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MVMA TWO-DIMENSIONAL CRASH VICTIM SIMULATION
ADVANCED AIRBAG SYSTEM SUBMODEL

Bruce M. Bowman, Associate Research Scientist

Highway Safety Research Institute
The University of Michigan
Huron Parkway and Baxter Road
Ann Arbor, Michigan 48109

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Huron Parkway and Baxter Road
Ann Arbor, Michigan 48109

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15. Supplementary Notes This report documents an Advanced Airbag System Submodel for use with Version 3 of the MVMA 2-D Crash Victim Simulation Model, but the report is compatible with, and to be used with, MVMA 2-D CVS Version 4 documentation, HSRI reports UM-HSRI-79-5-1,2,3.

16. Abstract This manual documents an Advanced Airbag System Submodel which has been implemented in the MVMA Two-Dimensional Crash Victim Simulation Model. Sections 2, 3, and 4 parallel and supplement Volumes 1, 2, and 3, respectively, of the MVMA 2-D CVS manuals (see Supplementary Notes). The Advanced Airbag System Submodel makes possible simulations in which an arbitrary number of airbags are represented, external and/or internal to each other. Phenomena represented include bag slap forces, pressure forces, membrane forces, deflation through vents and/or porous bag fabric, yielding of vehicle interior components in response to bag forces, tabularly-specified mass influx and source gas temperature as functions of time and fabric porosity as a function of pressure differential, user-specified bag profiles during inflation, i.e., an arbitrary number of profiles in a time history and arbitrary polygonal shape for each profile, and user-defined vehicle and occupant profiles for interaction with bags. In addition the model has analytical features and user inputs which take into account three-dimensional aspects of bag behavior.

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1.0 INTRODUCTION TO THE MVMA 2-D CRASH VICTIM SIMULATION AND THE ADVANCED AIRBAG SYSTEM SUBMODEL

1.1 Simulation of Vehicle Occupant Crash Dynamics

Since 1966, sophisticated analyses have been developed which can be used for estimating the dynamic response of a human or an anthropomorphic dummy in a crash environment. The use of such mathematical models as tools in automotive safety design has been made possible by modern large-storage, high-speed computers.

The problem of determining occupant dynamics in a crash environment can be simply stated. A description of a mechanical or biomechanical system, the occupant, is given. A description of a potentially interacting mechanical system, the occupant compartment, is given. The occupant's position and orientation and their rates of change are specified for some single instant in time. And finally, the motion in space of the occupant compartment as a function of time is specified. It is required to determine the subsequent motion of the occupant and the forces which describe his interaction with the vehicle interior.

Figure 1a illustrates the relationship between the motion and the forces. From the initial position and velocity conditions of the occupant relative to a vehicle-fixed reference frame, the instantaneous state of displacements between body and vehicle elements, and hence the interaction forces, may be determined. Further, the instantaneous interaction forces thus found, together with the motion equations of classical mechanics, namely Newton's Laws, determine the instantaneous accelerations essentially as $a = F/m$, or $\{a\} = [M]^{-1} \{F\}$ in a vector formulation.

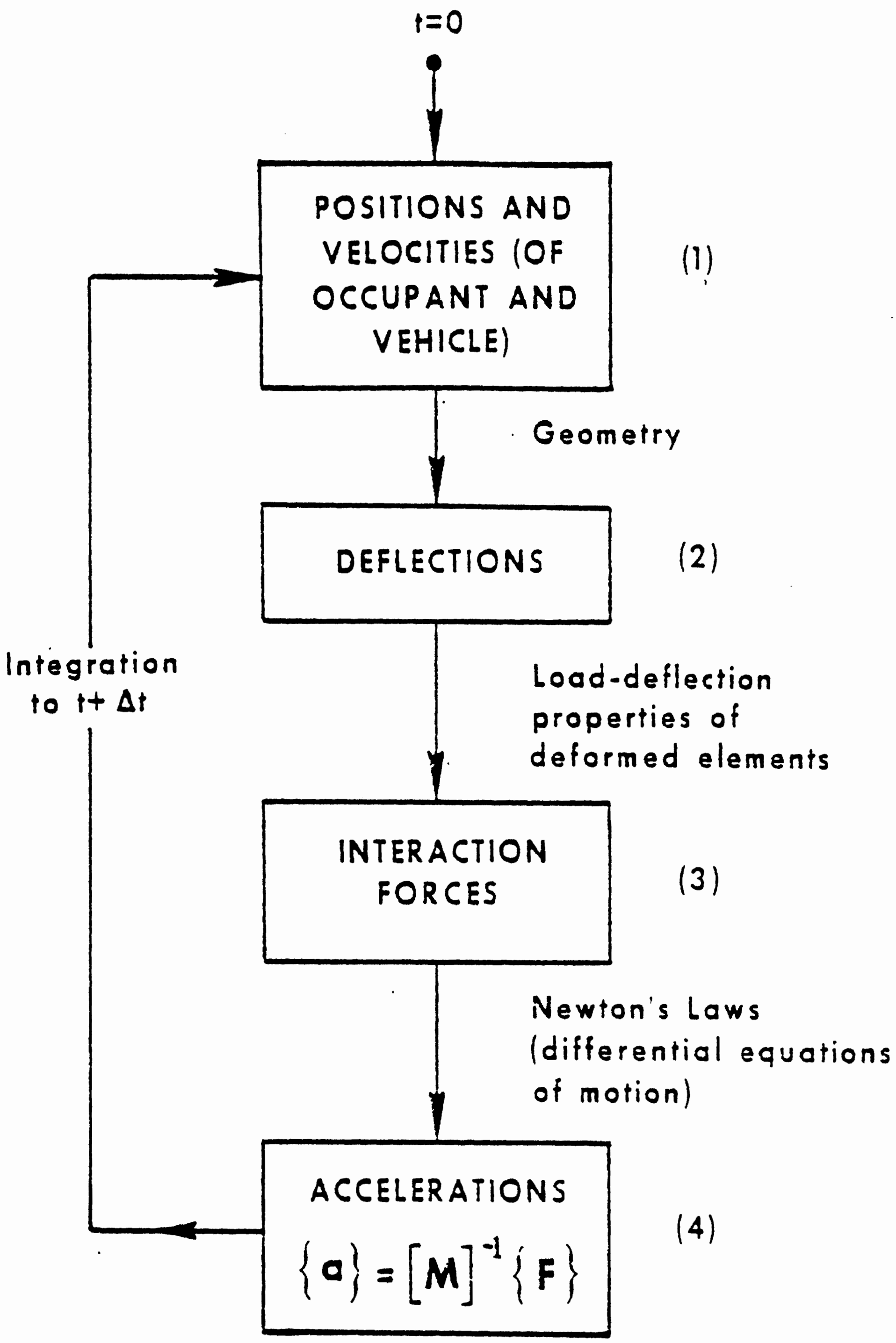

Figure 1a. Flow Diagram for Determining Occupant Dynamics

Integration of the accelerations then yields the occupant velocities and positions at a new time, different from the time at which forces were determined by an arbitrarily small amount, dt or Δt. New position and velocity conditions having been determined, new deflections can be determined and so forth so that the entire time histories for motion and forces are established. This flow sequence is an appropriate description for all mathematical models which could be used for determining occupant dynamics.

1.2 MVMA 2-D CVS Background

The MVMA Two-Dimensional Crash Victim Simulator (Version 1) came into being in 1973 [1]. This model was developed by the Highway Safety Research Institute and was an extension of the MODROS model, released in 1972 by General Motors [2]. The predecessors of MODROS, in turn, were ROS (1971) [3] and CAL 2-D (1966) [4], released by the then Cornell Aeronautical Labs.

Since 1973, the MVMA 2-D model has undergone continuing development at HSRI. Versions 2 and 3 were released in January and June of 1974 [5,6], and since 1974 there have been computer tape releases representing several additional stages of model development. The most recent official release of the computer model [7] (June 1979), called "Version 4," is over 24,000 Fortran lines in length and over four times as long as the immediate predecessor of the MVMA 2-D model, MODROS.

In addition, a "Validation Command Language" program was completed and released in December 1976 [8] and updated in June 1979 [9]. This program performs many post-processing operations on MVMA 2-D generated data and was developed to aid the automotive safety researcher in quantifying comparison between impact test results and predictions of mathematical simulations.

In April 1977, HSRI released a Tutorial System for the MVMA 2-D model [10]. This consists of a 397-page Self-Study Guide and a 298-page Audio-Visual Program with two hundred 35mm slides and nearly five hours of narration on tape cassettes. The Tutorial System Self-Study Guide is the most detailed document available for aiding the model user in preparation of input data sets. The Tutorial System was updated in June 1979 [11].

The most recent documentation is for Version 4 of the MVMA 2-D Crash Victim Simulator [7]. It is a three-volume set of manuals which updates the 1974 Version 3 documentation. The Version 4 documentation is compatible with both Version 3 and Version 4 computer models.

1.3 Description of the MVMA 2-D CVS Model

The MVMA Two-Dimensional Crash Victim Simulator is a model intended to be used for simulating crash events in which primary occupant motions may be expected to lie in a plane. Thus, it is most useful for simulating front-end and rear-end impacts. With care, however, it can be used for some oblique and side impacts as well. Applications have been diverse and not limited to vehicle crash simulations because of the model's great flexibility.

Some of the primary features of the model are listed below.

1. Nine-mass, ten-segment occupant linkage.
2. Contact-sensing ellipses for defining the occupant profile.
3. An extensible, two-joint neck.
4. A flexible shoulder.
5. Energy-absorbing joints.
6. Time-dependent muscle activity level.
7. General nonlinear materials with energy-absorbing capability

for all parts of the occupant and all parts of the vehicle interior.

8. A general vehicle-interior profile which is allowed to move or deform with respect to the vehicle frame.
9. A vehicle exterior for pedestrian studies.
10. A simple airbag submodel.
11. An energy-absorbing steering column.
12. Two different belt restraint-system submodels.
13. Horizontal, vertical, and pitching vehicle motions.

1.4 Description of the Advanced Airbag System Submodel and Documentation

This manual documents an Advanced Airbag System Submodel which has been developed at HSRI as an additional feature of the MVMA 2-D CVS model. The Advanced Airbag System is a submodel of considerable complexity and flexibility. Its features include those listed below.

1. Representation of an arbitrary number of airbags, external and/or internal to each other.
2. Bag slap forces.
3. Pressure forces.
4. Membrane forces.
5. Deflation through vents and/or porous bag fabric.
6. Yielding of vehicle interior components in response to bag forces.
7. Tabularly-specified mass influx and source gas temperature as functions of time and fabric porosity as a function of pressure differential.
8. User-specified bag profiles during inflation, i.e., an arbitrary number of profiles in a time-history and arbitrary polygonal shape for each profile.

9. User-defined vehicle and occupant profiles for interaction with bags.
10. Analytical features and user inputs which take into account three-dimensional aspects of bag behavior even though the MVMA 2-D CVS is a planar model.

The Advanced Airbag System Submodel has been implemented as a part of Version 3 of the MVMA 2-D CVS model. It is not expected that it will ever be incorporated into Version 4, which was being developed at the same time as the airbag model. Since Versions 3 and 4 of the model differ only in program flow and organization of storage, this represents no significant disadvantage to users with larger computers. Potential MVMA 2-D users with smaller computers may not be able to use Version 3 and therefore will not be able to make use of the Advanced Airbag System Submodel.

This manual is to be used together with the Version 4 documentation of the MVMA 2-D Crash Victim Simulation [7]. As previously explained, this three-volume set of manuals updates the 1974 Version 3 manuals but is compatible with Version 3 of the model. Volume 1 describes "The Analytical Model." Volume 2 is a "User's Guide" and Volume 3 is a "Programmer's Guide." This Advanced Airbag System Submodel manual contains sections which parallel and supplement the three volumes of the Version 4 manuals. They are Sections 2, 3, and 4, respectively.

2.0 THE ANALYTICAL MODEL

The primary features of the Advanced Airbag System Submodel are listed in Section 1.4. Here, the analytical development or representation of each of these features and others will be presented. This section is organized in parallel to the flow directed by the subprogram ADVBAG in the Dynamics Solution Processor ("GO") of the computer model. In addition to controlling the program flow for advanced airbag system calculations, Subroutine ADVBAG performs several specific functions of its own, including: a) pressure-volume iteration; b) iterative adjustment of angular position of bag for equilibrium; and c) determination of generalized forces. These functions of ADVBAG are discussed in this section along with discussion of the various functions performed by routines called by ADVBAG.

The flow directed by Subroutine ADVBAG is shown in the three-page flow diagram, Figure 1b. Names of subroutines called by ADVBAG are listed beside the descriptions of their functions and each box in the flow diagram is numbered in accordance with its subsection number within Section 2. For example, box 12 -- determination of bag slap forces -- is discussed in Section 2.12.

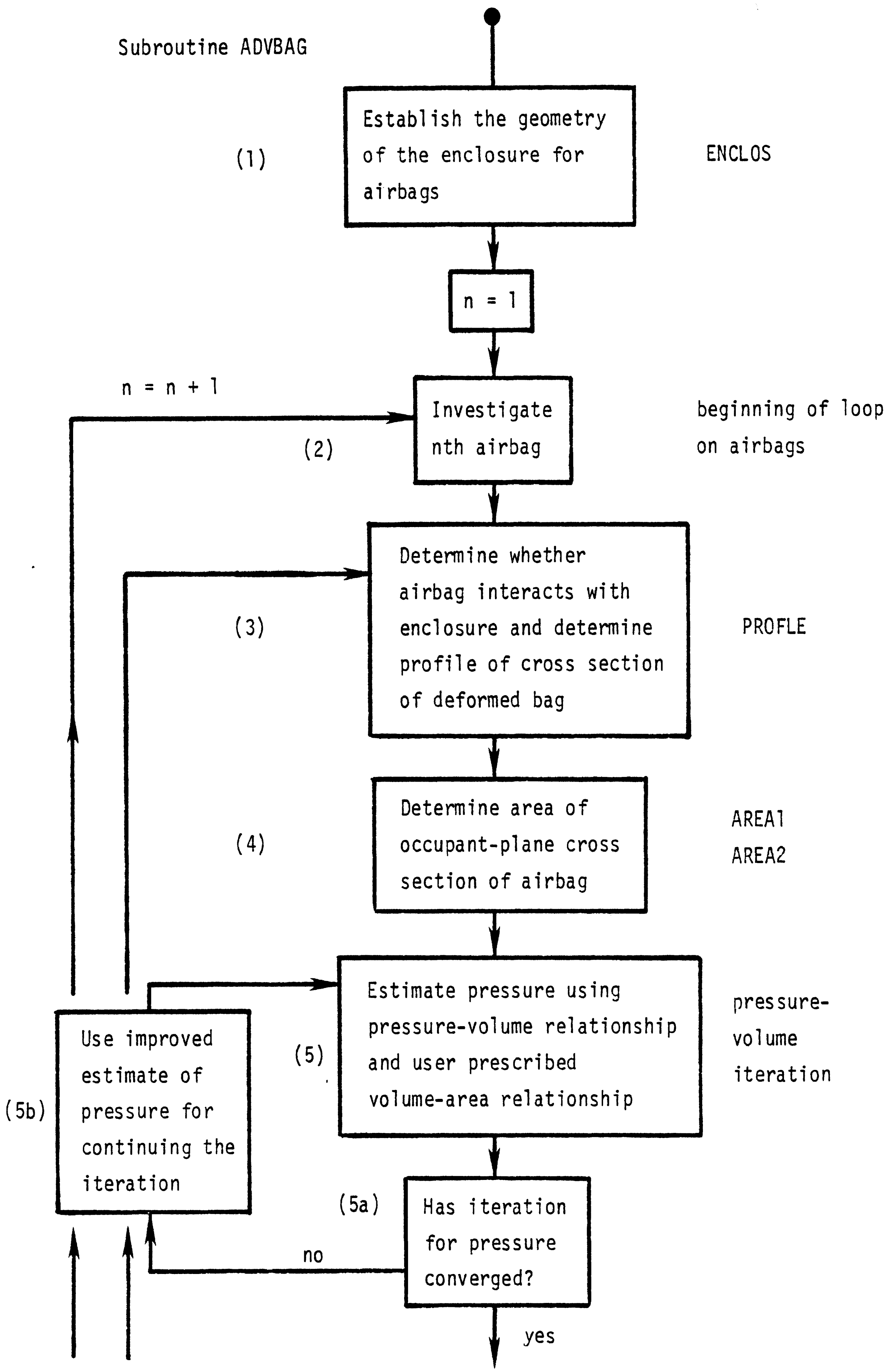

Figure 1b. Flow Diagram for Advanced Airbag System Submodel (page 1)

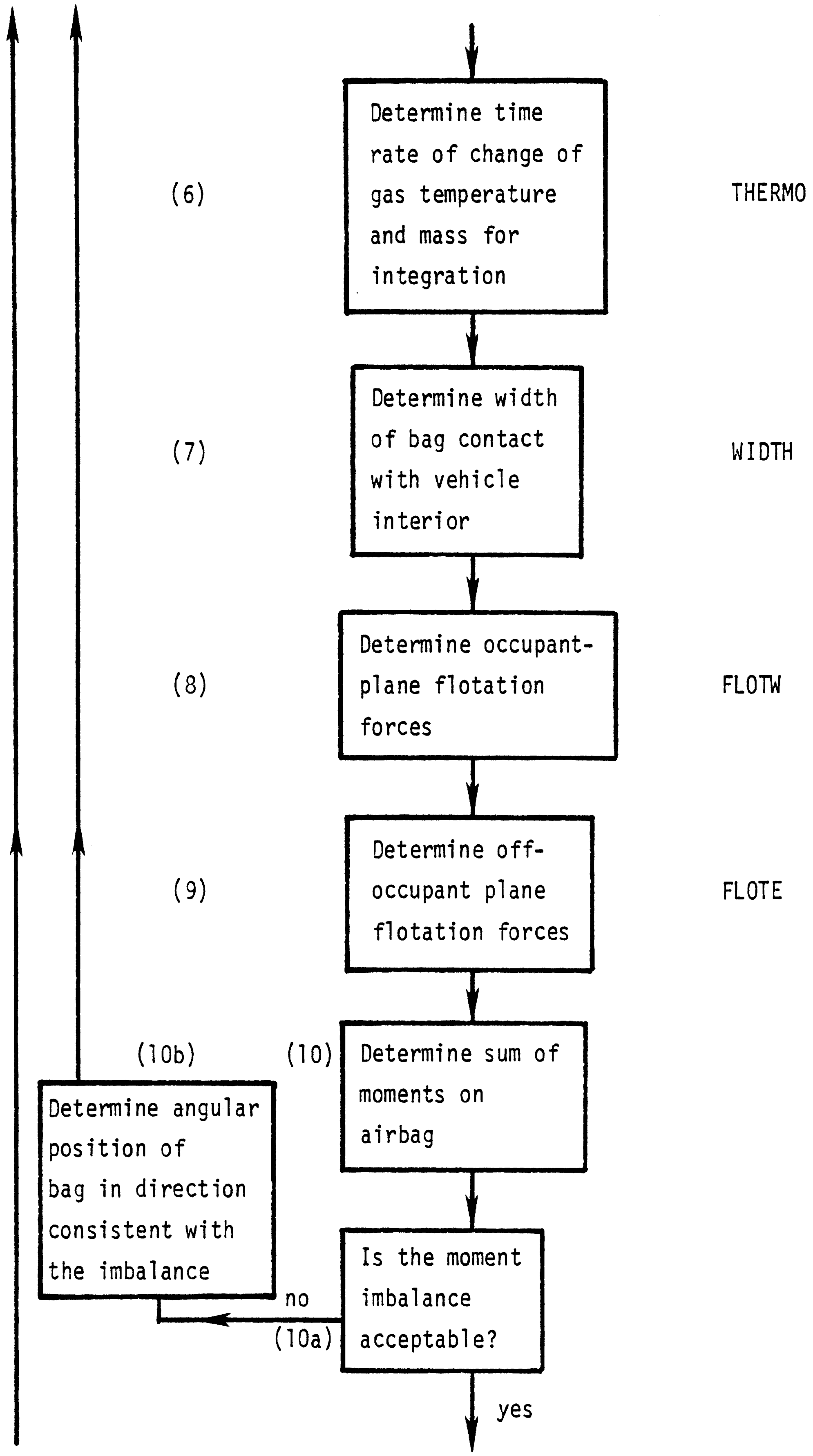

Figure 1b. Flow Diagram for Advanced Airbag System Submodel (page 2)

