NASA Contractor Report 2851

A Computer Program To Generate Equations of Motion Matrices, L217 (EOM)

Volume I: Engineering and Usage

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1.0 SUMMARY

The program L217 (EOM) is designed to formulate a set of second order linear differential equations that describe the motion of an airplane relative to its level equilibrium flight condition. The equations are formulated using the Lagrange energy approach and under the assumptions that:

- The airplane is in straight and level flight.
- All motions are small.

The option does exist to replace the structural damping with its equivalent viscous damping representation. Inertial coupling effects can also be included in the generalized inertia matrix to account for any control surface freedoms that may have been added to the basic set of structural modes.

Aerodynamic data may come from either the FLEXSTAB computer program system or the Doublet Lattice L216 aerodynamic program. The FLEXSTAB aerodynamic data can only be used with the quasi-steady aerodynamic formulation. The Doublet Lattice aerodynamic data can be used with either the quasi-steady or the full unsteady formulation.

Output from L217 (EOM) consists of:

- Equations of motion coefficients for either the quasi-steady or the full unsteady formulation.
- Aerodynamic forces for each aircraft component, such as wing, fuselage, vertical tail, etc.

Significant program restrictions are:

- **Total number of degrees of freedom cannot be greater than 100.**
- **Total number of aerodynamic elements must not exceed 400.**
- **Maximum number of interpolation points associated with any one aerodynamic surface is 100.**
- **Maximum number of gust zones (regions for calculating gradual penetration effects) is 35.**
- **Maximum number of reduced frequencies is 20.**

2.0 INTRODUCTION

The Equations of Motion program (L217) was developed for use as either a standalone program or as a module of the program system called DYLOFLEX (ref. 1). L217 (EOM) was designed to meet the DYLOFLEX contract requirements as defined in reference 2. These requirements specify the need for a computer program that can assemble and generate the data needed to formulate the equations of motion for a flight vehicle and to provide the necessary aerodynamic forces that can be used in the flight loads analysis of that vehicle.

The objective of this volume is to assist individuals wishing to use this program. To meet this objective, the following items are discussed:

- Engineering and mathematical equations used to formulate the problem.

- Program structure and design.

- Guidelines for the execution of the program.

A sample problem is also presented to aid the user in the execution of the program.

3.0 SYMBOLS AND ABBREVIATIONS

The following list contains items that appear throughout the text except for section 6.3 (card input).

Engineering notation	Definition
$[A],[B],[C]$	Partitions of the augmented generalized inertia matrix.
$[\mathring{A}]$	Diagonal matrix of element areas.
$[AIC]$	Aerodynamic influence coefficient matrix.
A_S	Slender body projected area.
b_r	Reference semichord.
$\{\Delta C_p\}$	Lifting pressure coefficients.
$\{\Delta C_{p_R}\}, \{\Delta C_{p_G}\}$	Lifting pressure coefficients due to the response motion of the airplane and gust encounter, respectively.
$\{C_{p_R}\}, \{C_{p_G}\}$	Slender body segment pressure coefficients due to response motion and gust encounter.
$\{C_p{}^Y\}_{SB}, \{C_p{}^Z\}_{SB}$	The magnitude of the slender body segment's pressure coefficient (at the segment evaluation point) due to Y and Z doublets, respectively.
$\{C_{p_u}\}_{IB}$	Upper surface pressure coefficients on interference body elements.
$\{C_2\}, \{C_3\}$	Generalized forcing function coefficients.
$[CP1_R],[CP2_R]$	Lifting pressure coefficients for generalized coordinate displacements and rates.
$[CP_G]$	Lifting pressure coefficients for gust zone velocities.
$[CPR]$	Lifting pressure coefficients for generalized coordinate responses.
$[CPG]$	Complex lifting pressure coefficients for gust zone velocities.
$[D]$	Doublet Lattice matrix of normalwash factors for thin and interference body boxes.

$d\delta_z/dx, d\delta_y/dx$	Derivative of surface local z and y displacement in the local x direction.
$[F]$	Doublet Lattice matrix of normalwash factors for slender body on lifting surface boxes.
f	Cyclic frequency (cps).
$\{F_A\}$	Aerodynamic forces.
$[\mathring{F}AC]$	Diagonal factor matrix that doubles the aerodynamic forces for slender bodies located on the plane of symmetry.
$\{f_\ell\}$	Distances from the gust reference point to the gust zone control points.
$[FG]$	Matrix of aerodynamic gust force coefficients for each gust zone.
$F_{n_{IB}}$	Interference element aerodynamic force normal to the element surface.
$[FR]$	Matrix of aerodynamic force coefficients for generalized coordinate response.
$\{F^y\},\{F^z\}$	Aerodynamic forces in the local y and z direction.
$[F1_R],[F2_R]$	Aerodynamic force coefficients for generalized coordinate displacements and rates.
$[F_{12}]$	Complex matrix of aerodynamic force coefficients for generalized coordinate responses.
$\{F'_{12}\}$	Complex matrix of aerodynamic force coefficients due to gust.
$[GC]$	Gust correlation matrix.
$[\mathring{g}_{SD}]$	Structural damping coefficients.
i	Imaginary number = $\sqrt{-1}$
k	Reduced frequency = $\omega b_r/V_T$ (radians).
L_S	Slender body segment length.
$[\mathring{m}_{CS}]$	Inertia matrix for control surfaces.

$[M_1]$	Generalized stiffness matrix.
$[M_2]$	Generalized damping matrix.
$[M_3]$	Generalized inertia matrix.
$[M_4]$	Generalized aerodynamic stiffness matrix.
$[M_5]$	Generalized aerodynamic damping matrix.
$\hat{n}$	Surface unit normal.
NDOF	Total number of degrees of freedom.
$NDOF_{CS}$	Number of control surface degrees of freedom.
$NDOF_{ST}$	Number of structural degrees of freedom.
NSB	Number of slender bodies.
NTB	Number of thin bodies.
Δn	Virtual displacement in the direction of the aerodynamic force.
[PC]	Interference body/slender body element correlation matrix.
P_ℓ, P_u	Lower and upper surface pressure.
ΔP	Pressure difference: $P_\ell - P_u$.
q	Generalized coordinate.
$\bar{q}$	Dynamic pressure $= 1/2\rho V_T^2$.
{Q}	Generalized aerodynamic forces.
[QR]	Matrix of generalized aerodynamic force coefficients for generalized coordinate responses.
{Q′}	Complex matrix of generalized aerodynamic gust force coefficients.
Δq	Virtual displacement of a generalized coordinate.
[R]	Euler rotational transformation matrix.
$[\mathring{r}_S]$	Matrix of slender body segment radii.

$[\mathring{r}_S{}']$	Matrix of slender body segment radius slopes = $[dr_S/dx]$.
$[RG]_{S/A}$	Gust rotation matrix for a symmetrical or antisymmetrical analysis.
$[\mathring{SF}]$	Matrix of symmetry factors.
T	Kinetic energy.
U	Strain energy.
V_T	True velocity.
v_G	Gust velocity.
$\bar{v}_{G_{V/L}}$	Magnitude of a sinusodial varying gust (vertical or lateral).
$\{w\}$	Normalwash, component of the flow velocity normal to the surface.
$\{w_A\}$	Augmented normalwash.
$\{-w_B\}$	Normalwash induced on lifting and interference surfaces by the slender bodies.
ΔW	Virtual work.
X, Y, Z	Rigid body linear displacements.
X_C, Y_C, Z_C	Axis correction values (reference axis system).
x_ℓ, y_ℓ, z_ℓ	Local axis system coordinates.
X_I, Y_I, Z_I	Inertial axis system coordinates.
XG	Gust reference point defined in the reference axis system.
$\{XG_{CP}\}$	Gust control points defined in the reference axis system.
X_{OA}, Y_{OA}, Z_{OA}	Coordinates of the aerodynamic axis system origin.
$X_{RAS}, Y_{RAS}, Z_{RAS}$	Reference axis system coordinates.
X_{SH}, Y_{SH}, Z_{SH}	Aerodynamic axis shift values.
α_G	Gust angle of attach = v_G/V_T.

β	Circumferential coordinate for slender body pressure distribution.
γ	Element dehedral angle (Doublet Lattice).
ϕ,θ,ψ	Rigid body rotational displacements.
θ_{IB}	Interference body dihedral angle (FLEXSTAB).
θ_{TB}	Thin body dihedral angle (FLEXSTAB).
$\theta_x,\theta_y,\theta_z$	Rotational displacements in the local axis system.
ρ	Density of air.
$\Phi(t)$	Wagner function.
$\psi(t)$	Kussner function.
ω	Angular frequency (rad/sec).
$[\Sigma_y],[\Sigma_z]$	Interference element summation matrices for the y and z slender body directions.
$\delta_{S/A}$	Gust delta function: = 1 for symmetric analysis. = -1 for antisymmetric analysis.
$\delta_x,\delta_y,\delta_z$	Linear displacements in the local axis system.
$[\mathring{\delta}_w]$	Sign function relating normalwash to flow incidence.
$[\tilde{\Phi}]$	Gradual penetration forcing function.
$[\phi_{\delta_n}]$	Mode shapes for displacement normal to the surface.
$[\phi'_{\delta_n}]$	Mode shape for surface streamwise slopes = $[d\phi_{\delta_n}/dx]$.
$[\mathring{1}]$	Unity matrix.
$\{\Psi\}$	Flow incidence matrix.
<u>Subscripts</u>	<u>Definitions</u>
Aug	Augmented.
CP	Control point.

CS	Control surface.
E	Excitation.
FP	Force point.
G	Gust.
I	Inertial axis system.
IB	Interference body.
Im	Imaginary part.
L	Lateral gust.
ℓ	Local axis system.
ℓ_s	Local structural axis system.
n	Normal to the surface.
O	Off the plane of symmetry.
p	Pitch.
R	Response quantity.
RAS	Reference axis system.
Re	Real part.
S	On the plane of symmetry.
S/A	Symmetric/antisymmetric.
SB	Slender body.
ST	Side translation.
TB	Thin body.
u	Upper surface.
Ua	Unaugmented.
V	Vertical gust.

VT	Vertical translation.
Y	Yaw.
y	Local y direction.
z	Local z direction.

<u>Superscripts</u>

y	Local y direction.
z	Local z direction.
′	Differentiation, d/dx
•	Differentiation, d/dt.

Matrix
<u>Symbols</u>

[ ]	Rectangular matrix.
$[\ ]^T$	Transpose matrix.
$[\ ]^{-1}$	Inverse matrix.
$[\overset{\circ}{\ }]$	Diagonal matrix.
{ }	Column matrix.
⌊ ⌋	Row matrix.

4.0 ENGINEERING AND MATHEMATICAL DESCRIPTION

4.1 FORMULATION OF THE EQUATIONS OF MOTION

The equations describing the motion of an airplane relative to its level equilibrium flight condition are formulated using the Lagrange energy equation (ref. 3).

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = q_i \quad i = 1, \ldots . n \qquad (1)$$

where:

T = Kinetic energy of the system

U = System's internal strain energy

Q_i = Set of generalized forces

q_i = Set of generalized coordinates

The airplane's motions are specified by the array of generalized coordinates q_i, i = 1, 2, ..., n. The kinetic and strain energies are calculated in terms of the airplane's mass and stiffness properties and the generalized coordinate velocities and displacements. The generalized forces consist of forces arising from damping effects and aerodynamic forces resulting from airplane motions and atmospheric turbulance. Placing the restrictions on the analysis that:

- The airplane must initially be in straight and level flight
- All motions are small

equation (1) then leads to a set of n second order linear differential equations. These equations can be either one of two forms, depending upon the type of representation used to describe the aerodynamics of the airplane.

The first form of the equations of motion comes from the use of the quasi-steady assumption in the formulation of the aerodynamic forces. Under this assumption, the aerodynamic forces are calculated by using the steady state aerodynamic characteristics with the instantaneous angle of incidence (ref. 4). Unsteady aerodynamic effects are approximated by convoluting the instantaneous incidence angle with Küssner and Wagner indicial lift growth functions. The resulting set of linear differential equations written in matrix form is:

$$\begin{aligned}([M_1]\{q\} + [M_2]\{\dot{q}\} + [M_3]\{\ddot{q}\}) + ([M_4]\{\dot{q}\}{*}\Phi(t) + [M_5]\{\ddot{q}\}{*}\Phi(t)) \\ = \{C_3\}\ \dot{\alpha}_G{*}\psi(t)\end{aligned} \qquad (2)$$

where:

$[M_1],[M_2],[M_3]$	= Generalized structural stiffness, damping, and inertia matrices, respectively
$[M_4],[M_5]$	= Generalized aerodynamic stiffness and damping, respectively
$\{C_3\}$	= Generalized forcing function coefficients
$\Phi(t)$, $\psi(t)$	= Wagner and Küssner indicial lift growth functions, respectively

All matrices are constant coefficient matrices; that is, they are not functions of frequency.

The second form of the equations of motion results from the use of a full unsteady aerodynamic formulation. This approach yields a set of matrix equations of the form:

$$([M_1]\{q\} + [M_2]\{\dot{q}\} + [M_3]\{\ddot{q}\}) + ([M_4]\{q\} + [M_5]\{\dot{q}\}) = \{C_3\}\,\alpha_g \qquad (3)$$

The matrix coefficients of equation (3) have the same definitions as those of equation (2). However, the aerodynamic coefficients are now of a different form. The aerodynamic stiffness and damping matrices, $[M_4]$ and $[M_5]$, are frequency dependent, and the generalized forcing function matrix, $\{C_3\}$, is frequency dependent and complex.

The matrix coefficients of equations (2) and (3) will be calculated for a whole airplane. L217 (EOM) can accept structural matrices for either half or whole airplane. Matrices for half an airplane will be multiplied by two.

Detailed discussions of the formulation of the matrix coefficients will appear in sections 4.3 through 4.8. First, however, it is necessary to define the axis systems and sign conventions assumed by the program.

4.2 AXIS SYSTEMS AND SIGN CONVENTIONS

In the Equations of Motion (L217) program, three types of axis systems are used in the formulation of the problem. All types are right-handed systems. The basic set of axes is the reference axis system (RAS). This arbitrarily described axis system is used to describe the airplane configuration. It is important that the same RAS be used throughout an analysis.

The second type of axis system is the local axis system (LAS). Each airplane component has a LAS associated with it. All the motion for a component is assumed to be defined in its respective local axis system. All aerodynamic calculations are performed in the LAS. All local axis systems must have an x-axis lying in the freestream direction with the positive x direction pointing aft. For lifting surfaces, the local x-y plane must lie in the plane of the surface with the positive y-direction pointing in the direction of increasing span. For slender bodies (and their associated interference bodies), the z-axis orientation will be a function of the type of motion the slender body will be allowed to experience. Slender bodies that undergo vertical motion (known as z-bodies) must have their local z-axis parallel to the Z reference axis. Slender bodies that experience lateral motion (known as y-bodies) must have their local z-axis parallel to the Y reference axis. Figure 1 illustrates typical reference and local axis system relationships.

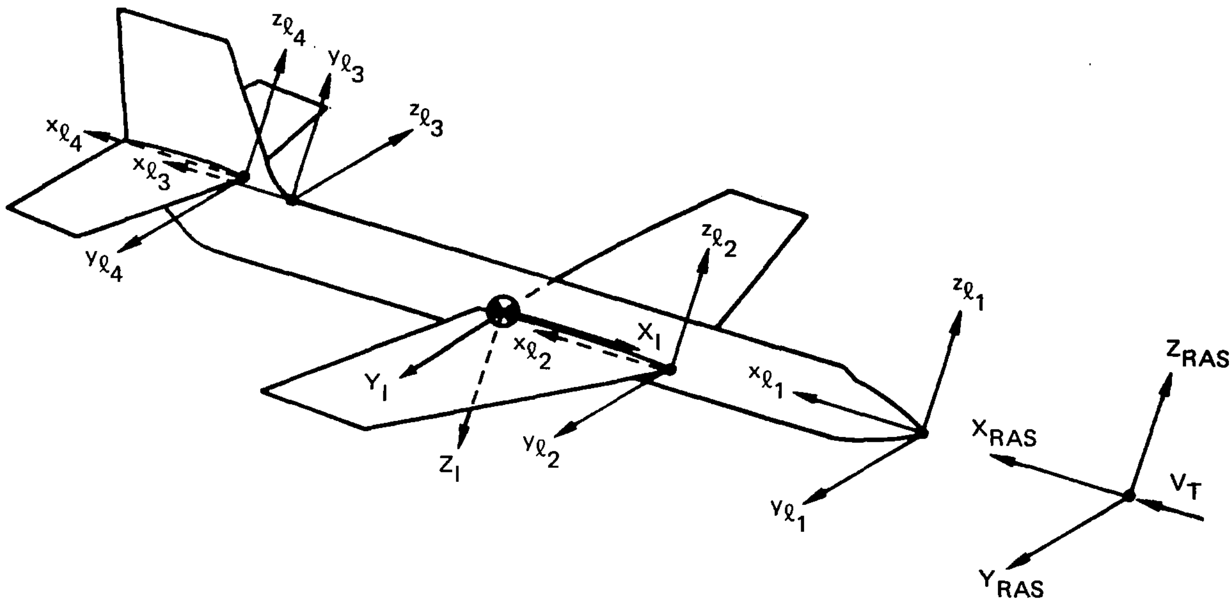


Figure 1. — Typical Axis System Orientations

In the discussions to follow, two types of local axis systems will be encountered - the local structural axis system and the local aerodynamic axis system. These two systems are a result of the differences between the structural idealization and the aerodynamic idealization. A more thorough discussion of the differences between the two types of local axis systems will be given when local axis shifting is considered (sec. 4.9).

The last axis system that enters into the formulation is the inertial axis system. The L217 (EOM) program assumes that the interial axis system lies in the plane of symmetry of the airplane and is oriented such that x is positive pointing toward the nose of the airplane and z is positive pointing downward (see fig. 1). All airplane rigid body motion is assumed to be referenced to the inertial axis system.

The rigid body displacement sign convention is shown in figure 2. Note that with this convention positive plunge is down; positive side slip is to the right (facing forward); positive pitch is nose up; positive roll is right wing tip down; and positive yaw is right wing tip moving aft. Double-headed arrows indicate a right-handed rotation about a given axis.

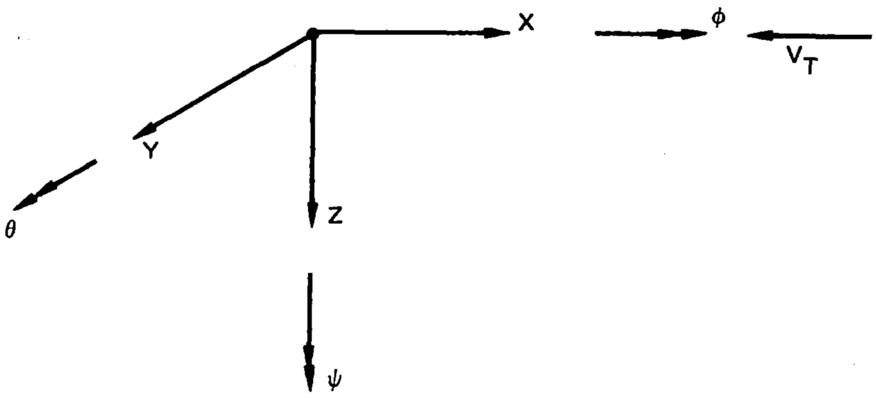


Figure 2. — Rigid Body Displacement Sign Convention

The sign convention for the local axis system displacements is shown in figure 3, with all surface slopes shown in their positive sense.

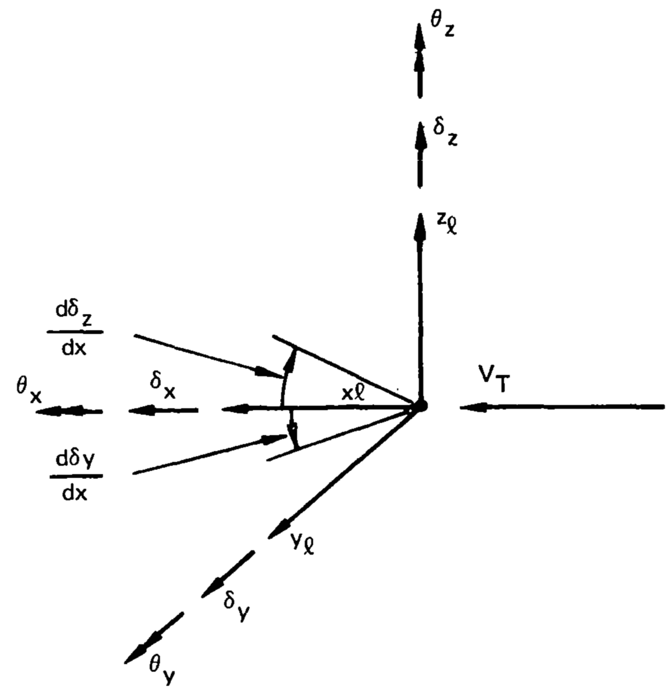


Figure 3. — Local Surface Displacement Sign Convention

The relationship between the surface slopes and the surface rotational displacements is:

$$\frac{d\delta_z}{dx} = -\theta_y \qquad (4)$$

$$\frac{d\delta_y}{dx} = \theta_z$$

In dealing with the different aerodynamic formulations and the different types of aerodynamic bodies, two types of pressure notations will be encountered. The FLEXSTAB aerodynamic approach will give both surface pressures on slender and interference bodies and surface pressure differences (lifting pressures) on thin bodies; whereas, the Doublet Lattice approach (L216) will always give lifting pressures for all bodies. In both approaches, pressure is always compressive (see fig. 4) and the lifting pressure is defined as $\Delta P = P_\ell - P_u$.

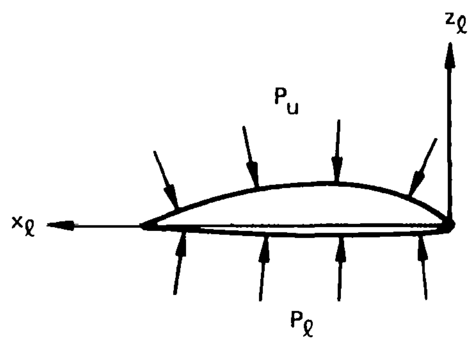


Figure 4. — Surface Pressures

4.3 STRUCTURAL MATRICES

The structurally related matrices of equations (2) and (3) consist of the generalized structural stiffness matrix, $[M_1]$, the damping matrix, $[M_2]$, and the inertia matrix, $[M_3]$. Since the generalized stiffness and inertia matrices are generally formed at the time of the structural vibration analysis external to the DYLOFLEX system, no calculation of these matrices is performed within L217 (EOM).

Structural damping is generally assumed to be proportional to displacement, but in phase with velocity. This representation is accomplished by making the generalized stiffness matrix, $[M_1]$, complex. The imaginary term of $[M_1]$ is expressed as:

$$i\,[\mathring{g}_{SD}][\mathring{M}_1]\{q\} \qquad (5)$$

where:

$[\mathring{M}_1]$ = Matrix composed of the diagonal elements of the generalized stiffness matrix, $[M_1]$

$[\mathring{g}_{SD}]$ = Diagonal matrix of damping factors

L217 (EOM) does not calculate an $[M_2]$ damping matrix when structural damping is chosen. This representation is generally associated with harmonic motion and is built into the solution program, L221 (TEV156) (ref. 5)

The option does exist to transform the structural damping into an equivalent viscous damping representation. In this instance, an $[M_2]$ matrix is calculated by L217 (EOM) as:

$$[\mathring{M}_2] = [\mathring{g}_{SD}][\mathring{M}_1^{1/2}][\mathring{M}_3^{1/2}] \tag{6}$$

4.4 INERTIAL COUPLING

In the analysis of an airplane configuration, many flight conditions are usually examined. Often the only difference between some of these conditions is that in one instance control surfaces may be free to move; while, in another instance, the control surfaces remain fixed. The capability exists within L215 (INTERP) (ref. 6) to modify the basic set of mode shapes to include the added freedoms of control surface motions about their hinge lines. This being the case, the generalized inertia and stiffness matrices then become incompatible with the modified modes. Therefore, the option exists within the EOM program to augment the generalized inertial, stiffness, and damping (if calculated within this program) matrices, making them compatible with the modified modes.

The generalized stiffness matrix (and damping matrix) will be increased by adding rows and columns of zeros in order to bring the matrix to the proper size. This is shown in equation (7).

$$[M_1]_{Aug} = \begin{array}{c} \\ NDOF_{ST} \\ NDOF_{CS} \end{array} \begin{array}{c} \begin{array}{cc} NDOF_{ST} & NDOF_{CS} \end{array} \\ \left[\begin{array}{c|c} [M_1]_{Ua} & [0] \\ \hline [0] & [0] \end{array}\right] \end{array} \tag{7}$$

where:

$[M_1]_{Aug}$ = Augmented generalized stiffness

$[M_1]_{Ua}$ = Original (unaugmented) generalized stiffness matrix obtained from the vibration analysis

$NDOF_{ST}$ = Number of structural (or basic) degrees of freedom that are determined in the vibration analysis

$NDOF_{CS}$ = Number of control surface freedoms that were added in L215 (INTERP)

The augmented generalized mass matrix contains nonzero rows and columns that represent the inertial coupling effects resulting from the additional freedoms. The augmented M_3 matrix can be written as:

$$[M_3]_{Aug} = \begin{array}{c} \\ NDOF_{ST} \\ NDOF_{CS} \end{array} \begin{array}{c} \begin{array}{cc} NDOF_{ST} & NDOF_{CS} \end{array} \\ \left[\begin{array}{c|c} [M_3]_{Ua} & [B] \\ \hline [A] & [C] \end{array}\right] \end{array} \tag{8}$$

where:

$[M_3]_{Aug}$ = Augmented generalized inertia matrix

$[M_3]_{Ua}$ = Unaugmented generalized inertia

[A],[B],[C] = Inertial coupling matrices

The inertial coupling matrices are formed by first assembling a diagonal inertia matrix for all mass points affected by the added control surface freedoms. This matrix, designated as the control surface inertial matrix, $[\mathring{m}_{CS}]$, will contain all the needed mass and rotational inertial properties for each node. The inertial properties input into the $[\mathring{m}_{CS}]$ matrix must meet the following requirements:

- The inertial matrix can include only those inertial properties that relate to the nodal displacements allowed.
- All inertial data must be for the whole airplane.
- All rotational inertials must be parallel and/or perpendicular to the freestream.

The mode shapes describing the displacement at each affected node are obtained by using the appropriate interpolation (SA) arrays defined in L215 (INTERP) and interpolating for any combination of surface vertical translation, the surface streamwise rotation, and the surface rotation perpendicular to the streamwise direction. The combination of nodal displacements used for a control surface is left to the discretion of the analyst. In submatrix form, the total set of mode shapes for the control surface nodes is:

$$[\phi]_{Total} = [\phi]_{ST} \,\vdots\, [\phi]_{CS} \tag{9}$$

The ordering of $[\phi]_{Total}$ corresponds to the order of the inertial data in $[\mathring{m}_{CS}]$. The inertia coupling matrices can now be defined as:

$$\begin{aligned} [A] &= [\phi]^T_{CS}\,[\mathring{m}_{CS}][\phi]_{ST} \\ [B] &= [A]^T \\ [C] &= [\phi]^T_{CS}\,[\mathring{m}_{CS}][\phi]_{CS} \end{aligned} \tag{10}$$

4.5 AERODYNAMIC OPTIONS

In L217 (EOM), the user has the capability of inputing aerodynamic data generated by either one of two aerodynamic methods, FLEXSTAB (ref. 7) or Doublet Lattice L216 (ref. 8). Together, these two methods offer the analyst four aerodynamic options in forming the equations of motion.

- FLEXSTAB AIC – quasi-steady approach.
- Doublet Lattice AIC – quasi-steady approach.
- Doublet Lattice AIC – full unsteady approach.
- Doublet Lattice Pressures and Generalized Forces – full unsteady approach.

In the FLEXSTAB AIC approach, the steady state aerodynamic influence coefficient (AIC) matrix is used to formulate the quasi-steady aerodynamics. These quasi-steady aerodynamic forces are used to form the generalized aerodynamic stiffness and damping and the generalized forcing function of equation (2). Data from the FLEXSTAB program system consists of the AIC matrix and the geometry data describing the aerodynamic idealization. Also, this approach requires the use of the modal interpolation arrays, SA arrays, from L215 (INTERP).

The Doublet Lattice AIC quasi-steady approach is similiar to that of FLEXSTAB. Here, the $k = 0$ (reduced frequency) aerodynamic data is used to make up the $[M_4]$, $[M_5]$, and $\{C_3\}$ matrices of equation (2). Data from this method consists of AIC-type matrices and the needed geometry. This approach also requires the SA arrays from L215 (INTERP).

The third option, Doublet Lattice AIC full unsteady approach, is similar to the previous Doublet Lattice option. Here, however, the AIC-type matrices are input at each k value for which one wishes to define the equations of motion. This aerodynamic data is used to form the nonconstant coefficient matrices of equation (3). This approach also requires the geometry data and the SA arrays previously mentioned.

The last option is that of using the Doublet Lattice-generated pressures and generalized forces. It is a full unsteady approach that is used in forming the nonconstant coefficient matrices of equation (3). This option requires the geometry data, aerodynamic pressures, and generalized forces calculated by Doublet Lattice, but it does not require the SA arrays from L215 (INTERP).

