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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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TABLE OF CONTENTS

	Page
Introduction	4
Summary	5
A. Single-Joint Attachment	5
B. Two-Joint Attachment	6
C. Tabulation of Maximum Wing Tip Loads	7
List of Symbols and Coefficients	8
List of Figures	11
List of Tables	12
References	13
Equations of Motion	15
A. Single-Joint Attachment	15
B. Two-Joint Attachment	17
Gust Disturbances	19
A. Pitch Motion	19
B. Roll Motion	21
C. Yaw Motion	23
Motion Study	25
A. Single-Joint Attachment	25
1. Pitch Motion	25
2. Roll Motion	28
3. Yaw Motion	29

TABLE OF CONTENTS (Cont'd.)

Page

B. Two-Joint Attachment 30
1. Pitch Motion 30
2. Roll Motion 32
3. Yaw Motion 34
Determination of Loads at Joint 35
A. Single-Joint Attachment 36
1. Pitch Motion 36
2. Roll Motion 36
3. Yaw Motion 37
B. Two-Joint Attachment 37
1. Pitch Motion 37
2. Roll Motion 38
3. Yaw Motion 39

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.

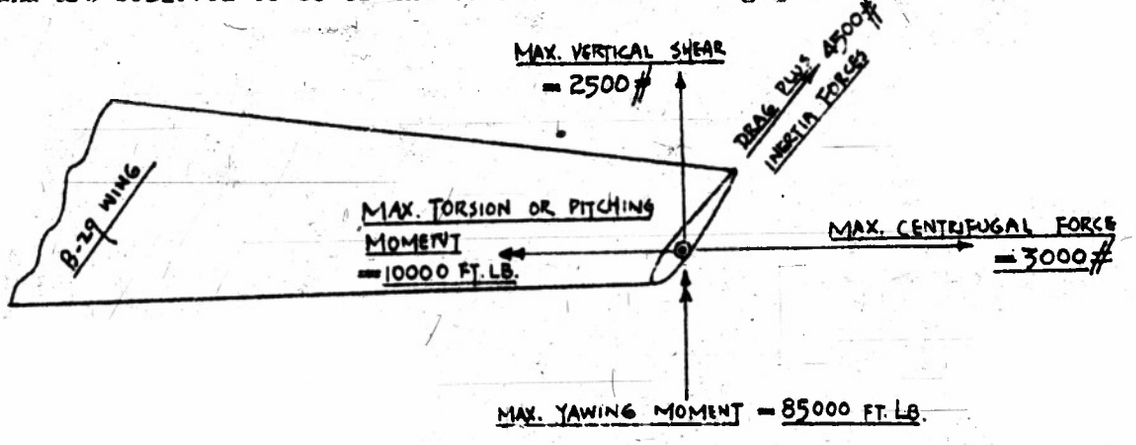
3. The yawing motion has been calculated for a side gust disturbance acting on the bomber tail, causing yawing of the combination only since the fighter is locked to the bomber for yaw. The results of an analytical solution are plotted in Figure 8 and the wing tip loads associated with this disturbance 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_o = 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 $\theta, \dot{\theta}, \beta, \dot{\beta}, \alpha, \dot{\alpha}$ etc denote partial differntiation with respect to the variables, as $L_{\dot{\phi}}$, L_{β} etc., etc. $= \frac{\partial L}{\partial \dot{\phi}}$, $\frac{\partial L}{\partial \beta}$ 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.

LIST OF FIGURES

		Page
Figure 1	Planform - Proposed Coupling Schemes	14
Figure 2	Gust Disturbance Shapes Used In Step-by-Step Solution of Equation of Motion	52
Figure 3	Time History of Motion and Loads During A Pitch Disturbance Single-Joint Attachment	53
Figure 4	Time History of Motion and Loads During A Roll Disturbance Single-Joint Attachment	54
Figure 5	Time History of Motion and Loads During A Yaw Disturbance Single-Joint Attachment	55
Figure 6	Time History of Motion and Loads During A Pitch Disturbance Two-Joint Attachment	56
Figure 7	Time History of Motion and Loads During A Roll Disturbance Two-Joint Attachment	57
Figure 8	Time History of Motion During A Yaw Disturbance - Two-Joint Attachment	58
Figure 9	Time History of Inertia Forces on Joint During A Yaw Disturbance - Two-Joint Attachment	59

LIST OF FIGURES

		Page
Table I	Step-by-Step Solution of Equations of Motion Single-Joint Attachment - Pitch Motion	40
Table II	Step-by-Step Solution of Equations of Motion Single-Joint Attachment - Roll Motion	42
Table III	Step-by-Step Solution of Equations of Motion and Determination of Loads at Joint - Single-Joint Attachment - Yaw Motion	44
Table IV	Step-by-Step Solution of Equations of Motion Two-Joint Attachment - Pitch Motion	45
Table V	Step-by-Step Solution of Equations of Motion Two-Joint Attachment - Roll Motion	46
Table VI	Step-by-Step Calculation of Equations of Motion and Determination of Loads at Joint - Two-Joint Attachment-Yaw Motion	47
Table VII	Calculation of Vertical Shear Load at Joint Single-Joint Attachment - Pitch Motion	48
Table VIII	Calculation of Vertical Shear Load at Joint Single-Joint Attachment - Roll Motion	49
Table IX	Calculation of Vertical Shear Load and Torsional Moment at Joint - Two-Joint Attachment - Pitch Motion	50
Table X	Calculation of Vertical Shear Load and Torsional Moment at Joint - Two-Joint Attachment - Roll Motion	51

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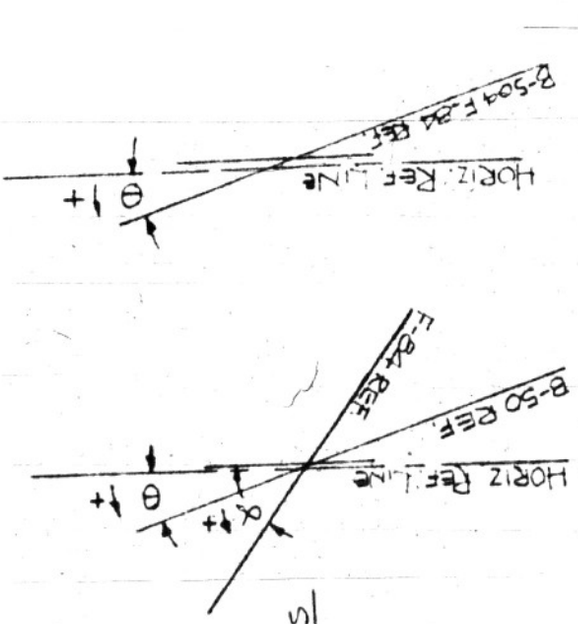
2. Lu, H.R., Helfman, S. and Cangelosi, J.: Theoretical Investigation of the Dynamic Stability of Bomber-Fighter Soupled Flight. Republic Aviation Corporation Report No. EDR-F-905-102, July 10, 1949

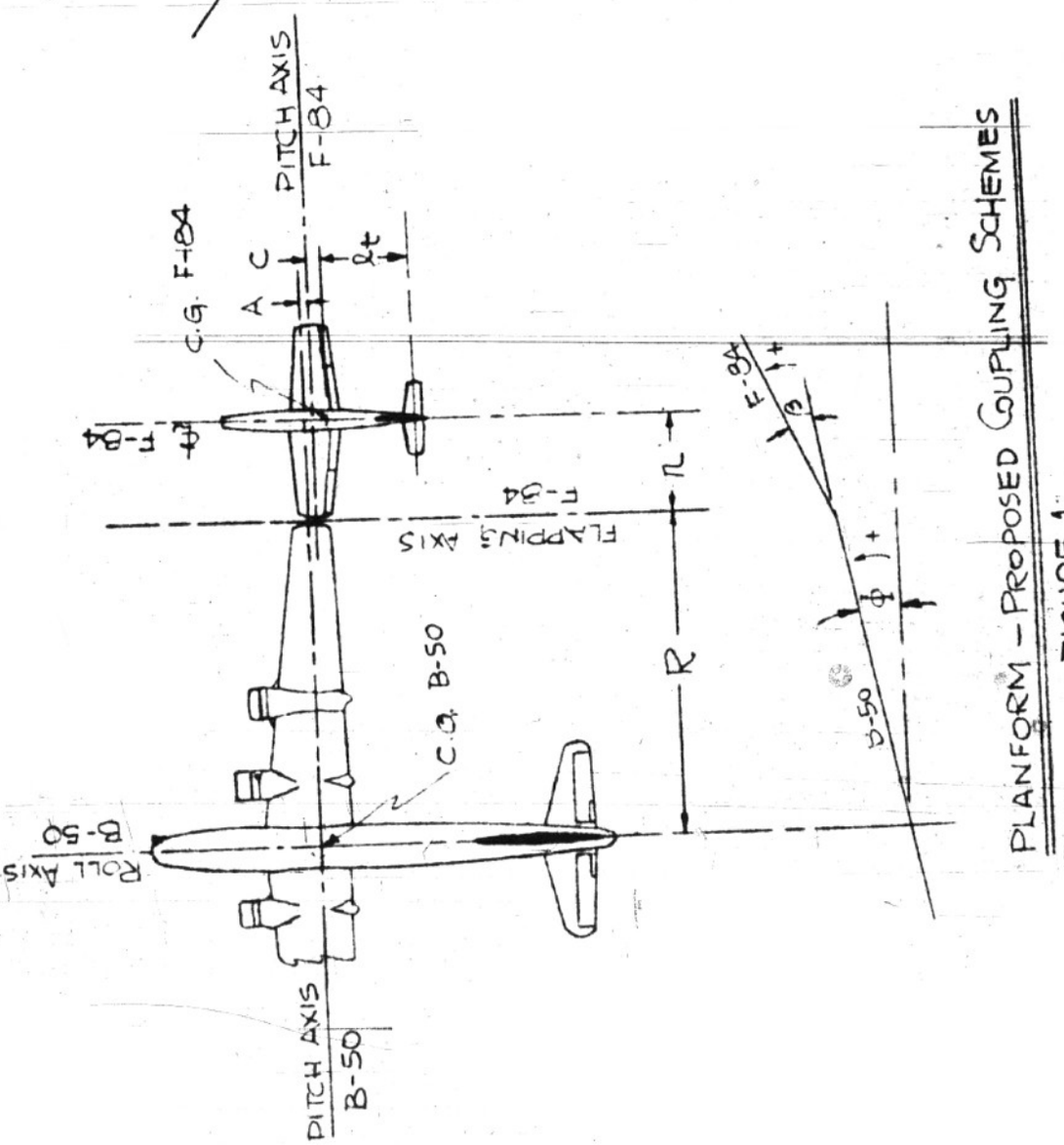
3. Stern, M.: Structural Investigation of F-84 and B-50 Wing-Tip to Wing-Tip Coupling Republic Aviation Corporation Report No. EDR-F905-1, July 15, 1949

FIGURE 1



TWO-JOINT ATTACHMENT

SINGLE-JOINT ATTACHMENT



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:

$I_{y-y} = 1000 \times 10^3$ slugs-ft.^{2}
$m = 453.4$ slugs
$A = 3.25$ ft.
$c = .5912$ ft.
$r = 18.3$ ft.
$k_x = 5.61$ ft.
$I_{y-y} = 18.59 \times 10^3$ slugs-ft.^{2}
$d = .2217$ ft.
$I_{x-x} = 1712 \times 10^3$ slugs-ft.^{2}
$R + r = 90$ ft.
$I_{z-z} = 2712 \times 10^3$ 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:

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

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

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

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:

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

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:

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

b) Flap of the F-84:

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

2. Roll Disturbance

a) Roll of the B-50:

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

b) Flap of the F-84:

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

3. Yaw Disturbance

a) Yaw of the combination:

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

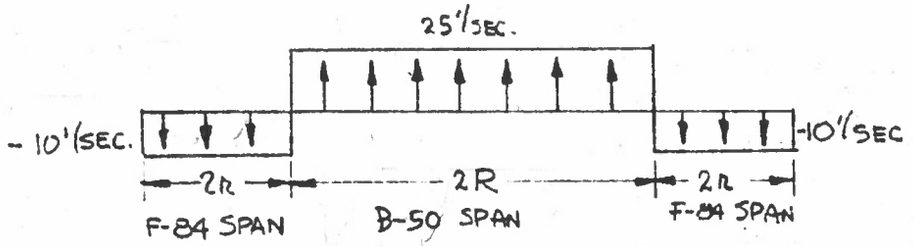
GUST DISTURBANCES

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):

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

$$M_o' = \left[-.93478\times10^{6}\times1.542 + (-.05296\times10^{-9})\times(-.617)\right]\bar{X}$$

(pg. , REF. 2.)

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

Bomber Pitch (Single-Joint):

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

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

Fighter Pitch (Single-Joint):

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

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

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

Fighter-Flapping (Single-Joint):

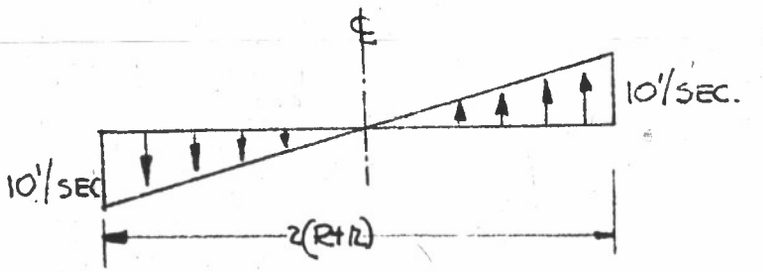
$$L_2 = \left(\frac{dC_L}{d\alpha}\right)_{F-84} q_D S\, \ell_w \cdot \Delta\alpha_{F-84}$$

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

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

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

$$L_o = q_D S b C_{\ell_p} \frac{\phi \cdot b}{2V}$$

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

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

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

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

$a_w = 17.62$ FT. [REF 2, Pg.]

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

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:

$$M_{1MAX} = qSc \frac{dC_m}{dC_L} C_{L_\phi} \cdot \phi^{\cdot}$$

$$M_{1MAX} = L_{w_\phi} \cdot c \frac{dC_m}{dC_L} \phi^{\cdot}$$

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

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

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

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

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

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

C. Yaw Motion

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:

$$N_0 = q S_{V_t}{}_{B-50} \left(\frac{dC_L}{d\alpha}\right)_{V_t}{}_{B-50} \cdot l_t{}_{B-50} \frac{v}{V}$$

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

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

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:

$A = 3.25$ Ft.	$k_a = K_a = 0$	Single-Joint
$e = .5912$ Ft.	$k_\theta = 0.1$	
$K = -1.0$ (2-joint)	$K_\theta = 0.03$	

A. Single-Joint Attachment

1. Pitch Motion

The equations of motion become:

Pitch of B-50:

$$[-53.73\,D^2 - 30.236\,D + 1.842]\beta + [1009.58\,D^2 + 713.37\,D + 108.30]\theta + [1.7423\,D^2 + 7.3613\,D + 833.2]\alpha = -1.4414 \times 10^3 \overline{X} \quad \text{.....(14)}$$

Flap of F-84:

$$[165.49\,D^2 + 101.20\,D - 5.187]\beta + [-26.966\,D^2 - 417.24]\theta + [-4.905\,D^2 - 20.725\,D - 2304]\alpha = -15.73 \times 10^2 \overline{X} \quad \text{.....(15)}$$

Pitch of F-84:

$$[-4.273\,D^2 + 2.308\,D + 5.309]\beta + [.8712\,D^2 + 8.4246]\theta + [18.753\,D^2 + 21.213\,D + 128.79]\alpha = 38.82\,\overline{X} \quad \text{.....(16)}$$

Dividing Equation 14 by 10^3 and rearranging:

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

Dividing Equation 15 by 10^2 and rearranging

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

and rearranging Equation 16:

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

Where:

$$A = -1.4414\,\bar{X} + .0302\,\dot{\beta} - .001842\,\beta - .71337\,\dot{\theta} - .1083\,\theta - .007361\,\dot{\alpha} - .8837\,\alpha$$

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

$$C = 38.82\,\bar{X} - 2.3083\,\dot{\beta} - 5.307\,\beta - 8.4246\,\theta - 21.213\,\dot{\alpha} - 128.79\,\alpha$$

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

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

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

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

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

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:

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

Flap of F-84:

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

Pitch of F-84:

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

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:

$$A_1 = -18.804\,\overline{X} - 8.065\,\phi' - .906\,\beta' + (.05103 + 2.986\,\phi' + 1.493\,\beta^2)\beta + 23.08\,\alpha + 1.2039\,\alpha'$$

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

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

Solving for ϕ'', etc.

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

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

3. Yaw Motion

The equations of the yaw motion become:

B-50 Yaw:

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

Where:

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

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

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

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. Yaw Motion

The equations of the yaw motion become:

B-50 Yaw:

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

F-84 Yaw:

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

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:

$$A_2 = -2.535e^{-3t}[1-e^{-2t}] - .532\ddot{\psi} - 4.725\dot{\psi} - .0139\ddot{\gamma} - .259\dot{\gamma}$$

$$B_2 = -.0737e^{-3t}[1-e^{-2t}] - .096\dot{\psi} - .1298\psi - .00696\dot{\gamma} - .1298\gamma$$

Solution of (32) and (33) yields:

$$\ddot{\gamma} = 15.6098\,B_2 - 1.2040\,A_2 \qquad (34)$$

$$\ddot{\psi} = .2869\,A_2 - 2.4174\,B_2 \qquad (35)$$

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:

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

Flap of F-84:

$$\left[1.6571\,D^2 + 1.134\,D + 10.93\right]\beta - \left[.3191\,D^2 + .2059\,D + 27.13\right]\theta = -15.73\,\bar{X} \qquad (37)$$

These equations of the form

$$\begin{aligned} 1.0506\,\theta'' - .0623\,\beta'' &= A_3 \\ -.3191\,\theta'' + 1.6571\,\beta'' &= B_3 \end{aligned}$$

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'' :

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

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

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:

$$\theta'' = .0587\,A + .00729\,B \qquad (40)$$

$$\beta'' = .0113\,A + .5967\,B \qquad (41)$$

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:

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

Flap of F-64:

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

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):

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

$$\begin{cases} \phi'' = .4706\ A_4 - .4328\ B_4 & (46) \\ \beta'' = -2.1516\ A_4 + 2.5824\ B_4 & (47) \end{cases}$$

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

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

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:

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

Substituting the values of the constants:

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

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:

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

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 : $$R_{F_{H_1}} \cong m R \gamma'' \left(\frac{R}{R+\ell_2}\right) + m(R+\ell_2)\psi'^2 \quad \ldots\ldots (52)$$

Chordwise Force: $$R_{F_{H_2}} \cong -m(R+\ell_2)\psi'' - m R \gamma'' \quad \ldots\ldots (53)$$

Substituting the known values of the coefficients:

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

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

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:

$$R_{F_V} = m R \beta'' - m(c+A)\theta'' - \Sigma(L_W + L_t) - \frac{L_2}{\ell_2} \quad \ldots\ldots (56)$$

or

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

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

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

or

$$M_T = 10^3 \left[18.595\ddot{\theta} + 20.41\dot{\theta} + 47.86\theta + .64\ddot{\beta} - 12.00\dot{\beta} + 13.24\beta - 38.82\bar{X} \right] \ldots\ldots\ldots (59)$$

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

2. Roll Motion

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

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

or substituting:

$$R_{F_V} = 10^3 \left[40.70\ddot{\phi} + 25.40\phi + 8.28\ddot{\beta} + 5.59\dot{\beta} + 59.73\beta + 94.21\bar{X} \right] \ldots (61)$$

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

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

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

or substituting:

$$M_T = 10^3 \left[2.993\ddot{\phi} - 94.480\phi + .608\ddot{\beta} - 12.280\dot{\beta} + 13.242\beta - 24.015\bar{X} \right] \ldots (62)$$

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: $$R_{F_{H_1}} \cong m R (\dot{\psi})^2 \quad \text{----------} \quad (64)$$