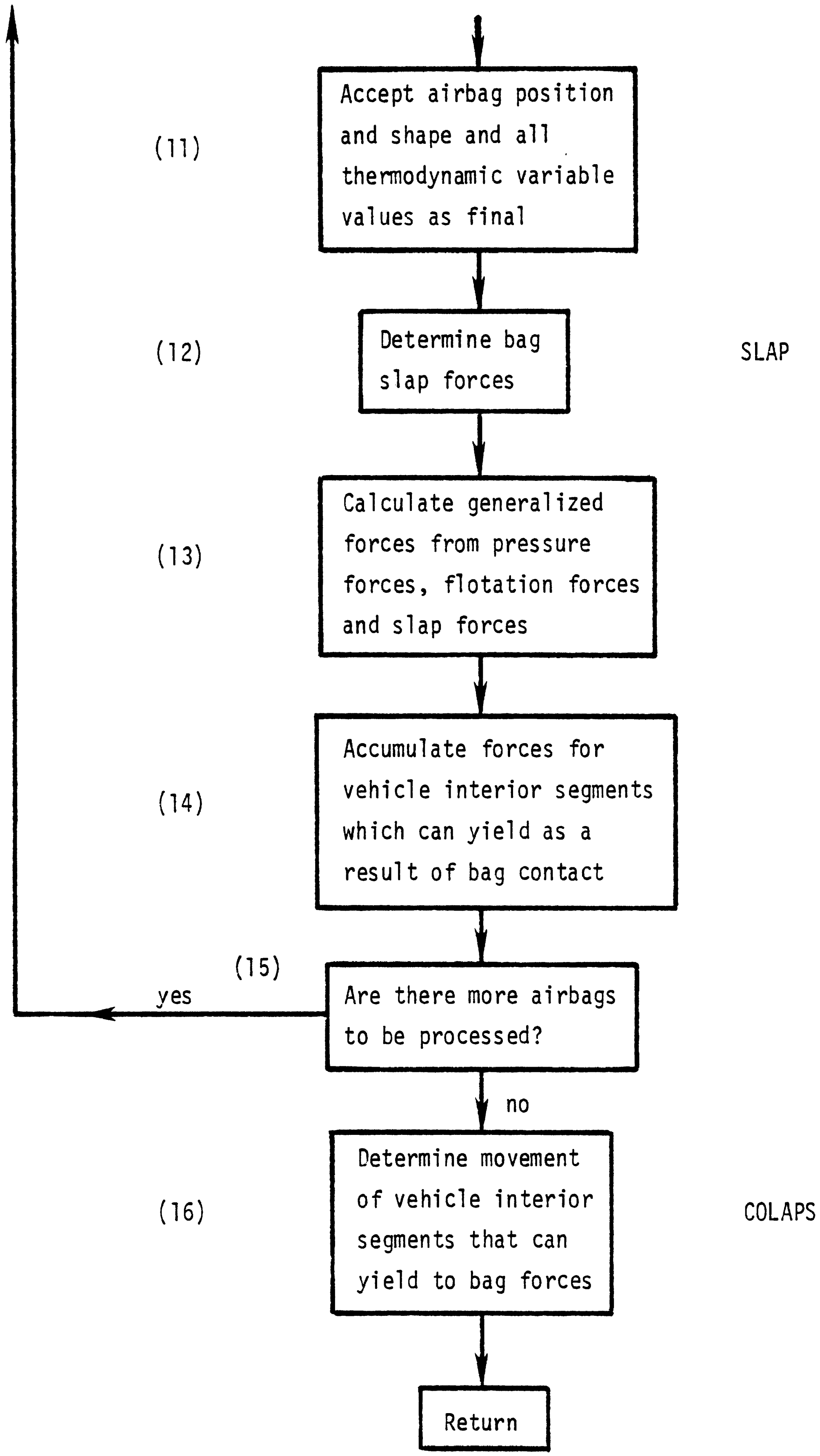

Figure 1b. Flow Diagram for Advanced Airbag System Submodel (page 3)

2.1 The Advanced Airbag System Enclosure

The airbags expand within a contact-sensing polygonal "box" of constantly changing shape and size. (See Figure 2.) This profile of contact-sensing straight-line surfaces is termed the "enclosure." The enclosure consists of three types of straight-line segments. 1) First, there are segments which are part of the vehicle interior profile. In general, the same vehicle surfaces which can sense direct contact by the occupant will also sense contact by the airbags. However, the model user can define any desired number of vehicle interior surfaces that will sense only contacts by airbags. The vehicle interior segments in the enclosure can be fixed within the vehicle frame or time-dependent motions for them can be prescribed in order to represent occupant-compartment intrusion or for any other purpose. In addition, these segments may deform, or "yield," in response to airbag contact forces. (See Section 2.16.) 2) Next, the enclosure includes nine user-defined contact-sensing segments which represent the occupant profile.* There are two segments for the head and for the pelvis. There is one segment each for the chest, midsection, upper leg, knee, and lower leg. 3) Finally, there are two segments defined by the program which close the enclosure, each joining the occupant profile to the vehicle interior profile. One extends from the top of the head to the "uppermost" segment in the vehicle interior portion of the enclosure and one extends from the end of the lower leg segment to the

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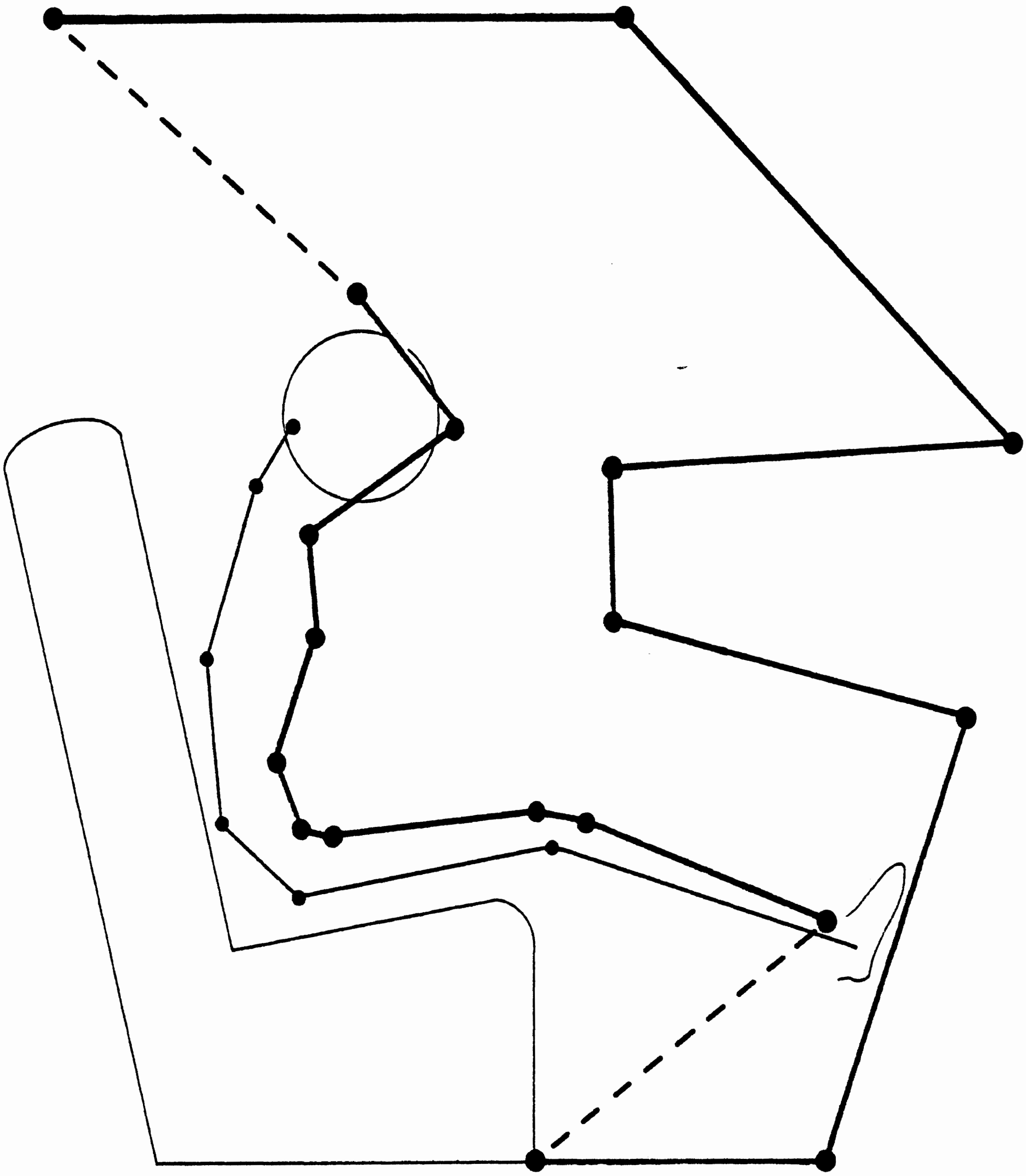
*The computer model considers eleven segments, two of which have zero length. These are between the chest and midsection and between the midsection and upper pelvis.



Enclosure = Bold lines (solid and dashed)

Figure 2. The Advanced Airbag System "Enclosure"

"lowermost" vehicle interior segment. In order that these two imaginary contact segments not participate in airbag deformation, the uppermost and lower most segments of the vehicle interior portion of the enclosure should be "roof" and "floor" lines which extend to positions rearward of the maximum likely rearward motion of the occupant.

It is necessary for the program to establish the geometry of the enclosure at each integration time step. The shape and size of the enclosure change with time because of occupant motion and also user-prescribed vehicle interior segment motions.

2.2 The n-Airbag System

In order to allow maximum flexibility in use of the Advanced Airbag System Submodel and to permit investigation of the most innovative airbag system design ideas, the model has been made to accommodate an arbitrary number of separate airbags. The user need only include in the data deck all necessary cards for each airbag desired in the system. Although program code is completely general for "n" airbags, there is at present a limit of 20 imposed by the dimension of one of the variable arrays. Airbags may be nested and/or separate so that a system such as that illustrated in Figure 3, for example, is possible. (The airbags are illustrated here with circular profiles, but Section 2.3 explains that all bag cross-section profiles are either polygonal or a set of arcs and straight-line segments.) In Figure 3, bags 2, 3, and 5 are "internal" bags, each of which inflates inside another bag and exhausts into that bag. The sets 2-3-4 and 5-6 each represent two-deep nestings. Nesting is limited to five deep.

Airbag contributions to the equations of motion for the occupant are determined by investigating the n airbags in a specific order. This order is determined by the program itself and is such that each nesting of airbags is processed inward-to-outward. The numbers shown in Figure 3 represent a possible ordering for processing the six airbags. The reason for a particular ordering is so that proper account may be taken of volume displaced by an internal bag within the total volume of an external bag. The net volume of the gas in the external bag is the volume needed for the equations of gas thermodynamics. This is discussed

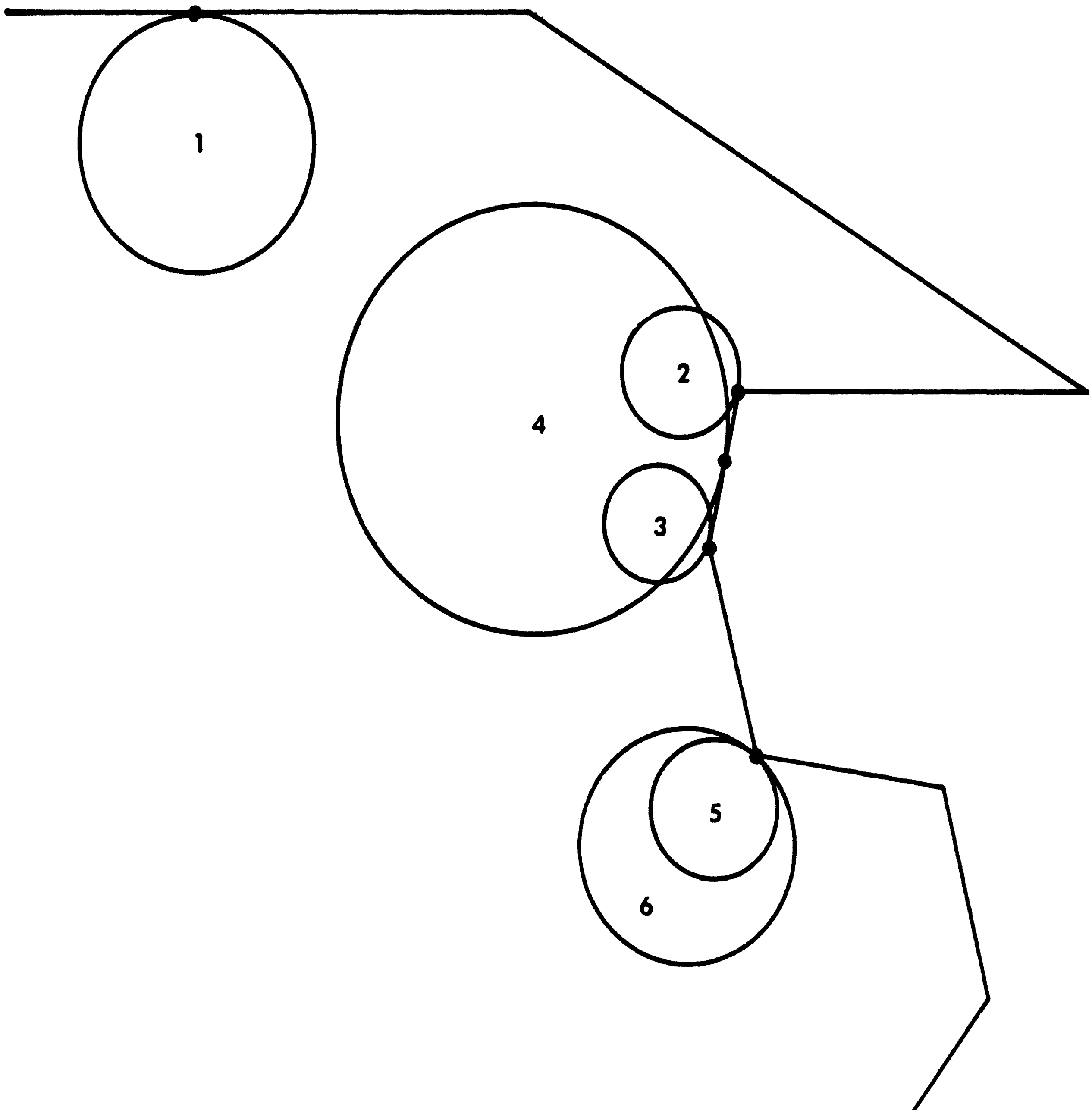


Figure 3. Example Airbag System With Six Bags

further in Section 2.5. Possible direct contact between airbags is not modeled in the Advanced Airbag System Submodel so all bags are independent from each other except for the volume adjustment just mentioned and allowance for venting from an internal bag into an external one.

2.3 Determination of Airbag Interaction with the Enclosure

For each airbag in the system, the user prescribes a time history of bag profiles for the deploying, uncontacted bag. Each such bag profile is a polygon defined by an ordered set of vertex points. Any number of unequally-spaced vertex points may be prescribed for each profile and this number need not be the same in successive profiles in the time history for a given airbag. It is important only that these points adequately define the shape of the uncontacted bag -- there is no need to be able to follow material points through the time history, so no vertex point for any profile must necessarily identify with any specific material point.* Implicit in this is that the airbag fabric is allowed to adjust itself -- or "relax" -- freely in directions tangential to contacted surfaces. Any number of bag profiles may be included in the time history for a given bag and the time spacing between profiles need not be constant. Each polygonal profile should represent an instantaneous side view of the bag cross section in the occupant plane and should be for a freely deploying, uncontacted bag.

Thus, possible contacts between an airbag and the enclosure are investigated by determining whether there is intersection between the polygon representing the uncontacted airbag and the polygon for the enclosure. If the enclosure and the airbag do interact, then it

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*There are two exceptions to this -- the so-called "reference point," discussed in Section 2.10.2, and the source point (or attachment point) for the airbag.

is necessary to determine the constrained profile of the deformed bag. In general this profile will include sections where the bag fabric is laid out along occupant contact line segments in the enclosure and along vehicle interior contact segments and also sections where the fabric is "free" -- not in contact with any part of the enclosure. The geometry of interaction between an airbag and the enclosure is determined by Subroutine PROFLE. The manner in which it performs its function is explained and illustrated below.

2.3.1 The Enclosure and the Uncontacted Airbag Profile. Figure 4 shows the polygonal profiles of an enclosure and an uncontacted bag for some time t. These example profiles have fewer than a normal number of segments -- sixteen and ten, respectively -- for the sake of clarity of illustration. The airbag attachment point is at a vertex of the enclosure (actually, slightly inside the enclosure -- see Card 926 in Section 3.2) and moves with that vertex if the adjacent enclosure segments undergo user-prescribed motion. Subroutine PROFLE determines that an airbag is in contact with the enclosure if it finds intersections between the two polygons. In the example, there are four intersections, marked in Figure 4 by single hatch lines.

2.3.2 The Primary Profile. A first approximation to the final deformed airbag profile is shown by dashed lines in Figure 5. This is called the "primary profile" and is determined in the following manner. First, where the uncontacted bag profile (Figure 4) lies outside the enclosure, the airbag/enclosure intersections define the

