = -15.73 \times 10^5\, X \text{ FT.-LBS.}$$

B. **Roll Motion**

The roll disturbance is assumed to be caused by an anti-symmetrical gust having a maximum value of 10'/sec. at the fighter wing tips as shown in the sketch below:



Roll of Combination:

The maximum roll disturbing moment is

$$L_0 = q S b C_{l_p} \frac{\dot{\phi} b}{2V}$$

From Reference 1 , page 10 , $C_{l_p} = -.6124$

$$L_{O_{MAX.}} = 103.5 \times 2240 \times 214.5 \times (-.6124) \times \frac{10}{440}$$

$$L_{O_{MAX}} = -0.692 \times 10^6 \text{ FT.-LBS.}$$

Roll of Fighter:

The maximum roll moment due to the disturbance on the F-84 airplane about the attachment hinge is

$$L_{I_{MAX.}} = L_{w_{\phi'}} \phi' a_w$$

$$L_{w_{\phi'}} = -92.91 \frac{q}{V} \quad [\text{REF. 2, Pg. }\quad]$$

$$L_{w_{\phi'}} = -92.91 \times \frac{103.5}{440} = -21.85 \times 10^3 \text{ LBS.}$$

$$a_w = 17.62 \text{ FT.} \quad [\text{REF 2, Pg. }\quad]$$

$$\phi' = \frac{\text{MAX. GUST VELOCITY}}{b/2} = \frac{2(10)}{214.5} = .093$$

Therefore:

$$L_{I_{MAX}} = -21.85 \times 10^3 (17.62)(.093)$$

$$L_{I_{MAX}} = -35.81 \times 10^3 \text{ FT.-LBS.}$$

Pitch of Fighter:

The pitch moment due to the anti-symmetric gust is difficult to evaluate. It is assumed that the neutral point of the F-84 airplane is at .34 MAC for the C.G. location of .28 MAC.

Therefore:

$$M_{1MAX} = qSc \frac{\partial C_m}{\partial C_L} C_{L_{\dot{\phi}}} \dot{\phi}$$

$$M_{1MAX} = L_{W_{\dot{\phi}}} c \frac{\partial C_m}{\partial C_L} \dot{\phi}$$

$$M_{1MAX} = -21.25 \times 10^3 (7.39)(-.06)(.093)$$

$$M_{1MAX} = .901 \times 10^3 \text{ FT.-LBS.}$$

The form of the gust is assumed to be that shown in Figure 2 plotted as a function of time. Therefore:

$$L_0 = -\frac{0.692}{.0368} \times 10^6 \, X = -18.804 \times 10^6 \, X \text{ FT.-LBS.}$$

$$L_1 = -\frac{35.81}{.0368} \times 10^3 \, X = -973.098 \times 10^3 \, X \text{ - FT.-LBS.}$$

$$M_1 = \frac{.901 \times 10^3}{.0368} \times 10^3 \, X = 24.484 \times 10^3 \, X \text{ FT.-LBS.}$$

C. <u>Yaw Motion</u>

The yawing motion is assumed to result from a side gust of 50'/sec. acting at the tails of the bomber and fighter. The form of the gust satisfies the expression

$$v = -250 \, e^{-3t} (1 - e^{-2t})$$

and is plotted as a function of time in Figure 2. Therefore, the various disturbance moments in yaw are:

B-50 Yaw:

$$N_0 = q S_{v_{t_{B-50}}} \left(\frac{dC_L}{d\alpha}\right)_{v_{t_{B-50}}} l_{t_{B-50}} \frac{v}{V}$$

$$N_0 = 103.5 \times 306 \times 2.808 \times 51.2 \times -\frac{250}{440}\left[e^{-3t}\left(1-e^{-2t}\right)\right]$$

$$N_0 = -2.535 \times 10^6 \left[e^{-3t}\left(1-e^{-2t}\right)\right] \text{ FT-LBS.}$$

F-84 Yaw:

$$N_1 = q S_{v_{t_{F-84}}} \left(\frac{dC_L}{d\alpha}\right)_{v_{t_{F-84}}} l_{t_{F-84}} \frac{v}{V}$$

$$N_1 = 103.5 \times 35.80 \times 1.93 \times 18.14 \times -\frac{250}{440}\left[e^{-3t}\left(1-e^{-2t}\right)\right]$$

$$N_1 = -.0737 \times 10^6 \left[e^{-3t}\left(1-e^{-2t}\right)\right] \text{ FT.-LBS.}$$

Combination Yaw:

$$N_2 = N_0 + 2N_1$$

$$N_2 = -2.6824 \left[e^{-3t}\left(1-e^{-2t}\right)\right] \times 10^6 \text{ FT.-LBS.}$$

MOTION STUDY

The time history of the resultant oscillations may be computed from the gust disturbances by solving the system of simultaneous differential equations derived in Reference 2 and given in this report. Since an analytical solution appears to be time-consuming, a step-by-step solution was resorted to. The basic equations of the step-by-step solution, using the variable ϕ as an example, are:

$$\dot{\phi}_n = \dot{\phi}_{n-1} + \ddot{\phi}_{n-1}\,\Delta t$$

$$\phi_n = \phi_{n-1} + \dot{\phi}_{n-1}\,\Delta t + \frac{\ddot{\phi}_{n-1}\,\Delta t^2}{2}$$

Hence, the values of the displacement and velocity are dependent upon the value of the acceleration which may be determined at every interval of time.

The calculations have been performed for the case of:

$$\left.\begin{array}{ll} A = 3.25 \text{ Ft.} & k_a = K_a = 0 \\ e = .5912 \text{ Ft.} & k_e = 0.1 \\ K = -1.0 \text{ (2-joint)} & K_e = 0.03 \end{array}\right\} \text{Single-Joint}$$

A. Single-Joint Attachment

1. Pitch Motion

The equations of motion become:

Pitch of B-50:

$$\left[-53.73\,D^2 - 30.236\,D + 1.842\right]\beta + \left[1009.58\,D^2 + 713.37\,D + 108.30\right]\theta$$
$$+ \left[1.7423\,D^2 + 7.3613\,D + 833.2\right]\alpha = -1.4414 \times 10^3\,\Sigma \quad \ldots (14)$$

Flap of F-84:

$$\left[165.49\,D^2 + 101.20\,D - 5.187\right]\beta + \left[-26.966\,D^2 - 417.24\right]\theta$$
$$+ \left[-4.905\,D^2 - 20.725\,D - 2304\right]\alpha = -15.73 \times 10^2\,\Sigma \quad \ldots (15)$$

Pitch of F-84:

$$\left[-4.273\,D^2 + 2.308\,D + 5.309\right]\beta + \left[.8712\,D^2 + 8.4246\right]\theta$$
$$+ \left[18.753\,D^2 + 21.213\,D + 128.79\right]\alpha = 38.82\,\Sigma \quad \ldots (16)$$

Dividing Equation 14 by 10^3 and rearranging:

$$1.0096\,\ddot{\theta} - .053713\,\ddot{\beta} + .0017423\,\ddot{\alpha} = A \quad \ldots (17)$$

Dividing Equation 15 by 10^2 and rearranging

$$-.26966\,\ddot{\theta} + 1.6549\,\ddot{\beta} - .04905\,\ddot{\alpha} = B \quad \ldots (19)$$

and rearranging Equation 16:

$$.8712\,\ddot{\theta} - 4.273\,\ddot{\beta} + 18.753\,\ddot{\alpha} = C \quad \ldots (20)$$

Where:

$$A = -1.4414\,\bar{X} + .0302\,\dot{\beta} - .001842\,\beta - .71337\,\dot{\theta} - .1083\,\theta - .00736\,\dot{\alpha} - .8832\,\alpha$$

$$B = -15.73\,\bar{X} - 1.012\,\dot{\beta} + .05187\,\beta + 4.1724\,\theta + .20725\,\dot{\alpha} + 23.04\,\alpha$$

$$C = 38.82\,\bar{X} - 2.3088\,\dot{\beta} - 5.309\,\beta - 8.4246\,\theta - 21.213\,\dot{\alpha} - 128.79\,\alpha$$

Solving for $\ddot{\theta}$, etc., etc.

$$\ddot{\theta} = \frac{\begin{vmatrix} A & -.053713 & .0017423 \\ B & 1.6549 & -.04905 \\ C & -4.273 & 18.753 \end{vmatrix}}{\begin{vmatrix} 1.0096 & -.053713 & .0017423 \\ -.26966 & 1.6549 & -.04905 \\ .8712 & -4.273 & 18.753 \end{vmatrix}}, \text{etc., etc.}$$

$$\ddot{\theta} = .98897\,A + .032885\,B + .0001788\,C \quad \ldots\ldots (21)$$

$$\ddot{\beta} = .1625\,A + .61363\,B + .00162\,C \quad \ldots\ldots (22)$$

$$\ddot{\alpha} = -.00937\,A + .1383\,B + .053678\,C \quad \ldots\ldots (23)$$

Table I presents the numerical step-by-step calculation and the results of the computation are plotted in Figure 3.

2. **Roll Motion**

The equations of motion for the roll become:

Roll of B-50:

$$[9.056D^2 + 8.065D]\phi + [1.516D^2 + .906D - .05103]\beta - [.2039D + 23.08]\alpha = -18.804\bar{X} + 1.493(2\dot{\phi}\dot{\beta} + \dot{\beta}^2)\beta \quad (24)$$

Flap of F-84:

$$[7.58D^2 + 4.503D]\phi + [1.655D^2 + 1.012D - .05187]\beta - [.2071D + 23.037]\alpha = -9.731\bar{X} - 7.476\dot{\phi}^2\beta \ldots \quad (25)$$

Pitch of F-84:

$$[21.01D^2 + 74.9D]\phi + [4.273D^2 - 2.306D - 5.309]\beta - [18.595D^2 + 21.21D + 128.76]\alpha = 24.484\bar{X} - 24.12\dot{\phi}^2\beta \quad (26)$$

Rearranging:

$$9.056\,\phi'' + 1.516\beta'' = A_1$$

$$7.58\,\phi'' + 1.655\beta'' = B_1$$

$$21.01\,\phi + 4.273\beta'' - 18.595\alpha'' = C_1$$

Where:

$$A_1 = -18.804\,\bar{X} - 8.065\,\dot{\phi} - .906\,\dot{\beta} + (.05103 + 2.986\,\dot{\phi}\,\dot{\beta} + 1.493\,\dot{\beta}^2)\beta + 23.08\,\alpha + .2039\,\dot{\alpha}$$

$$B_1 = -9.731\,\bar{X} - 4.503\,\dot{\phi} - 1.012\,\dot{\beta} + (.05187 - 7.476\,\dot{\phi}^2)\beta + .2071\,\dot{\alpha} + 23.037\,\alpha$$

$$C_1 = 24.484\,\bar{X} - 74.9\,\dot{\phi} + 2.306\,\dot{\beta} + (5.309 - 24.12\,\dot{\phi}^2)\beta + 21.21\,\dot{\alpha} + 128.76\,\alpha$$

Solving for $\ddot{\phi}$, etc.

$$\begin{cases} \ddot{\phi} = .4733\,A_1 - .4336\,B_1 & (27) \\ \ddot{\beta} = 2.5900\,B_1 - 2.1679\,A_1 & (28) \\ \ddot{\alpha} = .03664\,A_1 + .1053\,B_1 - .05377\,C_1 & (29) \end{cases}$$

Table II presents the numerical step-by-step calculation, and the results of the computation are plotted in Figure 4.

3. <u>Yaw Motion</u>

The equations of the yaw motion become:

B-50 Yaw:

$$[9.957\,D^2 + 0.532\,D + 4.725]\psi + [1.542\,D^2 + 0.0139\,D + 0.2596]\gamma = -2.539\,e^{-3t}[1 - e^{-2t}] \quad (30)$$

Where:

$$A_1 = -18.804\,\underline{X} - 8.065\,\phi^{\cdot} - .906\,\beta^{\cdot} + (.05103 + 2.986\,\phi^{\cdot}\beta^{\cdot} + 1.493\,\beta^{\cdot 2})\beta + 23.08\,\alpha + .2039\,\alpha^{\cdot}$$

$$B_1 = -9.731\,\underline{X} - 4.503\,\phi^{\cdot} - 1.012\,\beta^{\cdot} + (.05187 - 7.476\,\phi^{\cdot 2})\beta + .2071\,\alpha^{\cdot} + 23.037\,\alpha$$

$$C_1 = 24.484\,\underline{X} - 74.9\,\phi^{\cdot} + 2.306\,\beta^{\cdot} + (5.309 - 24.12\,\phi^{\cdot 2})\beta + 21.21\,\alpha^{\cdot} + 128.76\,\alpha$$

Solving for $\phi^{\cdot\cdot}$, etc.

$$\begin{cases} \phi^{\cdot\cdot} = .4733\,A_1 - .4336\,B_1 & (27) \\ \beta^{\cdot\cdot} = 2.5900\,B_1 - 2.1679\,A_1 & (28) \\ \alpha^{\cdot\cdot} = .03664\,A_1 + .1053\,B_1 - .05377\,C_1 & (29) \end{cases}$$

Table II presents the numerical step-by-step calculation, and the results of the computation are plotted in Figure 4.

3. <u>Yaw Motion</u>

The equations of the yaw motion become:

B-50 Yaw:

$$[9.957\,D^2 + 0.532\,D + 4.725]\psi + [1.542\,D^2 + 0.0139\,D + 0.2596]\gamma = -2.535\,e^{-3t}[1 - e^{-2t}] \quad (30)$$

F-84 Yaw:

$$[.768\,D^2 + .0696\,D + .1298]\psi + [.1830\,D + .00696\,D + .1298]\gamma$$
$$= -.0737\,e^{-3t}[1 - e^{-2t}] \quad \ldots\ldots \quad (31)$$

These equations may be rearranged to

$$9.957\,\ddot{\psi} + 1.542\,\ddot{\gamma} = A_2 \qquad (32)$$
$$.768\,\ddot{\psi} + .183\,\ddot{\gamma} = B_2 \qquad (33)$$

Where:

$$A_2 = -2.535\,e^{-3t}[1 - e^{-2t}] - .532\,\ddot{\psi} - 4.725\,\dot{\psi} - .0139\,\dot{\gamma} - .2596\,\gamma$$

$$B_2 = -.0737\,e^{-3t}[1 - e^{-2t}] - .0696\,\dot{\psi} - .1298\,\psi - .00696\,\dot{\gamma} - .1298\,\gamma$$

Solution of (32) and (33) yields:

$$\begin{cases} \ddot{\gamma} = 15.6098\,B_2 - 1.2040\,A_2 & (34) \\ \ddot{\psi} = .2869\,A_2 - 2.4174\,B_2 & (35) \end{cases}$$

Using these equations, a step-by-step analysis was made. Table III shows the calculations performed and the results are plotted in Figure 5.

B. Two-Joint Attachment

1. Pitch Motion

For the case considered, the pitch equations for the two-joint attachment become:

Pitch of Combination:

$$\left[1.0506\,D^2 + .76283\,D + 2.1903\right]\theta - \left[.0623\,D^2 + .06696\,D + .4324\right]\beta = -1.3761\,\bar{X} \tag{36}$$

Flap of F-84:

$$\left[1.6571\,D^2 + 1.184\,D + 10.93\right]\beta - \left[.3191\,D^2 + .2059\,D + 27.13\right]\theta = -15.73\,\bar{X} \tag{37}$$

These equations of the form

$$1.0506\,\theta'' - .0623\,\beta'' = A_3$$

$$-.3191\,\theta'' + 1.6571\,\beta'' = B_3$$

where:

$$A_3 = -1.376\,\bar{X} - .76283\,\theta' - 2.1903\,\theta + .06696\,\beta' + .4324\,\beta$$

$$B_3 = -15.73\,\bar{X} - 1.1841\,\beta' - 10.93\,\beta + .2059\,\theta' + 27.13\,\theta$$

Solving for θ'' and β'' :

$$\theta'' = \frac{\begin{vmatrix} A_3 & -.0623 \\ B_3 & 1.6571 \end{vmatrix}}{\begin{vmatrix} 1.0506 & -.0623 \\ -.3191 & 1.6571 \end{vmatrix}} = .9411\,A_3 + .0354\,B_3 \tag{38}$$

$$\beta'' = \frac{\begin{vmatrix} 1.0506 & A_3 \\ -.3191 & B_3 \end{vmatrix}}{\begin{vmatrix} 1.0506 & -.0623 \\ -.3191 & 1.6571 \end{vmatrix}} = .1812\,A_3 + .5967\,B_3 \tag{39}$$

For the step-by-step computations of Table IV, the values of A_3 have been multiplied by 16.039 and the values of B_3 by 4.857. The corresponding values for the accelerations are:

$$\theta'' = .0587\,A + .00729\,B \tag{40}$$

$$\beta'' = .0113\,A + .5967\,B \tag{41}$$

Where: $A = 16.039\,A_3$, $B = 4.857\,B_3$

The resulting motions are plotted as a function of time in Figure 6.

2. Roll Motion

The equations of motion for the two-joint attachment, using $K = -1$, become:

Roll of B-50:

$$[9.093\,D^2 + 7.423\,D]\phi + [1.524\,D^2 + .9457\,D + 10.752]\beta = -18.804\,\underline{X} + 1.495(2\phi'\beta' + \beta'^2)\beta \tag{42}$$

Flap of F-84:

$$[7.576\,D^2 + 4.353\,D]\phi + [1.657\,D^2 + 1.184\,D + 10.72]\beta = -9.731\,\underline{X} - 7.467\,\phi'^2\beta \tag{43}$$

These equations are of the form:

$$9.093\,\phi'' + 1.524\,\beta'' = A_4 \qquad (44)$$

$$7.576\,\phi'' + 1.657\,\beta'' = B_4 \qquad (45)$$

Where:

$$A_4 = -18.804\,\bar{X} - 7.423\,\phi' - .9457\,\beta' - (10.752 - 2.190\,\phi'\beta' - 1.495\,\beta'^2)\beta$$

$$B_4 = -9.731\,\bar{X} - 4.353\,\phi' - 1.184\,\beta' - (10.72 + 7.467\,\phi'^2)\beta$$

Solving Equations (44) and (45):

$$\phi'' = \frac{\begin{vmatrix} A_4 & 1.524 \\ B_4 & 1.657 \end{vmatrix}}{\begin{vmatrix} 9.093 & 1.524 \\ 7.576 & 1.657 \end{vmatrix}} \quad \text{etc.}$$

$$\phi'' = .4706\,A_4 - .4328\,B_4 \qquad (46)$$

$$\beta'' = -2.1516\,A_4 + 2.5824\,B_4 \qquad (47)$$

Table V presents the numerical step-by-step calculation and Figure 7 shows the resulting motion of the airplanes.

3. Yaw Motion

The equation for yaw becomes:

$$[10.12D^2 + .532D + 4.725]\psi = -2.6824\, e^{-3t}[1 - e^{-2t}]$$

The acceleration is

$$\ddot{\psi} = -.05343\dot{\psi} - .4745\psi - .2694[e^{-3t}(1 - e^{-2t})] \qquad (48)$$

Table VI presents the numerical solution for the motion plotted in Figure 8.

DETERMINATION OF LOADS AT JOINT

The joint loads are determined by obtaining the equilibrium of the forces, (aerodynamic, external and inertia), and the moments acting upon the F-84 airplane. This implies that the loads on the B-50 airplane are equal in magnitude, but of opposite sign.

The loads may be classified as:

1. Single-Joint Attachment

a) A vertical reaction force, R_{F_V}, acting at the hinge location for roll and pitch motions.

b) A horizontal reaction force acting at the hinge location for yaw motion, consisting of a spanwise component, $R_{F_{H_1}}$, and a chordwise component, $R_{F_{H_2}}$.

2. Two-Joint Attachment

a) A vertical reaction force, R_{F_V}, referred to the C.G. position, .28 c, of the fighter airplane for roll and pitch motion.

b) A horizontal reaction force referred to the C.G. position, .28 c, of the fighter for yaw motion consisting of a spanwise component, $R_{F_{H_1}}$, and a chordwise component, $R_{F_{H_2}}$.

c) A torsional moment, M_T, referred to the C.G. position .28 c, of the fighter airplane for roll and pitch motions.

d) A yawing moment, M_Y, referred to the C.G. position, .28 c, of the fighter airplane for yaw motion.

A. Single-Joint Attachment

1. Pitch Motion

The vertical reaction force is given by:

$$R_{F_V} = m\beta'' r - m(C\alpha'' + A\theta'') - mr\beta'^2 \sin\beta + m(C\alpha'^2 + A\theta'^2)\sin\alpha - \Sigma(L_w + L_t) - L_{w_\alpha}\Delta\alpha_{F-84}$$

Substituting the values of the constants:

$$R_{F_V} = 10^3[8.263\beta'' + 3.201\beta' - .283\beta - 8.297\beta'^2\sin\beta - .268\alpha'' - 1.133\alpha' - 128.180\alpha + .268\alpha'^2\sin\alpha - 1.474\theta'' - 22.800\theta + 1.474\theta'^2\sin\alpha + 73.670X] \quad \ldots (49)$$

The numerical calculations for the pitch reaction force are given in Table VII, and the results plotted in Figure 3.

2. Roll Motion

The vertical reaction force in roll is given by:

$$R_{F_V} = m\beta'' r + m(R+r)\phi'' + mR\phi'^2\beta - \Sigma(L_w + L_t) - \frac{L_1}{r} \quad \ldots (50)$$

Substituting the values of the constants and equivalents:

$$R_{F_V} = 10^3[8.263\beta'' + 4.652\beta' - .283\beta + 40.604\phi'' + 25.418\phi' + 32.327\phi'^2\beta - 1.133\alpha' - 128.180\alpha + 53.175X] \quad \ldots (51)$$

The numerical calculations for the roll reaction force are given in Table VIII, and the results plotted in Figure 4.

3. Yaw Motion

The yawing loads imposed by the motion can be expressed as:

Spanwise Force : $R_{F_{H_1}} \cong m r \gamma'' \left(\frac{R}{R+r}\right) + m(R+r)\psi'^2$ ..... (52)

Chordwise Force: $R_{F_{H_2}} \cong -m(R+r)\psi'' - m r \gamma''$ ..... (53)

Substituting the known values of the coefficients:

$$R_{F_{H_1}} \cong 10^3 \left[6.573\gamma'' + 40.806\psi'^2\right] \quad \text{..... (54)}$$

$$R_{F_{H_2}} \cong -10^3 \left[40.806\psi'' + 8.297\gamma''\right] \quad \text{..... (55)}$$

The numerical calculations for the yaw reaction forces are given in Table VI , and the results plotted in Figure 5.

B. Two-Joint Attachment

1. Pitch Moment

a) The equation for the vertical reaction force in pitch for the two-joint attachment is:

$$R_{F_V} = m r \beta'' - m(c+A)\theta'' - \Sigma(L_W + L_t) - \frac{L_2}{r} \quad \text{..... (56)}$$

or

$$R_{F_V} = 10^3 \left[8.274\beta'' + 5.592\beta' + 59.73\beta - 1.744\theta'' - 1.125\theta' - 150.97\theta + 87.63\Sigma\right] \quad \text{..... (57)}$$

b) The equation for the torsional moment referred to the center of gravity position of the F-84 is:

$$M_T = I_{y-y}\theta'' - \Sigma L_w \cdot d + \Sigma L_t \cdot l_t - M_{f_\theta}\theta - M_Z \quad \ldots\ldots (58)$$

or

$$M_T = 10^3 \left[18.595\theta'' + 20.41\theta' + 47.86\theta + .61\beta'' - 12.00\beta' + 13.24\beta - 38.82\bar{X} \right] \ldots\ldots (59)$$

The numerical calculations for the pitch reaction force and twisting moment are given in Table IX and the results plotted in Figure 6.

2. <u>Roll Motion</u>

a) The equation for the vertical reaction force in roll for the two-joint attachment is:

$$R_{F_V} = m(R+r)\phi'' + mr\beta'' - \Sigma(L_w + L_t) - \frac{L_1}{r} \quad \ldots\ldots (60)$$

or substituting:

$$R_{F_V} = 10^3 \left[40.70\phi'' + 25.40\phi' + 8.28\beta'' + 5.59\beta' + 59.73\beta + 54.21\bar{X} \right] \ldots (61)$$

b) The equation for the torsional moment referred to the C.G. of the F-84 is:

$$M_T = -\left[L_w \cdot d - L_t l_t \right] - \frac{L_1}{r}\bar{X} \quad \ldots\ldots\ldots (62)$$

where: $\bar{X}$ is static margin of F-84 = -.443 ft.

or substituting:

$$M_T = 10^3 \left[2.993\phi'' - 54.480\phi' + .608\beta'' - 12.280\beta' + 13.242\beta - 24.015\bar{X} \right] \ldots (62)$$

The numerical calculations for the roll reaction force and torsional moment are given in Table X and the results plotted in Figure 7.

3. Yaw Motion

a) The equation for the reaction forces associated with the yawing forces are:

Spanwise Force: $R_{F_{H_1}} \cong m r (\dot{\psi})^2$ - - - - - - - - - (64)

Chordwise Force: $R_{F_{H_2}} \cong m r \ddot{\psi}$ - - - - - - - - - (65)

or: $R_{F_{H_1}} \cong 10^3 [8.297 \dot{\psi}^2]$ - - - - - - (66)

$R_{F_{H_2}} \cong 10^3 [8.297 \ddot{\psi}]$ - - - - - - (67)

b) The yawing moment, referred to the chordwise position of the center of gravity of the F-84 is

$M_{\dot{\psi}} \cong m r^2 \ddot{\psi}$ - - - - - - - - - - (68)

The numerical calculation for the yaw reaction forces and moment are given in Table XI and the results plotted in Figure 9.