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

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

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

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

$$M_{\ddot{\psi}} \cong m R^2 \ddot{\psi} \quad \text{----------} \quad (68)$$

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)	(7)+(8)+(9)	-.009379 (45)	.053678 (57)	.1383 (67)	(11)+(12)+(13)	(2)(6)	(2)(10)	(2)(14)	(18)$_{n-1}$+(15)	(19)$_{n-1}$+(16)	(20)$_{n-1}$+(17)	(2)(18)
t	Δt	A	C	B	$\ddot{\theta}$	A	C	B	$\ddot{\beta}$	A	C	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	-.00046	-.00257	-.00021	-.00045	-.00277	-.00024	-.00012
.1	.05	-.02585	.00013	-.00974	-.03546	-.00421	.00121	-.18182	-.18482	.00025	.03997	-.04098	-.00057	-.00177	-.00924	-.00029	-.00265	-.01182	-.00050	-.00113
.15		-.04065	.00022	-.01541	-.05584	-.00661	.00198	-.28755	-.29218	.00038	.06545	-.06481	+.00102	-.00279	-.01461	+.00051	-.00505	-.02647	+.00025	-.00253
.2		-.04593	.00026	-.01765	-.06322	-.00749	.00236	-.32756	-.33267	.00047	.07823	-.07382	.00484	-.00316	-.01667	.00242	-.00822	-.04301	.00243	-.00411
.25		-.04593	.00028	-.01775	-.06340	-.00747	.00252	-.33124	-.33619	.00049	.08355	-.07465	.00933	-.00317	-.01683	.00467	-.01139	-.05988	.00710	-.00570
.3		-.04303	.00028	-.01678	-.05153	-.00700	.00255	-.31314	-.31759	.00044	.08438	-.07057	.01421	-.00298	-.01588	.00711	-.01437	-.07576	.01411	-.00719
.35		-.03793	.00027	-.01504	-.05270	-.00617	.00245	-.28067	-.28433	.00038	.08130	-.06324	.01842	-.00264	-.01422	.00921	-.01701	-.08998	.02332	-.00858
.4		-.03235	.00026	-.01303	-.04512	-.00527	.00231	-.24118	-.24613	.00033	.07660	-.05481	.02209	-.00226	-.01331	.01105	-.01927	-.10229	.03437	-.00954
.45		-.02661	.00024	-.01089	-.03726	-.00433	.00213	-.20330	-.20550	.00025	.07050	-.04581	.02493	-.00186	-.01028	.01247	-.02113	-.11257	.04684	-.01057
.5		-.02092	.00021	-.00869	-.02940	-.00340	.00191	-.16218	-.16367	.00020	.06343	-.03655	.02708	-.00147	-.00818	.01358	-.02260	-.12075	.06038	-.01130
.55		-.01580	.00019	-.00667	-.02228	-.00257	.00170	-.12451	-.12538	.00015	.05627	-.02806	.02836	-.00111	-.00627	.01418	-.02371	-.12702	.07456	-.01185
.6		-.01126	.00016	-.00478	-.01588	-.00183	.00141	-.08916	-.08952	.00011	.04880	-.02009	.02882	-.00079	-.00448	.01441	-.02450	-.13150	.08897	-.01225
.65		-.00761	.00014	-.00314	-.01061	-.00122	.00126	-.05860	-.05858	.00007	.04170	-.01321	.02856	-.00053	-.00293	.01418	-.02502	-.13443	.10325	-.01252
.7		-.004166	.00011	-.00151	-.00557	-.00067	.00102	-.02810	-.02776	.00003	.03397	-.00633	.02767	-.00028	-.00139	.01384	-.02531	-.13582	.11709	-.01266
.75		-.001938	.00009	-.00018	-.00203	-.00025	.00077	-.00700	-.00682	.00001	.02687	-.00076	.02612	-.00004	-.00020	.01306	-.02541	-.13596	.13015	-.01270
.8		+.000400	.00006	+.00095	+.00156	+.00019	.00048	+.00743	+.00786	-.00000	.01946	+.00461	.02407	+.00018	+.00105	.01203	-.02533	-.13491	.14218	-.01267
.85		.00202	.00004	.00222	.00428	.00052	.00028	.01414	.01476	-.00001	.01224	.00934	.02156	.00041	.00214	.01078	-.02511	-.13280	.15296	-.01256
.9		.00303	.00002	.00319	.00624	.00076	.00011	.02158	.02233	-.00001	.00523	.01343	.01864	.00059	.00312	.00934	-.02481	-.12974	.16228	-.01241
1.0	.10	.00375	-.00006	.00405	.00779	.00095	-.00004	.02854	.02962	-.00001	-.00179	.01765	.01523	.00076	.00389	.00762	-.02403	-.12217	.17051	-.01203
1.1		.00438	-.00005	.00569	.01002	.00122	-.00018	.03618	.03722	-.00001	-.01583	.02394	.00807	.00103	.00565	.00508	-.02303	-.11153	.18558	-.01153
1.2		.00432	-.00010	.00707	.01129	.00138	-.00035	.04199	.04302	-.00001	-.02966	.02975	.00050	.00113	.00718	.00100	-.02190	-.09835	.18559	-.01096
1.3		.00390	-.00014	.00815	.01171	.00143	-.00050	.04506	.04599	-.00001	-.04227	.03427	-.00803	.00117	.00514	-.00803	-.02073	-.08321	.17756	-.01037
1.4		.00249	-.00018	.00882	.01113	.00136	-.00064	.04596	.04664	-.00001	-.05287	.03711	-.01578	.00113	.00155	-.01578	-.01962	-.06687	.16178	-.00962
1.5		.00115	-.00021	.00926	.01020	.00124	-.00076	.04586	.04634	-.00001	-.06169	.03896	-.02274	.00104	.00119	-.02274	-.01860	-.04975	.13904	-.00860
1.6		.00037	-.00023	.00950	.00964	.00117	-.00085	.04521	.04553	-.00001	-.06853	.03994	-.02859	.00095	.00067	-.02859	-.01765	-.03223	.11045	-.00765
1.7		-.00012	-.00024	.00948	.00912	.00111	-.00092	.04425	.04444	-.00001	-.07312	.03989	-.03323	.00086	.00021	-.03323	-.01674	-.01976	.07722	-.00674
1.8		-.00027	-.00025	.00922	.00870	.00106	-.00097	.04317	.04327	-.00001	-.07523	.03877	-.03646	.00077	-.00023	-.03646	-.01587	-.00806	.04076	-.00587
1.9		-.00023	-.00025	.00864	.00816	.00099	-.00100	.04211	.04225	-.00001	-.07457	.03635	-.03822	.00068	-.00062	-.03822	-.01505	.01811	.01254	-.00505
2.0		+.00012	-.00024	.00782	.00770	.00093	-.00102	.04127	.04152	-.00001	-.07131	.03281	-.03844	.00059	-.00093	-.03844	-.01428	.03249	-.03590	-.00428
2.1		.00091	-.00022	.00681	.00750	.00090	-.00103	.04085	.04116	-.00001	-.06580	.02866	-.03715	.00050	-.00125	-.03715	-.01353	.04502	-.07705	-.00353
2.2		.00169	-.00019	.00551	.00701	.00084	-.00104	.04073	.04095	-.00001	-.05762	.02315	-.03449	.00041	-.00144	-.03449	-.01283	.05514	-.10754	-.00283
2.3		.00269	-.00016	.00404	.00653	.00078	-.00104	.04044	.04037	-.00001	-.04755	.01699	-.03059	.00033	-.00144	-.03059	-.01215	.06258	-.13813	-.00215

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

(11) A	(12) C	(13) B	(14) $\ddot{\alpha}$	(15) $\Delta\dot{\theta}$	(16) $\Delta\dot{\beta}$	(17) $\Delta\dot{\alpha}$	(18) $\dot{\theta}$	(19) $\dot{\beta}$	(20) $\dot{\alpha}$	(21) $\Delta t\dot{\theta}$	(22) $\Delta t\dot{\beta}$	(23) $\Delta t\dot{\alpha}$	(24) $\frac{\Delta t^2}{2}\ddot{\theta}$	(25) $\frac{\Delta t^2}{2}\ddot{\beta}$	(26) $\frac{\Delta t^2}{2}\ddot{\alpha}$	(27) θ	(28) β	(29) α	(30) $\dot{\theta}^2$	(31) $\dot{\beta}^2$	(32) $\dot{\alpha}^2$
-.009379	.053678	.1383																			
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
.000 14	.02188	-.02285	-.00083	-.00549	-.00257	-.00100	-.00540	-.00257	-.00100	-.00848	-.00353	-.00210	-.00900	-.00375	-.00096	-.00210	-.00069	-.00040	-.00020	.00968	0
.00024	.03997	-.04098	-.00057	-.00177	-.00624	-.00220	-.00265	-.01182	-.00411	-.00541	-.00225	-.00131	-.00544	-.00227	-.00131	-.00956	-.00414	-.00200	-.00050	.00140	0
.00038	.06545	-.06481	.00102	.00279	-.01461	.00510	-.00555	-.01647	.00100	-.00253	-.00105	-.00066	0	-.00044	-.00131	-.00499	-.00209	-.00100	-.00026	.00699	0
.00041	.07823	-.01382	.00484	-.00316	-.01663	.00242	-.00228	-.00430	.00243	-.00411	-.00171	-.00110	-.00470	-.00196	-.00090	-.00688	-.00288	-.00176	-.00068	.00855	0
.00041	.08355	-.07465	.00936	-.00317	-.01683	.00467	-.00139	-.00588	.00110	-.00675	-.00282	-.00170	-.00724	-.00302	-.00120	-.00878	-.00367	-.00210	-.00090	.00858	.00000
.00041	.08438	-.07057	.01421	-.00268	-.01588	.00111	-.00437	-.00757	.00141	-.00816	-.00341	-.00210	-.00868	-.00362	-.00143	-.00810	-.00341	-.00210	-.00081	.00736	.00000
.00036	.08130	-.06324	.01840	-.00264	-.01422	.00121	-.00170	-.00898	.00132	-.00158	-.00066	-.00041	-.00169	-.00070	-.00028	-.00120	-.00050	-.00031	-.00010	.00110	.00000
.00030	.07660	-.05481	.02022	-.00226	-.01131	.00101	-.00127	-.01029	.00034	-.00956	-.00399	-.00254	-.00115	-.00048	-.00028	-.00150	-.00063	-.00041	-.00010	.00220	.00000
.00024	.07050	-.04581	.02493	-.00186	-.01010	.00124	-.00112	-.01251	.00048	-.01057	-.00441	-.00279	-.00127	-.00053	-.00028	-.00166	-.00069	-.00041	-.00010	.00330	.00000
.00018	.06343	-.03655	.02708	-.00147	-.00818	.00151	-.00260	-.01221	.00048	-.01180	-.00492	-.00310	-.00140	-.00059	-.00028	-.00184	-.00076	-.00041	-.00010	.00440	.00000
.00012	.05627	-.02806	.02836	-.00111	-.00627	.00171	-.00293	-.01418	.00048	-.01318	-.00549	-.00341	-.00154	-.00065	-.00028	-.00202	-.00084	-.00041	-.00010	.00550	.00000
.00006	.04880	-.02009	.02882	-.00064	-.00440	.00191	-.00326	-.01441	.00048	-.01457	-.00607	-.00372	-.00168	-.00071	-.00028	-.00220	-.00091	-.00041	-.00010	.00660	.00000
.00000	.04170	-.01321	.02856	-.00053	-.00293	.00210	-.00357	-.01483	.00048	-.01596	-.00665	-.00403	-.00182	-.00077	-.00028	-.00238	-.00098	-.00041	-.00010	.00770	.00000
-.00006	.03397	-.00633	.02767	-.00028	-.00139	.00229	-.00384	-.01525	.00048	-.01582	-.00659	-.00434	-.00196	-.00083	-.00028	-.00256	-.00105	-.00041	-.00010	.00880	.00000
-.00012	.02687	.00076	.02612	-.00001	-.00014	.00248	-.00410	-.01541	.00048	-.01596	-.00665	-.00465	-.00210	-.00089	-.00028	-.00274	-.00112	-.00041	-.00010	.00990	.00000
-.00018	.01946	.00491	.02407	.00076	.00104	.00267	-.00437	-.01543	.00048	-.01582	-.00659	-.00496	-.00224	-.00095	-.00028	-.00292	-.00119	-.00041	-.00010	.01100	.00000
-.00024	.01224	.00913	.02156	.00214	.00211	.00287	-.00464	-.01525	.00048	-.01580	-.00659	-.00527	-.00238	-.00101	-.00028	-.00310	-.00126	-.00041	-.00010	.01210	.00000
-.00030	.00523	.01343	.01864	.00312	.00281	.00307	-.00491	-.01497	.00048	-.01580	-.00659	-.00558	-.00252	-.00107	-.00028	-.00328	-.00133	-.00041	-.00010	.01320	.00000
-.00036	-.00179	.01765	.01523	.00414	.00352	.00327	-.00518	-.01497	.00048	-.01580	-.00659	-.00589	-.00266	-.00113	-.00028	-.00346	-.00140	-.00041	-.00010	.01430	.00000
-.00042	-.01583	.02394	.00807	.00503	.00422	.00347	-.00545	-.01497	.00048	-.01580	-.00659	-.00620	-.00280	-.00119	-.00028	-.00364	-.00147	-.00041	-.00010	.01540	.00000
-.00048	-.02966	.02975	.00050	.00593	.00492	.00367	-.00572	-.01497	.00048	-.01580	-.00659	-.00651	-.00294	-.00125	-.00028	-.00382	-.00154	-.00041	-.00010	.01650	.00000
-.00054	-.04227	.03427	-.00803	.00683	.00562	.00387	-.00599	-.01497	.00048	-.01580	-.00659	-.00682	-.00308	-.00131	-.00028	-.00400	-.00161	-.00041	-.00010	.01760	.00000
-.00060	-.05287	.03911	-.01578	.00772	.00633	.00407	-.00626	-.01497	.00048	-.01580	-.00659	-.00713	-.00322	-.00137	-.00028	-.00418	-.00168	-.00041	-.00010	.01870	.00000
-.00066	-.06169	.03896	-.02274	.00862	.00703	.00427	-.00653	-.01497	.00048	-.01580	-.00659	-.00744	-.00336	-.00143	-.00028	-.00436	-.00175	-.00041	-.00010	.01980	.00000
-.00072	-.06853	.03994	-.02859	.00951	.00773	.00447	-.00680	-.01497	.00048	-.01580	-.00659	-.00775	-.00350	-.00149	-.00028	-.00454	-.00182	-.00041	-.00010	.02090	.00000
-.00078	-.07312	.03989	-.03323	.01041	.00844	.00467	-.00707	-.01497	.00048	-.01580	-.00659	-.00806	-.00364	-.00155	-.00028	-.00472	-.00189	-.00041	-.00010	.02200	.00000
-.00084	-.07523	.03877	-.03646	.01130	.00914	.00487	-.00734	-.01497	.00048	-.01580	-.00659	-.00837	-.00378	-.00161	-.00028	-.00490	-.00196	-.00041	-.00010	.02310	.00000
-.00090	-.07457	.03635	-.03822	.01218	.00984	.00507	-.00761	-.01497	.00048	-.01580	-.00659	-.00868	-.00392	-.00167	-.00028	-.00508	-.00203	-.00041	-.00010	.02420	.00000
-.00096	-.07131	.03187	-.03844	.01307	.01055	.00527	-.00788	-.01497	.00048	-.01580	-.00659	-.00899	-.00406	-.00173	-.00028	-.00526	-.00210	-.00041	-.00010	.02530	.00000
-.00102	-.06580	.02866	-.03715	.01395	.01125	.00547	-.00815	-.01497	.00048	-.01580	-.00659	-.00930	-.00420	-.00179	-.00028	-.00544	-.00217	-.00041	-.00010	.02640	.00000
-.00108	-.05762	.02315	-.03449	.01483	.01195	.00567	-.00842	-.01497	.00048	-.01580	-.00659	-.00961	-.00434	-.00185	-.00028	-.00562	-.00224	-.00041	-.00010	.02750	.00000
-.00114	-.04755	.01699	-.03059	.01572	.01266	.00587	-.00869	-.01497	.00048	-.01580	-.00659	-.00992	-.00448	-.00191	-.00028	-.00580	-.00231	-.00041	-.00010	.02860	.00000

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	$\dot\alpha$	$\dot\alpha^2$	ϕ^2 − (41) − (42)	α	A	M_2^{-3}	θ	$\dot\beta$	$\dot\beta^2$	+ (49)	β	$\dot\alpha$	ϕ^2 − (53) − (54)	α	C
	X FROM FIGURE 2/	.030236 (19)	.053932 (31)		−(36) (28)	−.71337 (18)	−.1083 (21)	−.0073613 (20)	.0017423 (32)	.0015178 (30)	−(43) (29)	+(34) +(33) +(32) +(1)	38.82 X FROM FIGURE 2/	−8.4246 (21)	−2.308 (19)	4.9053 (31)		−(50) (28)	−21.213 (20)	.1585 (33)	−(55) (24)	+(46) +(47) +(45)
										.8332							5.309			.8772 (30)	128.79	
①	(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	−.04191	−.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	.00813	.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	.7958	.0569	.27869	.07152	5.3805	.1893	−.1281				−.1433	1.0483
.55	−.02408	−.00384	.00087	.002712	.00011	.01691	.00085	−.00005				−.00121	−.01127	.6794	.0661	.29316	.07944	5.3881	.2246	−.1582				−.1959	.9092
.6	−.02064	−.003976	.00093	.002774	.00013	.01748	.00099	−.00007				−.00147	−.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				−.00294	−.00194	.4116	.0980	.31347	.09049	5.3995	.3347	−.2484				−.4088	.5005
.75	−.01211	−.00411	.00100	.002842	.00020	.01815	.00140	−.00010				−.00391	+.00040	.3416	.0874	.3138	.09067	5.3997	.3715	−.2761				−.4969	.3626
.8	−.01005	−.00408	.00100	.002842	.00021	.01807	.00153	−.00010				−.00483	+.00202	.2834	.1139	.3114	.08928		.4077	−.3016				−.5922	.2281
.85	−.00834	−.00402	.00096	.002793	.00023	.01772	.00167	−.00011				−.00569	.00303	.2368	.1299	.3065	.08661		.4430	−.3245				−.6942	.0975
.9	−.007018	−.00392			.00024	.01770	.00180	−.00012				−.00657	.00375	.1980	.14039	.2996	.08263		.4777	−.3442				−.8048	−.0333
1.0	−.001816	−.00369			.00027	.01714	.00206	−.00013				−.00671	.00438	.1359	.1603	.2820			.5405	−.3766				−1.0370	−.2949
1.1	−.003165	−.00337			.00028	.01643	.00230	−.00014				−.00729	.00432	.08928	.17929	.25744			.5763	−.3937				−1.2812	−.5626
1.2	−.002064	−.00297			.00028	.015623	.00253	−.00014				−.00784	.00370	.05823	.19726	.2270			.6440	−.3937				−1.52207	−.7874
1.3	−.001651	−.00252			.00028	.014788	.00275	−.00018				−.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				−.01449	−.00012	.02330	.25999	.07439			.74467	−.23430				−2.2303	−1.3622
1.7	−.00055	−.000446			.00026	.011938	.00352	−.00006				−.01493	−.00027	.01553	.27371	.03405			.74730	−.16381				−2.3083	−1.4015
1.8	−.000415	+.000067			.00026	.011318	.00369	−.00003				−.015122	−.00023	.01165	.28671	−.00511			.74147	−.08646				−2.3774	−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				−.01376	+.00169	0	.32183	−.10390			.68060	+.15496				−2.1270	−1.0736
2.2	0	.00167			.00024	.00916	.00427	.00008	0	0	.8332	−.01272	+.00269	0	.33234	−.12727			.64737	+.22812	0	0	128.79	−1.9664	−.78681