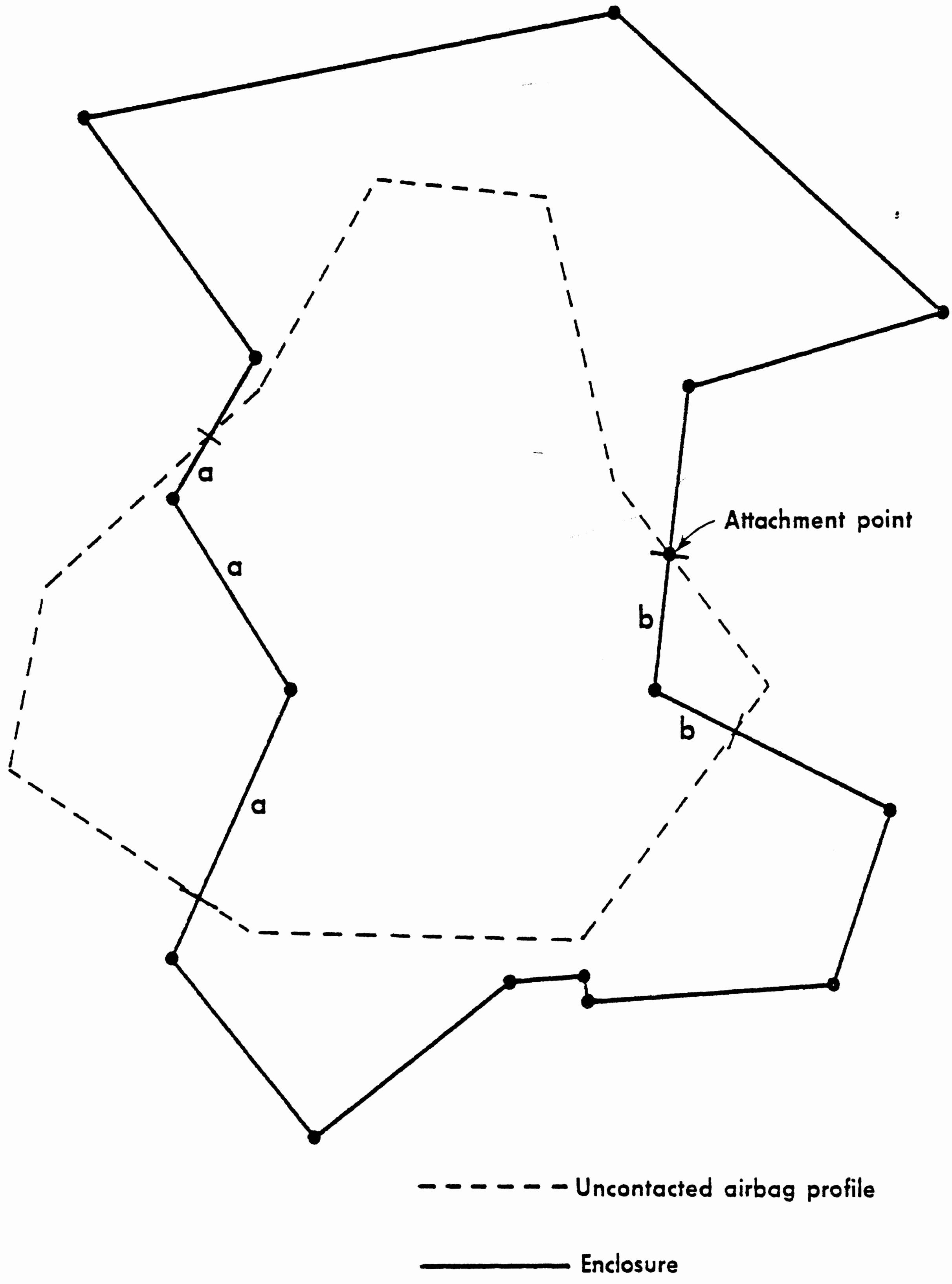

Figure 4. Example Enclosure and Uncontacted Airbag Profiles

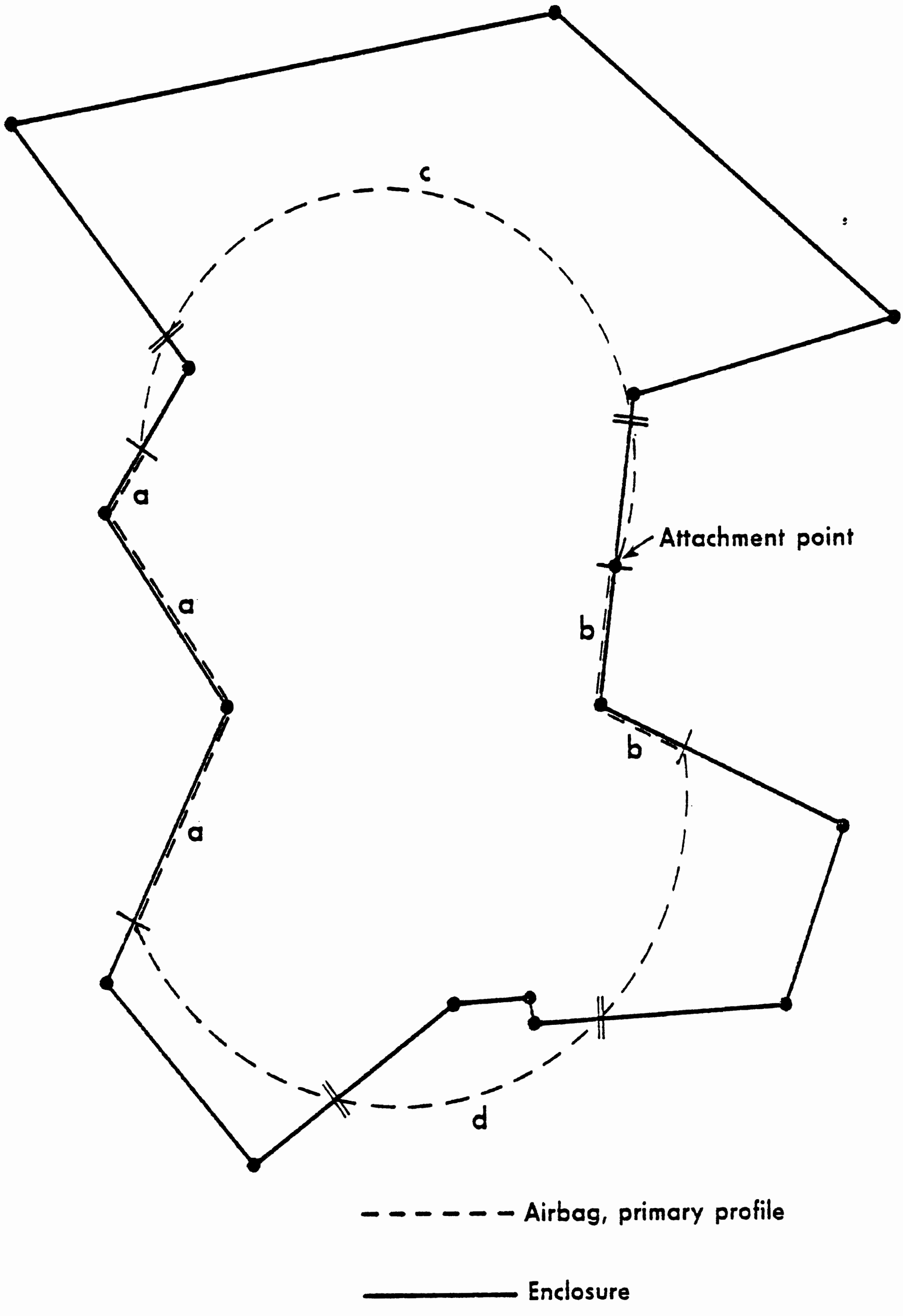

Figure 5. Example Primary Profile for Deformed Airbag

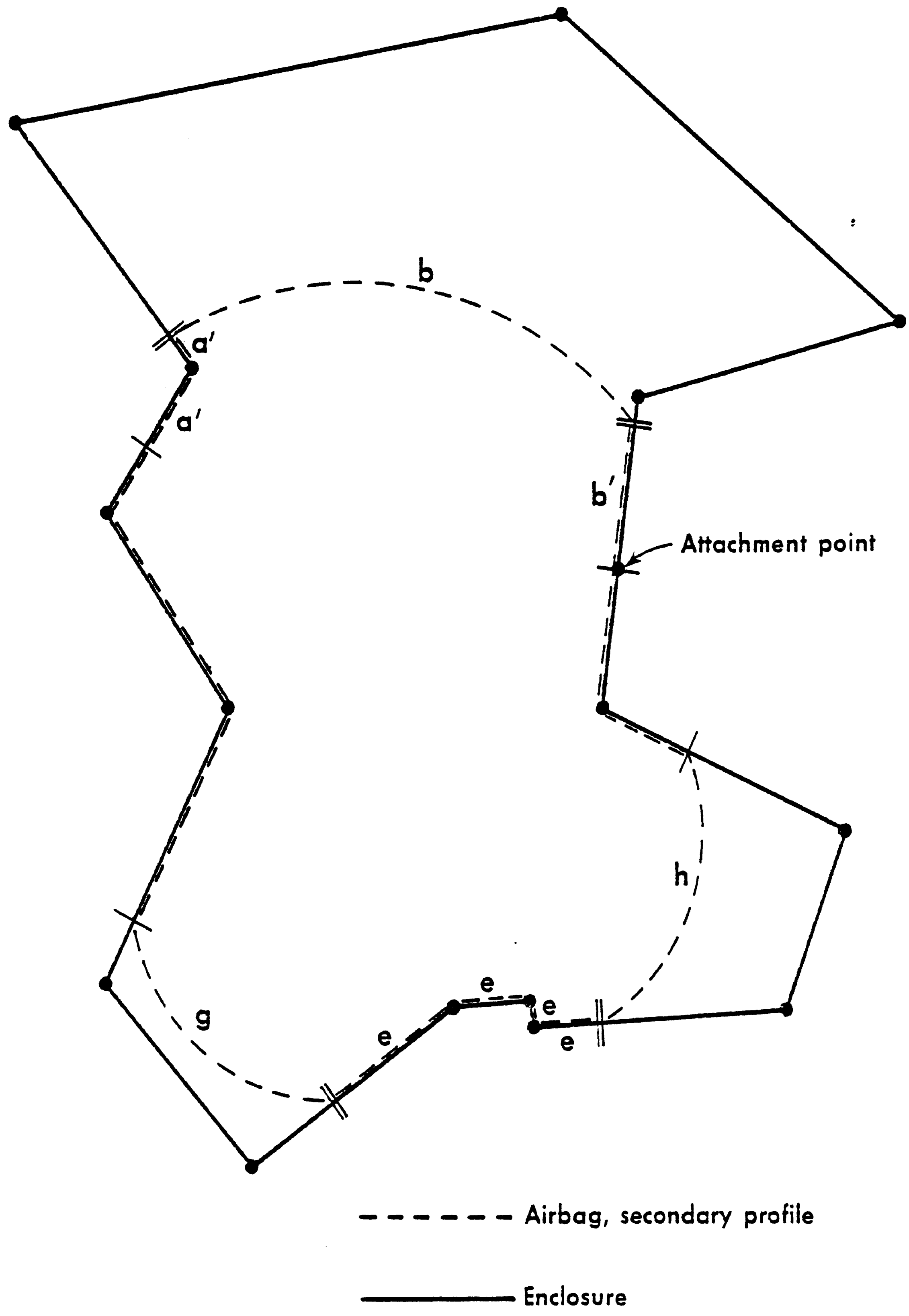

Figure 6. Example Secondary Profile for Deformed Airbag

extent of sections of the enclosure along which bag fabric is laid. Hatch lines for these intersections are shown in both Figure 4 and Figure 5, and all enclosure segments or parts of enclosure segments comprising the sections where bag fabric is laid out are labeled by "a" or "b".

The next step is to distribute the remaining fabric to the gaps between sections of the enclosure that are in contact with the airbag. These "bulges," the circular arcs "c" and "d" in Figure 5, complete the primary profile.

Arc dimensions are calculated in the following manner. Suppose C is the perimeter of the uncontacted bag in Figure 4, i.e., the sum of the lengths of all the straight-line segments in the airbag profile. Then, the radii of curvature of the arcs in the primary profile are chosen so that, where S_i is an arc length and l_j is a straight-line segment length of the primary profile,

$$\sum l_j + \sum S_i = C, \tag{1}$$

and the S_i's are all in the same proportion to the arc chord lengths, d_i, i.e.,

$$S_i = \gamma d_i , \tag{2}$$

where γ is a constant of proportionality. The first condition means that the bag perimeter (at time t) is held constant. The latter condition means that all the arcs will be geometrically similar. From equations 1 and 2, we obtain

$$\sum l_j + \gamma \sum d_i = C, \tag{3}$$

which yields

$$\gamma = \frac{C - \Sigma \ell_j}{\Sigma d_i} \quad . \tag{4}$$

Therefore, equations 2 and 4 give

$$S_i = \frac{C - \Sigma \ell_j}{\Sigma d_i} d_i \quad . \tag{5}$$

S_i is thus determined since every quantity in the right-hand side of equation 5 is known, the d_i chord lengths being simply the distances between the endpoints of the arcs.

With S_i as well as d_i thus determined, the radius of curvature of arc "i " can now be found. Consider Figure 7. Since

$$S_i = r_i \theta_i \tag{6}$$

and

$$\theta_i = 2 \sin^{-1} \frac{d_i}{2r_i} \quad , \tag{7}$$

we obtain an equation which can be solved for r_i:

$$f(r_i) = 2r_i \sin^{-1} \frac{d_i}{2r_i} - S_i = 0 \quad . \tag{8}$$

In the program, this equation is solved by a Newton's iteration with four-place accuracy always achieved in three iterations or less. If $d_i/S_i \leq 0.5$, the starter used is $r_i^{(0)} = S_i/2\pi$ and if $d_i/S_i > 0.5$, $r_i^{(0)} = S_i^2/4\sqrt{S_i^2 - d_i^2}$.

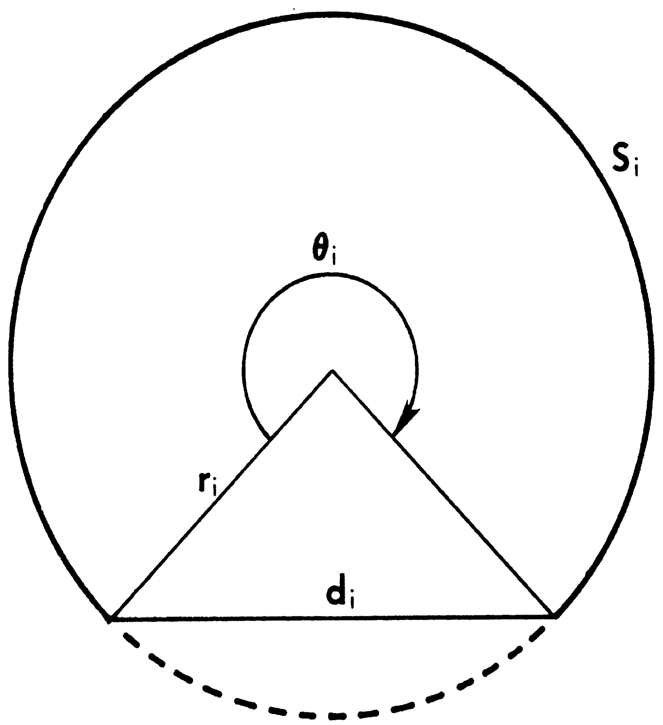

Figure 7. A Circular Arc

Finally, it will be required to know the coordinates (h, k) of the center of the circle for the established arc. (The subscript "i" is dropped in the following.) Figure 8 illustrates an arc with its endpoint coordinates and center coordinates. The arc endpoints (X_a, Z_a) and (X_b, Z_b) are known, being the locations of the single hatch marks in Figures 4 and 5 and determined as intersections of straight-line segments by Subroutine LSECT. Therefore, where θ and r come from equations 6 (or 7) and 8, we have

$$\alpha = \tan^{-1} \frac{z_b - z_a}{x_a - x_b}$$

$$\beta = \frac{\theta - \pi}{2} \tag{9}$$

and finally

$$h = x_b + r \cos(\alpha + \beta)$$

$$k = z_b - r \sin(\alpha + \beta) \quad . \tag{10}$$

2.3.3 The Secondary Profile. The "primary profile" established in the foregoing section is a first approximation to the final deformed airbag profile. With the primary profile as a base, an improved (and final) approximation to the deformed airbag profile is next determined. It is called the "secondary profile." Figure 9 shows the secondary profile for the example that was previously considered. This figure is the same as Figure 6, where it was included for convenient comparison of the uncontacted, primary, and secondary airbag profiles.

To determine the secondary profile, the arcs determined as part of the primary profile must be examined for possible "secondary"

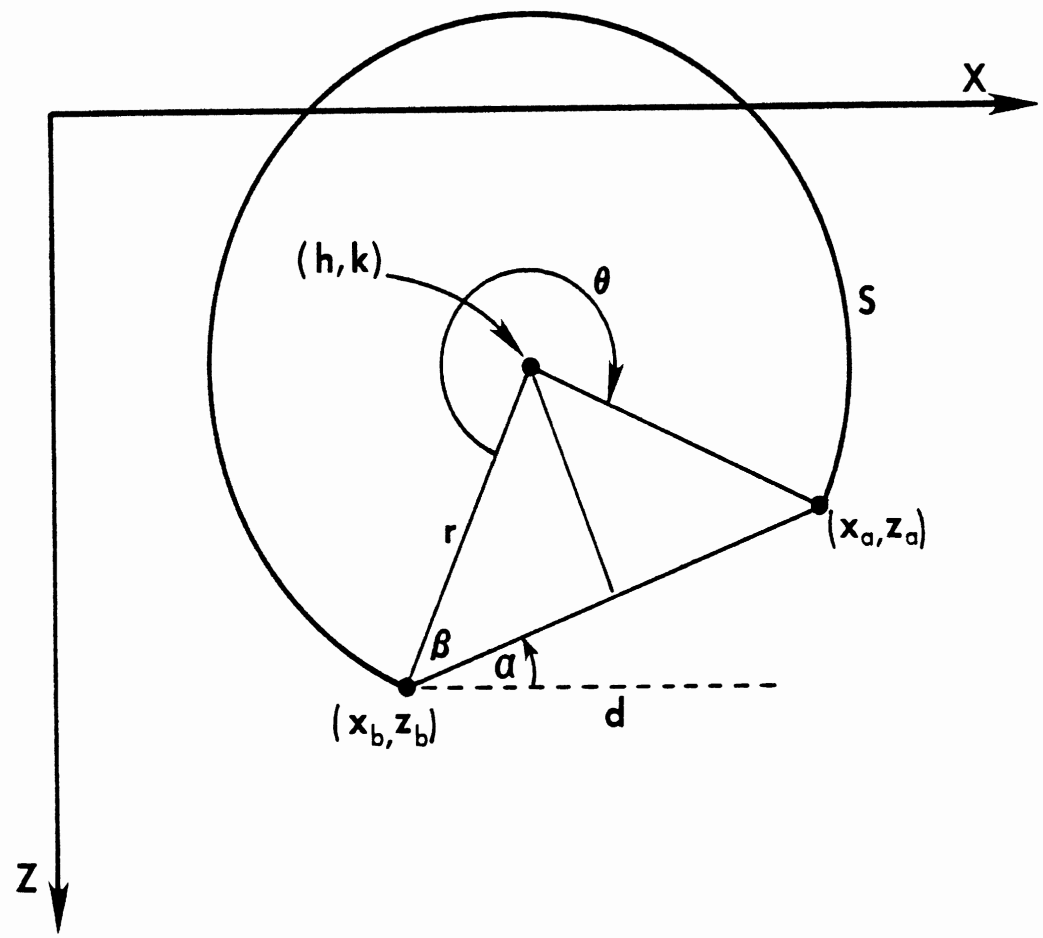

Figure 8. Coordinates of the Center of A Circular Arc

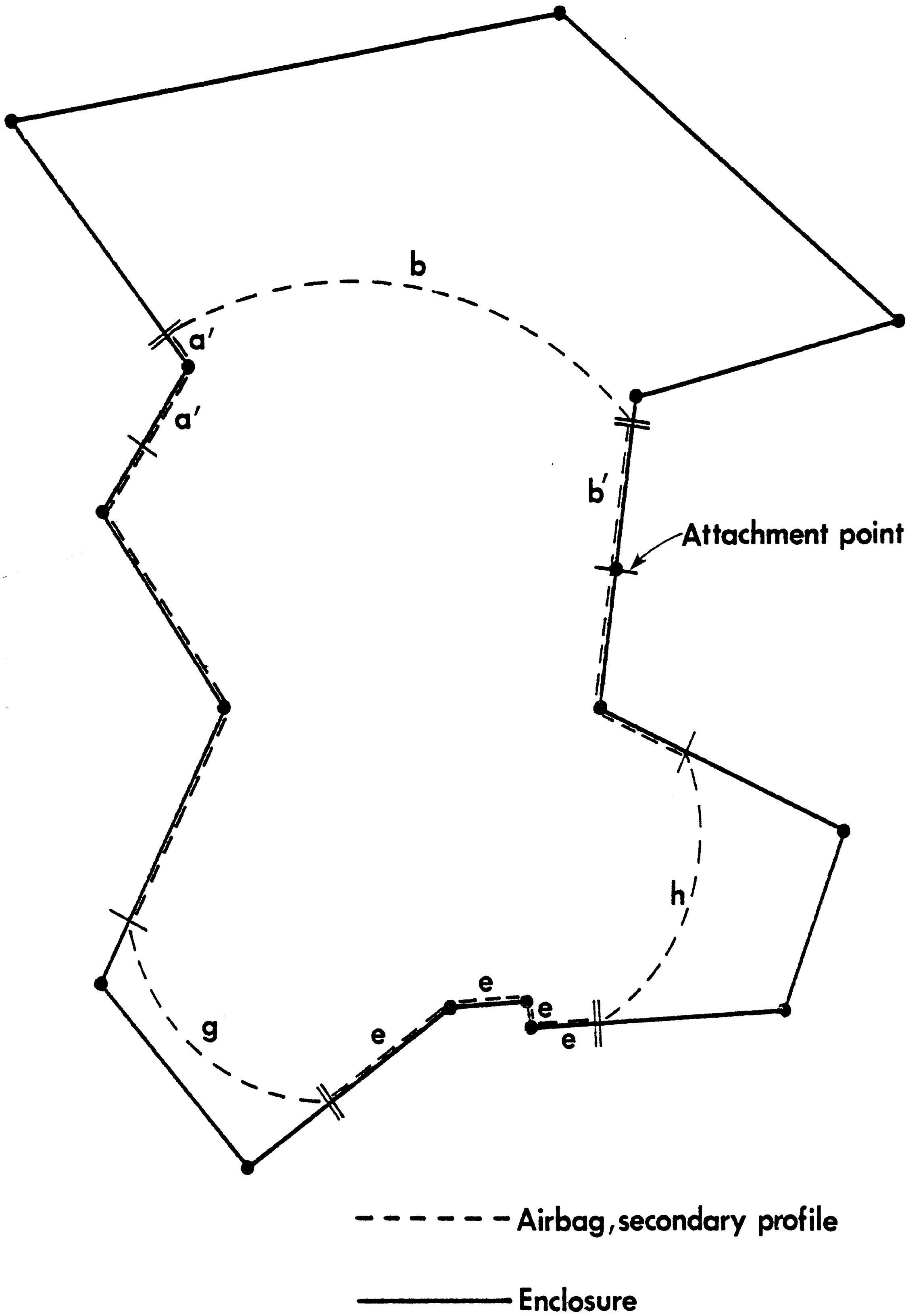

Figure 9. Example Secondary Profile for Deformed Airbag

intersections with the enclosure. For the example, Figure 5 shows both arcs making secondary intersections with the enclosure. These are the points marked by the double hatch lines in Figures 5, 6, and 9. (Intersections of circular arcs with line segments are determined by Subroutine ASECT, and the pertinent analysis is presented in Appendix A.) Again, bag fabric is laid out against sections of the enclosure outside of which the "base" profile extends. Thus, in Figures 6 and 9, straight-line segments marked by a', b', and e become additional parts of the enclosure that are in contact with the airbag. Finally, arcs must again be determined for the "gaps." In Figures 6 and 9, the secondary profile has three new arcs -- f, g, and h. Had there been an arc in the primary profile which made no secondary intersections with the enclosure, then it would have been retained intact as a part of the secondary profile. Arc coordinates for the secondary profile are determined in the manner previously described for primary profile arcs except that in place of Σl_j in equations 1 through 5, the following expression is used:

$$\Sigma S_k^{(1)} + \Sigma \ell_j' + \Sigma \ell_j \quad .$$

Here, Σl_j is as before, $\Sigma S_k^{(1)}$ is the sum of the lengths of all primary profile arcs which are retained in the secondary profile, and $\Sigma l_j'$ is the sum of the lengths of newly added straight-line segments in the secondary profile. The sum of these three terms is the total length of bag fabric unavailable for distribution to the secondary profile arcs.

2.3.4 Profile Descriptors of the Contacted Airbag. Strictly, the deformed airbag profile has now been completely defined since the coordinates of all vertex points and arc center points have been established. Segment and arc lengths have been calculated and also -- for the arcs -- radius of curvature, subtended angle, and chord length. In addition to these, several other descriptors are needed in the analysis and are determined by Subroutine PROFLE. These are: the center point coordinates of each straight-line segment in the profile; and the x- and z-components of the outward unit normal vectors to the straight-line segments and to the arc chords. Let (x_1,z_1) and (x_2,z_2) be the endpoints of a straight-line segment of the secondary profile, where (x_1,z_1) is encountered first in a counterclockwise traversal of the profile. The center point coordinates of the line segment are, of course, $(x_1 + x_2)/2$ and $(z_1 + z_2)/2$. The outward unit normal vector is determined as follows ("outward" indicating outward from the bag). The equation of the line through these points is found to be

$$(z_1 - z_2)x - (x_1 - x_2)z + z_2 x_1 - z_1 x_2 = 0.$$

Since the unit normal to the line $ax + cz + d = 0$

is $$\hat{n} = \frac{a}{\sqrt{a^2+c^2}}\hat{i} + \frac{c}{\sqrt{a^2+c^2}}\hat{k},$$

the x- and z-components of $\hat{n}$ are seen to be

$$g \equiv n_x = \frac{-(z_2 - z_1)}{\sqrt{(x_2-x_1)^2+(z_2-z_1)^2}} \tag{11}$$

$$h \equiv n_z = \frac{x_2 - x_1}{\sqrt{(x_2-x_1)^2+(z_2-z_1)^2}} .$$

The components of the outward unit normal to an arc chord have the same form as equations 11, but points 1 and 2 are, of course, the endpoints of the chord. In later analysis, the symbols G and H are used for the x- and z-components of the normal to a chord.