The advantage of using the Doublet Lattice AIC option rather than the Doublet Lattice pressures and generalized forces approach is that the former can be used with any number of different sets of mode shapes. The AIC-type matrices generated by Doublet Lattice are functions of Mach number, k value, and the airplane's external configuration, but are modal independent. If all these variables remain constant, and if the only difference between conditions is in the mode shapes used to define the structure's deformation, then the changes in aerodynamic forces due to the changes in the airplane's modal displacements can be calculated without having to rerun the complete aerodynamic problem. Since the majority of the cost in solving for the aerodynamic forces is the generation of the AIC-type matrices, this can provide a substantial cost savings.

The AIC option also has the added advantage of being able to account for gradual penetration of the gust. The Doublet Lattice pressure and generalized forces option does not have this advantage. The Doublet Lattice program L216, as used in the DYLOFLEX system, does not readily lend itself to the inclusion of the gust phase lag effects. Calculating gradual penetration effects in L216 (DUBFLX) would require extensive modification of the modal input to DUBFLX and the generalized aerodynamic forces output from DUBFLX. Therefore, the ability to account for gradual penetration of the gust in the DYLOFLEX system was limited to the AIC options of EOM.

Using the quasi-steady AIC approach, options one and two, offers additional savings in that the resulting aerodynamic matrices are also frequency independent. However, the user may sacrifice a certain amount of accuracy in predicting the aerodynamic forces in some instances where high frequency aerodynamics become significant.

4.6 FLEXSTAB AIC OPTION

The FLEXSTAB AIC option uses the geometry data and the steady state AIC matrix from FLEXSTAB and the modal interpolation arrays from L215 (INTERP) to calculate the aerodynamic forces on the airplane. These forces are then used to generate the aerodynamic-related matrices for the constant coefficient form of the equations of motion given in equation (2).

The basic equation in the formulation of the aerodynamics is that of the calculation of the pressure distribution over the different aerodynamic surfaces. Using the AIC matrix, which relates flow incidence to pressure, the pressure distribution over the different elements is given by the following equation:

$$\{C_P\} = [AIC]\{\Psi\} \qquad (11)$$

where:

$\{C_P\}$ = Matrix of pressure coefficients

$[AIC]$ = Steady-state aerodynamic influence coefficients

$\{\Psi\}$ = Matrix of flow incidences

The internal ordering and the size of the pressure coefficient and normalwash matrices is a function of the type of analysis performed, i.e. symmetrical or antisymmetrical, and the type of aerodynamic elements used. These factors determine the AIC matrix arrangement.

4.6.1 INCIDENCE AND NORMALWASH CALCULATIONS

The normalwash on a surface is defined as the component of the flow velocity normal to the surface. Dividing the normalwash by the freestream velocity gives the flow incidence for the surface. The relationship for flow incidence in terms of normalwash is defined in FLEXSTAB as:

$$\{\Psi\} = \frac{1}{V_T} [\delta^{\circ}_{w}]\{w_n\} \qquad (12)$$

where:

$[\delta^{\circ}_{w}]$ = A sign function that relates incidence flow and normalwash

= 1 for all normalwash defined in the local z direction

= -1 for all normalwash defined in the local y direction

$\{w_n\}$ = Normalwash

The normalwash caused by the airplane's motion can be expressed in terms of the airplane's generalized coordinates and mode shapes.

$$\{w_R\} = -\left\{V_T\, [\phi'_{\delta_n}]_{CP}\, \{q\} + [\phi_{\delta_n}]_{CP}\, \{\dot{q}\}\right\} \qquad (13)$$

where:

$[\phi_{\delta_n}]_{CP}$ = Mode shapes describing the motion normal to the surface at the surface control points

$[\phi'_{\delta_n}]_{CP}$ = Mode shapes describing the surface streamwise slope at the surface control points

$\{q\},\{\dot{q}\}$ = Generalized coordinate displacements and velocities

R = Normalwash due to the response of the aircraft

The FLEXSTAB AIC matrix requires this normalwash be evaluated at the control points of the slender and thin bodies. Normalwash due to interference body motions is not allowed by definition of an interference body.

The mode shapes describing surface normal displacements and streamwise slopes are calculated using the SA arrays generated in L215 (INTERP). The interpolated mode shapes describe linear displacements in the local z direction of the surface and the streamwise slope of these displacements. For thin bodies, this direction is normal to the thin body surface. Slender bodies, however, may require motion in either one or both the vertical direction (z-bodies) and/or the lateral direction (y-bodies). This is a function of the slender body location (on or off the plane of symmetry) and the type of analysis performed (symmetric or antisymmetric). Since all SA arrays give motions relative to the local z-axis direction, motion for y-bodies must be determined from SA arrays whose associated local z-axes are rotated in the lateral direction. The ordering of the elements within the normalwash matrix (which corresponds to the AIC column arrangement for the symmetrical and anti-symmetrical cases) is shown in figure 5.

Symmetric Analysis

$$\begin{Bmatrix} \{w_z\}_{SB} \\ \{w_{z/y}\}_{SB} \\ \{w_z\}_{TB} \end{Bmatrix} = \begin{Bmatrix} \{w_z\}_1 \\ \vdots \\ \{w_z\}_{NSB_S} \\ \hline \{w_{z/y}\}_1 \\ \vdots \\ \{w_{z/y}\}_{NSB_O} \\ \hline \{w_z\}_1 \\ \vdots \\ \{w_z\}_{NTB_O} \end{Bmatrix}$$

$\{w_z\}_1 \ldots \{w_z\}_{NSB_S}$	Normalwash in the slender body local z direction for slender bodies on the plane of symmetry. NSB_S = number of slender bodies on the plane of symmetry
$\{w_{z/y}\}_1 \ldots \{w_{z/y}\}_{NSB_O}$	Normalwash in the slender body local z and y directions (the z direction is followed by the y for each element) for slender bodies off the plane of symmetry. NSB_O = number of slender bodies off the plane of symmetry.
$\{w_z\}_1 \ldots \{w_z\}_{NTB_O}$	Normalwash in the thin body local z direction for thin bodies off the plane of symmetry. NTB_O = number of thin bodies off the plane of symmetry.

Anti-symmetric Analysis

$$\begin{Bmatrix} \{w_y\}_{SB} \\ \{w_{z/y}\}_{SB} \\ \{w_z\}_{TB} \end{Bmatrix} = \begin{Bmatrix} \{w_y\}_1 \\ \vdots \\ \{w_y\}_{NSB_S} \\ \hline \{w_{z/y}\}_1 \\ \vdots \\ \{w_{z/y}\}_{NSB_O} \\ \hline \{w_z\}_1 \\ \vdots \\ \{w_z\}_{NTB_S} \\ \hline \{w_z\}_1 \\ \vdots \\ \{w_z\}_{NTB_O} \end{Bmatrix}$$

$\{w_y\}_1 \ldots \{w_y\}_{NSB_S}$	Normalwash in the slender body local y direction for slender bodies on the plane of symmetry
$\{w_{z/y}\}_1 \ldots \{w_{z/y}\}_{NSB_O}$	Normalwash in the slender body local z and y directions for slender bodies off the plane of symmetry
$\{w_z\}_1 \ldots \{w_z\}_{NTB_S}$	Normalwash in the thin body local z direction for thin bodies on the plane of symmetry
$\{w_z\}_1 \ldots \{w_z\}_{NTB_O}$	Normalwash in the thin body local z direction for thin bodies off the plane of symmetry

Figure 5. — Ordering of Response Normalwash Matrices for the FLEXSTAB AIC Option

The normalwash due to a gust is defined as the component of the gust velocity normal to the surface. In L217 (EOM), the gust velocity is defined in the inertial axis system with a vertical gust defined positive in the minus z inertial direction (up gust) and a lateral gust defined positive in the positive y inertial direction (see fig. 6).

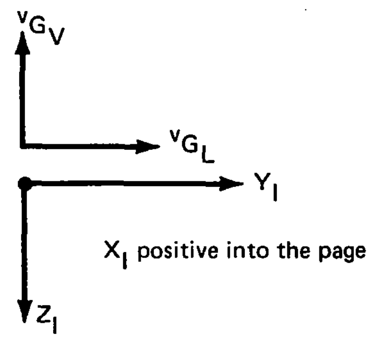


Figure 6. — Lateral and Vertical Gust Sign Conventions

In a symmetric analysis where only a vertical gust is applied to the airplane, the component of the gust velocity normal to the surface of a thin body is given by:

$$^{w}G_{TB} = {}^{v}G_V \cos \theta_{TB} \tag{14}$$

where:

θ_{TB} = Dihedral angle of the thin body

For slender bodies, the local z-direction normalwash is equal to the vertical gust velocity, $^{v}G_V$, and the local y-direction normalwash is zero. In matrix form, the normalwash due to the gust can be written as:

$$\{^{w}G\}_S = [\mathring{R}G]_S \{^{v}G_V\} \tag{15}$$

where:

$[\mathring{R}G]_S$ = Diagonal gust rotation matrix for a symmetrical analysis

$\{^{v}G_V\}$ = Vertical gust velocity at each control point defined in the inertial axis system

In an antisymmetrical analysis, only a lateral gust is applied to the airplane, and the component of gust velocity normal to a thin body surface is

$$^{w}G_{TB} = - {}^{v}G_L \sin \theta_{TB} \tag{16}$$

For slender bodies, the z-direction normalwash is now zero while the y-direction normalwash is equal to v_{G_L}. In matrix form, the normalwash matrix due to a lateral gust can be written as:

$$\text{where} \quad \{G\}_A = [\overset{\circ}{RG}]_A \{v_{G_L}\} \tag{17}$$

where:

$[\overset{\circ}{RG}]_A$ = Diagonal gust rotation matrix for an antisymmetric analysis

$\{v_{G_L}\}$ = Lateral gust velocities at each control point, defined in the inertial axis system.

By referring to figure 5 for the required ordering and using equations (14) and (16), the gust rotation matrix shown in figure 7 can be formed for either a symmetrical or an antisymmetrical analysis.

Gradual penetration of the gust can be accounted for by calculating a gust phase lag function, ϕ_G. The phase lag will be applied to the thin body panels and slender body segments in gust zone groupings, not to each individual panel or segment. The gust zones are defined by the X-reference coordinate of zone leading edges. Up to 35 zones may be used. Each gust zone will have a gust control point; that is, the point at which the gust phase lag for that zone will be evaluated. The gust control point is defined by the user in the reference axis system. The family of thin body panels and slender body segments whose control points fall within the same zone will experience the same gust phase lag. The point of zero phase lag is denoted as the gust reference point XG, and may be defined anywhere. The distances between the gust zone control points and the gust reference point are given in matrix form as:

$$\{f_\ell\} = \{XG_{CP}\} - XG \tag{18}$$

For a sinusoidal gust, the gust velocity at each zone control point is written as:

$$\left\{v_{G_{V/L}}\right\} = \bar{v}_{G_{V/L}} \left\{e^{-i\omega \frac{f_\ell}{V_T}}\right\} e^{i\omega t} \tag{19}$$

where $\bar{v}_{G_{V/L}}$ is the magnitude of the gust in the vertical or lateral direction.

To relate the gust at each zone control point to the thin body and slender body aerodynamic control points, a gust correlation matrix of ones and zeroes can be formed, [GC]. Finally, the gust normalwash for either symmetric or antisymmetric analysis can be written as:

$$\{w_G\}_{S/A} = [\overset{\circ}{RG}]_{S/A} \, [GC] \left\{e^{-i\omega \frac{f_\ell}{V_T}}\right\} v_{G_{V/L}} \, e^{i\omega t} \tag{20}$$

Symmetrical Analysis

$$[RG]_S = \left[\begin{array}{ccccc} [\overset{\circ}{1}]_1 & & & & 0 \\ & \ddots & & & \\ & & [\overset{\circ}{1}]_{NSB_S} & & \\ \hline & & [1\overset{\circ}{/}0]_1 & & \\ & & & \ddots & \\ & & & [1\overset{\circ}{/}0]_{NSB_O} & \\ \hline & & & [\cos\overset{\circ}{} \theta_{TB}]_1 & \\ & & & & \ddots \\ 0 & & & & [\cos\overset{\circ}{} \theta_{TB}]_{NTB_O} \end{array}\right]$$

Slender Bodies on the plane of symmetry

Slender Bodies off the plane of symmetry

Thin Bodies off the plane of symmetry

Anti-symmetrical Analysis

$$[RG]_A = \left[\begin{array}{ccccc} [\overset{\circ}{1}]_1 & & & & 0 \\ & \ddots & & & \\ & & [\overset{\circ}{1}]_{NSB_S} & & \\ \hline & & [0\overset{\circ}{/}1]_1 & & \\ & & & \ddots & \\ & & & [0\overset{\circ}{/}1]_{NSB_O} & \\ \hline & & & [-\sin\overset{\circ}{} \theta_{TB}]_1 & \\ & & & & \ddots \\ 0 & & & & [-\sin\overset{\circ}{} \theta_{TB}]_{NTB} \end{array}\right]$$

Slender Bodies on the plane of symmetry

Slender Bodies off the plane of symmetry

Thin Bodies on and off the plane of symmetry

N_{TB} = total number of thin bodies.
$= NTB_S + NTB_O$

$[1\overset{\circ}{/}0]$ = a diagonal matrix whose elements consist of alternating 1's and 0's with the first element being a 1.

Figure 7. – Gust Rotation Matrix for FLEXSTAB

4.6.2 AERODYNAMIC FORCES

The expression for the pressure distribution (eq. 11) can now be used with the normalwash defined in equations (13) and (20) to determine the pressure distributions due to airplane motion and atmospheric turbulence. The ordering of the elements within the pressure coefficient matrix reflects the row order of the AIC matrix. This ordering which is the same for both lateral and vertical analyses, is illustrated in figure 8.

The meaning of the elements of the pressure coefficient matrix differs with each body type. Therefore, the calculation of the aerodynamic forces for each body type will be discussed separately.

Slender Body Aerodynamic Forces

A slender body is a body of revolution divided into a number of streamwise segments (see fig. 9). The slender body pressure coefficients are defined at the midpoint of each slender body segment. The C_p^Y coefficients represent the magnitude of the circumferential pressure variation due to the Y-doublet of the segment at the Y-doublet evaluation point. Likewise, the C_p^Z coefficient is the magnitude of the circumferential pressure variation due to the Z-doublet of the segment at the Z-doublet evaluation point (see fig. 10).

The total circumferential distribution for a segment is the sum of the Y and Z distributions.

$$C_p(x) = -\, C_p^{\,Y} \cos\beta + C_p^{\,Z} \sin\beta \qquad (21)$$

where:

β = Circumferential variable used to define the pressure distribution of the Z and Y doublets over the surface of the segment.

Forces in the local y and z directions are obtained by integrating the appropriate component of equation (21) over the segment area.

$$\begin{aligned} F_y &= -\, \bar{q} \int_{L_S} r_S \int_0^{2\pi} C_p(x) \sin\beta \, d\beta \, dx \\ F_z &= -\, \bar{q} \int_{L_S} r_S \int_0^{2\pi} C_p(x) \cos\beta \, d\beta \, dx \end{aligned} \qquad (22)$$

where:

$\bar{q}$ = Dynamic pressure = $1/2\, \rho V_T^2$

L_S = Length of the segment

r_S = Radius of the segment

$$
\begin{Bmatrix} \{C_p^{\,Y}\}_{SB} \\ \{C_p^{\,Z}\}_{SB} \\ \{C_{p_u}\}_{IB} \\ \{\Delta C_p\}_{TB} \end{Bmatrix}
=
\begin{Bmatrix}
\{C_p^{\,Y}\}_1 \\ \vdots \\ \{C_p^{\,Y}\}_J \\ \vdots \\ \{C_p^{\,Y}\}_{NSB} \\ \hline
\{C_p^{\,Z}\}_1 \\ \vdots \\ \{C_p^{\,Z}\}_J \\ \vdots \\ \{C_p^{\,Z}\}_{NSB} \\ \hline
\{C_{p_u}\}_1 \\ \vdots \\ \{C_{p_u}\}_K \\ \vdots \\ \{C_{p_u}\}_{NIB} \\ \hline
\{\Delta C_p\}_1 \\ \vdots \\ \{\Delta C_p\}_I \\ \vdots \\ \{\Delta C_p\}_{NTB}
\end{Bmatrix}
$$

$\{C_p^{\,Y}\}_1 \ldots \{C_p^{\,Y}\}_J \ldots \{C_p^{\,Y}\}_{NSB}$	Slender body pressure coefficients due to the Y-doublets for all slender bodies. Ordering is slender bodies on the plane of symmetry followed by slender bodies off the plane of symmetry.
$\{C_p^{\,Z}\}_1 \ldots \{C_p^{\,Z}\}_J \ldots \{C_p^{\,Z}\}_{NSB}$	Slender body pressure coefficients due to the Z-doublets for all slender bodies. Ordering in the same as Y-doublet pressure coefficients
$\{C_{p_u}\}_1 \ldots \{C_{p_u}\}_K \ldots \{C_{p_u}\}_{NIB}$	Upper surface interference body panel pressures coefficients for all interference bodies. Ordered bodies on the plane of symmetry followed by bodies off the plane of symmetry.
$\{\Delta C_p\}_1 \ldots \{\Delta C_p\}_I \ldots \{\Delta C_p\}_{NTB}$	Thin body panel lifting pressure coefficients for thin bodies on the plane of symmetry followed by thin bodies off the plane of symmetry.

NSB = Total number of slender bodies

NIB = Total number of interference bodies

NTB = Total number of thin bodies

Figure 8. — Ordering Within the FLEXSTAB Pressure Coefficient Matrix

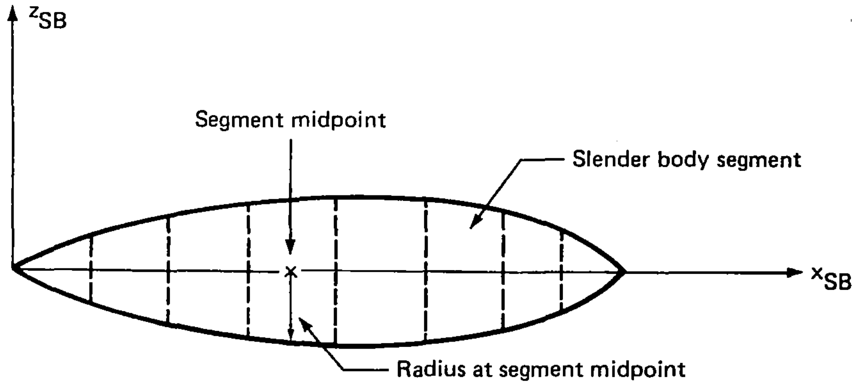


Figure 9. — Typical Slender Body

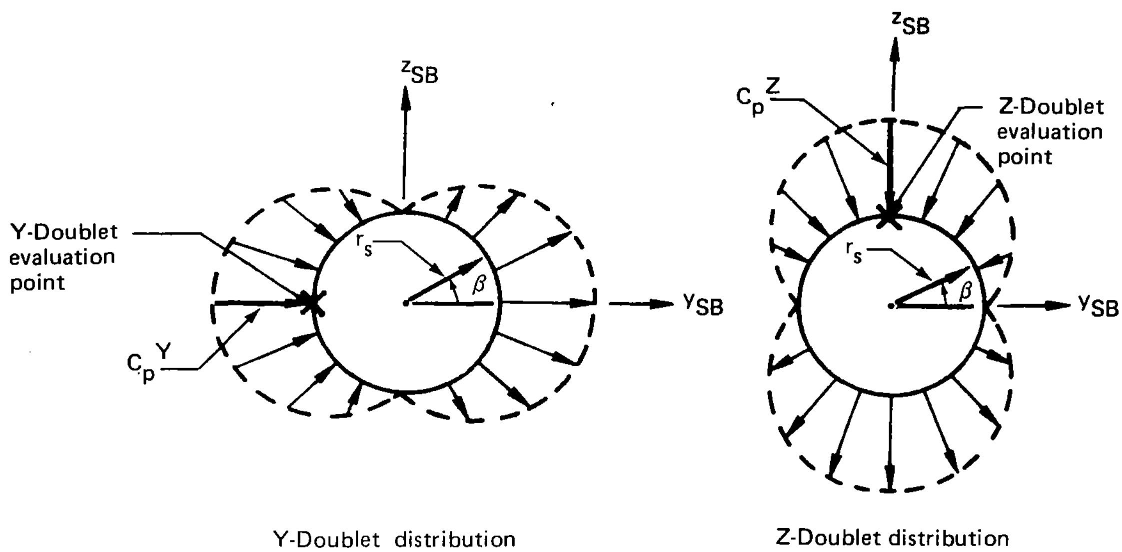


Figure 10. — Circumferential Pressure Distribution on a Slender Body Segment Due to a Y and Z Doublet

Performing the circumferential integration, the force expressions reduce to:

$$F_y = -\bar{q}\int_{L_S} r_S(-\pi C_p{}^Y)dx$$
$$F_z = -\bar{q}\int_{L_S} r_S(\pi C_p{}^Z)dx \qquad (23)$$

Making the assumption that $C_p{}^Y$ and $C_p{}^Z$ are constant over the length of the segment, and using the radius value at the segment midpoint, the final expressions for the y and z forces for any one segment are:

$$F_y = \bar{q}\, \bar{r}_S\, L_S\, \pi\, C_p{}^Y$$

$$F_Z = -\, q\, r_S\, L_S\, \pi\, C_p{}^Z \qquad (24)$$

Defining the slender body segment area as:

$$A_S = 2\, r_S\, L_S \qquad (25)$$

the y and z segment forces for the J^{th} slender body can be written in matrix form as:

$$\{F_y\}_J = \bar{q}\, [\overset{\circ}{\pi/2}]\, [\overset{\circ}{A_S}]_J\, \{C_p{}^Y\}_J$$

$$\{F_Z\}_J = \bar{q}\, [\overset{\circ}{-\pi/2}]\, [\overset{\circ}{A_S}]_J\, \{C_p{}^Z\}_J \qquad (26)$$

Interference Body Aerodynamic Forces

The interference panel pressure coefficients represent the upper surface pressure on each panel (see fig. 11). These pressures are evaluated at the panel centroid. By definition, interference bodies do not generate their own lift, but are present to account for the interference flow about a slender body caused by thin and other slender bodies. As a result, the lower surface panel pressure is zero. Thus, the lifting pressure coefficient for each panel is:

$$\Delta C_{p_{IB}} = C_{p_\ell} - C_{p_u} = -\, C_{p_u} \qquad (27)$$

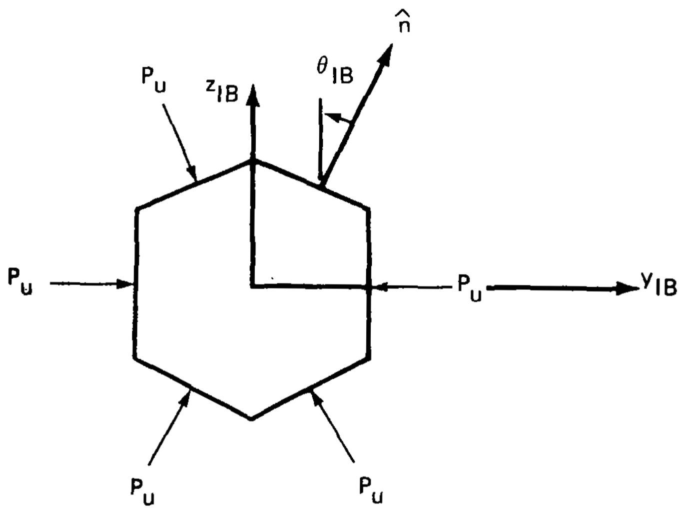


Figure 11. — Interference Body Panel Orientation Angle

The FLEXSTAB aerodynamic theory assumes constant pressure panels. Under this assumption, the panel normal force is given by:

$$F_{n_{IB}} = -\bar{q}\, A_{IB}\, C_{p_u} \qquad (28)$$

where:

A_{IB} = Interference panel area

Using the orientation angle of the local panel normal with respect to the local z-axis (see fig. 11), the y and z components for each interference body panel are:

$$\begin{aligned} F_{y_{IB}} &= -\bar{q} \sin\theta_{IB}\, A_{IB}\, C_{p_u} \\ F_{z_{IB}} &= -\bar{q} \cos\theta_{IB}\, A_{IB} C_{p_u} \end{aligned} \qquad (29)$$

For the K^{th} interference body, equation (29) for each panel can be written in matrix form as:

$$\begin{aligned} \{F_{y_{IB}}\}_K &= \bar{q}\,[-\overset{\circ}{\sin}\,\theta_{IB}]_K\,[\overset{\circ}{A}_{IB}]_K\,\{C_{p_u}\}_K \\ \{F_{z_{IB}}\}_K &= \bar{q}\,[-\overset{\circ}{\cos}\,\theta_{IB}]_K\,[\overset{\circ}{A}_{IB}]_K\,\{C_{p_u}\}_K \end{aligned} \qquad (30)$$

Addition of Interference and Slender Body Aerodynamic Forces

To obtain the total segment forces on any slender body that has an associated interference body, the interference and slender body forces must be added together. This addition is made under the assumption that no interference panels overlap slender body segment boundaries; that is, the circumferential interference body segments must lie within the corresponding slender body segment. This requirement is illustrated in figure 12. Note that the last two circumferential segments of the interference body lie within the same slender body segment.

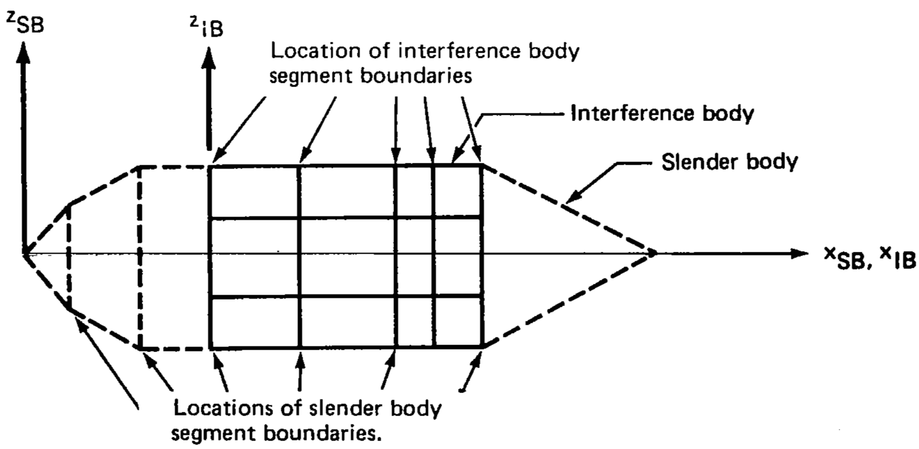


Figure 12. — Slender Body-Interference Body Alignment

The addition of the interference panel forces to the proper slender body segments can be accomplished by premultiplying the force expressions of equation (30) by a panel correlation matrix. This matrix is composed of ones and zeroes and is a rectangular matrix of size (number of slender body segments) by (number of interference body panels).

$$\{F_{y_{IB}}\}_J = [PC]_K^J \{F_{y_{IB}}\}_K$$
$$\{F_{z_{IB}}\}_J = [PC]_K^J \{F_{z_{IB}}\}_K \tag{31}$$

where:

$\{F_{y_{IB}}\}_J$, $\{F_{z_{IB}}\}_J$ = Sum of the K^{th} interference body panel y and z forces at the J^{th} slender body segments

$[PC]_K^J$ = Panel correlation matrix that adds the K^{th} interference body panels to the proper J^{th} slender body segments

Combining equations (31) and (30) and defining y and z force summation matrices as:

$$[\Sigma_y]_K = [PC]_K^J [-\sin^\circ \theta_{IB}]_K$$
$$[\Sigma_z]_K = [PC]_K^J [-\cos^\circ \theta_{IB}]_K \tag{32}$$

the interference body forces summed to the respective slender body segment midpoints can then be written as:

$$\{F_{y_{IB}}\}_J = \bar{q}\, [\Sigma_y]_K\, [\mathring{A}_{IB}]_K\, \{C_{p_u}\}_K$$
$$\{F_{z_{IB}}\}_J = \bar{q}\, [\Sigma_z]_K\, [\mathring{A}_{IB}]_K \{C_{p_u}\}_K \tag{33}$$

The total body force now becomes the sum of equations (33) and (26). Referring to the C_p matrix ordering shown in figure 7, the total slender body force distribution can be written in matrix form as:

$$\begin{Bmatrix} \{F_y\}_{SB} \\ \{F_z\}_{SB} \end{Bmatrix} = \bar{q} \begin{bmatrix} [\mathring{\pi}/2] & [0] & [\Sigma_y] \\ [0] & [-\mathring{\pi}/2] & [\Sigma_z] \end{bmatrix} \begin{bmatrix} [\mathring{A}_{SB}] & & \\ & [\mathring{A}_{SB}] & \\ & & [\mathring{A}_{IB}] \end{bmatrix} \begin{Bmatrix} \{C_p{}^Y\}_{SB} \\ \{C_p{}^Z\}_{SB} \\ \{C_{p_u}\}_{IB} \end{Bmatrix} \tag{34}$$

Thin Body Forces

The aerodynamic forces on each thin body panel are found by multiplying the lifting pressure on each panel by its area. For the I^{th} thin body, this is written in matrix form as:

$$\{F_z\}_I = \bar{q}\, [A_{TB}]_I\, \{\Delta C_p\}_I \tag{35}$$

Thin body forces act in the local z axis of the respective surfaces.