TABLE I — CONTINUED

(43) α	A	M_2	ϕ	$\dot{\beta}$	$\dot{\beta}^2$	(49)	(50)	β	$\dot{\alpha}$	$\ddot{\alpha}$	ϕ	(54)	(55)	α	C	L_2	β	β	ϕ	$\dot{\alpha}$	$\ddot{\alpha}$	$\dot{\alpha}$	(65) α	B
(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)	(57)	(58)	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)
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	-.01445	.4076	0	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	1.5665	-.5789	.0436	-.0003	-.0041	+.0001				+.0004	-.5398
-.00005	-.04307	1.3975	.0138	.1382	.0176	5.3266	.0458	-.0151					-.0082	1.5720	-.6663	.0606	-.0004	-.0068	.0001				.0015	-.5103
-.00013	-.03797	1.3005	.0205	.1749	.0282	5.3372	.0682	-.0299					-.0197	1.6145	-.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
-.000417	-.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
-.000973	-.01582	.7958	.0559	.27869	.07152	5.3805	.1893	-.1281					-.1433	1.0483	-.3225	.1222	-.0018	-.0277	.0013				.0256	-.2029
-.001327	-.01127	.6794	.0661	.29316	.07914	5.3881	.2246	-.1582					-.1959	.9092	-.2753	.1285	-.0022	-.0328	.0015				.0350	-.1463
-.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	6.2995	.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	.1939	.3114	.08928		.4077	-.3016					-.5922	.2281	-.1148	.1365	-.0039	-.0591	.0029				.1059	+.0675
-.00449	.00303	.2368	.2993	.3065	.08651		.4430	-.3245					-.6942	.0975	-.09595	.1344	-.0043	-.0644	.0032				.1242	+.0971
-.00517	.00375	.1980	.14059	.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	.2123	.19206			.68280	-.3767					-1.7438	-.9848	-.01888	.08424	-.0066	-.1061	.0037				.3120	.2683
-.01246	.00115	.03882	.23029	.15453			.71256	-.34318					-1.9420	-1.1492	-.01573	.06767	-.0069	-.1141	.0034				.3474	.2817
-.01363	.00037	.03106	.24553	.11483			.73317	-.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	-.00611			.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)$_{n-1}$	-.05377 (33)$_{n-1}$	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)	⑤/2	⑧/2	⑫/2
	Δt	.4733 A$_1$	.4336 B$_1$	$\ddot{\phi}$	2.5900 B	2.1679 A$_1$	$\ddot{\beta}$	.10528 B$_1$	.03664 A$_1$	-.05377 A$_1$	$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	$\dot{\alpha}$	$\phi\Delta t$	$\beta\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$	$\frac{\ddot{\beta}}{2}\Delta t^2$	$\frac{\ddot{\alpha}}{2}\Delta t^2$
	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔
	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
	.050	.16621	.07953	.08668	.47506	.76133	-.28627	.01931	.01287	-.01966	.01252	.004334	-.014314	.000626	.005562	-.018395	.000730	.000278	-.0009198	.000037	.000108	-.000358	.0000156
	.050	.25875	.13579	.13296	.75138	1.18518	-.43380	.03054	.02003	-.01628	.03429	.006648	-.02169	.001715	.012310	-.04009	.002445	.000611	-.00200	.000122	.000166	-.000542	.000043
	.050	.28731	.14309	.14422	.83475	1.31598	-.46124	.03474	.02224	+.00449	.06147	.007211	-.02306	.003074	.019421	-.06315	.005519	.000971	-.003158	.000276	.000186	-.000577	.000077
	.050	.28709	.14738	.13971	.88032	1.31498	-.43466	.03578	.02222	.02952	.08782	.006986	-.02176	.004376	.026407	-.08488	.009895	.001320	-.004244	.000495	.000175	-.000543	.000109
	.050	.26961	.14390	.12561	.85954	1.23445	-.37441	.03494	.02086	.05259	.10939	.006280	-.01875	.00547	.03269	-.10363	.01537	.00163	-.00518	.00077	.000160	-.00047	.00014
	.050	.24207	.13625	.10582	.81388	1.10879	-.29491	.03308	.01874	.07349	.12581	.005290	-.01475	.00621	.03798	-.11838	.02164	.00190	-.00592	.00108	.00013	-.00037	.00016
	.050	.21502	.12932	.08570	.77244	.98490	-.21246	.03140	.01665	.08668	.13473	.004290	-.01062	.00674	.04227	-.12900	.02838	.00211	-.00645	.00142	.00011	-.00027	.00017
	.050	.19254	.12523	.06731	.74804	.88190	-.13386	.03041	.01491	.09265	.13800	.003370	-.00669	.00690	.04564	-.13569	.03528	.00228	-.00678	.00176	.00008	-.00017	.00017
	.050	.17294	.12324	.04970	.73616	.79215	-.05599	.02992	.01339	.09242	.13673	.002490	-.00280	.00679	.04813	-.13849	.04207	.00241	-.00692	.00210	.00006	-.00007	.00017
	.050	.16053	.12546	.03507	.74944	.73529	+.01415	.03046	.01343	.08565	.12854	.001750	+.00071	.00643	.04988	-.13778	.04850	.00249	-.00689	.00243	.00004	+.00002	.00016
	.050	.15648	.13253	.02395	.79161	.71673	.07488	.03218	.01211	.07308	.11737	.001200	.00374	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003	.00009	.00015
	.050	.15893	.14347	.01546	.85698	.72796	.12902	.03484	.01230	.05611	.10331	.000770	.00645	.00517	.05185	-.12759	.05954	.00259	-.00638	.00298	.00002	.00016	.00013
	.050	.16577	.15721	.00856	.93906	.75929	.17977	.03817	.01283	.03603	.08702	.000430	.00899	.00436	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001	.00022	.00011
	.050	.17930	.17470	.00460	1.04354	.82121	.22227	.04242	.01388	+.01300	.06930	.000230	.01111	.00347	.05231	-.10749	.06736	.00263	-.00537	.00337	.00001	.00028	.00009
	.100	.19661	.19455	.00206	1.16208	.90087	.26151	.04724	.01522	-.01170	.05076	.000100	.01308	.00254	.05261	-.09441	.06990	.00263	-.00472	.00350	0	.00033	.00006
	.100	.21592	.21565	+.00027	1.28814	.98902	.29912	.05236	.01672	-.03118	+.03190	+.000030	.02991	+.00319	.05264	-.06450	.07309	.00526	-.00645	.00781	0	.00150	+.00016
	.100	.26485	.26541	-.00056	1.58536	1.21311	.37225	.06444	.02050	-.09178	-.00684	-.000060	.03723	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0	.00186	-.00003
	.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
	.100	.35568	.35718	-.00150	2.13351	1.62916	.50435	.06872	.02753	-.18934	-.07509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001	.00252	-.00038
	.100	.38858	.39264	-.00406	2.34535	1.77985	.56550	.09534	.03008	-.22810	-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002	.00283	-.00057
	.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
	.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
	.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
	.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
	.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
	.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
	.100	.24871	.30296	-.05485	1.80966	1.13646	.67320	.07356	.01921	-.28654	-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027	.00357	-.00097
	.100	.18329	.23757	-.05428	1.41906	.83956	.57950	.05768	.01419	-.25941	-.18754	-.00543	.05795	-.01875	.02362	.67158	-.08704	.00236	.06716	-.00870	-.00027	.00290	-.00094

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 (23)$_{n-1}$	.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 (5)/2
t	Δt	.4733 B_1	.4336 B_1	$\ddot{\phi}$	2.5900 B	2.1679 B_1	$\ddot{\beta}$	.10528 B_1	.03664 B_1	-.05377 B_1	$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	$\dot{\alpha}$	$\dot{\phi}\Delta t$	$\dot{\beta}\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$
(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	.08762	.006986	-.02176	.004376	.026407	-.08488	.009895	.001320	-.004244	.000495	.000175
.30	.050	.26961	.14390	.12561	.85954	1.23445	-.31491	.03494	.02086	.05359	.10939	.006280	-.01875	.00547	.03269	-.10363	.01537	.00163	-.00518	.00077	.000160
.35	.050	.24207	.13625	.10582	.81388	1.10879	-.29491	.03308	.01974	.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	.00314	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003
.65	.050	.15893	.14347	.01546	.85698	.72196	.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	.000450	.00899	.00435	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001
.75	.050	.17930	.17470	.00460	1.04354	.82127	.22221	.04242	.01388	+.01300	.06930	.000250	.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	-.06460	.07309	.00526	-.00645	.00781	0
1.00	.100	.26485	.26541	-.00056	1.58536	1.21311	.37225	.06444	.02050	-.04175	-.00684	-.000060	.03723	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0
1.10	.100	.31352	.31396	-.00044	1.87537	1.43604	.43983	.07623	.02427	-.04341	-.04292	-.000040	.04393	-.00429	.05254	+.01666	.06812	.00525	+.00167	.00681	0
1.20	.100	.35568	.35718	-.00150	2.13351	1.62916	.50435	.06872	.02758	-.04936	-.01509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001
1.30	.100	.38858	.39264	-.00406	2.34535	1.77985	.56550	.09534	.03008	-.02856	-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002
1.40	.100	.41131	.41912	-.00781	2.50852	1.88397	.61955	.10176	.03184	-.02652	-.12693	-.00078	.06196	-.01269	.05120	.18561	.03761	.00512	.01856	.00376	-.00004
1.50	.100	.41922	.43351	-.01435	2.58979	1.92017	.66962	.10527	.03245	-.02438	-.14666	-.00144	.06696	-.01467	.04976	.25257	.02294	.00498	.02526	.00229	-.00007
1.60	.100	.41143	.43480	-.02337	2.59717	1.88453	.71264	.10567	.03185	-.02036	-.16294	-.00234	.07126	-.01629	.04742	.32383	+.00665	.00474	.03238	+.00067	-.00012
1.70	.100	.38811	.42206	-.03395	2.52108	1.77770	.74338	.10248	.03005	-.02054	-.17631	-.00340	.07434	-.01763	.04402	.39817	-.01098	.00440	.03982	-.00116	-.00017
1.80	.100	.36317	.39627	-.04310	2.36700	1.61764	.74936	.09622	.02734	-.01013	-.18657	-.00431	.07494	-.01866	.03971	.47311	-.02964	.00397	.04731	-.00296	-.00022
1.90	.100	.30376	.35548	-.05172	2.12339	1.39186	.73203	.08631	.02352	-.00229	-.19212	-.00517	.07320	-.01927	.03454	.54631	-.04891	.00345	.05463	-.00489	-.00026
2.00	.100	.24871	.30296	-.05485	1.80966	1.13646	.67320	.07356	.01921	.00865	-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027
2.10	.100	.18329	.23757	-.05428	1.41906	.83956	.57950	.05768	.01419	.02594	-.18754	-.00543	.05795	-.01875	.02362	.67158	-.08704	.00236	.06716	-.00870	-.00027

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

$\ddot{\alpha}$	$\ddot{\phi}\Delta t$	$\ddot{\beta}\Delta t$	$\ddot{\alpha}\Delta t$	$\dot{\phi}$	$\dot{\beta}$	$\dot{\alpha}$	$\dot{\phi}\Delta t$	$\dot{\beta}\Delta t$	$\dot{\alpha}\Delta t$	$\frac{\ddot{\phi}}{2}\Delta t^2$	$\frac{\ddot{\beta}}{2}\Delta t^2$	$\frac{\ddot{\alpha}}{2}\Delta t^2$	ϕ	β	α
(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
.00417	.001228	-.004081	.000104	.001228	-.004081	.000104	.0000307	-.0001020	.0000026	.00001535	-.000051	.0000013	.0000461	-.000153	.0000039
.01252	.004334	-.014314	.000626	.005562	-.018395	.000738	.000278	-.0009198	.000037	.000108	-.000358	.0000186	.0000432	-.001431	.0000556
.03429	.006648	-.02169	.001715	.012310	-.04009	.002445	.000611	-.00200	.000122	.000166	-.000542	.0000431	.001209	-.003873	.0002221
.06147	.001211	-.02306	.003074	.019421	-.06315	.005519	.000971	-.003188	.000276	.000180	-.000877	.0000771	.002360	-.007708	.0005675
.08752	.006986	-.02176	.004376	.026407	-.08488	.009895	.001320	-.004244	.000495	.000175	-.000543	.0001091	.003885	-.012496	.001179
.10939	.006280	-.01875	.00547	.03269	-.10563	.01537	.00163	-.00518	.00077	.000160	-.00047	.00014	.00565	-.01815	.00209
.12581	.005290	-.01475	.00621	.03798	-.11838	.02164	.00190	-.00592	.00108	.00013	-.00037	.00016	.00768	-.02444	.00333
.13473	.004290	-.01062	.00674	.04227	-.12900	.02838	.00211	-.00645	.00142	.00011	-.00027	.00017	.00990	-.03116	.00492
.13800	.003370	-.00669	.00690	.04564	-.13569	.03528	.00228	-.00678	.00176	.00008	-.00017	.00017	.01226	-.03811	.00685
.13573	.002490	-.00280	.00679	.04813	-.13849	.04209	.00241	-.00692	.00210	.00006	-.00007	.00017	.01473	-.04510	.00912
.12854	.001750	+.00071	.00643	.04988	-.13778	.04850	.00249	-.00689	.00243	.00004	+.00002	.00016	.01726	-.05198	.01171
.11737	.001200	.00374	.00587	.05108	-.13404	.05437	.00255	-.00670	.00272	.00003	.00009	.00015	.01984	-.05859	.01458
.10331	.000770	.00645	.00517	.05185	-.12759	.05954	.00259	-.00638	.00298	.00002	.00016	.00013	.02245	-.06481	.01769
.08702	.000430	.00899	.00435	.05228	-.11860	.06389	.00261	-.00593	.00319	.00001	.00022	.00011	.02507	-.07052	.02099
.06930	.000230	.01111	.00347	.05231	-.10749	.06736	.00263	-.00537	.00337	.00001	.00028	.00009	.02771	-.07561	.02445
.05076	.000100	.01308	.00254	.05261	-.09441	.06990	.00263	-.00472	.00350	0	.00033	.00006	.03034	-.08000	.02801
.03190	.000030	.02991	.00319	.05264	-.06460	.07301	.00526	-.00645	.00781	0	.00150	.00016	.03560	-.08495	.03548
-.00684	-.000060	.03123	-.00068	.05258	-.02727	.07241	.00526	-.00273	.00724	0	.00186	-.00003	.04086	-.08582	.04269
-.04292	-.000040	.04393	-.00429	.05254	+.01666	.06812	.00525	+.00167	.00681	0	.00230	-.00021	.04611	-.08195	.04929
-.07509	-.00015	.05044	-.00751	.05239	+.06710	.06061	.00524	.00671	.00606	-.00001	.00252	-.00038	.05134	-.07272	.05497
-.10308	-.00041	.05655	-.01031	.05198	.12365	.05030	.00520	.01237	.00503	-.00002	.00283	-.00052	.05652	-.05752	.05948
-.12698	-.00078	.06496	-.01269	.05120	.18561	.03761	.00512	.01856	.00376	-.00004	.00310	-.00063	.06160	-.03586	.06261
-.14666	-.00144	.06696	-.01467	.04976	.25257	.02294	.00498	.02526	.00229	-.00007	.00335	-.00073	.06651	-.00725	.06417
-.16294	-.00234	.07126	-.01629	.04742	.32383	+.00665	.00474	.03238	+.00067	-.00012	.00356	-.00081	.07113	+.02869	.06403
-.17631	-.00340	.07434	-.01763	.04402	.39817	-.01098	.00440	.03982	-.00110	-.00017	.00370	-.00088	.07536	.07223	.06205
-.18657	-.00431	.07494	-.01866	.03971	.47311	-.02964	.00397	.04731	-.00296	-.00022	.00376	-.00093	.07911	.12329	.05816
-.19212	-.00317	.07320	-.01927	.03454	.54631	-.04891	.00345	.05463	-.00489	-.00026	.00366	-.00096	.08230	.18158	.05231
-.19380	-.00549	.06732	-.01938	.02905	.61363	-.06829	.00291	.06136	-.00683	-.00027	.00351	-.00097	.08548	.24631	.04451
-.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

t	$\dot\phi^2\beta$	$-2.12\dot\phi^2\beta$	$-74.9\dot\phi$	$2.306\dot\beta$	5.309β	$21.21\dot\alpha$	128.76α	Gust Factor	$M_2\times10^{-3}$	C_1	$L_2\times10^{-5}-7.476\dot\phi^2\beta$	$-4.503\dot\phi$	$-1.012\dot\beta$	1.1775β	$.2071\dot\alpha$	23.037α	B_1	$L_0\times10^{-6}$	$2\dot\phi\dot\beta$	$\dot\beta^2$
	(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	.2853	.2571	.2571	.1022	0	0	0	0	0	.00000	.1022	.19783	0	0
.050	0	0	-.091977	-.009411	-.000812	.002206	.000502	.5163	.465186	.365694	.18489	0	-.00553	.00413	-.00018	.00002	.00009	.18342	.35728	-.00001	.00002
.10	0	0	-.41659	-.042619	-.007597	.01548	.00721	.8288	.74675	.35263	.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	-.00460	.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	.97926	.88141	-.99664	.35031	.00007	-.11691	.08590	-.01471	.00205	.02716	.33187	.67696	-.00448	.00720
.30	-.000019	.00046	-2.44848	-.23897	-.09636	.32600	.26911	.91168	.82142	-1.36683	.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	.89230	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	-3.88351	-.29422	-.34408	1.26284	2.27776	.34103	.30727	-.6699	.12212	.00127	-.23348	.12912	-.07631	.01233	.40752	.36257	.23599	-.01323	.01628
.70	-.00019	.00458	-3.91877	-.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	+.2178	.08661	.00157	-.23648	.10878	-.08903	.01395	.56325	.44868	.16736	-.01129	.01155
.80	-.00022	.00531	-3.94049	-.21791	-.42472	1.48258	3.60487	.19973	.17996	-.6415	.07152	.00164	-.23690	.09354	-.09470	.01448	.64527	.49139	.13821	-.00993	.00891
.90	-.00024	.00579	-3.94274	-.14874	-.45100	1.55024	4.56840	.13899	.12487	-1.7065	.04963	.00179	-.23704	.06527	-.10003	.01514	.81735	.61211	.09590	-.00679	.00416
1.00	-.00024	.00579	-3.93824	-.06288	-.45562	1.53582	5.49676	.09511	.08569	-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	-4.2499	.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	-4.8465	.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	.00913	.00067	-.23055	-.18784	-.04223	.00779	1.44235	.99992	.01880	.01901	.03445
1.50	-.00002	.00048	-3.72702	.58243	-.03849	.48656	8.26253	.02194	.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	-5.743	.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	.00589	-.00105	-.19822	-.40295	.08505	+.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	.22389
1.90	.00022	-.00531	-2.58705	1.25979	.96401	-1.03738	6.73644	0	0	-5.32	0	-.00164	-.15553	-.55287	.21381	-.01013	1.20509	.69811	0	.03774	.29845
2.00	.00021	-.00507	-2.11585	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

(25)+(30)+(31)+(32)+(33)+(34)+(36)	.3581 (33)	-7.476 (28)	-4.503 (16)	-1.012 (17)	1.1775 (26)	.2071 (18)	23.037 (27)	(38)+---(41)	.692 (35)	2 (16) (17)	(17)²	(41)+(48)	1.493 (44) (29)	-.8065 (16)	-.906 (17)	.0510 (26)	.2039 (18)	23.08 (27)	(46)+(50)+(55)	
C_1	$L_2\times10^{-5}$	$-7.476\dot\phi^2\beta$	$-4.503\,\dot\phi$	$-1.012\,\dot\beta$	1.1775β	$.2071\dot\alpha$	23.037α	B_1	$L_0\times10^{-6}$	$2\phi\dot\phi$	$\dot\phi^2$	$2\phi\dot\phi+\dot\phi^2$	1.493β $(2\dot\phi+\dot\beta^2)$	$-8.065\,\dot\phi$	$-.906\dot\beta$	$.0510\alpha$	$.2039\dot\alpha$	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	.60103	
.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	.32641	.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	.17124	.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	.01797	.00428	-.00037	-.41196	.12144	-.00299	.01109	.33651	.33579	
.6699	.12212	.00127	-.23348	.12912	-.07631	.01233	.40152	.36257	.23599	-.01323	.01628	.00305	-.00030	-.41887	.11560	-.00331	.01214	.40329	.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	
1.1065	.04963	.00179	-.23704	.06527	-.10008	.01514	.81755	.61211	.09250	-.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	.90554	.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	1.47128	1.00277	.01501	.02514	.06379	.08893	-.00096	-.40131	-.22883	-.00037	.00468	1.48104	.86929	
5.74	.00487	-.00046	-.21353	+.32772	+.03378	+.00138	1.47506	.97339	.00940	.03072	.10487	.13559	+.00581	-.38744	-.29339	+.00146	+.00136	1.47781	.82001	
5.76	.00389	-.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	-.15552	+.55287	.21381	-.01013	1.20507	.69811	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 - CONTINUED