2.4 Area of Occupant-Plane Cross Section of Airbag

In Section 2.5, a user-supplied experimental relationship between airbag volume and cross-sectional area, with pressure divided by temperature as a parameter, is explained. This relationship introduces information from the three-dimensional world (volume) into the two-dimensional simulation. The "independent variable" in the relationship is airbag cross-sectional area in the occupant plane. This can be determined as explained in this section once Subroutine PROFLE has established the bag profile. Two cases must be considered: a) the uncontacted bag profile; b) the deformed bag profile, i.e., the secondary profile discussed in Section 2.3.

2.4.1 Area of the Uncontacted Airbag Profile. Figure 10 illustrates the user-defined polygonal profile of an uncontacted airbag with N segments. The area of the polygon is found from Green's Theorem as a closed line integral, or contour integral, around the polygon periphery. Specifically, if x- and z-axes are defined as illustrated and integration is in the direction "C" shown (i.e., counterclockwise), then the area is

$$A = \frac{1}{2} \oint (z\,dx - x\,dz) \quad . \tag{12}$$

Let

$$z^{(i)} = a_i\, x^{(i)} + b_i \tag{13}$$

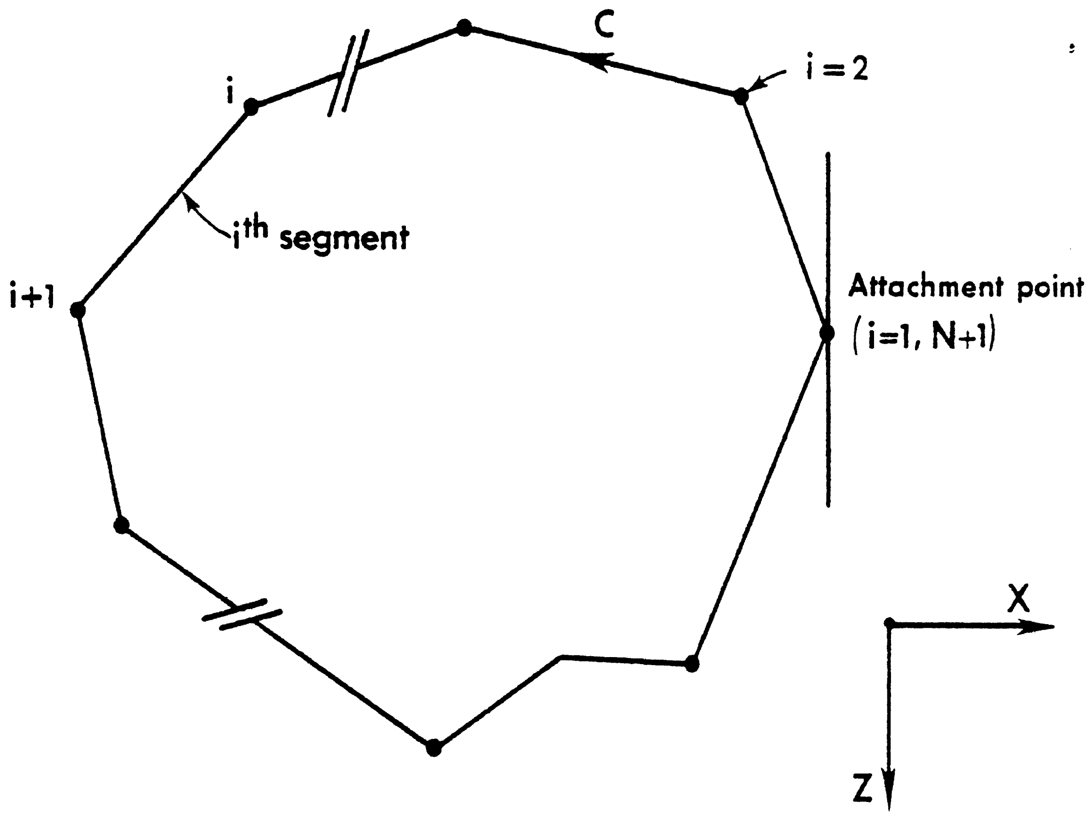

Figure 10. Contour of Uncontacted Bag Profile

be the equation of the i^{th} line segment. Then, since its endpoints, (X_i, Z_i) and (X_{i+1}, Z_{i+1}), lie on the line,

$$z_i = a_i x_i + b_i$$

and (14)

$$z_{i+1} = a_i x_{i+1} + b_i \quad .$$

The slope a_i and z-intercept b_i can be determined from (14) as

$$a_i = \frac{z_{i+1} - z_i}{x_{i+1} - x_i} \tag{15}$$

$$b_i = z_i - \frac{z_{i+1} - z_i}{x_{i+1} - x_i} x_i \quad . \tag{16}$$

Equations 12, 13, 15, and 16 now allow integration for the area. The result is

$$A = \frac{1}{2} \sum_{i=1}^{N} (z_i x_{i+1} - x_i z_{i+1}) \quad . \tag{17}$$

A superior computational form is used by Subroutine AREA1, viz.,

$$A = \frac{1}{2} \sum_{i=1}^{N} z_i (x_{i+1} - x_i) - x_i (z_{i+1} - z_i) \quad . \tag{18}$$

2.4.2 Area of the Deformed Airbag Profile. The deformed airbag profile, or "secondary profile," in general consists of a set of n connected arcs and m straight-line segments. Such a profile is illustrated in Figure 11.

A contour integration can again be used for finding the area enclosed by the profile. Arrows indicate the direction for integration around a contour which includes a chord for each arc. Note that the two components of the line integral for the chord across the base of

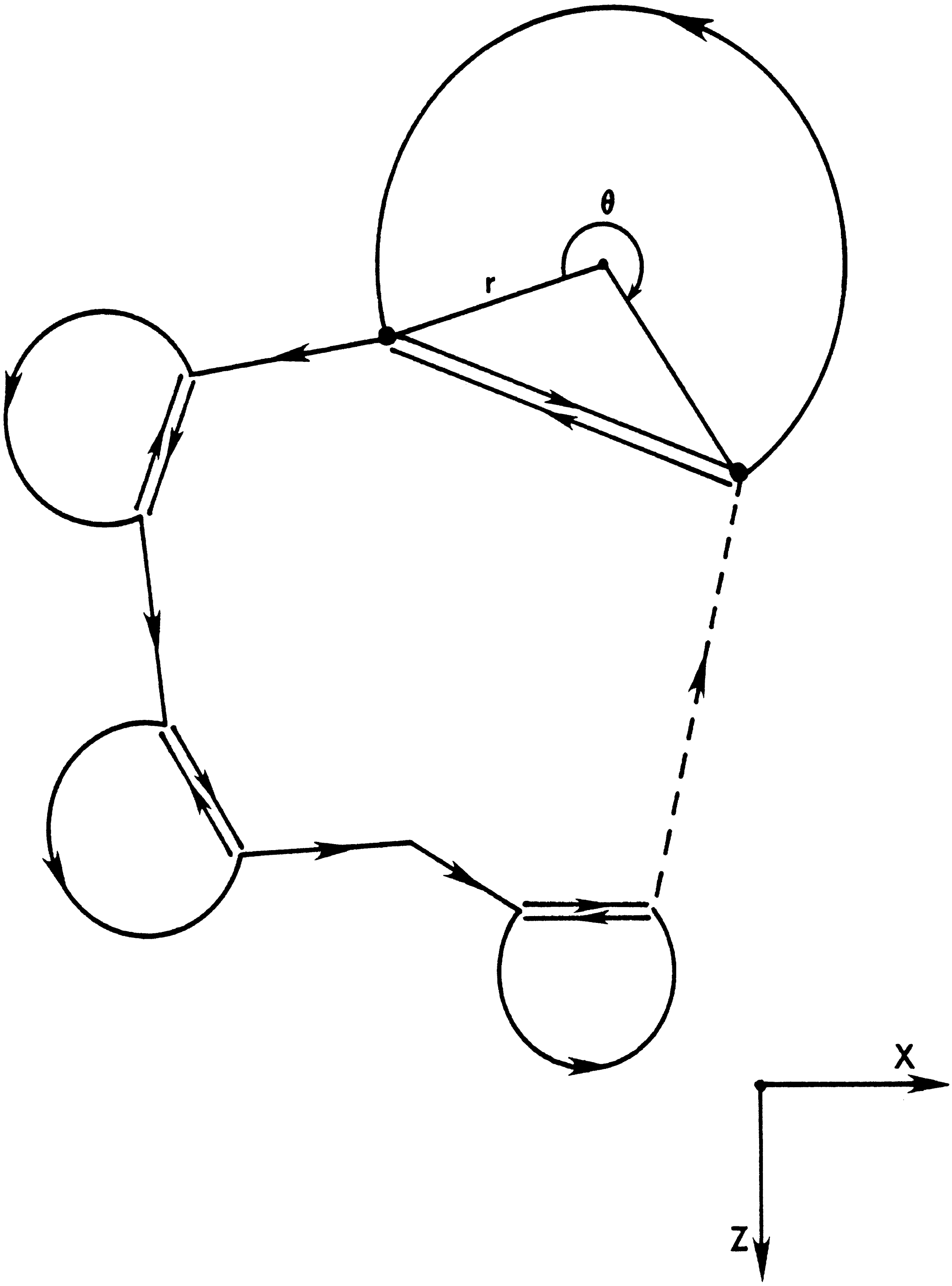

Figure 11. Contour of Deformed Airbag Profile

each arc will cancel so that integration around the contour shown is equivalent to integration around the airbag profile. Note also that the integral can be broken into two terms - one, the contour integral for a polygon of n + m sides and, second, the sum of the contour integrals for the n circle segments. The general result for the area of a polygon has already been established in Section 2.4.1. The area of a circle segment could be determined by a contour integration, but it is also found by other means to be

$$A_{c.s.} = \frac{1}{2} r^2 (\theta - \sin\theta) , \tag{19}$$

where r and θ are illustrated in the figure for one circle segment. Since r and θ have already been established for each arc of the secondary profile (equations 7 and 8), the area enclosed by the secondary profile is found by Subroutine AREA2 as

$$\begin{aligned} A = \frac{1}{2} \sum_{i=1}^{n+m} z_i (x_{i+1} - x_i) - x_i (z_{i+1} - z_i) \\ + \frac{1}{2} \sum_{j=1}^{m} r_j^2 (\theta_j - \sin\theta_j) \end{aligned} \quad . \tag{20}$$

2.5 Determination of Pressure and Volume

Cards 922 allow the model user to supply an experimental relationship which introduces information from the three-dimensional world into the two-dimensional simulation. In particular, total airbag volume is related to cross-sectional area of the contacted or uncontacted bag in the occupant plane. Volume is given as a function of cross-sectional area with the ratio of pressure to temperature as a parameter so that the "relationship" is really a family of curves. The curves are defined tabularly as illustrated by their piecewise-linear character in Figure 12. Points for these curves must be determined in the laboratory by a series of quasi-static tests in which the airbag is increasingly deformed in the plane of the occupant. It is anticipated that most such tests will deform the bag near its center cross section, but it should be possible to simulate the planar effects of striking an airbag toward one end (if the bag is cylindrical) by positioning the contacting form in the tests toward an end. The user-specified volume-area relationship together with the means for describing an uncontacted bag profile of arbitrary shape and size (Section 2.3) make it possible to simulate airbags that are basically spherical, basically cylindrical, or any other shape even though MVMA 2-D CVS occupant motions are in a plane.

The curves of Figure 12 represent the total airbag volume as a function of two variables, viz.,

$$V_T = f(A, P/T) . \tag{21}$$

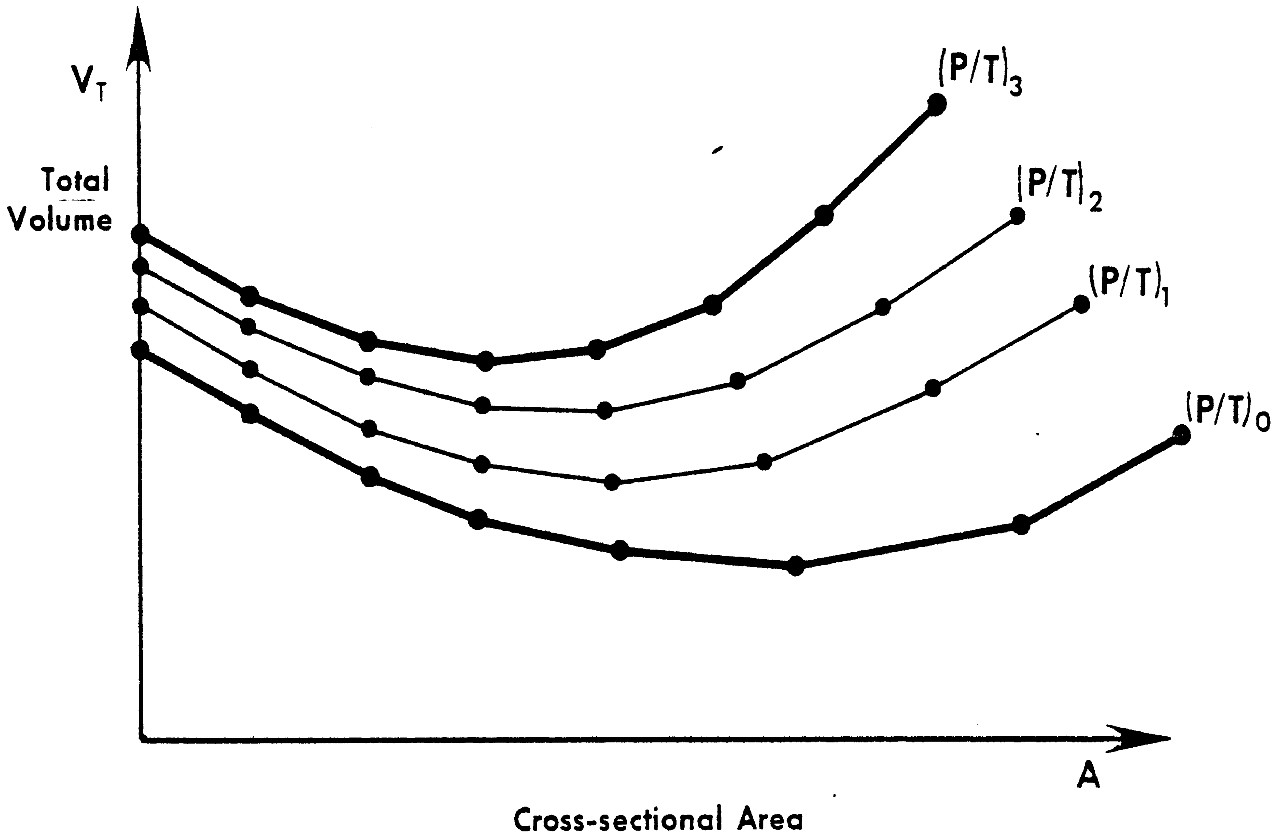

Figure 12. Total Airbag Volume vs. Cross Section Area in Occupant Plane, With Pressure/Temperature Ratio As a Parameter

In addition to satisfying this relationship, however, the thermodynamic state variables must satisfy the following condition:

$$PV_N = mRT \quad . \tag{22}$$

Here, the units of the gas constant, R, are chosen such that the mass of gas in the bag, m, may be used directly rather than the number of moles.* V_N is the net volume of gas inside the bag and will differ from V_T only if internal airbags are displacing a part of the total volume:

$$V_N = V_T - \sum V_{T,\,internal} \quad . \tag{23}$$

Mass m and temperature T in equations 21 and 22 are known at each instant of time from integration of the differential equations of gas thermodynamics discussed in Section 2.6. Therefore, since V_T and V_N are related by equation 23 and since A has been determined by equation 18 or 20, equations 21 and 22 may be considered two equations in two unknowns: V_N and P.

In practice, an algebraic solution cannot be obtained since P is not an independent variable in equation 21 and cannot be separated from the curve parameter P/T. A numerical solution is therefore necessary. This is the "pressure-volume iteration" performed by Subroutine ADVBAG. First, with an estimate for P (call it P_A) and the current value of T, the volume V_T in equation 21 is evaluated. This is done by making use of linear interpolations for both A and P/T

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*The model user may specify the value for the gas constant of the inflation gas directly or, alternatively, the molecular weight for the gas. In the latter case, the gas constant is calculated as explained in Appendix B.

on the V_T vs. A curves (Figure 12). Next, the calculated value for V_T is adjusted as in equation 23 to yield a value for V_N. This value is used in equation 22 to yield a value for P: $P_B = mRT/V_N$. If values P_A and P_B are sufficiently near, the iteration has converged. If not, their average value is taken as the next estimate for P_A, and P_B is again evaluated in the manner explained, etc. With typical values for all quantities, this procedure converges for P accurate to 0.1 lb/in^2 ($7x10^{-3}$atm) in three or four iterations. Much greater accuracy can be obtained with only a few additional iterations. Net volume, V_N, may be evaluated from either equation 21 or equation 22 once P is determined.

One note is made here. The assumption is made in the analytical model that an internal bag is "hard" relative to the surrounding bag, i.e., its pressure is much greater. This assumption is consistent with current ideas regarding the possible design of nested-bag systems. With this assumption, it is valid to neglect establishing conditions which balance the gas pressures inside nested bags, and consequently it is valid to subtract the previously established internal bag volumes, without adjustment, from the total volume of an external bag in order to obtain its net volume (equation 23).

2.6 Thermodynamics

The preceding section discusses the determination of gas pressure and volume for each airbag, subject to user-supplied constraints. With the pressure known, it is possible by considering contact areas to calculate the associated cushioning forces on the occupant -- the so-called airbag "pressure forces." However, the determination of P from equations 21 and 22 of Section 2.5 assumes that values for mass and temperature, m and T, are known. It is the purpose of this section to explain the calculation of those values.

Gas temperature and mass of a single bag are governed by a set of seven coupled differential equations.* If one bag exhausts into another bag, then the governing equations for the two bags become coupled, and other bags simlarly involved increase the amount of coupling. Regardless of inter-bag coupling, however, as long as the same type of gas is used for the inflation of each bag, the same set of seven basic equations explains the thermodynamics of each bag. The development of airbag thermodynamics in Volume 1 of the MVMA 2-D CVS manuals applies to the Advanced Airbag System as well as to the simple airbag system and will not be repeated here. The set of seven governing equations, however, is given below and comment will be made on each equation. In addition, there is a table of nomenclature which includes the units for variables in the simulation equations.

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*Strictly, equations 21, 22, and 23 of Section 2.5 should be considered a part of the system, making a total of ten coupled equations.

NOMENCLATURE FOR THERMODYNAMICS

Quantities

m	mass [kg or lbm]
f_1, f_2	temperature [°K or °R]
a	a constant [1 or 32.174(lbm/lb/ft/sec^2)^2]
b	a constant [1 or 12 in/ft]
P	pressure [N/m^2 or lb/in^2]
R	gas constant [joules/kg/C° or ft lb/lbm/F°]
C_p	specific heat at constant pressure [joules/kg/C° or ft lb/lbm/F°]
γ	ratio of specific heats
A	area [m^2 or in^2]
V	volume [m^3 or in^3]
Δt	integration time step [step]
W	work done by airbag in changing its boundary [Nm/sec or in lb/sec]
S	surface area of porous fabric [m^2 or in^2]
μ	porosity of bag fabric [m^3/m^2/sec or in^3/in^2/sec]

Subscripts

in	indicates gas coming into airbag
ex	indicates gas exhausted from airbag
ext	indicates condition of external gas
s	indicates condition of source of gas entering airbag
i	current time step
i-1	last time step

$$\dot{m}_{in} = f_1(t) \tag{24}$$

$$T_s = f_2(t) \tag{25}$$

$$\dot{m}_{ex,\,vent} = a\,\frac{A_{ex}\,P}{R}\left(\frac{2\,C_p}{T}\left\{\left(\frac{P_{ext}}{P}\right)^{2/\gamma} - \left(\frac{P_{ext}}{P}\right)^{(\gamma+1)/\gamma}\right\}\right)^{\frac{1}{2}} \tag{26}$$

$$\dot{m}_{ex,\,fabric} = \frac{P_{ext}\,[S\mu]}{R\,T_{ext}} \tag{27}$$

$$\dot{W} = \frac{P_{i-1} + P_i}{2\,\Delta t}\left(\left|V_{i-1} - V_i\right|\right) \tag{28}$$

$$\dot{m} = \dot{m}_{in} - \dot{m}_{ex,\,vent} - \dot{m}_{ex,\,fabric} \tag{29}$$

$$\dot{T} = \frac{\dot{m}_{in}\,C_p\,(T_s - T) + (\dot{m}_{in} - \dot{m}_{ex,\,total})\,RT - \dot{W}/b}{m\,(C_p - R)} \tag{30}$$

Equation 24: The time rate of mass influx ($\dot{m}_{in}$) from the airbag's primary source (supply cylinder) is a time-dependent function $f_1(t)$, prescribed by the user. In the case that the total mass influx includes exhaust from an internal bag, then $f_1(t)$ includes the exhaust rates $\dot{m}_{ex,vent}$ and $\dot{m}_{ex,fabric}$ (equations 26 and 27) for the internal bag.