Total Aerodynamic Forces

Combining equation (34) with equation (35) for all the thin bodies, the total set of aerodynamic forces can be written as:

$$\begin{Bmatrix} \{F_y\}_{SB} \\ \{F_z\}_{SB} \\ \{F_z\}_{TB} \end{Bmatrix} = \bar{q} \begin{bmatrix} [\mathring{\pi}/2] & [0] & [\Sigma_y] & [0] \\ [0] & [-\mathring{\pi}/2] & [\Sigma_z] & [0] \\ [0] & [0] & [0] & [\mathring{1}] \end{bmatrix} \begin{bmatrix} [\mathring{A}_{SB}] & & & \\ & [\mathring{A}_{SB}] & & \\ & & [\mathring{A}_{IB}] & \\ & & & [\mathring{A}_{TB}] \end{bmatrix} \begin{Bmatrix} \{C_p{}^Y\}_{SB} \\ \{C_p{}^Z\}_{SB} \\ \{C_{p_u}\}_{IB} \\ \{\Delta C_p\}_{TB} \end{Bmatrix} \quad (36)$$

Since the aerodynamic modeling in FLEXSTAB is for half an airplane, the slender body segment areas for bodies on the plane of symmetry will be half of the total area. Also, for interference bodies on the plane of symmetry, only half the interference shell is modeled. Therefore, to obtain whole body forces, the F_y and F_z elements for slender bodies on the plane of symmetry are multiplied by two. The final expression for the aerodynamic forces thus becomes:

$$\{F_A\} = \bar{q}\,[F\mathring{A}C]\,[\Sigma]\,[\mathring{A}]\,\{C_p\} \quad (37)$$

where:

$[F\mathring{A}C]$ = Diagonal factor matrix that doubles the aerodynamic forces for slender bodies on the plane of symmetry

4.6.3 GENERALIZED AERODYNAMIC FORCE COEFFICIENTS

The generalized forces shown in the Laplace energy equation (1) are formed by the use of the principle of virtual work.

$$Q_i = \frac{\partial \Delta W}{\partial \Delta q_i} \qquad i = 1, \ldots, n \quad (38)$$

where:

Q_i = Generalized force in the i^{th} freedom

ΔW = Virtual work

Δq_i = Virtual displacement of the i^{th} generalized coordinate

Virtual work is calculated by multiplying the external forces acting on the system by the virtual displacement of the structure at the point of application of the force and in the direction of the force.

$$\Delta W = \lfloor \Delta n \rfloor_{FP} \{F\} \tag{39}$$

Expressing the virtual displacement of the structure in terms of the structure's mode shapes and virtual displacement of the generalized coordinates, and performing the differentiation of equation (38), the expression for the generalized forces becomes:

$$\{Q\} = [\phi_{\delta_n}]^T_{FP} \{F\} \tag{40}$$

In the above expression, the modal displacements, θ_{δ_n}, describe the displacement of the structure at the point of application of the force (force point) and in the direction of the force.

Generalized Response Aerodynamic Forces

Using the pressure coefficient equation (11) and the expression for the normalwash due to airplane motion (13), the response pressure distribution is given by:

$$\begin{aligned} \{C_{p_R}\} &= - [AIC] [\phi'_{\delta_n}]_{CP} \{q\} - \frac{1}{V_T} [AIC] [\phi_{\delta_n}]_{CP} \{\dot{q}\} \\ &= [CP1_R] \{q\} + \frac{1}{V_T} [CP2_R] \{\dot{q}\} \end{aligned} \tag{41}$$

Substituting this expression into the aerodynamic force equation (37), the response aerodynamic forces are:

$$\begin{aligned} \{F_R\} &= \bar{q} [F\mathring{A}C] [\Sigma] [\mathring{A}] \left\{ [CP1_R] \{q\} + \frac{1}{V_T} [CP2_R] \{\dot{q}\} \right\} \\ &= [F1_R] \{q\} + [F2_R] \{\dot{q}\} \end{aligned} \tag{42}$$

Finally, the force expression (eq. 42) is substituted into the generalized force equation (40) to give:

$$\{Q_R\} = [\phi_{\delta_n}]^T_{FP} [\mathring{SF}] \left\{ [F1_R] \{q\} + [F2_R] \{\dot{q}\} \right\} \tag{43}$$

where:

$[\mathring{SF}]$ = Symmetry factor matrix that doubles the forces of the bodies off the plane of symmetry in order to calculate total airplane forces

It is important to note that the displacements at the force points are defined in the local aerodynamic axis system of each surface (see sec. 4.2). Thus a positive displacement acts in the same direction as a positive aerodynamic force, resulting in positive virtual work.

Bringing the response generalized forces to the left side of equation (1) and writing them as coefficients of generalized coordinate displacements and velocities, the M_4 and M_5 matrices become:

$$[M_4] = -\ [\phi_{\delta_n}]^T_{FP}\ [\mathring{S}F]\ [F1_R]$$
$$[M_5] = -\ [\phi_{\delta_n}]^T_{FP}\ [\mathring{S}F]\ [F2_R] \qquad (44)$$

Generalized Excitation Aerodynamic Forces

The generalized excitation aerodynamic forces are calculated in the same manner as the response forces. Using the gust normalwash given by equation (20), the gust pressure distribution is defined as:

$$\{C_{P_E}\} = \frac{1}{V_T}\ [AIC]\ [RG]_{S/A}\ [GC]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\ e^{i\omega t}$$
$$= \frac{1}{V_T}\ [CP_G]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\ e^{i\omega t} \qquad (45)$$

and the excitation forces become:

$$\{F_G\} = \frac{\bar{q}}{V_T}\ [F\mathring{A}C]\ [\Sigma]\ [\mathring{A}]\ [CP_G]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\ e^{i\omega t}$$
$$= [FG]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\ e^{i\omega t} \qquad (46)$$

Finally, the generalized excitation forces are:

$$\{Q_E\} = [\phi_{\delta_n}]^T_{FP}\ [FG]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}v_{G_{V/L}}\ e^{i\omega t}$$
$$= [\tilde{\phi}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}v_{G_{V/L}}\ e^{i\omega t} \qquad (47)$$
$$= \{C_3\}\ v_{G_{V/L}}\ e^{i\omega t}$$

4.7 DOUBLET LATTICE AIC OPTION

Basically, the Doublet Lattice AIC option performs the same type of aerodynamic calculation as the FLEXSTAB AIC option discussed in section 4.6, (relating the pressure distribution over the aircraft to the flow incidence at several aerodynamic control points). However, the differences between the two approaches lie in the method used to formulate this relationship and the fact that the Doublet Lattice approach can be used for unsteady as well as quasi-steady aerodynamics.

Unlike the FLEXSTAB approach, in which the AIC matrix contains all the interaction effects of slender, interference, and thin bodies, the Doublet Lattice formulation is separated into three distinct steps:

- First, slender body pressures are determined.
- Second, the normalwash induced on thin and interference bodies by the slender bodies is calculated.
- Finally, the thin and interference body pressures are calculated.

The Doublet Lattice AIC option uses the modal interpolation arrays from L215 (INTERP) and the geometry and aerodynamic data from L216 (DUBFLX). The aerodynamic data consists of frequency dependent matricies, [F] and [D], which relate flow incidence and lifting pressure.

In the discussion to follow, the full unsteady aerodynamic case will be examined first. The quasi-steady formulation will be presented afterward since it is a subset of the full unsteady approach.

4.7.1 SLENDER BODY AERODYNAMIC FORCES

The Doublet Lattice program does not pass slender body pressures to the EOM program for this option. These pressures are calculated within the EOM program using Miles' slender body theory employed in L216 (DUBFLX) (ref. 8). Based on this theory, the lifting pressure over the slender bodies is given by:

$$\{\Delta C_p\}_{SB} = 2\pi \left[[\mathring{r}'_s] + \frac{i\omega}{2V_T} [\mathring{r}_s] \right] \left\{ \frac{w_n}{V_T} \right\} + \frac{2\pi}{2} [\mathring{r}_s] \left\{ \frac{w_n'}{V_T} \right\} \tag{48}$$

where:

$\{\Delta C_p\}_{SB}$ = Array of slender body segment lifting pressures in the direction of the normalwash, w_n (n is either local y or z direction)

$[\mathring{r}_s], [\mathring{r}'_s]$ = Array of segment radii and streamwise slope of radii evaluated at segment midpoints ($r'_s = dr_s/dx$)

$\{w_n\}, \{w'_n\}$ = Normalwash and the streamwise derivative of the normalwash evaluated at the segment midpoints.

Slender bodies that undergo vertical motion (z-bodies) give lifting pressures in the z-direction. Y-bodies are slender bodies that experience lateral motion and give lifting pressures in the y-direction. As discussed in section 4.6.1, different SA arrays must be used with y-bodies and z-bodies. The ordering within the pressure matrix is all lifting pressures in the y-direction (Y-bodies) followed by all lifting pressures in the z-direction (Z-bodies).

$$\left\{\Delta C_p\right\}_{SB} = \left\{\begin{matrix} \left\{\Delta C_p{}^Y\right\}_{SB} \\ ---- \\ \left\{\Delta C_p{}^Z\right\}_{SB} \end{matrix}\right\} \tag{49}$$

Response Aerodynamic Forces

The response pressures on the slender bodies can be calculated by using equation (48) with the response normalwash defined in equation (13). The normalwash is evaluated at the segment midpoints and is formulated in the same order as the pressure stacking shown in equation (49). Making this substitution, the slender body lifting pressures are:

$$\begin{aligned}\{\Delta C_{p_R}\}_{SB} &= -2\pi\left[[\mathring{r}'_s] + \frac{i\omega}{2V_T}[\mathring{r}_s]\right]\left\{[\phi'\delta_n]_{CP}\{q\} + \frac{1}{V_T}[\phi\,\delta_n]_{CP}\{\dot{q}\}\right\} \\ &\quad - \frac{2\pi}{2}[\mathring{r}_s]\left\{[\phi''\delta_n]_{CP}\{q\} + \frac{1}{V_T}[\phi'\delta_n]_{CP}\{\dot{q}\}\right\}\end{aligned} \tag{50}$$

For simple harmonic motion, velocity and displacement are related by the expression:

$$\dot{q} = i\omega q \tag{51}$$

Using this relationship, equation (50) can be written in complex form as:

$$\begin{aligned}\{\Delta C_{p_R}\}_{SB} &= -2\pi\left[[\mathring{r}'_s][\phi'\delta_n]_{CP} + \frac{1}{2}[\mathring{r}_s][\phi''\delta_n]_{CP} - \frac{\omega^2}{2V_T^2}[\mathring{r}_s][\phi\,\delta_n]_{CP}\right]\{q\} \\ &\quad - i\frac{2\pi\omega}{V_T}\left[[\mathring{r}_s][\phi'\delta_n]_{CP} + [\mathring{r}'_s][\phi\,\delta_n]_{CP}\right]\{q\} \\ &= \left[[CPR_{SB}]_{Re} + i\,[CPR_{SB}]_{Im}\right]\{q\}\end{aligned} \tag{52}$$

The slender body forces are obtained by multiplying the pressures by the dynamic pressure and the segment projected areas.

$$\begin{aligned}\left\{\begin{matrix}\{FR^Y\}_{SB} \\ \{FR^Z\}_{SB}\end{matrix}\right\} &= \bar{q}\,[\mathring{A}_{SB}]\left[[CPR_{SB}]_{Re} + i\,[CPR_{SB}]_{Im}\right]\{q\} \\ &= \left[[FR_{SB}]_{Re} + i\,[FR_{SB}]_{Im}\,\{q\}\right]\end{aligned} \tag{53}$$

Excitation Aerodynamic Forces

The slender body lifting pressures due to the gust are calculated using the gust normalwash given in equation (20) with a modified version of the slender body pressure equation (48). In the modification of the pressure equation, terms dealing with the normalwash time rate of change and streamwise slope are neglected. At high frequencies, the unsteadiness produced by these terms violates the assumptions of the slender body theory. Therefore, the slender body excitation pressure will be approximated by:

$$\{\Delta C_{p_G}\}_{SB} = \frac{2\pi}{V_T}[\mathring{r}'_s]\,[R\mathring{G}_{SB}]_{S/A}[GC]_{SB}\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t}$$

$$= [CPG_{SB}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t} \tag{54}$$

The slender body gust forces become:

$$\{F_G\}_{SB} = \bar{q}\,[A\mathring{_{SB}}]\,[CPG_{SB}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}v_{G_{V/L}}\,e^{i\omega t}$$

$$= [FG_{SB}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t} \tag{55}$$

4.7.2 INDUCED NORMALWASH

The second step in the formulation of the aerodynamics is the calculation of the normalwash induced by the slender bodies on the thin and interference body boxes. Note that the term "box" in the Doublet Lattice option refers to the smallest division of a thin or interference body. It is equivalent to the term "panel" used in FLEXSTAB.

The Doublet Lattice program, L216, calculates a complex matrix of normalwash factors, [F], at each frequency of interest. The matrix is rectangular, with each row relating to a thin or interference body box and each column relating to a slender body segment. The induced normalwash at the box control points is given by the product of the normalwash factors and the slender body pressures. For the induced normalwash due to the airplane response motions, the equation is:

$$\frac{1}{V_T}\{-w_B\}_R = [F]\,\{\Delta C_{p_R}\}_{SB} \tag{56}$$

and due to the gust excitation, the expression is:

$$\frac{1}{V_T}\{-w_B\}_G = [F]\,\{\Delta C_{p_G}\}_{SB} \tag{57}$$

4.7.3 THIN AND INTERFERENCE BODY AERODYNAMIC FORCES

The relationship between the flow incidence at the thin and interference body box control points and the box lifting pressures is given by the equation:

$$\frac{1}{V_T}\begin{Bmatrix}\{w_A\}_{TB}\\ \{w_A\}_{IB}\end{Bmatrix} = [D]\begin{Bmatrix}\{\Delta C_p\}_{TB}\\ \{\Delta C_p\}_{IB}\end{Bmatrix} \tag{58}$$

where:

$[D]$ = A complex matrix of normalwash factors relating box lifting pressures to flow incidence at the box control points

$\{w_A\}_{TB}, \{w_A\}_{IB}$ = Augmented normalwashes at thin and interference body boxes

$\{\Delta C_p\}_{TB}, \{\Delta C_p\}_{IB}$ = Thin and interference body lifting pressures.

The matrix, $[D]$, is a frequency-dependent matrix and is calculated at each frequency of interest. The augmented normalwash of equation (58) is the sum of the normalwash due to the motion of the bodies or due to the gust encounter plus the normalwash induced by the slender bodies.

Response Aerodynamic Forces

By the definition of an interference body, that is, a body that does not generate its own lift, the normalwash due to interference body motion is set to zero. The thin body normalwash due to the airplane motions is given by equation (13). Using the induced normalwash expression of equation (56), the augmented response normalwash becomes:

$$\begin{aligned}\frac{1}{V_T}\begin{Bmatrix}\{w_{A_R}\}_{TB}\\ \{w_{A_R}\}_{IB}\end{Bmatrix} &= \frac{1}{V_T}\begin{Bmatrix}\{w_R\}_{TB}\\ \{0\ \}_{IB}\end{Bmatrix} + [F]\,\{\Delta C_{p_R}\}_{SB}\\ &= \left[\begin{bmatrix}-[\phi'_{\delta_z}]_{TB} - \frac{i\omega}{V_T}[\phi_{\delta_z}]_{TB}\\ [0]_{IB}\end{bmatrix} + [F]\,[CPR_{SB}]\right]\{q\}\end{aligned} \tag{59}$$

Substituting equation (59) into (58) and solving for the box pressures gives:

$$\begin{Bmatrix} \{\Delta C_{p_R}\}_{TB} \\ \{\Delta C_{p_R}\}_{IB} \end{Bmatrix} = [D]^{-1} \left[\begin{bmatrix} -[\phi'_{\delta_z}]_{TB} - \frac{i\omega}{V_T}[\phi_{\delta_z}]_{TB} \\ [0]_{IB} \end{bmatrix} + [F]\,[CPR_{SB}] \right] \{q\}$$

$$= \left[[CPR_{TB/IB}]_{Re} + i\,[CPR_{TB/IB}]_{Im} \right] \{q\} \tag{60}$$

Multiplying equation (60) by the matrix of box areas and the dynamic pressure gives the response aerodynamic forces for thin and interference bodies:

$$\{F_R\}_{TB/IB} = \bar{q}\,[\mathring{A}_{TB/IB}] \begin{Bmatrix} \{C_{p_R}\}_{TB} \\ \{C_{p_R}\}_{IB} \end{Bmatrix} \tag{61}$$

Excitation Aerodynamic Forces

The augmented gust normalwash is obtained by adding the gust normalwash defined for the thin body boxes and given by equation (20) to the induced normalwash due to the gust slender body forces given by equation (57).

$$\begin{Bmatrix} \{w_{A_G}\}_{TB} \\ \{w_{A_G}\}_{IB} \end{Bmatrix} = \left[\begin{bmatrix} \frac{1}{V_T}[RG_{TB}]_{S/A}\,[GC]_{TB} \\ [0]_{IB} \end{bmatrix} + [F][CPG_{SB}] \right] \begin{Bmatrix} e^{-i\omega \frac{f_\ell}{V_T}} \end{Bmatrix} \bar{v}_{G_{V/L}}\, e^{i\omega t} \tag{62}$$

Note that by the definition of an interference body, the normalwash on the interference body boxes due to a gust encounter is set equal to zero.

Substituting equation (60) into (58) and solving for the lifting pressures, results in:

$$\begin{Bmatrix} \{\Delta C_{p_G}\}_{TB} \\ \{\Delta C_{p_G}\}_{IB} \end{Bmatrix} = [D]^{-1} \left[\begin{bmatrix} \frac{1}{V_T}[RG_{TB}]_{S/A}[GC]_{TB} \\ [0]_{IB} \end{bmatrix} + [F][CPG_{SB}] \right] \begin{Bmatrix} e^{-i\omega \frac{f_\ell}{V_T}} \end{Bmatrix} \bar{v}_{G_{V/L}} e^{i\omega t}$$

$$= \left[[CPG_{TB/IB}]_{Re} + i[CPG_{TB/IB}]_{Im} \right] \begin{Bmatrix} e^{-i\omega \frac{f_\ell}{V_T}} \end{Bmatrix} \bar{v}_{G_{V/L}}\, e^{i\omega t} \tag{63}$$

The gust forces on the boxes become:

$$\{F_G\}_{TB/IB} = \bar{q}\,[\mathring{A}_{TB/IB}]\,[CPG_{TB/IB}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t}$$

$$= [FG_{TB/IB}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t} \tag{64}$$

4.7.4 GENERALIZED AERODYNAMIC FORCE COEFFICIENTS

Total Aerodynamic Forces

The total aerodynamic response and gust forces are obtained by summing the interference body box forces and the respective slender body segment forces, and then multiplying the resultant slender body forces for bodies on the plane of symmetry by two. The multiplication is needed since the modeling in the Doublet Lattice program is for half an airplane.

The total response aerodynamic forces can be written as:

$$\{F_R\} = [F\mathring{A}C]\left[\begin{bmatrix}[0]\\ [FR_{SB}]\end{bmatrix} + [\Sigma]\,[FR_{TB/IB}]\right]\{q\}$$

$$= \left[[FR]_{Re} + i\,[FR]_{Im}\right]\{q\} \tag{65}$$

Again, using the harmonic relationship between velocity and displacement, the response force of equation (65) can be written in terms of coefficients of q and q. Thus:

$$\{F_R\} = [FR]_{Re}\,\{q\} + \frac{1}{\omega}\,[FR]_{Im}\,\{\dot{q}\} \tag{66}$$

Similiarly, the total aerodynamic gust forces are:

$$\{F_G\} = [F\mathring{A}C]\left[\begin{bmatrix}[0]\\ [FG_{SB}]\end{bmatrix} + [\Sigma][FG_{TB/IB}]\right]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t}$$

$$= \left[[FG]_{Re} + i[FG]_{Im}\right]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\}\bar{v}_{G_{V/L}}\,e^{i\omega t} \tag{67}$$

The summing matrix in equations (65) and (67) is similar to that used in the FLEXSTAB AIC option, but with an arrangement corresponding to the Doublet Lattice ordering. In submatrix form, it is shown below:

$$[\Sigma] = \begin{bmatrix} [0] & [0\ ] & [0] \\ [0] & [\Sigma_y] & [0] \\ [0] & [0\ ] & [\Sigma_z] \end{bmatrix} \tag{68}$$

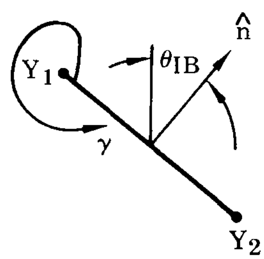
where:

$[\Sigma_y] \quad = [PC]\ [\sin\theta_{IB}]$

$[\Sigma_z] \quad = [PC]\ [\cos\theta_{IB}]$

The panel correlation matrix, $[PC]$, performs the same function of adding all the interference boxes to the proper slender body segments. In terms of the Doublet Lattice box dihedral angle, γ, the box unit normal orientation is:

$$\theta_{IB} = 360^0 - \gamma \tag{69}$$



Generalized Forces

Forming a matrix of normal displacements at the segment and box force points, the generalized response forces are given by:

$$\begin{aligned} \{Q_R\} &= [\phi_{\delta_n}]^T_{TB/SB}\ [\overset{\circ}{SF}]\ [FR]\ \{q\} \\ &= [QR]\ \{q\} \end{aligned} \tag{70}$$

and the generalized excitation forces are given by:

$$\begin{aligned} \{Q_E\} &= [\phi_{\delta_n}]^T_{TB/SB}\ [\overset{\circ}{SF}]\ [FG] \left\{ e^{-i\omega \frac{f_\ell}{V_T}} \right\} \bar{v}_{G_{V/L}} e^{i\omega t} \\ &= [\mathcal{F}] \left\{ e^{-i\omega \frac{f_\ell}{V_T}} \right\} \bar{v}_{G_{V/L}}\ e^{i\omega t} \end{aligned} \tag{71}$$

Bringing the generalized response forces to the left side of the equations of motion and writing them as coefficients of q and $\dot{q}$, the M_4 and M_5 matrices become:

$$[M_4] = -[QR]_{Re}$$
$$[M_5] = -\frac{1}{\omega}[QR]_{Im} \qquad (72)$$

The C_3 matrix is defined as:

$$\{C_3\} = [\bar{\phi}]\left\{e^{-i\omega\frac{f_\ell}{V_T}}\right\} \qquad (73)$$

4.7.5 QUASI-STEADY FORMULATION

The quasi-steady formulation in the Doublet Lattice AIC option is accomplished using the aerodynamic data ([D] and [F] matrices) calculated at $\omega = 0$, which makes them real matrices. Also, the harmonic motion relationship between q and $\dot{q}$ is not used, and the normalwash is written as real coefficients of generalized coordinate displacements and velocities.

Setting $\omega = 0$ in equation (50) and grouping terms as coefficients of q and $\dot{q}$, the response slender body lifting pressures are given by:

$$\{\Delta C_{p_R}\}_{SB} = -2\pi\left[[\mathring{r}'_s][\phi'_{\delta_n}]_{CP} + \frac{1}{2}[\mathring{r}_s][\phi''_{\delta_n}]_{CP}\right]\{q\}$$
$$-\frac{2\pi}{V_T}\left[[\mathring{r}'_s][\phi_{\delta_n}]_{CP} + \frac{1}{2}[\mathring{r}_s][\phi'_{\delta_n}]_{CP}\right]\{\dot{q}\} \qquad (74)$$
$$= [CP1_R]_{SB}\{q\} + [CP2_R]_{SB}\{\dot{q}\}$$

The expression for the slender body lifting pressures due to gust is given by equation (54).

The augmented normalwash on the thin and interference boxes becomes:

$$\frac{1}{V_T}\begin{Bmatrix}\{w_{A_R}\}_{TB}\\ \{w_{A_R}\}_{TB}\end{Bmatrix} = \left[\begin{bmatrix}-[\phi'_{\delta_z}]_{TB}\\ [0]_{IB}\end{bmatrix} + [F]\,[CP1_R]_{SB}\right]\{q\}$$
$$+\left[\begin{bmatrix}-\frac{1}{V_T}[\phi_{\delta_z}]_{TB}\\ [0]_{IB}\end{bmatrix} + [F]\,[CP2_R]_{SB}\right]\{\dot{q}\} \qquad (75)$$

where the [F] matrix is now real.

Using equation (75) with equation (60), the response lifting pressures on thin and interference boxes are:

$$\begin{Bmatrix} \{\Delta C_{PR}\}_{TB} \\ \{\Delta C_{PR}\}_{IB} \end{Bmatrix} = [D]^{-1} [WA1_R]_{TB/IB} \{q\} + [D]^{-1} [WA2_R]_{TB/IB} \{\dot{q}\} \tag{76}$$

With the lifting pressures established, the aerodynamic forces and generalized forces are obtained by substituting equations (74) and (76) into the proper force equation given in section 4.7-4. It should be noted that the gust forces computed by the two approaches differ in that the [D] and [F] matrices are real for the quasi-steady assumption.

4.8 DOUBLET LATTICE GENERALIZED FORCE AND PRESSURE OPTION

The last aerodynamic option is the Doublet Lattice generalized force and pressure option. In this option, the lifting pressures on all slender body segments, thin and interference body boxes, and the generalized response forces are calculated by the Doublet Lattice program, L216. The L217 (EOM) program uses the lifting pressures to calculate the aerodynamic forces on each aircraft component, places the generalized forces in the format required for the equations of motion, and uses the response forces to generate gust excitation forces. No modal data is required from L215 (INTERP) and the formulation of the excitation aerodynamics does not permit gradual penetration effects to be taken into account.

Aerodynamic Forces

The complete lifting pressure matrix read from the Doublet Lattice program is a frequency-dependent complex matrix containing all slender body segment, thin and interference body box pressures. The ordering follows that used in the Doublet Lattice program, which is:

- Thin bodies on the plane of symmetry followed by thin bodies off the plane of symmetry.
- Interference bodies on the plane of symmetry followed by those off the plane of symmetry.
- All y-slender bodies on the plane of symmetry followed by all those off the plane of symmetry.
- All z-slender bodies on the plane of symmetry followed by those off the plane of symmetry.

$$\{\Delta C_{p_R}\} = \begin{bmatrix} [CPR_{TB}] \\ [CPR_{IB}] \\ [CPR^{Y}{}_{SB}] \\ [CPR^{Z}{}_{SB}] \end{bmatrix} \{q\} \tag{77}$$

Multiplying the pressure matrix by the box and segment areas, summing the interference body boxes onto the respective slender body segments, and multiplying them by the factor matrix which accounts for slender bodies on the plane of symmetry, the total set of response forces is:

$$\begin{aligned} \{F_R\} &= \bar{q}\,[F\mathring{A}C]\,[\Sigma]\,[\mathring{A}]\,[CPR]\,\{q\} \\ &= \bar{q}\,[F_{12}]\,\{q\} \end{aligned} \tag{78}$$

Using the displacement-velocity harmonic relationship shown in equation (51), the forces can be written as coefficients of q and $\dot{q}$.

$$\begin{aligned} \{F1_R\} &= \bar{q}[F_{12}]_{Re}\ \{q\} \\ \{F2_R\} &= \frac{\bar{q}}{\omega}[F_{12}]_{Im}\ \{\dot{q}\} \end{aligned} \tag{79}$$

The gust forces are obtained by developing the relationship between the gust velocity and the rigid body displacements and then extracting the proper rigid body columns from the force matrix to form the aerodynamic forces due to gust. The sign convention shown in figure 6 will be used along with that shown in figure 2 to establish the relationships.

For a symmetrical analysis, the airplane experiences the rigid body motions of plunge and pitch. The plunge of the airplane will give the same aerodynamic effect as a positive gust encounter. Therefore, the relationship between the vertical gust velocity and the vertical translation generalized coordinate is given by:

$$v_{G_V} = \dot{q}_{VT} = i\omega q_{VT} \tag{80}$$

The pitch generalized coordinate is related to the vertical gust velocity by the equation:

$$v_{G_V} = V_T\ q_p \tag{81}$$

For an antisymmetric analysis, the rigid body motions of side translation and yaw are used to derive the gust relationships. The side translation generalized coordinate/lateral gust relationship is:

$$v_{G_L} = -\ \dot{q}_{ST} = -i\omega q_{ST} \tag{82}$$

and the yaw/lateral gust equation is:

$$v_{G_L} = V_T \, q_Y \tag{83}$$

Equations (81) and (83) are used in obtaining zero frequency gust forces, while equations (80) and (82) are used for all nonzero frequency gust forces.