TABLE I — STEP BY STEP SOLUTION OF EQUATIONS OF MOTION — SINGLE-JOINT ATTAC

		.99897 (45)	.0001788 (57)	.032885 (67)	(3)+(4)+(5)	.1625 (45)	.00162 (57)	.61363 (67)	(1)+(8)+(9)	-.009379 (45)	.053678 (57)	.1383 (67)	(11)+(12)+(13)	(2)(6)	(2)(10)	(2)(14)	(18)+(15)$_{n-1}$	(19)+(16)$_{n-1}$	(20)+(17)$_{n-1}$	(2)(18)
t	Δt	.99897 A	.0001788 C	.032885 B	$\ddot{\theta}$	.1625 A	.00162 C	.61363 B	$\ddot{\beta}$	-.009379 A	.053678 C	.1383 B	$\ddot{\alpha}$	$\Delta\dot{\theta}$	$\Delta\dot{\beta}$	$\Delta\dot{\alpha}$	$\dot{\theta}$	$\dot{\beta}$	$\dot{\alpha}$	$\Delta t\,\dot{\theta}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.025	.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.050	.025	-.01444	+.00007	-.00543	-.01980	-.00235	+.00066	-.10137	-.10306	+.00014	+.02188	-.02285	-.00083	-.000495	-.002577	-.000021	-.000445	-.002577	-.000024	-.000012
.1	.05	-.02585	.00013	-.00974	-.03546	-.00421	.00121	-.18182	-.18482	.00024	.03997	-.04098	-.00057	-.00177	-.00924	-.000029	-.002265	-.01182	-.000050	-.000113
.15		-.04065	.00022	-.01541	-.05584	-.00661	.00198	-.28755	-.29218	.00038	.06545	-.06481	+.00102	-.00279	-.001461	+.000051	-.005055	-.02644	+.000001	-.000253
.2		-.04593	.00026	-.01755	-.06322	-.00749	.00276	-.33756	-.33267	.00043	.07823	-.07382	.00484	-.00316	-.01667	.000242	-.008 22	-.04301	.000243	-.000411
.25		-.04593	.00028	-.01775	-.06340	-.00747	.00252	-.33124	-.33619	.00041	.08355	-.07465	.00933	-.00317	-.01683	.000467	-.01139	-.05988	.000710	-.000570
.3		-.04303	.00028	-.01678	-.05153	-.00700	.00255	-.31314	-.31759	.00044	.08438	-.07057	.01421	-.00298	-.01588	.000711	-.01437	-.07576	.001411	-.000719
.35		-.03793	.00027	-.01504	-.05270	-.00617	.00245	-.28067	-.28433	.00036	.08130	-.06324	.01842	-.00264	-.01422	.000921	-.01701	-.08998	.002332	-.000851
.4		-.03235	.00026	-.01303	-.04512	-.00527	.00231	-.24318	-.24613	.00031	.07660	-.05481	.02209	-.00226	-.01331	.001105	-.01927	-.10229	.003437	-.000954
.45		-.02661	.00024	-.01089	-.03726	-.00433	.00213	-.20330	-.20550	.00025	.07050	-.04581	.02493	-.00186	-.01028	.001247	-.02113	-.11257	.004684	-.001057
.5		-.02092	.00021	-.00869	-.02940	-.00340	.00191	-.16218	-.16367	.00020	.06343	-.03655	.02708	-.00147	-.00818	.001357	-.02260	-.12075	.006038	-.001130
.55		-.01580	.00019	-.00667	-.02228	-.00257	.00170	-.12451	-.12538	.00015	.05627	-.02806	.02856	-.00111	.00627	.001418	-.02371	-.12702	.007456	-.001185
.6		-.01126	.00016	-.00478	-.01588	-.00183	.00141	-.08916	-.08952	.00011	.04880	-.02009	.02882	-.00079	-.00448	.001441	-.02450	-.13150	.008897	-.001225
.65		-.00761	.00014	-.00314	-.01061	-.001238	.00126	-.05860	-.05858	.00008	.04170	-.01321	.02856	-.00053	-.00243	.001418	-.02507	-.13443	.010325	-.001252
.7		-.004166	.00011	-.00151	-.00557	-.000678	.001025	-.02810	-.02776	.00005	.03397	-.00633	.02767	-.00028	-.00139	.001384	-.02531	-.13582	.011709	-.001266
.75		-.001938	.00009	-.00018	-.00203	-.00315	.00811	-.00377	-.00288	.00018	.02687	-.00076	.02612	-.00102	-.00014	.001206	-.02541	-.13596	.013015	-.001270
.8		+.000400	.00065	+.001095	+.00156	+.000065	.00587	+.02043	+.02086	-.00006	.01946	+.00461	.02407	+.00078	+.00105	.001203	-.02537	-.13491	.014218	-.001267
.85		.00202	.00041	.00222	.00428	.00328	.00370	.04144	.04216	-.00018	.01224	.00134	.02156	.00214	.00211	.001078	-.02512	-.13280	.015296	-.001256
.9		.00303	.00017	.00319	.00624	.00492	.00158	.05958	.06023	-.00018	.00523	.01743	.01864	.00312	.00301	.000932	-.02481	-.12974	.016228	-.001241
1.0	.10	.00375	-.00006	.00405	.00779	.00609	-.00054	.07566	.07622	-.00018	-.00179	.01765	.01523	.00279	.00262	.001523	-.02403	-.12217	.017751	-.002403
1.1		.00438	-.00005	.00569	.01002	.00712	-.00478	.10622	.10645	-.00014	-.01583	.02394	.00807	.00102	.01065	.000807	-.02303	-.11153	.018558	-.002303
1.2		.00432	-.00010	.00707	.01129	.00702	-.00895	.13199	.13179	-.00014	-.02966	.02975	.00005	.00113	.01318	.000001	-.02190	-.09835	.018559	-.002190
1.3		.00390	-.00014	.00815	.01171	.00601	-.01276	.15206	.15139	-.00008	-.04227	.03427	-.00803	.00117	.01514	-.000803	-.02073	-.08321	.017756	-.002073
1.4		.00249	-.00018	.00882	.01113	.00406	-.01596	.16464	.16345	-.00003	-.05287	.03711	-.01578	.00113	.01635	-.001578	-.01962	-.06687	.016178	-.001962
1.5		.00115	-.00021	.00926	.01020	.00187	-.01862	.17286	.17119	-.00001	-.06169	.03896	-.02274	.00102	.01719	-.002274	-.01860	-.04975	.013904	-.001860
1.6		.00037	-.00023	.00950	.00964	.00006	-.00207	.17722	.17521	-.00001	-.06853	.03994	-.02859	.00095	.01721	-.002859	-.01765	-.03223	.011045	-.001765
1.7		-.00012	-.00024	.00948	.00912	-.00002	-.00221	.17698	.17475	+.00001	-.07312	.03989	-.03323	.00091	.01773	-.003323	-.01674	-.01476	.007722	-.001674
1.8		-.00027	-.00025	.00922	.00870	.00004	-.00227	.17202	.16971	.00001	-.07523	.03877	-.03646	.00087	.01697	-.003646	-.01587	+.00222	.004076	-.001587
1.9		-.00023	-.00025	.00864	.00816	-.00004	-.00225	.16126	.15891	.00001	-.07457	.03635	-.03822	.00081	.01590	-.003822	.01505	.01811	.000254	-.001505
2.0		+.00012	-.00024	.00782	.00770	+.00002	-.00215	.14585	.14372	-.00001	-.07131	.03281	-.03844	.00071	.01437	-.003844	-.01428	.03249	-.003590	-.001428
2.1		.00091	-.00022	.00681	.00750	.00015	-.00199	.12716	.12532	-.00001	-.06580	.02866	-.03715	.00075	.01257	-.003715	-.01353	.04502	-.007305	-.001353
2.2		.00169	-.00019	.00551	.00701	.00027	-.00174	.10273	.10126	-.00001	-.05762	.02315	-.03449	.00201	.01013	-.003449	-.01283	.05514	-.010754	-.001283
2.3		.00269	-.00016	.00404	.00653	.00044	-.00144	.07537	.07437	-.00001	-.04755	.01699	-.03059	.00063	.00744	-.003054	-.01218	.06258	-.013813	-.001218

ION OF EQUATIONS OF MOTION — SINGLE-JOINT ATTACHMENT — PITCH MOTION

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	-.009379 (45)	.053678 (51)	.1383 (67)	(11)+(12)+(13)	(2)/6	(2)/10	(2)/14	(18)+(15)/n-1	(19)+(16)/n-1	(20)+(17)/n-1	(2)/18	(2)/19	(2)/20	(2)/6	(2)/10	(2)/14	(21)/n-1 + (24)	(28)/n-1 + (25)	(29)/n-1 + (26)	(18)²	(19)²	(20)²
	-.009379 A	.053678 C	.1383 B	$\ddot{\alpha}$	$\Delta\dot{\theta}$	$\Delta\dot{\beta}$	$\Delta\dot{\alpha}$	$\dot{\theta}$	$\dot{\beta}$	$\dot{\alpha}$	$\Delta t\dot{\theta}$	$\Delta t\dot{\beta}$	$\Delta t\dot{\alpha}$	$\frac{\Delta t^2}{2}\ddot{\theta}$	$\frac{\Delta t^2}{2}\ddot{\beta}$	$\frac{\Delta t^2}{2}\ddot{\alpha}$	θ	β	α	$\dot{\theta}^2$	$\dot{\beta}^2$	$\dot{\alpha}^2$
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	+.000144	+.02188	-.02285	-.00083	-.000495	-.002577	-.000071	-.000445	-.002577	-.000024	-.000012	-.000064	+.000053	-.000062	-.000032	-.000016	-.000186	-.000097	-.000079	.000002	.000866	0
-	.00024	.03997	-.04098	-.00057	-.00177	-.00924	-.000029	-.002265	-.01182	-.000050	-.000113	-.000541	-.000025	-.000044	-.002231	-.000071	-.001756	-.000419	.000004	.000051	.000140	0
3	.000038	.06545	-.06481	+.00102	.00279	-.001461	+.000051	-.005055	-.02644	+.000001	-.000253	-.001322	0	-.000080	-.000365	+.000001	-.000499	-.002606	.000002	.000026	.000699	0
7	.000041	.07823	-.07382	.00484	-.00316	-.01663	.000242	-.00822	-.04307	.000243	-.000411	-.002154	+.000012	-.000079	-.000416	.000006	-.000989	-.006176	+.000016	.000068	.001855	0
1	.000041	.08355	-.07465	.00933	-.00317	-.01683	.000467	-.01139	-.05988	.000710	-.000570	-.002994	.000036	-.000079	-.000420	.000021	-.001638	-.008590	.000064	.000130	.003586	.000005
59	.000041	.08438	-.07057	.01421	-.00298	-.01588	.000711	-.01437	-.07576	.001411	-.000719	-.003788	.000071	-.000074	-.000397	.000018	-.002431	-.012775	.000153	.000206	.005140	.000002
33	.000036	.08130	-.06324	.01842	-.00264	-.01422	.000921	-.01701	-.08998	.002312	-.000851	-.004499	.000117	-.000064	-.000355	.000023	-.003347	-.017629	.000193	.000289	.008096	.000005
3	.000031	.07660	-.05481	.02209	-.00226	-.01131	.001105	-.01927	-.10229	.003437	-.000954	-.005114	.000172	-.000056	-.000308	.000028	-.004367	-.023051	.000513	.000371	.010463	.000011
0	.000025	.07050	-.04581	.02493	-.00186	-.01028	.001247	-.02113	-.11251	.004684	-.001057	-.005629	.000234	-.000047	-.000257	.000031	-.005471	-.028937	.000778	.000446	.012672	.000022
7	.000024	.06343	-.03655	.02708	-.00147	-.00818	.001354	-.02260	-.12075	.005038	-.001136	-.006038	.000301	-.000037	-.000205	.000034	-.006638	-.035180	.001113	.000511	.014581	.000036
8	.000012	.05627	-.02806	.02836	-.00111	-.00627	.001418	-.02371	-.12702	.007456	-.001185	-.006351	.000373	-.000028	-.000157	.000035	-.001851	-.041688	.001524		.016134	.000056
2	.000011	.04880	-.02009	.02882	-.000799	-.00448	.001447	-.02450	-.13150	.008897	-.001225	-.006575	.000445	-.000020	-.000112	.000036	-.009096	-.048375	.001602		.017292	.000079
58	.000011	.04170	-.01321	.02856	-.000553	-.00293	.001418	-.02507	-.13483	.010325	-.001252	-.006722	.000516	-.000013	-.000073	.000036	-.010361	-.055170	.002554		.018071	.000107
76	.000009	.03397	-.00633	.02767	-.000128	-.00139	.001384	-.02531	-.13582	.011709	-.001266	-.006791	.000585	-.000007	-.000035	.000035	-.011634	-.061996	.003174		.018447	.000127
88	.000008	.02687	-.00076	.02612	-.000102	-.00014	.001306	-.02541	-.13596	.013015	-.001270	-.006798	.000651	-.000003	-.000004	.000033	-.012901	-.068798	.003858		.018485	.000169
286	-.000007	.01946	+.00461	.02407	+.000078	+.00105	.001203	-.02537	-.13441	.014218	-.001267	-.006745	.000710	+.000001	+.000026	.000030	-.014172	-.075517	.004598		.018201	.000201
12	-.000009	.01224	.00134	.02156	.000214	.00211	.001078	-.02512	-.13280	.015296	-.001256	-.006640	.000765	.000005	.000053	.000027	-.015433	-.082104	.005390		.017636	
23	-.000010	.00523	.01343	.01864	.000312	.00301	.000932	-.02481	-.12974	.016228	-.001241	-.006490	.000811	.000008	.000075	.000023	-.016664	-.088594	.006201		.016845	
-2	-.000010	-.00179	.01765	.01523	.000379	.00262	.000821	-.02403	-.12217	.017751	-.001203	-.006217	.001375	.000039	.000381	.000076	-.019028	-.100430	.008052		.014926	
5	-.000010	-.01583	.02394	.00807	.000002	.01065	.000807	-.02303	-.11153	.018558	-.001203	-.005157	.001856	.000050	.000532	.000040	-.021281	-.111055	.009948		.012332	
19	-.000010	-.02966	.02975	.000005	.000113	.01318	.000001	-.02190	-.09835	.018559	-.001190	-.004835	.001856	.000056	.000659	0	-.022415	-.120231	.011804		.009673	
39	-.000008	-.04227	.03427	-.000803	.000117	.01514	-.000803	-.02073	-.08321	.017756	-.001073	-.004121	.001776	.000059	.000757	-.000040	-.025429	-.127795	.013540		.006824	
45	-.000008	-.05287	.03711	-.01578	.000113	.01635	-.001578	-.01962	-.06687	.016178	-.001962	-.006687	.001618	.000056	.000817	-.000079	-.027335	-.133665	.015039		.004472	
19	-.000008	-.06169	.03896	-.02274	.000102	.017119	-.000224	-.01860	-.04975	.013904	-.001860	-.004975	.001390	.000051	.000856	-.000114	-.029847	-.137784	.016355		.002475	
21	-.000008	-.06853	.03994	-.02859	.000095	.017521	-.000859	-.01785	-.03223	.011045	-.001765	-.003223	.001105	.000048	.000826	-.000143	-.030861	-.140131	.017317		.001039	
75	+.000008	-.07312	.03989	-.03323	.000912	.017473	-.003323	-.01674	-.04476	.007722	-.001674	-.004476	.000772	.000046	.000824	-.000166	-.032490	-.140777	.017923		.000218	
71	.000008	-.07523	.03877	-.03646	.000870	.01697	-.003676	-.01587	+.00222	.004076	-.001587	+.000222	.000448	.000044	.000849	-.000182	-.034073	-.139662	.018149		.000005	
97	-.000008	-.07457	.03635	-.03822	.000816	.01590	-.003822	-.01505	.01811	.000254	-.001505	.01811	.000035	.000041	.000795	-.000191	-.035197	-.133056	.017983		.000328	
72	-.000008	-.07131	.03287	-.03844	.000770	.01437	-.003844	-.01428	.03249	-.003590	-.001428	.003249	-.000357	.000039	.000719	-.000192	-.036886	-.133088	.017432		.001035	
32	-.000008	-.06580	.02866	-.03715	.000750	.01253	-.003715	-.01353	.04502	-.007305	-.001353	.004502	-.000731	.000038	.000621	-.000186	-.038201	-.127959	.016515		.002027	
26	-.000008	-.05762	.02315	-.03449	.000201	.01013	-.003449	-.01283	.05514	-.010754	-.001283	.005514	-.001075	.000035	.000506	-.000172	-.039449	-.121939	.015268		.003041	
37	-.000008	-.04755	.01699	-.03059	.000633	.00744	-.003059	-.01218	.06258	-.013813	-.001218	.006258	-.001381	.000032	.000372	-.000153	-.040635	-.115309	.013734		.003916	

neglect

neglect

TABLE I
STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION
SINGLE-JOINT ATTACHMENT—PITCH MOTION

TABLE I — CONTINUED

t	M_0^{-6}	$\dot\beta$	$\dot\beta^2$	+ (35)	β	$\dot\theta$	θ	$\dot\alpha$	$\dot\alpha^2$	$\dot\phi^2$	α	A	M_2^{-3}	θ	$\dot\beta$	$\dot\beta^2$	+ (49)	β	$\dot\alpha$	$\dot\alpha^2$	$\dot\phi^2$	α	C
	-1.3761 X FROM FIGURE 2	.030236 (19)	.053932 (31)		-(36) (28)	-.71337 (18)	-.1083 (21)	-.0073613 (20)	.0017423 (32)	.00 1578 (30)	-(43) (29)	(33)+(34)+(35)+(36)+(37)+(38)+(39)	36.82 X FROM FIGURE 2	-8.4246 (27)	-2.308 (19)	4.9053 (31)		-(50) (28)	-21.213 (20)	.1585 (33)	.8712 (30)	-(55) (29)	(46)+(47)+(48)+(51)+(52)
	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)	(57)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.025	-.01445	0	0	0	0	0	0	0	0	0	0	0	-.01445	.4076	0	0	0	0	0	0	0	0	0	0	.4076
.050	-.02615	-.00008	0	.001842	0	+.00035	0	0			.8332	0	-.02588	.7376	+.0002	+.0059	0	5.309	+.0005	+.0004			128.79	.0001	.7447
.1	-.04197	-.000357	+.000008	.001850	0	.00162	+.00002	0				0	-.04069	1.1840	.0015	.0273	.0007	5.3097	+.0049	.0011				.0005	1.2193
.15	-.04885	-.00080	+.00004	.00188	+.00001	.00361	.00005	0				0	-.04598	1.3781	.0042	.0610	.0034	5.3124	.0138	0				.0003	1.4574
.2	-.05064	-.00130	.00010	.001942	.00001	.00586	.00011	0				-.00002	-.04578	1.4286	.0083	.0994	.0091	5.3181	.0275	-.0052				-.0021	1.5565
.25	-.04954	-.00181	.00019	.002032	.00002	.00815	.00018	0				-.00005	-.04307	1.3975	.0138	.1382	.0176	5.3266	.0458	-.0151				-.0082	1.5720
.3	-.04610	-.00229	.00031	.002152	.00003	.01025	.00026	-.00001				-.00013	-.03797	1.3005	.0205	.1749	.0282	5.3372	.0682	-.0299				-.0197	1.5145
.35	-.04197	-.00272	.00044	.002279	.00004	.01213	.00036	-.00002				-.000244	-.03238	1.1840	.0282	.2077	.0397	5.3487	.0943	-.0495				-.03774	1.4270
.4	-.03743	-.00309	.00056	.002406	.00006	.01375	.00047	-.00003				-.000487	-.02664	1.0659	.0368	.2361	.0513	5.3603	.1236	-.0729				-.0661	1.3134
.45	-.03261	-.00340	.00068	.002535	.00007	.01507	.00059	-.00003				-.00065	-.02094	.9200	.0461	.25981	.0622	5.3712	.1554	-.0994				-.1002	1.1817
.5	-.02821	-.00365	.00079	.002628	.00009	.01612	.00072	-.00004				-.00093	-.01582	.7959	.0569	.27869	.07152	5.3805	.1893	-.1281				-.1433	1.0483
.55	-.02408	-.00384	.00087	.002712	.00011	.01691	.00085	-.00005				-.00127	-.01127	.6794	.0661	.29316	.07944	5.3881	.2246	-.1582				-.1959	.9092
.6	-.02064	-.003976	.00093	.002774	.00013	.01748	.00099	-.00007				-.00167	-.00762	.5823	.0766	.30350	.08482	5.3938	.2609	-.1887				-.2578	.7768
.65	-.01720	-.00406	.00097	.002817	.00016	.01786	.00112	-.00008				-.00213	-.00447	.4853	.0873	.31026	.08864	5.3976	.2978	-.2190				-.3289	.6328
.7	-.01459	-.00440	.00099	.002837	.00018	.01806	.00126	-.00009				-.00264	-.00194	.4115	.0980	.31347	.09049	5.3995	.3347	-.2484				-.4088	.5005
.75	-.01211	-.00411	.00100	.002842	.00020	.01813	.00140	-.00010				-.00321	+.00040	.3416	.0874	.3138	.09067	5.3997	.3715	-.2761				-.4969	.3626
.8	-.01005	-.00408	.00100	.002842	.00021	.01807	.00153	-.00010				-.00383	+.00202	.2834	.1939	.3114	.08928		.4077	-.3016				-.5922	.2281
.85	-.008394	-.00462	.00096	.002793	.00023	.01772	.00167	-.00011				-.00449	.00303	.2368	.2997	.3065	.08661		.4430	-.3245				-.6942	.0995
.9	-.007018	-.00392			.00024	.01770	.00180	-.00012				-.00519	.00375	.1980	.14039	.2996	.08263		.4777	-.3442				-.8048	-.0333
1.0	-.004816	-.00369			.00027	.01714	.00206	-.00013				-.00671	.00438	.1359	.1603	.2820			.5405	-.3766				-1.0370	-.2949
1.1	-.003165	-.00337			.00028	.01643	.00230	-.00014				-.00829	.00432	.08928	.17929	.25744			.5963	-.3937				-1.2812	-.5626
1.2	-.002064	-.00297			.00028	.015623	.00253	-.00014				-.00984	.00370	.05823	.19726	.2270			.6440	-.3937				-1.5207	-.7874
1.3	-.001651	-.00252			.00028	.014788	.00275	-.00013				-.01128	.00250	.04658	.21423	.19206			.68280	-.3767				-1.7438	-.9848
1.4	-.001376	-.00202			.00028	.01399	.00296	-.00012				-.01256	.00115	.03882	.23029	.15453			.71256	-.34318				-1.9420	-1.1492
1.5	-.001101	-.00150			.00027	.013267	.00316	-.00010				-.01368	.00037	.03106	.24563	.11483			.73317	-.29495				-2.1063	-1.2767
1.6	-.00083	-.000975			.00027	.012589	.00334	-.00008				-.01469	-.00012	.02330	.25999	.07439			.74467	-.23430				-2.2303	-1.3622
1.7	-.00055	-.000446			.00026	.011938	.00352	-.00006				-.01563	-.00027	.01553	.27371	.03405			.74730	-.16381				-2.3083	-1.4015
1.8	-.000413	+.000067			.00026	.011318	.00369	-.00003				-.01522	-.00023	.01165	.28671	-.00511			.74147	-.08646				-2.3374	1.3892
1.9	-.000275	+.000548			.00025	.01074	.00384	0				-.01498	+.00012	.00776	.29905	-.04180			.72785	-.00539				-2.3160	-1.3286
2.0	0	+.000982			.00025	.01019	.00399	+.00003				-.01462	+.00092	0	.31074	-.07498			.70726	+.07615				-2.2451	-1.2259
2.1	0	.00136			.00025	.00965	.00414	.00005				-.01396	+.00169	0	.32183	-.10390			.68060	+.15496				-2.1270	-1.0736
2.2	0	.00167			.00024	.00915	.00427	.00008	0	0	.8332	-.01272	+.00269	0	.33234	-.12727			.64737	+.22812	0	0	128.79	-1.9664	.98681

TABLE I — CONTINUED

(43) α	(45) A	(46) M_2	(47) θ	(48) $\dot\beta$	(49) $\dot\beta^2$	(50) β	(52) $\dot\alpha$	(53) α^2	(54) θ^2	(55)	(56) α	(57) C	(58) L_2	(59) β	(60) β	(61) θ	(62) $\dot\alpha$	(63) θ^2	(64) $\dot\alpha^2$	(65)	(66) α	(67) B
	(33)+(34)+(35)+(36)+(37)	3.682 X FROM FIGURE 2/	-8.4246 (27)	-2.308 (19)	4.9053 (31)	(50) (28)	-21.213 (20)	.1585 (32)	.8712 (30)	128.79 -(53)-(54)	-(55) (29)	(46)+(47)+(48)	+(51)+(52)+(56) -15.13 X FROM FIGURE 2/	-1.012 (19)	.05187 (28)	4.1724 (27)	.20725 (20)	.26966 (30)	.049053 (32)	23.04 -(63)-(64)	(65) (29)	(58)+(59)+(60)+(61)+(62)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	-.01445	.4076	0	0	0	0	0	0	0	0	0	.4076	-.1652	0	0	0	0	0	0	0	0	-.1652
0	-.02588	.7376	+.0002	+.0059	0	5.309	+.0005	+.0004		128.79	.0001	.7447	-.2989	+.0026	0	0	0			23.04	0	-.2963
0	-.04069	1.1840	.0015	.0273	.0007	5.3097	+.0049	.0011			.0005	1.2193	-.4798	.0120	0	-.0007	0				-.0001	-.4686
0	-.04598	1.3781	.0042	.0610	.0034	5.3124	.0138	0			.0003	1.4574	-.5584	.0268	-.0001	-.0021	0				0	-.5338
-.00002	-.04598	1.4286	.0083	.0944	.0091	5.3181	.0275	-.0052			-.0021	1.5565	-.5789	.0436	-.0003	-.0041	+.0001				+.0004	-.5398
-.00005	-.04307	1.3975	.0138	.1382	.0176	5.3266	.0458	-.0151			-.0082	1.5720	-.5663	.0606	-.0004	-.0068	.0001				.0915	-.5103
-.00013	-.03797	1.3005	.0205	.1749	.0282	5.3372	.0682	-.0299			-.0197	1.5145	-.5270	.0767	-.0007	-.0101	.0003				.0035	-.4579
-.000244	-.03238	1.1840	.0282	.2077	.0397	5.3487	.0943	-.0495			-.03774	1.4270	-.4798	.0911	-.0009	-.0140	.0005				.0068	-.3963
-.000437	-.02664	1.0659	.0368	.2361	.0513	5.3603	.1236	-.0729			-.0661	1.3134	-.4279	.1035	-.0012	-.0182	.0007				.0118	-.3313
-.00065	-.02094	.9200	.0461	.25981	.0622	5.3712	.1554	-.0994			-.1002	1.1817	-.3728	.1139	-.0015	-.0228	.0010				.0179	-.2643
-.00073	-.01582	.7958	.0559	.27869	.07152	5.3805	.1893	-.1281			-.1433	1.0483	-.3225	.1222	-.0018	-.0277	.0013				.0256	-.2029
-.001237	-.01127	.6794	.0661	.29316	.07914	5.3881	.2246	-.1582			-.1959	.9092	-.2753	.1285	-.0022	-.0328	.0015				.0350	-.1453
-.00167	-.00762	.5823	.0766	.30350	.08482	5.3938	.2609	-.1887			-.2578	.7768	-.2360	.1331	-.0025	-.0380	.0018				.0461	-.0965
-.00213	-.0047	.4853	.0873	.31026	.08864	5.3976	.2978	-.2190			-.3289	.6328	-.1966	.1360	-.0029	-.0432	.0021				.0588	-.0458
-.00264	-.00194	.4115	.0980	.31347	.09049	5.3995	.3347	-.2484			-.4088	.5005	-.1667	.1374	-.0032	-.0485	.0024				.0731	-.0055
-.00324	+.00040	.3416	.0874	.3138	.09067	5.3997	.3715	-.2761			-.4969	.3626	-.1384	.1376	-.0036	-.0539	.0027				.0889	+.0333
-.00383	+.00202	.2834	.1139	.3114	.08928		.4077	-.3016			-.5922	.2281	-.1148	.1365	-.0039	-.0591	.0029				.1059	+.0675
-.00449	.00303	.2368	.12993	.3065	.08651		.4430	-.3245			-.6942	.0975	-.09595	.1344	-.0043	-.0644	.0032				.1242	+.0971
-.00517	.00375	.1980	.14039	.2996	.08263		.4777	-.3442			-.8048	-.0333	-.08022	.1313	-.0046	-.0695	.0034				.1429	.1233
-.00671	.00438	.1359	.1603	.2820			.5405	-.3766			-1.0370	-.2949	-.06506	.1236	-.0052	-.0794	.0037				.1865	.1731
-.00829	.00432	.08928	.17929	.25744			.5763	-.3937			-1.2812	-.5626	-.03618	.11287	-.0058	-.0888	.0038				.2292	.21509
-.00984	.00370	.05823	.19726	.2270			.6440	-.3937			-1.5202	-.7874	-.02360	.09963	-.0062	-.0977	.0038				.2720	.2478
-.01128	.00250	.04658	.21423	.19205			.68280	-.3767			-1.7438	-.9848	-.01888	.08424	-.0066	-.1061	.0037				.3120	.2683
-.01236	.00115	.03882	.23029	.15453			.71256	-.34318			-1.9420	-1.1492	-.01573	.06767	-.0069	-.1141	.0034				.3474	.2817
-.01363	.00037	.03106	.24553	.11483			.75317	-.29495			-2.1063	-1.2767	-.01258	.05035	-.0071	-.1216	.0029				.3768	.2888
-.01449	-.00012	.02330	.25999	.07439			.74467	-.23430			-2.2303	-1.3622	-.00944	.03262	-.00727	-.1288	.00229				.3990	.28842
-.01493	-.00027	.01553	.27371	.03405			.74730	-.16381			-2.3083	-1.4015	-.00629	.01493	-.00730	-.1356	.00160				.41295	.28033
-.01512	-.00023	.01165	.28671	-.00511			.74147	-.08646			-2.3374	-1.3892	-.00472	-.00224	-.00724	-.1420	.00085				.41815	.26280
-.01498	+.00012	.00776	.29905	-.04180			.72785	-.00539			-2.3160	-1.3286	-.00315	-.01833	-.00711	-.1481	.00005				.41433	.23769
-.01452	+.00092	0	.31074	-.07498			.70726	+.07615			-2.2451	-1.2259	0	-.03287	-.00690	-.1539	-.00074				.40163	.20722
-.01376	+.00169	0	.32183	-.10390			.68060	+.15496			-2.1270	-1.0736	0	-.04656	-.00664	-.1594	-.00151				.38051	.16741
-.01272	+.00269	0	.33234	-.12727			.64737	+.22812	0	0	128.79 -1.9664	-.88681	0	-.05680	-.00632	-.1646	-.00223	0	0	23.04	.35177	.12283