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	$\dot\psi_{n-1}+\ddot\psi_n(\Delta t)$	$\dot\gamma_{n-1}+\ddot\gamma_n(\Delta t)$		$\psi_{n-1}+\dot\psi_{n-1}(\Delta t)+\ddot\psi_n\frac{(\Delta t)^2}{2}$	$\gamma_{n-1}+\dot\gamma_{n-1}(\Delta t)+\ddot\gamma_n\frac{(\Delta t)^2}{2}$	$-.532\dot\psi$	-4.725ψ	$-.01398\dot\gamma$	$-.2496\gamma$	$+N_0$	A_2	-2.535γ (Fig 2) ⑩+⑪+⑫+⑬+⑭	$-.00696\dot\psi$	$-.1298\psi$	$-.00696\dot\gamma$	$-.1298\gamma$	$+N_1$	B_2	$-.0737\gamma$ (Fig 2) ⑯+⑰+⑱+⑲+⑳
t	Δt	$\ddot\psi$	$\ddot\gamma$	$\dot\psi$	$\dot\gamma$	$\frac{(\Delta t)^2}{2}$	ψ	γ													
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	+.1086	.00125	−.0002	+.0006	+.0013	+.0028	−.0001	−.0002	−.3397	−.3378	+.0000	+.0000	−.0001	−.0001	−.0099	−.0100	
.15	.05	−.0728	+.2510	−.0056	+.1611	.00125	−.0006	+.0020	+.0030	+.0026	−.0003	−.0005	−.4056	−.4088	+.0000	+.0001	−.0002	−.0003	−.0117	−.0121	
.20	.05	−.0858	+.2939	−.0099	+.2138	.00125	−.0012	+.0042	+.0052	+.0034	−.0005	−.0011	−.4598	−.4647	+.0001	+.0002	−.0002	−.0005	−.0133	−.0139	
.25	.05	−.0954	+.3243	−.0147	+.2650	.00125	−.0020	+.0072	+.0078	+.0044	−.0007	−.0019	−.4715	−.4768	+.0001	+.0003	−.0004	−.0009	−.0137	−.0146	
.30	.05	−.0957	+.3215	−.0194	+.3161	.00125	−.0031	+.0110	+.0104	+.0014	−.0010	−.0028	−.4634	−.4728	+.0001	+.0004	−.0005	−.0014	−.0135	−.0148	
.40	.10	−.0911	+.3013	−.0286	+.3982	.00125	−.0064	+.0223	+.0152	+.0302	−.0014	−.0058	−.4208	−.4325	+.0002	+.0008	−.0007	−.0029	−.0122	−.0147	
.50	.10	−.0740	+.2259	−.0360	+.4712	.00500	−.0104	+.0356	+.0191	+.0490	−.0017	−.0092	−.3534	−.3002	+.0002	+.0014	−.0008	−.0036	−.0104	−.0142	
.60	.10	−.0517	+.1340	−.0411	+.5251	.00500	−.0147	+.0498	+.0219	+.0691	−.0019	−.0129	−.2915	−.2148	+.0003	+.0019	−.0009	−.0065	−.0085	−.0137	
.80	.20	−.0286	+.0451	−.0468	+.6441	.00500	−.0247	+.0795	+.0249	+.1186	−.0020	−.0226	−.1825	−.0656	+.0003	+.0023	−.0010	−.0103	−.0053	−.0131	
1.00	.20	+.0128	−.1255	−.04427	+.7190	.02000	−.0333	+.1008	+.0236	+.1512	−.0016	−.0262	−.1090	+.6440	+.0003	+.0043	−.0008	−.0131	−.0032	−.0125	
1.25	.25	+.0429	−.2074	−.0336	+.8522	.02000	−.0403	+.1079	+.0178	+.1946	−.0008	−.0239	−.0532	+.1265	+.0002	+.0052	−.0004	−.0139	−.0015	−.0104	
1.50	.25	+.0615	−.3150	−.0228	+.9216	.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	+.2274	+.0014	−.0150	−.0101	+.2037	+.0000	+.0062	+.0007	−.0075	−.0003	−.0009	
2.00	.25	+.0605	−.2588	+.0103	−.1639		−.0431	+.0081	−.0055	+.2037	+.0023	−.0072	−.0051	+.1932	−.0001	+.0056	+.0011	−.0011	−.0002	+.0054	
2.25	.25	+.0424	−.1483	+.0209	−.2010		−.0366	−.0143	−.0111	+.1712	+.0028	+.0120	0	+.1764	−.0001	+.0047	+.0014	+.0060	0	+.0120	
2.50	.25	+.0216	−.0250	+.0263	−.2078		−.0243	−.0989	−.0140	+.1385	+.0029	+.0257	0	+.1530	−.0002	+.0038	+.0014	+.0128	0	+.0179	
2.75	.25	+.0007	+.0950	+.0264	−.1834		−.02268	−.1418	−.0141	+.1027	+.0026	+.0243	0	+.1324	−.0003	+.0029	+.0013	+.0114	0	+.0224	
3.00	.25	−.0162	+.1908	+.0224	−.1358		−.0176	−.1697	−.0119	+.0891	+.0019	+.0141	0	+.1172	−.0002	+.0022	+.0009	+.0770	0	+.0251	
3.25	.25	−.0270	+.2506	+.0156	−.0731		−.0145	−.1802													

END 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			-.9052 ③	-.8279 ④	$R_{F_{H_2}}$ (POUNDS) APPROXIMATELY ㉓	$R_{F_{H_1}}$ APPROXIMATELY 6576 ㉕
-4.725 Ψ	-.01398 $\dot{\delta}$	-.2596 δ	$+N_0$	A_2	-.00696 $\dot{\psi}$	-.1298 Ψ	-.00696 $\dot{\delta}$	-.1298 δ	$+N_1$	B_2				
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	-.0119	-.0121	+2937	-2078	+859	+1650
+.0054	-.0005	-.0011	-.4588	-.4447	+.0001	+.0002	-.0002	-.0005	-.0133	-.0139	+3461	-2433	+1029	+1933
+.0091	-.0007	-.0019	-.4715	-.4568	+.0001	+.0003	-.0004	-.0009	-.0137	-.0146	+3849	-2685	+1164	+2133
+.0114	-.0010	-.0028	-.4639	-.4428	+.0001	+.0004	-.0005	-.0014	-.0135	-.0148	+3860	-2662	+1198	+2184
+.0302	-.0014	-.0059	-.4208	-.3825	+.0002	+.0008	-.0007	-.0029	-.0122	-.0148	+3677	-2494	+1183	+1981
+.0490	-.0017	-.0092	-.3534	-.3002	+.0002	+.0014	-.0008	-.0046	-.0104	-.0142	+2986	-1903	+1083	+1511
+.0647	-.0019	-.0129	-.2915	-.2147	+.0003	+.0019	-.0009	-.0065	-.0085	-.0137	+2085	-1151	+934	+914
+.1186	-.0020	-.0226	-.1825	-.0656	+.0003	+.0032	-.0010	-.0101	-.0052	-.0131	+1152	-373	+779	+296
+.1594	-.0016	-.0262	-.1090	+.6440	+.0003	+.0043	-.0008	-.0131	-.0032	-.0125	-518	+1039	+521	-825
+.1946	-.0008	-.0220	-.0532	+.1265	+.0002	+.0052	-.0004	-.0139	-.0015	-.0104	-1730	+2049	+319	-1627
+.2065	+.0003	-.0239	-.0254	+.1216	+.0002	+.0057	+.0002	-.0120	-.0007	-.0067	-2480	+2608	+128	-2071
+.2215	+.0014	-.0150	-.0101	+.2037	+.0000	+.0062	+.0007	-.0075	-.0003	-.0009	-2907	+2522	-385	-2042
+.2077	+.0023	-.0022	-.0051	+.1932	-.0001	+.0056	+.0011	-.0011	-.0002	+.0054	-2442	+2142	-300	-1702
+.1713	+.0028	+.0120	0	+.1764	-.0001	+.0047	+.0014	+.0060	0	+.0120	-1710	+1228	-482	-975
+.1258	+.0029	+.0252	0	+.1530	-.0002	+.0038	+.0014	+.0128	0	+.0179	-871	+207	-664	-164
+.1037	+.0026	+.0369	0	+.1324	-.0002	+.0029	+.0013	+.0184	0	+.0224	-471	-286	-813	+625
+.0891	+.0019	+.0441	0	+.1172	-.0002	+.0023	+.0009	+.0220	0	+.0251	+656	-1580	-920	+1155
											+1091	-2075	-984	+1645

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)$_{m-1}$ (24) +(6)$_{m-1}$ (7)$_{m-1}$ +(26) +(29) (8)$_{m-1}$ +(25) +(27)

← EQUATION ___ , Pg. ___ → ← EQUATION ___ , Pg. ___ → ← EQ. 40 , Pg. ___ → ← EQ. 41 , A

t	Δt	θ··	β··	β·	θ·	θ	β	-12.235 × θ·	-35.129 × θ	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	.123 × F
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	-.01704	0	0	0	0	0	0	0	0	-.1766	0	0	0	0	-.6112	-.01037	-.00246	-.00199	-.07
.04		-.02946	-.15299	-.00159	-.00030	-.000003	-.000015	.00362	.000106	-.00135	-.000104	-.35314	-.000296	-.000395	.00886	.000796	-1.22246	-.02061	-.00485	-.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	-.31685	-.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	-.00186	-.00649	.15010	.04426	-.06776	-.04504	-.78573	-.01227	-.16603	.35964	.34478	-2.71998	-.04130	-.01599	-.00795	-.28
.30		-.05166	-.24129	-.07363	-.01956	-.001797	-.00922	.17814	.06313	-.07908	-.06392	-.74159	-.01956	-.23680	.42344	.48935	-2.56717	-.03776	-.01359	-.00727	-.23
.34		-.04519	-.20011	-.08328	-.01663	-.00242	-.01235	.20342	.08501	-.08944	-.08568	-.68641	-.01663	-.31889	.47895	.65595	-2.37616	-.03364	-.01149	-.00648	-.19
.38		-.03869	-.15902	-.09129	-.01843	-.00312	-.01585	.22550	.10964	-.09824	-.10989	-.63123	-.01843	-.41126	.52498	.84130	-2.16515	-.02959	-.00910	-.00569	-.15
.42		-.03195	-.11636	-.09765	-.01998	-.00389	-.01962	.24444	.13662	-.10467	-.13609	-.57164	-.01998	-.51246	.56156	1.04188	-1.97886	-.02533	-.00662	-.00488	-.111
.46		-.02581	-.07437	-.10230	-.02126	-.00471	-.02362	.26008	.16560	-.10967	-.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	-.10254	-.02396	-.00932	-.04465	.29320	.32758	-.10971	-.30966	-.26927	-.02396	-1.22878	.58855	2.37066	-.93215	-.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	-.70252	+.00095	+.00817	+.000184	+.13
.78		+.01235	+.15517	-.08834	-.02331	-.01217	-.05616	.28517	.42770	-.09457	-.389497	-.17436	-.02331	-1.64434	.50802	2.98186	-.60359	+.00318	+.00918	+.000612	+.15
.82		+.01512	+.16886	-.08213	-.02281	-.01310	-.05957	.27913	.46008	-.08721	-.41314	-.15008	-.02281	-1.72583	.47232	3.16285	-.51955	+.00515	+.00957	+.000972	+.16
.86		+.01743	+.17890	-.07537	-.02221	-.01400	-.06272	.27173	.49174	-.08015	-.43498	-.13022	-.02221	-1.84456	.43348	3.33009	-.45078	+.00689	+.01054	+.00133	+.17
.90		+.01947	+.18633	-.06822	-.02151	-.01487	-.06559	.26320	.52244	-.07327	-.45490	-.11256	-.02151	-1.95973	.39233	3.48257	-.38966	+.00851	+.01096	+.00164	+.18
.94		+.02125	+.19118	-.06077	-.02073	-.01572	-.06818	.25367	.55209	-.06626	-.47249	-.09711	-.02073	-2.07094	.34947	3.61955	-.33618	+.01001	+.01124	+.00193	+.18
.98		+.02295	+.19496	-.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	-.04870	-.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	+.19769	-.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	-.03197	-.53025	-.04414	-.01592	-2.55771	.12636	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. ___ → FIG. 2 / Pg. 52

	1.0774 ×β̇	6.935 ×β	-22.071 ×X	θ̇	131.773 ×θ	-5.751 ×β̇	-33.092 ×β	-76.404 ×X	.0587 ×A	.00729 ×B	.0113 ×A	.1228 ×B	β̈Δt	θ̈Δt	β̇Δt	θ̇Δt	β̈Δt²/2	θ̈Δt²/2	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	-.00846	-.00199	-.07505	-.00154	-.000296	0	0	-.000015	-.000003	-.1766	-.6112	.0080
106	-.00135	-.000104	-.35314	-.000296	-.000395	.00886	.000796	-1.22246	-.02061	-.00585	-.00397	-.14902	-.00306	-.000589	-.000031	-.000006	-.000031	-.000006	-.35117	-1.21349	.0160
327	-.00414	-.000534	-.48556	-.000885	-.00198	.02646	.00409	-1.68088	-.02816	-.01223	-.00542	-.20594	-.00423	-.00081	-.000092	-.000018	-.000042	-.000008	-.47988	-1.67702	.0220
144	-.00948	-.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	-.02102	-.00845	-.76807	-.00486	-.03097	.14469	.06447	-2.65886	-.04320	-.01812	-.00832	-.30522	-.01254	-.00245	-.00151	-.000294	-.00025	-.00005	-.75711	-2.51056	.0365
72	-.04049	-.01716	-.80559	-.00731	-.06272	.21682	.13140	-2.78875	-.04444	-.01830	-.00856	-.30630	-.01267	-.00251	-.00151	-.000292	-.00025	-.00005	-.74463	-2.40703	.0367
374	-.05410	-.02938	-.81001	-.00982	-.10779	.28971	.22490	-2.80403	-.04371	-.01755	-.00841	-.29558	-.01216	-.00245	-.00202	-.000393	-.00024	-.000049	-.74463	-2.40703	.0367
426	-.06776	-.04504	-.78573	-.01227	-.16603	.35964	.34478	-2.71998	-.04130	-.01599	-.00795	-.26981	-.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	.0281
164	-.09894	-.10989	-.63123	-.01843	-.41126	.52498	.84730	-2.18515	-.02959	-.00910	-.00569	-.15333	-.00636	-.00155	-.00365	-.000737	-.00013	-.000031	-.50402	-1.24857	.0226
662	-.10487	-.13609	-.57164	-.01998	-.51246	.56156	1.04188	-1.97886	-.02533	-.00662	-.00488	-.11149	-.00465	-.00128	-.00391	-.000798	-.00009	-.000026	-.43154	-.982869	.0259
560	-.10987	-.16383	-.51205	-.02126	-.62118	.58833	1.25419	-1.77257	-.02114	-.00417	-.00407	-.07030	-.00297	-.00101	-.00404	-.00085	-.00006	-.000020	-.36007	-.572485	.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	+.00112	-.000524	-.00426	-.00094	+.000029	-.000006	-.22855	+.04389	.0182
069	-.11427	-.25156	-.35314	-.02354	-.97789	.61245	1.92586	-1.22246	-.01000	+.00229	-.00193	+.03861	+.00147	-.000368	-.00426	-.00094	+.000054	-.000002	-.17032	+.31441	.0160
1400	-.11200	-.28090	-.30899	-.02385	-1.10281	.60401	2.15049	-1.06966	-.00686	+.00407	-.00132	+.06854	+.00269	-.000112	-.00420	-.00095	+.000075	+.000001	-.11657	+.55818	.0140
2758	-.10991	-.30966	-.26927	-.02396	-1.22878	.58855	2.37066	-.93215	-.00400	+.00565	-.00077	+.09509	+.00377	+.000066	-.00409	-.00096	+.000094	+.000004	-.06586	+.77434	.0122
3123	-.10576	-.33753	-.23315	-.02390	-1.35502	.56685	2.58404	-.80988	-.00139	+.00701	-.00027	+.11814	+.00472	+.000225	-.00394	-.00096	+.000094	+.000004	-.02372	+.96209	.0106
3467	-.10079	-.36423	-.20305	-.02367	-1.48047	.53973	2.78839	-.70292	+.00095	+.00817	+.000184	+.13767	+.00551	+.000365	-.00375	-.00095	+.000111	+.000007	+.00624	+1.12106	.0092
3770	-.09487	-.38949	-.17436	-.02331	-1.60434	.50802	2.98186	-.60359	+.00318	+.00918	+.000612	+.15456	+.00621	+.000494	-.00353	-.00093	+.000124	+.000011	+.03414	+1.25364	.0079
4008	-.08821	-.41314	-.15008	-.02281	-1.72583	.47232	3.16285	-.51955	+.00515	+.00997	+.000992	+.16786	+.00678	+.000665	-.00328	-.00091	+.000135	+.000012	+.01728	+1.36698	.0068
4174	-.08115	-.43498	-.13022	-.02221	-1.84456	.43348	3.33009	-.45078	+.00689	+.01054	+.00133	+.17757	+.00716	+.000697	-.00301	-.00089	+.000143	+.000014	+.01731	+1.44602	.0059
4244	-.07427	-.45490	-.11256	-.02151	-1.95973	.39233	3.48257	-.38966	+.00851	+.01096	+.00164	+.18469	+.00745	+.000779	-.00273	-.00086	+.000149	+.000016	+.01491	+1.50399	.0051
4209	-.06626	-.47279	-.09711	-.02073	-2.07094	.34947	3.61955	-.33618	+.01001	+.01124	+.00193	+.18925	+.00765	+.00085	-.00243	-.00083	+.000153	+.000017	+.01059	+1.54116	.0044
4061	-.05705	-.48859	-.08166	-.01988	-2.17794	.30549	3.74049	-.28269	+.01154	+.01141	+.00222	+.19224	+.00778	+.00092	-.00213	-.00080	+.000156	+.000018	+.01958	+1.56546	.0037
3808	-.04870	-.50223	-.07063	-.01896	-2.28099	.26075	3.84452	-.24449	+.01283	+.01138	+.00247	+.19172	+.00777	+.00097	-.00181	-.00076	+.000176	+.000020	+.02150	+1.56123	.0032
3408	-.04135	-.51368	-.05738	-.01799	-2.37850	.21607	3.93252	-.19865	+.01425	+.01132	+.00274	+.19076	+.00774	+.00102	-.00150	-.00072	+.000195	+.000022	+.02277	+1.55345	.0026
2867	-.03334	-.52304	-.04297	-.01697	-2.47074	.17155	4.00420	-.18337	+.01516	+.01097	+.00292	+.18477	+.00751	+.00105	-.00119	-.00068	+.000215	+.000022	+.02585	+1.50467	.0024
2185	-.02577	-.53025	-.04414	-.01592	-2.55771	.12836	4.05941	-.15251	+.01633	+.01065	+.00314	+.17945	+.00730	+.00108	-.00089	-.00064	+.000215	+.000022	+.02827	+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