Extracting the proper rigid body column from the $[F_{12}]$ matrix shown in equation (78), the gust forces at $\omega = 0$ are:

$$\{F_G\}_{S/A} = \bar{q}\,\{F'_{12}\}\,\dot{q}_{P/Y} = \frac{\bar{q}}{V_T}\{F'_{12}\}\,V_{G_{V/L}} \tag{84}$$

and for $\omega > 0$ the gust forces are:

$$\{F_G\}_{S/A} = \bar{q}\,\{F'_{12}\}\,\dot{q}_{VT/ST} = \delta_{S/A}\,\frac{i\bar{q}}{\omega}\{F'_{12}\}\,V_{G_{V/L}} \tag{85}$$

where:

$\{F'_{12}\}$ = A complex column matrix of aerodynamic force coefficients formed by extracting the proper rigid body column from the $[F_{12}]$ matrix given by equation (78)

$\delta_{S/A}$ = 1 for a symmetrical analysis.
-1 for an antisymmetrical analysis.

Generalized Aerodynamic Force Coefficients

The generalized response force coefficients are read from the Doublet Lattice program in the form of complex matrices calculated at each ω value of interest. Relating these coefficients to the $[M_4]$ and $[M_5]$ matrices provides:

$$[M_4] = -\,2\bar{q}\,[QR]_{Re}$$
$$[M_5] = -\frac{2\bar{q}}{\omega}[QR]_{Im} \tag{86}$$

The generalized excitation forces are formed by again extracting the proper rigid body columns from the generalized response force coefficients. Since there is no gradual penetration, the $[\tilde{\Phi}]$ matrix degenerates to a $\{C_3\}$ matrix. For $\omega = 0$, the generalized excitation is:

$$\{Q_E\} = \{C_3\}\,v_{G_{V/L}} = \frac{2\bar{q}}{V_T}\,\{Q'\}\,v_{G_{V/L}} \tag{87}$$

and for $\omega > 0$:

$$\{Q_E\} = \{C_3\}\,v_{G_{V/L}} = 2\delta_{S/A}\,\frac{iq}{\omega}\{Q'\}\,v_{G_{V/L}} \tag{88}$$

where:

$\{Q'\}$ = A complex column matrix of generalized aerodynamic force coefficients formed by extracting the proper rigid body column from $[QR]$ matrix.

4.9 COORDINATE TRANSFORMATION AND AERODYNAMIC AXIS SHIFTING

All interpolation that is performed in L217 (EOM) using the SA arrays from L215 (INTERP) is carried out in the local structural axis system of each aircraft component (sec. 4.7 of ref. 6). The aerodynamic geometry data is input in the reference axis system and, therefore, it must be transformed into the local structural axis for interpolation. This transformation is complicated by two factors. First, in most cases the origin of the local structural axis system and the origin of the local aerodynamic axis system are not the same. Second, due to the requirements for good aerodynamic modeling, certain components may have to be placed outboard or inboard, above or below, or fore or aft, of their actual locations. Therefore, for proper interpolation, the reference axis system locations of points on such a surface must be corrected in order to reflect their true orientation.

In order to account for the difference, the transformation equation for each component has coordinate shift values which can be used to define the correct position of any surface points. The transformation equation for any point on a surface is:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_{\ell s} = [R] \left[\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_{RAS} - \begin{Bmatrix} X_{OA} \\ Y_{OA} \\ Z_{OA} \end{Bmatrix}_{RAS} + \begin{Bmatrix} X_{SH} \\ Y_{SH} \\ Z_{SH} \end{Bmatrix}_{RAS} \right] \tag{89}$$

where:

$x_{\ell s}, y_{\ell s}, z_{\ell s}$ = Local structural axis system location of any point on a surface

$X_{RAS}, Y_{RAS}, Z_{RAS}$ = Reference axis system location of the point

$X_{OA_{RAS}}, Y_{OA_{RAS}}, Z_{OA_{RAS}}$ = Reference axis system location of the origin of the aerodynamic axes of the surface

$X_{SH_{RAS}}, Y_{SH_{RAS}}, Z_{SH_{RAS}}$ = Reference axis system shift values that will properly orient the aerodynamic axes to the structural axes

$[R]$ = Rotation matrix that rotates the coordinates from the reference axis system into the local structural axis system

The rotation matrix is defined as:

$$[R] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{bmatrix} \tag{90}$$

with θ being the surface dihedral angle.

The reference axis system coordinates of the point and the origin of the aerodynamic axis system, and the surface dihedral angle are obtained from the aerodynamic geometry data read by L217 (EOM). The shifting values are input by the user for each surface.

To understand the calculation of the shifting values, consider the horizontal tail shown in figure 13. Here, a typical aft body modeling problem is illustrated. Both FLEXSTAB and Doublet Lattice require interference bodies to be of constant cross-section. Thus, in the aft portions of the fuselage where in reality the body tapers, the interference body must be kept constant. This could place the horizontal tail outboard, forward, aft, above or below its actual location. Just calculating the differences between the local aerodynamic and structural axis system origin would not reflect the true position of the aerodynamic points with respect to the interpolation axes (which are the local structural axes). Therefore, a set of correction values are needed.

Taking into account these corrections, the equation for the shift values is:

$$\begin{Bmatrix} X_{SH} \\ Y_{SH} \\ Z_{SH} \end{Bmatrix}_{RAS} = \begin{Bmatrix} X_{OA} \\ Y_{OA} \\ Z_{OA} \end{Bmatrix}_{RAS} - \begin{Bmatrix} X_{OS} \\ Y_{OS} \\ Z_{OS} \end{Bmatrix}_{RAS} + \begin{Bmatrix} X_{C} \\ Y_{C} \\ Z_{C} \end{Bmatrix}_{RAS} \tag{91}$$

where:

$X_{OS_{RAS}}, Y_{OS_{RAS}}, Z_{OS_{RAS}}$ = Reference axis system location of the structural axis system used for the SA array.

$X_{C_{RAS}}, Y_{C_{RAS}}, Z_{C_{RAS}}$ = Desired correction values to apply to the aerodynamic points. These values are defined in the reference axis system and are positive in the positive reference axis system directions measuring from the aerodynamic axis system to the structural axis system.

The proper calculation of the shifting values requires the user to know the location of the local structural axis system origin used in L215 (INTERP), and the local aerodynamic axis system origin established by FLEXSTAB or Doublet Lattice. This last

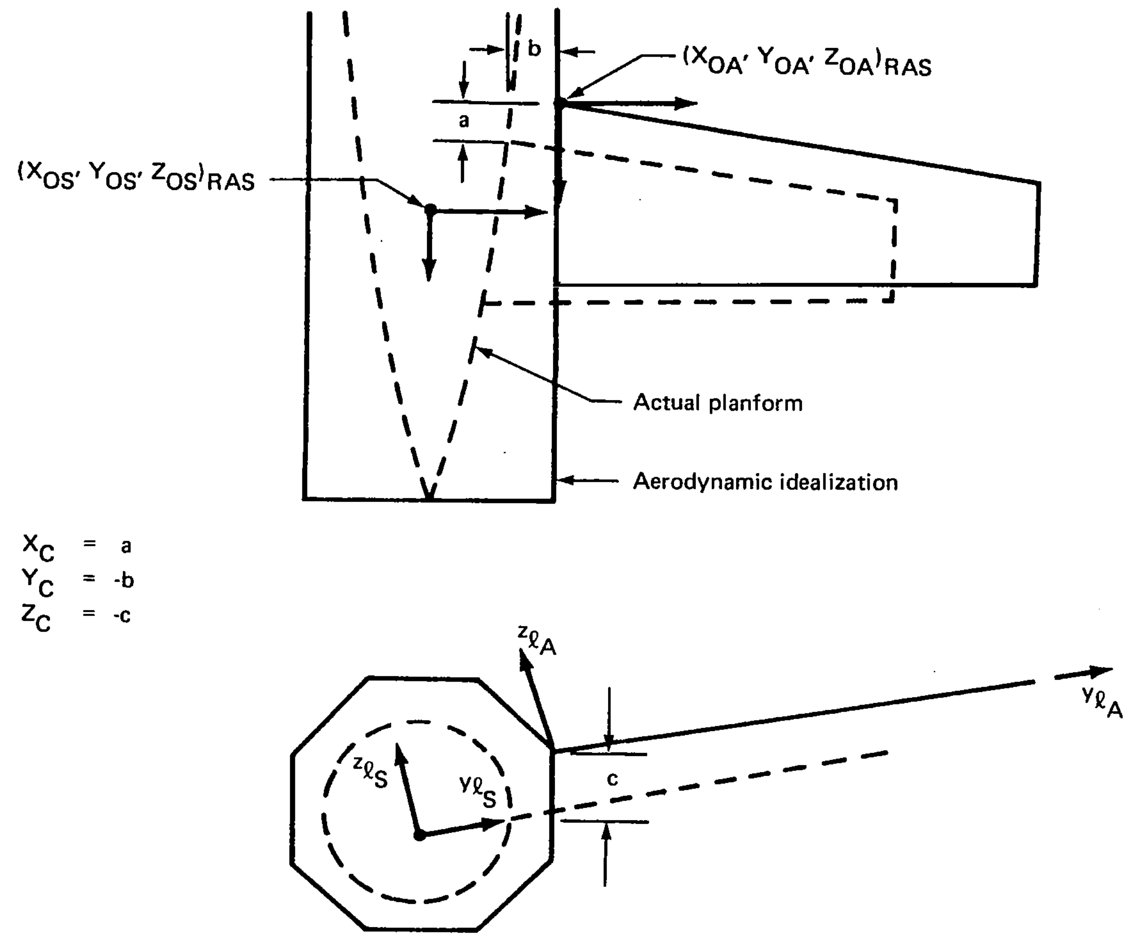


Figure 13. – Aerodynamic Axis Shifting

value for FLEXSTAB aerodynamics is defined by the analyst when setting up the FLEXSTAB idealization. Doublet Lattice, however, defines the aerodynamic origin internally. In Doublet Lattice, the aerodynamic origins are defined in the following way:

- For slender bodies, the origin is the leading edge location of the first segment.

- For thin bodies (or panels), the origin is the X1, Y1, Z1 coordinates of the panel.

5.0 PROGRAM STRUCTURE AND DESCRIPTION

Program L217 (EOM) is structured as an overlay system consisting of a main overlay and four primary overlays listed below and displayed in figure 14.

(L217,0,0) L217vc

(L217,2,0) STRUCT

(L217,3,0) FLXAIC

(L217,4,0) DLAIC

(L217,5,0) DLPRES

5.1 PROGRAM L217vc

The main overlay,(L217,0,0), is named L217vc (the "v" and "c" are version and correction identifiers). It reads data cards that direct the execution of the primary overlays and also aids communication between the primary overlays via labelled common blocks.

5.2 PROGRAM STRUCT

The 2,0 primary overlay, STRUCT (L217,2,0), generates the equations of motion matrices that are dependent upon the structural data only.

$[M_1]$ = Generalized stiffness

$[M_2]$ = Generalized damping (optional)

$[M_3]$ = Generalized inertia

Depending on the options chosen, STRUCT may read from several magnetic files:

GSTIFF A generalized stiffness matrix $[K]$. ($[K] = [M_1]_{Ua}$)

GMASS A generalized mass matrix $[M]$. ($[M] = [M_3]_{Ua}$)

SATAP Arrays of modal data to be used in the generation of control surface freedoms to be added to $[K]$ and $[M]$.

Because certain constants ($\bar{q}$ and V_T) and defined in STRUCT, and because the matrices generated by STRUCT are required in each of the aerodynamic overlays, STRUCT must be executed prior to any of the aerodynamic overlays.

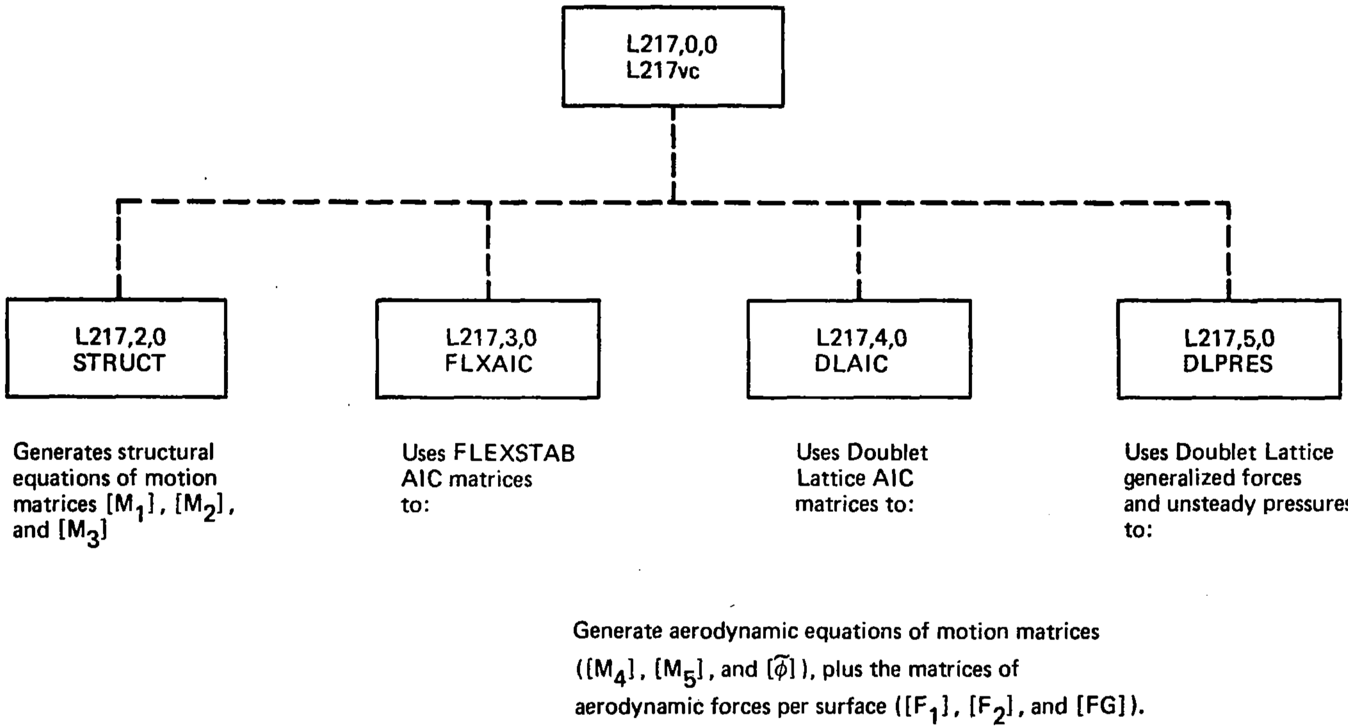


Figure 14. – L217 (EOM) Overlay Structure

5.3 AERODYNAMIC DATA PROCESSING

The remaining primary overlays generate the equations of motion matrices that are dependent upon the aerodynamic data. The matrices are:

$[FREQM]$ = Array of frequencies at which the aerodynamics are defined

$[M_4]$ = Generalized aerodynamic stiffness matrix

$[M_5]$ = Generalized aerodynamic damping matrix

$\{f_\ell\}$ = Array distance(s) from the gust reference point to the gust control point(s) of the gust zones

$[\tilde{\Phi}]$ = Gust forcing function matrix

The matrices are written onto the file "EOMTAP" following the structural matrices generated by STRUCT.

In addition, the aerodynamic overlays produce the aerodynamic force matrices per surface and write them onto the file "EOMLOD" for subsequent use in L218 (LOADS) (ref. 9). The file includes the following matrices for each surface:

$[x,y]$ = Local axis coordinates of surface node points

$\{A\}$ = Area of surface elements

$[F_1]$ = Real part of aerodynamic response forces

$[F_2]$ = Imaginary part of aerodynamic response forces

$[FG]$ = Gust forces

The last three matrices are repeated for each frequency at which they are defined.

5.3.1 PROGRAM FLXAIC

The 3,0 primary overlay, FLXAIC (L217,3,0), generates the aerodynamic equations of motion and force matrices using the FLEXSTAB (ref. 7) aerodynamic influence coefficient (AIC) matrix. FLXAIC reads from the files:

"GDTAPE" FLEXSTAB geometry data.

"SDINDX" Table describing the file of aerodynamic data, SDDATA.

"SDDATA" AIC matrix $[A_{P_\Theta}]$ for a symmetric or antisymmetric case.

"SATAP" Arrays of modal data.

5.3.2 PROGRAM DLAIC

The 4,0 primary overlay, DLAIC (L217,4,0), generates the aerodynamic equations of motion and force matrices using the Doublet Lattice (ref. 8) AIC matrices. DLAIC reads from the files:

"NGETP" Doublet Lattice geometry data.

"NAETP" Doublet Lattice aerodynamic data ($[F]$, $[D]^{-1}$, etc.).

"SATAP" Arrays of modal data.

5.3.3 PROGRAM DLPRES

The 5,0 primary overlay, DLPRES (L217,5,0), generates the aerodynamic equations of motion and force matrices using the Doublet Lattice (ref. 8) generalized forces and unsteady aerodynamics. DLPRES reads from the files:

"NGETP" Doublet Lattice geometry data.

"NAETP" Doublet Lattice aerodynamic data ($[Q]$,$[\Delta CP]$, etc.).

Although L217 (EOM) serves as a module of the DYLOFLEX system, it can be operated as a standalone program. L217 (EOM) is heavily dependent upon data generated prior to its execution. Figure 15 displays the different files that the program may require, according to user specified options. When the program is run by itself, it becomes the user's responsibility to generate the files of input data in the format required by the program.

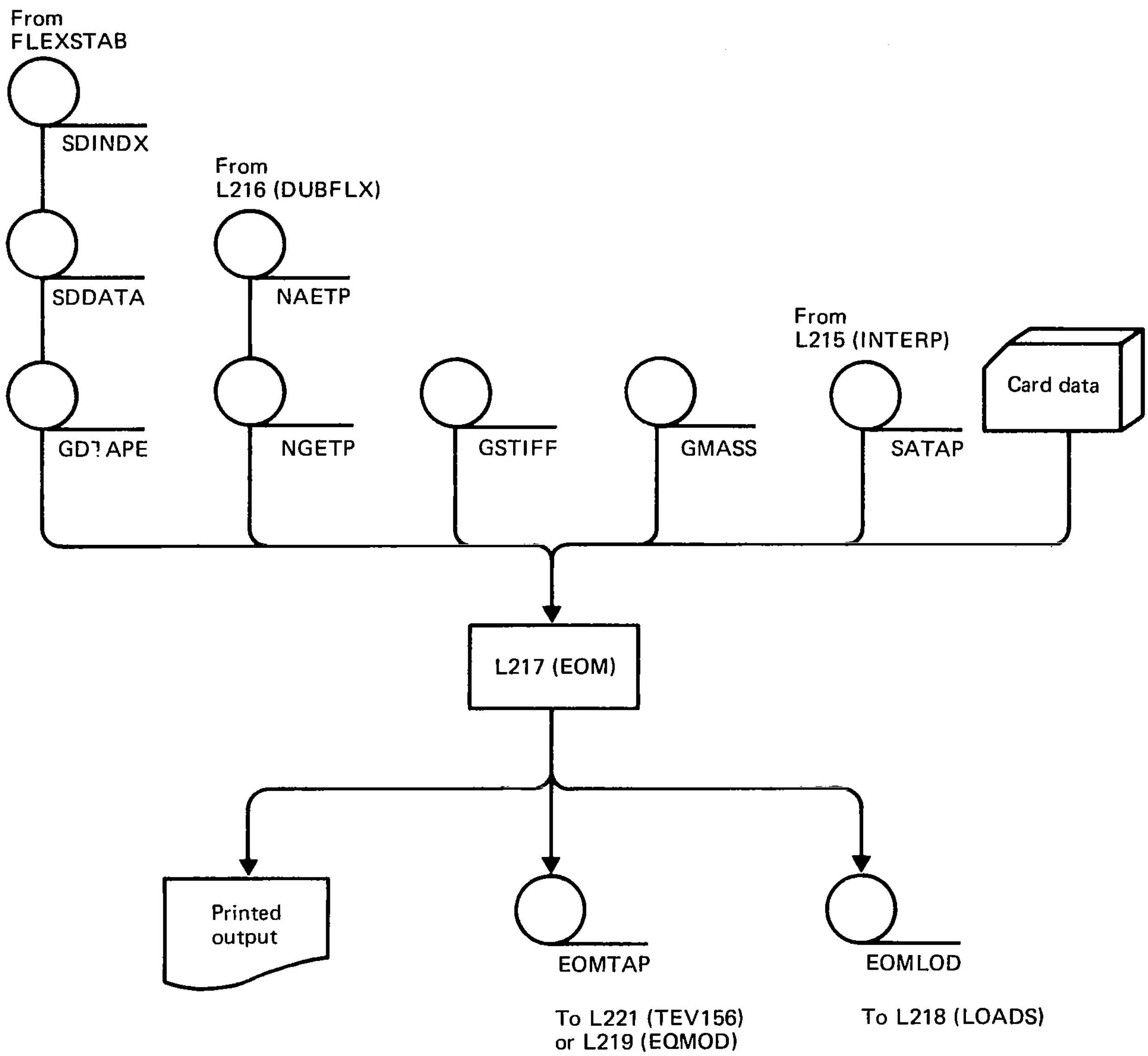


Figure 15. — L217 (EOM) Communication Via External Files

6.0 COMPUTER PROGRAM USAGE

The program was designed for use on the CDC 6600. The machine requirements to execute L217 (EOM) are:

Card reader	Read control cards and card input data.
Printer	Print standard output information, optional intermediate calculations, and diagnostic messages.
Disk storage	All magnetic files not specifically defined as magnetic tapes are assumed to be disk files.
Tape drive	For permanent storage of data. Magnetic files are copied to and from magnetic tapes with control cards before and after program execution.

The program L217 (EOM) is written in FORTRAN and may be compiled with either the RUN or FTN compiler. L217 (EOM) may be executed on either the KRONOS 2.1 or NOS operating system.

6.1 CONTROL CARDS

The following list is a typical set of control cards used to execute L217 (EOM) using the absolute binaries from the program's master tape.

```
Job Card
Account Card
    •
    •
    •
REQUEST(MASTER,F=I,LB=KL,VSN=66XXXX)      {Retrieve the
REWIND(MASTER)                            {program from
SKIPF(MASTER)                             {its master tape
COPYBF(MASTER,L217)
RETURN(MASTER)
    •                                     {Prepare input
    •                                     {data files
    •
L217.                                     {Execute L217 (EOM)
    •
    •                                     {Save output
    •                                     {data files
EXIT.
DMP(0,field length)
---End-of-record

 | Card Input |
 |    Data    |

---End-of-file
```

The following list is a typical set of control cards used to execute L217 (EOM) using the relocatable binaries from the program's master tape.

```
Job Card
Account Card
      •
      •
      •
REQUEST(MASTER,F=I,LB=KL,VSN=66XXXX)      {Retrieve the
REWIND(MASTER)                            {program from
SKIPF(MASTER,2)                           {its master
COPYBF(MASTER,REL217)                     {tape
RETURN(MASTER)
      •                                   {Prepare input
      •                                   {data files.
      •
                                          {Retrieve DYLIB,
                                          {the DYLOFLEX
                                          {alternate library

LDSET(LIB=DYLIB,PRESET=INDEF)             {Load L217 (EOM)
LOAD(REL217)
NOGO.
RETURN(REL217,DYLIB)

L217.                                     {Execute L217

      •                                   {Save output
      •                                   {data files
      •
EXIT.
DMP(0,field length)
---End-of-record

  ┌────────────┐
  │ Card Input │
  │    Data    │
  └────────────┘

---End-of-file
```

6.2 RESOURCE ESTIMATES

The computer resources used (core requirements, tapes, printed output, central processor seconds, etc.) are a function of the problem size and the program options used.

Field Length

The field length (core) required by L217 (EOM) is dependent upon the problem size and the program module(s) used. Core must be requested for the largest module run, either the structural data overlay or one of the aerodynamic overlays. The structural and aerodynamic overlays (primaries) are broken into even smaller chunks called secondary overlays. Therefore, core must be requested for the longest secondary overlay to be executed. The equation to calculate the field length of an overlay is

$$\text{Field Length} = FL_p + FL_a$$

where FL_p is the program length, and FL_a is the array storage required.

The following pages contain FL_p and a simplified formula for FL_a for all L217 (EOM) secondary overlays. The user must determine which ones will be executed, which is the longest for the problem to be run, and the required field length.

It should be noted that FL_p is given as an octal base number. Normally, FL_a will be calculated as a decimal number and converted to octal before being added to FL_p.

The structural overlay is relatively short. One of the aerodynamic overlays will usually be the largest.

The following abbreviations are used in the field length formulas:

$NDOF_{CS}$	Number of control surface freedoms being added (card 2.1).
$NDOF_{ST}$	Number of original structural freedoms (card 2.1).
NMODES	Number of modes defined (number of generalized coordinates total) = $NDOF_{ST} + NDOF_{CS}$.
M_{max}	Minimum of 20 or NMODES.
NELE	Number of control surface masses and inertias added to the structural matrices (card 2.9.1).
NGCP	Number of gust control points (card 3.9.1).
NIBFP	Number of interference body force points.
NSBFP	Number of slender body force points.

NTBFP Number of thin body force points.

NAFP Number of output aerodynamic force points = NTBFP + NSBFP.

NBOX Number of aerodynamic boxes = NTBFP + NIBFP.

NTOTF Number of aerodynamic elements total = NTBFP + NIBFP + NSBFP.

N_{max} Maximum number of nodes on a surface.

Primary Overlay L217,2,0

Program Name STRUCT

If control surface freedoms are added, FORMAC will be longest.

If not, FORM13 will be the longest.

Secondary Overlay	Program Name	FL_p (octal)	FL_a (decimal)
L217,2,1	RSTRCT	35000	6000
L217,2,2	FORMAC	74000	NELE*(NMODES+1)+600 +($NDOF_{CS}$*$NDOF_{ST}$)
L217,2,3	FORM13	47000	$NMODES^2$ + NMODES

Primary Overlay L217,3,0

Program Name FLXAIC

For large problems L217,3,4-FLXFRC will be the longest.

For small problems L217,3,3-FLXMOD will be the longest.

Secondary Overlay	Program Name	FL_p (octal)	FL_a (decimal)
L217,3,1	FLXCDS	36000	0
L217,3,2	FLXGEO	66000	0
L217,3,3	FLXMOD	73000	3*NAFP*(M_{max} + 2)
L217,3,4	FLXFRC	42000	4*NAFP*(M_{max} + 1) + 5*NTOTF
L217,3,5	FLXODR	42000	NAFP*(M_{max} + 5) + NMODES*N_{max}
L217,3,6	FLXEOM	42000	2*NMODES*(NMODES+NGCP) + NAFP*(M_{max} + 1)

Primary Overlay L217,4,0

Program Name DLAIC

For large problems, L217,4,6 -SOLVDW is usually the longest.

For small problems, L217,4,3 -DLAMOD is usually the longest.

Secondary Overlay	Program Name	FL_p (octal)	FL_a (decimal)
L217,4,1	DLACDS	37000	0
L217,4,2	DLAGEO	65000	0
L217,4,3	DLAMOD	75000	M_{max}*(3*NAFP+NTBFP)+5*NAFP
L217,4,4	CPANDW	40000	NTBFP*(M_{max}+2*NMODES) + 2*(NAFP+NMODES)
L217,4,5	FORMWS	41000	2*NBOX*NMODES
L217,4,6	SOLVDW	52000	NBOX*(NBOX+4*(NMODES+NGCP)+3)[1]
L217,4,7	DLAFRC	41000	2*((NSBFP*NMODES)+NBOX +(NAFP*M_{max}))+5*NTOTF
L217,4,8	DLAODR	43000	2*(NMODES*N_{max}+NAFP*M_{max}) +6*NAFP
L217,4,9	DLAEOM	43000	2*NMODES*(NMODES+NGCP) +NAFP*(3*M_{max}+1)

[1]The formula given above for SOLVDW is to perform a solution in core. SOLVDW will partition the problem and run with as little as FL_a = NBOX*(NMODES+NGCP)

Primary Overlay L217,5,0

Program Name DLPRES

DLPEOM will normally be the longest.

Secondary Overlay	Program Name	FL_p (octal)	FL_a (decimal)
L217,5,1	DLPCDS	35000	0
L217,5,2	DLPGEO	63000	0
L217,5,4	DLPFRC	40000	7*NTOTF + 3*NAFP
L217,5,5	DLPODR	42000	N_{max}*(NMODES+4)+8*NAFP
L217,5,6	DLPEOM	41000	4*NMODES^2 + 2*NMODES

Time Estimate

The central processing time required (CP seconds) is dependent upon the options chosen and the problem size. The total time will be the sum of the time required by each overlay executed:

$$CP_{TOT} = CP_{STRUCT} + CP_{FLXAIC} + CP_{DLAIC} + CP_{DLPRES}$$

$$CP_{STRUCT} \leqslant 10$$

$$CP_{FLXAIC} \leqslant 10$$

$$CP_{DLAIC} \leqslant \left(\frac{NBOX}{40}^{2}\right) * NFREQM$$

$$CP_{DLPRES} \leqslant 5 * NFREQM$$

where:

NFREQM = Number of frequencies at which the aerodynamics are defined

NBOX = Number of boxes on the thin and interference bodies

Printed Output

The amount of printed output is dependent upon card options (cards 2.4, 2.6, 2.7 and 3.11), the size of the arrays printed, and the number of frequencies at which aerodynamic data is processed. At compilation time, the print line limit is set to 40 000 which should be sufficient for any single L217 (EOM) data case.

6.3 CARD INPUT DATA

The task(s) performed by L217 (EOM) are broken into several subtasks, each with its own section of code known as a primary overlay. The entire set of primary overlays is driven by a small program (main overlay) named L217vc.