Equation 25: This is a differential equation of order 0. It expresses the temperature of the airbag's primary source (T_s) as a user-prescribed, time-dependent function -- $f_2(t)$. In the case that an internal bag exhausts into the airbag, equation 30 (for $\dot{T}$) will include terms in which T_s is interpreted as the temperature of the gas in the internal bag.

Equation 26: This equation expresses the mass rate of exhaust ($\dot{m}_{ex,vent}$) through a ruptured deflation membrane for a vent of area A_{ex}. (A discharge coefficient of unity is assumed but can be made effectively smaller by the user, if desired, by decreasing the specified value for A_{ex} in proportion.) If the airbag is an internal bag, then P_{ext} is the pressure in the bag just outside. Otherwise, P_{ext} is the atmospheric pressure.

Equation 27: In addition to exhausting through deflation vents, an airbag is allowed to exhaust through the pores of the bag fabric. This equation expresses the associated mass rate of exhaust ($\dot{m}_{ex,fabric}$) as a function of S and μ, both user-prescribed terms. S is the surface area of the airbag's porous fabric, from which, if specified by the user, will be subtracted the contacted surface area of the bag. μ is the fabric porosity expressed in terms of volume of gas per unit area of porous fabric per unit time and specified by the user as a function of pressure differential.

Equation 28: The rate of work ($\dot{W}$) is taken as the average of the last and current pressures multiplied by the time rate of change of airbag volume.

Equation 29: The net rate of increase of mass of gas in the airbag ($\dot{m}$) is equal to the sum of mass influx rates (from the primary source and from the exhaust from internal bags) decreased by the exhaust rate through ruptured deflation membranes and through porous fabric.

Equation 30: The rate of increase of gas temperature in the airbag ($\dot{T}$) also depends on both gas influx and exhaust. Since airbags can be nested, the complete expression for $\dot{T}$ could include many terms of the sort in the numerator, each quantity there being interpreted appropriately for the particular gas flow considered (as in equations 24 through 29).

It is clear that the equations 24 through 28 can be evaluated at each time step. Since all terms in the right-hand sides of equations 29 and 30 are then known, $\dot{m}$ and $\dot{T}$ can now be considered to have been determined.

Evaluation of $\dot{m}$ and $\dot{T}$ in the manner described in this section is the primary function of Subroutine THERMO. It also integrates $\dot{m}$ and $\dot{T}$ to give the values for mass m and temperature T needed in equations 21 and 22 for the pressure-volume iteration.

2.7 Width of Airbag Contact With the Vehicle Interior

Whenever the occupant is in contact with an airbag, the airbag will in turn be pressing against the vehicle-interior portion of the enclosure. It is necessary to estimate the out-of-plane (y-dimension) width of airbag/vehicle contact for the following reasons: First, the pressure force on the vehicle interior depends on the dimensions of the contact area; in turn, angular position equilibrium of the airbag (Section 2.10) and possible yielding of the vehicle interior because of airbag forces (Sections 2.14 and 2.16) depend on the pressure force. Second, the off-occupant-plane flotation forces on the occupant (Section 2.9) depend indirectly on the y-dimension contact width.

Figure 13 is a view along (tangential to) the vehicle-interior surface of an airbag which has been contacted by the occupant. The airbag profile in this view is assumed to be symmetric with respect to the occupant plane (X-Z), which is perpendicular to the page and indicated by the dashed line. The dimension w_0 is the occupant width, which is obtained from user inputs. The dimension w is the y-dimension airbag/vehicle contact width to be determined. It will also be necessary to find other parameters of the illustrated profile. Determination of the parameters of this profile is the function of Subroutine WIDTH.

Four constraints are imposed on this profile of the deformed airbag. First, the half-perimeter of the profile is made to be equal to a user input, viz., W, the side-to-side width of the completely deflated bag. Second, as previously stated, the profile is assumed to be symmetric with respect to the occupant plane. Third, the arcs are circular. Fourth, the slope of the profile is continuous where the airbag arc meets the vehicle-interior surface. The second and third

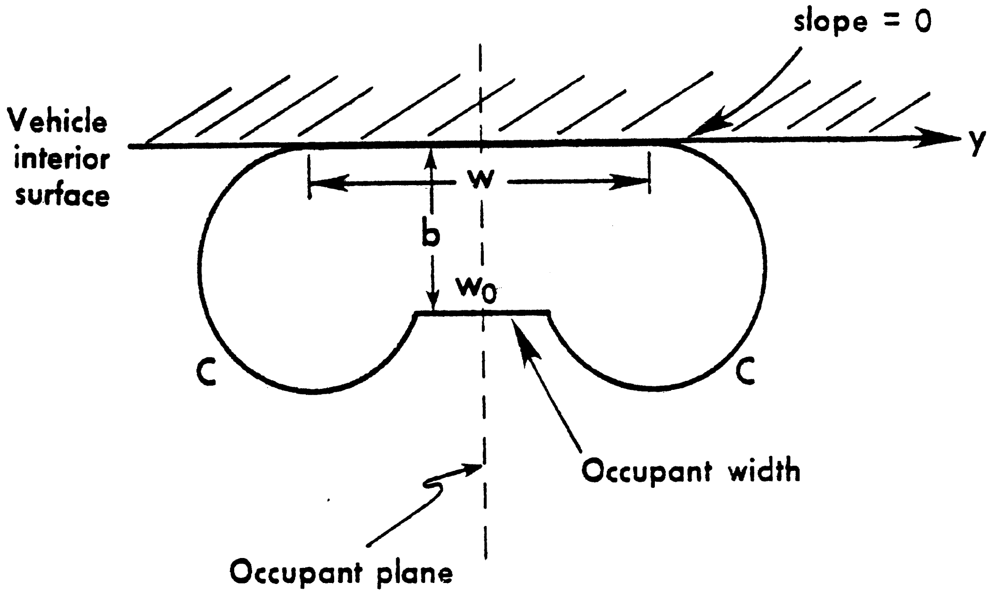

Figure 13. View Along Vehicle-Interior Surface of a Contacting Airbag

assumptions are implicit in the following analysis. Only the first and fourth need be formulated explicitly.

2.7.1 Perimeter Constraint. Where C is the length of each arc and W is the side-to-side width of the completely deflated bag, the perimeter constraint is:

$$2C + w + w_0 = 2W \quad . \tag{31}$$

The occupant width w_0 is a weighted average of widths of the occupant segments in the secondary profile for this airbag. The occupant segment widths are known since the model user specifies a y-width for contact segments attached to each body link. Weighting is in proportion to secondary profile segment length.

2.7.2 Slope Constraint. Figure 14 shows half of a typical profile. There are various dimensions pertinent to expressing the slope constraint. w and w_0 have already been discussed. R, S, and θ are arc dimensions. R is the radius of curvature, θ/2 is the angle subtended by the circular extension of arc C which is necessary to complete a circle, and S/2 is the arc length of the extension. The quantity b is a weighted average of distances between the parts of the occupant and the parts of the vehicle interior that are in contact with the airbag. Weighting is in proportion to secondary profile segment length and occupant segment width.*

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*Weighting is therefore in proportion to contact area and consequently also in proportion to pressure force on the secondary profile segment.

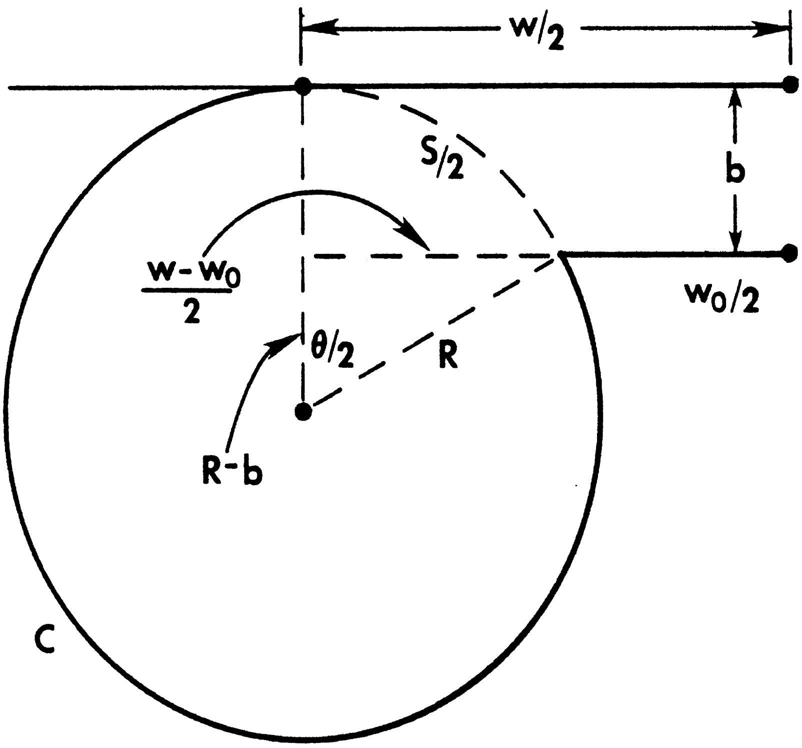

Figure 14. Off-Occupant-Plane Profile of Contacted Airbag

Equations 32 and 33 may be written immediately from Figure 14:

$$R = \frac{\left(\frac{w - w_0}{2}\right)^2 + b^2}{2b} \tag{32}$$

$$\frac{\theta}{2} = \tan^{-1} \frac{w - w_0}{2(R-b)} \tag{33}$$

Relations 32 and 33 together guarantee continuity of the slope of the profile where the airbag arc and the vehicle-interior surface meet.

2.7.3 Determination of Airbag Contact Width. Calculation of the arctangent in equation 33 must be done with a double argument function so that resulting values for $\theta/2$ can be anywhere in the range $-\pi$ to $+\pi$. Next, if $\theta/2$ is less than zero, it is replaced by $\theta/2 + 2\pi$. This does not alter the validity of equation 33, and it is necessary in order to put $\theta/2$ in the range 0 to 2π. With $\theta/2$ in this range, the arc length S/2 can now be calculated:

$$S/2 = R\theta/2 \ . \tag{34}$$

From Figure 14, it is seen that the arc length C can now be determined:

$$C = 2\pi R - \frac{S}{2} \ . \tag{35}$$

If equations 32 through 35 are now used to eliminate C in equation 31, the following equation results:

$$f(x) = 2x + \left[2\pi H - \tan^{-1}\frac{2xb}{(x^2-b^2)}\right]\left[\frac{x^2+b^2}{b}\right] - 2(W - w_0) = 0, \tag{36}$$

where

$$x = \frac{w - w_0}{2} \tag{37}$$

and

$$H = \begin{cases} 1 & \text{if } \tan^{-1} \dfrac{w - w_0}{2(R-b)} > 0 \\ 0 & \text{otherwise} \end{cases} \quad . \tag{38}$$

Equation 36 is solved for x by a Newton's iteration. The derivative function required for the iteration is given by equation 39:

$$f'(x) = 4 + \left[2\pi H - \tan^{-1} \frac{2xb}{(x^2 - b^2)}\right] \frac{2x}{b} \quad . \tag{39}$$

The initial estimate for x is taken as $w_0/2$ if the occupant has not previously been in contact with the airbag and otherwise $(w_{last} - w_0)/2$, where w_{last} is the value of w at the preceding time step. For typical values, the iteration converges with four-place accuracy in four iterations.

When x has been determined, the y-dimension width w of airbag contact against the vehicle interior is found from equation 37 as

$$w = 2x + w_0 \quad . \tag{40}$$

C, R, and θ/2 can be found from equations 31, 32, 34, 35, and 37 to be

$$C = W - x - w_0 \tag{41}$$

$$R = \frac{x^2 + b^2}{2b} \tag{42}$$

$$\frac{\theta}{2} = 2\pi - \frac{C}{R} \tag{43}$$

2.8 Occupant-Plane Flotation Forces

2.8.1 Airbag Forces (Including Pressure Forces). There are two types of airbag forces which can act on any occupant or vehicle-interior segment in contact with an airbag. Both are illustrated in Figure 15. One is "pressure force" and the other is "flotation force."

Each straight-line segment in the secondary profile determined for each airbag (Section 2.3) may be thought of as the side view (y-direction) of a planar "panel" in contact with the airbag. Each panel is a part of either the vehicle-interior profile or the profile of contact-sensing line segments fixed to the occupant. The length in the x-z plane -- ℓ -- of each "panel" is determined by Subroutine PROFLE when the secondary profile has been established. The y-dimension widths of each panel are either taken from user inputs or determined as in Section 2.7. Since the widths at each end of a secondary profile segment need not be the same, each panel is, in general, trapezoidal in shape.* Such a panel is shown in Figure 15-2 in contact with an airbag. Figure 15-1 is a perspective view of an airbag contacted on one side by such a panel and on the other side by a plane. In general, of course, airbag contacts will be made by more than a single panel and deformed airbag shapes will not be as simple as illustrated in Figure 15, but a single panel is shown here to make as clear as possible the types of forces which can result from contacts. The coordinates $\bar{x}$ and $\bar{z}$ are not used anywhere in the analysis, but serve here simply to define planes containing the contacting trapezoid and perpendicular to it. The

*All vehicle-interior panel widths, i.e., contact widths, will be equal to w from Section 2.7, and these panels are therefore rectangular.

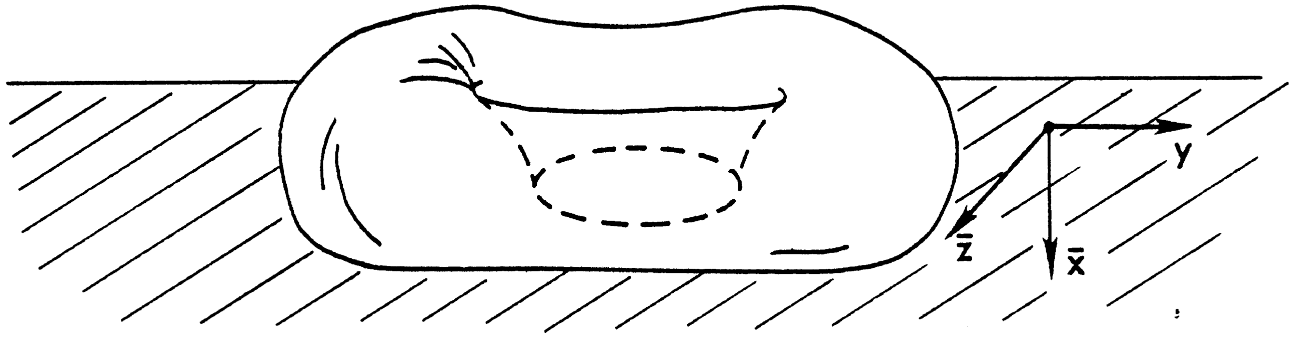

Figure 15-1. Perspective View of Airbag Deformed by a Single "Panel"

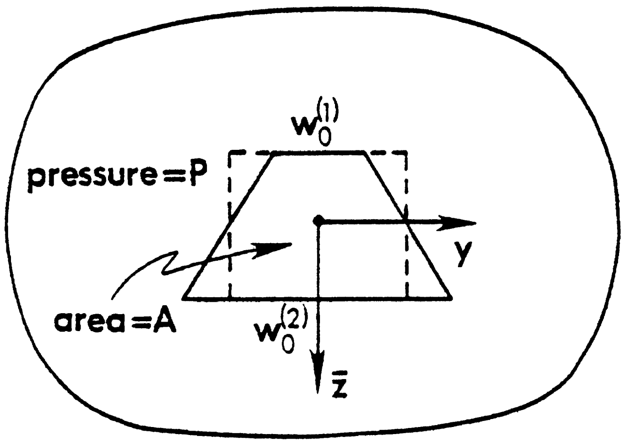

Figure 15-2. Trapezoidal Occupant or Vehicle-Interior "Panel" in Contact with Airbag

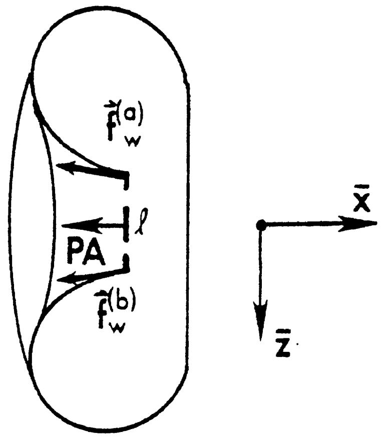

Figure 15-3. Occupant-Plane Flotation Forces

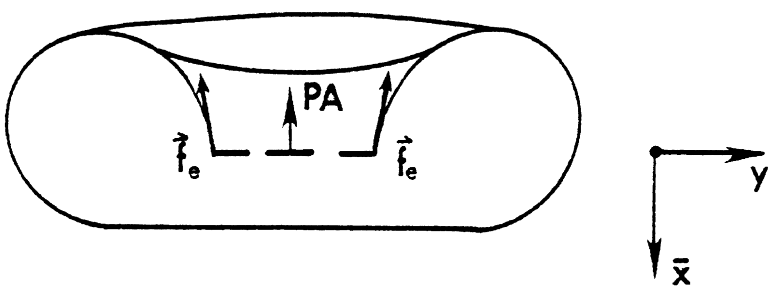

Figure 15-4. Off-Occupant-Plane Flotation Forces

Figure 15. Airbag Forces

$\bar{x}$-$\bar{z}$ plane is identical to the occupant plane, x-z.

The first, and simpler, type of airbag force acting on any contacting panel is "pressure force." Its magnitude is simply the product of the airbag pressure (Section 2.5) and the trapezoid area. This is the force PA shown in Figures 15-3 and 15-4.

The second type of airbag force is "flotation force." This force is also sometimes termed either "membrane force" or "skin tension force." As implied by these names, this force derives from tension in the airbag fabric, which exists whenever the bag must contain a pressure greater than the external pressure. If a contact produces only a local flattening of the bag and not a local concavity, the fabric tension reacts only against itself, for the airbag cannot "pull" a contacting panel but can only "push" it. If there is a concavity, however, such as illustrated in Figures 15-3 and 15-4, flotation forces will assist the pressure force in reacting against the contacting panel. These forces act at the edges of the contacting panel, and accordingly there are two types of flotation forces to be considered in the Advanced Airbag System Submodel: 1) occupant-plane forces, shown in Figure 15-3, which act at vertices in the secondary profile and lie wholly within the occupant plane (or at least parallel to it); and 2) off-occupant-plane forces, shown in Figure 15-4, which result from billowing of the "sides" of the bag about the contacting panel. The latter forces lie entirely off the occupant plane but in general have both x- and z- components, although their y-components are assumed to cancel.

2.8.2 Analysis. This subsection contains the analysis pertinent to occupant-plane flotation forces. Section 2.9 deals with off-occupant-plane flotation forces.

Figure 16 illustrates a portion of a secondary profile containing a straight-line segment with an airbag arc on either side. Occupant-plane flotation forces acting at points a, b, c, and d on straight-line segments of the profile are shown as $\vec{f}_a$, $\vec{f}_b$, $\vec{f}_c$, and $\vec{f}_d$. These forces act tangentially to the arcs at the vertex points. It is required to determine the components of the flotation force vectors acting at each end of each straight-line segment. This is done by first analyzing each arc in the profile. Consider the arc ab in Figure 16. The total pressure force on the arc can be shown to be independent of the arc radius of curvature, being equal simply to PA, where P is the gas pressure in the airbag and A is the area of the trapezoid covered by the extension of the arc into plus and minus y, viz., a trapezoid of height equal to the arc chord length and bases equal to w_a and w_b. The pressure force against the airbag bulge is in the direction of the normal to the chord, $\hat{m}$ in Figure 16. This outward force against the bulge (arc) is balanced by inward forces from the adjoining occupant- or vehicle-interior straight-line segments, viz., the negatives of the vectors $\vec{f}_a$ and $\vec{f}_b$.

Figure 17 shows an arc and its adjoining straight-line segments in greater detail. The flotation force vectors $\vec{f}_a$ and $\vec{f}_b$ resolve into the $\hat{m}$-$\hat{m}_\perp$ frame as indicated in equations 44 through 47.