TABLE I CONTINUED

TABLE II : STEP BY STEP SOLUTION OF EQUATIONS OF MOTION - SINGLE JOINT ATTACHMENT

		.4733 (56)n-1	.4336 (45)n-1	(3)-(4)	2.5900 (45)n-1	2.1679 (56)n-1	(6)-(7)	.10528 (43)n-1	.03664 (56)n-1	-.05372 (57)n-1	(9)+(10)+(11)	(2)(5)	(2)(8)	(2)(12)	(16)n-1 + (13)	(17)n-1 + (14)	(18)n-1 + (15)	(2)(19)	(2)(17)	(2)(18)	(5)/N (2)²	(8)/N (2)²	(12)/N (2)²	
	Δt	.4733 A	.4336 B	$\ddot{\phi}$	2.5900 B	2.1679 A	$\ddot{\beta}$	.10528 B	.03664 A	-.05377 A	$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	$\dot{\alpha}$	$\dot{\phi}\Delta t$	$\dot{\beta}\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$	$\frac{\ddot{\beta}}{2}\Delta t^2$	$\frac{\ddot{\alpha}}{2}\Delta t^2$	
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(2
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	.025	.09343	.04431	.04912	.26470	.42794	-.16324	.01076	.00723	-.01382	.00417	.001228	-.004081	.000104	.001228	-.004081	.000104	.0000307	-.0001020	.0000026	.00001535	-.000051	.0000013	.000
	.050	.16621	.07953	.08668	.47506	.76133	-.28627	.01931	.01287	-.01966	.01252	.004334	-.014314	.000626	.005562	-.018395	.000730	.000278	-.0009198	.000037	.000108	-.000358	.0000156	.000
	.050	.25875	.13579	.13296	.75138	1.18518	-.43380	.03054	.02003	-.01628	.03429	.006648	-.02169	.001715	.012210	-.04009	.002445	.000611	-.00200	.000122	.000166	-.000542	.000043	.001
	.050	.28731	.14309	.14422	.83475	1.31598	-.46124	.03474	.02224	+.00449	.06147	.007211	-.02306	.003074	.019421	-.06315	.005519	.000971	-.003158	.000276	.000186	-.000577	.000077	.002
	.050	.28709	.14738	.13971	.88032	1.31498	-.43466	.03578	.02222	.02952	.08782	.006986	-.02176	.004376	.026407	-.08488	.009895	.001320	-.004244	.000495	.000175	-.000543	.000109	.003
	.050	.26981	.14390	.12561	.85954	1.23445	-.37491	.03494	.02086	.05259	.10939	.006280	-.01875	.00547	.03269	-.10363	.01537	.00163	-.00518	.00077	.000160	-.00047	.00014	.00
	.050	.24207	.13625	.10582	.81388	1.10879	-.29491	.03308	.01874	.07349	.12581	.005290	-.01475	.00627	.03798	-.11838	.02164	.00190	-.00592	.00108	.00013	-.00037	.00016	.00
	.050	.21502	.12932	.08570	.77244	.98490	-.21246	.03140	.01665	.08668	.13473	.004290	-.01062	.00674	.04227	-.12900	.02838	.00211	-.00645	.00142	.00011	-.00027	.00017	.00
	.050	.19254	.12523	.06731	.74804	.88190	-.13386	.03041	.01491	.09263	.13800	.003370	-.00669	.00690	.04564	-.13569	.03528	.00228	-.00678	.00176	.00008	-.00017	.00017	.01
	.050	.17294	.12324	.04970	.73616	.79215	-.05599	.02992	.01339	.09242	.13573	.002490	-.00280	.00679	.04813	-.13849	.04207	.00241	-.00692	.00210	.00006	-.00007	.00017	.01
	.050	.16053	.12546	.03507	.74944	.73529	+.01415	.03046	.01343	.08565	.12854	.001750	+.00071	.00643	.04988	-.13778	.04850	.00249	-.00689	.00243	.00004	+.00002	.00016	.01
	.050	.15648	.13253	.02395	.79161	.71673	.07488	.03218	.01211	.07308	.11737	.001200	.00374	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003	.00009	.00015	.01
	.050	.15893	.14347	.01546	.85698	.72796	.12902	.03484	.01230	.05617	.10331	.000770	.00645	.00517	.05185	-.12759	.05954	.00259	-.00638	.00298	.00002	.00016	.00013	.02
	.050	.16577	.15721	.00856	.93906	.75929	.17977	.03817	.01283	.03603	.08702	.000430	.00899	.00435	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001	.00022	.00011	.02
	.050	.17930	.17470	.00460	1.04354	.82127	.22227	.04242	.01388	+.01300	.06930	.000230	.01111	.00347	.05231	-.10749	.06736	.00263	-.00537	.00337	.00001	.00028	.00009	.02
	.100	.19661	.19455	.00206	1.16208	.90057	.26151	.04724	.01522	-.01170	.05076	.000100	.01308	.00254	.05261	-.09441	.06990	.00263	-.00472	.00350	0	.00033	.00006	.03
	.100	.21592	.21565	+.00027	1.28814	.98902	.29912	.05236	.01672	-.03118	+.03190	+.000030	.02991	+.00319	.05264	-.06450	.07309	.00526	-.00645	.00731	0	.00150	+.00016	.03
	.100	.26485	.26541	-.00056	1.58536	1.21311	.37225	.06444	.02050	-.09173	-.00684	-.000060	.03723	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0	.00186	-.00005	.04
	.100	.31352	.31396	-.00044	1.87537	1.43604	.43933	.07623	.02427	-.14344	-.04292	-.000040	.04393	-.00429	.05254	+.01666	.06812	.00525	+.00167	.00681	0	.00230	-.00021	.04
	.100	.35568	.35718	-.00150	2.13351	1.62916	.50435	.08872	.02753	-.18934	-.07509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001	.00252	-.00038	.06
	.100	.38858	.39264	-.00406	2.34535	1.77985	.56550	.09534	.03008	-.22830	-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002	.00283	-.00052	.05
	.100	.41131	.41912	-.00781	2.50352	1.88397	.61955	.10176	.03184	-.26053	-.12693	-.00078	.06196	-.01269	.05120	.18561	.03761	.00512	.01856	.00376	-.00004	.00310	-.00063	.06
	.100	.41922	.43357	-.01435	2.58979	1.92017	.66962	.10527	.03245	-.28438	-.14666	-.00144	.06696	-.01467	.04976	.25257	.02294	.00498	.02526	.00229	-.00007	.00335	-.00073	.06
	.100	.41143	.43480	-.02337	2.59717	1.88453	.71264	.10557	.03185	-.30036	-.16294	-.00234	.07126	-.01629	.04742	.32383	+.00665	.00474	.03238	+.00067	-.00012	.00356	-.00081	.07
	.100	.38811	.42206	-.03395	2.52108	1.77770	.74338	.10248	.03005	-.30804	-.17631	-.00340	.07434	-.01763	.04402	.39817	-.01098	.00440	.03982	-.00110	-.00017	.00370	-.00088	.07
	.100	.35317	.39627	-.04310	2.36700	1.61764	.74936	.09622	.02734	-.31013	-.18657	-.00431	.07494	-.01866	.03971	.47311	-.02964	.00397	.04731	-.00296	-.00022	.00375	-.00093	.07
	.100	.30376	.35548	-.05172	2.12339	1.39186	.73203	.08631	.02352	-.30225	-.19272	-.00517	.07320	-.01927	.03454	.54631	-.04891	.00345	.05463	-.00489	-.00026	.00366	-.00096	.08
	.100	.24871	.30296	-.05485	1.80966	1.13646	.67320	.07356	.01921	-.28651	-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027	.00357	-.00097	.08
	.100	.18329	.23757	-.05428	1.41906	.83956	.57950	.05768	.01419	-.25941	-.18754	-.00543	.05795	-.01875	.02362	.67158	-.08704	.00236	.06716	-.00870	-.00027	.00290	-.00094	.08

TABLE II : STEP BY STEP SOLUTION OF EQUATIONS OF MOTION - SINGLE JOINT AT

		.4733 (36)$_{n-1}$	.4336 (45)$_{n-1}$	(3)-(4)	2.5900 (45)$_{n-1}$	2.1679 (36)$_{n-1}$	(6)-(7)	.10528 (25)$_{n-1}$	.03664 (36)$_{n-1}$	-.05377 (53)$_{n-1}$	(9)+(10)+(11)	(2)(5)	(2)(8)	-(2)(12)	(16)$_{n-1}$+(13)	-(17)$_{n-1}$+(14)	(18)$_{n-1}$+(15)	(2)(16)	(2)(17)	(2)(18)	(2)^2(5)/2
t	Δt	.4733A,	.4336B,	$\ddot{\phi}$	2.5900B	2.1679A,	$\ddot{\beta}$	.10528B,	.03664A,	-.05377A,	$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	$\dot{\alpha}$	$\dot{\phi}\Delta t$	$\dot{\beta}\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.025	.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.050	.025	.09343	.04431	.04912	.26470	.42794	-.16324	.01076	.00723	-.01382	.00417	.001228	-.004081	.000104	.001228	-.004081	.000104	.0000307	-.0001020	.0000026	.00001535
.10	.050	.16621	.07953	.08668	.47506	.76133	-.28627	.01931	.01287	-.01966	.01252	.004334	-.014314	.000626	.005562	-.018395	.000730	.000278	-.0009198	.000037	.000108
.15	.050	.25875	.12579	.13296	.75138	1.18518	-.43380	.03054	.02003	-.01628	.03429	.006648	-.02169	.001715	.012210	-.04009	.002445	.000611	-.00200	.000122	.000166
.20	.050	.28731	.14309	.14422	.83475	1.31598	-.46124	.03474	.02224	+.00449	.06147	.007211	-.02306	.003074	.019421	-.06315	.005519	.000971	-.003158	.000276	.000180
.25	.050	.28709	.14738	.13971	.88032	1.31498	-.43466	.03578	.02222	.02952	.08752	.006986	-.02176	.004376	.026407	-.08488	.009895	.001320	-.004244	.000495	.000175
.30	.050	.26951	.14390	.12561	.85954	1.23445	-.37491	.03494	.02086	.05359	.10939	.006280	-.01875	.00547	.03269	-.10363	.01537	.00163	-.00518	.00077	.000160
.35	.050	.24207	.13625	.10582	.81388	1.10879	-.29491	.03308	.01874	.07349	.12581	.005290	-.01475	.00621	.03798	-.11838	.02164	.00190	-.00592	.00108	.00013
.40	.050	.21502	.12932	.08570	.77244	.98490	-.21246	.03140	.01665	.08668	.13473	.004290	-.01062	.00674	.04227	-.12900	.02838	.00211	-.00645	.00142	.00011
.45	.050	.19254	.12523	.06731	.74804	.88190	-.13386	.03041	.01491	.09265	.13800	.003370	-.00669	.00690	.04564	-.13569	.03528	.00228	-.00678	.00176	.00008
.50	.050	.17294	.12324	.04970	.73616	.79215	-.05599	.02992	.01339	.09242	.13573	.002490	-.00280	.00679	.04813	-.13849	.04207	.00241	-.00692	.00210	.00006
.55	.050	.16053	.12546	.03507	.74944	.73529	+.01415	.03046	.01243	.08565	.12854	.001750	+.00071	.00643	.04988	-.13778	.04850	.00249	-.00689	.00243	.00004
.60	.050	.15648	.13253	.02395	.79161	.71673	.07488	.03218	.01211	.07308	.11737	.001200	.00374	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003
.65	.050	.15893	.14347	.01546	.85698	.72796	.12902	.03484	.01230	.05617	.10331	.000770	.00645	.00517	.05185	-.12759	.05954	.00259	-.00638	.00298	.00002
.70	.050	.16577	.15721	.00856	.93906	.75929	.17977	.03817	.01283	.03601	.08702	.000430	.00899	.00435	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001
.75	.050	.17930	.17470	.00460	1.04354	.82127	.22221	.04242	.01388	+.01300	.06930	.000230	.01111	.00347	.05251	-.10749	.06736	.00263	-.00537	.00337	.00001
.80	.100	.19661	.19455	.00206	1.16208	.90057	.26151	.04724	.01522	-.01170	.05076	.000100	.01308	.00254	.05261	-.09441	.06990	.00263	-.00472	.00350	0
.90	.100	.21592	.21565	+.00027	1.28814	.98902	.29912	.05236	.01672	-.03118	+.03190	+.000030	.02991	+.00319	.05264	-.06450	.07309	.00526	-.00645	.00731	0
1.00	.100	.26485	.26541	-.00056	1.58536	1.21311	.37225	.06444	.02050	-.09175	-.00684	-.000060	.03723	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0
1.10	.100	.31352	.31396	-.00044	1.87537	1.43604	.43983	.07623	.02427	-.14341	-.04292	-.000040	.04393	-.00429	.05254	+.01666	.06812	.00525	+.00167	.00681	0
1.20	.100	.35568	.35718	-.00150	2.13351	1.62916	.50435	.06872	.02753	-.18936	-.07509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001
1.30	.100	.38858	.39264	-.00406	2.34535	1.77985	.56550	.09534	.03008	-.22836	-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002
1.40	.100	.41131	.41912	-.00781	2.50352	1.88397	.61955	.10176	.03184	-.26053	-.12693	-.00078	.06196	-.01269	.05120	.18561	.03761	.00512	.01856	.00376	-.00004
1.50	.100	.41922	.43357	-.01435	2.58979	1.92017	.66962	.10527	.03245	-.28438	-.14666	-.00144	.06696	-.01467	.04976	.25257	.02294	.00498	.02526	.00229	-.00007
1.60	.100	.41143	.43480	-.02337	2.59717	1.88453	.71264	.10567	.03185	-.30034	-.16294	-.00234	.07126	-.01629	.04742	.32383	+.00665	.00474	.03238	+.00067	-.00012
1.70	.100	.38811	.42206	-.03395	2.52108	1.77770	.74338	.10248	.03005	-.30854	-.17631	-.00340	.07434	-.01763	.04402	.39817	-.01098	.00440	.03982	-.00110	-.00017
1.80	.100	.35317	.39627	-.04310	2.36700	1.61764	.74936	.09622	.02734	-.31013	-.18657	-.00431	.07494	-.01866	.03971	.47311	-.02964	.00397	.04731	-.00296	-.00022
1.90	.100	.30376	.35548	-.05172	2.12339	1.39186	.73203	.08631	.02352	-.30225	-.19212	-.00517	.07320	-.01927	.03454	.54631	-.04891	.00345	.05463	-.00489	-.00026
2.00	.100	.24871	.30296	-.05485	1.80966	1.13646	.67320	.07356	.01921	-.28657	-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027
2.10	.100	.18329	.23757	-.05428	1.41906	.83956	.57950	.05768	.01419	-.25941	-.18754	-.00543	.05795	-.01875	.02362	.67158	-.08704	.00236	.06716	-.00870	-.00027

BY STEP SOLUTION OF EQUATIONS OF MOTION - SINGLE JOINT ATTACHMENT - ROLL MOTION

-.05377	$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	α	$\dot{\phi}\Delta t$	$\dot{\beta}\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$	$\frac{\ddot{\beta}}{2}\Delta t^2$	$\frac{\ddot{\alpha}}{2}\Delta t^2$	ϕ	β	α
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-.01382	.00417	.001228	-.004081	.000104	.001228	-.004081	.000104	.0000307	-.0001020	.0000026	.00001535	-.000051	.0000013	.0000461	-.000153	.0000039
-.01966	.01252	.004334	-.014314	.000626	.005562	-.018395	.000730	.000278	-.0009198	.000037	.000108	-.000358	.0000186	.000432	-.001431	.000056
-.01628	.03429	.006648	-.02169	.001715	.012210	-.04009	.002445	.000611	-.00200	.000122	.000166	-.000542	.000043	.001209	-.003973	.000221
+.00449	.06147	.001211	-.02306	.003074	.019421	-.06315	.005519	.000971	-.003158	.000276	.000180	-.000577	.000071	.002360	-.007708	.000575
.029521	.08752	.006986	-.02176	.004376	.026467	-.08488	.009895	.001320	-.004244	.000495	.000175	-.000543	.000109	.003855	-.012495	.001179
.05259	.10939	.006280	-.01875	.00547	.03269	-.10363	.01537	.00163	-.00518	.00077	.000160	-.00047	.00014	.00565	-.01815	.00209
.07349	.12581	.005290	-.01475	.00627	.03798	-.11838	.02164	.00190	-.00592	.00108	.00013	-.00037	.00016	.00768	-.02444	.00333
.08668	.13473	.004290	-.01062	.00674	.04227	-.12900	.02838	.00211	-.00645	.00142	.00011	-.00027	.00017	.00990	-.03116	.00492
.09269	.13800	.003370	-.00669	.00690	.04564	-.13569	.03528	.00228	-.00678	.00176	.00008	-.00017	.00017	.01226	-.03811	.00685
.09242	.13673	.002490	-.00280	.00679	.04813	-.13849	.04209	.00241	-.00692	.00210	.00006	-.00007	.00017	.01473	-.04510	.00912
.08565	.12854	.001750	+.00071	.00643	.04988	-.13778	.04850	.00249	-.00689	.00243	.00004	+.00002	.00016	.01726	-.05198	.01171
.07308	.11737	.001200	.00374	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003	.00009	.00015	.01984	-.05859	.01458
.05617	.10331	.000770	.00645	.00517	.05185	-.12759	.05954	.00259	-.00638	.00298	.00002	.00016	.00013	.02245	-.06481	.01769
.03603	.08702	.000430	.00899	.00435	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001	.00022	.00011	.02507	-.07052	.02099
+.01300	.06930	.000230	.01111	.00347	.05231	-.10749	.06736	.00263	-.00537	.00337	.00001	.00028	.00009	.02771	-.07561	.02445
-.01170	.05076	.000100	.01308	.00254	.05261	-.09441	.06990	.00263	-.00472	.00350	0	.00033	.00006	.03034	-.08000	.02801
-.03113	+.03190	+.000030	.02991	+.00319	.05264	-.06460	.07303	.00526	-.00645	.00781	0	.00150	+.00016	.03560	-.08495	.03548
-.09173	-.00684	-.000060	.03723	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0	.00186	-.00003	.04086	-.08582	.04269
-.14372	-.04292	-.000040	.04393	-.00429	.05254	+.01666	.06812	.00525	+.00167	.00681	0	.00230	-.00021	.04611	-.08195	.04929
-.18934	-.07509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001	.00252	-.00038	.05134	-.07272	.05497
-.22853	-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002	.00283	-.00052	.05652	-.05752	.05948
-.26053	-.12698	-.00078	.06196	-.01269	.05120	.18561	.03761	.00512	.01856	.00376	-.00004	.00310	-.00063	.06160	-.03586	.06261
-.28435	-.14666	-.00144	.06696	-.01467	.04976	.25257	.02294	.00498	.02526	.00229	-.00007	.00335	-.00073	.06651	-.00725	.06417
-.30036	-.16294	-.00234	.07126	-.01629	.04742	.32383	+.00665	.00474	.03238	+.00067	-.00012	.00356	-.00081	.07113	+.02869	.06403
-.30884	-.17631	-.00340	.07434	-.01763	.04402	.39817	-.01098	.00440	.03982	-.00110	-.00017	.00370	-.00088	.07536	.07223	.06205
-.31013	-.18657	-.00431	.07494	-.01866	.03971	.47311	-.02964	.00397	.04731	-.00296	-.00022	.00376	-.00093	.07911	.12329	.05816
-.30225	-.19212	-.00317	.07320	-.01927	.03454	.54631	-.04891	.00345	.05463	-.00489	-.00026	.00366	-.00096	.08230	.18158	.05231
-.28651	-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027	.00357	-.00097	.08548	.24631	.04451
-.25941	-.18754	-.00543	.05795	-.01875	.02362	.67158	-.08704	.00236	.06716	-.00870	-.00027	.00290	-.00094	.08757	.31637	.03487

TABLE II
STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION
SINGLE-JOINT ATTACHMENT - ROLL MOTION

TABLE II CONTINUED

FIGURE 2

	(16)² × (26)	-24.12 (28)	-74.9 (18)	2.306 (17)	5.309 (26)	21.21 (18)	128.76 (27)	X_t/X_{MAX}	-.9010 (33)	(25)+(30)+(31)+(32)+(33)+(34)+(35)	.3581 (33)	-7.476 (28)	-4.503 (16)	-1.012 (17)	1.1775 (26)	.2071 (18)	23.037 (27)	(30)+---(44)	.692 (35)	2(16)(17)	(17)²
t	$\dot{\phi}^2\beta$	$-24.12\dot{\phi}^2\beta$	$-74.9\dot{\phi}$	$2.306\dot{\beta}$	5.309β	$21.21\dot{\alpha}$	128.76α	Gust Factor	$M_2 \times 10^{-3}$	C_1	$L_2 \times 10^{-5}$	$-7.476\dot{\phi}^2\beta$	$-4.503\dot{\phi}$	$-1.012\dot{\beta}$	1.1775β	$.2071\dot{\alpha}$	23.037α	B_1	$L_0 \times 10^{-6}$	$2\dot{\phi}\dot{\beta}$	$\dot{\beta}^2$
	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.025	0	0	0	0	0	0	0	.2833	.2571	.2571	.1022	0	0	0	0	0	.00000	.1022	.19783	0	0
.050	0	0	-.091977	-.009411	-.000812	.002206	.000302	.5163	.465186	.365694	.18489	0	-.00553	.00413	-.00018	.00002	.00009	.18342	.35728	-.00001	.00002
.10	0	0	-.41659	-.042419	-.007597	.01548	.00721	.8288	.74675	.36263	.29679	0	-.02506	.01862	-.00169	.00015	.00129	.29011	.57352	-.00020	.00034
.15	-.000001	.000024	-.91453	-.09245	-.021093	.05186	.02846	.95923	.86427	-.08347	.3435	.00001	-.05498	.04057	-.00468	.00051	.00509	.33002	.66379	-.00098	.00161
.20	-.000003	.000072	-1.45463	-.14562	-.04092	.11706	.07404	1.0000	.9010	-.54900	.3581	.00002	-.08745	.06391	-.00908	.00114	.01325	.33989	.69200	-.00245	.00397
.25	-.000009	.00022	-1.97788	-.19573	-.06634	.20987	.15181	.97826	.88141	-.99664	.35031	.00007	-.11891	.08590	-.01471	.00205	.02716	.33187	.67696	-.00448	.00720
.30	-.000019	.00046	-2.44848	-.23897	-.09636	.32600	.26911	.91168	.82142	-1.36682	.32647	.00014	-.14720	.10487	-.02137	.00318	.04815	.31424	.63088	-.00678	.01074
.35	-.000035	.00084	-2.84470	-.27298	-.12975	.45898	.42877	.82880	.74675	-1.61209	.29679	.00026	-.17102	.11980	-.02878	.00448	.07671	.29824	.57353	-.00899	.01401
.40	-.000056	.00135	-3.16602	-.29747	-.16543	.60194	.63350	.74185	.66841	-1.72372	.26566	.00042	-.19034	.13055	-.03669	.00588	.11334	.28882	.51336	-.01091	.01664
.45	-.000079	.00191	-3.41844	-.31290	-.20233	.74829	.88201	.64674	.58271	-1.71875	.23160	.00059	-.20552	.13732	-.04487	.00731	.15780	.28423	.44754	-.01239	.01841
.50	-.000110	.00241	-3.60494	-.31936	-.23944	.89250	1.17429	.55707	.50192	-1.59206	.19949	.00075	-.21693	.14015	-.05311	.00871	.21010	.28926	.36549	-.01333	.01918
.55	-.00013	.00314	-3.78601	-.31772	-.27696	1.02869	1.50778	.47826	.43091	-1.38917	.17126	.00097	-.22461	.13943	-.06121	.01004	.26976	.30564	.33096	-.01374	.01898
.60	-.00015	.00362	-3.82589	-.30910	-.31105	1.15319	1.87732	.40761	.36726	-1.04465	.14597	.00112	-.23001	.13565	-.06899	.01126	.33588	.33088	.28207	-.01369	.01797
.65	-.00017	.00410	-3.88357	-.29422	-.34408	1.26284	2.27776	.34103	.30727	-.6699	.12212	.00127	-.23348	.12912	-.07631	.01233	.40752	.36257	.23599	-.01323	.01628
.70	-.00019	.00458	-3.91577	-.27349	-.37439	1.35511	2.70267	.28804	.25952	-.2417	.10315	.00142	-.23542	.12002	-.08304	.01323	.48355	.40291	.19932	-.01240	.01407
.75	-.00021	.00507	-3.93300	-.24787	-.40141	1.42871	3.14818	.24185	.21791	+.2175	.08661	.00157	-.23648	.10878	-.08903	.01395	.56325	.44868	.16736	-.01129	.01155
.80	-.00022	.00531	-3.94049	-.21771	-.42472	1.48258	3.60487	.19973	.17996	.6915	.07152	.00164	-.23690	.09354	-.09470	.01448	.64527	.49135	.13821	-.00993	.00891
.90	-.00024	.00579	-3.94274	-.14874	-.45100	1.55024	4.56840	.13859	.12487	1.7063	.04963	.00179	-.23704	.06327	-.10003	.01514	.81735	.61211	.09590	-.00679	.00416
1.00	-.00024	.00579	-3.93824	-.06288	-.45562	1.53582	5.49676	.09311	.08669	2.6673	.03406	.00179	-.23677	+.02760	-.10105	.01500	.98345	.72408	.06587	-.00287	.00074
1.10	-.00023	.00555	-3.93525	+.03842	-.43507	1.44483	6.34658	.06250	.05631	3.5213	.02238	.00172	-.23659	-.01686	-.09650	.01411	1.13549	.82375	.04325	+.00175	+.00028
1.20	-.00020	.00482	-3.92401	.15473	-.38607	1.28554	7.07794	.04076	.03672	4.249	.01460	.00150	-.23591	-.06791	-.08563	.01255	1.26634	.90554	.02821	+.00703	.00450
1.30	-.00016	.00386	-3.89330	.28514	-.30837	1.06686	7.65864	.03261	.02938	4.84	.01168	.00120	-.23407	-.12613	-.06773	.01042	1.37024	.96661	.02257	.01285	.01529
1.40	-.00009	.00217	-3.83488	.42802	-.19038	.79771	8.06166	.02717	.02448	5.23	.00973	.00067	-.23055	-.18784	-.04223	.00779	1.44235	.99992	.01880	.01901	.03445
1.50	-.00002	+.00048	-3.72702	.58243	-.03849	.48656	8.26253	.02174	.01959	5.58	.00179	+.00015	-.22407	-.25560	-.00853	.00475	1.47128	1.00277	.01504	.02514	.06379
1.60	+.00006	-.00145	-3.55176	.74675	+.15232	+.14105	8.24450	.01359	.01224	5.74	.00487	-.00046	-.21353	-.32772	+.03378	+.00138	1.47506	.97339	.00940	.03072	.10487
1.70	+.00014	-.00338	-3.29710	.91818	+.38347	-.23289	7.98956	.01087	.00979	5.76	.00389	-.00105	-.19822	-.40295	.03505	+.00227	1.42945	.91390	.00752	.03506	.15854
1.80	+.00019	-.00458	-2.97428	1.09099	.65455	-.62866	7.48868	0	0	5.62	0	-.00142	-.17881	-.47879	.14517	-.00614	1.33983	.81984	0	.03758	.22289
1.90	.00022	-.00531	-2.58705	1.25979	.96401	-1.03738	6.73644	0	0	5.32	0	-.00164	-.15553	-.55287	.21381	-.01013	1.20507	.69871	0	.03774	.29845
2.00	.00021	-.00507	-2.17585	1.41503	1.30766	-1.44843	5.73111	0	0	4.82	0	-.00157	-.13081	-.62099	.29003	-.01414	1.02538	.54790	0	.03566	.37654