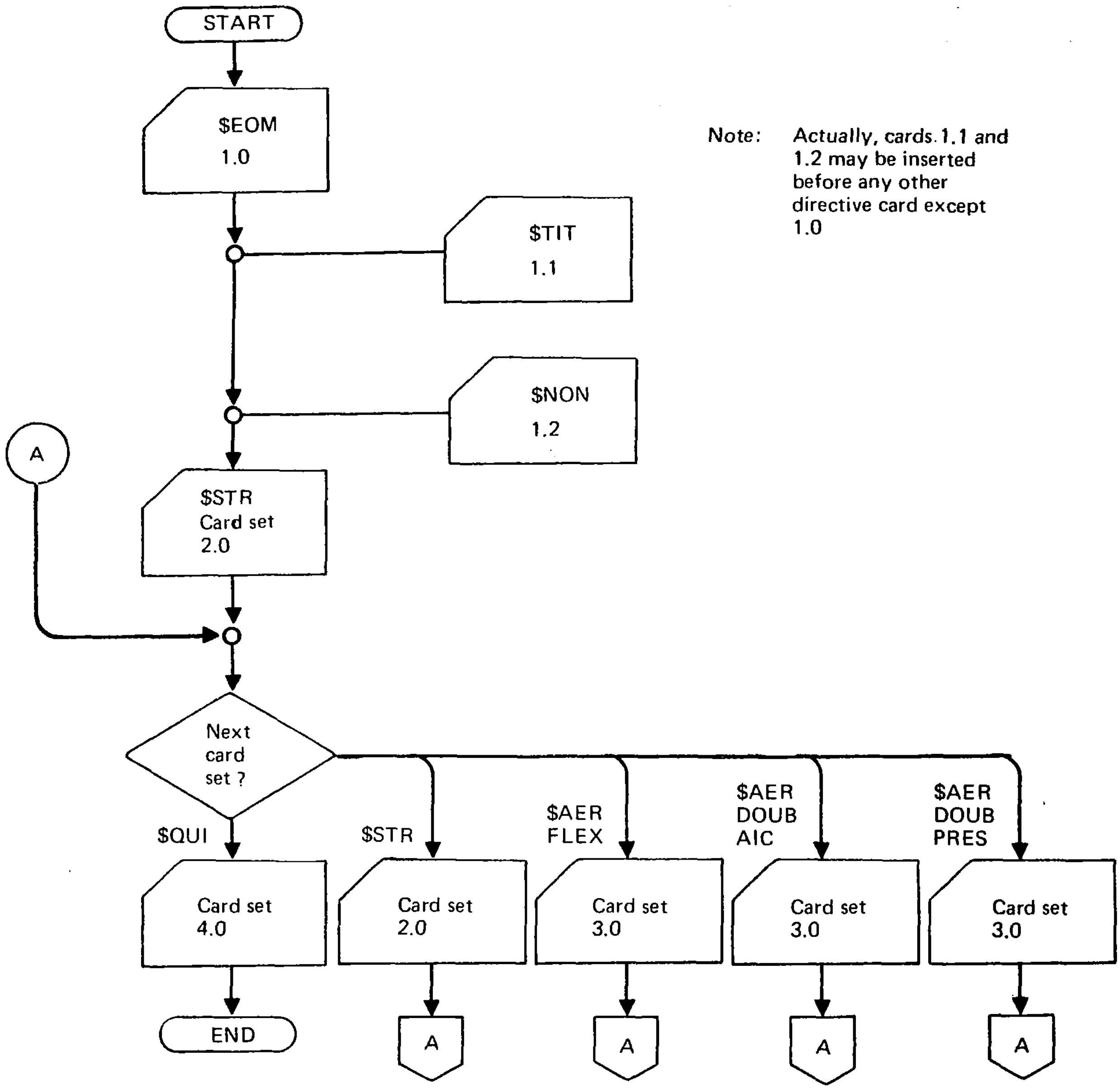
L217vc reads program directive cards to:

- Assure that the data being read is intended for EOM
- Determine which section of code (primary overlay) of EOM is to be executed next.

Each primary overlay reads one set of card input data. A listing of the primary overlays and the card set numbers follows. The same card set (3) is read by all overlays processing aerodynamic data.

Overlay Name	Purpose of Primary Overlay	Card Set Read
STRUCT	Generate $[M_1]$, $[\mathring{M}_2]$ and $[M_3]$, the equations of motion matrices based upon structural data.	2
FLXAIC	Generates the aerodynamic coefficient matrices for the equations of motion based on the quasi-steady aerodynamic assumption and using the aerodynamic data from FLEXSTAB (ref. 7)	3
DLAIC	Generates the aerodynamic coefficient matrices for the equations of motion based using Doublet Lattice AIC's (ref. 8). Either quasi-steady or full unsteady aerodynamics can be used.	3
DLPRES	Generates the aerodynamic coefficient matrices for the equations of motion using the Doublet Lattice generalized forces (ref. 8) for full unsteady aerodynamics.	3

The order in which these card sets are input (and the overlays are executed) is displayed in figure 16. The overlay STRUCT must be executed before any of the aerodynamic overlays.



Note: Actually, cards 1.1 and 1.2 may be inserted before any other directive card except 1.0

Figure 16. – L217 (EOM) Card Input Data Flow

Format of Card Input Data

All card data is read in fixed fields (specific columns of the cards). On the pages that follow, the required card columns are defined next to each keyword or variable. The following conventions are used throughout the program:

- All floating point variables are read with format E10.0.
- All integer variables are read with the format I5.
- All hollerith variables (keywords, etc), are read with the format A10.

Therefore, all data fields end on a card column that is a multiple of five.

When the program is trying to recognize keywords, it checks only the first four characters.

6.3.1 PROGRAM L217

The driving module of L217 (EOM) (the main overlay itself is also known as L217vc) will read and check the first four characters of the input card to determine the type of execution that is to take place.

Note: All underlined capital characters contained in the KEYWORD/VARIABLE field of the input card sets must be left-justified and punched in the card columns specified in the COLS. field of the input card sets.

L217 (EOM) Program Directive Cards

All program directive cards have a "$" in column one, the first character of the four character keywords.

Card Set. 1.0–Introduce L217 (EOM) Data

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$EOM	A10	Keyword introducing EOM data. This must be the first card read by EOM.
11-70			Available for comments

Card 1.1–Title Card Labelling Printout

Optional card to be omitted or repeated as often as desired before any program directive card except $EOM.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$TITle	A10	Keyword indicating a title card to be read, printed, and ignored.
11-70			Available for comments

Card 1.2–Indicate a Program Checkout Run

Optional card used only for program checkout purposes.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$NON-stop	A10	Keyword telling the program to try continuing execution even if fatal errors are diagnosed.
11-70			Available for comments

6.3.2 STRUCTURAL CARD INPUT DATA

After reading card 1.0, (cards 1.1 and 1.2 are optional), the next card that must be read is card 2.0, which introduces the structural input data. Cards 2.1 through 2.3 define the problem size, the type of analysis, and the type of generalized mass and stiffness data input. Card 2.4 is optional and is used to print out intermediate data for problem checkout purposes. Card 2.5, defining the modal input, is only required if control surface inertial coupling is to be calculated. Cards 2.6 through 2.8 define the generalized inertial, stiffness, and damping (if calculated in L217 (EOM)). Finally, card 2.9 defines the control surface inertial and nodal data needed for the inertial coupling calculations.

Once the processing of the structural data has been completed, the program reads another card to determine what is to be done next. The user may specify an aerodynamic data set, or new structural data ($STR – card set 2), or may terminate the program's execution with card set 4 ($QUIT).

All the cards in the set are optional except for cards 2.0 ($STR), 2.1 (SIZE), and 2.10 (END). Card 2.1 must follow card 2.0 and card 2.10 must terminate the data set and precede the next program directive card. The flow of cards is displayed in figure 17.

For any optional card (2.2 through 2.9) that is omitted, the keywords or variables appearing on the card will assume their default values.

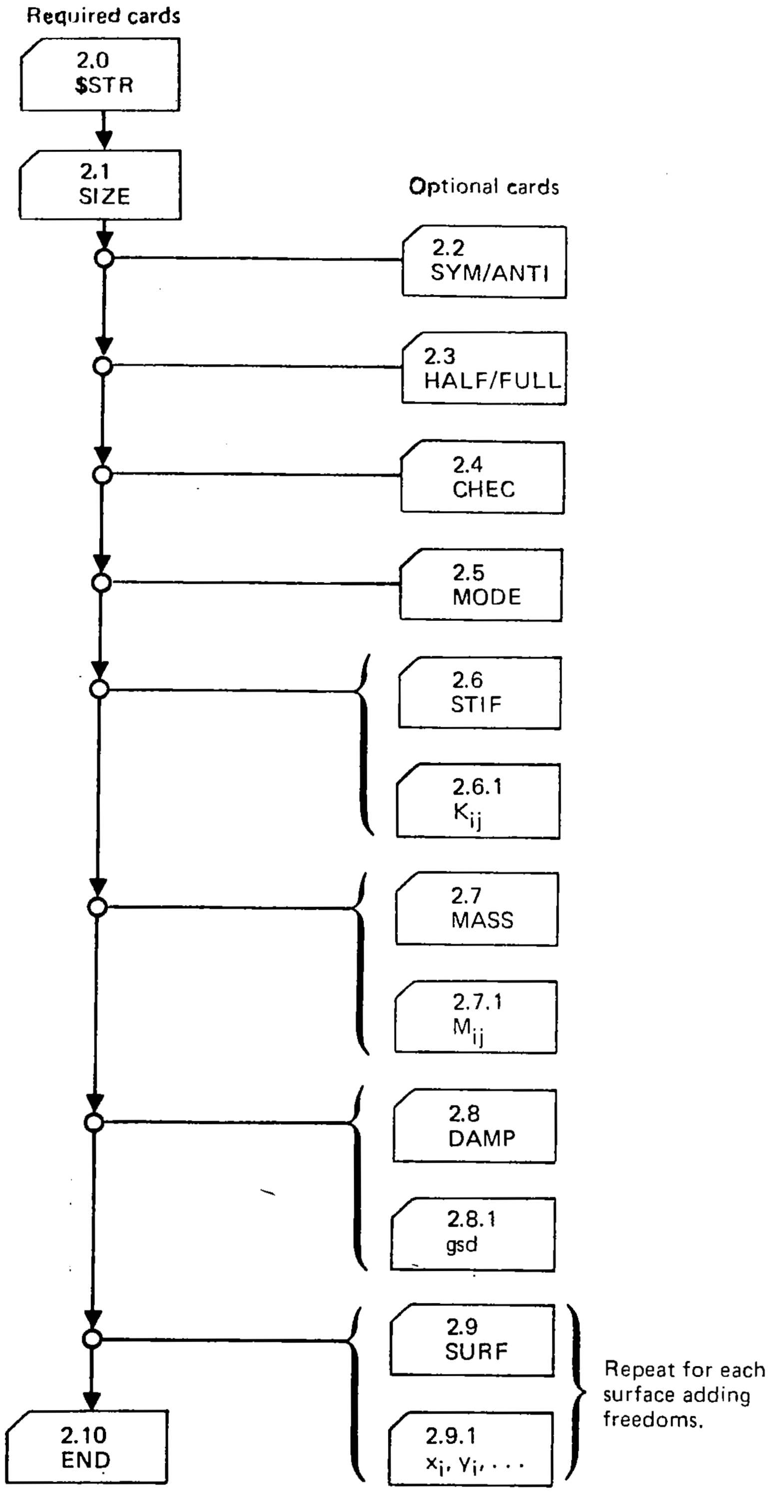


Figure 17. – L217 (EOM) Structural Card Input Data, Card Set 2.0

Card Set 2.0–Introduce Structural Card Input Data

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$STRuctural	A10	Keyword introducing the structural card input data and causing the STRUCT overlay to be called into execution. The structural card input data (Cards 2.1-2.10) must appear between $STR and the next program directive card (either $TIT, $CHE, or $AER).
11-70			Available for comments

Default values have been established for most of the items input in the structural data set. All cards in the set are optional, with the exception of 2.0 ($STR), 2.1 (SIZE), and 2.10 (END). Card 2.1 must follow 2.0, and 2.10 must terminate the structural data and precede the next program directive card. Cards 2.2 through 2.9 may be in any order.

Card 2.1–Size of Equations of Motion Matrices

Card 2.1 must follow card 2.0.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	SIZE	A10	Keyword indicating a "SIZE" card.
11-15	NDOFST	I5	The number of structural degrees of freedom. *The size of the input generalized mass and stiffness* matrices.
16-20	NDOFCS	I5	The number of control surface degrees of freedom to be added to the structural freedoms.

NOTE: The equations of motion matrices generated by L217 (EOM) will contain NDOF degrees of freedom where NDOF = NDOFST + NDOFCS. If the control surface freemdoms were accounted for in the generation of the structural data, then NDOFCS = 0 and NDOFST is set equal to the total number of freedoms coming from the vibration program.

Card 2.2–Symmetric/Antisymmetric Analysis

Card 2.2 is optional. The default analysis type is symmetric.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	ISYM	A10	One of two keywords may be used to choose the type of analysis to be performed by L217 (EOM). SYMMetric ANTI-symmetric Default: SYMM
11-70			Available for comments

Card 2.3–Full/Half Airplane

Card 2.3 is optional. By default, the input generalized mass and stiffness matrices are assumed to be for a full airplane.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	IHALF	A10	One of two keywords may be used to specify that the input generalized mass and stiffness are for full or half airplane. FULL HALF Default: FULL
11-70			Available for comments

Card 2.4–Checkout Printout

Card 2.4 is optional.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	CHECkout	A10	Keyword requesting the printing of intermediate data calculated during the structural data processing.
11-15	ICKPRT	I5	Option indicating the amount of intermediate data to be printed. =1 Print message when each overlay is entered plus [ϕ] , interpolated mode shapes at control surface nodes, [$\mathring{M}CS$], and the final [M_1] , [M_2] , and [M_3] . =3 Print all items listed under 1 plus control surface data summary, [A] , and [C] . =5 Print all items listed under 1 and 3 plus [ϕ_{ST}], [ϕ_{CS}] , and a message each time a VARDIM routine is called.

Card 2.5–File Containing the Input Mode Shapes

Card 2.5 is optional. The default file name is "SATAP."

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	MODEs	A10	Keyword indicating a card defining the modal input data file name.
11-20	SATAP	A10	Name of the file (tape or disk) containing the modal input data which will be used to calculate the inertia coupling effects for the added control surface freedoms. The name must start in column 11, begin with a letter, and have less than seven characters. Default: SATAP="SATAP"

Card 2.6–Generalized Stiffness Matrix Source

Card 2.6 is optional. Default values are shown below.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	STIFfness	A10	Keyword indicating stiffness matrix data.
11-20	KTAPE	A10	Name of the file containing the generalized stiffness matrix [K] . Either "CARDS" or a file name starting in column 11, beginning with a letter, and having less than seven characters. If KTAPE="CARDS" the matrix will be read from cards (see Card 2.6.1) and the next two variables are meaningless. Default: KTAPE="GSTIFF"
21-25	KFILE	I5	Number of logical files to skip on KTAPE before reading [K] . Default: KFILE=0
26-30	KMAT	I5	Number of matrices to skip on KTAPE before reading [K] . Default: KMAT=0
31-40	PRINt	A10	Option requesting the printing of [K] as read. Default: Do not print except when KTAPE=CARDS
41-70			Available for comments

Card 2.6.1–Rows of Generalized Stiffness Matrix on Cards

Card 2.6.1 is input only if KTAPE = CARDS on card 2.6.

Repeat card 2.6.1 for each row of [K]; i = 1, NDOFST.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	K(i,1)	7E10.0	The (i,1) element of [K] the generalized stiffness matrix.
11-20 . . .	K(i,2) . . . K(i,j)		The (i,2) element of [K] . . . The (i,j) element of [K]
	K(i,NDOFST)		Repeat the card with 7 numbers per card until all elements of row i are defined.

Card 2.7–Generalized Mass Matrix Source

Card 2.7 is optional. Default values are shown below.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	MASS	A10	Keyword indicating mass matrix data.
11-20	MTAPE	A10	Name of the file containing the generalized mass matrix [M] . Either "CARDS" or a file name - starting in column 11, beginning with a letter, and having less than seven characters. If MTAPE="CARDS" the matrix will be read from cards (see Card 2.7.1) and the next two variables are meaningless. Default: MTAPE="GMASS"
21-25	MFILE	I5	Number of logical files to skip on MTAPE before reading [M] . Default: MFILE=0
26-30	MMAT	I5	Number of matrices to skip on MTAPE before reading [M] . Default: MMAT=0
31-40	PRINt	A10	Option requesting the printing of [M] as read. Default: Do not print except when MTAPE=CARDS
41-70			Available for comments

Card 2.7.1–Rows of Generalized Mass Matrix of Cards

Card 2.7.1 is input only if MTAPE = CARDS in card 2.7.

Repeat card 2.7.1 for each row of [M], i = 1, NDOFST.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	M(i,1)	7E10.0	The (i,1) element of [M] , the generalized mass matrix.
11-20 : .	M(i,2) : . M(i,j)		The (i,2) element of [M] : . The (i,j) element of [M]
	M(i,NDOFST)		Repeat the card with 7 numbers per card until all elements of row i are defined.

Card 2.8–Introduce Structural Damping

Card 2.8 is optional. The default is no viscous structural damping.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	DAMPing	A10	Keyword introducing the structural damping factors following in Card 2.8.1
11-70			Available for comments

Card 2.8.1–Structural Damping Factors

Card 2.8.1 must follow card 2.8. It is repeated until all NDOFST terms are defined.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	gSD (1)	7E10.0	Element 1 of {gSD}
11-20 . . .	gSD (2) . . . gSD (i)		Element 2 of {gSD} . . . Element i of {gSD}
	gSD (NDOFST)		Repeat the card with 7 numbers per card until all elements are defined.

Card 2.9–Introduce the Addition of Control Surface Freedoms

Omit cards 2.9 and 2.9.1 if NDOFCS = 0 on card 2.1.

Repeat cards 2.9 and 2.9.1 for each control surface affected by the additional freedoms.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	SURFace	A10	Keyword introducing a new surface.
11-15	IS	I5	Modal Interpolation Program surface number (Reference 5) specifying where mode shapes for this surface are to be found.
16-20	NNODEI	I5	Number of nodes (mass points) on this control surface.
21-30	Trans	A10	A "T" in column 21 requests a translational freedom for each mass point.
31-40	Rot1	A10	An "R" in column 31 requests a streamwise rotational freedom, θ_y , for each mass point. (local aerodynamic axes)
41-50	Rot2	A10	An "R" in column 41 requests a rotational freedom, θ_x , which is perpendicular to the freestream, for each mass point. (local aerodynamic axes)
51-60	Local	A10	An "L" in column 51 indicates that the coordinates on Card 2.9.1 are in the local structural axis system. Default: Reference Axis System

Card 2.9.1–Mass Data for Surface IS

Card 2.9.1 must follow card 2.9.

It is repeated NNODEI times, once for each node on the control surface.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	Xi	E10.0	The coordinates of node i on surface IS. The coordinates are in the reference axis system unless specified as Local on Card 2.9.
11-20	Yi	E10.0	
21-30	Zi	E10.0	
31-40	MASSi	E10.0	The mass at node i. Whole airplane.
41-50	INERTYi	E10.0	The mass moments of inertia node i about the local aerodynamic y and x axes. Whole airplane. Note: INERTYi is required only if ROT1=R on Card 2.9. INERTXi is required only if ROT2=R on Card 2.9.
51-60	INERTXi	E10.0	
61-70			Available for comments

Card 2.10–End Structural Card Input Data

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	END	A10	Keyword indicating the end of structural card input data.
11-70			Available for comments

6.3.3 AERODYNAMIC CARD INPUT DATA

After card set 2 (2.0 through 2.10) and the processing of structural data, the next card read by L217 (EOM) must introduce aerodynamic card data. Card 3.0 introduces the aerodynamic card data and indicates the source of the AIC's or generalized forces, FLEXSTAB or Doublet Lattice. Some of the cards within card set 3.0 (3.13 through 3.16) vary according to the source of the aerodynamic data used.

Once the processing of the aerodynamic data has been completed, the program reads another card to determine what is to be done next. The user may specify another aerodynamic data set, or new structural data ($STR–card set 2), or may terminate the program's execution with card set 4.0 ($QUIT).

Default values have been established for many of the items defined in the aerodynamic card set. All cards in the set are optional with the exception of 3.0 ($AER), 3.1 (CONSTANTS), and 3.17 (END). Card 3.1 must follow 3.0 and card 3.17 must terminate the data set and precede the next program directive card. Optional cards 3.2 through 3.8 need only be present if the analyst wishes to use file names and/or spacing parameters that are different from the default values appearing in the data card write-up. The flow of cards is displayed in figure 18.

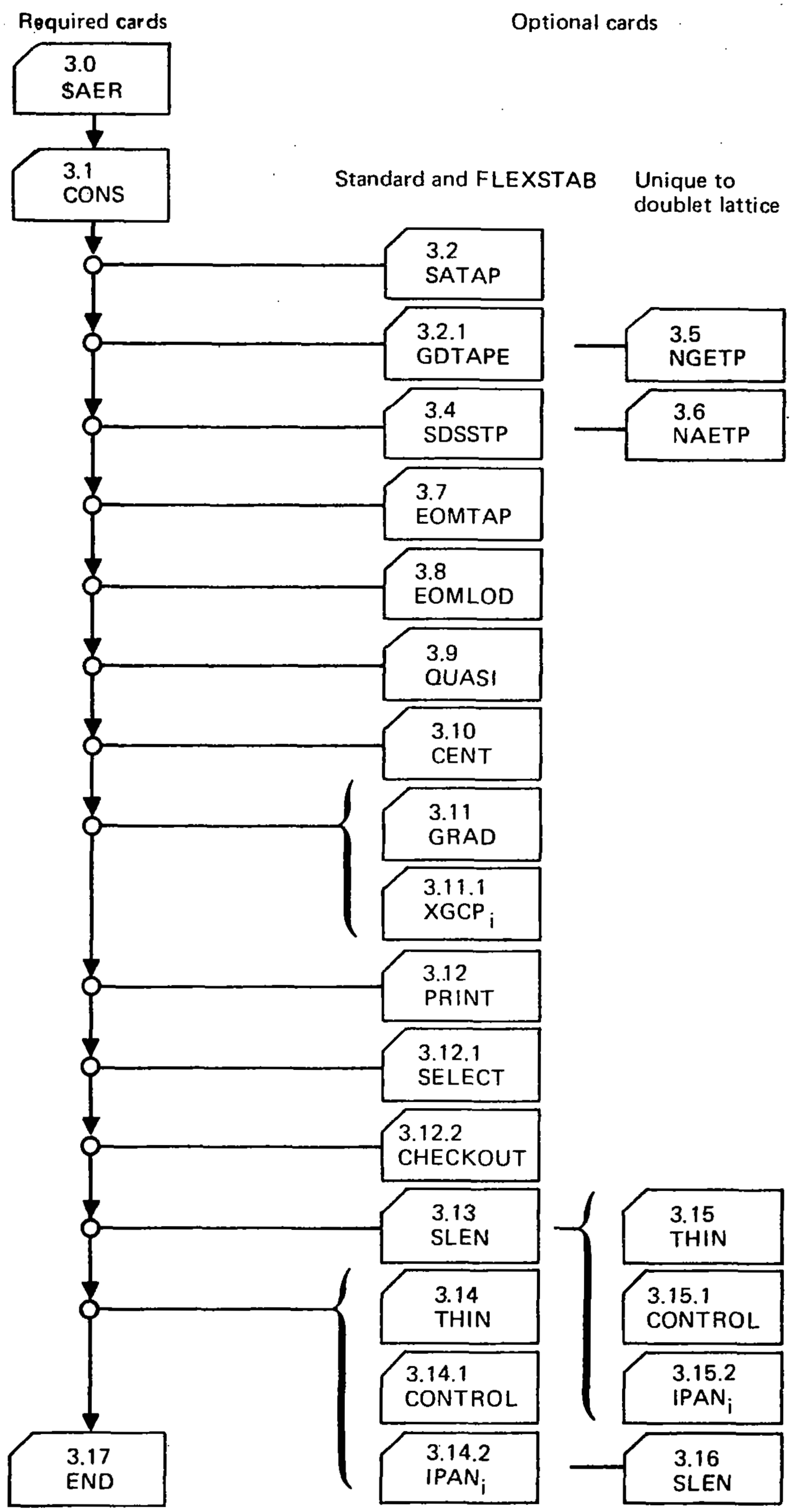


Figure 18. — L217 (EOM) Aerodynamic Card Input Data, Card Set 3.0

Card Set 3.0–Introduce Aerodynamic Card Input Data and Choose the Aerodynamic Type

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$AER	A10	Keyword introducing the set of cards describing the aerodynamic data processing. Check the next two words for aerodynamic type.
11-20	ISOURC	A10	Keyword indicating the source of the aero data. There are two possibilities: FLEXstab - FLEXSTAB DOUBlet - Doublet Lattice
21-30	ITYPE	A10	Keyword indicating the type of aero data to be used. There are two possibilities: AIC - AIC matrices PRESsure - Generalized forces and pressures Note: If the source is FLEXSTAB the type must be AIC. The PRES option is valid only with Doublet Lattice. Lattice.
31-70			Available for comments

Card 3.1–Aerodynamic Constants

Card 3.1 must follow card 3.0.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	CONStants	A10	Keyword indicating a card of aerodynamic constants.
11-20	RHO	E10.0	ρ - density of air at altitude.
21-30	VEL	E10.0	V_T = velocity (true airspeed) [units of length per second] Note: $\bar{q}$, the dynamic pressure, is calculated as $\bar{q} = \frac{1}{2}\rho V_T^2$
31-35	NTDEF	I5	Indicates the number of the mode corresponding to the translation (vertical or side) freedom. That mode will be used to find the gust forces when using Doublet Lattice pressures at a non-zero reduced frequency.
36-40	NPDEF	I5	Indicates the number of the mode corresponding to the pitch or yaw freedom. That mode will be used to find the gust forces when using Doublet Lattice pressures at a reduced frequency of zero.

NTDEF and NPDEF are not used, except with Doublet Lattice generalized forces and pressures.

Card 3.2–File Containing the Input Mode Shapes

Card 3.2 is optional. The default file name is "SATAP."

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	SATAp	A10	Keyword introducing replacement name for the modal interpolation data file.
11-20	ISATAP	A10	Name of the file (tape or disk) containing the modal input data. The name must start in column eleven, begin with a letter, and have less than seven characters. Default: ISATAP = "SATAP"
21-70			Available for comments

Cards 3.3 and 3.4–FLEXSTAB Input Data Files

Omit cards 3.3 and 3.4 if Doublet Lattice aerodynamics are being used. The cards are optional even if FLEXSTAB aerodynamics are being used. Default file names are shown below.

Card 3.3–File Containing FLEXSTAB Geometry Data

Card 3.3 is optional. The default file name and case number are "GDTAPE" and 1, respectively.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	GDTApe	A10	Keyword introducing replacement name for the FLEXSTAB geometry data file.
11-20	GDTAPE	A10	Name of the file (tape or disk) containing the FLEXSTAB geometry data. The name must start in column eleven, begin with a letter, and have less than seven characters.
21-25	IGCASE	I5	FLEXSTAB geometry data case number from which L217 (EOM) must extract geometry information. Default: IGCASE = 1
26-70			Available for comments

Card 3.4–Files Containing FLEXSTAB Aerodynamic Data

Card 3.4 is optional. The default file names are "SDINDX" and "SDDATA."

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	SDSStp	A10	Keyword introducing replacement name for the FLEXSTAB aerodynamic data file.
11-20	SDINDX	A10	Name of the file (tape or disk) containing the index table to the FLEXSTAB aerodynamic data. The name must start in column eleven, begin with a letter, and have less than seven characters. Default: SDINDX = "SDINDX"
21-30	SDDATA	A10	Name of the file (tape or disk) containing the FLEXSTAB aerodynamic data. Note: SDINDX ≠ SDDATA. The name must begin in column 21, begin with a letter, and have less than seven characters. Default: SDDATA = "SDDATA"
31-35	ISCASE	I5	FLEXSTAB aerodynamic data case number from which L217 (EOM) must extract $[A_{P_\theta}]$ Default: ISCASE = 1
36-70			Available for comments

Cards 3.5 and 3.6–Files Containing Doublet Lattice Data

Omit cards 3.5 and 3.6 if FLEXSTAB aerodynamics are being used.

The cards are optional even if Doublet Lattice aerodynamic data is being used. Default file names are shown below.

Card 3.5–File Containing Doublet Lattice Geometry Data

Card 3.5 is optional. The default file name is "NGETP" and the default IGCASE = 1.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	NGETp	A10	Keyword introducing a replacement name for the input Doublet Lattice geometry file.
11-20	NGETP	A10	Name of the file (tape or disk) which contains the Doublet Lattice geometry data.
21-25	IGCASE	I5	Number of the data case (logical file) on "NGETP" to be used.
26-70			Available for comments

Card 3.6–File Containing Doublet Lattice Aerodynamic Data

Card 3.6 is optional. The default file name is "NAETP" and the default case number is 1.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	NAETp	A10	Keyword introducing a replacement name for the input Doublet Lattice Aerodynamic file.
11-20	NAETP	A10	Name of the file (tape or disk) which contains the Doublet Lattice aerodynamic data.
21-25	IACASE	I5	Number of the data case (logical file) on "NAETP" to be used.
26-70			Available for comments

Card 3.7–File to Contain the Equations of Motion Coefficients

Card 3.7 is optional. The default name is "EOMTAP."