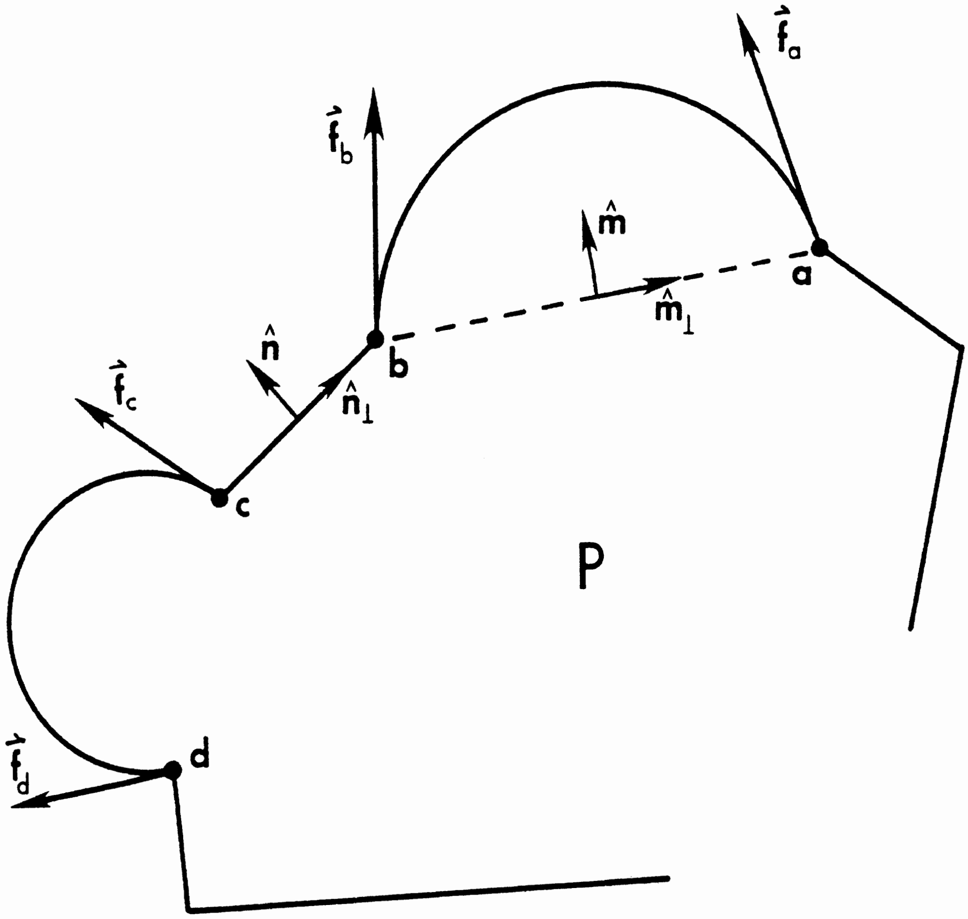

Figure 16. Occupant-Plane Flotation Forces

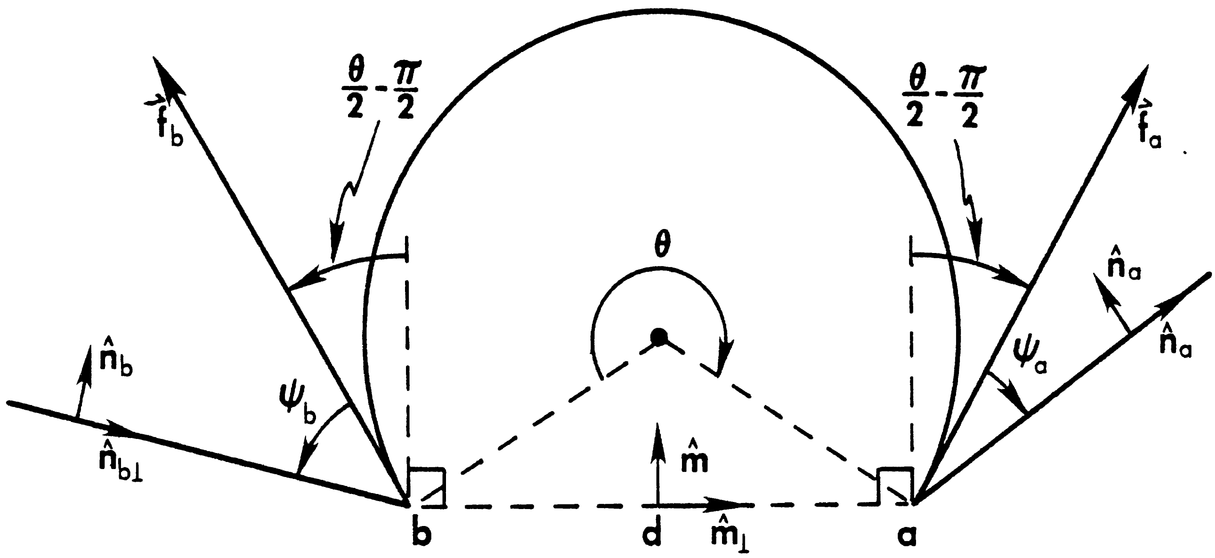

Figure 17. Segment and Arc Geometry for Occupant-Plane Flotation Forces

Endpoint a: $$f_{am_\perp} = f_a \sin\left(\frac{\theta}{2} - \frac{\pi}{2}\right) = -f_a \cos\frac{\theta}{2} \quad (44)$$

$$f_{am} = f_a \cos\left(\frac{\theta}{2} - \frac{\pi}{2}\right) = f_a \sin\frac{\theta}{2} \quad (45)$$

Endpoint b: $$f_{bm_\perp} = -f_b \sin\left(\frac{\theta}{2} - \frac{\pi}{2}\right) = f_b \cos\frac{\theta}{2} \quad (46)$$

$$f_{bm} = f_b \cos\left(\frac{\theta}{2} - \frac{\pi}{2}\right) = f_b \sin\frac{\theta}{2} \quad (47)$$

In these equations, f_a and f_b are the magnitudes of the respective vectors. In general, these magnitudes will be equal since the skin tension along the arc will be constant, i.e.,

$$f_a = f_b \quad . \quad (48)$$

Then, using equations 48 in equations 45 and 47, we obtain

$$f_{am} = f_{bm} \quad . \quad (49)$$

The total $\hat{m}$-component force balancing the pressure force on the arc is therefore $2f_{am}$. Consequently,

$$2 f_{am} = P\left(d\,\frac{w_a + w_b}{2}\right) , \quad (50)$$

where the right-hand side is the pressure force previously described. Then, using the results 45, 48, and 50, we obtain

$$f_a = f_b = \frac{P d\,(w_a + w_b)}{4 \sin\frac{\theta}{2}} \quad . \quad (51)$$

(Sin $\frac{\theta}{2}$ is always positive for $0<\theta<2\pi$.)

With f_a and f_b determined, the vectors $\vec{f}_a$ and $\vec{f}_b$ are therefore

$$\vec{f}_a = \left(-f_a \cos\frac{\theta}{2}\right)\hat{m}_\perp + \left(f_a \sin\frac{\theta}{2}\right)\hat{m} \quad (52)$$

$$\vec{f}_b = \left(f_b \cos\frac{\theta}{2}\right)\hat{m}_\perp + \left(f_b \sin\frac{\theta}{2}\right)\hat{m} \quad . \quad (53)$$

The balance against pressure force represented by equation 50 will be satisfied if the angles at both endpoints satisfy either Case I or Case II. The pressure force balance will not be satisfied whenever Case III applies at either endpoint of a line segment. The imbalance comes about, in effect, because the profile determination algorithm (Section 2.3) requires circular arcs and does not accommodate relaxation adjustments between fabric arcs and fabrics straight-line segments at any given timestep once the secondary profile is established. In practice, Case III is uncommon.

The angles ψ_b and ψ_a will now be determined.

Endpoint b

The x- and z-components of the outward unit normal $\hat{n}$ have been determined in Section 2.3.4; they are g and h in equation 11. Therefore, $\hat{n}_b$ is known and is given by equation 54. $\hat{n}_\perp$ is the unit vector normal to $\hat{n}$ and is toward the more-clockwise endpoint of the segment. $\hat{n}_{b\perp}$ is given by equation 55. The basis ($\hat{i}_v$, $\hat{k}_v$) is for the vehicle coordinate frame.

$$\hat{n}_b = g_b \hat{i}_v + h_b \hat{k}_v \tag{54}$$

$$\hat{n}_{b\perp} = -h_b \hat{i}_v + g_b \hat{k}_v \quad . \tag{55}$$

Similarly, the unit vectors for the arc chord in Figure 17 are

$$\hat{m} = G \hat{i}_v + H \hat{k}_v \tag{56}$$

$$\hat{m}_\perp = -H \hat{i}_v + G \hat{k}_v \quad , \tag{57}$$

so that from equation 53 we have

$$\vec{f}_b = f_b \cos\frac{\theta}{2}\left[-H\hat{i}_v + G\hat{k}_v\right] + f_b \sin\frac{\theta}{2}\left[G\hat{i}_v + H\hat{k}_v\right] . \tag{58}$$

Referring now to Figure 17 and to equations 54 through 58, we determine the components of $\vec{f}_b$ in the $\hat{n}_b$ and negative $-\hat{n}_{b\perp}$ directions as

$$N = \vec{f}_b \cdot \hat{n}_b \tag{59}$$

$$D = \vec{f}_b \cdot (-\hat{n}_{b\perp}), \tag{60}$$

or

$$N = \frac{Pd\,(w_a + w_b)}{4}\left\{g_b\left[-H\cot\frac{\theta}{2} + G\right] + h_b\left[G\cot\frac{\theta}{2} + H\right]\right\} \tag{61}$$

$$D = \frac{Pd\,(w_a + w_b)}{4}\left\{h_b\left[-H\cot\frac{\theta}{2} + G\right] - g_b\left[G\cot\frac{\theta}{2} + H\right]\right\} \tag{62}$$

where f_b, $\cos\frac{\theta}{2}$, and $\sin\frac{\theta}{2}$ have been eliminated by using equation 51. The angle ψ_b may now be calculated as

$$\psi_b = \tan^{-1}\frac{N}{D} , \tag{63}$$

where a double argument arctangent evaluation is required in order to differentiate Cases I, II, and III of Figures 18-1, 2, 3. Equations 59 through 62 give the resolution of $\vec{f}_b$ into force components normal to and along segment b, and the result from equation 63 along with the earlier discussion of Cases I, II, and III will indicate which components should be retained and which should be set to zero. Let $f_n^{(b)}$ and $f_{n_\perp}^{(b)}$ denote the finally-determined "outward" and "clockwise" components of the occupant-plane flotation force at point "b" on the segment counterclockwise from arc ab. The flotation force vector is

$$\vec{f}^{(b)} = f_n^{(b)} \hat{n}_b + f_{n_\perp}^{(b)} \hat{n}_{b\perp} \qquad (64)$$

and its components are as indicated in equations 65 through 67 below.

Case I:

$$\text{If } 0 \le \psi_b \le \frac{\pi}{2}:$$

$$f_n^{(b)} = N$$
$$f_{n_\perp}^{(b)} = -D \qquad (65)$$

Case II:

$$\text{If } \frac{\pi}{2} < \psi_b \le \pi:$$

$$f_n^{(b)} = N$$
$$f_{n_\perp}^{(b)} = 0 \qquad (66)$$

Case III:

$$\text{If } \psi_b < 0:$$

$$f_n^{(b)} = f_{n_\perp}^{(b)} = 0 \qquad (67)$$

In this flotation force model, these vectors are allowed to act in full on their respective line segments only if they make acute angles with the segments. The reason for this is that the deformed airbag should be able only to push -- and not pull -- against any segment of either the occupant or the vehicle interior. Two situations are illustrated in Figures 18-1 and 18-2.

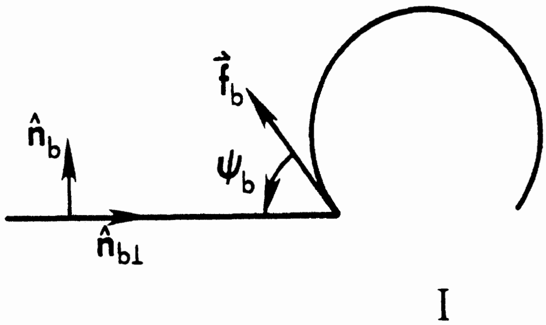

Figure 18-1. Case I: $0 \leq \psi_\ell \leq \frac{\pi}{2}$

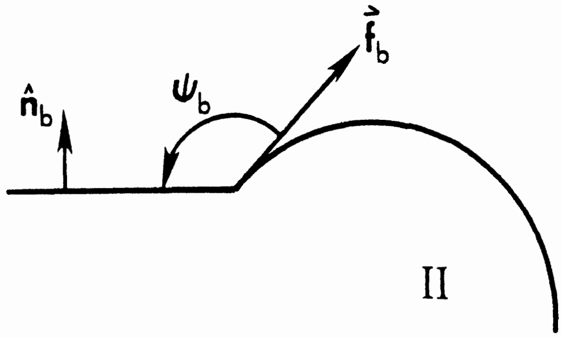

Figure 18-2. Case II: $\frac{\pi}{2} < \psi_\ell \leq \pi$

In Case I, $\vec{f}_b$ is applied fully, i.e., it acts against the line segment in both $\hat{n}_b$ and $-\hat{n}_{b\perp}$ directions. In Case II, only the component normal to the line segment will be retained. If the angle between $\vec{f}_b$ and $\hat{n}_b$ is greater than π, then no component of $\vec{f}_b$ will be used. This is illustrated as Case III, in Figure 18-3.

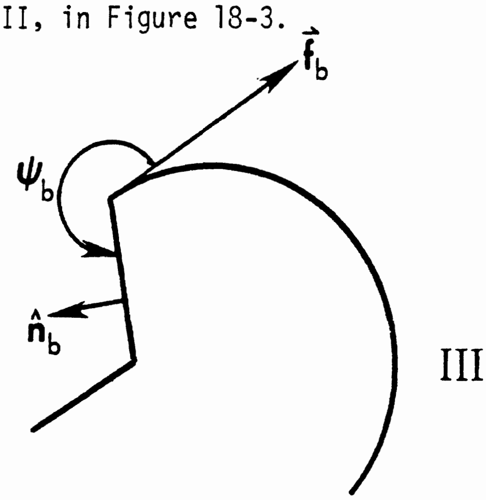

Figure 18-3. Case III: $\pi < \psi_\ell < 2\pi$ (or $\psi_\ell < 0$)

Endpoint a

The components of the flotation force vector at point "a" on the segment clockwise from arc ab can be similarly determined. The forms of equations 54 through 57 still apply so that, from equation 52, we obtain

$$\vec{f}_a = -f_a \cos\frac{\theta}{2}\left[-H\,\hat{i}_v + G\,\hat{k}_v\right] + f_a \sin\frac{\theta}{2}\left[G\,\hat{i}_v + H\,\hat{k}_v\right] . \tag{68}$$

Then

$$\psi_a = \tan^{-1}\frac{N}{D} , \tag{69}$$

where

$$N = \vec{f}_a \cdot \hat{n}_a \tag{70}$$

$$D = \vec{f}_a \cdot \hat{n}_{a\perp} , \tag{71}$$

or

$$N = \frac{Pd\,(w_a + w_b)}{4}\left\{g_a\left[H\cot\frac{\theta}{2} + G\right] + h_a\left[-G\cot\frac{\theta}{2} + H\right]\right\} \tag{72}$$

$$D = \frac{Pd\,(w_a + w_b)}{4}\left\{-h_a\left[H\cot\frac{\theta}{2} + G\right] + g_a\left[-G\cot\frac{\theta}{2} + H\right]\right\} . \tag{73}$$

The flotation force vector is

$$\vec{f}^{(a)} = f_n^{(a)} \hat{n}_a + f_{n_\perp}^{(a)} \hat{n}_{a\perp} \tag{74}$$

where the components are as indicated in equations 75 through 77.

Case I:

If $0 \leq \psi_a \leq \frac{\pi}{2}$:

$$f_n^{(a)} = N$$
$$f_{n_\perp}^{(a)} = D \tag{75}$$

Case II:

If $\frac{\pi}{2} < \psi_a \leq \pi$:

$$f_n^{(a)} = N$$
$$f_{n_\perp}^{(a)} = 0 \tag{76}$$

Case III:

If $\psi_a < 0$:

$$f_n^{(a)} = f_{n_\perp}^{(a)} = 0 \tag{77}$$

2.9 Off-Occupant-Plane Flotation Forces

2.9.1 Airbag Forces. Off-occupant-plane flotation forces on the occupant result from billowing of the "sides" of an airbag about the occupant. Such forces were illustrated and discussed briefly in Section 2.8.1. Figure 15 from that section is included here as Figure 19. The off-occupant-plane flotation forces are $\vec{f}_e$ in Figure 19-4. These forces have in common with the occupant-plane forces discussed and derived in Section 2.8 that they result from tension in the airbag fabric. Whenever a contact produces a local concavity, with billowing on each side of the occupant plane rather than only a local flattening of the airbag, these fabric tension forces will assist the pressure force and any occupant-plane flotation forces in reacting against the contacting occupant "panel." These forces lie entirely off the occupant plane but in general they have both x- and z-components. Their y-components will cancel as long as the airbag, occupant, and occupant motion are symmetric with respect to the x-z plane, but they must be assumed to cancel in any case for the analysis which follows since the MVMA 2-D CVS is a planar model and, of course, has no out-of-plane generalized coordinates to which generalized forces could be applied.

2.9.2 Analysis. For the purpose of estimating off-occupant-plane flotation forces on the occupant, the size and shape of the deformed airbag in three dimensions is approximated by three connected rectangular "blocks" as illustrated in Figure 20, where all dimensions are determined by various constraints relating them to user inputs and calculated quantities. With known values for these dimensions, it

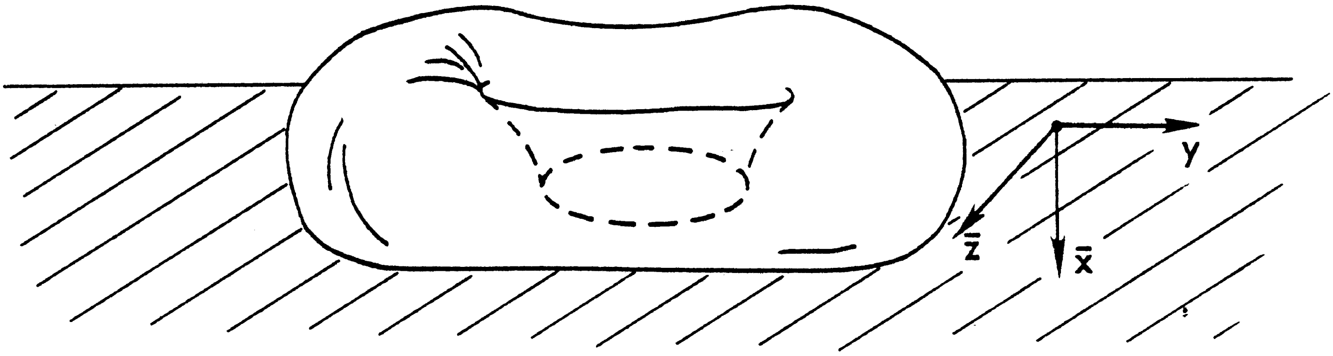

Figure 19-1. Perspective View of Airbag Deformed by a Single "Panel"

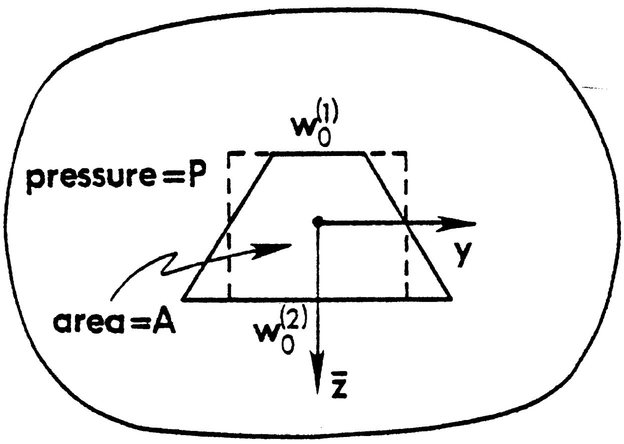

Figure 19-2. Trapezoidal Occupant or Vehicle-Interior "Panel" in Contact with Airbag

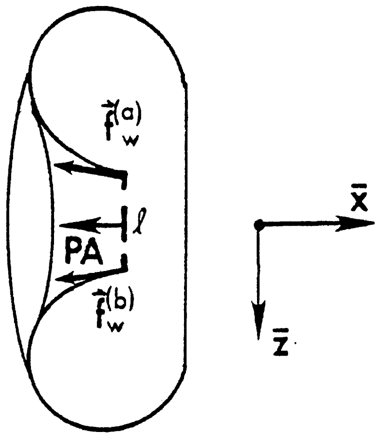

Figure 19-3. Occupant-Plane Flotation Forces

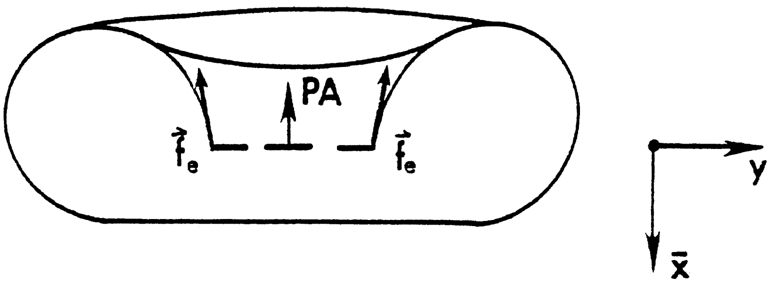

Figure 19-4. Off-Occupant-Plane Flotation Forces

Figure 19. Airbag Forces

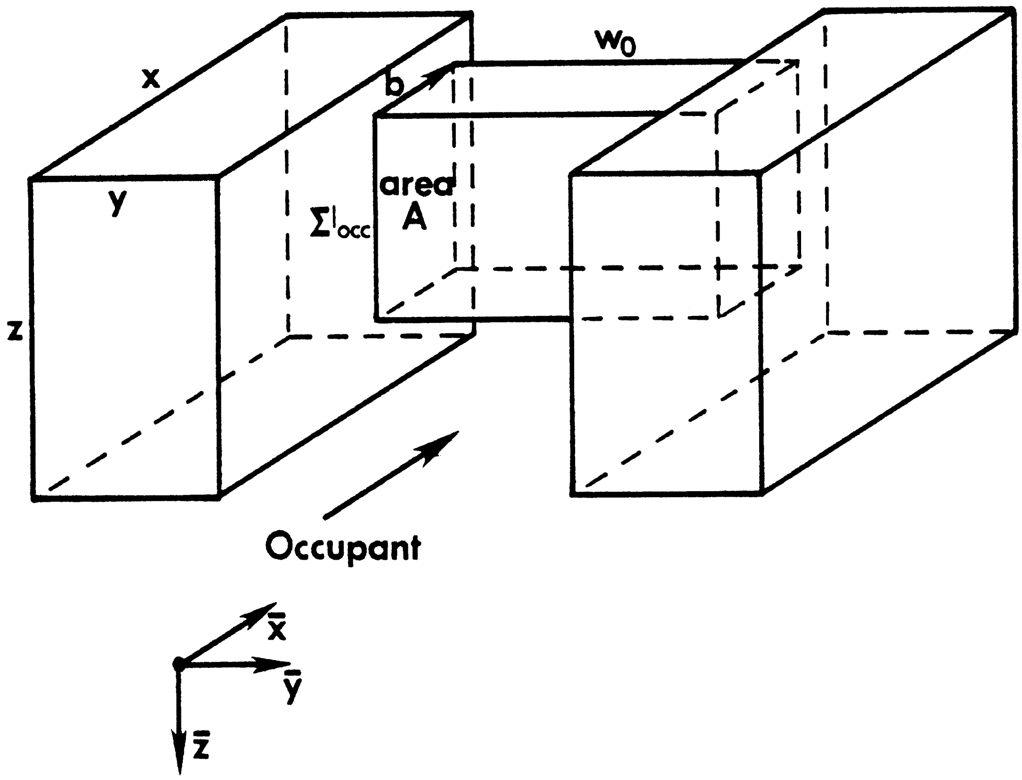

Figure 20. Approximated Shape of the Deformed Airbag in Three Dimensions for Estimation of Off-Occupant-Plane Flotation Forces

will be possible to relate the magnitude of the total off-occupant-plane flotation force on the occupant to the product of the airbag pressure and the area yz.