TABLE II CONTINUED

(21)+(30)+(31)+(32)+(33)+(34)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)
	.3581 (33)	-7.476 (28)	-4.503 (16)	-1.012 (17)	1.1775 (26)	.2071 (18)	23.037 (21)	(38)+---(44)	.692 (33)	2(16)(17)	(17)²	(47)+(48)	1.493(47)(26)	-.8065 (16)	-.906 (17)	.0510 (26)	.2039 (18)	23.08 (27)	(46)+(50)+(55)
C_1	$L_2 \times 10^{-3}$	$-7.476\dot{\phi}^2\beta$	$-4.503\dot{\phi}$	$-1.012\dot{\beta}$	1.1775β	$.2071\dot{\alpha}$	23.037α	B_1	$L_0 \times 10^{-6}$	$2\dot{\phi}\dot{\beta}$	$\dot{\beta}^2$	$2\dot{\phi}\dot{\beta}+\dot{\beta}^2$	$1.493\beta(2\dot{\phi}\dot{\beta}+\dot{\beta}^2)$	$-8.065\dot{\phi}$	$-.906\dot{\beta}$	$.0510\beta$	$.2039\dot{\alpha}$	23.08α	A_1
(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.2571	.1022	0	0	0	0	0	.00000	.1022	.19783	0	0	0	0	0	0	0	0	0	.19740
365694	10409	0	-.00553	.00413	-.00018	.00002	.00009	.18342	.35728	-.00001	.00002	.00001	0	-.009904	.00370	-.00001	.00002	.00009	.35118
30283	29679	0	-.02505	.01862	-.00169	.00015	.00129	.29011	.57352	-.00020	.00034	.00014	0	-.04486	.01667	-.00007	.00015	.00129	.54670
.08341	3435	.00001	-.05498	.04057	-.00460	.00051	.00509	.33002	.66379	-.00098	.00161	.00063	0	-.09847	.03632	-.00020	.00050	.00510	.60703
.5490	3581	.00002	-.08745	.06391	-.00908	.00114	.01325	.33989	.69200	-.00245	.00399	.00154	-.00002	-.15663	.05721	-.00039	.00113	.01327	.60657
.99664	35031	.00007	-.11891	.08590	-.01411	.00205	.02716	.33187	.67696	-.00448	.00720	.00272	-.00005	-.21297	.07690	-.00064	.00201	.02721	.56942
1.3668	32647	.00014	-.14720	.10487	-.02137	.00318	.04815	.31424	.63088	-.00678	.01074	.00396	-.00011	-.26364	.09389	-.00093	.00313	.04824	.51146
1.61209	29679	.00026	-.17102	.11980	-.02878	.00448	.07671	.29824	.57353	-.00899	.01401	.00502	-.00018	-.30631	.10725	-.00125	.00441	.07686	.45431
1.72372	26566	.00042	-.19034	.13055	-.03669	.00588	.11334	.28882	.51336	-.01091	.01664	.00573	-.00027	-.34091	.11687	-.00159	.00579	.11355	.40680
1.71875	23160	.00059	-.20552	.13732	-.04487	.00731	.15780	.28423	.44754	-.01239	.01841	.00602	-.00034	-.36809	.12294	-.00194	.00719	.15810	.36540
1.5920	19949	.00075	-.21673	.14015	-.05311	.00871	.21010	.28926	.38549	-.01333	.01918	.00585	-.00039	-.38817	.12547	-.00230	.00858	.21049	.33917
1.3591	17126	.00097	-.22461	.13943	-.06121	.01004	.26976	.30564	.33096	-.01374	.01898	.00524	-.00041	-.40228	.12483	-.00265	.00989	.27027	.33061
1.0446	14597	.00112	-.23001	.13565	-.06899	.01126	.33588	.33088	.28207	-.01369	.01897	.00428	-.00037	-.41196	.12144	-.00299	.01109	.33651	.33579
.6699	12212	.00127	-.23348	.12912	-.07631	.01233	.40152	.36257	.23599	-.01323	.01628	.00305	-.00030	-.41847	.11560	-.00331	.01214	.40829	.35024
-.2417	10315	.00142	-.23542	.12002	-.08304	.01323	.48355	.40291	.19932	-.01240	.01407	.00167	-.00018	-.42164	.10745	-.00360	.01303	.48445	.37883
+.2175	.08661	.00157	-.23648	.10878	-.08903	.01395	.56325	.44868	.16736	-.01129	.01155	+.00026	-.00003	-.42349	.09739	-.00386	.01373	.56431	.41541
.6915	.07152	.00164	-.23690	.09554	-.09420	.01448	.64527	.49735	.13821	-.00993	.00891	-.00162	+.00012	-.42430	.08554	-.00408	.01425	.64647	.45621
1.7065	.04963	.00179	-.23704	.06527	-.10008	.01514	.81755	.61211	.09590	-.00679	.00416	-.00263	+.00033	-.42454	+.05844	-.00433	.01490	.81888	.55958
2.6613	.03406	.00179	-.23677	+.02760	-.10105	.01500	.98345	.72408	.06582	-.00287	.00074	-.00213	+.00027	-.42406	+.02471	-.00438	.01476	.98529	.66241
3.52	.02238	.00172	-.23659	-.01686	-.09650	.01411	1.13549	.82375	.04325	+.00135	+.00028	+.00203	-.00026	-.42374	-.01509	-.00418	+.01389	1.13761	.75149
4.24	.01460	.00150	-.23591	-.06791	-.08563	.01255	1.26634	.90564	.02821	+.00705	.00450	+.01153	-.00126	-.42253	-.06079	-.00371	.01236	1.26871	.82100
4.84	.01168	.00120	-.23407	-.12613	-.06773	.01042	1.37024	.96661	.02251	.01285	.01529	+.03814	-.00242	-.41922	-.11203	-.00293	.01026	1.37280	.86903
5.23	.00973	.00067	-.23055	-.18784	-.04223	.00779	1.44235	.99992	.01880	.01901	.03445	.05346	-.00286	-.41293	-.16816	-.00183	.00767	1.44504	.88503
5.58	.00179	+.00015	-.22407	-.25560	-.00853	.00475	1.47828	1.00277	.01504	.02514	.06379	.08893	-.00076	-.40131	-.22883	-.00037	.00468	1.48104	.86929
5.74	.00487	-.00046	-.21353	-.32772	+.03378	+.00138	1.47506	.97339	.00940	.03072	.10487	.13559	+.00581	-.38244	-.29339	+.00146	+.00136	1.47781	.82001
5.76	.0389	-.00105	-.19822	-.40295	.08505	+.00227	1.42945	.91390	.00762	.03506	.15854	.19360	+.02087	-.35502	-.36074	+.00368	-.00224	1.43211	.74618
5.62	0	-.00142	-.17881	-.47879	.14517	-.00614	1.33983	.81984	0	.03768	.22389	.26141	.04812	-.32026	-.42864	.00629	-.00604	1.34233	.64180
5.32	0	-.00164	-.15558	-.55287	.21381	-.01013	1.20507	.69871	0	.03774	.29845	.33619	.09115	-.27857	-.49496	.00926	-.00997	1.20731	.52422
4.82	0	-.00157	-.13081	-.62099	.29003	-.01414	1.02558	.54790	0	.03566	.37654	.41220	.15158	-.23429	-.55595	.01256	-.01392	1.02729	.38727

TABLE III – STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION & DETERM
SINGLE-JOINT ATTACHMENT – YAW MOTION

		$.28689 A_2 - 2.41742 B_2$	$15.6098 B_2 - 1.20401 A_2$	$\dot{\psi}_{n-1} + \ddot{\psi}_n(\Delta t)$	$\dot{\gamma}_{n-1} + \ddot{\gamma}_n(\Delta t)$		$\psi_{n-1} + \dot{\psi}_n(\Delta t) + \ddot{\psi}_n \frac{(\Delta t)^2}{2}$	$\gamma_{n-1} + \dot{\gamma}_n(\Delta t) + \ddot{\gamma}_n \frac{(\Delta t)^2}{2}$					$-2.535\,\lambda$ (FIG. 2)						$-.0737\,\lambda$ (FIG. 2)	
t	Δt	$\ddot{\psi}$	$\ddot{\gamma}$	$\dot{\psi}$	$\dot{\gamma}$	$\frac{(\Delta t)^2}{2}$	ψ	γ	$-.532\dot{\psi}$	-4.725ψ	$-.0139\dot{\gamma}$	$-.2946\gamma$	$+N_0$	A_2	$-.00696\dot{\psi}$	$-.1298\psi$	$-.00696\dot{\gamma}$	$-.1298\gamma$	$+N_1$	B_2
Secs.	Secs.	Rad/Sec²	Rad/Sec²	Rad/Sec	Rad/Sec	(Sec)²	Rad.	Rad.												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.05	.05	0	0	0	0	.00125	0	0	0	0	0	0	-.2282	-.2282	0	0	0	0	-.0066	-.0066
.10	.05	-.0494	+.1712	-.0025	+.0086	.00125	-.0002	+.0006	+.0013	+.0008	-.0001	-.0002	-.3397	-.3378	+.0000	+.0000	-.0001	-.0001	-.0099	-.0100
.15	.05	-.0728	+.2510	-.0056	+.02111	.00125	-.0006	+.0020	+.0030	+.0026	-.0003	-.0005	-.4056	-.4008	+.0000	+.0001	-.0002	-.0003	-.0114	-.0121
.20	.05	-.0858	+.2939	-.0099	+.0358	.00125	-.0012	+.0042	+.0052	+.0054	-.0005	-.0011	-.4488	-.4497	+.0001	+.0002	-.0002	-.0005	-.0133	-.0139
.25	.05	-.0954	+.3243	-.0147	+.0520	.00125	-.0020	+.0072	+.0078	+.0094	-.0007	-.0019	-.4715	-.4568	+.0001	+.0003	-.0004	-.0009	-.0137	-.0146
.30	.05	-.0957	+.3215	-.0194	+.0681	.00125	-.0031	+.0110	+.0104	+.0116	-.0010	-.0028	-.4639	-.4428	+.0001	+.0004	-.0005	-.0014	-.0135	-.0148
.40	.10	-.0911	+.3013	-.0286	+.0982	.00125	-.0064	+.0223	+.0152	+.0302	-.0014	-.0058	-.4208	-.3825	+.0002	+.0008	-.0007	-.0029	-.0122	-.0147
.50	.10	-.0740	+.2259	-.0360	+.1212	.00500	-.0104	+.0356	+.0191	+.0490	-.0017	-.0092	-.3574	-.3002	+.0002	+.0014	-.0008	-.0036	-.0104	-.0142
.60	.10	-.0517	+.1390	-.0411	+.1751	.00500	-.0147	+.0498	+.0219	+.0694	-.0019	-.0129	-.2915	-.2148	+.0003	+.0019	-.0009	-.0065	-.0085	-.0137
.80	.20	-.0286	+.0451	-.0468	+.1441	.00500	-.0247	+.0715	+.0249	+.1186	-.0020	-.0226	-.1825	-.0656	+.0003	+.0023	-.0010	-.0103	-.0053	-.0131
1.00	.20	+.0128	-.1255	-.04427	+.1190	.02000	-.0333	+.1008	+.0236	+.1572	-.0016	-.0262	-.1090	+.6440	+.0003	+.0043	-.0008	-.0131	-.0032	-.0125
1.25	.25	+.0429	-.2074	-.0336	+.0522	.02000	-.0403	+.1079	+.0178	+.1946	-.0008	-.0229	-.0532	+.1265	+.0002	+.0052	-.0004	-.0139	-.0015	-.0104
1.50	.25	+.0615	-.3150	-.0228	+.0216	.03125	-.0441	+.0922	+.0122	+.2085	+.0003	-.0239	-.0254	+.1716	+.0002	+.0057	+.0002	-.0120	-.0007	-.0067
1.75	.25	+.0780	-.3106	-.0048	+.0992		-.0476	+.0527	+.0026	+.22[illegible]	+.0014	-.0150	-.0101	+.2037	+.0000	+.0062	+.0007	-.0075	-.0003	-.0009
2.00	.25	+.0605	-.2588	+.0103	-.1639		-.0431	+.0086	-.0055	+.2037	+.0023	-.0072	-.0051	+.1932	-.0001	+.0056	+.0011	-.0011	-.0002	+.0054
2.25	.25	+.0424	-.1482	+.0209	-.2010		-.0366	-.0443	-.0111	+.17[illegible]	+.0028	+.0120	0	+.1764	-.0001	+.0047	+.0014	+.0060	0	+.0120
2.50	.25	+.0216	-.0250	+.0263	-.2078		-.0293	-.0989	-.0140	+.1385	+.0029	+.0257	0	+.1530	-.0002	+.0038	+.0014	+.0128	0	+.0179
2.75	.25	+.0007	+.0950	+.0264	-.1834		-.0268	-.1418	-.0141	+.107[illegible]	+.0026	+.0363	0	+.1324	-.0002	+.0029	+.0013	+.0184	0	+.0224
3.00	.25	-.0162	+.1908	+.0224	-.1358		-.0176	-.1697	-.0119	+.08[illegible]	+.0019	+.0441	0	+.1172	-.0002	+.0022	+.0009	+.0220	0	+.0251
3.25	.25	-.0270	+.2506	+.0156	-.0731		-.0145	-.1802												

AND DETERM

TABLE III – STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION & DETERMINATION OF WING-TIP LOADS
SINGLE-JOINT ATTACHMENT – YAW MOTION

			-2.535 Y (FIG. 2) (10)+(11)+(12)+(13)+(14)					-.0737 Y (FIG. 2) (16)+(17)+(18)+(19)+(20)					APPROXIMATELY (22)+(23)	APPROXIMATELY 6576 (4)
-4.725 Ψ	-.01398	-.25968	+ N_0	A_2	-.00696 Ψ	-.1298 Ψ	-.00696 δ	-.1298 δ	+ N_1	B_2		-10352 (3)	-8279 (4)	$R_{F_{H_2}}$ (POUNDS)	$R_{F_{H_1}}$
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)		(22)	(23)	(24)	(25)
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
0	0	0	-.2282	-.2282	0	0	0	0	-.0066	-.0066		0	0	0	0
+.0008	-.0001	-.0002	-.3397	-.3378	+.0000	+.0000	-.0001	-.0001	-.0099	-.0100		+2000	-1420	+580	+1125
+.0026	-.0003	-.0005	-.4056	-.4008	+.0000	+.0001	-.0002	-.0003	-.0117	-.0121		+2937	-2078	+859	+1650
+.0054	-.0005	-.0011	-.4788	-.4447	+.0001	+.0002	-.0002	-.0005	-.0133	-.0139		+3461	-2433	+1028	+1933
+.0098	-.0007	-.0019	-.4715	-.4568	+.0001	+.0003	-.0004	-.0009	-.0137	-.0146		+3849	-2685	+1164	+2133
+.0116	-.0010	-.0028	-.4639	-.4628	+.0001	+.0004	-.0005	-.0014	-.0135	-.0148		+3860	-2662	+1198	+2184
+.0302	-.0014	-.0058	-.4208	-.3825	+.0002	+.0008	-.0007	-.0029	-.0122	-.0148		+3677	-2494	+1183	+1981
+.0490	-.0017	-.0092	-.3574	-.3002	+.0002	+.0014	-.0008	-.0046	-.0104	-.0142		+2986	-1903	+1083	+1511
+.0697	-.0019	-.0129	-.2915	-.2148	+.0003	+.0019	-.0009	-.0065	-.0085	-.0117		+2085	-1151	+934	+914
+.1166	-.0020	-.0226	-.1825	-.0656	+.0003	+.0032	-.0010	-.0103	-.0053	-.0131		+1152	-373	+779	+296
+.1524	-.0016	-.0262	-.1090	+.0440	+.0003	+.0043	-.0008	-.0131	-.0032	-.0125		-518	+1039	+521	-825
+.1946	-.0008	-.0279	-.0532	+.1265	+.0002	+.0052	-.0004	-.0139	-.0015	-.0104		-1730	+2049	+319	-1627
+.2065	+.0003	-.0239	-.0254	+.1716	+.0002	+.0057	+.0002	-.0120	-.0007	-.0067		-2480	+2608	+128	-2071
+.2226	+.0014	-.0150	-.0101	+.2037	+.0000	+.0062	+.0007	-.0075	-.0003	-.0009		-2907	+2522	-385	-2042
+.2037	+.0023	-.0022	-.0051	+.1932	-.0001	+.0056	+.0011	-.0011	-.0002	+.0054		-2442	+2142	-300	-1702
+.1[illegible]	+.0028	+.0120	0	+.1764	-.0001	+.0047	+.0014	+.0060	0	+.0020		-1710	+1228	-482	-975
+.128[illegible]	+.0029	+.0257	0	+.1530	-.0002	+.0038	+.0014	+.0128	0	+.0179		-871	+207	-664	-164
+.109[illegible]	+.0026	+.0367	0	+.1324	-.0002	+.0029	+.0013	+.0184	0	+.0224		-[illegible]	-786	-813	+625
+.08[illegible]	+.0019	+.0441	0	+.1172	-.0002	+.0022	+.0009	+.0220	0	+.0251		+656	-1580	-924	+1255
												+1091	-2075	-984	+1648

TABLE III
STEP-BY STEP SOLUTION OF EQUATIONS OF MOTION
SINGLE-POINT ATTACHMENT – YAW MOTION
AND DETERMINATION OF WING-TIP LOADS

TABLE - IV - STEP-BY-STEP CALCULATION OF EQUATIONS OF TWO-JOINT ATTACHMENT - PITCH MOTION.

		⑤ +⑳	㉑ +㉒	㉓ +$⑤_{n-1}$	㉔ +$⑥_{n-1}$	$⑦_{n-1}$ +㉖ +㉙	$⑧_{n-1}$ +㉕ +㉑	← EQUATION ___, Pg. ___			→ EQUATION ___, Pg. ___							← EQ. 40, Pg. ___ →		← EQ. 41, A	
t	Δt	$\ddot{\theta}$	$\ddot{\beta}$	$\dot{\beta}$	$\dot{\theta}$	θ	β	-12.235 × $\dot{\theta}$	-35.129 × θ	1.074 × $\dot{\beta}$	6.935 × β	-22.071 × X	$\dot{\theta}$	131.773 × θ	-5.751 × $\dot{\beta}$	-53.092 × β	-76.404 × X	.0587 × A	.00729 × B	.0113 × Ā	.12 × B̄
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒
0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
.02		-.01482	-.07704	0	0	0	0	0	0	0	0	-.1766	0	0	0	0	-.6112	-.01037	-.00846	-.00199	-.07
.04		-.02946	-.15299	-.00159	-.00030	-.000003	-.000015	.00362	.000106	-.00135	-.000104	-.35314	-.000296	-.000395	.00886	.000796	-1.22246	-.02061	-.00885	-.00397	-.14
.06		-.04038	-.21136	-.00460	-.00089	-.000015	-.000077	.01083	.000527	-.00494	-.000534	-.48556	-.000885	-.00198	.02646	.00409	-1.68088	-.02816	-.01223	-.00542	-.20
.08		-.04896	-.25310	-.00883	-.00169	-.000041	-.000211	.02071	.00144	-.00948	-.00146	-.59592	-.00169	-.00540	.05077	.01120	-2.06291	-.03382	-.01464	-.00651	-.24
.10	.02	-.05482	-.28263	-.01385	-.00266	-.000085	-.000438	.03257	.00299	-.01488	-.00304	-.67316	-.00266	-.01120	.07974	.02325	-2.33032	-.03848	-.01634	-.00741	-.27
.14	.04	-.06132	-.31354	-.02516	-.00486	-.000235	-.00122	.05940	.00826	-.02702	-.00845	-.76807	-.00486	-.03097	.14469	.06447	-2.65886	-.04320	-.01812	-.00832	-.30
.18		-.06274	-.33685	-.03770	-.00731	-.000476	-.00247	.08941	.01672	-.04049	-.01716	-.80559	-.00731	-.06272	.21682	.13140	-2.78875	-.04444	-.01830	-.00856	-.30
.22		-.06126	-.30399	-.05038	-.00982	-.000818	-.00424	.12012	.02874	-.05410	-.02938	-.81001	-.00982	-.10779	.28971	.22490	-2.80403	-.04371	-.01755	-.00841	-.29
.26		-.05729	-.27736	-.06255	-.01227	-.00126	-.00649	.15010	.04426	-.06776	-.04504	-.78573	-.01227	-.16603	.35964	.34478	-2.71998	-.04130	-.01599	-.00795	-.28
.30		-.05166	-.24129	-.07363	-.01456	-.001797	-.00922	.17814	.06313	-.07908	-.06392	-.74159	-.01456	-.23680	.42344	.46935	-2.56717	-.03776	-.01359	-.00727	-.23
.34		-.04519	-.20011	-.08328	-.01663	-.00242	-.01235	.20342	.08501	-.08944	-.08568	-.68641	-.01663	-.31889	.47995	.65595	-2.37616	-.03364	-.01149	-.00648	-.19
.38		-.03869	-.15902	-.09129	-.01843	-.00312	-.01585	.22550	.10964	-.09824	-.10989	-.63123	-.01843	-.41126	.52498	.84130	-2.18515	-.02959	-.00910	-.00569	-.15
.42		-.03195	-.11636	-.09765	-.01998	-.00389	-.01962	.24444	.13662	-.10487	-.13609	-.57164	-.01998	-.51246	.56156	1.04188	-1.97886	-.02533	-.00662	-.00488	-.111
.46		-.02581	-.07437	-.10230	-.02126	-.00471	-.02362	.26008	.16560	-.10987	-.16383	-.51205	-.02126	-.62118	.58833	1.25419	-1.77257	-.02114	-.00417	-.00407	-.07
.50		-.01877	-.03328	-.10528	-.02227	-.00558	-.02777	.27246	.19616	-.11306	-.19261	-.45246	-.02227	-.73582	.60544	1.47458	-1.56628	-.01699	-.00178	-.00327	-.03
.54		-.01310	+.00281	-.10461	-.02302	-.00649	-.03201	.28165	.22799	-.11449	-.22200	-.40169	-.02302	-.85521	.61309	1.69958	-1.39055	-.01342	+.00032	-.00258	+.00
.58		-.00771	+.03669	-.10649	-.02354	-.00742	-.03627	.28806	.26069	-.11437	-.25156	-.35314	-.02354	-.97789	.61245	1.92586	-1.22246	-.01000	+.00229	-.00193	+.03
.62		-.00279	+.06722	-.10503	-.02385	-.00837	-.04051	.29183	.29400	-.11240	-.28890	-.30899	-.02385	-1.10281	.60401	2.15049	-1.06966	-.00686	+.00407	-.00132	+.06
.66		+.00165	+.09432	-.10234	-.02396	-.00932	-.04465	.29320	.32758	-.10791	-.30966	-.26927	-.02396	-1.22878	.58855	2.37066	-.93213	-.00400	+.00565	-.00077	+.09
.70		+.00562	+.11788	-.09857	-.02390	-.01028	-.04867	.29239	.36123	-.10576	-.33753	-.23575	-.02390	-1.35502	.56685	2.58404	-.80988	-.00139	+.00701	-.00027	+.11
.74		+.00913	+.13785	-.09385	-.02367	-.01123	-.05252	.28964	.39467	-.10079	-.36423	-.20305	-.02367	-1.48647	.53973	2.78839	-.70292	+.00095	+.00817	+.000184	+.13
.78		+.01235	+.15517	-.08834	-.02331	-.01217	-.05616	.28517	.42770	-.09487	-.389497	-.17436	-.02331	-1.64434	.50802	2.98186	-.60359	+.00318	+.00918	+.000612	+.15
.82		+.01512	+.16886	-.08213	-.02281	-.01310	-.05957	.27913	.46008	-.08821	-.41314	-.15008	-.02281	-1.72583	.47232	3.16285	-.51955	+.00515	+.00997	+.000972	+.16
.86		+.01743	+.17890	-.07537	-.02221	-.01400	-.06272	.27173	.49174	-.08375	-.43498	-.13022	-.02221	-1.84456	.43348	3.33009	-.45078	+.00689	+.01054	+.00133	+.17
.90		+.01947	+.18633	-.06822	-.02151	-.01487	-.06559	.26320	.52244	-.07927	-.45490	-.11256	-.02151	-1.95973	.39233	3.48257	-.38966	+.00851	+.01096	+.00164	+.18
.94		+.02125	+.19118	-.06077	-.02073	-.01572	-.06818	.25367	.55209	-.06526	-.47279	-.09711	-.02073	-2.07094	.34947	3.61955	-.33618	+.01001	+.01124	+.00193	+.18
.98		+.02295	+.19446	-.05312	-.01988	-.01653	-.07045	.24327	.58061	-.05705	-.48859	-.08166	-.01988	-2.17794	.30549	3.74049	-.28269	+.01154	+.01141	+.00222	+.19
1.02		+.02421	+.19419	-.04534	-.01896	-.01731	-.07242	.23198	.60808	-.04970	-.50223	-.07063	-.01896	-2.28099	.26075	3.84492	-.24449	+.01283	+.01138	+.00247	+.19
1.06		+.02557	+.19350	-.03757	-.01799	-.01805	-.07407	.22010	.63408	-.04035	-.51368	-.05738	-.01799	-2.37850	.21607	3.93252	-.19865	+.01425	+.01132	+.00274	+.19
1.10		+.02613	+.18769	-.02983	-.01697	-.01875	-.07542	.20763	.65867	-.03364	-.52304	-.05297	-.01697	-2.47074	.17155	4.00420	-.18337	+.01516	+.01097	+.00272	+.18
1.14		+.02698	+.18259	-.02232	-.01592	-.01941	-.07646	.19478	.68185	-.02797	-.53025	-.04414	-.01592	-2.55771	.12836	4.05941	-.15281	+.01633	+.01065	+.00314	+.17
1.18	.04			-.01502			-.07720														