①	②	③ = .4706 (28)	④ = −.4328 (29)	⑤ = ③ × ④	⑥ = −2.1516 (28)	⑦ = 2.5824 (29)	⑧ = ⑥ × ⑦	⑨ = ⑤ × ⑧	⑩ = ⑤ × ⑨	⑪ = ⑫ + ⑩
t	Δt	.4706 A_4	−.4328 B_4	ϕ''	−2.1516 A_4	2.5824 B_4	β''	$\phi''\Delta t$	$\beta''\Delta t$	ϕ'
SEC.	SEC.			RADIANS/SEC²			RADIANS/SEC²			RAD/SEC
0	.02	0	0	0	0	0	0	0	0	0
.02	.02	.14965	−.06882	.08083	−.68421	.41060	−.27361	.001617	−.005472	0
.04	.02	.22537	−.10526	.12011	−1.03040	.62804	−.40236	.002402	−.008047	.001617
.06	.02	.27224	−.12897	.14327	−1.24470	.76956	−.47514	.002865	−.009503	.004019
.08	.02	.30504	−.14793	.15711	−1.31467	.88266	−.51201	.003142	−.010240	.006884
.10	.04	.31380	−.15598	.15782	−1.43469	.93070	−.50399	.006313	−.020160	.010026
.14		.29756	−.15447	.13872	−1.36046	.94774	−.41272	.005549	−.016509	.016339
.18		.26697	−.15460	.11116	−1.22060	.92966	−.29094	.004446	−.011638	.021888
.22		.24236	−.15589	.08789	−1.10807	.92166	−.18641	.003516	−.007456	.026334
.26		.22109	−.15783	.06649	−1.01082	.92243	−.08839	.002660	−.003536	.029250
.30		.20372	−.16005	.04783	−.93143	.93018	−.00125	.001913	−.000050	.032510
.34		.19064	−.15721	.03281	−.87159	.94175	.07016	.001312	.002806	.034423
.38		.17961	−.16318	.01956	−.82118	.95497	.13379	.000782	.005352	.035735
.42		.16044	−.16261	.00323	−.73354	.95780	.20426	.000129	.008170	.036517
.46		.16444	−.16227	.00126	−.75181	.97367	.22486	.000050	.008874	.036646
.50		.15749	−.15987	−.00462	−.72231	.97023	.24792	−.000185	.009917	.036696
.54		.15242	−.15612	−.00985	−.69686	.96825	.27139	−.000394	.010856	.036511
.58		.14581	−.15138	−.01406	−.66665	.95389	.28724	−.000562	.011490	.036147
.62		.13920	−.14342	−.00692	−.63646	.93152	.29506	−.000617	.011802	.035557
.66		.13287	−.13428	−.01851	−.60748	.90322	.29514	−.000740	.011830	.034828
.70		.12193	−.12427	−.02149	−.55746	.85572	.29827	−.000860	.011931	.034138
.74		.11073	−.11258	−.02355	−.50625	.80124	.29499	−.000942	.011800	.033278
.78		.09986	−.09968	−.02441	−.45657	.74146	.28489	−.000976	.011396	.032336
.82		.08627	−.08574	−.02521	−.39947	.67176	.27229	−.001008	.010892	.031340
.86		.07328	−.07109	−.02560	−.33868	.59475	.25607	−.001024	.010243	.030352
.90		.06005	−.05347	−.02569	−.27457	.51175	.23700	−.001027	.009480	.029318
.94		.04582	−.03753	−.02527	−.20948	.42416	.21468	−.001011	.008587	.028331
.98	.04	.02607	−.02543	−.02740	−.11918	.31903	.19985	−.001096	.007994	.027274
1.02	.03	.01135	−.00366	−.02618	−.05190	.22395	.17205	−.000785	.005162	.026
1.05	.05	−.00012	.04514	−.02555	.00056	.15174	.15230	−.001278	.007615	.025
1.10	.10	−.02115	.08441	−.02481	.09671	−.02184	.13334	−.002481	.013334	.024
1.20		−.06990	.13335	−.02416	.31960	−.27291	.04669	−.002416	.004669	.021
1.30		−.10805	.16723	−.02364	.49401	−.50367	−.00966	−.002364	−.000966	.019
1.40		−.15855	.19155	−.02520	.72492	−.79566	−.07074	−.002520	−.007074	.016
1.50		−.19219	.20624	−.02496	.87865	−.99779	−.11914	−.002496	−.011914	.014
1.60		−.21645	.21112	−.02490	.98963	−1.14297	−.15334	−.002490	−.015334	.011
1.70		−.23060	.20661	−.02436	1.05433	−1.23056	−.17623	−.002436	−.017623	.009
1.80		−.23442	.19355	−.02330	1.07178	−1.25972	−.18794	−.002330	−.018794	.006
1.90		−.22828		−.02167	1.04370	−1.23278	−.18904	−.002167	−.018904	.004
2.00	.10	−.21307		−.01952	.97418	−1.15488	−.18070	−.001952	−.018070	.002
2.10										

①	②	⑫ = ③ × ⑪	⑬ = ② × ⑪	⑭ = ② × ⑫	⑮ = ⑤/2	⑯ = ⑧/2	⑰ = ⑥ + ⑬	⑱ = ⑦ + ⑭	⑲ = 2 ⑫ ⑬	⑳ = ⑫²	㉑ = ⑬²	㉒ = 1.4451 ⑮
t	Δt	β'	$\phi'\Delta t$	$\beta'\Delta t$	$\frac{\phi''\Delta t^2}{2}$	$\frac{\beta''\Delta t^2}{2}$	ϕ	β	$2\phi'\beta'$	β'^2		
SEC.	SEC.	RAD/SEC			RADIANS		RADIANS	RADIANS				
0	.02	0	0	0	0	0	0	0	0	0	0	0
.02	.02	.00005472	.00000323	−.00001094	.00000167	−.00000055	0	0	0	0	0	0
.04	.02	.00013519	.00000804	−.00002704	.00000828	−.00000845	.00000485	−.00001164	—	—	—	—
.06	.02	.00023022	.00001388	−.00004604	.00000831	−.00001103	.00000319	−.00001070	—	—	—	—
.08	.02	.00033262	.00002011	−.00006651	.00001126	−.00001403	.00000556	−.00001838	—	—	—	—
.10	.04	.00043422	.00006541	−.00021357	.00001111	−.00003330	.00001531	−.00004378	—	—	—	—
.14		.00060931	.00008766	−.00027977	.00000889	−.00002333	.00002318	−.00007505	—	—	—	—
.18		.00079519	.00010534	−.00032634	.00000670	−.00001491	.00003460	−.00011001	—	—	—	—
.22		.00097970	.00011945	−.00035610	.00000530	−.00000711	.00004744	−.00014711	—	—	—	—
.26		.00114561	.00013002	−.00037024	.00000382	−.00000101	.00006077	−.00018484	—	—	—	—
.30		.00129261	.00013771	−.00037094	.00000260	−.00000056	.00007492	−.00022189	.0064	.0086	.0150	.0224
.34		.00141985	.00014291	−.00035925	.00000161	−.00000107	.00008947	−.00025215	.00642	.00806	.0145	.0217
.38		.00153453	.00014613	−.00033778	.00000093	−.00000163	.00010424	−.00028996	.0062	.0071	.0133	.0199
.42		.00163283	.00014664	−.00030511	.00000041	−.00000177	.00011893	−.00031884	.0056	.0058	.0114	.017
.46		.00171409	.00014681	−.00026962	.00000014	−.00000198	.00013362	−.00034403	.0049	.0045	.0094	.014
.50		.00177492	.00014600	−.00023200	.00000008	−.00000217	.00014818	−.00036505	.0042	.0033	.0075	.0112
.54		.00181446	.00014451	−.00018651	.00000011	−.00000230	.00016255	−.00038153	.0034	.0021	.0055	.0082
.58		.00183546	.00014233	−.00014466	.00000014	−.00000236	.00017666	−.00039329	.00246	.00125	.0037	.0055
.62		.00183233	.00013954	−.00010933	.00000014	−.00000237	.00019047	−.00040026	.00163	.00055	.00218	.0032
.66		.00181154	.00013661	−.00008461	.00000017	−.00000239	.00020399	−.00040250	.00078	.00013	.00041	.0014
.70		.00177507	.00013317	−.00006017	.00000019	−.00000230	.00021713	−.00040028	—	—	—	—
.74		.00172293	.00012893	−.00003489	.00000020	−.00000228	.00022987	−.00039303	.00079	—	—	—
.78		.00165254	.00012345	−.00000945	.00000020	−.00000218	.00024221	−.00038130	—	—	—	—
.82		.00156214	.00011680	.00001380	.00000020	−.00000215	.00025415	−.00036532	.002	.001	.003	.005
.86		.00145173	.00010901	.00003790	.00000020	−.00000190	.00026568	−.00034537	.0026	.002	.00046	.007
.90		.00132132	.00010009	.00006169	.00000020	−.00000172	.00027679	−.00032178	.003	.003	.006	.009
.94		.00117088	.00009016	.00008516	.00000020	−.00000162	.00028747	−.00029490	.0035	.004	.0075	.0113
.98	.04	.00101044	.00007932	.00010832	.00000012	−.00000077	.00028771	−.00026498				
1.02	.03	.00076000	.00006779	.00012779	.00000032	−.00000190	.00029519	−.00024442				
1.05	.05	.00041202	.00004579	.00014179	.00000124	−.00000485	.00030689	−.00019773				
1.10	.10	.00002156	.00000962	.00009642	.00000122	−.00000234	.00031605	−.00009196				
1.20		−.00001914	−.00001059	.00010159	−.00000118	−.00000049	.00033597	.00000197				
1.30		−.00009678	−.00005362	.00010362	−.00000126	−.00000353	.00034957	.00010810				
1.40		−.00014426	−.00009355	.00009355	−.00000125	−.00000595	.00036257	.00019912				
1.50		−.00011176	−.00008164	.00008164	−.00000125	−.00000766	.00037308	.00027481				
1.60		−.00006927	−.00006531	.00006531	−.00000122	−.00000881	.00038110	.00033346				
1.70		−.00002684	−.00004868	.00004868	−.00000116	−.00000943	.00038672	.00037333				
1.80		.00000451	−.00002989	.00002989	−.00000109	−.00000945	.00039007	.00039382				
1.90		.00002234	−.00001098	.00001098	−.00000098	−.00000904	.00039132	.00039339				
2.00	.10	.00002534	−.00000769				.00039037	.00039227				
2.10												

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

t	⑭ $\frac{\ddot{\phi}\Delta t^2}{2}$	⑮ $\frac{\ddot{\beta}\Delta t^2}{2}$	⑯	⑰ ϕ	⑱ β	⑲ $2\dot{\phi}\dot{\beta}$	⑳ $\dot{\beta}^2$	㉑	㉒ 1.445 ㉑	㉓ 10.75 − ㉒	㉔ $L \times 10^{-5}$	㉕ $-7.423\dot{\phi}$	㉖ $-.9457\dot{\beta}$	㉗ $-⑲\dot{\beta}$	㉘ A_4	㉙ $\dot{\phi}^2$	㉚ $7.476\dot{\phi}^2$	㉛ 10.72 + ㉚ $7.476\dot{\phi}^2$	㉜ $L_1 \times 10^{-5}$	㉝ $.353\dot{\phi} - 1.184\dot{\beta}$	㉞ $-⑱\dot{\beta}$	㉟	㊱ B_4
				RADIANS	RADIANS																		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.318	0	0	0	0	0	0	0	.159
.00001617	−.000055	0	0	0	0	0	0	0	0	10.75	.318	−.012003	.005175	.001764	.4789	—	—	10.72	.159	0	0	0	.2432
.001094	.000024	−.000081	.0000485	−.000164	—	—	—	—	—	10.75	.474	−.017833	.012785	.005536	.5785	—	—	10.72	.246	−.007039	.006479	.001759	.298
.002704	.000028	−.000095	.000153	−.000515	—	—	—	—	—	10.75	.590	−.022133	.021772	.011507	.6482	—	—	10.72	.299	−.017495	.016006	.005621	.3418
.004604	.000031	−.000103	.000319	−.001070	—	—	—	—	—	10.75	.666	−.025100	.031456	.019759	.6668	—	—	10.72	.333	−.029966	.027258	.011475	.3604
.006657	.000126	−.000403	.000556	−.001838	—	—	—	—	—	10.75	.690	−.027473	.050521	.047064	.6323	—	—	10.72	.345	−.043643	.039382	.019703	.367
.009137	.000111	−.000330	.001331	−.004378	—	—	—	—	—	10.75	.656	−.027284	.066134	.080679	.5673	—	—	10.72	.328	−.057124	.063252	.046932	.360
.012797	.000089	−.000233	.002318	−.007505	—	—	—	—	—	10.75	.583	−.026475	.077114	.11836	.515	—	—	10.72	.292	−.069278	.082800	.080454	.3569
.017263	.000070	−.000149	.003460	−.011001	—	—	—	—	—	10.75	.515	−.025548	.084119	.15814	.4698	—	—	10.72	.257	−.079632	.09657	.117931	.3572
.022561	.000053	−.000071	.004744	−.014711	—	—	—	—	—	10.75	.449	−.022158	.087753	.19870	.4329	—	—	10.72	.224	−.087994	.10541	.157706	.3602
.028702	.000038	−.000001	.006077	−.018484	—	—	—	—	—	10.75	.388	−.024132	.088578	.23803	.40509	—	—	10.72	.194	−.094152	.10959	.198155	.3646
.035709	.000026	.000056	.007492	−.022189	.0064	.0086	.0150	.0224		10.7256	.335	−.025552	.088493	.27599	.38166	.00127	.0095	10.7295	.143	−.094984	.10965	.237872	.3698
.043592	.000016	.000107	.008947	−.025725	.0062	.00806	.0145	.0217		10.7283	.286	−.026526	.087987	.31113	.34093	.00133	.0099	10.73	.111	−.095555	.10633	.276022	.36315
.053378	.000003	.000163	.010424	−.028996	.0062	.0071	.0133	.0199		10.733	.221	−.027202	.087223	.34224	.34942	.00134	.0100	10.73	.104	−.095952	.09044	.342132	.37704
.063051	.000001	.000177	.011893	−.031884	.0056	.0058	.0114	.017		10.736	.175	−.027739	.086375	.36935	.33571	.00135	.0100	10.73	.086	−.095974	.07981	.369142	.37571
.072696	−.000004	.000198	.013362	−.034403	.0049	.0045	.0094	.014		10.739	.1485	−.027102	.085437	.39203	.32388	.00133	.0099	10.73	.074	−.095893	.06807	.391702	.37494
.083300	.000008	.000217	.014818	−.036505	.0042	.0033	.0075	.0112		10.742	.124	−.026810	.084110	.40984	.30984	.0013	.0098	10.73	.062	−.095722	.05522	.409382	.36938
.094365	.000011	.000230	.016255	−.038153	.0034	.0021	.0055	.0082		10.744	.1039	−.026397	.083324	.42759	.29581	.00126	.0094	10.734	.051	−.095477	.04161	.421988	.36072
.106406	.000014	.000236	.017666	−.039329	.00246	.0023	.0037	.0055		10.747	.0890	−.025890	.082208	.43016	.28234	.00122	.0091	10.729	.044	−.095182	.02764	.429442	.34976
.119933	.000014	.000237	.019047	−.040026	.00163	.00055	.00218	.0032		10.749	.0790	−.025341	.081089	.43261	.25909	.00117	.00875	10.729	.034	−.094860	.01363	.431844	.33137
.134461	.000017	.000239	.020399	−.040250	.00078	.00013	.00091	.0014		10.75	.0724	−.024702	.080039	.43030	.23529	.00111	.0083	10.728	.026	−.094486	−.00049	.429422	.31027
.150017	.000019	.000236	.021713	−.040028	.00079	—	—	—		10.748	.0414	−.024003	.01155	.42243	.21220	.00105	.0079	10.729	.0155	−.094076	−.01446	.421644	.28712
.166489	.000020	.000228	.022987	−.039303	—	—	—	—		10.747	.0310	−.023279	.02233	.40978	.18566	—	—	10.727	.0114	−.093651	−.02796	.409102	.26013
.183945	.000020	.000218	.024221	−.038130	—	—	—	—		10.745	.0278	−.022530	.03263	.39259	.15741	—	.007	10.726	.0087	−.093212	−.04085	.391882	.23031
.201380	.000020	.000215	.025415	−.036532	.002	.001	.003	.005		10.743	.0166	−.021770	.04232	.37103	.12761	.00086	.0064	10.726	.0065	−.092766	−.05298	.370442	.19810
.218790	.000020	.000190	.026568	−.034537	.0026	.002	.0046	.007		10.741	.0131	−.021008	.05128	.34562	.09736	.0008	.006	10.726	.0034	−.092319	−.06420	.345144	.16425
.236169	.000020	.000172	.026689	−.032178	.003	.003	.006	.009		10.739	.0069	−.020190	.05940	.31669	.05539	.000771	.0057	10.725	0	−.091840	−.07437	.316312	.12354
.253516	.000020	.000162	.027747	−.029490	.0035	.004	.0075	.0113		10.7	0	−.019377	.06696	.28485	.02412	.0007	.0050	10.725	0	−.091363	−.08384	.284190	.08672
.270832	.000012	.000077	.028771	−.026498						10.7		−.018794	.07185	.25953	−.00026					−.091021	−.08995	.258922	.05876
.287279	.000032	.000190	.029519	−.024442								−.017846	.07905	.21256	−.04995					−.090465	−.09896	.212076	.00846
.304179	.000124	.000485	.030689	−.019773								−.016004	.09166	.10316	−.14854					−.089385	−.11475	.102922	−.10568
.320972	.000122	.000234	.031605	−.009596								−.014210	.09607	.00857	−.22960					−.088333	−.12028	−.008577	−.19504
.337159	.000118	−.000049	.033397	.000197								−.012457	.09516	−.11621	−.33692					−.087304	−.11913	−.115944	−.30811
.353062	.000126	−.000353	.034957	.010810								−.010585	.08847	−.21405	−.40837					−.086207	−.11076	−.213554	−.38638
.369355	.000125	−.000595	.036257	.019912								−.008732	.07724	−.29542	−.45995					−.085121	−.09666	−.294734	−.44260
.385164	.000125	−.000766	.037308	.027481								−.006884	.06271	−.35847	−.49002					−.084027	−.07851	−.357644	−.47652
.400681	.000122	−.000881	.038110	.033346								−.005076	.04604	−.40133	−.49813					−.082977	−.05764	−.400404	−.48781
.415868	.000116	−.000943	.038672	.037333								−.003346	.0282	−.42335	−.48508					−.081962	−.03539	−.422377	−.47738
.430729	.000109	−.000945	.039007	.039382								−.001738	.01039	−.42500	−.45277					−.081019	−.01301	−.424012	−.44721
.445298	.000098	−.000904	.039132	.039539																			
.459709			.039037	.039422																			

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

REPUBLIC AVIATION CORPORATION

Report No. EDR-F905-103
Page No. 47
Date JULY 18, 1949

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	$(\Delta t)^2$	$\ddot{\psi} = .05343\ddot{\psi}_{n-1} - .47453\psi + N_{n-1}$	$\dot{\psi} = \ddot{\psi}\Delta t + \dot{\psi}_{n-1}$	$\psi = \psi_{n-1} + \dot{\psi}\Delta t + \ddot{\psi}\frac{(\Delta t)^2}{2}$	$N = -.26939\, e^{-.3t}(1-e^{-.3t})$	$(\dot{\psi})^2$	$R_{F.H_2} = 40352\ddot{\psi}$ (LBS)	$R_{FH_1} \simeq 40352(\dot{\psi})^2$ (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	- 1152	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	-.01898	-.00542	-.03798	.00036	- 1698	14
.60	.10	.0100	-.03479	-.02242	-.00783	-.03098	.00050	- 1388	20
.80	.20	.0400	-.02807	-.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	+.00292	-.04626	0	.00001	+ 920	0
3.25	.25	.0625	+.02179	+.00842	-.04347	0	.00007	+ 879	3
3.50	.25	.0625	+.02018	+.01345	-.03947	0	.00018	+ 814	7
3.75	.25	.0625	+.01801	+.01796	-.03442	0	.00032	+ 727	13
4.00	.25	.0635	+.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	.00057	- 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 (12)	(3)²	SIN (4)	8263.45 (2)	4652 (3)	-283.47 (4)	-8297.2 (5)	(10)+(11)	TABLE II COL. (4)	TABLE II COL. (6)	TABLE II COL. (8)	(13)²	SIN (14)	-268.05 (12)	-1132.5 (13)	-128180 (14)	268.05 (15)	(10)+(15)+(20)		(10)+(12)
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
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	-.00859	.0036	-.00859	-2809.6	-279.1	2.4	+.3	-3088.9	.0015	.0007	.000044		.000064	-2.5	-.9	-8.2		-11.5		-3088.9
.3	-.285	-.0900	-.01763	.0081	-.01763	-2355.1	-418.7	5.0	1.2	-2767.6	.0026	.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	-99.1		-111.1		-2208.4
.5	-.128	-.1270	-.041689	.0161	-.04169	-1057.7	-590.6	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	-.05517	-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	-607.3	.0260	.0130	.003858		.003858	-7.0	-14.7	-494.5		-516.2		-607.3
.8	+.042	-.1330	-.082104	.0177	-.08210	347.0	-618.7	23.3	12.1	-236.3	.0215	.0153	.005390		.005390	-5.8	-17.3	-690.9		-714.0	+	-236.3
.9	.076	-.1230	-.100413	.0151	-.1003	619.7	-572.2	28.5	12.6	-89.6	.0155	.0176	.008052		.008052	-4.2	-19.9	-1032.1		-1056.2		-89.6
1.0	.105	-.1120	-.111065	.0125	-.1110	867.7	-521.0	31.5	11.5	+389.7	.0080	.0185	.009948		.009948	-2.1	-21.0	-1275.1		-1298.2		+389.7
1.2	.150	-.0240	-.127795	.0071	-.1274	1239.5	-390.2	36.2	7.5	892.4	-.0080	.0178	.013544		.013544	+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	.016366		.016365	+6.2	-15.9	-2096.4		-2106.1		1256.5
1.5	.17521	-.03223	-.140131	.00104	-.140	1448.0	-149.9	40	1	1324.1	-.0216	.01105	.017317			8	-13.6	-2220		-2225	.0	1324.1
1.6	.17475	-.01475	-.140737	.00022	-.140	1444.0	-68.7	40	0	1434.3	-.03383	.00772	.017923			9	-9	-2297		-2297	.0	1434.3
1.7	.16971	+.00222	-.139662	.000005	-.139	1402.0	+10.3	40	0	1467.3	-.03646	.00408	.018149			10	-5	-2326		-2321	.0	1467.3
1.8	.15897	+.01813	-.137066	.000328	-.137	1314.0	84.2	39	0	1417.2	-.03822	.00025	.017988			10	0	-2305		-2295	.0	1417.2
1.9	.14372	+.03249	-.133088	.001065	-.1330	1188	151.0	37.7	1	1377.7	-.03844	-.00359	.017432			10	4	-2234		-2220	.0	1377.7
2.0	.12537	.04802	-.127957	.002307	-.1274	1036	223.0	36.3	2	1297.3	-.03716	-.00731	.016516			10	8	-2117		-2099	.0	1297.3
2.1	.10126	.05614	-.121939	.003041	-.1219	837	257.0	34.6	3	1131.6	-.3449	-.01075	.015268			9	12	-1957		-1936	.0	1131.6
2.2	.07437	.06258	-.115309	.00392	-.1158	615	291.0	33	4	943	-.3059	-.0181	.013734	0		8	16	-1760	0	-1736	.0	943