The dimension b is already known as its determination was required in Section 2.7.2; it is a weighted average of distances between parts of the occupant and parts of the vehicle interior that are in contact with the airbag.* The direction of $\vec{b}$ is determined by Subroutine WIDTH as well as its magnitude, and this direction is reasonably taken for the line of action of off-occupant-plane flotation forces. In the figure, $\bar{x}$ is a coordinate in the direction of $\vec{b}$ and the $\bar{x}$-$\bar{z}$ plane is coincident with the occupant plane, x-z. $\bar{y}$ is the direction normal to the simulation plane. $\bar{x}$, $\bar{y}$, and $\bar{z}$ are not used in the analysis but only in the figure.

The dimension w_0 is also already known, its determination required in Section 2.7.1. It is a weighted average of widths of the occupant segments in the secondary profile. The occupant segment widths are taken from values specified by the model user for contact segments attached to each body link.

Other dimensions are found in the following manner. First, the total volume V_T of the contacted airbag is known from equation 21 of Section 2.5, which discusses the pressure-volume iteration (which determines pressure P, as well). This value may be set equal to the sum of the volumes of the three blocks in Figure 20, i.e.,

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*Weighting is in proportion to contact "panel" area and therefore in proportion to pressure force on each secondary profile segment.

$$2xyz + Aw_0 = V_T \quad . \tag{78}$$

Here, the value for the cross-sectional area A of the middle block is appropriately taken as the area of the deformed airbag profile in the occupant plane, i.e., the area of the secondary profile, which is determined in Section 2.4.2 (equation 20). Equation 78 is the first of three constraints used for determining x, y, and z.

The second constraint is equation 79.

$$2w_0 + 2(2x + 2y - b) = 2W \tag{79}$$

This equation causes the length of the deformed airbag periphery in the $\bar{x}$-$\bar{y}$ plane to be the perimeter value prescribed by the user. This perimeter length, 2W, was previously used in equation 31 of Section 2.7.1. The third constraint, equation 80, requires that the perimeter in the $\bar{x}$-$\bar{z}$ plane of each end block of the deformed airbag equal the airbag perimeter length C determined from the user-prescribed uncontacted airbag profile, i.e.,

$$2x + 2z = C \quad . \tag{80}$$

(See Sections 2.3.1 and 2.3.2)

Equations 78, 79, and 80 can be solved for x, y, and z. To simplify the form of the results, we may define a quantity V_E

$$V_E = \frac{V_T - Aw_0}{2} \tag{81}$$

so that equation 78 becomes

$$xyz = V_E \quad . \tag{82}$$

Equation 79 can also be simplified to yield equation 83:

$$2x + 2y = W - w_0 + b \tag{83}$$

Now, if equation 80 is used to eliminate z in equation 82, we obtain

$$y = \frac{V_E}{x\left(\frac{c}{2} - x\right)} \quad . \tag{84}$$

Equations 83 and 84 then yield

$$x^3 - \frac{c + W + b - w_0}{2} x^2 - \frac{c}{4}\left(w_0 - b - W\right) x - V_E = 0 . \tag{85}$$

This equation has a single real root, which is determined by Subroutine FLOTE by a Newton's iteration with an initial estimate of $x^{(o)}=b$. With x thus determined, equations 84 and 82 successively yield y and z.

Off-occupant-plane flotation forces are next determined as follows. First, if x is less than or equal to b (see Figure 20), there is no billowing of the airbag off the occupant plane, so these flotation forces are set to zero. On the otherhand, if x is sufficiently larger than b, say greater than α, the concavity in the true three-dimensional surface of the billowing bag will be deep enough that the membrane force vector at the bag/occupant interface corresponding to the line labeled "Σl_{occ}" in Figure 20 will be fully parallel to the occupant plane, i.e., it will have no y (or $\bar{y}$) component. Accordingly, in this flotation force model, the magnitude F_E of the total off-occupant-plane force on the occupant is in this case set to the full value of the membrane forces, viz., considering both sides of the occupant, $2(\frac{1}{2}Pyz)$.

That is,

$$F_E = 0 \quad \text{for } x \leq b$$
$$F_E = P_{yz} \quad \text{for } x \geq \alpha \,, \tag{86}$$

where the value for α is defined within the program, arbitrarily, as 2b. For values of x between b and α, F_E is determined from a linear interpolation:

$$F_E = P_{yz}\frac{x-b}{\alpha-b} \quad \text{for } b < x < \alpha \,. \tag{87}$$

2.9.3 Distribution of the Total Off-Occupant-Plane Flotation Force. The value F_E determined in the preceding section represents a resultant flotation force from all occupant segments of the secondary profile and acting against the occupant in a direction $-\hat{b}$. $\hat{b}$ is the unit vector for the vector $\vec{b}$ of the preceding section and Section 2.7.2 and is shown in Figure 21.

The force $-F_E\hat{b}$ must now be distributed appropriately between the occupant segments of the secondary profile so that forces can be applied separately to body links represented in the secondary profile. Weighting for this distribution is in proportion to segment length l_i.

Thus, the magnitude of the force on segment "i" in the direction of $-\hat{b}$ (and applied at its midpoint) is

$$f_i = \frac{F_E\,\ell_i}{\Sigma \ell_i} \;; \tag{88}$$

the force vector is

$$\vec{f}_i = \frac{-F_E\,\ell_i}{\Sigma \ell_i}\,\hat{b} \,. \tag{89}$$

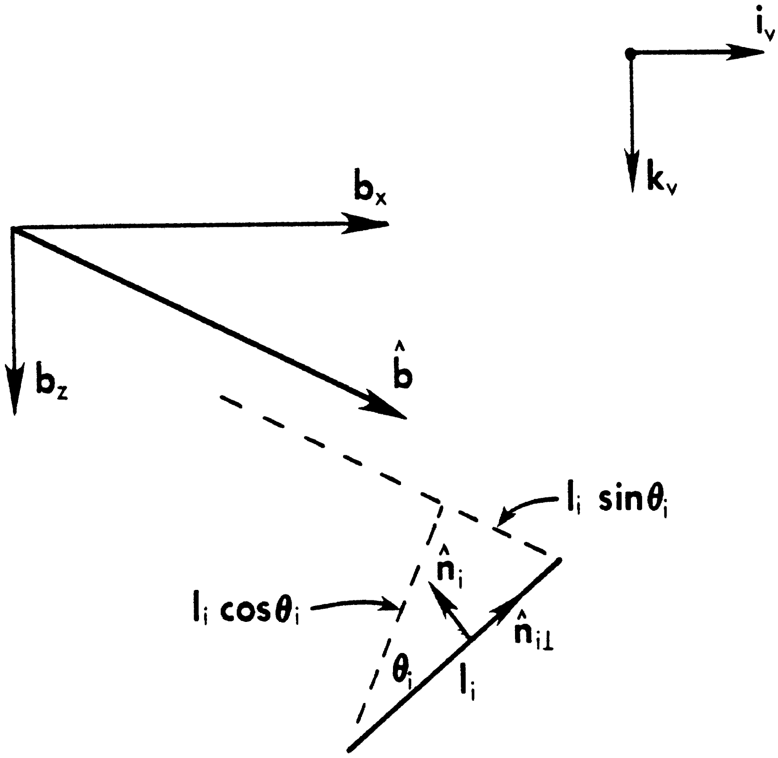

Figure 21. Distribution of the Total Off-Occupant-Plane Flotation Force

Finally, it remains to resolve $\vec{f}_i$ into components normal to and tangential to segment "i", i.e., in the directions of $\hat{n}_i$ and $\hat{n}_{i\perp}$. Thus, where from equation 89 we have

$$f_n^{(i)} = \frac{-F_E \ell_i (\hat{n}_i \cdot \hat{k})}{\sum \ell_i} \tag{90}$$

and

$$f_{n_\perp}^{(i)} = \frac{-F_E \ell_i (\hat{n}_{i\perp} \cdot \hat{k})}{\sum \ell_i} \quad , \tag{91}$$

the flotation force vector is

$$\vec{f}_i = f_n^{(i)} \hat{n}_i + f_{n_\perp}^{(i)} \hat{n}_{i\perp} \; . \tag{92}$$

2.10 Airbag Position for Equilibrium

Section 2.3 discusses the manner in which the profile in the occupant plane is determined for the contacted airbag. This is the so-called "secondary profile." It is derived from the time-dependent, polygonal airbag periphery prescribed by the user for a freely deploying airbag. The derivation described in Section 2.3 for the secondary profile is strictly geometrical and does not involve forces acting on the bag. It is clear, however, that airbag shape and position must depend on forces upon it. This section describes the adjustment of airbag position (and, consequently, forces) for obtaining a condition of equilibrium.*

The manner in which this is done is as follows. After determination of the secondary profile which results from the user-specified uncontacted airbag profile, the external forces on the airbag are determined. These are the negatives of the pressure forces and flotation forces acting on the occupant and the vehicle interior, the determinations of which have been described in the foregoing sections. The moments of all of these force vectors with respect to the bag attachment point are determined and their sum is found. If the sum is sufficiently small (smaller than a user-prescribed value), then the airbag posiiton and all forces are satisfactory. If the moment sum is too large, then an angular adjustment of airbag position is indicated. This is illustrated in Figure 22 for a teardrop-shaped bag. The angular adjustment used is a rotation of the entire polygonal profile prescribed by the user for

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*A static -- not dynamic -- equilibrium is sought since the airbag is assumed to have negligible effective mass and no degrees of freedom are assigned to it.

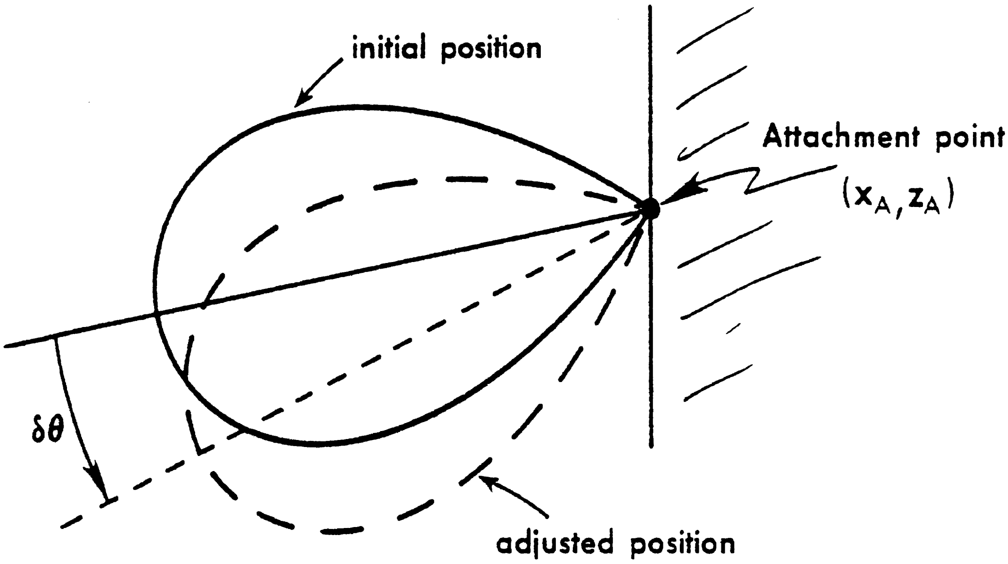

Figure 22. Rotation of Uncontacted Airbag Profile Toward Equilibrium Position

the uncontacted bag. The rotation is about the attachment point and is, of course, in the direction indicated by the sign of the net moment on the bag. After this trial angular adjustment is determined, a new secondary profile is established and the new forces on the airbag are then determined. The moment imbalance on the airbag is again calculated, and, it it is still too large, the above-described steps are repeated so that the imbalance is repeatedly reduced.

The analytical details of this procedure will now be described.

2.10.1 Summation of Moments. Let $\vec{F}_i$ represent external forces acting on the airbag (at endpoints and midpoints of straight-line segments of the secondary profile). Let $\vec{r}_i$ be the position vectors from the bag attachment point "A" to the point of application of the force $\vec{F}_i$. Then, where $\hat{j}$ is the out-of-plane unit vector, the summation of moments on the airbag is

$$\sum M_i^{(A)} = \sum (\vec{r}_i \times \vec{F}_i) \cdot \hat{j} \quad . \tag{93}$$

In terms of the normal and tangential force components previously determined to be acting on the occupant or vehicle-interior segments, the forces on the bag are

$$\vec{F}_i = -f_{in} \hat{n}_i - f_{in_\perp} \hat{n}_{i\perp} \quad . \tag{94}$$

The vectors $\vec{r}_i$ are

$$\vec{r}_i = (x_i - x_A) \hat{i}_v + (z_i - z_A) \hat{k}_v . \tag{95}$$

The resolutions of $\hat{n}_i$ and $\hat{n}_{i\perp}$ into the vehicle frame, from equations 54 and 55, are

$$\hat{n}_i = g_i \hat{i}_V + h_i \hat{k}_V \tag{96}$$

$$\hat{n}_{i\perp} = -h_i \hat{i}_V + g_i \hat{k}_V \quad , \tag{97}$$

where g_i and h_i are the direction cosines for the segment to which force "i" is applied. (g and h are given by equations 11.) Equations 93 through 97 therefore give the following result for the summation of moments on the airbag:

$$\sum M_i^{(A)} = \sum \Big\{ (z_i - z_A)(-f_{im} g_i + f_{im_\perp} h_i) + (x_i - x_A)(f_{im} h_i + f_{im_\perp} g_i) \Big\} . \tag{98}$$

2.10.2 Airbag Reference Angle. Section 2.3 describes the time-history of polygonal uncontacted airbag profiles which the model user prescribes. The user is allowed to vary the number of points describing the bag periphery at the different times in the time history, i.e., it is not necessary to prescribe the motion of a fixed set of material points on the bag -- Subroutine PROFLE needs no information about specific material points. However, the varying number of points on the periphery poses a problem for determining proper angular position of an airbag at any given time. It is assumed that in general successive profiles in the user-prescribed time history will be similar; and at successive integration time points, occupant and vehicle-interior lines will not be in greatly different positions. Therefore, the best procedure for finding, at any given time point, an airbag orientation for which the moment balance is satisfactory should entail "pushing off" from the equilibrium position determined at the preceding time step. But an angular position cannot be defined in the absence of a "marker" on the bag, so although a fixed set of material points is not required through the time history, the user is required to identify one point on each profile -- a "marker" -- which represents a specific material point that persists through the time history. Such a point, called the "reference point," is identified on each 926-Card in the data deck. The angle determined in the vehicle frame by a line drawn through the reference point and the bag attachment point is called the airbag "reference angle." This is illustrated in Figure 23.

At time t the reference angle is calculated as

$$\theta_R(t) = \tan^{-1} \frac{z_R - z_A}{-(x_R - x_A)} \quad . \tag{99}$$

Suppose it is required to investigate the moment imbalance for a bag angle of $\bar{\theta}$. Then, in accordance with the previously described procedure, the user-prescribed profile must be rotated by an amount

$$r = \bar{\theta} - \theta_R \tag{100}$$

before the secondary profile and resulting forces are determined. It is therefore necessary to find the coordinates $(\bar{x}_j, \bar{z}_j)$ of each vertex "j" of the rotated profile as a function of r. Figure 24 illustrates the position vectors to vertex "j" of the unrotated and rotated profiles. The angle of the unrotated position vector is

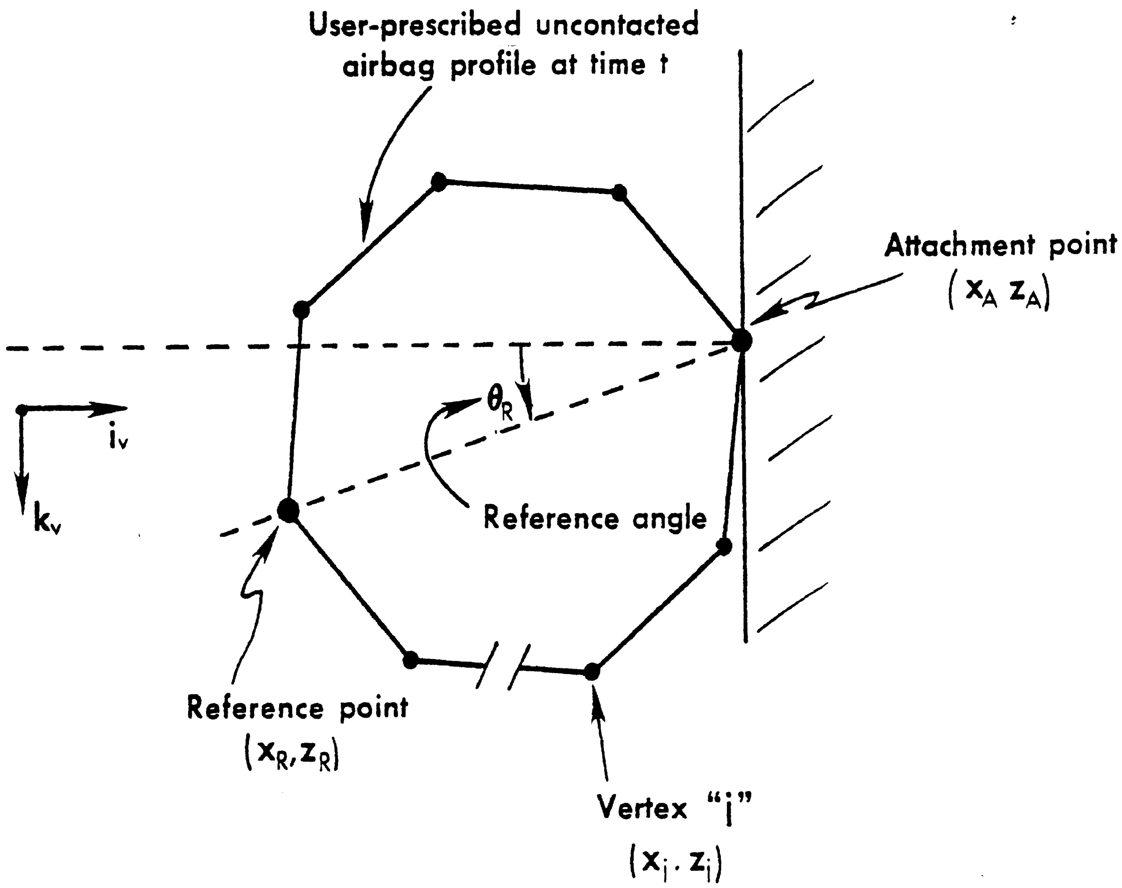

Figure 23. Airbag Reference Point and Reference Angle

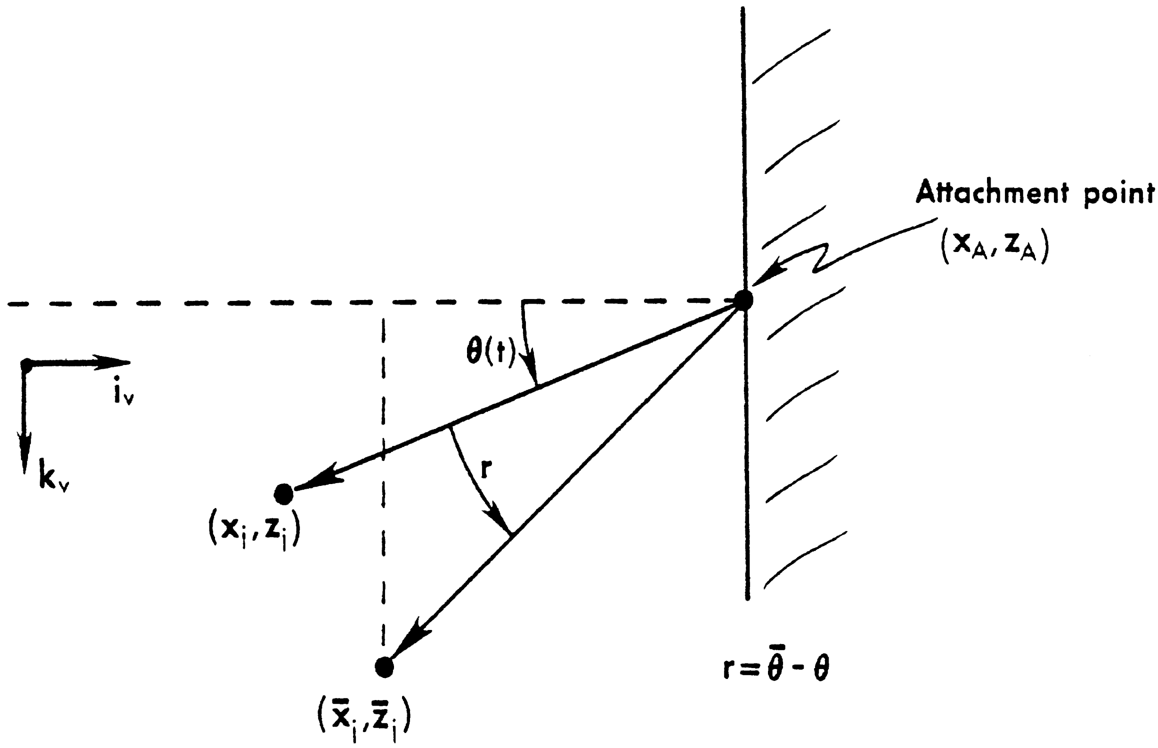

Figure 24. Rotation Through Angle r of Position Vector to Vertex "j"