IV - STEP-BY-STEP CALCULATION OF EQUATIONS OF MOTION
TWO-JOINT ATTACHMENT - PITCH MOTION

EQUATION ___, Pg. ___ | EQUATION ___, Pg. ___ | EQ. 40, Pg. ___ | EQ. 41, Pg. ___ | ⑦×② | ③×② | ⑤×② | ⑥×② | ⑧×②/2 | ⑬×②/2 | ⑨×⑫ + ⑦×⑬ | ⑭×⑰ + ⑤×⑯ | FIG. 2 Pg. 52

	1.074 ×β'	6.935 ×β	-22.071 ×X	θ'	131.773 ×θ	-5.751 ×β'	-53.092 ×β	-76.404 ×X	.0587 ×A	.00729 ×B	.0113 ×A	.1228 ×B	β''Δt	θ''Δt	β'Δt	θ'Δt	β''Δt²/2	θ''Δt²/2	A	B	X
	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕	㉖	㉗	㉘	㉙	㉚	㉛
	0	0	0	0	0	0	0	0	0	0	0	0							0	0	0
	0	0	-.1766	0	0	0	0	-.6112	-.01037	-.00446	-.00199	-.07505	-.00154	-.000296	0	0	-.000015	-.000003	-.1766	-.6112	.0080
106	-.00135	-.000104	-.35314	-.000296	-.000395	.00886	.000796	-1.22246	-.02061	-.00885	-.00397	-.14902	-.00306	-.000589	-.000031	-.000006	-.000031	-.000006	-.35117	-1.21349	.0160
327	-.00494	-.000534	-.48556	-.000885	-.00198	.02646	.00409	-1.68088	-.02816	-.01223	-.00542	-.20594	-.00423	-.00081	-.000092	-.000018	-.000042	-.000008	-.47988	-1.67702	.0220
144	-.00748	-.00146	-.59592	-.00169	-.00540	.05077	.01120	-2.06291	-.03382	-.01464	-.00651	-.24659	-.00503	-.00097	-.000177	-.000034	-.00005	-.000010	-.57618	-2.00803	.0270
299	-.01488	-.00304	-.67316	-.00266	-.01120	.07974	.02325	-2.33032	-.03848	-.01634	-.00741	-.27583	-.01131	-.00219	-.000554	-.000106	-.00023	-.000044	-.65552	-2.24125	.0305
326	-.02702	-.00845	-.76807	-.00486	-.03097	.14469	.06447	-2.65886	-.04320	-.01812	-.00832	-.30522	-.01254	-.00245	-.00181	-.000194	-.00025	-.000049	-.73588	-2.48553	.0348
72	-.04049	-.01716	-.80559	-.00731	-.06272	.21682	.13140	-2.78875	-.04444	-.01830	-.00856	-.30830	-.01267	-.00251	-.00151	-.000292	-.00025	-.00005	-.75711	-2.51056	.0365
374	-.05410	-.02938	-.81001	-.00982	-.10779	.28971	.22490	-2.80403	-.04371	-.01735	-.00841	-.29558	-.01216	-.00245	-.00202	-.000393	-.00024	-.000049	-.74463	-2.40703	.0367
126	-.06776	-.04504	-.78573	-.01227	-.16603	.35964	.34478	-2.71998	-.04130	-.01599	-.00795	-.26941	-.01109	-.00229	-.00250	-.000491	-.00022	-.000046	-.70357	-2.19367	.0356
313	-.07908	-.06392	-.74159	-.01456	-.23680	.42344	.48935	-2.56717	-.03776	-.01359	-.00727	-.23403	-.00965	-.00207	-.00295	-.000582	-.00019	-.000041	-.64332	-1.90574	.0336
501	-.08944	-.08568	-.68641	-.01663	-.31889	.47695	.65595	-2.37616	-.03364	-.01149	-.00648	-.19363	-.00800	-.00181	-.00333	-.000665	-.00016	-.000036	-.57310	-1.57678	.0381
164	-.09894	-.10989	-.63123	-.01843	-.41126	.52498	.84730	-2.18515	-.02959	-.00910	-.00569	-.15333	-.00636	-.00155	-.00365	-.000737	-.00013	-.000031	-.50402	-1.24657	.0286
662	-.10487	-.13609	-.57164	-.01998	-.51246	.56156	1.04188	-1.97886	-.02533	-.00662	-.00488	-.11149	-.00465	-.00128	-.00391	-.000799	-.00009	-.000026	-.43154	-.902869	.0259
560	-.10987	-.16383	-.51205	-.02126	-.62118	.58833	1.25419	-1.77257	-.02114	-.00417	-.00407	-.07030	-.00297	-.00101	-.00409	-.00085	-.00006	-.000020	-.36007	-.572489	.0232
616	-.11306	-.19261	-.45246	-.02227	-.73582	.60544	1.47458	-1.56628	-.01699	-.00178	-.00327	-.03601	-.00133	-.00075	-.00421	-.00089	-.00003	-.000015	-.28951	-.24436	.0205
799	-.11449	-.22200	-.40169	-.02302	-.85521	.61309	1.69958	-1.39055	-.01342	+.00032	-.00258	+.00533	+.000112	-.000524	-.00426	-.00092	+.000002	-.000010	-.22855	+.04389	.0182
069	-.11437	-.25156	-.35314	-.02354	-.97789	.61245	1.92586	-1.22246	-.01000	+.00229	-.00193	+.03861	+.00147	-.000308	-.00426	-.00094	+.000029	-.000006	-.17032	+.31441	.0160
400	-.11200	-.28890	-.30899	-.02385	-1.10281	.60401	2.15049	-1.06966	-.00686	+.00407	-.00132	+.06854	+.00269	-.000112	-.00420	-.00095	+.000054	-.000002	-.11657	+.53818	.0140
758	-.10991	-.30966	-.26927	-.02396	-1.22878	.58855	2.37066	-.93215	-.00400	+.00565	-.00077	+.09509	+.00377	+.000066	-.00409	-.00096	+.000075	+.000001	-.06886	+.77434	.0122
123	-.10576	-.33753	-.23345	-.02390	-1.35502	.56685	2.58404	-.80988	-.00139	+.00701	-.00027	+.11814	+.00472	+.000225	-.00394	-.00096	+.000094	+.000004	-.02372	+.96209	.0106
467	-.10079	-.36423	-.20305	-.02367	-1.48047	.53973	2.78839	-.70292	+.00095	+.00817	+.000184	+.13767	+.00551	+.000365	-.00375	-.00095	+.00011	+.000007	+.00624	+1.12106	.0092
770	-.09487	-.389497	-.17436	-.02331	-1.60434	.50802	2.98186	-.60359	+.00318	+.00918	+.000612	+.15456	+.00621	+.000494	-.00353	-.00093	+.000124	+.000001	+.05414	+1.25364	.0079
008	-.08[illegible]21	-.41314	-.15008	-.02281	-1.72583	.47232	3.16285	-.51955	+.00515	+.00997	+.000992	+.16786	+.00678	+.000665	-.00328	-.00091	+.000135	+.000012	+.01728	+1.36698	.0068
9174	-.08[illegible]15	-.43498	-.13022	-.02221	-1.84456	.43348	3.33009	-.45078	+.00689	+.01054	+.00133	+.17757	+.00716	+.000697	-.00301	-.00089	+.000143	+.000014	+.01731	+1.44602	.0059
2244	-.07[illegible]27	-.45490	-.11256	-.02151	-1.95973	.39233	3.48257	-.38966	+.00851	+.01096	+.00164	+.18469	+.00745	+.000779	-.00273	-.00086	+.000149	+.000016	+.17491	+1.50399	.0051
1209	-.06[illegible]26	-.47279	-.09711	-.02073	-2.07094	.34947	3.61955	-.33618	+.01001	+.01124	+.00193	+.18925	+.00765	+.00085	-.00243	-.00083	+.000153	+.000017	+.17059	+1.54116	.0044
2061	-.05[illegible]05	-.48859	-.08166	-.01988	-2.17794	.30549	3.74049	-.28269	+.01154	+.01141	+.00222	+.19224	+.00778	+.00092	-.00213	-.00080	+.000156	+.000018	+.19658	+1.56546	.0037
2808	-.04[illegible]70	-.50223	-.07063	-.01896	-2.28099	.26075	3.84452	-.24449	+.01283	+.01138	+.00247	+.19172	+.00777	+.00097	-.00181	-.00076	+.00016	+.000020	+.21450	+1.56123	.0032
3408	-.04[illegible]35	-.51368	-.05738	-.01799	-2.37850	.21607	3.93252	-.19865	+.01425	+.01132	+.00274	+.19076	+.00774	+.00102	-.00150	-.00072	+.00015	+.00002	+.24277	+1.55345	.0026
5867	-.03[illegible]04	-.52304	-.05297	-.01697	-2.47074	.17155	4.00420	-.18337	+.01516	+.01097	+.00292	+.18477	+.00751	+.00105	-.00119	-.00068	+.00015	+.00002	+.25825	+1.50467	.0024
3185	-.0[illegible]77	-.53025	-.04414	-.01592	-2.55771	.12836	4.05941	-.15281	+.01633	+.01065	+.00314	+.17945	+.00730	+.00108	-.00089	-.00064	+.00015	+.00002	+.27827	+1.46133	.0020

TABLE IV
STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION
TWO-JOINT ATTACHMENT - PITCH MOTION

TABLE V – STEP-BY-STEP SOLUTION OF EQUATIONS OF TWO-JOINT ATTACHMENT-ROLL MOTION

		= .4706 (18)	= -.4328 (36)	= (3)+(4)	= -2.1516 (18)	= 2.5324 (36)	= (6)+(7)	= (2)×(5)	= (2)×(8)	= (11)$_{n-1}$+(9)	= (3)$_{n-1}$+(10)	= (2)×(11)	= (2)×(12)	= (5)(2)²/2	= (8)(2)²/2	= (11)$_{n-1}$+(13)	= (14)$_{n-1}$+(15)	= 2(16)(13)	= (13)²	= (19)+(20)		= 1.4512
① t	② Δt	③ .4706 A_4	④ -.4328 B_4	⑤ ϕ''	⑥ -2.1516 A_4	⑦ 2.5324 B_4	⑧ β''	⑨ $\phi''\Delta t$	⑩ $\beta''\Delta t$	⑪ ϕ'	⑫ β'	⑬ $\phi'\Delta t$	⑭ $\beta'\Delta t$	⑮ $\frac{\phi''\Delta t^2}{2}$	⑯ $\frac{\beta''\Delta t^2}{2}$	⑰ ϕ	⑱ β	⑲ $2\phi'\beta'$	⑳ β'^2	㉑		㉒
SEC.	SEC.			RADIANS/SEC²			RADIANS/SEC²			RAD/SEC	RAD/SEC					RADIANS	RADIANS					
0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
.02	.02	.14965	-.06882	.08083	-.68421	.41060	-.27361	.001617	-.005472	0	0	0		.00001617	-.000055	0	0	0	0	0		0
.04	.02	.22537	-.10526	.12011	-1.03040	.62804	-.40236	.002402	-.002047	.001617	.005472	.0000323	-.000094	.000024	-.000081	.0000485	-.000164	—	—	—		—
.06	.02	.27224	-.12897	.14327	-1.24470	.76956	-.47514	.002865	-.009503	.004239	.013519	.0000804	-.000204	.000028	-.000095	.000153	-.000515	—	—	—		—
.08	.02	.30504	-.14793	.15711	-1.31467	.88266	-.51201	.003142	-.010240	.006234	.023022	.000138	-.000404	.000031	-.000103	.000319	-.001070	—	—	—		—
.10	.04	.31380	-.15598	.15782	-1.43469	.93070	-.50399	.006313	-.020160	.010026	.033262	.000201	-.000665	.000126	-.000403	.000556	-.001838	—	—	—		—
.14		.29756	-.15447	.13872	-1.36046	.94774	-.41272	.005549	-.016509	.016339	.053422	.000654	-.002137	.000111	-.000330	.001331	-.004378	—	—	—		—
.18		.26697	-.15460	.11116	-1.22060	.92966	-.29094	.004446	-.011638	.031388	.086931	.000876	-.002797	.000089	-.000233	.002318	-.007505	—	—	—		—
.22		.24236	-.15589	.08789	-1.10807	.92166	-.18641	.003516	-.007456	.042634	.129519	.001053	-.003263	.000070	-.000149	.003460	-.011001	—	—	—		—
.26		.22109	-.15783	.06649	-1.01082	.92243	-.08839	.002660	-.003536	.049230	.179705	.001194	-.003561	.000053	-.000071	.004724	-.014711	—	—	—		—
.30		.20372	-.16005	.04783	-.93143	.93018	-.00125	.001913	-.000050	.053250	.232561	.001300	-.003702	.000038	-.000001	.006077	-.018484	—	—	—		—
.34		.19064	-.15721	.03281	-.87159	.94175	.07016	.001312	.002806	.054423	.286261	.001377	-.003704	.000026	.000056	.007492	-.022189	.0064	.0086	.0150		.0224
.38		.17961	-.16318	.01956	-.82118	.95497	.13379	.000782	.005352	.055275	.341985	.001429	-.003592	.000016	.000107	.008947	-.025215	.00642	.00806	.0145		.0217
.42		.16044	-.16261	.00323	-.73354	.97180	.20426	.000129	.008170	.056517	.398453	.001461	-.003378	.000003	.000163	.010424	-.028996	.0062	.0071	.0133		.0199
.46		.16444	-.16227	.00126	-.75181	.97367	.22186	.000050	.008874	.056646	.456283	.001466	-.003051	.000001	.000177	.011893	-.031884	.0056	.0058	.0114		.017
.50		.15799	-.15987	-.00462	-.72231	.97023	.24792	-.000185	.009917	.056196	.514409	.001468	-.002696	-.000004	.000198	.013362	-.034403	.0049	.0045	.0094		.014
.54		.15242	-.15612	-.00985	-.69686	.96825	.27139	-.000394	.010856	.055[illegible]	.569492	.001460	-.002300	-.000008	.000217	.014818	-.036505	.0042	.0033	.0075		.0112
.58		[illegible]581	-.15138	-.01406	-.66665	.95389	.28724	-.000562	.011490	.0361[illegible]	.625[illegible]	.001445	-.001865	-.000011	.000230	.016255	-.038153	.0034	.0021	.0055		.0082
.62		.13920	-.14342	-.0692	-.63646	.93152	.29506	-.000617	.011802	.0355[illegible]	.685346	.001423	-.001466	-.000014	.000236	.017666	-.039329	.00246	.00125	.0037		.0055
.66		.13287	-.13428	-.01851	-.60748	.90322	.29514	-.000740	.011830	.0342[illegible]	.733-4	.001395	-.000933	-.000014	.000237	.019047	-.040026	.00163	.00055	.00218		.0032
.70		.12193	-.12427	-.02149	-.55746	.85572	.29827	-.000860	.011931	.034138	.7[illegible]4	.001366	-.000461	-.000017	.000239	.020399	-.040250	.00078	.00013	.00091		.0014
.74		.11073	-.11258	-.02355	-.50625	.80124	.29499	-.000942	.011800	.0332[illegible]	.7[illegible]7	.001331	-.000017	-.000019	.000236	.021713	-.040028	—	—	—		—
.78		.09986	-.09968	-.02441	-.45657	.74146	.28489	-.000976	.011396	.0323[illegible]	.8[illegible]7	.001293	.000489	-.000020	.000228	.022987	-.039303	.00079	—	—		—
.82		[illegible]37	-.08574	-.02521	-.39947	.67176	.27229	-.001008	.010892	.0313[illegible]	.8[illegible]3	.001254	.000945	-.000020	.000218	.024221	-.038130	—	—	—		—
.86		[illegible]8	-.07109	-.02560	-.33868	.59475	.25607	-.001024	.010243	.030352	.9[illegible]4	.001214	.001380	-.000020	.000215	.025415	-.036532	.002	.001	.003		.005
.90		[illegible]005	-.05347	-.02569	-.27457	.51175	.23700	-.001027	.009480	.029318	.9[illegible]3	.001173	.001790	-.000020	.000190	.026568	-.034537	.0026	.002	.00046		.007
.94		.04582	-.03753	-.02527	-.20948	.42416	.21468	-.001011	.008527	.028[illegible]	.9[illegible]28	.001132	.002169	-.000020	.000172	.026639	-.032178	.003	.003	.006		.009
.98	.04	.02607	-.02543	-.02740	-.11918	.31903	.19985	-.001096	.007994	.027[illegible]	.9[illegible]5	.001088	.002516	-.000020	.000162	.027747	-.029490	.0035	.004	.0075		.0113
1.02	.03	.01135	-.00366	-.02618	-.05190	.22395	.17205	-.000785	.005162	.026[illegible]	[illegible]	.001044	.002832	-.00012	.000077	.028771	-.026498					
1.05	.05	-.00012	.04514	-.02555	.00056	.15174	.15230	-.001278	.007615	.0253[illegible]	[illegible]	.000760	.002279	-.00032	.000190	.029519	-.024442					
1.10	.10	-.02115	.08447	-.02481	.09671	-.02184	.13334	-.002481	.013334	.0240[illegible]	[illegible]	.001202	.004179	-.000124	.000485	.030689	-.019773					
1.20		-.06990	.13335	-.02416	.31960	-.27291	.04669	-.002416	.004669	.0215[illegible]	[illegible]	.002156	.009692	-.000122	.000234	.031605	-.009996					
1.30		-.10805	.16723	-.02364	.49491	-.50367	-.00966	-.002364	-.000966	.019144	[illegible]	.001914	.010159	-.000118	-.000049	.033597	.000197					
1.40		-.15855	.19155	-.02520	.72492	-.79566	-.07674	-.002520	-.007674	.0167[illegible]	[illegible]	.001678	.010362	-.000126	-.000353	.034957	.010810					
1.50		-.19219	.20624	-.02496	.87865	-.99779	-.11914	-.002496	-.011914	.0142[illegible]	[illegible]	.001426	.009355	-.000125	-.000595	.036257	.019912					
1.60		-.21645	.21112	-.02490	.98963	-1.14297	-.15334	-.002490	-.015334	.011[illegible]	[illegible]	.001176	.008164	-.000125	-.000766	.037308	.027481					
1.70		-.23060	.20661	-.02436	1.05433	-1.23056	-.17623	-.002436	-.017623	.009[illegible]	[illegible]	.000927	.006531	-.000122	-.000881	.038110	.033346					
1.80		-.23442	.19355	-.02330	1.07178	-1.25972	-.18794	-.002330	-.018794	.006[illegible]	[illegible]	.000684	.004868	-.000116	-.000943	.038672	.037333					
1.90		-.22828		-.02167	1.04370	-1.23278	-.18904	-.002167	-.018904	.004[illegible]	[illegible]	.000451	.002989	-.000109	-.000945	.039007	.039382					
2.00	.10	-.21307		-.01952	.97418	-1.15488	-.18070	-.001952	-.018070	.002[illegible]	[illegible]	.000234	.001098	-.000098	-.000904	.039132	.039339					
2.10										.000[illegible]	[illegible]	.000039	-.000769			.039037	.037922					

STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION
TWO-JOINT ATTACHMENT-ROLL MOTION

t	(14) = (2)Δt	(15) = (5)Δt²/2	(16) = (8)Δt²/2	(17) = (1) + (14) + (15)	(18) = (4) + (14) + (16)	(19) = 2(9)(12)	(20) = (13)²	(21) = (19) + (20)	(22) = 1.495 (21)	(23) = 10.75 − (22)	(24) = 18.804 (FIG. 21)	(25) = −7.423 (11)	(26) = −.9457 (12)	(27) = −(23) (19)	(28) = (26) − (23) + (28)(27)	(29) = (11)²	(30) = 7.476 (29)	(31) = 10.72 + (30)	(32) = 3.731 Δ	(33) = −4.353 (11)	(34) = −1.184 (12)	(35) = −(31) (18)	(36) = (32) + (33) + (34) + (35)
		$\frac{\dot\phi\Delta t^2}{2}$	$\frac{\dot\beta\Delta t^2}{2}$	ϕ	β	$2\dot\phi\dot\beta$	$\dot\beta^2$		1.495 (21)	10.75 − (22)	$L \times 10^{-5}$	$-7.423\dot\phi$	$-.9457\dot\beta$	$-(23)\dot\beta$	A_4	$\dot\phi^2$	$7.476\dot\phi^2$	$10.72 + 7.476\dot\phi^2$	$L_1 \times 10^{-5}$	$.353\dot\phi$	$-1.184\dot\beta$	$-(31)\dot\beta$	B_4
				RADIANS	RADIANS																		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	.00001617	−.000055	0	0	0	0	0	0	0	0	.318	0	0	0	.318	0	0	0	.159	0	0	0	.159
.001094	.000024	−.000081	.0000485	−.000164	—	—	—	—	10.75	.474	−.012003	.005175	.001764	.4789	—	—	—	10.72	.246	−.007039	.006479	.001759	.2432
.002704	.000028	−.000095	.000153	−.000515	—	—	—	—	10.75	.590	−.029833	.012785	.005536	.5785	—	—	—	10.72	.294	−.017495	.016006	.005621	.298
.004604	.000031	−.000103	.000319	−.001070	—	—	—	—	10.75	.662	−.051100	.021772	.011507	.6482	—	—	—	10.72	.333	−.029966	.027258	.011475	.3418
.006653	.000126	−.000403	.000556	−.001838	—	—	—	—	10.75	.690	−.074473	.031456	.019759	.6668	—	—	—	10.72	.345	−.043643	.039382	.019703	.3604
.008137	.000111	−.000330	.001331	−.004378	—	—	—	—	10.75	.656	−.121284	.050521	.047064	.6323	—	—	—	10.72	.328	−.071124	.063252	.046932	.367
.012797	.000089	−.000233	.002318	−.007505	—	—	—	—	10.75	.583	−.162475	.066134	.080679	.5673	—	—	—	10.72	.292	−.095278	.082800	.080454	.360
.020263	.000070	−.000149	.003460	−.011001	—	—	—	—	10.75	.515	−.19548	.07714	.11836	.515	—	—	—	10.72	.257	−.114632	.09657	.117931	.3569
.03561	.000053	−.000071	.004744	−.014711	—	—	—	—	10.75	.449	−.22158	.08419	.15814	.4698	—	—	—	10.72	.224	−.12994	.10541	.157700	.3572
.03702	.000038	−.000001	.006077	−.018484	—	—	—	—	10.75	.388	−.24132	.08753	.19870	.4329	—	—	—	10.72	.194	−.14152	.10959	.198155	.3602
.203709	.000026	.000056	.007492	−.022189	.0064	.0086	.0150	.0224	10.7276	.335	−.25552	.08578	.23803	.40509	—	—	—	10.72	.167	−.14984	.10965	.237870	.36468
.203592	.000016	.000107	.008947	−.025225	.00642	.00806	.0145	.0217	10.7283	.286	−.26526	.08493	.27599	.38166	.00127	.0095	10.7295	.143	−.15555	.10633	.276020	.3698
.203378	.000003	.000163	.010424	−.028996	.0062	.0071	.0133	.0199	10.733	.221	−.27107	.07987	.31113	.34093	.00133	.0099	10.73	.111	−.15896	.09999	.311120	.36315
.203051	.000001	.000177	.011893	−.031884	.0056	.0058	.0114	.017	10.736	.175	−.27202	.07223	.34224	.34942	.00134	.0100	10.73	.104	−.15952	.09044	.342120	.37704
.202696	−.000004	.000198	.013362	−.034403	.0049	.0045	.0094	.014	10.739	.1485	−.27139	.06375	.36935	.33571	.00135	.0100	10.73	.086	−.15974	.07981	.369140	.37571
.202300	.000008	.000217	.014818	−.036505	.0042	.0033	.0075	.0112	10.742	.124	−.27102	.05437	.39203	.32388	.00133	.0099	10.73	.074	−.15893	.06807	.391700	.37494
.201865	.000011	.000230	.016255	−.038153	.0034	.0021	.0055	.0082	10.744	.1039	−.26810	.04410	.40984	.30984	.0013	.0098	10.73	.062	−.15722	.05522	.409380	.36938
.201406	.000014	.000236	.017666	−.039329	.00246	.00123	.0037	.0055	10.747	.0790	−.26392	.03324	.42759	.29581	.00126	.0094	10.729	.049	−.15477	.04161	.429980	.36072
.200933	.000014	.000237	.019047	−.040026	.00163	.00055	.00218	.0032	10.749	.0290	−.25890	.02208	.43016	.28234	.00122	.0091	10.729	.034	−.15182	.02764	.429440	.34976
.200461	−.000017	.000239	.020399	−.040250	.00078	.00013	.00091	.0014	10.749	.0090	−.25341	.01089	.43261	.25909	.00117	.00875	10.728	.026	−.14860	.01363	.431840	.33137
.200017	−.000019	.000236	.021713	−.040028	—	—	—	—	10.75	.0524	−.24702	.00039	.43030	.23529	.00111	.0083	10.728	.0207	−.14486	−.00049	.429420	.31027
.200489	−.000020	.000228	.022987	−.039303	.00079	—	—	—	10.748	.0414	−.24003	−.01155	.42243	.21220	.00105	.0079	10.729	.0155	−.14076	−.01446	.421640	.28712
.200945	−.000020	.000218	.024221	−.038130	—	—	—	—	10.747	.0310	−.23279	−.02233	.40978	.18566	—	—	10.727	.0114	−.13651	−.02796	.409100	.26013
.201380	−.000020	.000215	.025415	−.036532	.002	.001	.003	.005	10.745	.0228	−.22530	−.03263	.39259	.15741	—	.007	10.726	.0083	−.13212	−.04085	.391880	.23031
.201790	−.000020	.000190	.026568	−.034537	.0026	.002	.0046	.007	10.743	.0166	−.21770	−.04232	.37103	.12761	.00086	.0064	10.726	.0065	−.12766	−.05298	.370440	−.19810
.202169	−.000020	.000172	.026639	−.032178	.003	.003	.006	.009	10.741	.0131	−.21008	−.05128	.34562	.09736	.0008	.006	10.726	.0034	−.12319	−.06420	.345140	.16425
.202516	−.000020	.000162	.027747	−.029490	.0035	.004	.0075	.0113	10.739	.0069	−.20190	−.05940	.31669	.05539	.00072	.0075	10.725	0	−.11840	−.07437	.316310	.12354
.202832	−.000012	.000077	.028771	−.026498					10.7	0	−.19377	−.06696	.28485	.02412	.0007	.0050	10.725	0	−.11363	−.08384	.284190	.08672
.202779	−.00032	.000190	.029519	−.024442					10.7		−.18794	−.07185	.25953	−.00026					−.11021	−.08995	.258920	.05876
.204179	−.000124	.000485	.030689	−.019773							−.17846	−.07905	.21256	−.04495					−.10465	−.09896	.212070	.00846
.209692	−.000122	.000234	.031605	−.009996							−.16004	−.09166	.10316	−.14854					−.09385	−.11475	.102920	−.10568
.210159	−.000118	−.000049	.033597	.000197							−.14210	−.09607	−.00857	−.22960					−.08333	−.12028	−.008570	−.19504
.210562	−.000126	−.000353	.034957	.010810							−.12457	−.09516	−.11621	−.33692					−.07304	−.11913	−.115940	−.30811
.209355	−.000125	−.000595	.036257	.019912							−.10585	−.08847	−.21405	−.40837					−.06207	−.11076	−.213550	−.38638
.208164	−.000125	−.000766	.037308	.027481							−.08132	−.07721	−.29542	−.45995					−.05121	−.09666	−.294730	−.44260
.206681	−.000122	−.000881	.038110	.033346							−.06884	−.06271	−.35847	−.49002					−.04027	−.07851	−.357640	−.47652
.204868	−.000116	−.000943	.038672	.037333							−.05076	−.04604	−.40133	−.49813					−.02977	−.05764	−.400400	−.48781
.202989	−.000109	−.000945	.039007	.039382							−.03346	−.0282	−.42335	−.48508					−.01962	−.03539	−.422370	−.47738
.201098	−.000098	−.000904	.039132	.039539							−.01738	−.01039	−.42500	−.45277					−.01019	−.01301	−.424010	−.44721
.199769			.039037	.039422																			