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	EOMTap	A10	Keyword introducing replacement name for the output equations of motion file.
11-20	EOMTAP	A10	Name of the file (tape of disk) to contain the equations of motion matrices. The name must begin in column eleven, begin with a letter, and have less than seven characters.
21-70			Available for comments

Card 3.8–File to Contain Aerodynamic Force Matrices

Card 3.8 is optional. The default file name is "EOMLOD."

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	EOMLod	A10	Keyword introducing replacement name for the output file to contain the force matrices required by L218, the Load Equations program.
11-20	EOMLOD	A10	Name of the file (tape or disk) to contain the force matrices required by L218, the Load Equations program. The name must begin in column eleven, begin with a letter, and have less than seven characters.
21-70			Available for comments

Card 3.9–Doublet Lattice Quasi-Steady Option

Card 3.9 is optional. The quasi-steady solution may be requested only with Doublet Lattice AIC aerodynamic data for a reduced frequency (k-value) of zero.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	QUASi	A10	Keyword requesting a Quasi-Steady solution for the Doublet Lattice AIC option.
11-70			Available for comments

The quasi-steady option limits processing to the first reduced frequency solution from Doublet Lattice files. Therefore, the first reduced frequency must be zero.

Card 3.10–FLEXSTAB Thin Body Control Point Option

Card 3.10 is optional. It may be used only with FLEXSTAB aerodynamics.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	CENTroids	A10	Keyword requesting L217 (EOM) to use the centroids of thin bodies' panels for both the force points and the control points. Default: Centroids are used for force points and control points will remain as defined in FLEXSTAB.
11-70			Available for comments

Cards 3.11 and 3.11.1–Gradual Penetration

Cards 3.11 and 3.11.1 are optional. They are used only when gradual penetration is desired. Gradual penetration can *not* be requested when using Doublet Lattice generalized forces and pressures.

Card 3.11–Introduce Gradual Penetration Control Points

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	GRAD. pen.	A10	Keyword introducing gradual penetration card input data.
11-20	XG	E10.0	The gust reference point in the reference axis system.
21-25	NGCP	I5	The number of gust control points. (1≤NGCP≤35)
26-70			Available for comments

Card 3.11.1-Gradual Penetration Control Points

Card 3.11.1 is input only after card 3.11. Card 3.11.1 must be repeated for each gradual penetration control point; i = 1,NGCP (from card 3.11).

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$XGCP_i$	E10.0	The reference axis x-coordinate of the gust control point for zone i $XGCP_{i+1} > XGCP_i$
11-20	$XGLE_i$	E10.0	The reference axis x-coordinate of the leading edge of zone i. $XGCP_i \geq XGLE_i$, $XGLE_{i+1} > XGLE_i$
21-70			Available for comments

The program will group all aerodynamic elements into the zones generated by the $XGLE_i$ of card 3.11.1. The gust will reach each panel of zone i at the time it reaches the gust control point $XGCP_i$. $XGLE_i$ must be forward of the first element's control point.

Card 3.12-Request Printed Output

Card 3.12 is optional. If omitted the following items are printed by default: Card input data and interpretation of card input data. Summary of geometry data read from GDTAPE or NGETP.

Card 3.12 must be input once for each optional item to be printed.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	PRINt	A10	Keyword introducing optional item to be printed.
11-20	ITEM	A10	Name of the item to be printed chosen from the following list: MODES: Modal displacements at aerodynamic and force points FORCEs: Aerodynamic forces for each surface EQUAtion: Equations of motion coefficient M_1 through M_5, f_ℓ and $\tilde{\phi}$

Card 3.12.1–Select Frequencies for Printout

Card 3.12.1 is optional. If omitted, the items requested by card 3.12 will be printed for the first reduced frequency only.

COL.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	SELEct	A10	Keyword introducing numbers of frequencies at which data will be printed.
11-15	$IFREQ_1$	12I5	Numbers of frequencies at which data will be printed. If more than 12 frequencies are desired use two SELEct cards.
16-20 . . .	$IFREQ_2$ . . .		

NOTE: The selected array of frequencies applies to *all* print items.

Card 3.12.2-Checkout Printout

Card 3.12.2 is optional and is used to generate intermediate data for problem checkout.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	CHECkout	A10	Keyword requesting the printing of intermediate data calculated during the aerodynamics data processing.
11-15	ICKPRT	I5	Option indicating the amount of intermediate data to be printed. =1 Print message when each overlay is entered and indicate field length required for each overlay. =3 Print items under 1 above plus many of the intermediate calculations i.e. - for FLXAIC print[AIC] , [AIC][ϕ],[AIC][ϕ'] and the full [F1] , [F2] , [FG]. - for DLAIC print[CP_{SB}],[CPG_{SB}],[F],[W],[WG], [ΔCp] and others. - for DLPRES print [ΔCp] and[F_{12}]. =5 Print items under 1 and 3 above plus a message each time a VARDIM routine is called.

Cards 3.13 through 3.16 Mode Shape Definition

The L215 program, modal interpolation (ref. 6) provides all of the mode shapes used inside L217 (EOM). The modal data is defined per surface in arrays called $\{SA\}$ written by L215 (ref. 6) onto the magnetic file named "SATAP."

Cards 3.13 through 3.14.2 are used to define the correspondence between FLEXSTAB bodies and the modal interpolation SA arrays. Cards 3.15 and 3.16 serve the same purpose for Doublet Lattice bodies/surfaces. It should be noted that order of thin and slender bodies is different for the two aerodynamic programs. The correlation of modal data and aerodynamic bodies is only concerned with them and slender bodies. Interference bodies are not considered, since their effects are accounted for when dealing with their respective slender bodies (see sec. 4.0).

The thin and slender bodies in FLEXSTAB are ordered in the following manner:

- Slender bodies on the plane of symmetry.
- Slender bodies off the plane of symmetry.
- Thin bodies on the plane of symmetry.
- Thin bodies off the plane of symmetry.

Within each catagory of slender and thin bodies, the ordering must match the ordering used in the FLEXSTAB aerodynamic geometry program.

The ordering of the Doublet Lattice data must correspond to the lifting surface panel/slender body order established in the Doublet Lattice aerodynamic program (L216) which is:

- Primary vertical lifting surface panel (thin bodies) on the plane of symmetry.
- Other primary lifting surface panels (thin bodies) off the plane of symmetry.
- Y-motion slender bodies.
- Z-motion slender bodies.

Within each major catagory, the user must assure that the order matches that of the Doublet Lattice run which created the aerodynamic data. (Note: When using Doublet Lattice aerodynamics, the term "thin body" refers to a primary lifting surface panel.)

Cards 3.13 Through 3.14.2–FLEXSTAB Body Modes

Omit cards 3.13 through 3.14.2 if Doublet Lattice aerodynamics are being used.

Card 3.13–FLEXSTAB Slender Body Modes

Repeat card 3.13 for each FLEXSTAB slender body in the order they appear on GDTAPE.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	SLENder body	A10,10X	Keyword introducing a card defining mode shapes for a slender body.
21-25	ISY	I5	The numbers of the Modal Interpolation Program (ref. 6) surfaces (SA arrays) to be used to determine the Y and Z motion, respectively, for this slender body. If ISn = 0, modal displacements of zero will be used. (See section 4.6.1).
26-30	ISZ	I5	
31-35	ISTORE	I5	File number (a surface number) of EOMLOD in which the aero force matrices will be written. ISTORE > 0.
36-40		5X	Not Used
41-50	XSHIFT	E10.0	Shifting values (defined in the reference axis system) which are used to account for the difference between the local structural axis system and the local aerodynamic axis system, and/or to account for any desired axis corrections needed.
51-60	YSHIFT	E10.0	
61-70	ZSHIFT	E10.0	

***Normally, ISTORE will be equal to ISY or ISZ. If both ISY and ISZ are defined ISTORE should be equal to ISZ.**

3.14–FLEXSTAB Thin Body Modes

Repeat cards 3.14 through 3.14.2 for each FLEXSTAB thin body in the order they appear on GDTAPE.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	THIN body	A10,10X	Keyword introducing a card defining mode shapes for a thin body.
21-25	IS	I5	Number of the Modal Interpolation Program (ref. 6) surface. (SA array) to be used to determine the motion of this thin body. (See section 4.6.1).
26-30		5X	Not Used
31-35	ISTORE	I5	File number (a surface number) of EOMLOD on which the aero force matrices will be written.*
36-40		5X	Not Used
41-50	XSHIFT	E10.0	Axis shifting values (defined in the reference axis
51-60	YSHIFT	E10.0	system) which account for the difference between the
61-70	ZSHIFT	E10.0	local structural and aerodynamic axis system and/or any axis correction desired.

*If ISTORE is left blank ISTORE = IS is assumed. If IS = 0 (mode shapes of zero) then ISTORE must be non-zero.

Cards 3.14.1 and 3.14.2 are optional. They are input in pairs to define mode shapes for subsurfaces (control surfaces) of the previously defined thin body.

Card 3.14.1–FLEXSTAB Control Surface Modes

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	CONTrol surface	A10,10X	Keyword introducing a card defining mode shapes for a control surface.
21-25	IS	I5	Number of the Modal Interpolation Program (Ref. 6) surface corresponding with the motion of the control surface.
26-30	NCSPAN	I5	Number of panels on the control surface.
31-35	ICSTOR	I5	File number (a surface number) of EOMLOD in which the aero forces will be written. If ICSTOR is left blank it is set equal to ISTORE of the parent thin body.
36-70			Available for comments.

Card 3.14.2–Panels on the FLEXSTAB Control Surface

Card 3.14.2 must follow card 3.14.1.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-5	$IPAN_1$	14I5	Numbers of the panels of the thin body which are on the control surface.
6-10	$IPAN_2$ . . .		$IPAN_i$; i = 1, NCSPAN
66-70	$IPAN_{14}$		
			Repeat the card with 14 numbers per card until all panels on the control surface are specified.

$IPAN_i$ indicates the panel number as counted relative to the first panel on the parent thin body.

Cards 3.15 Through 3.16–Doublet Lattice Body Modes

Omit cards 3.15 through 3.16 if FLEXSTAB aerodynamics are being used.

Card 3.15–Doublet Lattice Thin Body (Primary Lifting Surface Panel) Modes

Repeat cards 3.15 through 3.15.2 for each Doublet Lattice thin body in the order they appear on NGETP.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	THIN body	A10,10X	Keyword introducing a card defining mode shapes for a thin body.
21-25	IS	I5	Number of the Modal Interpolation Program (ref. 6) surface (SA array) to be used to determine the motion of this thin body.
26-30		5X	Not Used
31-35	ISTORE	I5	File number (a surface number) of EOMLOD in which the aero force matrices will be stored.*
36-40		5X	Not Used
41-50	XSHIFT	E10.0	Aerodynamic axis shifting values (defined in reference axis system) which accounts for the difference between the local structural and aerodynamic axis systems and/or any axis correction desired.
51-60	YSHIFT	E10.0	
61-20	ZSHIFT	E10.0	

* If ISTORE is left blank the program sets ISTORE = IS.

If IS = 0 (mode shapes of zero) then ISTORE must be non-zero.

Cards 3.15.1 and 3.15.2 are optional. They are input in pairs; one pair for each control surface on the previously defined thin body requiring different mode shape definitions.

Card 3.15.1–Doublet Lattice Control Surface Modes

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	CONTrol surface	A10,10X	Keyword introducing a card defining mode shapes for a control surface.
21-25	IS	I5	Surface number specified to the Modal Interpolation Program (Ref. 5) when defining mode shapes for this control surface.
26-30	NCSBOX	I5	Number of boxes on the control surface.
31-35	ICSTOR	I5	File number (a surface number) of EOMLOD in which the aero forces will be written. If ICSTOR is left blank it is set equal to ISTORE of the parent thin body.
36-70			Available for comments.

Card 3.15.2–Boxes on a Doublet Lattice Control Surface

Card 3.15.2 must follow card 3.15.1.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-5	$IBOX_1$	14I5	Numbers of the boxes of the thin body which are on the control surface.
6-10	$IBOX_2$		$IBOX_i$; i = 1, NCSBOX
11-15	$IBOX_3$		
.	.		
.	.		
.	.		
66-70	$IBOX_{NCSBOX}$		
			Repeat the card with 14 numbers per card until all panels on the control surface have been specified.

$IBOX_i$ indicates the box number as counted relative to the first box on the parent thin body.

Card 3.16–Doublet Lattice Slender Body Modes

Repeat card 3.16 for each Doublet Lattice slender body in the order they appear on NAETP.

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-20	SLENder body	A10 10X	Keyword introducing a card defining mode shapes for a slender body.
21-25	ISY	I5	Number of the Modal Interpolation Program (ref. 6) surface (SA array) to be used to determine the Y or Z motion, respectively, for this slender body. Specify only one! (See section 4.6.1 and 4.7.1)
26-30	ISZ	I5	
31-35	ISTORE	I5	File number (a surface number) of EOMLOD in which the aero force matrices will be written.*
36-40		5X	Not Used
41-50	XSHIFT	E10.0	Aerodynamic axis shifting values (defined in the reference axis system) which account for the difference between the local structural axis and the local aero-dynamic axis and/or any axis corrections desired.
51-60	YSHIFT	E10.0	
61-70	ZSHIFT	E10.0	

* Normally, ISTORE will be equal to ISY or ISZ (whichever is defined).

Card 3.17–End of Aerodynamic Card Data

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	END	A10	Keyword signaling the end of FLEXSTAB or Doublet Lattice aerodynamic card input data.
11-70			Available for comments

Card Set 4.0–Terminate L217 (EOM) Execution

COLS.	KEYWORD/ VARIABLE	FORMAT	DESCRIPTION
1-10	$QUIt	A10	Keyword requesting that L217 (EOM) execution be terminated.
11-70			Available for comments

6.3.4 SUMMARY OF CARD INPUT DATA

Requirements or Function	Key Words and/or Variables	Card Format	Reference Card Set (CS)
	$FROM	A10	1.0
Job title card (Optional)	$TITle	A10	1.1
Job checkout card (Optional)	$NON-stop	A10	1.2
Begin input of Structural Data	$STRuctural	A10	2.0
Number of degrees of freedom	SIZE NDOFST NDOFCS	A10,2I5	2.1
Type of analysis (Optional	SYMMetric ANTI-symmetric	A10	2.2
(Optional)	FULL HALF	A10	2.3
(Optional)	CHECkout ICKPRT	A10,I5	2.4
Modal Interpolation data to use for control surface inertial coupling (Optional)	MODEs SATAP	2A10	2.5
Source of Stiffness Data	STIFfness KTAPE KFILE KMAT PRINt	2A10,2I5,A10	2.6
Omit card 2.6.1 if KTAPE ≠ CARDS (card 2.6)			
Repeat card 2.6.1 for each row of K; i = 1, NDOFST	K(i,j) j = 1, NDOFST	7E10.0	2.6.1
Source of Mass Data	MASS MTAPE MFILE NMAT PRINt	2A10,2I5,A10	2.7
Omit card 2.7.1 if MTAPE ≠ CARDS (card 2.7)			
Repeat card 2.7.1 for each row of M i = 1, NDOFST	M(i,j) j = 1, NDOFST	7E10.0	2.7.1

Requirements or Function	Key Words and/or Variable	Card Format	Reference Card Set (CS)
Introduce Structural Damping (Optional)	DAMPing	A10	2.8
Damping Factors (Must follow card 2.8)	gsd (i) i = 1,NDOFST	7E10.0	2.8.1
	Omit cards 2.9 and 2.9.1 if NDOFCS = 0 (card 2.1)		
Cards 2.9 and 2.9.1 are repeated for each control surface affected by the additional control surface freedoms.	SURFace IS NNODEI Trans Rot1 Rot2 Local	A10,2I5,4A10	2.9
	Repeat card 2.9.1 NNODEI times (card 2.9)		
	X_i Y_i Z_i $MASS_i$ $INERTY_i$ $INERTX_i$	6E10.0	2.9.1
End of Structural Data	END	A10	2.10
Introduction of Aerodynamic Data	$AER FLEXstab AIC DOUBlet PRESsure	3A10	3.0
Aerodynamic constants	CONStants RHO VEL NTDEF NPDEF	A10,2E10.0, 2I5	3.1
Mode Shape Input file (Optional)	SATAp= ISATAP	2A10	3.2
FLEXSTAB Aerodynamic Data. Read only if FLEXSTAB aerodynamic option chosen (card 3.0) (Optional)	GDTApe= GDTAPE IGCASE	2A10,I5	3.3
	SDSStp= SDINDX SDDATA ISCASE	3A10,I5	3.4
Doublet Lattice Aerodynamic Data. Read only if Doublet Lattice option chosen (card 3.0) (Optional)	NGETp= NGETP IGCASF	2A10,I5	3.5
	NAETp= NAETP IACASF	2A10,I5	3.6

Requirements or Function	Key Words and/or Variables	Card Format	Reference Card Set (CS)
(Optional)	EOMTap= EOMTAP	2A10	3.7
(Optional)	EOMLod= EOMLOD	2A10	3.8
Quasi-Steady option. Only if Doublet Lattice AIC Aerodynamics used (card 3.0)	QUASi-steady	A10	3.9
Thin Body Control Point option. Read only if FLEXSTAB Aerodynamics used. (card 3.0) (Optional)	CENTroids	A10	3.10
	Omit cards 3.11 and 3.11.1 if Doublet Lattice pressures used (card 3.0)		
Gradual Penetration	GRAD. pen XG NGCP	A10,E10.0, I5	3.11
Gradual Penetration Control Points. Repeat card 3.11.1 for each Control Point i=1, NGCP	$XGCP_i$ $XGLE_i$	2E10.0	3.11.1
Print request (Optional) Repeat card 3.12 for each item desired	PRINt MODES FORCEs EQUAtions	2A10	3.12
Frequency Selection (Optional)	SELEct $IFREQ_1$ $IFREQ_2$ . . .	A10,12I5	3.12.1
Checkout Printout (Optional)	CHECkout ICKPRT	A10,I5	3.12.2

Requirements or Function	Key Words and/or Variables	Card Format	Reference Card Set (CS)
	If Doublet Lattice Aerodynamics are used omit cards 3.13 through 3.14.2		
Repeat card 3.13 for each FLEXSTAB Slender Body	SLENder body ISY ISZ ISTORE XSHIFT YSHIFT ZSHIFT	A10,10X,3I5, 5X,3E10.0	3.13
Repeat cards 13.4 through 3.14.2 for each FLEXSTAB Thin Body	THIN body IS ISTORE XSHIFT YSHIFT ZSHIFT	A10,10X,I5,5X, I5,5X,3E10.0	3.14
Control Surface modes (Optional)	CONTrol surface IS NCSPAN ICSTOR	A10,10X,3I5	3.14.1
Control Surface panels. Must follow card 3.14.1	$IPAN_i$ i = 1, NCSPAN (card 3.14.1)	14I5	3.14.2
	Omit cards 3.15 through 3.16 if FLEXSTAB Aerodynamics are used.		
Repeat cards 3.15 through 3.15.2 for each Doublet Lattice Thin Body	THIN body IS ISTORE XSHIFT YSHIFT ZSHIFT	A10,10X,I5,5X, I5,5X,3E10.0	3.15
Control Surface Modes (Optional)	CONTrol surface IS NCSBOX ICSTOR	A10,10X,3I5	3.15.1
Card 3.15.2 must follow 3.15.1	$IBOX_i$ i = 1, NCSBOX (card 3.15.1)	14I5	3.15.2
Repeat card 3.16 for each Doublet Lattice Slender Body	SLENder body ISY ISZ ISTORE XSHIFT YSHIFT ZSHIFT	A10,10X,3I5, 5X,3E10.0	3.16
End of Aerodynamic Data	END	A10	3.17
	$QUIt	A10	4.0

6.4 MAGNETIC FILE INPUT DATA

When used as a module in the DYLOFLEX, much of the data required by L217 (EOM) is prepared by upstream programs and written on magnetic files (disk or tape) to be read and used by L217. The file names and the programs that normally generate them are:

Default Name	Generating Program	References
GSTIFF	–	–
GMASS	–	–
SATAP	Modal Interpolation L215	6
NGETP	Doublet Lattice L216	8
NAETP	Doublet Lattice L216	8
GDTAPE	FLEXSTAB	7
SDINDX	FLEXSTAB	7
SDDATA	FLEXSTAB	7

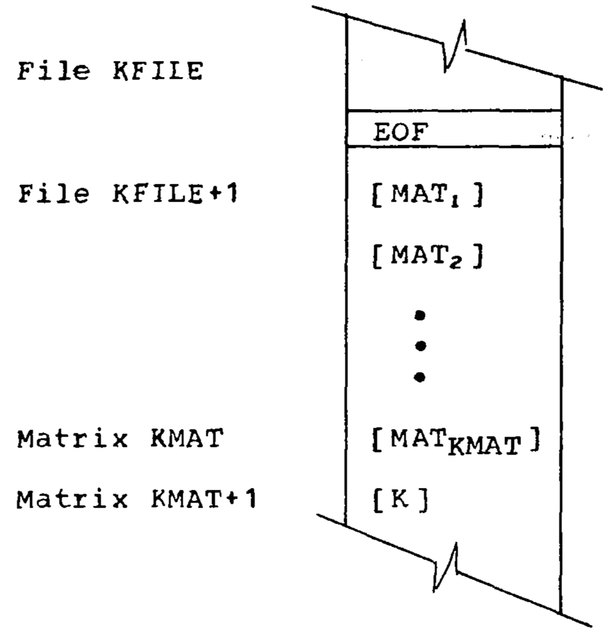
Note that different file names may be specified via card input data (see cards 2.5 through 2.7 and 3.2 through 3.6). Also, the files may be generated by different computer programs as long as the content and format matches that described on the following pages.

6.4.1 "GSTIFF"-GENERALIZED STIFFNESS MATRIX

"GSTIFF," the generalized stiffness matrix, may be read by L217 (EOM) from a magnetic file (tape or disk) in the READTP/WRTETP format (see ref. 2). L217 (EOM) rewinds the file before attempting to read the stiffness matrix $[K]$. If requested via card input data the program will also skip "KFILE" logical files and "KMAT" matrices before reading $[K]$ (see fig. 19).

6.4.2 "GMASS"-GENERALIZED MASS MATRIX

"GMASS," the generalized mass matrix, may be read by L217 (EOM) from a magnetic file (tape or disk) in the READTP/WRTETP format (see ref. 2). L217 (EOM) rewinds the file before attempting to read the mass matrix $[M]$. If requested via card input data, the program will also skip logical "MFILE" files and "MMAT" matrices before reading $[M]$ (see fig. 20).

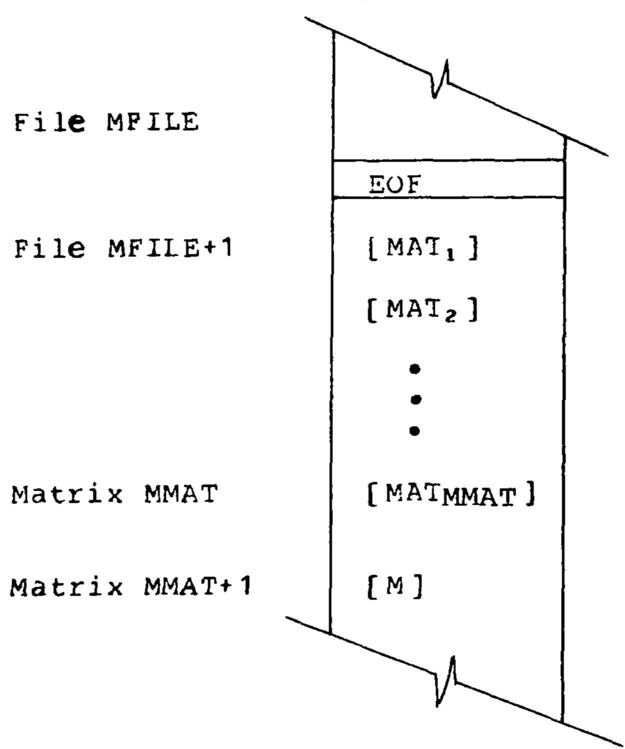


[K] the generalized stiffness matrix is of size

$NDOF_{ST} \times NDOF_{ST}$

where $NDOF_{ST}$ is the number of structural degrees of freedom.

Figure 19. — Contents of GSTIFF



[M] the generalized mass matrix is of size

$NDOF_{ST} \times NDOF_{ST}$

where $NDOF_{ST}$ is the number of structural degrees of freedom.

Figure 20. — Contents of GMASS

6.4.3 "SATAP"-MODAL DATA FILE

The mode shape data required by L217 (EOM) is generated by the program L215 (INTERP) (ref. 6) and written on a magnetic file, "SATAP", (card 2.3) in the READTP/WRTETP format described in reference 2.

L215 (INTERP) writes one logical file of data for each surface for which mode shapes are defined. The file number has a one-to- one correspondence with the surface number. Thus, when L217 (EOM) needs modal data for surface "IS," it rewinds "SATAP" and skips "IS-1" logical files before reading.

The contents of one file on "SATAP" are displayed in figure 21.

Matrix Size	Matrices in file i of SATAP
NNODES x NMODES	$[\phi_x]$
NNODES x NMODES	$[\phi_y]$
NNODES x NMODES	$[\phi_z]$
NNODES x NMODES	$[\phi_{\theta_x}]$
NNODES x NMODES	$[\phi_{\theta_y}]$
NNODES x NMODES	$[\phi_{\theta_z}]$
NNODES x 6	[geom]
NSA x 1	{SA}
	End-of-File

where NMODES = number of modes

NNODES = number of nodes

and NSA $\leq$ 10000

Note: NSA is dependent on the method of interpolation (See Reference 5)

Figure 21. — Contents of a File on SATAP

$[\phi_x]$, $[\phi_y]$ and $[\phi_z]$ contain the modal deflections at the nodes in the x, y and z directions of the local structural coordinate system.

$[\phi\Theta_x]$, $[\phi\Theta_y]$ and $[\phi\Theta_z]$ contain the modal rotations about the x, y and z axes at the nodes in the local structural coordinate system.

[geom] contains the nodal descriptions. For each node the following six items are defined:

X = coordinate in the reference axis system

Y = coordinate in the reference axis system

Z = coordinate in the reference axis system

ϕ_X = rotation about the x-axis in radians

ϕ_Y = rotation about the y-axis in radians

ϕ_Z = rotation about the z-axis in radians

{SA} contains information to allow interpolation for mode shapes over the nodes. The length and contents of {SA} vary with the interpolation type (surface spline, beam spline, motion point, motion axis, polynomial). See reference 6 for a complete description.

6.4.4 "NGETP"-DOUBLET LATTICE GEOMETRY FILE

When Doublet Lattice L216 (ref. 8) geometry data is required by L217 (EOM), it is read in the READTP/WRTETP format from "NGETP," a magnetic file (tape or disk) (see ref. 1). L217 (EOM) rewinds the file before attempting to read the data. If the user specifies a data case, "IGCASE," other than number one, the program will also skip "IGCASE-1" logical files before reading.

For each data case, "NGETP" contains 18 matrices followed by an end-of-file (see fig. 22). All geometry is defined in the reference axis system.

The following variables are used to define array sizes on "NGETP."

NBOD = number of primary lifting surface panels (thin bodies), plus the number of slender bodies

NBOX = number of aerodynamic boxes on all primary lifting (thin body) and interference surfaces

NTOT = number of aerodynamic elements (boxes plus slender body segments) on all surfaces (primary lifting, interference, and slender bodies)

NSBE = number of slender body segments (counting all slender bodies)

Three of the matrices on "NGETP" are described below. The others are self-explanatory.

Matrix Size	Matrix	Description
15 x 1	{GCM}	Geometry Control Matrix
8 x NBOD	[BODTAB]	Table of thin and slender bodies
* x 1	{PSG}	Primary surface geometry
* x 1	{ISG}	Interference surface geometry
* x 1	{SBG}	Slender body geometry
NBOX x 1 NBOX x 1 NBOX x 1	{XC4} {YC4} {ZC4}	Coordinates of 1/4 chord points on all thin and interference surface elements
NBOX x 1 NBOX x 1 NBOX x 1	{X3C4} {Y3C4} {Z3C4}	Coordinates of 3/4 chord points on all thin and interference surface elements
NTOT x 1	{A}	Areas of all elements
NTOT x 1	{Y}	Dihedral angles of all elements
NTOT x 1	{IBSB}	Table defining correspondence between interference body and slender body elements
NSBE x 1	{SBL}	Slender body segment lengths
NSBE x 1	{SBX}	Slender body segment midpoint
NSBE x 1	{SBR}	Slender body segment midpoint radii
NSBE x 1	{SBRS}	Slender body segment midpoint radius slopes.
	End-of-File	

* Difficult to calculate and not required by L217 (EOM)

Figure 22. — Contents of a File on NGETP

{GCM}-Geometry Control Matrix

Element	Type	Description
ICASE	I	Case number.
ICOND	I	Condition number
IGEOM	I	Geometry data successfully saved if "IGEOM = 1".
REFCHD	R	Reference chord length.
REFSPN	R	Reference span length.
ACAP	R	Reference area.
FMACH	R	Mach number.
NTBB	I	Number of thin body boxes.
NIBB	I	Number of interference body boxes.
NSBE	I	Number of slender body segments.
NTB	I	Number of thin bodies (the number of lifting surface panels).
NSB	I	Number of slender bodies.
NPLS	I	Number of primary lifting surfaces.
NPIS	I	Number of interference surfaces.
-	-	Not Used.

where:

R = Real

I = Integer

[BODTAB]-Table of Thin and Slender Bodies

Note: There is one thin body for each lifting surface panel. The matrix will contain one column for each body.