AT JOINT — 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
$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2$		SIN α	$\ddot{\alpha}$	$\dot{\alpha}$	α	$\dot{\alpha}^2 \sin\alpha$	$\ddot{\theta}$	$\dot{\theta}$	θ	$\dot{\theta}^2$		$\ddot{\theta}$	θ	$\dot{\theta}^2 \sin\alpha$		FIGURE 2	$\frac{73,669.8}{X}$	R_{F_V}
					-268.05	-1132.5	-128180	268.05							-1473.6	-22800	1473.6				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-2637.0	.021	0	0	0	0	-.3	0	0		-.3	-.0610	-.0055	-.000499		+75.2	+11.4		86.6	.0305	2246.9	-212.9
-3085.9	.0075	.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	.016	.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
-2206.4	.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		.001521	-7.6	-8.5	-195.0		-211.1	-.0230	-.0235	-.007861		33.9	179.0		212.9	.0205	1610.2	-119.1
-1258.6	.0286	.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	-494.6		-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	630.4	-75.0
-89.6	.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	.0050	.0185	.009948		.009948	-2.1	-21.0	-1295.1		-1298.2	.0100	-.0230	-.021281		-14.7	485.2		470.5	.0035	257.8	-189.2
29.4	-.0080	.0178	.013544		.013544	+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	-.029144		-14.7	664.5		649.8	.0010	72.1	-127.1
1331	-.0286	.01105	.017317			8	-12.6	-2220		-2225	.00964	-.01765	-.030861		-14	704		690	.0008	59	-138
1411	-.03322	.00772	.017925			9	-9	-2297		-2297	.00912	-.01674	-.03249		-13	741		728	.0006	44	-109
1462	-.03646	.00408	.018149			10	-5	-2326		-23.21	.00870	-.01587	-.034037		-13	776		763	.00045	33	-73
1472	-.03822	.00025	.017983			10	0	-2305		-2295	.00816	-.01606	-.03350		-12	809		797	.0003	22	-59
1381	-.03844	-.00359	.017432			10	4	-2224		-2220	.00770	-.01428	-.03689		-11.35	841		830	0	0	-12
1251	-.03716	-.00731	.016515			10	8	-2117		-2099	.00750	-.01363	-.03820		-11.06	871		860	0	0	+44
1111	-.3449	-.01075	.015268			9	12	-1957		-1936	.00701	-.01283	-.03945		-10.33	899		889	0	0	+85
941	-.3059	-.01381	.013734	0		8	16	-1760	0	-1736	.00665	-.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)
t	$\ddot{\beta}$	$\dot{\beta}$	β	$\ddot{\beta}$	$\dot{\beta}$	β		$\ddot{\phi}$	$\dot{\phi}$	ϕ^2	$\phi^2\beta$	$\ddot{\phi}$	$\dot{\phi}$	$\phi^2\beta$		$\ddot{\alpha}$	$\dot{\alpha}$	$\ddot{\alpha}$	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	−182	1	−3770	.13296	.012210			5399	310	0	5709	.001445	.000221	−3	−28	29679	−1622
.15	−.46124	−.06315	−.003708	−3811	−294	2	−4103	.14422	.014421			5856	494	0	6349	.001519	.000575	−6	−74	34350	−1877
.2	−.42466	−.08488	−.012335	−3590	−395	4	−3781	.13971	.016407			5673	671	0	6344	.009895	.001179	−11	−151	35810	−1957
.3	−.29491	−.11838	−.02444	−2437	−551	7	−2981	.10582	.028798			4297	965	−1	5261	.02164	.00333	−25	−326	32647	−1784
.4	−.13386	−.13569	−.01811	−1106	−621	11	−1727	.06731	.04564			2733	1160	−3	3891	.03528	.00685	−40	−878	26566	−1452
.5	+.01415	−.13778	−.05198	+117	−641	15	−709	.03507	.04988			1424	1269	−4	2688	.04850	.00871	−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	−.02561	1837	−500	21	1358	.00460	.05251			187	1335	−7	1515	.06736	.02445	−76	−3134	10315	−564
.8	.29912	−.06850	−.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	.08012	.04929	−77	−6318	3446	−188
1.1	.50435	.06710	−.07272	4168	312	21	4501	−.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	.08031	.05948	−57	−7624	1460	−80
1.3	.61955	.18561	−.03586	5120	863	10	5993	−.00781	.05120			−347	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	7382	−.02327	.04742			−949	1205	+6	263	.00665	.06403	−8	−8207	779	−43
1.6	.74338	.39817	.07223	6143	1853	−20	7915	−.03295	.04402			−1379	1119	6	253	−.01098	.06205	+17	−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	.72303	.54611	.18158	5975	2514	−51	8465	−.05172	.03454			−2100	878	+6	−1215	−.04891	.05231	55	−6705	0	0
1.9	.62320	.61363	.24631	.6563	2859	−70	8347	−.05485	.02405			−2227	611	+6	−1609	−.06829	.04451	71	−5705	0	0
2.0	.57850	.67158	.31637	.4789	3124	−90	7823	−.05428	.02362			−2204	602	+6	−1598	−.08204	.03487	99	−4470	0	0

Single Joint
Double Joint

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

TABLE II COL. (4)	ϕ^2 (10)	(11) ×(4)	$\phi^2\ddot{\phi}$ (12)	40604.1 (9)	$\ddot{\phi}$ (13)	25,418 (10)	$\dot{\phi}$ (14)	32,327 (11) ×(4)	$\phi^2\phi$ (15)	(13)×(14)×(15)	$\ddot{z}$ (16)	TABLE II COL. (18)	α (17)	COL. (21) -1132.5 ×(17)	$\dot{\alpha}$ (18)	-128,180 ×(18)	$\dot{z}$ (19)	TABLE II COL. (39)	L_2 (20)	-.05464 ×(21)	$-L_2$ (22)	(19)×(22)	(5)×(23)	R_{FV} (24)
	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
13210					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	-436			32647	-1784		-2235		45
04564					2733	1160		-3			3891	.03528	.00685	-40	-878			26566	-1952		-2397		-233
04988					1424	1259		-4			2688	.04850	.01121	-55	-1501			19949	-1090		-2645		-466
05185					628	1318		-6			1940	.05954	.01769	-67	-2268			14597	-738		-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		-1332
05258					-23	1337		-8			1306	.07241	.04269	-82	-5472			4963	-271		-5825		-1546
05254					-18	1336		-7			1310	.06812	.04929	-77	-6318			3446	-186		-6581		-1540
05239					-61	1332		-7			1264	.06061	.05497	-69	-7046			2433	-133		-7248		-1983
05198					-165	1321		-7			1149	.05031	.05948	-57	-7624			1460	-80		-7161		-1348
05120					-317	1301		-7			977	.03761	.06261	-43	-8025			1168	-64		-8132		-1162
04996					-583	1265		-7			675	.02294	.06417	-26	-8225			973	-53		-8304		-917
04742					-949	1205		+6			263	.00665	.06403	-8	-8207			779	-43		-8358		-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					-2223	611		+6			-1609	-.06824	.04451	71	-5705			0	0		-5628		1110
02362					-2204	600		+6			-1598	-.08704	.03489	99	-4470			0	0		-4371		1854

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
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
0	[illegible]	0	0	0	0	0	0	0	0	0
.02	−.01488	0	0	−.077045	0	0	.0680	.025846	0	0
.04	−.08946	−.000296	−.000003	−.152988	−.001541	−.000015	.0160	.051376	.000333	.000453
.06	−.04036	−.000885	−.000015	−.21136	−.004601	−.000077	.0220	.070423	.000996	.00226
.08	−.04896	−.001693	−.000041	−.25310	−.008824	−.000211	.0270	.085451	.001905	.00619
.10	−.05452	−.002662	−.000085	−.28263	−.013854	−.000438	.0305	.095561	.002995	.012832
.14	−.06132	−.004855	−.000235	−.31354	−.025159	−.001218	.0348	.106944	.00546	.03544
.18	−.06274	−.007308	−.000476	−.3685	−.037701	−.002475	.0365	.109419	.00822	.07186
.22	−.06128	−.009818	−.000818	−.363997	−.050375	−.004236	.0367	.106844	.01105	.12345
.26	−.05729	−.012266	−.00126	−.277357	−.062535	−.006494	.0356	.09991	.013802	.190222
.30	−.05166	−.01456	−.001797	−.241294	−.07362	−.009217	.0336	.09009	.01638	.27129
.34	−.045141	−.01663	−.002420	−.200105	−.083281	−.012355	.0311	.07882	.018764	.36535
.38	−.03969	−.01843	−.003121	−.15902	−.091265	−.015846	.0286	.06748	.020735	.47118
.42	−.03165	−.01998	−.003889	−.116362	−.097646	−.019624	.0257	.05572	.022476	.58712
.46	−.02881	−.02126	−.004714	−.074371	−.102300	−.023623	.0232	.04414	.023914	.71167
.50	−.018187	−.02227	−.005584	−.033278	−.105275	−.02777	.0205	.03275	.02565	.84367
.54	−.01310	−.02302	−.00649	+.002587	−.101606	−.032012	.0182	.02265	.02590	.97960
.58	−.00778	−.02354	−.00742	+.036685	−.106494	−.036274	.0160	.01345	.02649	1.12033
.62	−.00279	−.02385	−.008369	+.067224	−.105027	−.040505	.0140	.004861	.02683	1.26342
.66	+.00165	−.02396	−.009325	+.09472	−.102338	−.044652	.0122	−.002878	.02694	1.40771
.70	+.00542	−.023898	−.010283	+.117176	−.09565	−.048671	.0106	−.009805	.02689	1.55242
.74	+.00918	−.023673	−.011235	+.137851	−.09385	−.05252	.0092	−.015916	.02663	1.69615
.78	+.01235	−.023308	−.012175	+.155173	−.088336	−.05616	.0079	−.021545	.02622	1.83606
.82	+.01512	−.022814	−.013097	+.166857	−.082129	−.059573	.0068	−.026266	.02567	1.97272
.86	+.01743	−.022209	−.013998	+.176897	−.075375	−.062723	.0059	−.030393	.02499	2.11324
.90	+.01947	−.021512	−.014872	+.186328	−.068219	−.065595	.0051	−.033956	.02420	2.24526
.94	+.02125	−.020733	−.015716	+.191182	−.060966	−.068175	.0044	−.037057	.02332	2.37264
.98	+.02295	−.019883	−.016528	+.190459	−.053119	−.070453	.0037	−.040027	.02237	2.49523

t SEC.	8.274 × β''	5.592 × β'	57.73 × β	87.63 × X	$R_{F_v} \times 10^{-3}$ LBS (① + ② + ③ + ④ + ⑤)	18.595 × θ''	20.91 × θ'	47.86 × θ	.61 × β''	−12.00 × β'	13.24 × β
①	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒
0	0	0	0	0	0	0	0	0	0	0	0
.02	−.43747	0	0	.70104	.08942	−.27558	0	0	−.04699	0	0
.04	−1.36552	−.00862	−.00489	1.40208	.17891	−.34781	−.00604	−.000143	−.09332	.01849	−.000199
.06	−1.1488	−.02573	−.00460	1.92786	.22241	−.75067	−.01806	−.000718	−.128929	.05521	−.001019
.08	−2.09415	−.04937	−.01260	2.36601	.30250	−.90111	−.03455	−.001962	−.154391	.10593	−.002777
.10	−2.33615	−.077977	−.02616	2.67271	.36776	−1.01938	−.05433	−.004068	−.172404	.16625	−.005300
.14	−2.5942	−.14069	−.07275	3.04952	.38971	−1.14025	−.09909	−.011247	−.19126	.30191	−.016133
.18	−2.62162	−.21082	−.14743	3.19849	.40773	−1.16665	−.14915	−.022761	−.19328	.45241	−.032177
.22	−2.51527	−.29170	−.25302	3.21602	.40771	−1.13913	−.20038	−.03915	−.18543	.60450	−.050668
.26	−2.29485	−.34970	−.38789	3.11963	.39112	−1.06534	−.25039	−.06030	−.16919	.75042	−.068598
.30	−1.99647	−.41173	−.55653	2.9443	.36340	−.96054	−.29717	−.08400	−.14713	.88355	−.122033
.34	−1.65567	−.46571	−.73764	2.72529	.32872	−.83934	−.33934	−.11582	−.12206	.99937	−.163568
.38	−1.31573	−.51066	−.94648	2.50621	.29293	−.71903	−.37618	−.14937	−.09700	1.09542	−.209600
.42	−.96278	−.54604	−1.17214	2.26962	.25398	−.59110	−.40277	−.18613	−.07095	1.17175	−.259116
.46	−.61535	−.57206	−1.41100	2.03302	.21433	−.47062	−.42385	−.22561	−.04537	1.22760	−.312776
.50	−.27534	−.58670	−1.65494	1.79642	.17426	−.34912	−.43451	−.26725	−.02030	1.26330	−.367700
.54	−.03225	−.59614	−1.92208	1.57487	.13843	−.24352	−.46984	−.31061	+.00172	1.27527	−.423800
.58	+.30253	−.59551	−2.16665	1.40208	.10374	−.14329	−.48053	−.35516	+.02238	1.27793	−.480200
.62	+.55621	−.58731	−2.41936	1.22682	.07153	−.08188	−.47682	−.40054	+.04101	1.26032	−.536200
.66	+.76040	−.57227	−2.66706	1.06909	.04202	−.03068	−.48902	−.44629	+.05753	1.22806	−.591900
.70	+.97531	−.55117	−2.90712	.92888	.01540	.10450	−.48776	−.49214	+.07190	1.18278	−.649400
.74	+1.14058	−.52481	−3.13702	.806196	−.00819	.16977	−.48316	−.53771	+.08409	1.12620	−.695300
.78	+1.2839	−.49397	−3.35444	1.69228	−.02950	.22965	−.47572	−.58269	+.09465	1.06003	−.743500
.82	+1.39712	−.45926	−3.55629	.595168	−.04800	.28116	−.46563	−.62682	+.10300	.98555	−.788750
.86	+1.48019	−.42150	−3.74644	.517017	−.06285	.32411	−.45328	−.66994	+.10913	.90450	−.830450
.90	+1.54166	−.38148	−3.91799	.44691	−.07541	.36204	−.43906	−.71177	+.11366	.81863	−.868480
.94	+1.58144	−.33960	−4.07221	.38557	−.08559	.39514	−.42316	−.75217	+.11662	.72919	−.902640
.98	+1.60895	−.29704	−4.20816	.32423	−.09445	.42675	−.40581	−.79103	+.11862	.63743	−.932800

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

	-150.97 × θ	8.274 × β''	5.5[illegible] × β'	57.73 × β	87.63 × X	$R_{F_V} \times 10^{-3}$ LBS	18.595 × θ''	20.91 × θ'	47.86 × θ	.61 × β''	-12.00 × β'	13.24 × β	38.82 × 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
9	0	-.63717	0	0	.70104	.06942	-.27558	0	0	-.04699	0	0	+.30056	-.36614
33	.00045	-1.26552	-.00862	-.00689	1.40208	.17691	-.34781	-.00604	-.001143	-.09332	.01849	-.000199	-.62112	-1.25014
76	.00226	-1.7408	-.02573	-.00460	1.92786	.22241	-.75067	-.01506	-.000718	-.121929	.05521	-.001019	-.85404	-1.69842
15	.00617	-2.09415	-.04937	-.01260	2.36601	.30250	-.90111	-.03455	-.001962	-.158391	.10593	-.002799	-1.04818	-2.03702
95	.012532	-2.3[illegible]5	-.077477	-.02616	2.67271	.36776	-1.01938	-.05833	-.004068	-.172404	.16625	-.00580	-1.18401	-2.27374
2	.03544	-2.5942	-.14069	-.07275	3.04452	.36971	-1.14025	-.09909	-.011247	-.19126	.30191	-.01613	-1.35094	-2.507067
2	.07188	-2.62162	-.21052	-.14743	3.19849	.40773	-1.16665	-.14915	-.022781	-.19328	.45241	-.03277	-1.41693	-2.52735
5	.12345	-2.85127	-.28170	-.25302	3.24602	.40771	-1.13913	-.20038	-.03915	-.18543	.60450	-.05608	-1.4247	-2.44037
02	.190222	-2.29485	-.34970	-.38789	3.11963	.39112	-1.06534	-.25039	-.060304	-.16919	.75042	-.06598	-1.36199	-2.26277
38	.27129	-1.99647	-.41123	-.55653	2.94437	.36340	-.96054	-.29717	-.08100	-.14713	.88355	-.122033	-1.30435	-2.03373
04	.36535	-1.63567	-.45571	-.737764	2.72529	.32172	-.839304	-.33934	-.115621	-.12206	.99937	-.16358	-1.20730	-1.78804
35	.47118	-1.31573	-.510466	-.9 4648	2.50621	.29293	-.719403	-.37618	-.149371	-.09700	1.09542	-.209101	-1.11625	-1.56658
76	.58712	-.96278	-.54604	-1.17214	2.26962	.25398	-.594110	-.40877	-.16613	-.07098	1.17175	-.259727	-.99767	-1.39773
14	.71167	-.61535	-.57206	-1.41100	2.03302	.21433	-.470621	-.43385	-.22561	-.04537	1.22760	-.31277	-.90652	-1.16124
25	.84307	-.29534	-.58870	-1.65894	1.79642	.17426	-.349124	-.45451	-.26725	-.02030	1.26330	-.36773	-.79581	-.99192
20	.97960	-.03225	-.59614	-1.92208	1.59487	.13843	-.24352	-.46984	-.310611	+.00172	1.27927	-.42384	-.70652	-.87335
19	1.12035	.30353	-.59551	-2.16665	1.40208	.10374	-.14329	-.48053	-.355161	+.02238	1.27793	-.48027	-.62112	-.76007
43	1.26342	.55621	-.58731	-2.41936	1.22682	.07153	-.08188	-.48682	-.40054	+.04101	1.26032	-.53629	-.54346	-.71768
34	1.40771	.78040	-.57227	-2.66706	1.06909	.04202	-.03068	-.48902	-.44629	+.05753	1.22806	-.59119	-.47360	-.68383
56	1.55[illegible]4	.97531	-.55117	-2.90712	.92888	.01540	.02450	-.48776	-.49814	+.07190	1.18278	-.64940	-.41149	-.67661
75	1.69615	1.14058	-.52481	-3.13702	.806196	-.00819	.06977	-.48316	-.53971	+.08409	1.12620	-.69536	-.35714	-.64331
45	1.83646	1.2839	-.49397	-3.35444	.69228	-.02950	.22965	-.47572	-.58269	+.09465	1.06003	-.74356	-.30668	-.72432
48	1.97703	1.39712	-.45926	-3.55629	.59568	-.04800	.28116	-.46563	-.62682	+.10300	.98555	-.78875	-.26398	-.77547
64	2.11324	1.49019	-.42150	-3.74644	.517017	-.06285	.32411	-.45328	-.66994	+.10913	.90450	-.83045	-.22904	-.84497
80	2.24526	1.54161	-.38148	-3.91799	.44691	-.07541	.36204	-.43906	-.71177	+.11366	.81865	-.86848	-.19798	-.92296
32	2.37264	1.58184	-.33960	-4.0721	.38557	-.08559	.39514	-.42316	-.75217	+.11662	.72919	-.90264	-.17081	-1.00783
237	2.49523	1.60895	-.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. →			⑮	+⑯+⑰	+⑱+⑲