TABLE V
STEP-BY-STEP SOLUTION OF EQUATIONS OF MOTION
TWO-JOINT ATTACHMENT-ROLL MOTION

TABLE VI

STEP BY STEP ANALYSIS OF THE YAWING MOTION OF A B-50 & TWO F-84's LOCKED TOGETHER RIGIDLY IN YAW (50 FT/SEC. GUST)

1	2	3	4	5	6	7	8	9	10
t	Δt	$(\Delta t)^2$	$\ddot{\psi} = .05343\dot{\psi} - .47453\psi + N_{n-1}$	$\dot{\psi} = \ddot{\psi}\Delta t + \dot{\psi}_{n-1}$	$\psi = \psi_{n-1} + \dot{\psi}\Delta t + \ddot{\psi}\frac{(\Delta t)^2}{2}$	$N = -.26939\, e^{-3t}(1-e^{-2t})$	$(\dot{\psi})^2$	$R_{F_{H_2}} = 40352\,\ddot{\psi}$ (LBS)	$R_{F_{H_1}} \simeq 40352(\dot{\psi})^2$ (LBS.)
0	0	0	0	0	0	0	0	0	0
.05	.05	.0025	0	0	0	-.02425	0	0	0
.10	.05	.0025	-.02424	-.00121	-.00009	-.03610	0	-978	0
.15	.05	.0025	-.03599	-.00301	-.00028	-.04310	.00001	-1452	0
.20	.05	.0025	-.04281	-.00515	-.00059	-.04876	.00003	-1727	1
.25	.05	.0025	-.04820	-.00756	-.00103	-.05011	.00006	-1945	2
.30	.05	.0025	-.04922	-.00997	-.00159	-.04920	.00010	-1986	4
.40	.10	.0100	-.04801	-.01477	-.00331	-.04445	.00022	-1937	9
.50	.10	.0100	-.04209	-.01848	-.00542	-.03798	.00036	-1698	14
.60	.10	.0100	-.03479	-.02242	-.00783	-.03098	.00050	-1388	20
.80	.20	.0400	-.02607	-.02763	-.01388	-.01939	.00076	-1052	31
1.00	.20	.0400	-.01133	-.02990	-.01963	-.01158	.00089	-457	36
1.25	.25	.0625	-.00067	-.03007	-.02717	-.00566	.00090	-27	36
1.50	.25	.0625	+.00884	-.02786	-.03358	-.00269	.00078	+357	31
1.75	.25	.0625	+.01473	-.02418	-.03917	-.00108	.00058	+594	23
2.00	.25	.0625	+.01879	-.01948	-.04345	-.00053	.00038	+758	15
2.25	.25	.0625	+.02113	-.01420	-.04634	0	.00020	+853	8
2.50	.25	.0625	+.02275	-.00851	-.04776	0	.00006	+918	2
2.75	.25	.0625	+.02312	-.00273	-.04772	0	.00001	+933	0
3.00	.25	.0625	+.02279	+.00297	-.04626	0	.00001	+920	0
3.25	.25	.0625	+.02179	+.00842	-.04347	0	.00007	+879	3
3.50	.25	.0625	+.02018	+.01346	-.03947	0	.00018	+814	7
3.75	.25	.0625	+.01801	+.01796	-.03442	0	.00032	+727	13
4.00	.25	.0625	+.01537	+.02180	-.02849	0	.00048	+620	19
4.25	.25	.0625	+.01235	+.02489	-.02188	0	.00062	+498	25
4.50	.25	.0625	+.00905	+.02715	-.01481	0	.00074	+365	30
4.75	.25	.0625	+.00558	+.02854	-.00750	0	.00081	+225	33
5.00	.25	.0625	+.00203	+.02905	-.00017	0	.00084	+62	34
5.25	.25	.0625	-.00147	+.02868	+.00695	0	.00082	-59	33
5.50	.25	.0625	-.00483	+.02747	+.01367	0	.00075	-195	30
5.75	.25	.0625	-.00795	+.02548	+.01979	0	.00065	-321	26
6.00	.25	.0625	-.01075	+.02279	+.02515	0	.00052	-434	20
6.25	.25	.0625	-.01315	+.01950	+.02961	0	.00038	-531	15
6.50	.25	.0625	-.01509	+.01573	+.03307	0	.00025	-609	10
6.75	.25	.0625	-.01653	+.01160	+.03545	0	.00013	-667	5
7.00	.25	.0625	-.01744	+.00724	+.03672	0	.00005	-704	2
7.25	.25	.0625	-.01781	+.00279	+.03686	0	.00001	-719	0
7.50	.25	.0625	-.01764	-.00162	+.03590	0	0	-712	0

TABLE VII — VERTICAL SHEAR LOAD AT JOINT — SINGLE-JOINT ATTACHMENT — PITCH AT JOIN

	TABLE I COL. (10)	TABLE I COL. (11)	TABLE I COL. (28)	$\dot{\beta}^2$	SIN (4)	8263.45 (2)	4652 (3)	-283.47 (4)	-8297.2 (5)	(11)+(8)	(11)+(19)	TABLE I COL. (14)	TABLE I COL. (30)	TABLE I COL. (28)	$\dot{\alpha}^2$	SIN (14)	-268.05 (12)	-1132.5 (13)	-128180 (14)	268.05 (15)	(11)+(15)+(20)	(11)+(8)	(11)+(19)
						8263.45	4652	-283.47	-8297.2								-268.05	-1132.5	-128180	268.05			
t	$\ddot{\beta}$	$\dot{\beta}$	β	$\dot{\beta}^2$	SIN β	$\ddot{\beta}$	$\dot{\beta}$	β	$\dot{\beta}^2$ SIN β			$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2$	SIN α	$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2$ SIN α			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(11)	(11)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
.1	-.293	-.0270	-.002606	.00073	-.00261	-2421.2	-126.6	+.7	0	-2637.0	.001	0	0	0	0	-.3	0	0		-.3	-2637.0	
.2	-.340	-.0600	-.008590	.0036	-.00859	-2809.6	-279.1	2.4	+.3	-3081.9	.0015	.0007	.000044		.000044	-2.5	-.9	-8.2		-11.5	-3081.9	
.3	-.285	-.0900	-.01763	.0081	-.01763	-2355.1	-418.7	5.0	1.2	-2767.6	.0255	.0023	.000293		.000293	-5.0	-2.6	-37.6		-45.2	-2767.6	
.4	-.205	-.1120	-.028937	.0128	-.02894	-1694.0	-525.7	8.2	3.1	-2208.4	.0250	.0047	.000778		.000778	-6.7	-5.3	-99.7		-111.7	-2208.4	
.5	-.128	-.1270	-.041169	.0161	-.04169	-1057.7	-590.8	11.8	5.6	-1631.1	.0295	.0075	.001621		.001521	-7.6	-8.5	-195.0		-211.1	-1631.1	
.6	-.055	-.1350	-.055170	.0182	-.05617	-454.5	-628.0	16.6	8.3	-1052.6	.0285	.0162	.002554		.002554	-7.6	-11.6	-327.4		-346.6	-1052.6	
.7	0	-.1370	-.068778	.0188	-.06880	0	-637.5	19.5	10.7	-607.5	.0260	.0130	.003858		.003858	-7.0	-14.7	-494.5		-516.2	-607.5	
.8	+.042	-.1330	-.082104	.0177	-.08210	347.0	-618.7	23.3	12.1	-226.3	.0215	.0153	.005390		.005390	-5.8	-17.3	-690.9		-714.0	-226.3	
.9	.076	-.1230	-.10043	.0151	-.1003	619.7	-572.2	28.5	12.6	-28.6	.0155	.0176	.008052		.008052	-4.2	-19.9	-1032.1		-1056.2	-28.6	
1.0	.105	-.1120	-.111055	.0125	-.1110	867.7	-521.0	31.5	11.5	+389.7	.0050	.0185	.009948		.009948	-2.1	-21.0	-1275.1		-1298.2	+389.7	
1.2	.150	-.0240	-.127195	.0071	-.1274	1239.5	-390.2	36.2	7.5	892.4	-.0080	.0178	.01354		.01354	+2.1	-20.2	-1735.6		-1753.7	892.4	
1.4	.175	-.0500	-.137788	.0025	-.1374	1446.1	-232.6	39.06	2.8	1256.5	-.0230	.0140	.016356		.016365	+6.2	-15.9	-2096.4		-2106.1	1256.5	
1.5	.17521	-.03223	-.140131	.00104	-.140	1448.0	-149.9	40	1	1331	-.0216	.01105	.017317			8	-13.6	-2220		-2225	1331	
1.6	.17475	-.01475	-.140737	.00022	-.140	1444.0	-68.7	40	0	14[illegible]	-.03323	.00772	.017923			9	-9	-2297		-2297	14[illegible]	
1.7	.16971	+.00222	-.139662	.000005	-.139	1402.0	+10.3	40	0	146[illegible]	-.03646	.00408	.018149			10	-5	-2326		-2321	146[illegible]	
1.8	.15897	+.018113	-.137066	.000328	-.137	1314.0	84.2	39	0	14[illegible]	-.03822	.00025	.017988			10	0	-2305		-2295	14[illegible]	
1.9	.14372	+.03249	-.133088	.001065	-.1330	1188	151.0	37.7	1	13[illegible]	-.03844	-.00359	.017432			10	4	-2234		-2220	13[illegible]	
2.0	.12537	.04802	-.127957	.002309	-.1274	1036	209.0	36.3	2	12[illegible]	-.03716	-.00731	.016516			10	8	-2117		-2099	12[illegible]	
2.1	.10126	.05614	-.121939	.003041	-.1219	837	257.0	34.6	3	11[illegible]	-.3449	-.01075	.015268			9	12	-1957		-1936	11[illegible]	
2.2	.07437	.06258	-.115309	.00392	-.1153	615	291.0	33	4	9[illegible]	-.3059	-.01381	.013734	0		8	16	-1760	0	-1736	9[illegible]	

AT JOINT — SINGLE-JOINT ATTACHMENT — PITCH MOTION

(11) (12)+(13)	TABLE I COL. (12)	TABLE I COL. (13)	TABLE I COL. (14)	(15) $\dot{\alpha}^2$	SIN (16)	-268.05 (17)	-1132.5 (18)	-128180 (19)	268.05 (20)	(21) (18)+(19)+(20)	TABLE I COL. (6)	TABLE I COL. (18)	TABLE I COL. (21)	(23) $\dot{\theta}^2$	-1473.6 (22)	-22800 (24)	1473.6 (25)	(26) (16)+(27)+(28)	FIGURE 2	73,669.8 (30)	(11)+(21)+(29)+(31)
	$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2$	SIN $\dot{\alpha}$	$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2$ SIN α		$\ddot{\theta}$	θ	θ	$\dot{\theta}^2$	$\ddot{\theta}$	θ	$\dot{\theta}^2$ SIN α		X	X	R_{F_V}
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-2637.0	.001	0	0	0	0	-.3	0	0		-.3	-.0610	-.0055	-.000499		+75.2	+11.4		86.6	.0305	2246.9	-212.9
-3081.9	.0015	.0007	.000064		.000064	-2.5	-9	-8.2		-11.5	-.0640	-.0115	-.001638		94.2	37.3		131.6	.0868	2711.0	-254.8
-2767.6	.0115	.0023	.000293		.000293	-5.0	-2.6	-37.6		-45.2	-.0630	-.0170	-.003347		78.1	76.3		154.4	.0335	2467.9	-190.5
-2205.4	.0250	.0047	.000778		.000778	-6.7	-5.3	-99.7		-111.7	-.0375	-.0215	-.005471		55.3	124.7		180.0	.0272	2003.8	-136.3
-1631.1	.0285	.0075	.001621		.001621	-7.6	-8.5	-195.0		-211.1	-.0230	-.0235	-.007861		33.9	179.0		212.9	.0205	1510.2	-119.1
-1052.6	.0285	.0162	.002554		.002554	-7.6	-11.6	-327.4		-346.6	-.0105	-.0250	-.010261		15.5	236.2		251.7	.0150	1105.0	-48.5
-607.5	.0260	.0130	.003858		.003858	-7.0	-14.7	-494.5		-516.2	0	-.0255	-.012907		0	294.3		294.3	.0105	775.5	-55.7
-226.3	.0215	.0153	.005390		.005390	-5.8	-17.3	-690.9		-714.0	+.0045	-.0250	-.015423		-6.6	351.6		346.0	.0072	530.4	-75.0
-88.6	.0155	.0176	.008052		.008052	-4.2	-19.9	-1032.1		-1056.2	.0080	-.0240	-.019028		-11.8	433.8		422.0	.0050	368.3	-177.3
+389.7	.0080	.0185	.009948		.009948	-2.1	-21.0	-1295.1		-1298.2	.0100	-.0230	-.021281		-14.7	485.2		470.5	.0035	257.8	-180.2
292.4	-.0080	.0178	.013554		.013554	+2.1	-20.2	-1735.6		-1753.7	.0120	-.0200	-.025429		-17.7	579.8		562.1	.0015	110.6	-188.7
1256.5	-.0230	.0140	.016365		.016365	+6.2	-15.9	-2096.4		-2106.1	.0100	-.0185	-.029444		-14.7	664.5		649.8	.0010	73.1	-127.1
1332	-.0286	.01105	.017317			8	-12.6	-2220		-2225	.00964	-.01765	-.030861		-14	704		690	.0008	59	-138
1400	-.03322	.00772	.017925			9	-9	-2297		-2297	.00912	-.01674	-.03249		-13	744		728	.0006	44	-109
1462	-.03646	.00408	.018149			10	-5	-2326		-2321	.00870	-.01587	-.034037		-13	776		763	.00045	33	-73
1412	-.03822	.00025	.017983			10	0	-2305		-2295	.00816	-.01506	-.03550		-12	809		797	.0003	22	-59
1300	-.03844	-.00359	.017432			10	4	-2234		-2220	.00770	-.01428	-.03689		-11.35	841		830	0	0	-12
1200	-.03716	-.00731	.016515			10	8	-2117		-2099	.00750	-.01353	-.03820		-10.05	871		860	0	0	+44
1100	-.03449	-.01075	.015268			9	12	-1957		-1936	.00701	-.01283	-.03945		-10.33	899		889	0	0	+85
900	-.03059	-.01381	.013734	0		8	16	-1760	0	-1736	.00653	-.01218	-.04064	0	-9.62	926	0	916	0	0	+125

TABLE VII
CALCULATION OF VERTICAL SHEAR LOAD AT JOINT
SINGLE-JOINT ATTACHMENT - PITCH MOTION

TABLE VIII — VERTICAL SHEAR LOAD AT JOINT — SINGLE-JOINT ATTACHMENT — ROLL

	Table II Col. (8)	Table II Col. (17)	Table II Col. (26)	8263.45 × (2)	4651.7 × (3)	−283.44 × (4)	(5)×(6)×(7)	Table II Col. (5)	Table II Col. (16)	(10)²	(11)×(4)	40604.1 × (9)	25,418 × (10)	32,327 × (11)×(4)	(13)×(14)×(15)	Table II Col. (18)	Table II Col. (21)	−1132.5 × (17)	−128,180 × (18)	Table II Col. (39)	−.05464 × (21)
				8263.45	4651.7	−283.44						40604.1	25,418	32,327				−1132.5	−128,180		−.05464
t	$\ddot{\beta}$	$\dot{\beta}$	β	$\ddot{\beta}$	$\dot{\beta}$	β		$\ddot{\phi}$	$\dot{\phi}$	$\dot{\phi}^2$	$\dot{\phi}^2\beta$	$\ddot{\phi}$	$\dot{\phi}$	$\dot{\phi}^2\beta$		$\ddot{\alpha}$	$\dot{\alpha}$	$\dot{\alpha}$	α	L_2	L_2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
0	−0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.05	−.28627	−.01840	−.001431	−2366	−86	0	−2450	+.08668	.007556			3520	142	0	3661	.000730	.000056	−1	−7	18489	−1010
.1	−.47780	−.04009	−.003973	−3585	−187	1	−3770	.13296	.012210			5399	310	0	5709	.002445	.000221	−3	−28	29679	−1622
.15	−.46124	−.06315	−.007708	−3811	−294	2	−4103	.14422	.019421			5856	494	0	6349	.005519	.000575	−6	−74	34350	−1877
.2	−.42466	−.08488	−.012495	−3590	−395	4	−3981	.13971	.026407			5673	671	0	6344	.009895	.001179	−11	−151	35810	−1957
.3	−.29491	−.11838	−.02444	−2437	−551	7	−2981	.10582	.03798			4297	965	−1	5261	.02164	.00333	−25	−476	32647	−1784
.4	−.13386	−.13569	−.03811	−1106	−621	11	−1727	.06731	.04564			2733	1160	−3	3891	.03528	.00685	−40	−878	26566	−1452
.5	+.01415	−.13278	−.05198	+117	−641	15	−509	.03507	.04988			1424	1259	−4	2688	.04850	.0171	−55	−1501	19949	−1090
.6	.12902	−.12759	−.06481	1066	−594	18	+491	.01546	.05185			628	1318	−6	1940	.05954	.01769	−67	−2268	14597	−798
.7	.22222	−.10749	−.07561	1837	−500	21	1358	.00460	.05251			187	1335	−7	1515	.06736	.02445	−76	−3134	10315	−564
.8	.29912	−.06450	−.08495	2472	−300	24	2148	.00027	.05264			11	1338	−8	1341	.07309	.03548	−83	−4548	7152	−391
.9	.37225	−.02727	−.08582	3076	−127	24	2974	−.00056	.05258			−23	1337	−8	1306	.07741	.04269	−82	−5472	4963	−271
1.0	.43933	+.01666	−.08195	3630	+78	23	3731	−.00044	.05254			−18	1336	−7	1310	.08172	.04929	−77	−6318	3466	−186
1.1	.50435	.06710	−.07272	4168	312	21	4504	−.00050	.05239			−61	1332	−7	1264	.08061	.05497	−69	−7046	2423	−133
1.2	.56550	.12365	−.05752	4673	575	16	5264	−.00406	.05198			−165	1321	−7	1149	.05031	.05948	−57	−7624	1460	−80
1.3	.61955	.18561	−.03586	5120	863	10	5993	−.00781	.05120			−317	1301	−7	977	.03761	.06261	−43	−8025	1168	−64
1.4	.68962	.25257	−.00725	5533	1175	2	6710	−.01435	.04976			−583	1165	−7	675	.02294	.06417	−26	−8225	973	−53
1.5	.71264	.32387	+.02869	5889	1506	−8	7387	−.02327	.04742			−949	1205	+6	263	.00665	.06403	−8	−8207	779	−43
1.6	.74338	.39812	.07223	6143	1853	−20	7915	−.03395	.04402			−1379	1119	6	253	−.01098	.06205	+12	−7854	487	−27
1.7	.74936	.47311	.12329	6192	2201	−35	8358	−.04310	.03971			−1750	1009	6	−734	−.02964	.05816	34	−7455	389	−21
1.8	.73303	.54611	.18158	5975	2514	−51	8465	−.05172	.03454			−2100	878	+6	−1215	−.04891	.05231	55	−6705	0	0
1.9	.67320	.61363	.24631	.5563	2859	−70	8347	−.05485	.02405			−2227	611	+6	−1609	−.06829	.04451	77	−5705	0	0
2.0	.57950	.67158	.31637	.4789	3124	−90	7823	−.05428	.02362			−2204	602	+6	−1598	−.08204	.03487	99	−4470	0	0

Single-joint

SHEAR LOAD AT JOINT — SINGLE-JOINT ATTACHMENT — ROLL MOTION

TABLE II COL. (16)	(10)²	(11)×(4)	40604.1 × (9)	25,418 × (10)	32,327 × (11)×(4)	(13)+(14)+(15)	TABLE II COL. (18)	TABLE II COL. (27)	-1132.5 × (17)	-128,180 × (18)	TABLE II COL. (38)	-.05464 × (21)	(19)+(20)+(22)	(8)+(16)+(23)
ϕ	$\dot{\phi}^2$	$\dot{\phi}^2\beta$	40604.1 $\ddot{\phi}$	25,418 $\dot{\phi}$	32,327 $\dot{\phi}^2\beta$		$\dot{\alpha}$	α	-1132.5 $\dot{\alpha}$	-128,180 α	L_2	-.05464 L_2		R_{FV}
(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0556			3520	142	0	3661	.000730	.000056	-1	-7	18489	-1010	-1018	+193
12210			5399	310	0	5709	.002445	.000221	-3	-28	29679	-1622	-1653	286
19421			5856	494	0	6349	.005519	.000575	-6	-74	34350	-1877	-1957	290
26407			5673	671	0	6344	.009895	.001179	-11	-151	35810	-1957	-2119	243
3798			4297	965	-1	5261	.02164	.00333	-25	-426	32647	-1784	-2235	45
04564			2733	1160	-3	3891	.03528	.00685	-40	-878	26566	-1952	-2397	-233
04988			1424	1269	-4	2688	.04850	.01171	-55	-1501	19949	-1090	-2645	-466
05185			628	1318	-6	1940	.05954	.01769	-67	-2268	14597	-798	-3132	-701
05251			187	1335	-7	1515	.06736	.02445	-76	-3134	10315	-564	-3774	-901
05264			11	1338	-8	1341	.07309	.03548	-83	-4548	7152	-391	-5021	-1532
05258			-23	1337	-8	1306	.07241	.04269	-82	-5972	4963	-271	-5825	-1546
05254			-18	1336	-7	1310	.06812	.04929	-77	-6318	3406	-186	-6581	-1540
05239			-61	1332	-7	1264	.06061	.05497	-69	-7046	2433	-133	-7248	-1483
05198			-165	1321	-7	1149	.05031	.05948	-57	-7624	1460	-80	-7761	-1348
05120			-317	1301	-7	977	.03761	.06261	-43	-8025	1168	-64	-8132	-1162
04976			-583	1265	-7	675	.02294	.06417	-26	-8225	973	-53	-8304	-919
04742			-949	1205	+6	263	.00665	.06403	-8	-8207	779	-43	-8258	-608
04402			-1379	1119	6	-253	-.01098	.06205	+12	-7954	487	-27	-7969	-307
03971			-1750	1009	6	-734	-.02964	.05816	34	-7455	389	-21	-7442	+182
03454			-2100	878	+6	-1215	-.04891	.05231	55	-6705	0	0	-6650	600
02405			-2227	611	+6	-1609	-.06829	.04451	77	-5705	0	0	-5628	1110
02362			-2204	600	+6	-1598	-.08704	.03487	99	-4470	0	0	-4371	1854