Element Location	Element	Type	Description
(1,I)	ITYPE	I	1 = slender body and 3 = thin body.
(2,I)	IPOS	I	0 = off-POS and 1 = on-POS.
(3,I)	Xo	R	Origin for local aerodynamic axis system of the body (in the referenced axis coordinate).
(4,I)	Yo	R	
(5,I)	Zo	R	
(6,I)	γ	R	Dihedral angle of the body.
(7,I)	IFIRST	I	Pointers to the first and last boxes of the body in the total array of the structure's boxes.
(8,I)	LAST	I	

where:

R = Real

I = Integer

{IBSB}-Correspondence Between Interference Body Boxes and Slender Body Segments

Each interference body box will be associated with one or two slender body segments: two if the physical slender body is represented by two slender bodies, one for y motion and another for z motion. Therefore, each element i of the matrix {IBSB} will contain 0, 1, or 2 numbers.

If element i represents a thin body box or a slender body segment, then $IBSB_i = 0$.

If element i represents an interference body box, the first slender body segment with which it is associated, JSB1, will appear in the right-most 30 bits of $IBSB_i$. If there is a second segment, JSB2, it will appear in the left-most 30 bits.

$IBSB_I$ =

JSB2	JSB1
1 30	60

6.4.5 "NAETP"-DOUBLET LATTICE AERODYNAMIC FILE

When Doublet Lattice L216 (ref. 8) aerodynamic data is required by L217 (EOM), it is read from "NAETP," a magnetic file (tape or disk), in the READTP/WRTETP format (see ref. 1). L217 (EOM) rewinds the file before attempting to read the data. If the user specifies a data case, "IACASE," other than number one, the program will skip "IACASE-1" logical files on "NAETP" before reading data.

The number of matrices on "NAETP" for each data case depends upon the option chosen in Doublet Lattice. The variable "IAERO" can be extracted from element 3 of the aerodynamic control matrix, the first matrix for each case. If:

IAERO = 1 — Matrices [D] and [F] are written onto "NAETP" for each reduced frequency

IAERO = 2 — Matrices $[\Delta C_p]$ and [Q] are written onto "NAETP" for each reduced frequency

IAERO = 3 — Matrices [D], [F], $[\Delta C_p]$ and [Q] are all written onto "NAETP"

The following variables define the size of matrices on "NAETP" displayed in figure 23.

NFREQM = Number of reduced frequencies at which the aerodynamic data is defined

NBOX = Number of lifting surface boxes (lifting and interference)

NTOT = Number of elements on all surfaces (lifting, interference, and slender)

NMODE = Number of modes used in Doublet Lattice

Matrix Size	Matrix	Description	
(NFFEQM+14) x 1	{ACM}	Aerodynamic Control Matrix (see next page)	A
1 x 2NSBFP	$\lfloor F \rfloor_1$	[F] matrix by rows	A
1 x 2NSBFP	$\lfloor F \rfloor_2$		A
•	•		A
•	•		A
•	•		A
1 x 2NSBFP	$\lfloor F \rfloor$		A
	I-Matrix Trapezoidal	Two matrices in a variable number of records representing the quasi-inverse	A
	10HQUASI-END	Record terminating Quasi-Inverse	A
2NTOT x 1	$\{CP\}_1$	[CP] - pressure coefficient Matrix by columns	B
2NTOT x 1	$\{CP\}_2$		B
	•		B
	•		B
	•		B
2NTOT x 1	{CP}		B
2NMODE x NMODE	[Q]	Generalized Air Forces	B
	End-of-File		

(A) Available only if IAERO = 1 or 3

(B) Available only if IAERO = 2 or 3

(A) and/or (B) are repeated for each reduced frequency: IFREQ = 1, NFREQM

Figure 23. — Contents of a File on NAETP

Aerodynamic Control Matrix

Element Location	Element	Type	Description
1	ICASE	I	Case number.
2	ICOND	I	Condition number.
3	IAERO	I	Option indicating the aerodynamic data saved. = 1 [D] and [F] saved for each frequency. = 2 {CP} and [Q] saved for each frequency. = 3 both 1 and 2 above.
4	FMACH	R	Mach number.
5	NFREQM	I	Number of reduced frequencies.
6	NBOX	I	Number of lifting surface boxes.
7	NSB	I	Number of slender body elements.
8	NMODE	I	Number of modes.
9	REFCHD	R	Reference chord.
10	REFSPN	R	Reference span.
11	ACP	R	Reference area.
12	BR	R	Reference length.
13	-	-	Not used.
14	-	-	Not used.
15	RFREQ(1)	R	First reduced frequency.
•			
•			
•			
	RFREQ (NFREQM)	R	Last reduced frequency.

where:

R = Real

I = Integer

6.4.6 "GDTAPE"-FLEXSTAB GEOMETRY FILE

Each configuration (i.e., each data case) processed by the GD program is written sequentially on "GDTAPE" as one logical file. A file begins with a 50-word header record followed by two records for every slender, interference, and thin body in the configuration. The file ends with a 50-word trailer record and an end-of-file (EOF) mark. A complete description of "GDTAPE" is provided in appendix A of reference 7, volume 2.

The GD program has the ability to process the geometry definitions for more than one airplane configuration; therefore, there may be more than one logical file (i.e., one file per aircaft configuration).

After the GD program terminates, the "GDTAPE" magnetic tape is generated by the job control card:

COPYBF(TAPE1,GDTAPE,n)

where n = number of logical files generated by the GD program.

Prior to running L217 (EOM), the data on tape must be recopied to the disk file, named "GDTAPE" by the job control card:

COPYBF(TAPE,GDTAPE,n)

6.4.7 "SDINDX/SDDATA"-FLEXSTAB AERODYNAMIC FILE

SDSSTP is a binary tape generated by the FLEXSTAB SD&SS program (ref. 7) and is composed of many logical files. In general, these files consist of:

- A master catalog of the contents of SDSSTP. This catalog is always the first file on the tape.

- Miscellaneous data required by the TH, SLOADS, and ALOADS programs. These data are stored in one file and consist of such information as moments of inertia, center of gravity location, number and size of the stability derivative matrices, etc.

- Slender body and thin body lifting pressure data. These data are stored in one logical file.

- The $[K_1]$ and $[M_1]$ structural matrices. These matrices (if they exist) are copied from SICTP3 onto SDSSTP.

- Stability derivative matrices.

- Displacement and camber slope matrices.

- Elastic axis load matrices (optional).

- Gust matrices (optional)

- Any user-specified matrices. An option in the SD&SS program allows the user to specify matrices to be stored on SDSSTP, in addition to those that normally are saved.

Each matrix is stored as one logical file. The first file on SDSSTP, is the master catalog. It is composed of several data records. There are two types of data records in this catalog–matrix records and terminal records. A matrix record contains information pertaining to the data stored in one particular file of SDSSTP. Thus, for each file on SDSSTP (not counting the master catalog), there is a corresponding matrix record in the master catalog. A terminal record is used to signify the end of the catalog.

If the SD&SS recycle capability is used (i.e., more than one data case is executed), the overall format of SDSSTP changes slightly. For each successive data case, only those matrices that are different from those of the initial case are saved (i.e., no duplication of data exists on SDSSTP). This change is also reflected in the first file (the master catalog). Additional matrix records corresponding to the files (matrices) added to SDSSTP are also included. Terminal records are used to indicate the end of the sequence of matrix records for each data case. In other words, the master catalog contains: a sequence of matrix records pertaining to the matrices saved from the initial case; a terminal record; another sequence of matrix records reflecting the new matrices added to SDSSTP from the second data case; another terminal record; and so on, for as many cases as executed. A detailed description of SDSSTP is contained in appendix A of reference 7, volume 2.

After execution of the SD&SS program, the SDSSTP tape is generated by the job control cards:

COPYBF(TAPE12,SDSSTP,1)	(Master catalog)
COPY(TAPE14,SDSSTP)	(Matrices, SDSS data, and SPRES data)
COPYBF(EOF,SDSSTP,1)	(EOF mark on tape)

Before executing L217 (EOM), the data on tape SDSSTP must be copied to disk by the job control cards:

COPYBF(SDSSTP,SDINDX)	(Master catalog)
COPY(SDSSTP,SDDATA)	(Matrices required)

6.5 OUTPUT DATA

L217 (EOM) will produce a printed output listing and two magnetic files (tape or disk).

6.5.1 PRINTED OUTPUT

The program will initialize and terminate the printed output, with special pages indicating the program name, version, and date of run.

All card input data will be printed as it is read. Where appropriate, the card images will be augmented by interpretative comments and/or diagnostics.

The geometry from the aerodynamic program will be printed in tabular form with control information based upon card input instructions.

An explanation of the SIGMA and RG arrays appearing in the geometry tables follows.

[SIGMA]

Each row is of [SIGMA] (also known as [Σ]) indicates where the forces on aerodynamic element i are to be stored. The primary purpose of SIGMA is to add the interference body forces to the slender body forces. However, as noted later, other factors are included in SIGMA for a FLEXSTAB AIC data case.

SIGMA(i,1) Indicates which force point will receive the SIGMA(i,2) fraction of the force of aerodynamic element i.

SIGMA(i,3) Indicates which force point will receive the SIGMA(i,4) fraction of the force of aerodynamic element i.

For a FLEXSTAB AIC data case, the following ΔC_p factors are included in the second and fourth columns of SIGMA:

- $\pi/2$ for slender body Y-motion elements.
- $-\pi/2$ for slender body Z-motion elements.
- 1.0 for thin body elements.
- -1.0 for interference body elements.

{RG}

The gust rotation matrix has elements for all thin body and slender body control points.

For a thin body element i

Symmetric analysis: $RG = \cos\gamma_i$

Antisymmetric analysis: $RG = -\sin\gamma_i$

where γ_i is the element's dihedral angle

For a slender body element i

Symmetric analysis: Y-motion element $RG_i = 0.$

Z-motion element $RG_i = 1.$

Antisymmetric analysis: Y-motion element $RG_i = -1.$

Z-motion element $RG_i = 0.$

Note: The gust rotation matrix, which is printed, contains the sign function δ_W shown in equation (12).

All other printed output must be requested with card input options.

During the processing of structural data, the program will optionally print:

[K] Generalized stiffness matrix read from tape (see card 2.4).

[M] Generalized mass matrix read from tape (see card 2.5).

Cards 3.12 and 3.12.1 may be used to cause the following items to be printed during the processing of aerodynamic data:

- Interpolated mode shapes.
- Contents of the file "EOMLOD" (the forces).
- Contents of the file "EOMTAP" (the equations of motion).

Additional intermediate calculations may be requested using the checkout option, card 3.12.2.

6.5.2 MAGNETIC FILE OUTPUT

L217 (EOM) will generate two magnetic files, "EOMTAP" and "EOMLOD." Both are written in the READTP/WRTETP format described in reference 1.

"EOMTAP"

The file known as "EOMTAP" will contain the equations of motion matrices generated by the L217 (EOM) program. The matrices are written onto "EOMTAP" by the subroutine WRTETP (see ref. 1 for a description of WRTETP formats). The contents of "EOMTAP" are displayed in figure 24.

"EOMLOD"

The file known as "EOMLOD" will contain aerodynamic geometry and forces for use in the DYLOFLEX LOADS program (ref. 7). The data is written onto "EOMLOD" by the subroutine WRTETP (see ref. 1 for a description of WRTETP formats). The contents of "EOMLOD" are displayed in figure 25.

Contents of Aerodynamic {HEADER} Array

The array HEADER will always contain 30 words.

Word	Contents
1	7HDYLOFLX.
2	6HL2217vc.
3	Date of run in format 10Hyr/mo/da.
4	NDOF = number of degrees of freedom ($1 \leq NDOF \leq 100$).
5	NID = 0.
6	NGCP = number of gust control points ($1 \leq NGCP \leq 35$).
7	NFREQM = number of reduced frequencies ≥ 1.
8	q = dynamic pressure = 1/2
9	V = velocity = true airspeed.
10-20	Future use = 0.
21	1 indicates $[M_1]$ is on "EOMTAP."
22	0 or 1; a 1 indicates $[M_2]$ is on "EOMTAP."

Size of Matrix	Matrix	Description
30 x 1	{HEADER}	DYLOFLEX Header Matrix describing the file
NDOF x NDOF	$[M_1]$	Generalized stiffness
NDOF x NDOF	$[M_2]$	Generalized structural damping (Viscous)
NDOF x NDOF	$[M_3]$	Generalized Mass
NFREQM x 1	{FREQM}	Frequencies [Hz] for which the following aerodynamic matrices are defined
NDOF x NDOF	$[M_4]$	Generalized aerodynamic stiffness forces.
NODF x NDOF	$[M_5]$	Generalized aerodynamic damping forces.
NGCP x 1	$\{f_\ell\}$	Distance between gust control point and the gust zones
NDOF x NGCP	$[\tilde{\phi}]$	Excitation aerodynamic generalized forces
	End-of-File	

where

($[M_4]$, $[M_5]$ and $[\tilde{\phi}]$ are repeated for frequencies 2, 3 ..., NFREQM.)

NDOF = number of generalized coordinates (number of modes)

NFREQM = number of frequencies at which the aerodynamics are defined

NGCP = number of gust control points (zones)

1 Contents of HEADER are described on the following page.

2 $[M_2]$ is present only if requested by Card 2.8.

3 $\{f_\ell\}$ is present only for the first frequency

4 $[\tilde{\phi}]$ is complex. Therefore, the actual size written on the file is 2NDOF x NGCP.

Figure 24. – Contents of EOMTAP

Size of Matrix	Matrix	Description
NELE x 2	[X,Y]	Local coordinates of the surface's elements
NELE x 1	{A}	Areas of the surface's elements
NFREQM x 1	{FREQM}	Frequencies for which the aerodynamic matrices below are defined
NELE x NDOF	$[F_1]$	Response air forces (coefficients of q)
NELE x NDOF	$[F_2]$	Response air forces (coefficients of $\dot{q}$)
NELE x NGCP	[FG]	Gust air forces (complex)
	End-of-File	
		$[F_1]$, $[F_2]$ and [FG] are repeated for each frequency

where

NELE = number of aerodynamic elements on surface i.

NDOF = number of generalized coordinates

NGCP = number of gradual penetration gust zones.

1 [FG] is complex. Therefore, the actual size written on the file is 2NELE x NGCP.

The logical file shown above is repeated for every surface (see ISTORE on Cards 3.12-3.15). There will be empty files for imbedded surfaces not defined.

Figure 25. — Contents of EOMLOD

23 1 indicates $[M_3]$ is on "EOMTAP."

24 1 indicates $[M_4]$ is on "EOMTAP."

25 1 indicates $[M_5]$ is on "EOMTAP."

26 0 indicates $[M_6]$ is *not* on "EOMTAP."

27 0 indicates $\{C_2\}$ is *not* on "ECMTAP."

28 0 indicates $\{C_3\}$ is *not* on "EOMTAP."

29 1 indicates $\{f_\ell\}$ is on "EOMTAP."

30 1 indicates $[\tilde{\Phi}]$ is on "EOMTAP."

6.6 RESTRICTIONS

L217 (EOM) problem size maximums are displayed below.

Variable	Maximum	Variable Description
NMODES	100	Number of modes.
NTOTF	400	Total number of aerodynamic elements on all bodies (thin, slender, and interference).
NGCP	35	Number of gust control points (zones).
NFREQM	20	Number of reduced frequencies at which aerodynamics are defined.
Nmax	100	Number of aerodynamic elements for an interpolation surface.

6.7 DIAGNOSTICS

All errors detected by L217 (EOM) will result in the printing of a diagnostic message. The message will be introduced by the line,

********FATAL ERROR n IN name

where "n" indicates the error number (see the list below) and "name" indicates the routine printing the message. The introductory line will be followed by other lines describing the error conditions.

Error Number	Description of Error
1	Premature end-of-file on card input.
2	Keyword on data card is inappropriate or unrecognizable.
3	Structural data not processed correctly before processing aerodynamic card input data.
4	Illegal file name.
5	Illegal file or matrix spacing.
6	Variable outside allowable range.
7	FETAD error trying to generate a file's FIT, buffer, and RA+2 entry.
8	FETDEI error trying to release a file's FIT, buffer, and RA+2 entry.
9	READTP error trying to read a matrix from a file (see sec. 6.7.1 for a list of READTP error codes.)
10	WRTETP error trying to write a matrix on a file (see sec. 6.7.2 for a list of WRTETP error codes).
11	STARTR error trying to initialize blank common storage array.
12	INITIR error trying to generate storage for an array.
13	DELETR error trying to erase storage of an array.
15	AINTL or AINTG error trying to interpolate for modes.

6.7.1 READTP ERROR CODES

Error Code	
= 0	If no errors are detected during reading.
= 1000+I	If an FSF (forward space file) error occurred, where I is the number of file marks remaining to be skipped when an end-of-information was encountered.
= 2	If the number of matrices or files to be skipped, before reading starts, is less than zero.

= 3	If the dimensioned number of rows in the matrix is less than or equal to zero.
= 3000+I	If an FSR (forward space record) error occurred, where I is the number of records remaining to be skipped when either an end-of-file or end-of-information was encountered.
= 4	Number of rows in the matrix is greater than the dimensioned row size in the program.
= 5	If the name check failed.
= 6	If the number of rows in the matrix (M) times the number of columns (N) is greater than the buffer size, or $M * N \leq 0$.
= 7	An end-of-file was read. If it occurs while reading the matrix ID, no information is stored in the user's area. If it occurs while reading the matrix, the ID information will be stored. Note that the records will always be in pairs and an end-of-file should always be encountered with the ID record.

6.7.2 WRTETP ERROR CODES

Error Code	
= 0	If no errors are detected during writing.
= 1000+I	If an FSF (forward space file) error occurred, where I is the number of file marks remaining to be skipped when an end-of-information was encountered.
= 2	If the number of matrices or files to be skipped, before writing starts, is less than zero.
= 3	If the dimensioned number of rows in the matrix is less than or equal to zero.
= 3000+I	If an FSR (forward space record) error occurred, where I is the number of records remaining to be skipped when either an end-of-file or an end-of-information was encountered.
= 4	If the actual number of rows is greater than the dimensioned number of rows in the matrix.
= 6	If the number of rows in the matrix (M) times the number of columns (N) is greater than the buffer size.

7.0 SAMPLE PROBLEM

The sample problem chosen is the fuselage, wing, and horizontal tail combination shown in figure 26. One control surface is placed on the wing. Two rigid body modes (vertical trnaslation and pitch) make up the structural degrees of freedom. The control surface degree of freedom was added to the basic modes in L215 (INTERP). The FLEXSTAB aerodynamic option was chosen for this example.

Generalized stiffness and mass data is read from file GMASS. Interpolation data is on the file MODH7. There are four interpolation arrays. Two rotary inertias are input for the control surface due to the rotation of the surface about its swept hinge line.

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124
May 1977

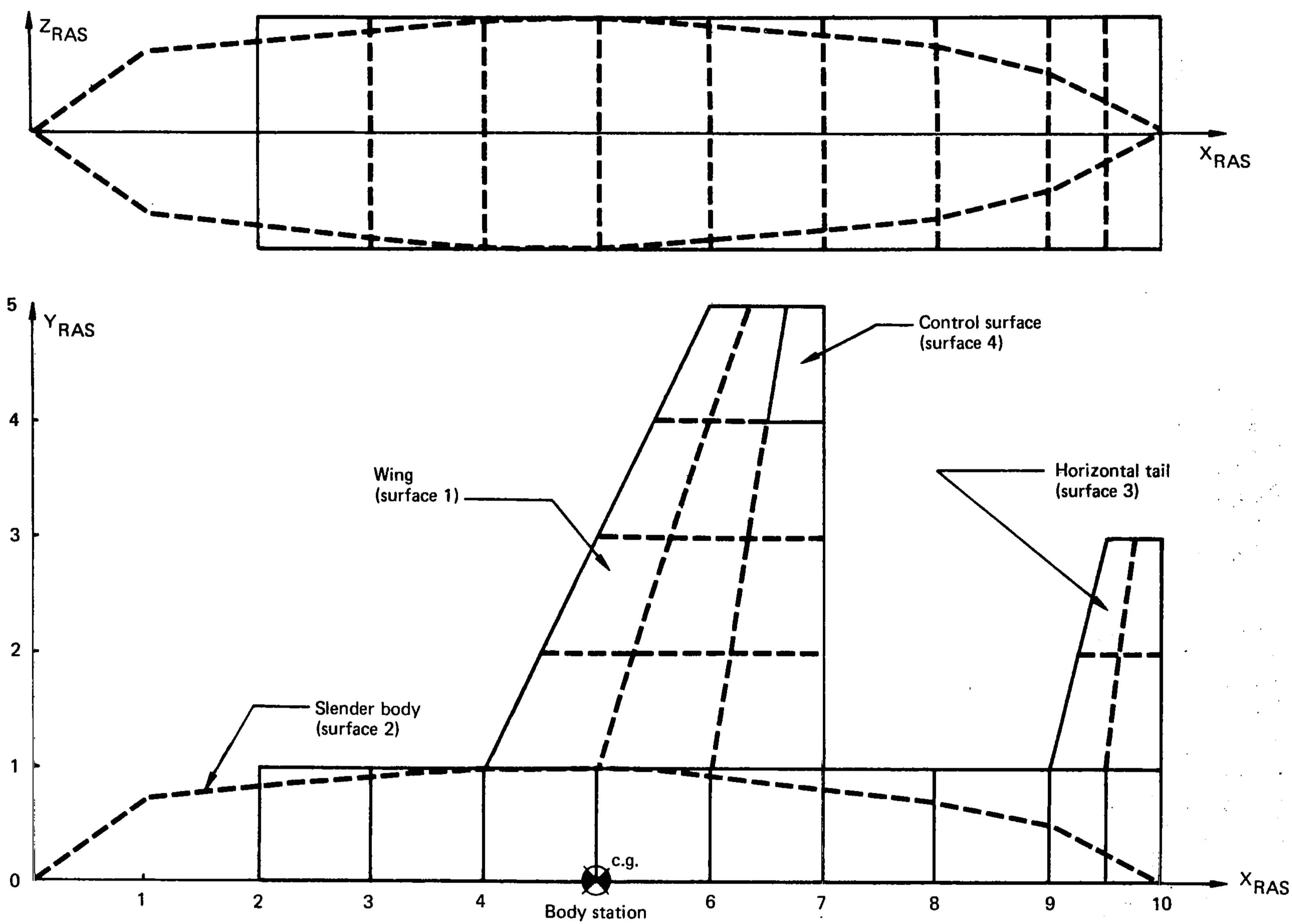


Figure 26. — Sample Problem Configuration

```
$TITLE    L217(EOM) USAGE DOCUMENT SAMPLE PROBLEM
$TITLE    USING FLEXSTAB AERODYNAMIC DATA FOR H7WC.
$TITLE    MODES ARE IN THE INERTIAL AXIS SYSTEM.
$TITLE    TRANSLATION IS POSITIVE DOWN, PITCH IS POSITIVE NOSE UP.
$STRUCTURAL DATA
SIZE           2     1
SYMMETRIC ANALYSIS
HALF AIRPLANE
MODES     MODH7
STIFFNESS GMASS          0    1PRINT
MASS      GMASS          0    0PRINT
DAMPING
0.        0.
SURFACE        4    1TRANS      ROTY       ROTX       LOCAL
3.25      4.5        0.0        0.1        1.0        2.0
END
$AERO     FLEXSTAB AIC
CONSTANTS 6.11015E-8    9954.4     1     2
SATAP     MODH7
GDTAPE    GDH7
SDSSTP    SDIH7      SDSH7
PRINT     MODES
PRINT     FORCES
PRINT     EQUATIONS
SLENDER BODY                 2     2
THIN BODY                1               .5         1.         0.
CONTROL SURFACE          4    1
  12
THIN BODY                3               0.         1.         0.
END
$QUIT
```

```
*****************************************************
*                                                   *
*   PROGRAM L217A0  VERSION FEB  5, 77 NOW RUNNING. *
*   THE PROGRAM IS PART OF THE DYLOFLX SYSTEM       *
*   DEVELOPED FOR NASA UNDER CONTRACT NAS1-13918.   *
*   DATE OF RUN IS  77/03/02.                       *
*   TIME OF RUN IS  18.16.01.                       *
*                                                   *
*****************************************************
```

PROGRAM DIRECTIVE CARDS READ BY L217A0

```
( $EOM                                                                     )
( $TITLE     L217(EOM) USAGE DOCUMENT SAMPLE PROBLEM                       )
( $TITLE     USING FLEXSTAB AERODYNAMIC DATA FOR H7WC.                     )
( $TITLE     MODES ARE IN THE INERTIAL AXIS SYSTEM.                        )
( $TITLE     TRANSLATION IS POSITIVE DOWN, PITCH IS POSITIVE NOSE UP.      )
( $STRUCTURAL DATA                                                         )
```

```
--- NOW IN STRUCT TO PREPARE EQUATIONS OF MOTION
    MATRICES (M1, M2, AND M3) DEPENDENT ONLY UPON
    STRUCTURAL INPUT DATA (MASS, STIFFNESS, ETC.).

    STRUCTURAL CARD INPUT DATA FOLLOWS.

   (SIZE          2    1                                                            )

    TOTAL NUMBER OF DEGREES OF FREEDOM =     3
    (     2) STRUCTURAL AND (     1) CONTROL SURFACE.

   (SYMMETRIC ANALYSIS                                                              )
   (HALF AIRPLANE                                                                   )
   (MODES      MODH7                                                                )

    THE MODE SHAPES WILL BE READ FROM MODH7


   (STIFFNESS GMASS          0     1PRINT                                           )

    THE GENERALIZED STIFFNESS MATRIX WILL BE READ FROM GMASS
    AFTER SKIPPING      1 MATRICES.
    AND PRINTED AS READ.


   (MASS       GMASS          0     OPRINT                                          )

    THE GENERALIZED MASS MATRIX WILL BE READ FROM GMASS
    AND PRINTED AS READ.


   (DAMPING                                                                         )

    THE DAMPING FACTORS WILL BE READ FROM CARDS
    AND PRINTED AS READ.



    THE MATRIX DAMP         IS      1 BY      2
    ROW      1
   (0.         0.                                                                   )



   (SURFACE         4     1TRANS      ROTY       ROTX       LOCAL                   )

    CONTROL SURFACE    4 HAS    1 NODES.
    TRANSLATION FREEDOMS WILL BE USED.
    ROTATION DZ/DX FREEDOMS WILL BE USED.
    ROTATION DZ/DY FREEDOMS WILL BE USED.
    THE COORDINATES ARE IN THE LOCAL AERO. AXIS SYSTEM.

       X           Y           Z          MASS       INERTIA    INERTIA
   (3.25       4.5        0.0        0.1        1.0        2.0                      )

   (END                                                                             )
```

MATRIX --

LABEL GENERALIZED STIFFNESS

SIZE 2 ROWS AND 2 COLUMNS

COLUMN	1	2
ROW 1	0.	0.
ROW 2	0.	0.

```
MATRIX  ----------------------------------------------------------------

LABEL   GENERALIZED MASS

SIZE         2 ROWS AND     2 COLUMNS
        ----------------------------------------------------------------

COLUMN          1             2

ROW     1    .1763E+03  -.1100E+00

ROW     2   -.1100E+00   .4800E+01


--- STRUCT IS FINISHED.
    MAXIMUM FIELD LENGTH USED BY STRUCT WAS 073343
    RETURN TO L217 DRIVING PROGRAM AND READ ANOTHER PROGRAM DIRECTIVE CARD.
```

PROGRAM DIRECTIVE CARDS READ BY L217A0

($AERO   FLEXSTAB AIC

```
--- NOW IN FLXAIC TO PREPARE EQUATIONS OF MOTION
    BASED UPON FLEXSTAB AIC MATRIX.


    FLEXSTAB CARD INPUT DATA FOLLOWS.

   (CONSTANTS 6.11015E-8    9954.4    1    2                                          )
    RHO =  .61102E-07
    VEL =  .99544E+04

    Q = .5*RHO*VEL**2 =   .30273E+01


   (SATAP     MODH7                                                                   )
    MODES WILL BE READ FROM MODH7


   (GDTAPE    GDH7                                                                    )
    FLEXSTAB GEOMETRY WILL READ FROM GDH7    (CASE     1).


   (SDSSTP    SDIH7     SDSH7                                                         )
    FLEXSTAB AERO DATA WILL BE READ FROM SDIH7   AND SDSH7   (CASE     1).


   (PRINT     MODES                                                                   )


   (PRINT     FORCES                                                                  )


   (PRINT     EQUATIONS                                                               )


   (SLENDER BODY                2    2                                                )
      Y-MOTION WILL NOT BE RETAINED.
   (THIN BODY              1              .5       1.       0.                        )
   (CONTROL SURFACE        4    1                                                     )
   (   12                                                                             )
   (THIN BODY              3              0.       1.       0.                        )
   (END                                                                               )

    FLEXSTAB CASE IDENTIFICATION =        THIS RUN IS A TEST CASE USING THE DOUBLAT TEST CASE H7WC         GD-2

    USER IDENTIFICATION          =        CASE H7WC HAS ONE CONTROL SURFACE                                GD-3

    MACH NUMBER =   .8000E+00

    UNITS ARE IN INCH
```

GEOMETRY SUMMARY FOR DOUBLET LATTICE CASE 1

BOX ELEMENT COORDINATES ARE AT QUARTER CHORD.