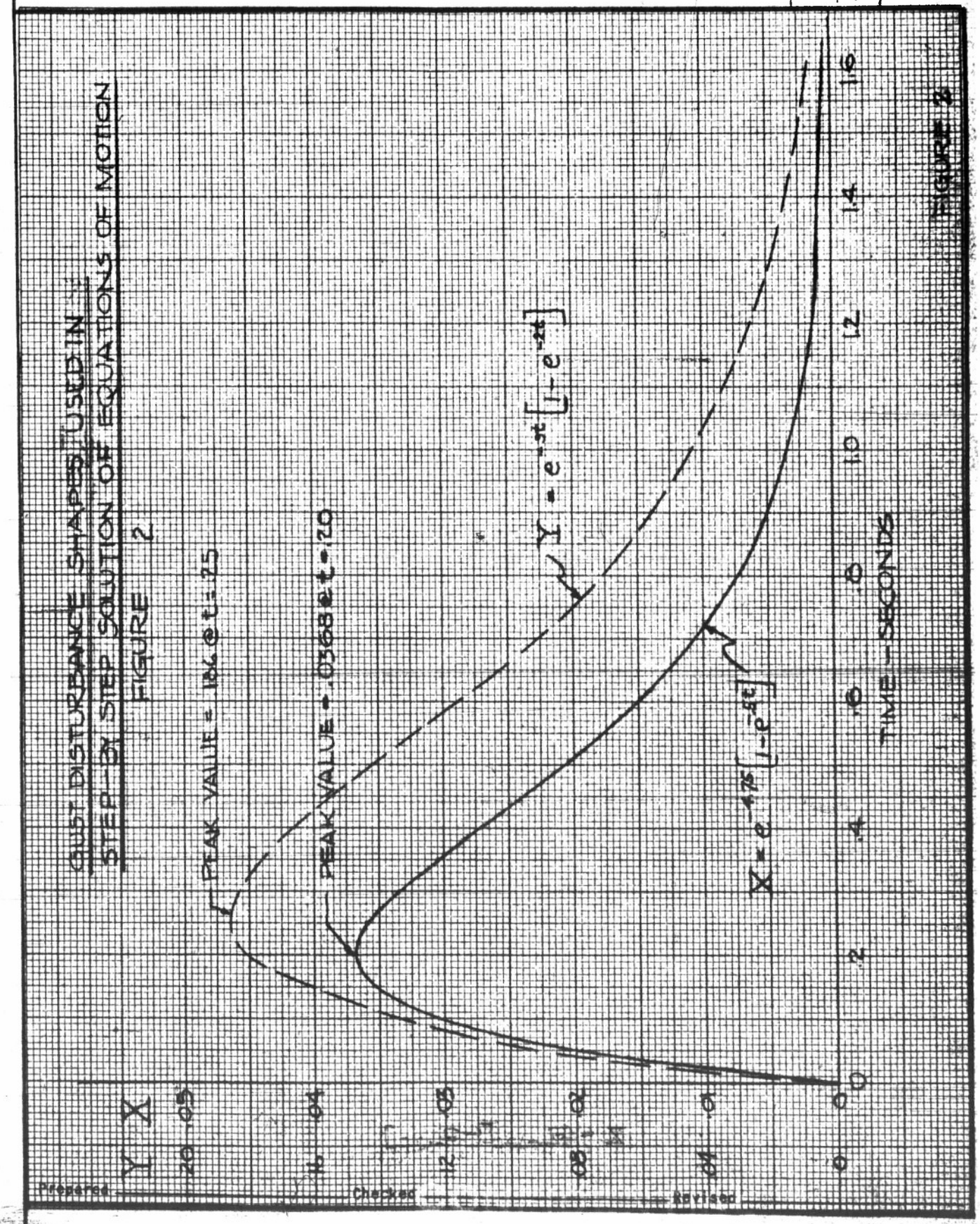
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑
t	$\ddot{\phi}$	$\dot{\phi}$	$\ddot{\beta}$	$\dot{\beta}$	β	L_1	40.70 ②	25.40 ③	8.28 ④	5.59 ⑤	59.73 ⑥	−4.63 ⑦	$R_{F_V} \times 10^{-3}$	2.993 ②	−59.480 ③	.608 ④	−12.230 ⑤	13.242 ⑥	+2.053 ⑦	$M_I \times 10^{-3}$
SECONDS	RAD/SEC²	RAD/SEC	RAD/SEC²	RAD/SEC	RADIANS	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	−3.93416	−.07557	−.03076	−1.3612	.53146	.42021	−.23105	−.28888	.16601	−.00682	.60358	.65505
.08	.15711	.006884	−.51201	−.023022	−.000704	.333	6.39438	.17485	−4.23944	−.12863	−.06394	−1.5417	.54537	.46080	−.40946	−.31130	.28271	−.0417	.68365	.69223
.10	.15782	.010026	−.50399	−.033262	−.001838	.345	6.42327	.25464	−4.17304	−.18593	−.10978	−1.5973	.61181	.46288	−.59635	−.30645	.40846	−.04434	.70829	.65249
.12	.13872	.016339	−.41272	−.053422	−.004378	.328	5.64590	.41501	−3.41732	−.29813	−.26149	−1.5186	.56183	.40686	−.97184	−.25093	.65602	−.05797	.61338	.45520
.18	.11116	.021888	−.29094	−.069931	−.007505	.292	4.52421	.55595	−2.40898	−.39031	−.44227	−1.3473	.48467	.32603	−1.3018	−.17689	.85875	−.04938	.59448	−.20610
.22	.08789	.026334	−.18641	−.081569	−.011001	.257	3.57712	.66288	−1.54347	−.45547	−.65709	−1.1891	.39456	.25778	−1.5663	−.11334	1.00167	−.14567	.52762	−.03829
.26	.06649	.029850	−.08639	−.089025	−.014711	.224	2.70614	.75819	−.73187	−.49765	−.87869	−1.0371	.31900	.19502	−1.7754	−.05374	1.09322	−.19480	.45987	−.27591
.30	.04783	.032510	−.00125	−.092561	−.018484	.194	1.94668	.82575	−.01035	−.51478	−1.1040	−.89822	.24239	.14029	−1.9336	−.00076	1.13665	−.24476	.39828	−.50349
.34	.03281	.034423	.07016	−.092611	−.022189	.167	1.33536	.87434	.58093	−.51779	−1.3253	−.77321	.17437	.09623	−2.0475	.04266	1.13726	−.29383	.34285	−.72233
.38	.01956	.035735	.13379	−.089805	−.025725	.143	.71609	.90767	1.10778	−.50209	−1.5365	−.66209	.11089	.05737	−2.1255	.08134	1.10280	−.34065	.29358	−.93108
.42	.00323	.036517	.20426	−.084453	−.028996	.111	.13146	.92753	1.54008	−.47201	−1.7319	−.51393	−.11888	.02993	−2.1720	.11309	1.03708	−.38397	.22788	−1.1480
.46	.00126	.036646	.22186	−.076283	−.031884	.104	.05128	.93081	1.83700	−.42648	−1.9043	−.48152	−.00672	.00369	−2.1970	.13489	.93625	−.42221	.21351	−1.3130
.50	−.00462	.036696	.24792	−.067409	−.034403	.0865	−.18803	.93208	2.05278	−.32626	−2.0548	−.40049	−.03537	−.03383	−2.1826	.15074	.82778	−.45556	.17658	−1.4969
.54	−.00985	.036511	.27139	−.057492	−.036505	.0741	−.40090	.92738	2.24711	−.32138	−2.1804	−.34308	−.07127	−.02948	−2.1167	.16800	.70600	−.48340	.15213	−1.6614
.58	−.01406	.036117	.28724	−.046636	−.038193	.062	−.57224	.91737	2.37835	−.26600	−2.2789	−.28706	−.10318	−.04208	−2.1482	.17464	.57269	−.50522	.12729	−1.8209
.62	−.01692	.035555	.29506	−.035146	−.039329	.0519	−.68864	.90310	2.44310	−.19611	−2.3491	−.24030	−.12831	−.05064	−2.1146	.17939	.43154	−.52079	.10655	−1.9681
.66	−.01851	.034878	.29514	−.023344	−.040626	.0445	−.75336	.88590	2.44873	−.13044	−2.3008	−.20604	−.14606	−.05540	−2.0459	.17481	.28666	−.53002	.09136	−2.1023
.70	−.02149	.034138	.29827	−.011514	−.040250	.0345	−.87464	.86711	2.46968	−.06436	−2.2041	−.15774	−.16608	−.04432	−2.0305	.18135	.14139	−.53299	.07083	−2.2327
.74	−.02355	.033278	.29499	.000417	−.040028	.0262	−.95849	.84526	2.44252	.00233	−2.1087	−.12131	−.18056	−.03048	−1.9738	.17935	−.00512	−.53005	.05379	−2.3518
.78	−.02449	.032336	.28489	.012217	−.039303	.0201	−.99349	.82133	2.38389	.06822	−2.0475	−.09584	−.18839	−.03016	−1.9238	.17921	−.15002	−.52048	.04250	−2.4511
.82	−.02521	.031360	.27229	.023613	−.038130	.0155	−1.02605	.79654	2.29456	.13203	−2.0350	−.07177	−.19222	−.07845	−1.8652	.16555	−.28997	−.50492	.03182	−2.5382
.86	−.02560	.030352	.25607	.034505	−.036532	.0114	−1.04192	.77094	2.12026	.19281	−2.0204	−.05278	−.19265	−.07662	−1.8053	.15691	−.42372	−.48515	.02340	−2.6091
.90	−.02569	.029328	.23700	.044748	−.034637	.0083	−1.04558	.74473	1.96236	.25014	−2.0629	−.03843	−.18948	−.07689	−1.7443	.14409	−.54950	−.45734	.01704	−2.6670
.94	−.02527	.026301	.21468	.054228	−.032178	.0065	−1.02849	.71225	1.77755	.30314	−1.9219	−.03010	−.18105	−.09563	−1.6324	.13053	−.66592	−.42610	.01334	−2.7072
.98		.023650		.062815	−.029490	.0034		.70231		.35114	−1.7614	−.01574			−1.6442		−.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 +㉑ +⑳

⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑
5.59 ⑤	59.73 ⑥	-4.63 ⑦	$R_{F_V} \times 10^{-5}$	2.9932 ②	-59.480 ③	.608 ④	-12.280 ⑤	13242 ⑥	+2.053 ①	$M_I \times 10^{-3}$
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	-.12046	.35201	.35228	-.09618	-.24463	.06119	-.00247	.49683	.57332
6 -.07557	-.03076	-1.36122	.53146	.42021	-.23205	-.28888	.16601	-.00682	.60358	.65505
4 -.12863	-.06394	-1.54179	.59537	.46080	-.40946	-.31130	.28271	-.01417	.66365	.69223
4 -.18593	-.10978	-1.59735	.61181	.46288	-.59635	-.30645	.40846	-.02434	.70829	.65249
32 -.24268	-.16149	-1.51864	.56183	.40686	-.97184	-.25093	.65602	-.05797	.69338	.45520
8 -.29071	-.44227	-1.34733	.48467	.32603	-1.30189	-.17689	.85875	-.09938	.59948	.20610
17 -.45599	-.65709	-1.18991	.39956	.35778	-1.56635	-.11334	1.00167	-.14561	.52762	-.03824
7 -.49765	-.87869	-1.03142	.31900	.19502	-1.77548	-.05374	1.09322	-.19480	.45987	-.27594
5 -.51443	-1.10405	-.89822	.24239	.14029	-1.93369	-.00076	1.13665	-.24476	.39828	-.50349
3 -.51779	-1.32535	-.77321	.17437	.09623	-2.04750	.04266	1.13726	-.29383	.34285	-.72233
8 -.50209	-1.53655	-.66209	.11089	.05737	-2.12552	.08134	1.10280	-.34065	.29358	-.93108
28 -.47205	-1.73193	-.51393	.11888	.02993	-2.17203	.11309	1.05708	-.38397	.22768	-1.14802
20 -.42642	-1.90443	-.48152	+.00672	.00369	-2.19970	.13489	.93615	-.42231	.21351	-1.33076
18 -.32648	-2.05489	-.40049	-.03537	-.01383	-2.18268	.15074	.82778	-.45556	.17638	-1.49691
1 -.32128	-2.1804	-.34308	-.07127	-.02948	-2.11167	.16800	.70600	-.49340	.15413	-1.66142
35 -.26078	-2.27709	-.28306	-.10218	-.04208	-2.14824	.17464	.57269	-.50522	.12729	-1.82092
0 -.19613	-2.3491	-.24030	-.12831	-.05064	-2.11481	.17939	.43359	-.52019	.10695	-1.96812
13 -.13094	-2.3908	-.20604	-.14606	-.05540	-2.09459	.17981	.28666	-.53002	.09136	-2.10213
68 -.06436	-2.40413	-.15774	-.16608	-.04436	-2.03052	.18135	.14139	-.55299	.07083	-2.22377
52 .00023	-2.39087	-.12131	-.18056	-.03048	-1.97938	.17935	-.00512	-.53005	.05279	-2.35189
89 .06824	-2.37457	-.09584	-.18839	-.01306	-1.92335	.17321	-.15002	-.52045	.04250	-2.45117
56 .13209	-2.27750	-.01177	-.19212	-.00215	-1.86529	.16555	-.28997	-.50492	.03182	-2.53876
26 .19289	-2.18204	-.05278	-.19265	-.01662	-1.80536	.15691	-.43372	-.48515	.02340	-2.60911
36 .25011	-2.06290	-.03843	-.18948	-.01688	-1.74442	.14409	-.54950	-.45734	.01704	-2.66703
55 .30311	-1.92199	-.03010	-.18105	-.09569	-1.68324	.13053	-.66592	-.42610	.01334	-2.70112
.35114	-1.76144	-.01574			-1.64117		-.77137	-.39051	.00698	

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



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

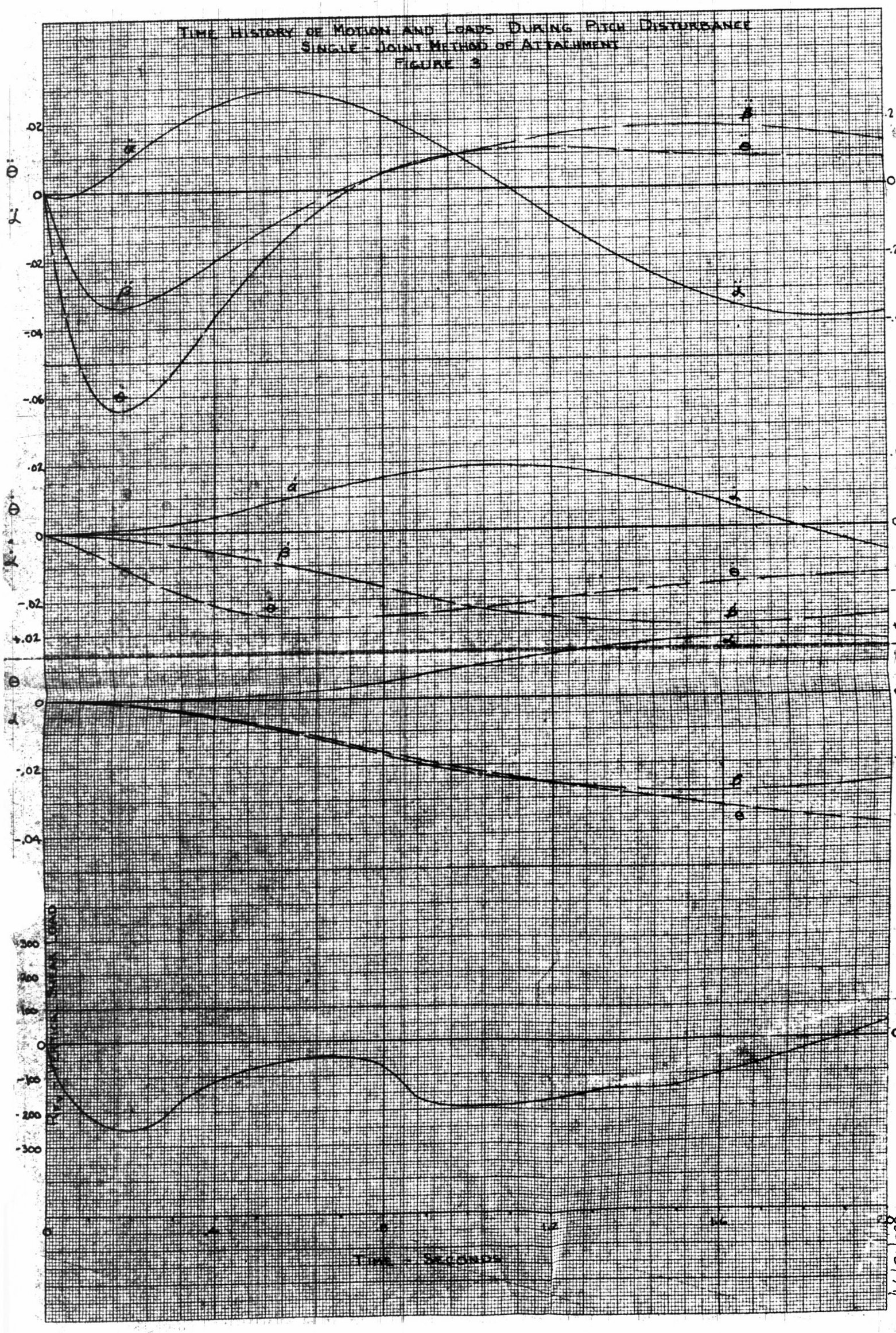

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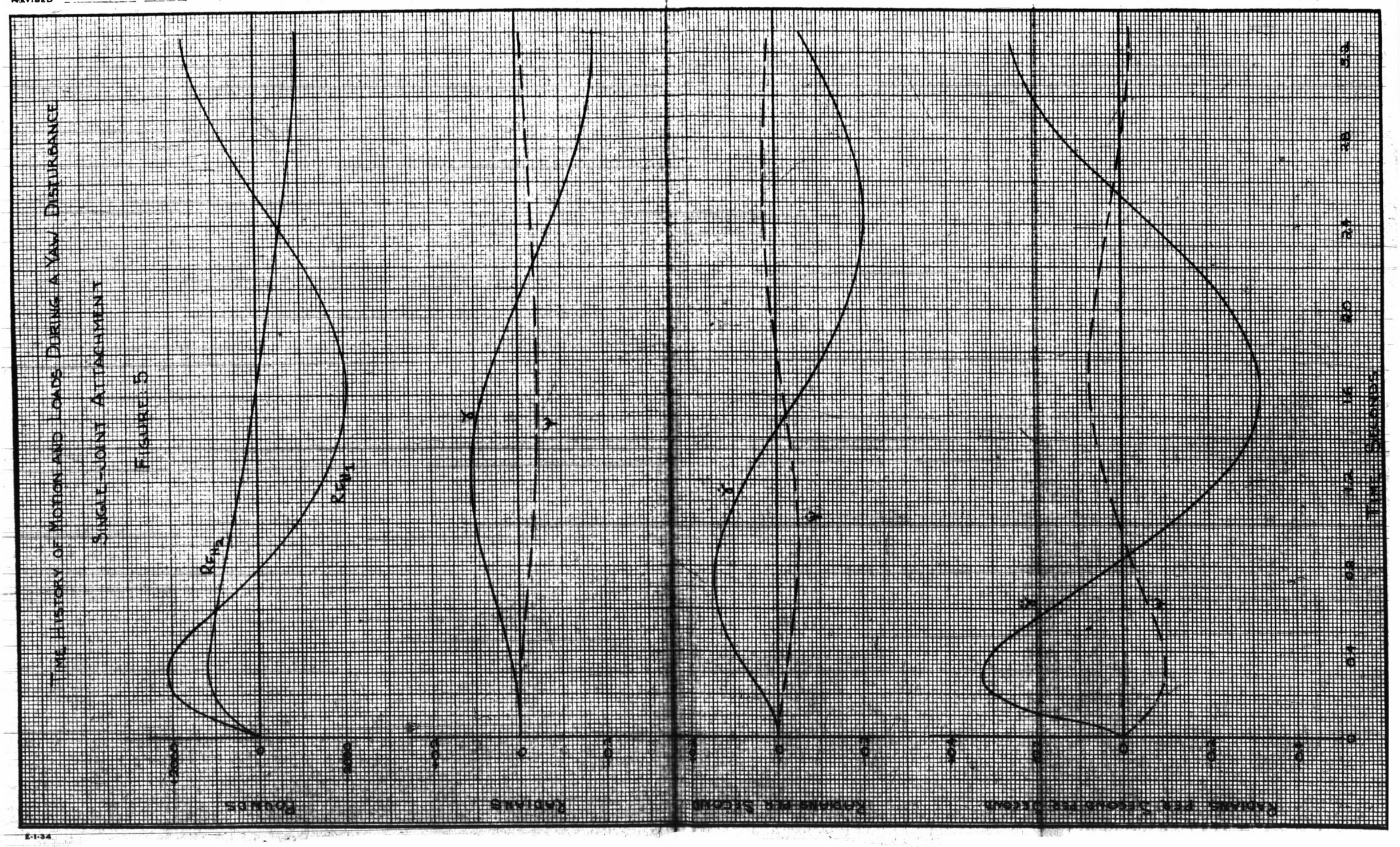
FIGURE 15