neglect

neglect

TABLE VIII
CALCULATION OF VERTICAL SHEAR LOAD AT JOINT
SINGLE-JOINT ATTACHMENT - ROLL MOTION

TABLE - IX CALCULATION OF LOADS AT WING TIP JOINT
TWO-JOINT ATTACHMENT - PITCH MOTION

t SEC.	θ'' rad/sec.² (COL. 3 TABLE IV)	θ' RAD./SEC. (COL. 6 TABLE IV)	θ RADIAN (COL. 9 TABLE IV)	β'' RAD/SEC.² (COL. 4 TABLE IV)	β' RAD./SEC. (COL. 5 TABLE IV)	β RADIANS (COL. 8 TABLE IV)	X (FIG. 2)	1.744 × θ''	−1.125 × θ'	−150.97 × θ	8.274 × β''	5.592 × β'	59.73 × β	87.63 × X	$R_{F_V} \times 10^{-3}$ LBS (⑧+⑩+⑪+⑫+⑬+⑭+⑮)	18.595 × θ''	20.91 × θ'	47.86 × θ	.61 × β''	−12.00 × β'	13.24 × β
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒
0	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.02	−.01482	0	0	−.077045	0	0	.0680	.025846	0	0	−.63747	0	0	.70104	.06942	−.27558	0	0	−.04699	0	0
.04	−.02946	−.000296	−.000003	−.152988	−.001541	−.000015	.0160	.051376	.000333	.000453	−1.26552	−.00862	−.00089	1.40208	.17691	−.34781	−.00604	−.000143	−.09332	.01849	−.000199
.06	−.04038	−.000885	−.000015	−.21136	−.004601	−.000077	.0220	.070423	.000996	.00226	−1.7448	−.02573	−.00460	1.92786	.22241	−.75067	−.01806	−.000718	−.128929	.05521	−.001019
.08	−.04846	−.001693	−.000041	−.25310	−.008828	−.000211	.0270	.085451	.001905	.00619	−2.09415	−.04937	−.01260	2.36601	.30250	−.90111	−.03455	−.001962	−.154391	.10593	−.00277
.10	−.05452	−.002662	−.000085	−.28263	−.013854	−.000438	.0305	.09561	.002995	.012832	−2.33[illegible]	−.07777	−.02616	2.67271	.36776	−1.01938	−.05433	−.004068	−.172404	.16625	−.00570
.14	−.06133	−.004855	−.000235	−.31354	−.025159	−.001218	.0348	.10694	.00546	.03548	−2.5942	−.14069	−.07275	3.04952	.36971	−1.14025	−.09909	−.011247	−.19126	.30191	−.01613
.18	−.06274	−.007308	−.000476	−.34685	−.037701	−.002475	.0365	.109419	.00822	.07186	−2.62162	−.21082	−.14743	3.19849	.40773	−1.16665	−.14915	−.022761	−.19228	.45241	−.03277
.22	−.06128	−.009818	−.000818	−.363997	−.050375	−.004236	.0367	.106844	.01105	.12345	−2.51527	−.28170	−.25302	3.21662	.40771	−1.13913	−.20038	−.03915	−.18543	.60450	−.05668
.26	−.05729	−.012268	−.00126	−.377357	−.062535	−.006494	.0356	.09991	.013602	.190222	−2.29485	−.34970	−.38789	3.11963	.39112	−1.06534	−.25039	−.06304	−.16919	.75042	−.08598
.30	−.05166	−.01456	−.001797	−.241294	−.073629	−.009217	.0336	.09009	.01638	.27129	−1.99647	−.41173	−.55653	2.94437	.36340	−.96054	−.29717	−.08400	−.14719	.88355	−.12203
.34	−.04544	−.01663	−.002420	−.200105	−.083281	−.012355	.0311	.07882	.018764	.36535	−1.65567	−.45571	−.73797	2.72529	.32872	−.83930	−.33934	−.115421	−.12206	.99937	−.16358
.38	−.03969	−.01843	−.003121	−.15902	−.091265	−.015846	.0286	.06748	.020735	.47118	−1.31573	−.51066	−.94648	2.50621	.29293	−.71403	−.37618	−.149371	−.09700	1.09542	−.20980
.42	−.03155	−.01998	−.003889	−.116362	−.097646	−.019624	.0257	.05572	.022476	.58712	−.96274	−.54604	−1.17214	2.26962	.25398	−.59410	−.40277	−.16613	−.07096	1.17175	−.25944
.46	−.02831	−.02126	−.004714	−.074371	−.102300	−.023623	.0232	.04414	.023914	.71167	−.61535	−.57206	−1.41100	2.03302	.21433	−.47062	−.43385	−.22561	−.04537	1.22760	−.31277
.50	−.01877	−.02237	−.005564	−.033278	−.105275	−.02777	.0205	.03275	.02565	.84367	−.37534	−.58870	−1.65494	1.79642	.17426	−.34912	−.45451	−.26725	−.02030	1.26330	−.3677
.54	−.01310	−.02302	−.006649	+.002807	−.101606	−.032012	.0782	.02285	.02590	.97960	−.23225	−.59614	−1.92208	1.57487	.13843	−.24352	−.46984	−.310611	+.00172	1.27527	−.4238
.58	−.00772	−.02354	−.00942	+.036685	−.106494	−.036274	.0160	.01345	.02649	1.12033	.30253	−.59551	−2.16665	1.40208	.10374	−.14329	−.48053	−.355161	+.02238	1.27793	−.4402
.62	−.00279	−.02385	−.005369	+.067224	−.105027	−.040505	.0140	.00486	.02683	1.26342	.57621	−.58731	−2.41936	1.22682	.07153	−.08188	−.48682	−.40054	+.04101	1.26032	−.5362
.66	+.00165	−.02396	−.009325	+.09472	−.102338	−.044652	.0122	−.00278	.02694	1.40471	.76040	−.57237	−2.66706	1.06909	.04202	+.03068	−.48902	−.44629	+.05753	1.22806	−.59119
.70	+.00542	−.023898	−.010283	+.117176	−.091565	−.046671	.0106	−.009805	.02689	1.55442	.97531	−.55117	−2.90712	.92888	.01540	.12450	−.48776	−.49214	+.07190	1.18278	−.6944
.74	+.00918	−.023673	−.011235	+.137851	−.09385	−.05252	.0092	−.015916	.02663	1.69615	1.14058	−.52481	−3.13702	.806196	−.00819	.16977	−.48816	−.53771	+.08409	1.12620	−.69536
.78	+.01235	−.023308	−.012175	+.155173	−.088336	−.05616	.0079	−.021545	.02622	1.83606	1.2839	−.49397	−3.35444	1.69228	−.02950	.22965	−.47572	−.58269	+.09465	1.06003	−.74356
.82	+.01512	−.022814	−.013097	+.168857	−.082129	−.059573	.0068	−.026266	.02567	1.97203	1.39712	−.45926	−3.55629	.59568	−.04800	.28116	−.46563	−.626[illegible]82	+.10300	.98555	−.78875
.86	+.01743	−.022209	−.013998	+.178697	−.075375	−.062723	.0059	−.030393	.02499	2.11324	1.48019	−.42150	−3.74644	.517017	−.06285	.32411	−.45328	−.66994	+.10913	.90450	−.83045
.90	+.01947	−.021512	−.014472	+.186328	−.066219	−.065595	.0051	−.033956	.02420	2.24522	1.54166	−.34148	−3.91799	.44691	−.07541	.36204	−.43906	−.71177	+.11366	.81863	−.86848
.94	+.02125	−.020733	−.015716	+.191182	−.060966	−.068175	.0044	−.037057	.02332	2.37264	1.56144	−.33960	−4.0721	.36557	−.08559	.39514	−.42316	−.75217	+.11662	.72919	−.90264
.98	+.02295	−.019883	−.016528	+.194459	−.053119	−.070453	.0037	−.040027	.02237	2.49523	1.60895	−.27704	−4.20816	.32423	−.09445	.42675	−.40581	−.79103	+.11862	.63743	−.93280

TABLE - IX CALCULATION OF LOADS AT WING TIP JOINT
TWO-JOINT ATTACHMENT - PITCH MOTION

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	$\times -150.97 \times \theta$	$8.274 \times \beta''$	$5.592 \times \beta'$	$57.73 \times \beta$	$87.63 \times X$	$R_{F_V} \times 10^{-3}$ LBS	$18.595 \times \theta''$	$20.91 \times \theta'$	$47.86 \times \theta$	$.61 \times \beta''$	$-12.00 \times \beta'$	$13.24 \times \beta$	$38.82 \times X$	$M_T \times 10^{-3}$ FT. LBS
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	-.63717	0	0	.70104	.06942	-.27558	0	0	-.04699	0	0	-.31056	-.36614
33	.000453	-1.26552	-.00862	-.00089	1.40208	.17891	-.54781	-.00604	-.000143	-.09332	.01849	-.000199	-.62112	-1.25014
76	.00226	-1.7448	-.02573	-.00460	1.92786	.22241	-.75067	-.01806	-.000718	-.128929	.05521	-.001019	-.85404	-1.69842
15	.00613	-2.09415	-.04937	-.01260	2.36601	.30250	-.90111	-.03455	-.001962	-.158391	.10593	-.002799	-1.04814	-2.03702
77	.012832	-2.3115	-.077477	-.02616	2.67271	.36776	-1.01938	-.05433	-.004068	-.172404	.16625	-.00550	-1.18401	-2.27374
02	.03548	-2.5542	-.14069	-.07275	3.04452	.36971	-1.14025	-.09969	-.011287	-.19126	.30191	-.01613	-1.35094	-2.50707
2	.07188	-2.62162	-.21082	-.14743	3.19849	.40773	-1.16665	-.14915	-.022787	-.19228	.45241	-.03277	-1.41693	-2.52735
5	.12349	-2.51527	-.28170	-.25302	3.24602	.40711	-1.13913	-.20038	-.03915	-.18543	.60450	-.05608	-1.42477	-2.44037
02	.190222	-2.29485	-.34970	-.38789	3.11963	.39112	-1.06534	-.25039	-.060304	-.16919	.75042	-.08598	-1.36199	-2.26277
38	.27129	-1.99647	-.41123	-.55653	2.94437	.36340	-.96054	-.29717	-.08600	-.14713	.88355	-.122033	-1.30435	-2.03373
04	.36533	-1.62567	-.45571	-.737964	2.72529	.32872	-.839304	-.33934	-.115821	-.12206	.99937	-.16358	-1.20730	-1.78804
35	.47118	-1.31573	-.510466	-.94648	2.50621	.29293	-.719403	-.37618	-.149371	-.09700	1.09542	-.209601	-1.11625	-1.56658
76	.58712	-.96278	-.54604	-1.17214	2.26962	.25398	-.594110	-.40877	-.18613	-.07098	1.17175	-.259821	-.99767	-1.39773
14	.71167	-.61535	-.57206	-1.41100	2.03302	.21433	-.470621	-.43385	-.22561	-.04537	1.22760	-.31277	-.90052	-1.16124
25	.84307	-.28534	-.58870	-1.65694	1.79642	.17426	-.349124	-.45451	-.26725	-.02030	1.26330	-.36773	-.79581	-.99142
20	.97960	.023225	-.59614	-1.92208	1.59487	.13843	-.24352	-.46984	-.310611	+.00172	1.27927	-.42384	-.70652	-.87335
19	1.12035	.34353	-.59551	-2.16665	1.40208	.10374	-.14329	-.48053	-.355161	+.02238	1.27793	-.48027	-.62112	-.78007
43	1.26342	.55621	-.58731	-2.44936	1.22682	.07153	-.08188	-.48682	-.40054	+.04101	1.26032	-.53629	-.54348	-.71768
34	1.40071	.78040	-.57227	-2.66706	1.06909	.04202	+.03068	-.48902	-.44629	+.05753	1.22806	-.59119	-.47360	-.68383
89	1.55[illegible]	.97531	-.55117	-2.90712	.92888	.01540	.12450	-.48776	-.49214	+.07190	1.18278	-.64440	-.41149	-.67661
63	1.69615	1.14058	-.52481	-3.13702	.806196	-.00819	.16977	-.48316	-.53971	+.08409	1.12620	-.69536	-.35714	-.64331
22	1.83606	1.2839	-.49397	-3.35444	.69228	-.02950	.22965	-.47572	-.58269	+.09465	1.06003	-.74356	-.30668	-.72432
67	1.97203	1.39712	-.45926	-3.55629	.59568	-.04800	.28116	-.46563	-.62682	+.10300	.98555	-.78875	-.26398	-.77547
99	2.11324	1.49019	-.42150	-3.74644	.517017	-.06285	.32411	-.45328	-.66994	+.10913	.90450	-.83045	-.22904	-.84497
20	2.2452	1.54161	-.38148	-3.91799	.44691	-.07541	.36204	-.43906	-.71177	+.11366	.81865	-.86848	-.19798	-.92296
32	2.37264	1.54124	-.33960	-4.0721	.38557	-.08559	.39514	-.42316	-.75217	+.11662	.72919	-.90264	-.17081	-1.00983
237	2.49523	1.66895	-.29704	-4.20816	.32423	-.09445	.42675	-.40581	-.79103	+.11862	.63743	-.93280	-.14363	-1.09047

TABLE IX

CALCULATION OF LOADS AT WING-TIP JOINT
TWO-JOINT ATTACHMENT - PITCH MOTION

TABLE X — STEP-BY-STEP SOLUTION OF LOADS AT WING-TIP
TWO-JOINT ATTACHMENT
ROLL MOTION

	COL. ⑤ TABLE IV	COL. ⑦ TABLE IV	COL. ⑨ TABLE IV	COL. ⑪ TABLE IV	COL. ⑬ TABLE IV	COL. ⑮ TABLE IV	← EQUATION (61), REFERENCE →				⑧+⑨+⑩+⑪+⑫+⑬			← EQUATION (63), PG. →					⑤+⑰+⑱+⑲+㉑
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑
t	$\ddot{\phi}$	$\dot{\phi}$	$\ddot{\beta}$	$\dot{\beta}$	β	L_1	40.70 ②	25.40 ③	8.28 ④	5.59 ⑤	59.73 ⑥	-4.63 ⑦	$R_{F_V} \times 10^{-3}$	2.993 ②	-59.480 ③	.608 ④	-12.280 ⑤	13.242 ⑥	+2.053 ⑦	$M_I \times 10^{-3}$
SECONDS	RAD/SEC²	RAD/SEC	RAD/SEC²	RAD/SEC	RADIANS	FT-LBS	LBS.	LBS.	LBS.	LBS	LBS.	LBS.	POUNDS	FT-LBS.	FT-LBS.	FT-LBS.	FT-LBS.	FT-LBS.	FT-LBS.	FT-LBS
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.02	.08083	0	-.27361	0	0	.159	3.28978	0	-2.2655	-0	0	-.73617	.28811	.23707	0	-.16635	0	0	.32640	.39712
.04	.12011	.001617	-.40236	-.005472	-.000641	.242	4.88847	.04107	-3.33154	-.03059	-.00980	-1.0946	.35301	.35228	-.09618	-.24463	.06719	-.00217	.49683	.57332
.06	.14327	.004019	-.47514	-.013519	-.000515	.294	5.83104	.10208	-3.9346	-.07557	-.03076	-1.3612	.53146	.42021	-.23905	-.28888	.16601	-.00682	.60358	.65505
.08	.15711	.006884	-.51201	-.023022	-.000704	.333	6.39438	.17485	-4.23944	-.12863	-.06394	-1.54179	.59537	.46080	-.40946	-.31130	.28271	-.0417	.68365	.69223
.10	.15782	.010026	-.50399	-.033262	-.001838	.345	6.42327	.25464	-4.17304	-.12593	-.10978	-1.59735	.61181	.46288	-.59635	-.30645	.40846	-.04434	.70829	.65249
.14	.13872	.016339	-.41272	-.053422	-.004378	.328	5.64590	.41501	-3.41732	-.29863	-.26149	-1.51864	.56183	.40686	-.97184	-.25093	.65602	-.05797	.61338	.45520
.18	.11116	.021888	-.29094	-.069931	-.007505	.292	4.52421	.55595	-2.40898	-.39031	-.44227	-1.34733	.48467	.32603	-1.30189	-.17689	.85875	-.04938	.59448	-.20610
.22	.08789	.026334	-.18641	-.081569	-.011001	.257	3.57712	.66288	-1.54347	-.45597	-.65709	-1.18991	.39956	.25778	-1.56635	-.11334	1.00167	-.14567	.52762	-.03829
.26	.06649	.029850	-.08639	-.089025	-.014711	.224	2.70614	.75819	-.73187	-.49765	-.87869	-1.03712	.31900	.19502	-1.77548	-.05374	1.09322	-.19480	.45987	-.27591
.30	.04783	.032510	-.00125	-.092561	-.012484	.194	1.94668	.82575	-.01035	-.51143	-1.10405	-.89822	.24239	.14029	-1.93369	-.00076	1.13665	-.24476	.39828	-.50349
.34	.03281	.034423	.07016	-.092611	-.022189	.167	1.33536	.87434	.58093	-.51779	-1.32535	-.77321	.17437	.09623	-2.04750	.04266	1.13726	-.29383	.34285	-.72233
.38	.01956	.035735	.13379	-.089805	-.025725	.143	.79609	.90767	1.10778	-.50209	-1.53655	-.66209	.11089	.05737	-2.12552	.08134	1.10280	-.34065	.29358	-.93108
.42	.00323	.036517	.20426	-.084453	-.028996	.111	.13146	.92753	1.54008	-.47231	-1.73193	-.51393	-.11888	.02993	-2.17203	.11309	1.03708	-.38397	.22788	-1.14802
.46	.00126	.036646	.22186	-.076283	-.031884	.104	.05128	.93081	1.83700	-.42642	-1.90443	-.48152	+.00672	.00369	-2.2970	.13489	.93625	-.42221	.21351	-1.31307
.50	-.00462	.036696	.24792	-.067409	-.034403	.0865	-.18803	.93208	2.05278	-.32612	-2.05489	-.40049	-.03537	-.03383	-2.18268	.15074	.82778	-.45556	.17658	-1.49699
.54	-.00985	.036511	.27139	-.057492	-.036505	.0741	-.40090	.92738	2.24711	-.32138	-2.1804	-.34308	-.07127	-.02948	-2.17167	.16800	.70600	-.48340	.15213	-1.66142
.58	-.01406	.036117	.28724	-.046636	-.038193	.062	-.57224	.91737	2.37835	-.2[illegible]	-2.2789	-.28106	-.10318	-.04208	-2.14824	.17464	.57269	-.50522	.12729	-1.82092
.62	-.01692	.035555	.29506	-.035146	-.039329	.0519	-.68864	.90310	2.44310	-.196[illegible]	-2.3491	-.24030	-.12831	-.05064	-2.11481	.17939	.43154	-.52079	.10655	-1.96811
.66	-.01851	.034878	.29574	-.023344	-.040626	.0445	-.75336	.88590	2.44873	-.1304[illegible]	-2.3008	-.20604	-.14606	-.05540	-2.07459	.17481	.28666	-.53002	.09136	-2.102[illegible]3
.70	-.02149	.034138	.29827	-.011514	-.040250	.0345	-.87464	.86711	2.46968	-.0643[illegible]	-2.40413	-.15774	-.16608	-.04432	-2.03053	.18135	.14139	-.53299	.07083	-2.23427
.74	-.02355	.033278	.29499	.000417	-.040028	.0262	-.95849	.84526	2.44252	.0023[illegible]	-2.39087	-.12131	-.18056	-.07048	-1.97938	.17935	-.00512	-.53005	.05379	-2.35184
.78	-.02449	.032336	.28489	.012217	-.039303	.0207	-.99349	.82133	2.35889	.0682[illegible]	-2.34757	-.09584	-.18839	-.07306	-1.92335	.17321	-.15002	-.52045	.04250	-2.45117
.82	-.02521	.031360	.27229	.023613	-.038130	.0155	-1.02605	.79654	2.25456	.1320[illegible]	-2.27150	-.07177	-.19222	-.07545	-1.86529	.16555	-.28997	-.50492	.03182	-2.53826
.86	-.02560	.030352	.25607	.034505	-.036532	.0114	-1.04192	.77094	2.12026	.1928[illegible]	-2.18204	-.05278	-.19265	-.07662	-1.80536	.15691	-.42372	-.48515	.02340	-2.60914
.90	-.02569	.029328	.23700	.044748	-.034637	.0083	-1.04558	.74473	1.96236	.2501[illegible]	-2.06290	-.03843	-.18948	-.07689	-1.74443	.14409	-.54950	-.45734	.01704	-2.66703
.94	-.02527	.026301	.21468	.054228	-.032178	.0065	-1.02849	.71225	1.77755	.3031[illegible]	-1.92199	-.03010	-.18105	-.09563	-1.68324	.13053	-.66592	-.42610	.01334	-2.7072
.98		.027650		.062815	-.029490	.0034		.70231		.35114	-1.76144	-.01574			-1.64462		-.77137	-.39051	.00698	
1.02						0														

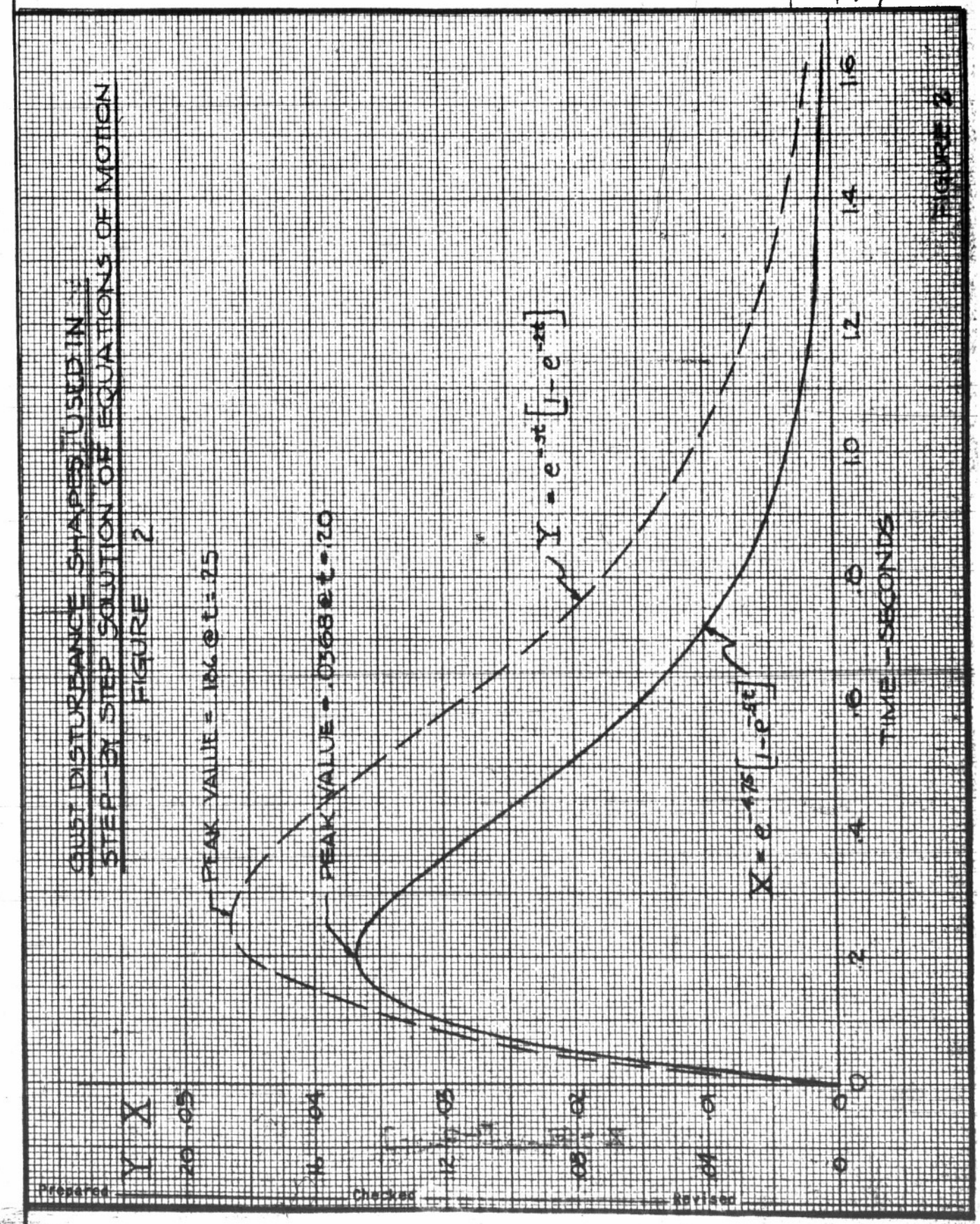
TABLE X — STEP-BY-STEP SOLUTION OF LOADS AT WING-TIP
TWO-JOINT ATTACHMENT
ROLL MOTION

1) REFERENCE → (8)+(9) +(10)+(11) +(12)+(13)

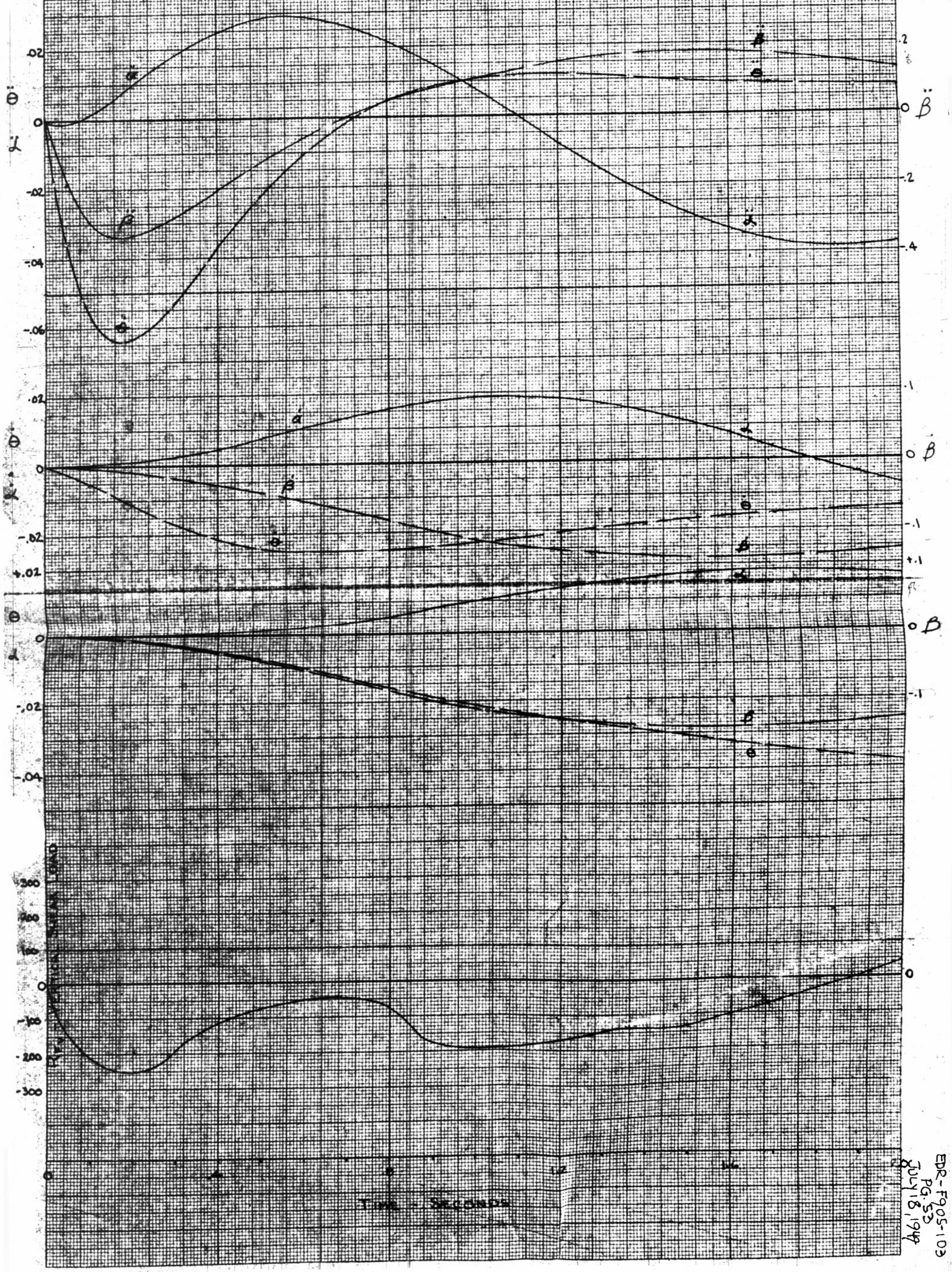
← EQUATION (63) PG. → (15)+(16) +(17)+(18) +(19)+(20)