SYMMETRIC ANALYSIS REQUESTED.

NO.	REF. AXIS X	COORDINATES Y	Z	DIHEDRAL IN DEG.	AREA	TYPE	POS	MODAL SURFACE IN	OUT	SIGMA NO.	FRACTION	NO.	FRACTION	FAC	SF
1	.50	0.00	0.00	0.00	.35	SB	ON	0	2	1	.15708E+01	0	0.	2	1
2	1.50	0.00	0.00	0.00	.75	SB	ON	0	2	2	.15708E+01	0	0.	2	1
3	2.50	0.00	0.00	0.00	.85	SB	ON	0	2	3	.15708E+01	0	0.	2	1
4	3.50	0.00	0.00	0.00	.93	SB	ON	0	2	4	.15708E+01	0	0.	2	1
5	4.50	0.00	0.00	0.00	.98	SB	ON	0	2	5	.15708E+01	0	0.	2	1
6	5.50	0.00	0.00	0.00	.95	SB	ON	0	2	6	.15708E+01	0	0.	2	1
7	6.50	0.00	0.00	0.00	.85	SB	ON	0	2	7	.15708E+01	0	0.	2	1
8	7.50	0.00	0.00	0.00	.75	SB	ON	0	2	8	.15708E+01	0	0.	2	1
9	8.50	0.00	0.00	0.00	.60	SB	ON	0	2	9	.15708E+01	0	0.	2	1
10	9.50	0.00	0.00	0.00	.25	SB	ON	0	2	10	.15708E+01	0	0.	2	1
11	.50	0.00	0.00	0.00	.35	SB	ON	2	2	11	-.15708E+01	0	0.	2	1
12	1.50	0.00	0.00	0.00	.75	SB	ON	2	2	12	-.15708E+01	0	0.	2	1
13	2.50	0.00	0.00	0.00	.85	SB	ON	2	2	13	-.15708E+01	0	0.	2	1
14	3.50	0.00	0.00	0.00	.93	SB	ON	2	2	14	-.15708E+01	0	0.	2	1
15	4.50	0.00	0.00	0.00	.98	SB	ON	2	2	15	-.15708E+01	0	0.	2	1
16	5.50	0.00	0.00	0.00	.95	SB	ON	2	2	16	-.15708E+01	0	0.	2	1
17	6.50	0.00	0.00	0.00	.85	SB	ON	2	2	17	-.15708E+01	0	0.	2	1
18	7.50	0.00	0.00	0.00	.75	SB	ON	2	2	18	-.15708E+01	0	0.	2	1
19	8.50	0.00	0.00	0.00	.60	SB	ON	2	2	19	-.15708E+01	0	0.	2	1
20	9.50	0.00	0.00	0.00	.25	SB	ON	2	2	20	-.15708E+01	0	0.	2	1
21	2.50	.50	1.00	0.00	1.00	IB		0	0	3	0.	13	-.10000E+01	0	0
22	3.50	.50	1.00	0.00	1.00	IB		0	0	4	0.	14	-.10000E+01	0	0
23	4.50	.50	1.00	0.00	1.00	IB		0	0	5	0.	15	-.10000E+01	0	0
24	5.50	.50	1.00	0.00	1.00	IB		0	0	6	0.	16	-.10000E+01	0	0
25	6.50	.50	1.00	0.00	1.00	IB		0	0	7	0.	17	-.10000E+01	0	0
26	7.50	.50	1.00	0.00	1.00	IB		0	0	8	0.	18	-.10000E+01	0	0
27	8.50	.50	1.00	0.00	1.00	IB		0	0	9	0.	19	-.10000E+01	0	0
28	9.25	.50	1.00	0.00	.50	IB		0	0	10	0.	20	-.10000E+01	0	0
29	9.75	.50	1.00	0.00	.50	IB		0	0	10	0.	20	-.10000E+01	0	0
30	2.50	1.00	.50	90.00	1.00	IB		0	0	3	0.	13	0.	0	0
31	3.50	1.00	.50	90.00	1.00	IB		0	0	4	0.	14	0.	0	0
32	4.50	1.00	.50	90.00	1.00	IB		0	0	5	0.	15	0.	0	0
33	5.50	1.00	.50	90.00	1.00	IB		0	0	6	0.	16	0.	0	0
34	6.50	1.00	.50	90.00	1.00	IB		0	0	7	0.	17	0.	0	0
35	7.50	1.00	.50	90.00	1.00	IB		0	0	8	0.	18	0.	0	0
36	8.50	1.00	.50	90.00	1.00	IB		0	0	9	0.	19	0.	0	0
37	9.25	1.00	.50	90.00	.50	IB		0	0	10	0.	20	0.	0	0
38	9.75	1.00	.50	90.00	.50	IB		0	0	10	0.	20	0.	0	0
39	2.50	1.00	-.50	90.00	1.00	IB		0	0	3	0.	13	0.	0	0
40	3.50	1.00	-.50	90.00	1.00	IB		0	0	4	0.	14	0.	0	0
41	4.50	1.00	-.50	90.00	1.00	IB		0	0	5	0.	15	0.	0	0
42	5.50	1.00	-.50	90.00	1.00	IB		0	0	6	0.	16	0.	0	0
43	6.50	1.00	-.50	90.00	1.00	IB		0	0	7	0.	17	0.	0	0
44	7.50	1.00	-.50	90.00	1.00	IB		0	0	8	0.	18	0.	0	0
45	8.50	1.00	-.50	90.00	1.00	IB		0	0	9	0.	19	0.	0	0
46	9.25	1.00	-.50	90.00	.50	IB		0	0	10	0.	20	0.	0	0
47	9.75	1.00	-.50	90.00	.50	IB		0	0	10	0.	20	0.	0	0
48	2.50	.50	-1.00	180.00	1.00	IB		0	0	3	0.	13	.10000E+01	0	0
49	3.50	.50	-1.00	180.00	1.00	IB		0	0	4	0.	14	.10000E+01	0	0
50	4.50	.50	-1.00	180.00	1.00	IB		0	0	5	0.	15	.10000E+01	0	0

51	5.50	.50	-1.00	180.00	1.00	TB	0	0	6	0.	16	.10000E+01	0	0
52	6.50	.50	-1.00	180.00	1.00	TB	0	0	7	0.	17	.10000E+01	0	0
53	7.50	.50	-1.00	180.00	1.00	TB	0	0	8	0.	18	.10000E+01	0	0
54	8.50	.50	-1.00	180.00	1.00	TB	0	0	9	0.	19	.10000E+01	0	0
55	9.25	.50	-1.00	180.00	.50	TB	0	0	10	0.	20	.10000E+01	0	0
56	9.75	.50	-1.00	180.00	.50	TB	0	0	10	0.	20	.10000E+01	0	0
57	4.70	1.48	0.00	0.00	.92	TB OFF	1	1	21	.10000E+01	0	0.	1	2
58	5.62	1.48	0.00	0.00	.92	TB OFF	1	1	22	.10000E+01	0	0.	1	2
59	6.54	1.48	0.00	0.00	.92	TB OFF	1	1	23	.10000E+01	0	0.	1	2
60	5.12	2.48	0.00	0.00	.75	TB OFF	1	1	24	.10000E+01	0	0.	1	2
61	5.87	2.48	0.00	0.00	.75	TB OFF	1	1	25	.10000E+01	0	0.	1	2
62	6.62	2.48	0.00	0.00	.75	TB OFF	1	1	26	.10000E+01	0	0.	1	2
63	5.53	3.48	0.00	0.00	.58	TB OFF	1	1	27	.10000E+01	0	0.	1	2
64	6.12	3.48	0.00	0.00	.58	TB OFF	1	1	28	.10000E+01	0	0.	1	2
65	6.71	3.48	0.00	0.00	.58	TB OFF	1	1	29	.10000E+01	0	0.	1	2
66	5.94	4.47	0.00	0.00	.42	TB OFF	1	1	30	.10000E+01	0	0.	1	2
67	6.37	4.47	0.00	0.00	.42	TB OFF	1	1	31	.10000E+01	0	0.	1	2
68	6.79	4.47	0.00	0.00	.42	TB OFF	4	1	32	.10000E+01	0	0.	1	2
69	9.34	1.48	0.00	0.00	.44	TB OFF	3	3	33	.10000E+01	0	0.	1	2
70	9.78	1.48	0.00	0.00	.44	TB OFF	3	3	34	.10000E+01	0	0.	1	2
71	9.53	2.47	0.00	0.00	.31	TB OFF	3	3	35	.10000E+01	0	0.	1	2
72	9.84	2.47	0.00	0.00	.31	TB OFF	3	3	36	.10000E+01	0	0.	1	2

NO.	CONTROL POINT GEOMETRY REF. AXIS COORDINATES X	Y	Z	BODY TYPE	MODAL INTERPOLATION SURFACE(S)		KG	GUST ZONE
1	.50	0.00	0.00	SB	2	2	1.00000	1
2	1.50	0.00	0.00	SB	2	2	1.00000	1
3	2.50	0.00	0.00	SB	2	2	1.00000	1
4	3.50	0.00	0.00	SB	2	2	1.00000	1
5	4.50	0.00	0.00	SB	2	2	1.00000	1
6	5.50	0.00	0.00	SB	2	2	1.00000	1
7	6.50	0.00	0.00	SB	2	2	1.00000	1
8	7.50	0.00	0.00	SB	2	2	1.00000	1
9	8.50	0.00	0.00	SB	2	2	1.00000	1
10	9.50	0.00	0.00	SB	2	2	1.00000	1
11	5.02	1.48	0.00	TB	1	1	1.00000	1
12	5.94	1.48	0.00	TB	1	1	1.00000	1
13	6.86	1.48	0.00	TB	1	1	1.00000	1
14	5.38	2.48	0.00	TB	1	1	1.00000	1
15	6.13	2.48	0.00	TB	1	1	1.00000	1
16	6.89	2.48	0.00	TB	1	1	1.00000	1
17	5.74	3.48	0.00	TB	1	1	1.00000	1
18	6.32	3.48	0.00	TB	1	1	1.00000	1
19	6.91	3.48	0.00	TB	1	1	1.00000	1
20	6.09	4.47	0.00	TB	1	1	1.00000	1
21	6.51	4.47	0.00	TB	1	1	1.00000	1
22	6.94	4.47	0.00	TB	4	1	1.00000	1
23	9.49	1.48	0.00	TB	3	3	1.00000	1
24	9.93	1.48	0.00	TB	3	3	1.00000	1
25	9.64	2.47	0.00	TB	3	3	1.00000	1
26	9.95	2.47	0.00	TB	3	3	1.00000	1

MATRIX --

LABEL MODAL DEFLECTIONS - PARTITION 1 MODES 1 THROUGH 3

SIZE 26 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	-.1000E+01	.4500E+01	0.
ROW 2	-.1000E+01	.3500E+01	0.
ROW 3	-.1000E+01	.2500E+01	0.
ROW 4	-.1000E+01	.1500E+01	0.
ROW 5	-.1000E+01	.5000E+00	0.
ROW 6	-.1000E+01	-.5000E+00	0.
ROW 7	-.1000E+01	-.1500E+01	0.
ROW 8	-.1000E+01	-.2500E+01	0.
ROW 9	-.1000E+01	-.3500E+01	0.
ROW 10	-.1000E+01	-.4500E+01	0.
ROW 11	-.1000E+01	-.1831E-01	0.
ROW 12	-.1000E+01	-.9432E+00	0.
ROW 13	-.1000E+01	-.1857E+01	0.
ROW 14	-.1000E+01	-.3861E+00	0.
ROW 15	-.1000E+01	-.1133E+01	0.
ROW 16	-.1000E+01	-.1886E+01	0.
ROW 17	-.1000E+01	-.7319E+00	0.
ROW 18	-.1000E+01	-.1322E+01	0.
ROW 19	-.1000E+01	-.1911E+01	0.
ROW 20	-.1000E+01	-.1093E+01	0.
ROW 21	-.1000E+01	-.1515E+01	0.
ROW 22	-.1000E+01	-.1937E+01	-.3540E+00
ROW 23	-.1000E+01	-.4493E+01	0.
ROW 24	-.1000E+01	-.4934E+01	0.
ROW 25	-.1000E+01	-.4636E+01	0.
ROW 26	-.1000E+01	-.4953E+01	0.

MATRIX ---

LABEL MODAL SLOPES - PARTITION 1 MODES 1 THROUGH 3

SIZE 26 ROWS AND 3 COLUMNS

COLUMN		1	2	3
ROW	1	0.	-.1000E+01	0.
ROW	2	0.	-.1000E+01	0.
ROW	3	0.	-.1000E+01	0.
ROW	4	0.	-.1000E+01	0.
ROW	5	0.	-.1000E+01	0.
ROW	6	0.	-.1000E+01	0.
ROW	7	0.	-.1000E+01	0.
ROW	8	0.	-.1000E+01	0.
ROW	9	0.	-.1000E+01	0.
ROW	10	0.	-.1000E+01	0.
ROW	11	0.	-.9992E+00	0.
ROW	12	0.	-.9998E+00	0.
ROW	13	0.	-.1006E+01	0.
ROW	14	0.	-.1000E+01	0.
ROW	15	0.	-.1000E+01	0.
ROW	16	0.	-.9991E+00	0.
ROW	17	0.	-.9966E+00	0.
ROW	18	0.	-.9967E+00	0.
ROW	19	0.	-.9967E+00	0.
ROW	20	0.	-.1001E+01	0.
ROW	21	0.	-.1001E+01	0.
ROW	22	0.	-.1001E+01	-.9864E+00
ROW	23	0.	-.1000E+01	0.
ROW	24	0.	-.1000E+01	0.
ROW	25	0.	-.1000E+01	0.
ROW	26	0.	-.1000E+01	0.

MATRIX

LABEL FORCE PT. MODAL DEFLECTIONS - PART. 1 MODES 1 THRU 3

SIZE 36 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	0.	0.
ROW 2	0.	0.	0.
ROW 3	0.	0.	0.
ROW 4	0.	0.	0.
ROW 5	0.	0.	0.
ROW 6	0.	0.	0.
ROW 7	0.	0.	0.
ROW 8	0.	0.	0.
ROW 9	0.	0.	0.
ROW 10	0.	0.	0.
ROW 11	-.1000E+01	.4500E+01	0.
ROW 12	-.1000E+01	.3500E+01	0.
ROW 13	-.1000E+01	.2500E+01	0.
ROW 14	-.1000E+01	.1500E+01	0.
ROW 15	-.1000E+01	.5000E+00	0.
ROW 16	-.1000E+01	-.5000E+00	0.
ROW 17	-.1000E+01	-.1500E+01	0.
ROW 18	-.1000E+01	-.2500E+01	0.
ROW 19	-.1000E+01	-.3500E+01	0.
ROW 20	-.1000E+01	-.4500E+01	0.
ROW 21	-.1000E+01	.3047E+00	0.
ROW 22	-.1000E+01	-.6209E+00	0.
ROW 23	-.1000E+01	-.1538E+01	0.
ROW 24	-.1000E+01	-.1264E+00	0.
ROW 25	-.1000E+01	-.8708E+00	0.

ROW	26	-.1000E+01	-.1622E+01	0.
ROW	27	-.1000E+01	-.5252E+00	0.
ROW	28	-.1000E+01	-.1116E+01	0.
ROW	29	-.1000E+01	-.1705E+01	0.
ROW	30	-.1000E+01	-.9453E+00	0.
ROW	31	-.1000E+01	-.1367E+01	0.
ROW	32	-.1000E+01	-.1789E+01	-.2082E+00
ROW	33	-.1000E+01	-.4339E+01	0.
ROW	34	-.1000E+01	-.4780E+01	0.
ROW	35	-.1000E+01	-.4525E+01	0.
ROW	36	-.1000E+01	-.4842E+01	0.

THE MATRICES PRINTED BELOW ARE WRITTEN ONTO THE FILE NAMED EOMLOD

```
MATRIX   ----------------------------------------------------------------

LABEL    FREQUENCIES AT WHICH THE AERO FORCES ARE DEFINED
         IN CYCLES / SECOND.

SIZE          1 ROWS AND      1 COLUMNS
         ----------------------------------------------------------------


COLUMN        1
          0.
```

MATRIX

LABEL ELEMENT LOCAL COORD. (X,Y)
SURFACE 1

SIZE 12 ROWS AND 2 COLUMNS

COLUMN	1	2
ROW 1	.1202E+01	.1485E+01
ROW 2	.2121E+01	.1485E+01
ROW 3	.3040E+01	.1485E+01
ROW 4	.1617E+01	.2481E+01
ROW 5	.2370E+01	.2481E+01
ROW 6	.3123E+01	.2481E+01
ROW 7	.2032E+01	.3476E+01
ROW 8	.2619E+01	.3476E+01
ROW 9	.3206E+01	.3476E+01
ROW 10	.2444E+01	.4467E+01
ROW 11	.2867E+01	.4467E+01
ROW 12	.3289E+01	.4467E+01

```
MATRIX   ------------------------------------------------------------

LABEL    ELEMENT AREAS
         SURFACE  1

SIZE        12 ROWS AND      1 COLUMNS
         ------------------------------------------------------------

COLUMN          1

ROW      1    .9167E+00

ROW      2    .9167E+00

ROW      3    .9167E+00

ROW      4    .7500E+00

ROW      5    .7500E+00

ROW      6    .7500E+00

ROW      7    .5833E+00

ROW      8    .5833E+00

ROW      9    .5833E+00

ROW     10    .4167E+00

ROW     11    .4167E+00

ROW     12    .4167E+00
```

MATRIX --

LABEL F1-RESPONSE AIR FORCES (Q COEF.)
SURFACE, 1 AT FREQUENCY 1

SIZE 12 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	.2865E+02	.5213E+00
ROW 2	0.	.9162E+01	.4511E+00
ROW 3	0.	.4115E+01	.4035E+00
ROW 4	0.	.2691E+02	.6343E+00
ROW 5	0.	.7455E+01	.5074E+00
ROW 6	0.	.3616E+01	.4981E+00
ROW 7	0.	.2319E+02	.8238E+00
ROW 8	0.	.6002E+01	.7589E+00
ROW 9	0.	.2863E+01	.9914E+00
ROW 10	0.	.1736E+02	.1169E+01
ROW 11	0.	.3635E+01	.1534E+01
ROW 12	0.	.1654E+01	.5895E+01

MATRIX

LABEL F2-RESPONSE AIR FORCES (Q DOT COEF.)
SURFACE, 1 AT FREQUENCY 1

SIZE 12 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	.2879E-02	.1873E-02	.1879E-04
ROW 2	.9187E-03	.2796E-02	.1626E-04
ROW 3	.4065E-03	.2249E-02	.1455E-04
ROW 4	.2703E-02	.2445E-02	.2287E-04
ROW 5	.7486E-03	.2156E-02	.1829E-04
ROW 6	.3630E-03	.1678E-02	.1796E-04
ROW 7	.2332E-02	.2649E-02	.2970E-04
ROW 8	.6029E-03	.1569E-02	.2736E-04
ROW 9	.2875E-03	.1136E-02	.3574E-04
ROW 10	.1744E-02	.2340E-02	.4215E-04
ROW 11	.3652E-03	.9041E-03	.5530E-04
ROW 12	.1661E-03	.6086E-03	.2125E-03

```
MATRIX    -------------------------------------------------------------

LABEL     FGUST- GUST AIR FORCES (COMPLEX)
          SURFACE, 1 AT FREQUENCY   1

SIZE          12 ROWS AND      1 COLUMNS
(COMPLEX)
          -------------------------------------------------------------

COLUMN                     1

ROW      1      .2879E-02  0.

ROW      2      .9187E-03  0.

ROW      3      .4065E-03  0.

ROW      4      .2703E-02  0.

ROW      5      .7486E-03  0.

ROW      6      .3630E-03  0.

ROW      7      .2332E-02  0.

ROW      8      .6029E-03  0.

ROW      9      .2875E-03  0.

ROW     10      .1744E-02  0.

ROW     11      .3852E-03  0.

ROW     12      .1661E-03  0.
```

```
MATRIX  --------------------------------------------------------------

LABEL   ELEMENT LOCAL COORD. (X,Y)
        SURFACE  2

SIZE       10 ROWS AND      2 COLUMNS
        --------------------------------------------------------------
```

COLUMN		1	2
ROW	1	.5000E+00	0.
ROW	2	.1500E+01	0.
ROW	3	.2500E+01	0.
ROW	4	.3500E+01	0.
ROW	5	.4500E+01	0.
ROW	6	.5500E+01	0.
ROW	7	.6500E+01	0.
ROW	8	.7500E+01	0.
ROW	9	.8500E+01	0.
ROW	10	.9500E+01	0.

MATRIX --

LABEL ELEMENT AREAS
SURFACE 2

SIZE 10 ROWS AND 1 COLUMNS

COLUMN		1
ROW	1	.3500E+00
ROW	2	.7500E+00
ROW	3	.8500E+00
ROW	4	.9250E+00
ROW	5	.9750E+00
ROW	6	.9500E+00
ROW	7	.8500E+00
ROW	8	.7500E+00
ROW	9	.6000E+00
ROW	10	.2500E+C0

MATRIX

LABEL F1-RESPONSE AIR FORCES (Q COEF.)
SURFACE, 2 AT FREQUENCY 1

SIZE 20 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	0.	0.
ROW 2	0.	0.	0.
ROW 3	0.	0.	0.
ROW 4	0.	0.	0.
ROW 5	0.	0.	0.
ROW 6	0.	0.	0.
ROW 7	0.	0.	0.
ROW 8	0.	0.	0.
ROW 9	0.	0.	0.
ROW 10	0.	0.	0.
ROW 11	0.	.5733E+01	0.
ROW 12	0.	.5529E+01	0.
ROW 13	0.	.7111E+01	.2481E+00
ROW 14	0.	.8840E+01	.2782E+00
ROW 15	0.	.1266E+02	.5107E+00
ROW 16	0.	.9193E+01	.6590E+00
ROW 17	0.	.4291E+01	.6191E+00
ROW 18	0.	.5811E+00	.4368E+00
ROW 19	0.	-.2807E+01	.3383E+00
ROW 20	0.	-.2405E+01	.2621E+00

MATRIX

LABEL F2-RESPONSE AIR FORCES (Q DOT COEF.)
SURFACE, 2 AT FREQUENCY 1

SIZE 20 ROWS AND 3 COLUMNS

COLUMN		1	2	3
ROW	1	0.	0.	0.
ROW	2	0.	0.	0.
ROW	3	0.	0.	0.
ROW	4	0.	0.	0.
ROW	5	0.	0.	0.
ROW	6	0.	0.	0.
ROW	7	0.	0.	0.
ROW	8	0.	0.	0.
ROW	9	0.	0.	0.
ROW	10	0.	0.	0.
ROW	11	.5760E-03	-.2041E-02	0.
ROW	12	.5554E-03	-.1119E-02	0.
ROW	13	.7142E-03	.1331E-02	.8944E-05
ROW	14	.8879E-03	.1953E-02	.1003E-04
ROW	15	.1272E-02	.3145E-02	.1841E-04
ROW	16	.9224E-03	.3475E-02	.2376E-04
ROW	17	.4298E-03	.2662E-02	.2232E-04
ROW	18	.5801E-04	.1535E-02	.1575E-04
ROW	19	-.2812E-03	.4383E-03	.1220E-04
ROW	20	-.2405E-03	.2435E-03	.9451E-05

```
MATRIX   ----------------------------------------------------------

LABEL    FGUST- GUST AIR FORCES (COMPLEX)
         SURFACE, 2 AT FREQUENCY   1

SIZE          20 ROWS AND     1 COLUMNS
(COMPLEX)
         ----------------------------------------------------------
```

COLUMN			1
ROW	1	0.	0.
ROW	2	0.	0.
ROW	3	0.	0.
ROW	4	0.	0.
ROW	5	0.	0.
ROW	6	0.	0.
ROW	7	0.	0.
ROW	8	0.	0.
ROW	9	0.	0.
ROW	10	0.	0.
ROW	11	.5760E-03	0.
ROW	12	.5554E-03	0.
ROW	13	.7142E-03	0.
ROW	14	.8879E-03	0.
ROW	15	.1272E-02	0.
ROW	16	.9224E-03	0.
ROW	17	.4298E-03	0.
ROW	18	.5801E-04	0.
ROW	19	-.2812E-03	0.
ROW	20	-.2405E-03	0.

MATRIX --

LABEL ELEMENT LOCAL COORD. (X,Y)
SURFACE 3

SIZE 4 ROWS AND 2 COLUMNS

COLUMN		1	2
ROW	1	.3393E+00	.1476E+01
ROW	2	.7798E+00	.1476E+01
ROW	3	.5250E+00	.2467E+01
ROW	4	.8417E+00	.2467E+01

```
MATRIX  -----------------------------------------------------------------

LABEL   ELEMENT AREAS
        SURFACE  3

SIZE        4 ROWS AND      1 COLUMNS
        -----------------------------------------------------------------

COLUMN          1

ROW      1     .4375E+00

ROW      2     .4375E+00

ROW      3     .3125E+00

ROW      4     .3125E+00
```

MATRIX --

LABEL F1-RESPONSE AIR FORCES (Q COEF.)
SURFACE, 3 AT FREQUENCY 1

SIZE 4 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	.5428E+00	.4364E+00
ROW 2	0.	.1000E+00	.1095E+00
ROW 3	0.	.1402E+01	.4224E+00
ROW 4	0.	.2187E+00	.8212E-01

MATRIX --

LABEL F2-RESPONSE AIR FORCES (Q DOT COEF.)
SURFACE, 3 AT FREQUENCY 1

SIZE 4 ROWS AND 3 COLUMNS

COLUMN		1	2	3
ROW	1	.6043E-04	.4C59E-02	.1573E-04
ROW	2	.1089E-04	.1154E-02	.3946E-05
ROW	3	.1409E-03	.3504E-02	.1523E-04
ROW	4	.2219E-04	.8214E-03	.2961E-05

MATRIX --

LABEL FGUST- GUST AIR FORCES (COMPLEX)
SURFACE, 3 AT FREQUENCY 1

SIZE 4 ROWS AND 1 COLUMNS
(COMPLEX)

COLUMN		1	
ROW	1	.6043E-04	0.
ROW	2	.1089E-04	0.
ROW	3	.1409E-03	0.
ROW	4	.2219E-04	0.

THE MATRICES PRINTED BELOW ARE WRITTEN ONTO THE FILE NAMED EOMTAP

MATRIX --

LABEL M1

SIZE 3 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	0.	0.
ROW 2	0.	0.	0.
ROW 3	0.	0.	0.

MATRIX --

LABEL M2

SIZE 3 ROWS AND 3 COLUMNS

COLUMN		1	2	3
ROW	1	0.	0.	0.
ROW	2	0.	0.	0.
ROW	3	0.	0.	0.

MATRIX --

LABEL M3

SIZE 3 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	.3526E+03	-.2200E+00	.1644E-01
ROW 2	-.2200E+00	.9600E+01	.1014E+01
ROW 3	.1644E-01	.1014E+01	.1030E+01

```
MATRIX  -----------------------------------------------------------

LABEL   FREQM

SIZE        1 ROWS AND      1 COLUMNS
        -----------------------------------------------------------

COLUMN       1
           0.
```

MATRIX --

LABEL M4

SIZE 3 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	0.	.3225E+03	.3383E+02
ROW 2	0.	.6407E+02	.5046E+02
ROW 3	0.	.6887E+00	.2455E+01

MATRIX --

LABEL M5

SIZE 3 ROWS AND 3 COLUMNS

COLUMN	1	2	3
ROW 1	.3239E-01	.7551E-01	.1220E-02
ROW 2	.6482E-02	.1417E+00	.1819E-02
ROW 3	.6918E-04	.2535E-03	.8851E-04

```
MATRIX  --------------------------------------------------------------

LABEL   DISTANCES FROM GUST REF. PT. TO ZONES.

SIZE         1 ROWS AND       1 COLUMNS
        --------------------------------------------------------------

COLUMN        1
            0.
```

```
MATRIX  -----------------------------------------------------------

LABEL   PHIT

SIZE        3 ROWS AND      1 COLUMNS
(COMPLEX)
        -----------------------------------------------------------


COLUMN                  1

ROW     1   -.3239E-01  0.

ROW     2   -.6482E-02  0.

ROW     3   -.6918E-04  0.

--- FLXAIC IS FINISHED.
    MAXIMUM FIELD LENGTH USED BY FLXAIC WAS 072551
    RETURN TO L217 TO READ ANOTHER DIRECTIVE CARD.
```

PROGRAM DIRECTIVE CARDS READ BY L217A0

($QUIT

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