SIDE-FLOW AERODYNAMIC DERIVATIVES DURING A YAW DISTURBANCE

THE FLIGHT OF MORE AND ONE



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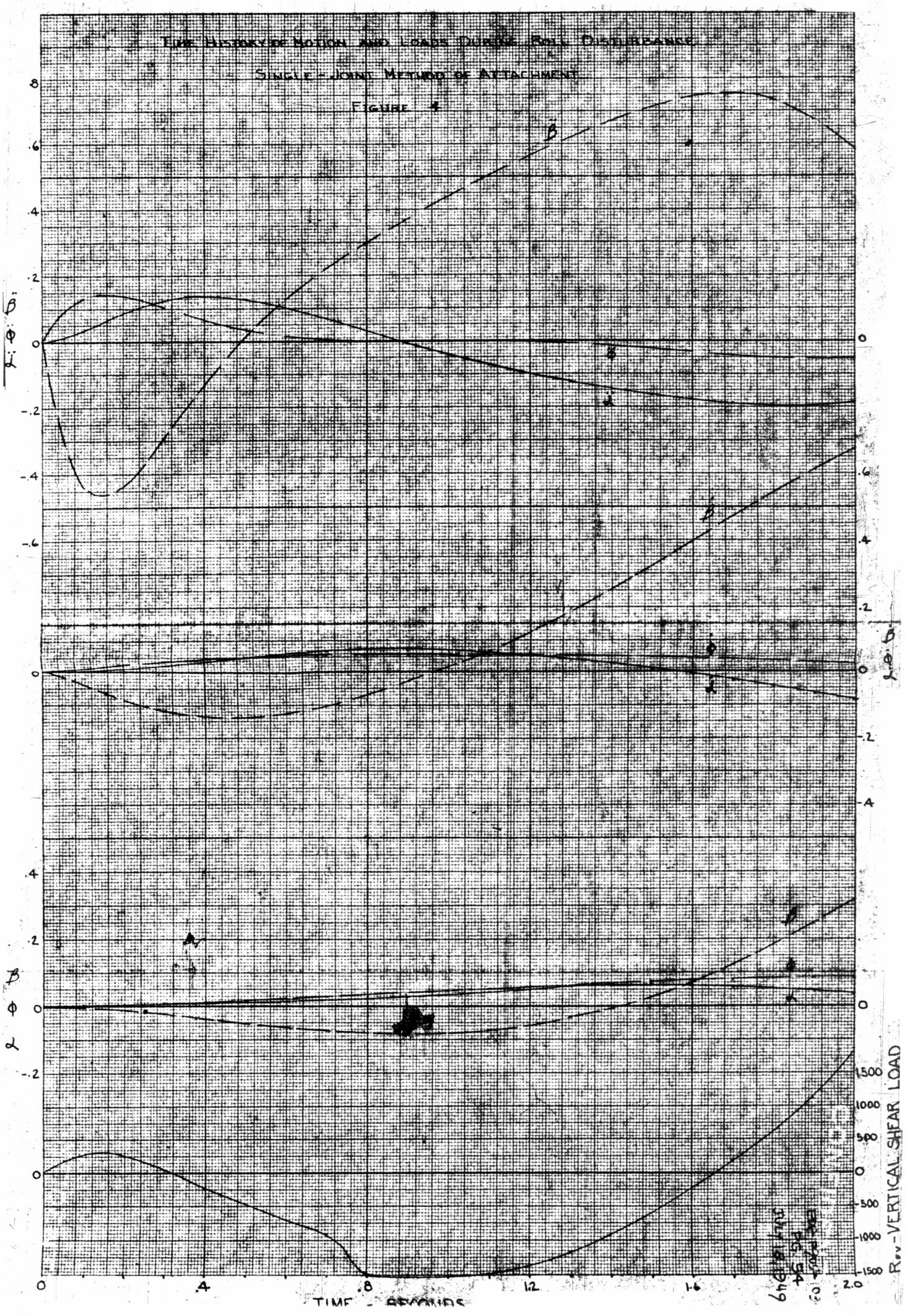
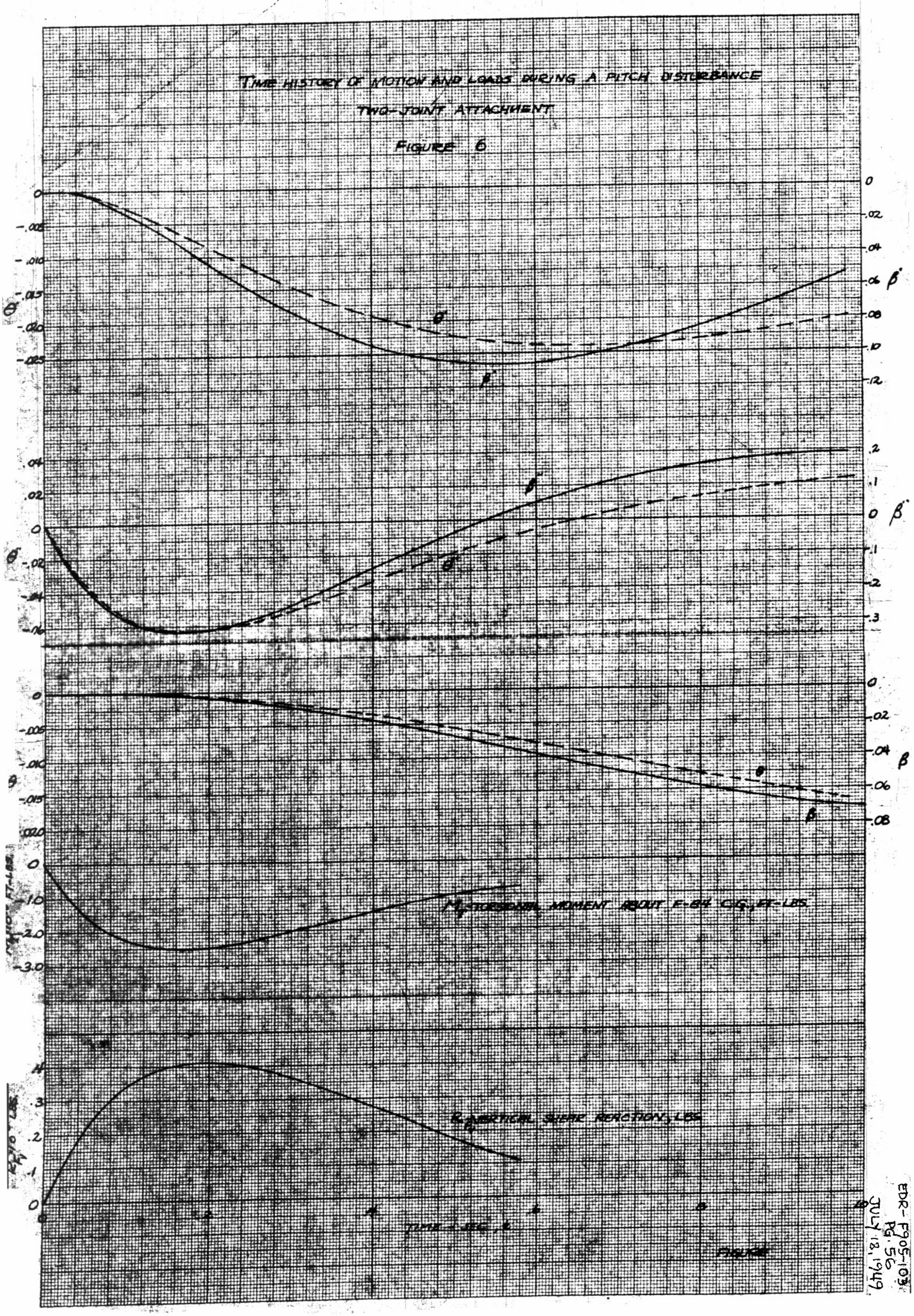
TIME HISTORY OF MOTION AND LOADS DURING ROLL DISTURBANCE

SINGLE-JOINT METHOD OF ATTACHMENT

FIGURE 4





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

FIGURE 7-7

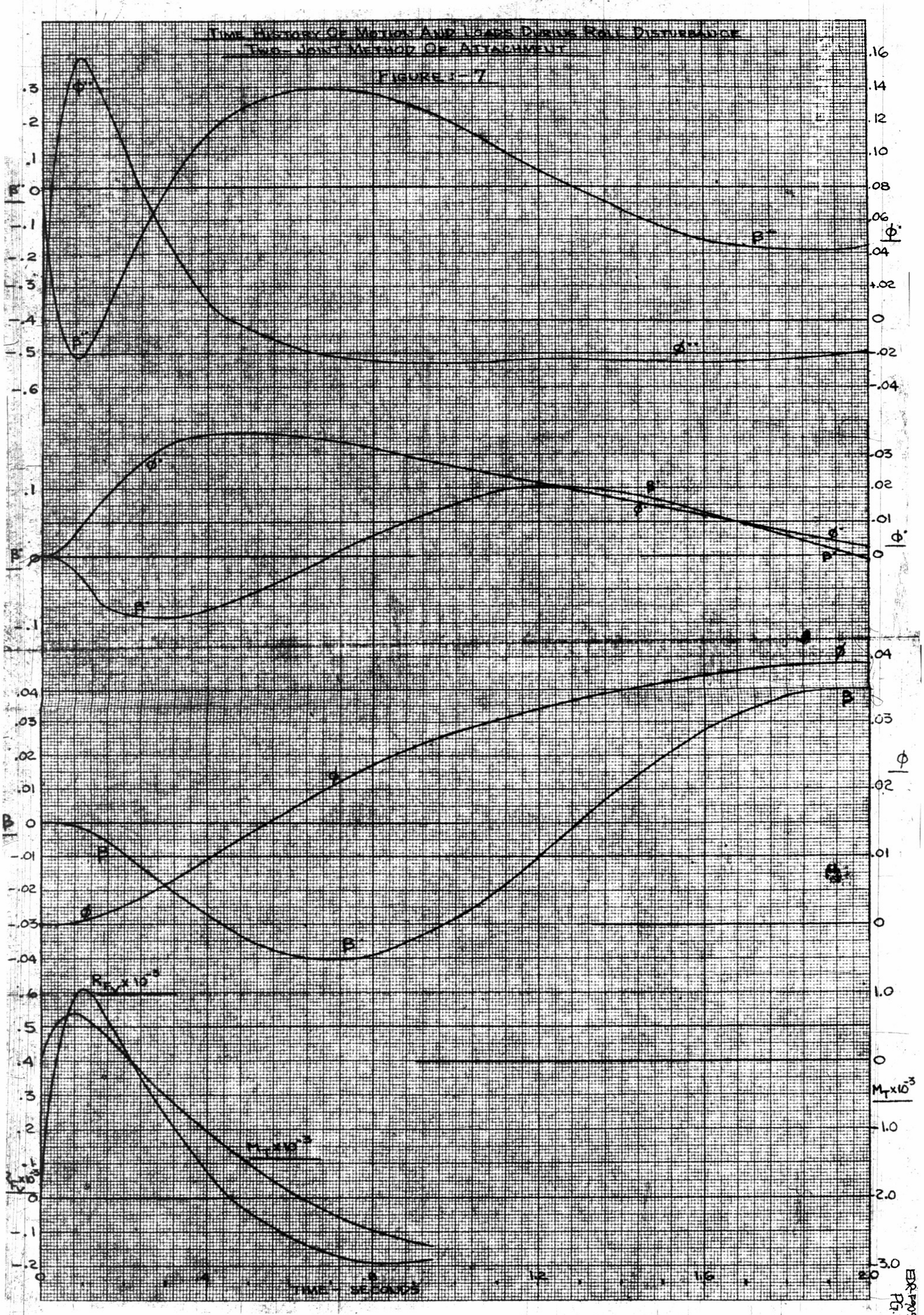

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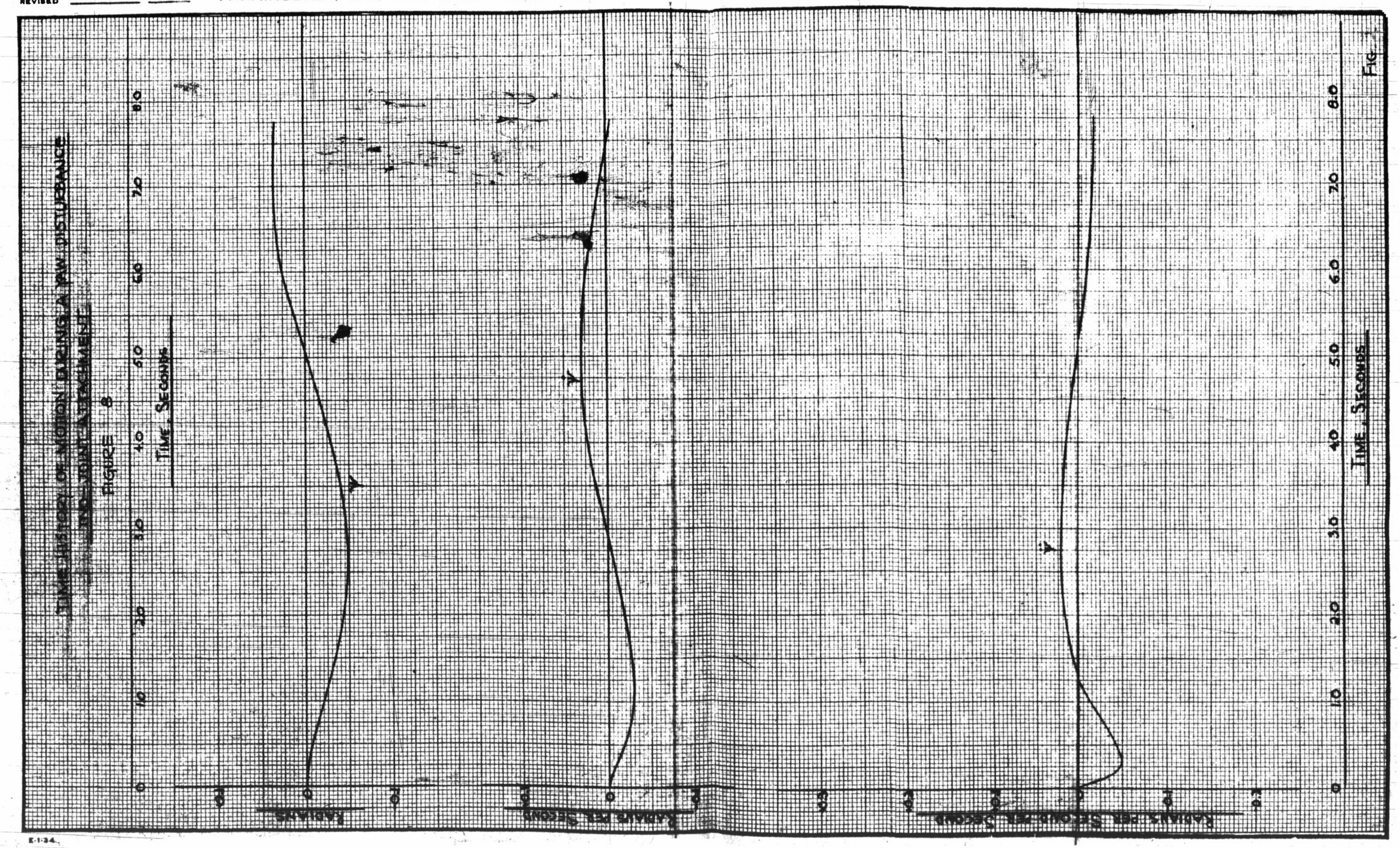
FIG. 8

TIME HISTORY OF ROTATION DURING A YAW DISTURBANCE
AND A TRIM CHANGE



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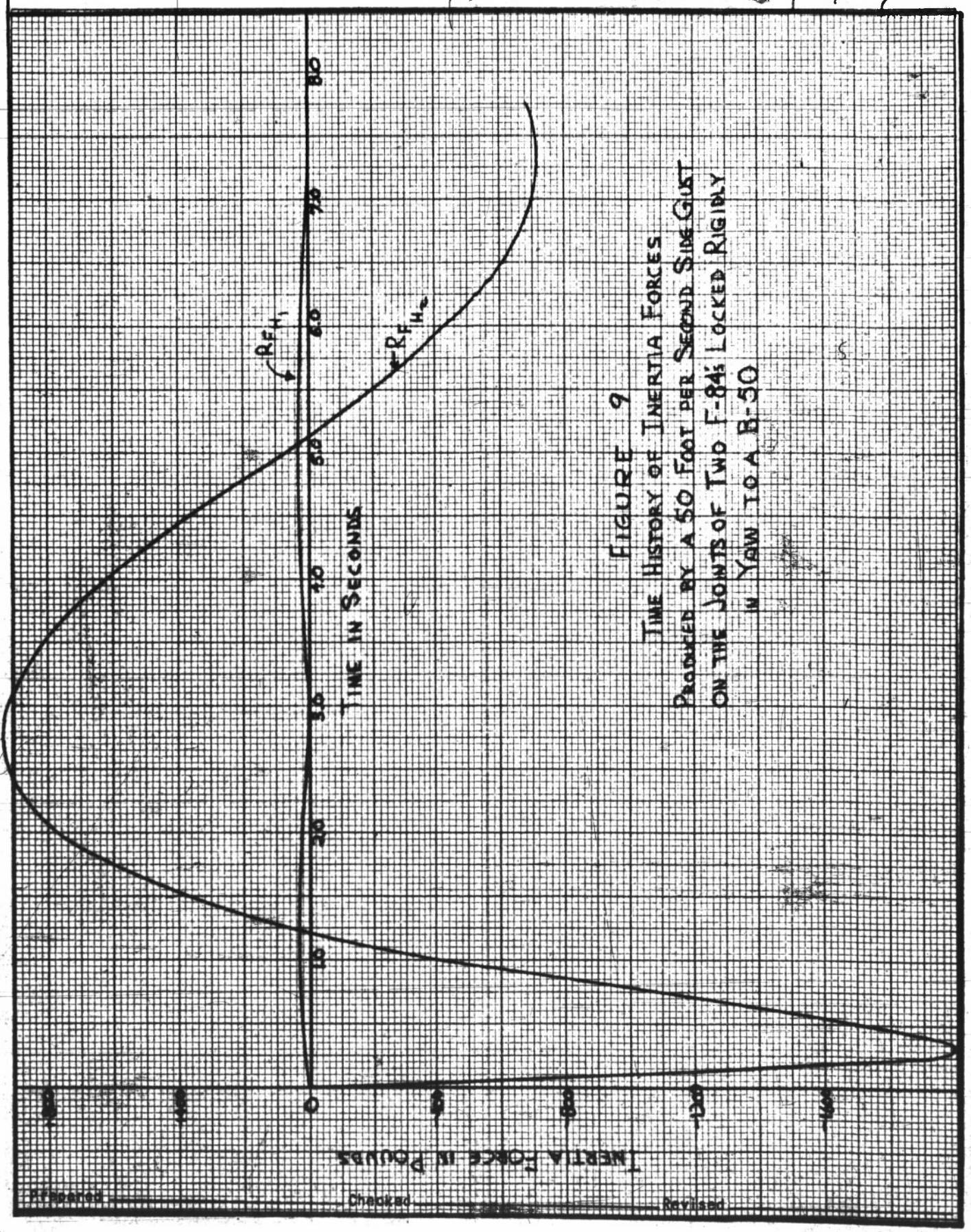

FIGURE 9
TIME HISTORY OF INERTIA FORCES
PRODUCED BY A 50 FOOT PER SECOND SINE GUST
ON THE JOINTS OF TWO F-84's LOCKED RIGIDLY
IN YAW TO A B-50

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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

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