(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
5.59 (5)	59.73 (6)	-4.63 (7)	$R_{F_V} \times 10^{-3}$	2.993 (2)	-59.480 (3)	.608 (4)	-12.280 (5)	13.242 (6)	+2.053 (7)	$M_I \times 10^{-3}$
LBS	LBS	LBS	POUNDS	FT-LBS	FT-LBS	FT-LBS	FT-LBS	FT-LBS	FT-LBS	FT-LBS
0	0	0	0	0	0	0	0	0	0	0
5 0	0	-.73617	.28811	.23707	0	-.16635	0	0	.32640	.39712
4 -.03059	-.00980	-1.2046	.35301	.35228	-.09618	-.24463	.06719	-.00217	.49683	.57332
6 -.07557	-.03076	-1.36122	.53146	.42021	-.23905	-.28888	.16601	-.00682	.60358	.65505
4 -.128693	-.06394	-1.54179	.59537	.46080	-.40946	-.31130	.28271	-.01417	.68365	.69223
4 -.18593	-.10978	-1.59735	.61181	.46288	-.59635	-.30645	.40846	-.02434	.70829	.65249
32 -.29863	-.26149	-1.51864	.56483	.40686	-.97184	-.25093	.65602	-.05797	.67338	.45520
8 -.39091	-.44227	-1.34733	.48467	.32603	-1.30189	-.17689	.85875	-.09938	.59948	.20610
47 -.45597	-.65709	-1.18991	.39956	.25778	-1.56635	-.11334	1.00167	-.14567	.52762	-.03829
7 -.49765	-.87869	-1.03712	.31900	.19502	-1.77548	-.05374	1.09322	-.19480	.45987	-.27591
5 -.51147	-1.10405	-.89822	.24239	.14029	-1.93369	-.00076	1.13665	-.24476	.39828	-.50399
3 -.51770	-1.32535	-.77321	.17437	.09623	-2.04750	.04266	1.13726	-.29383	.34285	-.72233
8 -.50201	-1.53655	-.66209	.11089	.05737	-2.12552	.08134	1.10280	-.34065	.29358	-.93108
08 -.47201	-1.73193	-.51393	-.11888	.02993	-2.17203	.11309	1.03708	-.38397	.22788	-1.14802
00 -.42642	-1.90443	-.48152	+.00672	.00369	-2.17970	.13489	.93675	-.42221	.21351	-1.31307
78 -.37682	-2.05489	-.40049	-.03537	-.01383	-2.18268	.15074	.82778	-.45556	.17658	-1.49699
1 -.32133	-2.1804	-.34308	-.07127	-.02948	-2.17167	.16500	.70600	-.48340	.15213	-1.66142
35 -.260	-2.2789	-.28706	-.10318	-.04208	-2.14824	.17464	.57269	-.50522	.12729	-1.82092
0 -.19691	-2.3491	-.24030	-.12831	-.05064	-2.11481	.17939	.43159	-.52079	.10635	-1.96891
13 -.13041	-2.3908	-.20604	-.14606	-.05540	-2.07459	.17981	.28666	-.53002	.09136	-2.10213
68 -.06436	-2.40413	-.15974	-.16608	-.06432	-2.03053	.18135	.14139	-.53299	.07083	-2.23427
52 .00231	-2.39087	-.12131	-.18056	-.07048	-1.97938	.17935	-.00512	-.53005	.05379	-2.35189
89 .06829	-2.34757	-.09584	-.18839	-.07306	-1.92335	.17321	-.15002	-.52045	.04250	-2.45117
56 .13203	-2.27750	-.07177	-.19222	-.07545	-1.86529	.16555	-.28997	-.50492	.03182	-2.53826
26 .19281	-2.18204	-.05278	-.19265	-.07662	-1.80536	.15691	-.42372	-.48375	.02340	-2.60914
36 .25014	-2.06290	-.03843	-.18948	-.07689	-1.74443	.14409	-.54950	-.45734	.01704	-2.66703
55 .30313	-1.92199	-.03010	-.18105	-.09563	-1.68334	.13053	-.66592	-.42610	.01334	-2.70712
.35114	-1.76144	-.01574			-1.64462		-.77137	-.39051	.00698	

TABLE X
CALCULATION OF LOADS AT WING-TIP
TWO-JOINT ATTACHMENT - ROLL MOTION


GUST DISTURBANCE SHAPES USED IN
STEP-BY STEP SOLUTION OF EQUATIONS OF MOTION
FIGURE 2
PEAK VALUE = .186 @ t = .25
PEAK VALUE = .0368 @ t = .20
$Y = e^{-5t}[1-e^{-2t}]$
$X = e^{-4.75}[1-e^{-5t}]$
TIME - SECONDS
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
Y
X
.20
.16
.12
.08
.04
0
.05
.04
.03
.02
.01
0
FIGURE 2

TIME HISTORY OF MOTION AND LOADS DURING PITCH DISTURBANCE
SINGLE - JOINT METHOD OF ATTACHMENT
FIGURE 3



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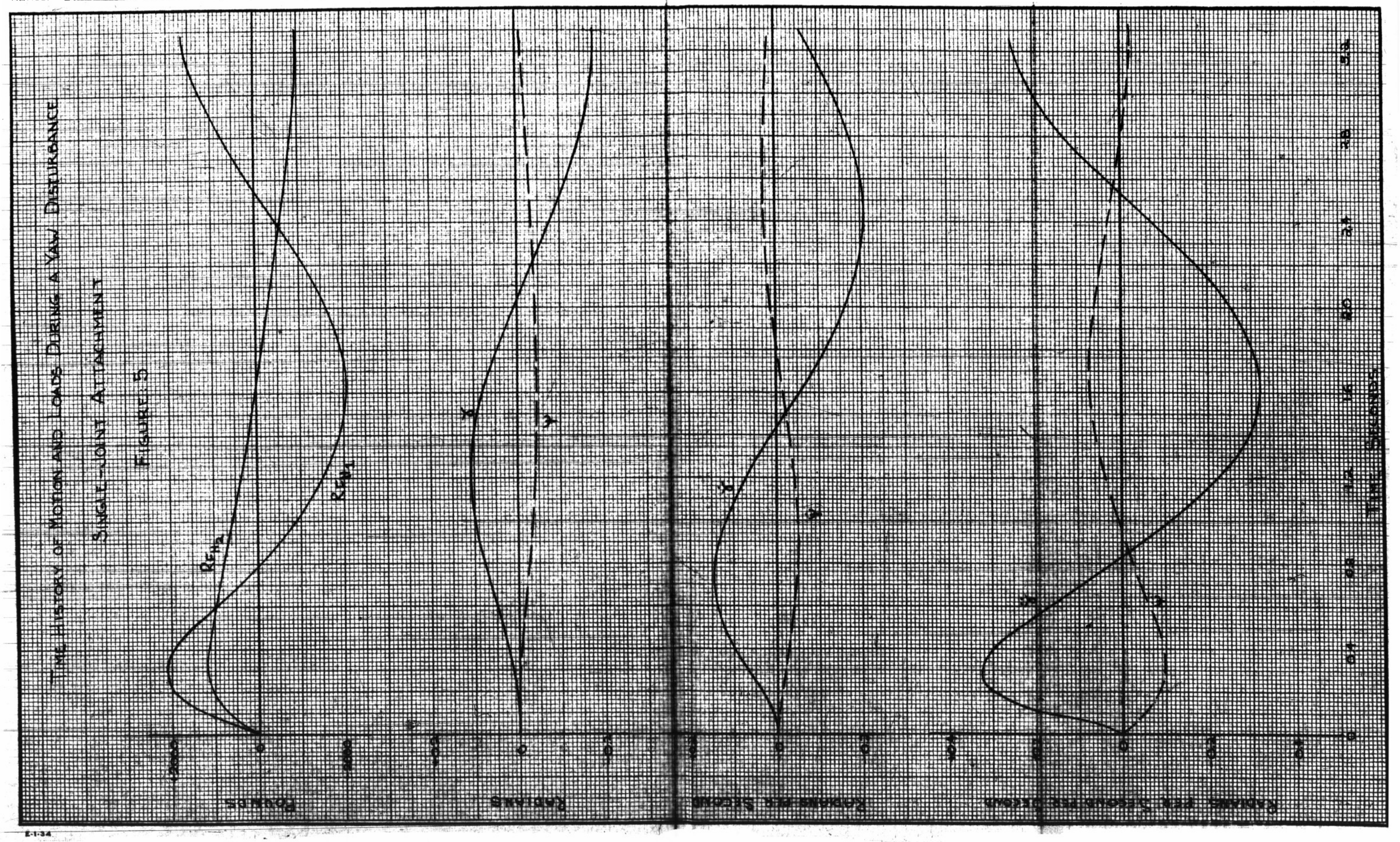
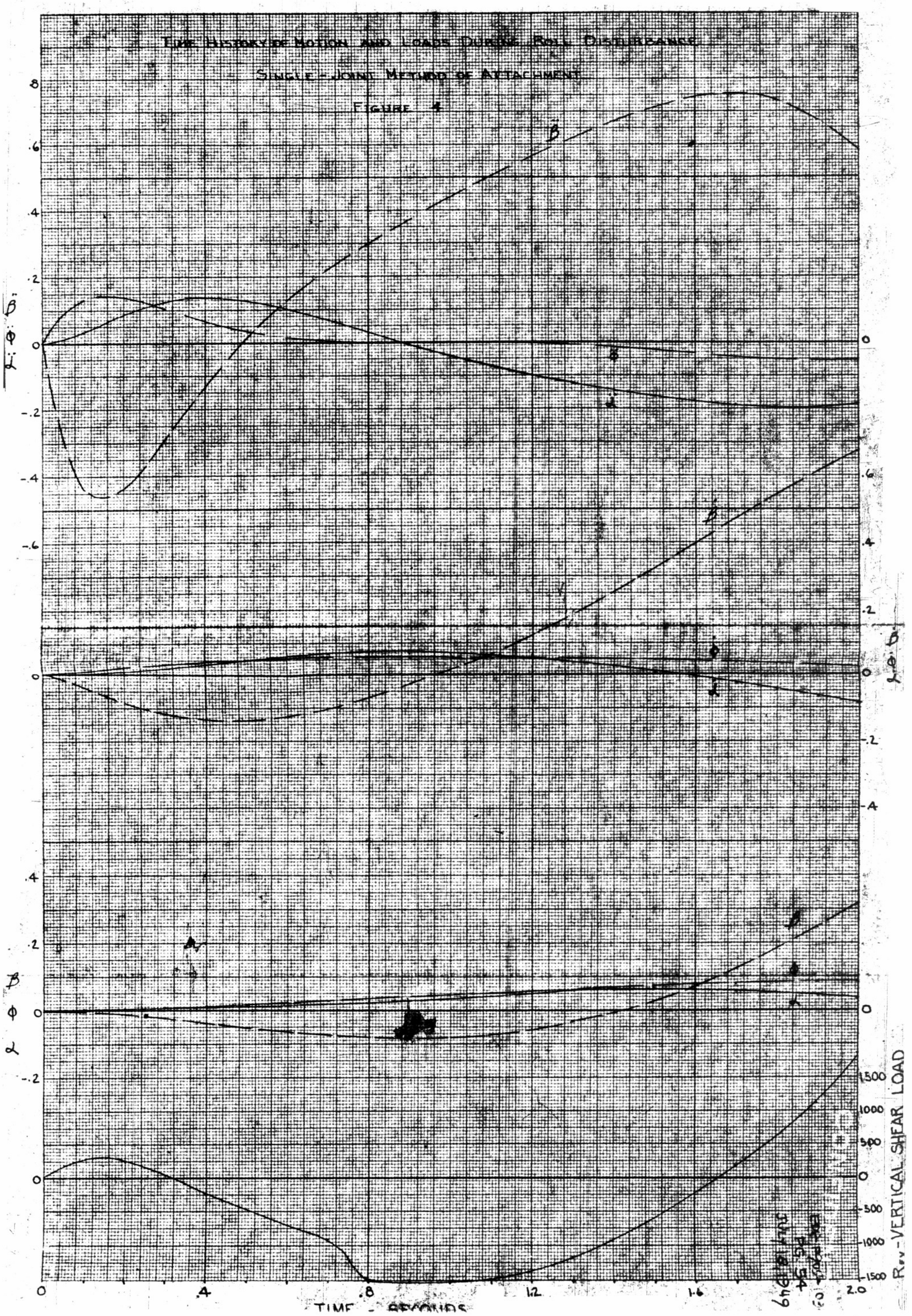


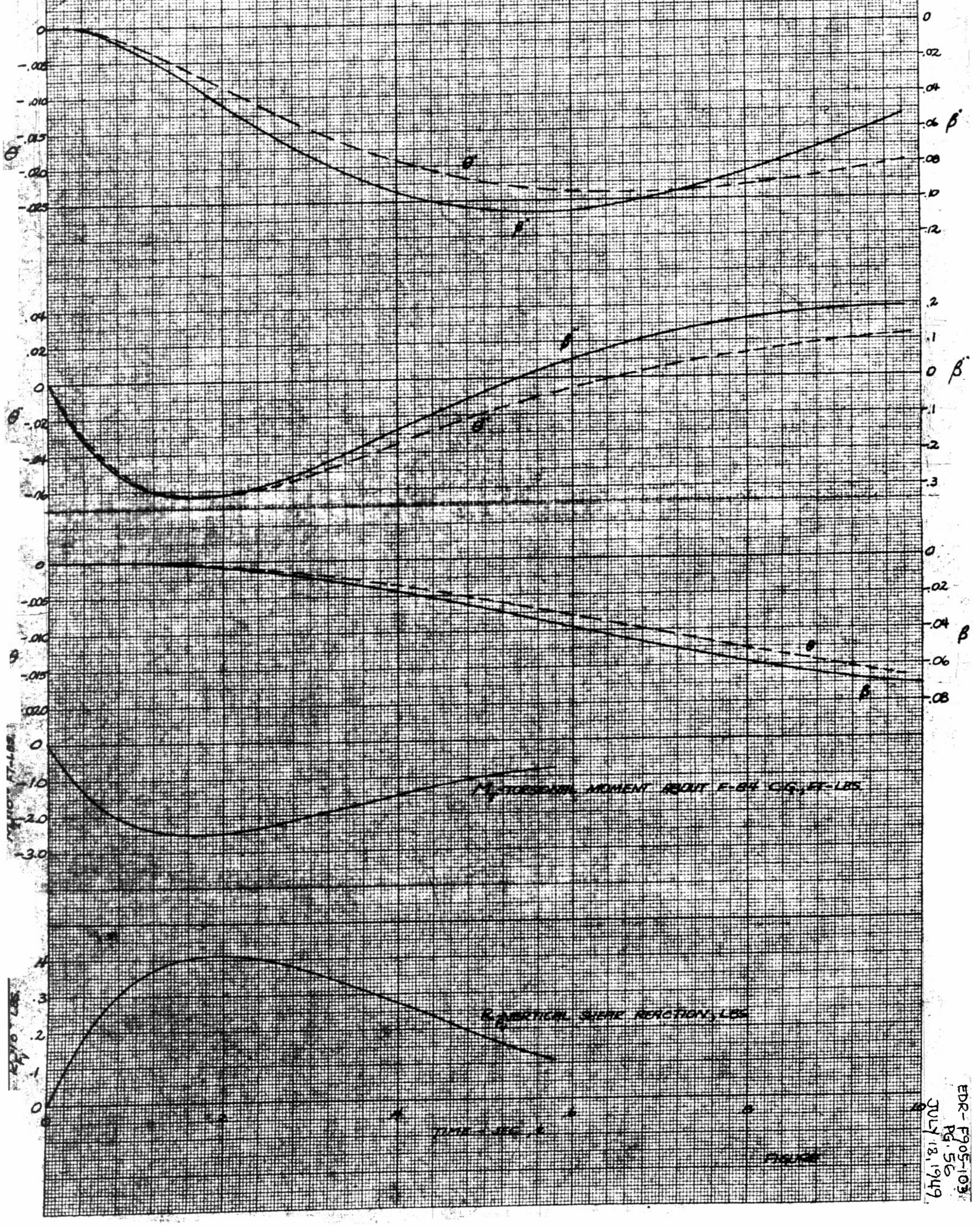
NO. 340D-N DIETZGEN GRAPH PAPER MILLIMETER
EUGENE DIETZGEN CO.



TIME HISTORY OF MOTION AND LOADS DURING A PITCH DISTURBANCE

TWO-JOINT ATTACHMENT

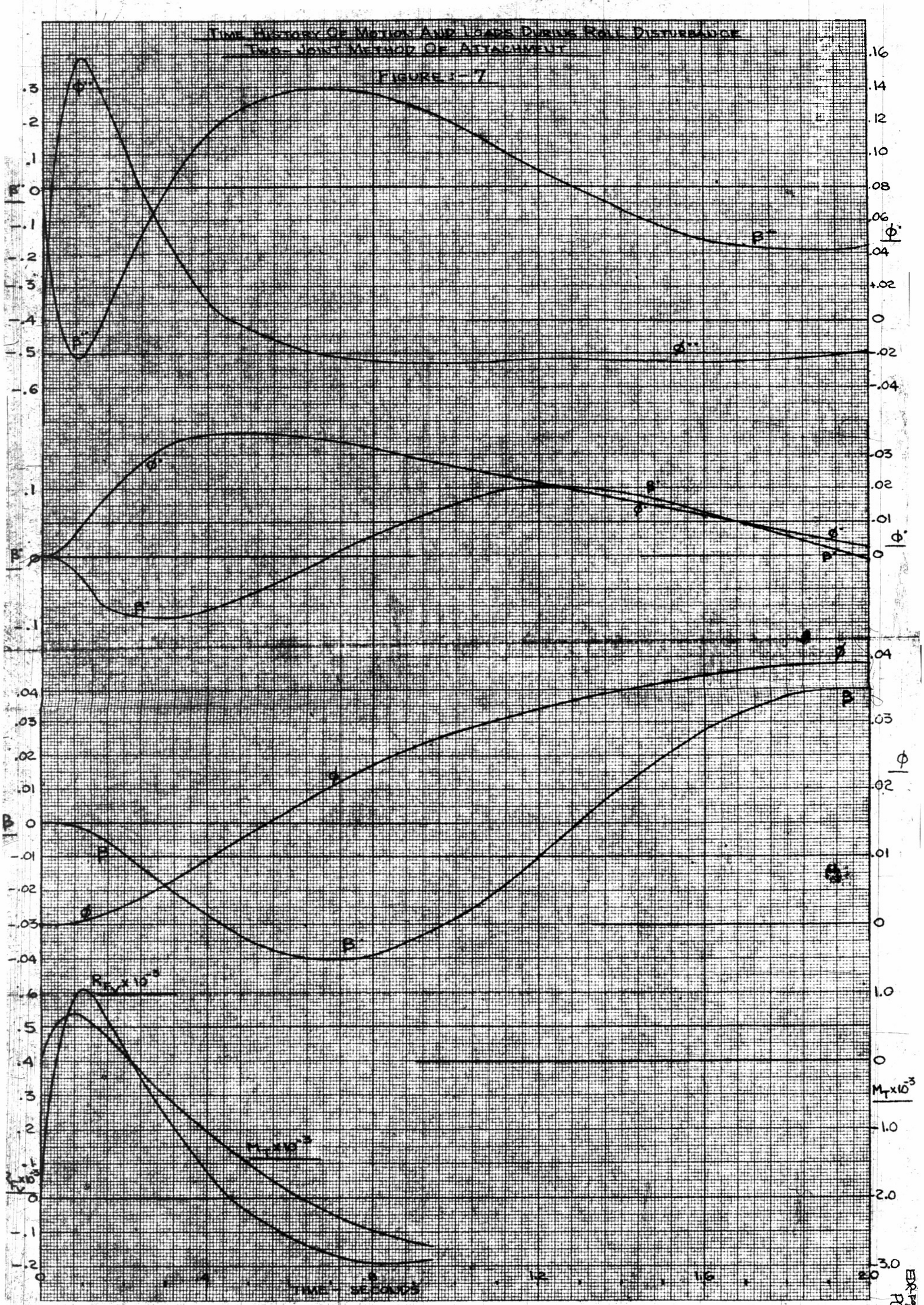
FIGURE 6

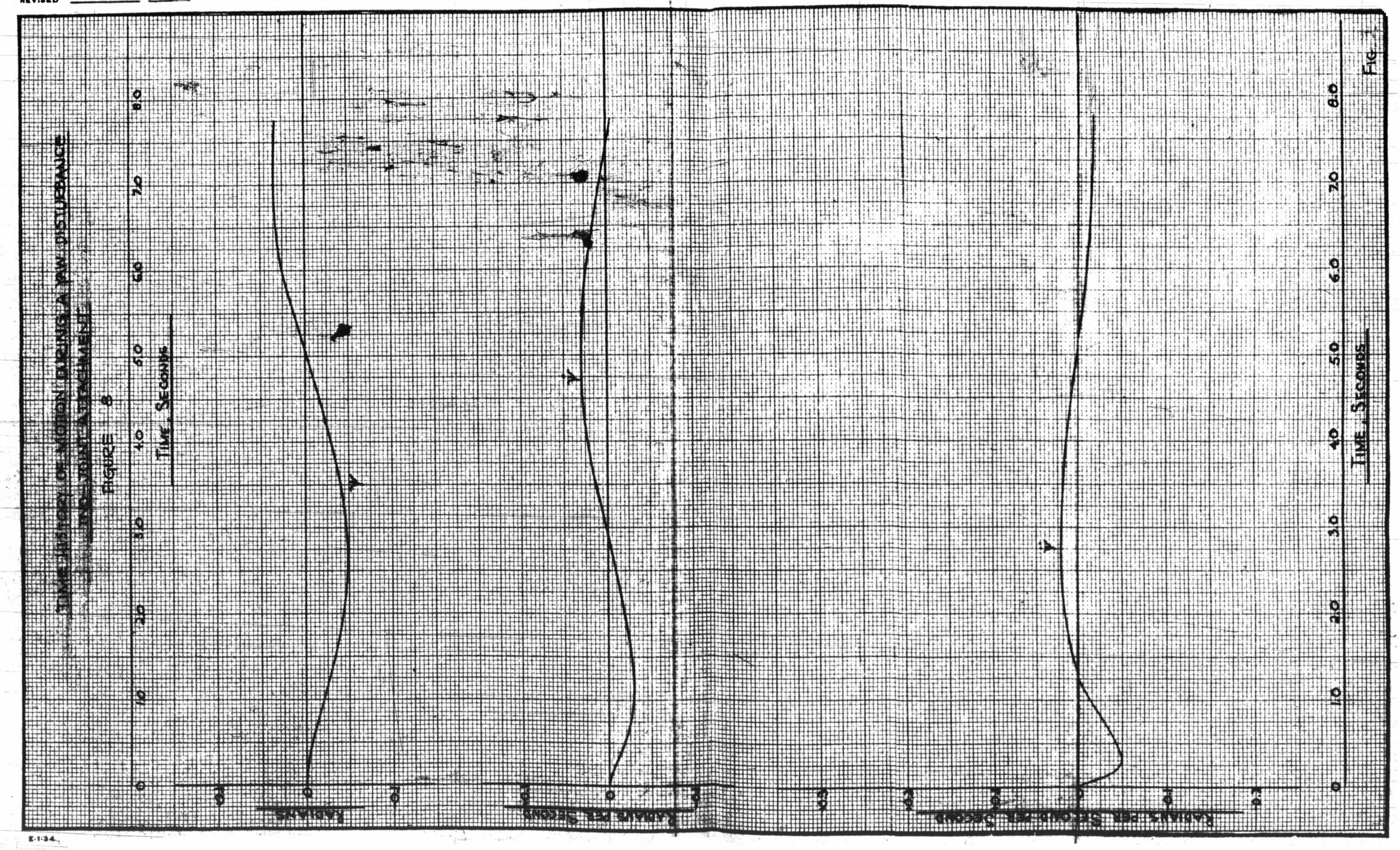


FIGURE

TIME HISTORY OF MOTION AND LOADS DURING ROLL DISTURBANCE
TWO-JOINT METHOD OF ATTACHMENT

FIGURE 1-7




TIME HISTORY OF MOTION DURING A YAW DISTURBANCE
TWO-JOINT ATTACHMENT
FIGURE 8
TIME, SECONDS
RADIANS
RADIANS PER SECOND
RADIANS PER SECOND PER SECOND
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
FIG.

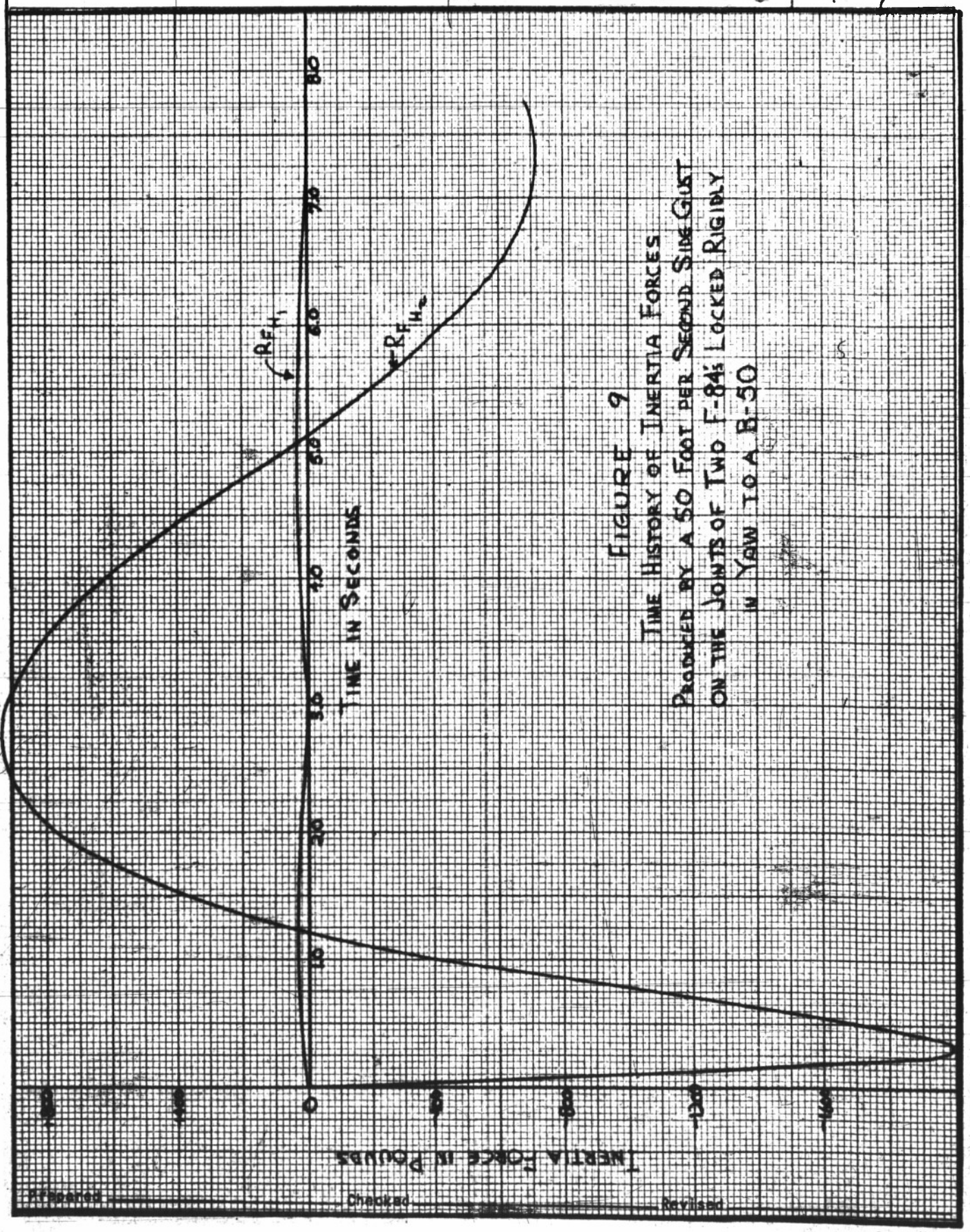


FIGURE 9
TIME HISTORY OF INERTIA FORCES
PRODUCED BY A 50 FOOT PER SECOND SINE GUST
ON THE JOINTS OF TWO F-84's LOCKED RIGIDLY
IN YAW TO A B-50

S-1-10A
V. 9/49

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REPUBLIC AVIATION CORP., FARMINGDALE, L.I., N.Y.
(REPORT NO. EDR-F905-103)

CALCULATIONS OF MOTIONS AND LOADS RESULTING FROM GUST DISTURBANCES ACTING UPON AIRCRAFT IN COUPLED FLIGHT

H.R. LU; S. HELFMAN; J. CANGELOSI; AND OTHERS 18 JULY '49
59PP TABLES, GRAPHS

USAF PROJECT MX-1016

AERODYNAMICS (2)
AERODYNAMIC LOADS (8)

AIRPLANES - GUST LOADS
AIRPLANES - STABILITY
AIRPLANES - WING-TIP COUPLING
PROJECT MX-1016

CONFIDENTIAL