$$\theta_j(t) = \tan^{-1}\frac{z_j - z_A}{-(x_j - x_A)} \quad . \tag{101}$$

The length of each position vector is

$$d_j = \sqrt{(x_j - x_A)^2 + (z_j - z_A)^2} \quad . \tag{102}$$

The coordinates $(\bar{x}_j, \bar{z}_j)$ for the rotated profile are therefore

$$\bar{x}_j = x_A - d_j \cos(\theta_j + \alpha) \tag{103}$$

$$\bar{z}_j = z_A + d_j \sin(\theta_j + \alpha) \quad . \tag{104}$$

2.10.3 <u>Determination of Angular Adjustments for Reducing Moment Imbalance</u>. Up to three angular adjustments of airbag position are allowed at each time step by Subroutine ADVBAG.* An airbag angle is sought which makes the net moment on the airbag less than a user-specified convergence epsilon.

Figure 25 illustrates a succession of moment <u>vs</u>. angle results from the angle adjustment procedure. The quantity Δ indicates the moment imbalance, viz., the net moment itself:

$$\Delta = \sum M_i^{(A)} \quad . \tag{105}$$

The quantity $\delta\theta$ is a trial angular adjustment to the initial estimate of the proper airbag angle, namely, the angle of the reference point vector at the preceding time step for which moment balance was attained.

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*Initial investigations have indicated that three iterations should be sufficient for reasonable input data, but it would be a simple matter to allow more.

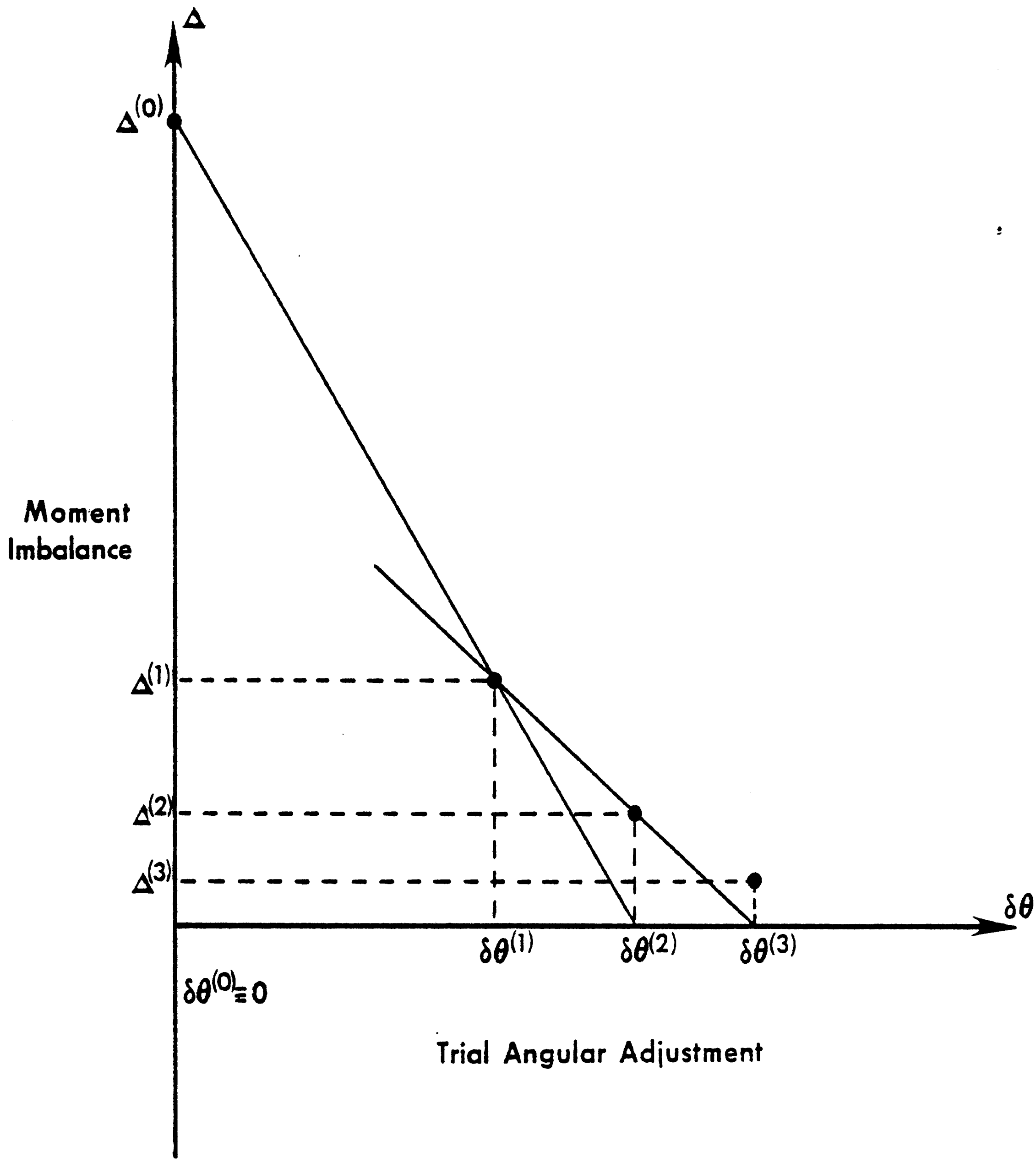

Figure 25. Moment Imbalance vs. Trial Angular Adjustment

Superscripts indicate the number of the adjustment, i.e., the iteration count. The initially calculated moment imbalance is $\Delta^{(o)}$. The sign of angular adjustments for reducing the magnitude of the imbalance should be that of $\Delta^{(o)}$ itself. The magnitude of the first trial adjustment is determined in one of two ways, depending on the specification made by the user. First, this adjustment can be a fixed, inputted angle, θ_a. Second, the user can instead supply a compliance C for the airbag from which a trial adjustment is calculated. Thus, we have either

$$\delta\theta^{(1)} = \theta_a \, \mathrm{sgn} \, \Delta^{(o)} \tag{106}$$

or

$$\delta\theta^{(1)} = C \, \Delta^{(o)} \quad . \tag{107}$$

With this adjustment to the angular orientation of the airbag, a new secondary profile, forces, and moment imbalance are calculated. The moment imbalance is $\Delta^{(1)}$ in Figure 25. Next, the results $\Delta^{(0)}$, $\Delta^{(1)}$, and $\delta\theta^{(1)}$ are used to extrapolate (or interpolate) to the desired moment imbalance of zero. This yields an improved trial adjustment, $\delta\theta^{(2)}$, as illustrated. After determining the actual imbalance associated with $\delta\theta^{(2)}$, i.e., $\Delta^{(2)}$, an extrapolation using $\Delta^{(1)}$, $\Delta^{(2)}$, $\delta\theta^{(1)}$, and $\delta\theta^{(2)}$ yields a value for the trial adjustment $\delta\theta^{(3)}$.

2.11 Airbag Position, Forces, and Thermodynamic Variables

This section serves largely as a summary of the preceding sections and the part of the flow preceding block 11 in Figure 1b.

First, at each integration time step, the positions of the occupant and parts of the vehicle interior are used to define a polygonal "enclosure" -- an instantaneously unyielding surface with which the airbags can interact. The remainder of the program flow preceding block 11, i.e., blocks 2 through 10, deals with a specific airbag, one of the N airbags which the model user can include in his airbag system design. The computer program first establishes the shape and size of the airbag cross section in the occupant plane. If the bag is deformed, i.e., in contact with the "enclosure," then airbag forces must be calculated. If not, then the forces are zero and the next airbag is processed. The first step toward determination of airbag forces is solution for the airbag pressure and volume. The procedure used incorporates the appropriate thermodynamics and also introduces user-prescribed experimental relationships between three-dimensional and two-dimensional characteristics of the airbag response to symmetric loading. For the latter, it is necessary to calculate the occupant-plane cross-sectional bag area. Airbag thermodynamics calculations take into account such things as supply gas influx rate, venting through ruptured deflation membranes and/or porous airbag fabric, and the effects of volume displacement and venting for airbags inside the one being processed, should there be internal bags. Pressure forces on the occupant and vehicle interior may be calculated as soon as airbag pressure is known. But there are additional airbag forces to be determined. These are flotation forces, or "skin tension forces." They assist the pressure forces in acting against a contacting occupant or vehicle interior "panel" whenever a concavity in the bag surface results from the contact. Two flotation force contributions are calculated, one from edges of a concavity which are normal to the occupant plane and one from edges which are parallel to but to either side of the occupant plane. Finally, when airbag shape and position and all forces have been determined, it is possible to investigate the state of static moment equilibrium for the airbag. If the moment imbalance is satisfactorily small, all calculated values describing airbag dimensions, thermodynamics for the gas in the bag, and forces acting on the occupant and vehicle interior are accepted as final. If the imbalance is too large, then the angular position of the airbag is progressively adjusted with re-determination of bag shape, thermodynamics, and airbag forces until a satisfactory moment balance is attained.

In the following sections, corresponding to blocks 12 through 16 of Figure 1, bag slap forces are first determined and then generalized forces from all pressure forces, flotation forces, and slap forces are developed so that the effect of all forces can be introduced into the Lagrange equations of motion. Finally, the forces from all airbags are accumulated on vehicle interior segments, and potential yielding of those segments is investigated.

2.12 Bag Slap Forces

Bag slap forces in the Advanced Airbag System Submodel are considered to result from impact by the airbag. The slap force model assumes the bag can be viewed as a ball of gas enclosed by fabric and moving toward impact with a surface or surfaces. This enclosed ball of gas should have some of the properties of a solid and some of the properties of a fluid. Accordingly, it is modeled as a four-parameter, viscoelastic solid, as illustrated in Figure 26.* The user specifies values for the four stiffness and damping parameters and also for the effective mass, m, of the gas-fabric system.** In the figure, k and c are fluid properties while K and C are solid properties. V is the impact velocity and x is a dimension explained later.

In the slap force model (Subroutine SLAP), a single bag slap force F_S is determined for the impacting system in Figure 26, and F_S is then distributed over all impacted surfaces. The details of the procedure will now be described.

2.12.1 The Equations of Motion. Consider the surface illustrated in Figure 26 to represent the occupant. Assume that for the duration of the bag slap force, occupant velocities relative to the

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*It can be demonstrated that any three-parameter solid can be modeled by an equivalent four-parameter solid. The four-parameter model is, of course, more general and was considered more convenient for the user. The relationships between three- and four-parameter models are given in Appendix C.

**It would not be unreasonable to calculate an estimate for an effective mass taking into account gas influx and other factors rather than using a constant value.

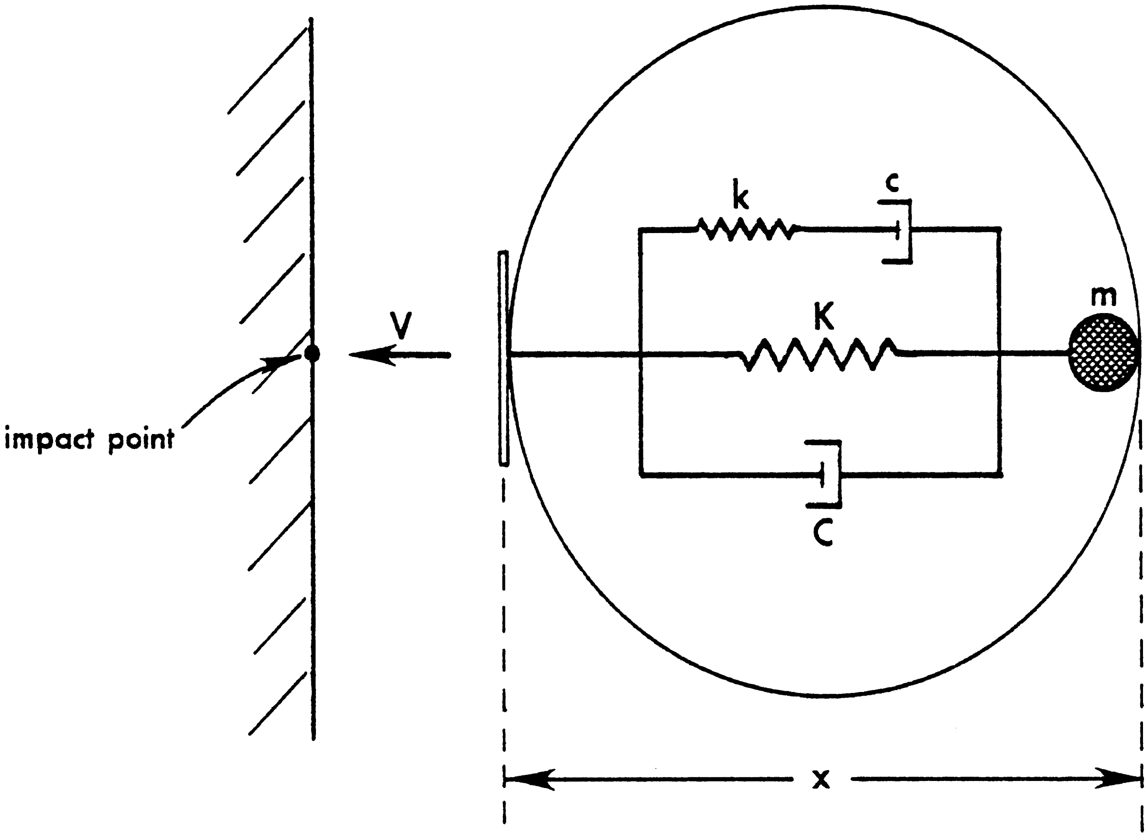

Figure 26. Four-Parameter Viscoelastic Solid for Bag Slap Model

bag are small and may be neglected. Thus, the differential equations for the dimension x will not contain occupant coordinates nor will the equations for occupant generalized coordinates contain x explicitly. This simplifies the problem considerably. The equations of motion for the system shown in the figure are

$$\dot{F}_{fl} + \frac{k}{c} F_{fl} = -k\dot{x} \qquad (108)$$

$$m\ddot{x} = -K(x-l_o) - C\dot{x} + F_{fl} \qquad (109)$$

with the initial conditions for impact at time t_c as given in equations 110:

$$x(t_c) = x_{t_c}, \quad \dot{x}(t_c) = \dot{x}_{t_c}, \quad F_{fl}(t_c) = F_{t_c}. \qquad (110)$$

(See Reference 12.) In equations 108 and 109, F_{fl} is the compression force in the fluid element k-c. At the instant of impact, its value should be zero, so for the initial conditions, F_{t_c} will be 0. In equation 109, l_o represents an unstrained "length" for the bag dimension x. Since the force $K(x-l_o)$ should be zero at time t_c, x_{t_c} is set to the value l_o. l_o is arbitrary, however, for this system of equations since we are never interested in the value of x explicitly; l_o may therefore be set to zero (or consider a coordinate transformation $\bar{x} = x-l_o$), and x_{t_c} is then 0. The initial rate of compression of the viscoelastic solid in the figure will be V, and therefore $\dot{x}_{t_c} = -V$. Equations 108, 109, and 110 may now be re-written as follows:

$$\dot{F}_{fl} + \frac{k}{c} F_{fl} = -k\dot{x} \quad (111)$$

$$m\ddot{x} = -Kx - C\dot{x} + F_{fl} \quad (112)$$

with initial conditions

$$x(t_c) = 0, \quad \dot{x}(t_c) = -V, \quad F_{fl}(t_c) = 0 . \quad (113)$$

These differential equations are integrated in parallel with all other equations of motion so we may consider x and F_{fl} and their derivatives in equations 111 and 112 to have been determined. The total force F_S on the occupant is then the sum of the compressive forces in the k-c, K, and C elements, i.e.,

$$F_s = -Kx - C\dot{x} + F_{fl} , \quad (114)$$

or from equation 112,

$$F_s = m\ddot{x} . \quad (115)$$

Since an impacting airbag should not be able to "pull" against the occupant, but only "push," Subroutine SLAP sets F_S to 0 for all times after the time at which F_S (or $\ddot{x}$) first becomes negative. This time, therefore, defines the end of the impact phase of airbag/occupant interaction.

2.12.2 The Impact Velocity. The impact velocity V of Figure 26 and equation 113 has not yet been given an analytical definition. An impact velocity is easily defined for such a simple system as illustrated in Figure 26, but the actual situation is more complicated. There will not be a single point of impact as illustrated, but rather a general interaction (overlapping) of the expanding airbag profile and the set of straight-line segments representing the occupant profile. Further, only the segments of the enclosure specified by the user as being able to sense bag slap forces from a particular airbag should be considered in any definition of an overall impact velocity V.

The following procedure is used. At each integration time after initial contact at t_c and through the end of the impact phase, it is determined, for each straight-line segment of the secondary profile, whether the associated segment of the vehicle enclosure is one which is allowed to sense bag slap forces from the airbag.* If so, then the segment will be apportioned a part of the total slap force from equation 115. This is discussed in Section 2.12.3. But in addition, <u>at</u> the time of initial contact, each such segment of the secondary profile contributes to the determination of an initial impact velocity V in equation 113. A weighted "distance" to the i^{th} segment from the airbag attachment point (X_A, Z_A) is calculated as

$$\tilde{D}_i = \ell_i \sqrt{(X_A - X_i(t_c))^2 + (Z_A - Z_i(t_c))^2} , \tag{116}$$

where (X_i, Z_i) is the midpoint of the secondary profile segment and ℓ_i is its length. The average distance is then calculated as

$$\bar{D} = \sum_{i=1}^{m} \tilde{D}_i \Big/ \sum_{i=1}^{m} \ell_i \quad , \tag{117}$$

---

*A secondary profile will always have been determined since SLAP is not called unless Subroutine PROFLE has determined that the uncontacted airbag profile interacts with the enclosure.

where there are n participating segments. Now, if bag deployment velocity were regarded as being constant, we would calculate an average impact velocity of $V=\overline{D}/(t_c-t_f)$, where t_f is the airbag "fire" time. On the otherhand, if a constant acceleration "a" were assumed, V would equal $a(t_c-t_f)$, where $D = \frac{1}{2}\, a(t_c-t_f)^2$. V would therefore be $2\,\overline{D}/(t_c-t_f)$. The impact velocity is therefore determined as

$$V = \frac{\lambda \overline{D}}{(t_c - t_f)} \quad , \tag{118}$$

where λ is a user input. λ values are probably most reasonably between 1 and 2, but there are no imposed restrictions.

2.12.3 Distribution of the Total Bag Slap Force. The total bag slap force F_S from equation 115 will now be distributed to the n contacted segments able to sense bag slap force from the airbag. Only normal components of force will be applied to the n segments.

The negative of the direction of the overall force vector $\vec{F}_S$ is considered to be an "average" of the directions from each of the n segments to the airbag attachment point. The weighted averages of the X- and Z-components of the position vectors are

$$D_X = \frac{\Sigma \ell_i (X_A - X_i(t_c))}{\Sigma \ell_i} \tag{119}$$

$$D_Z = \frac{\Sigma \ell_i (Z_A - Z_i(t_c))}{\Sigma \ell_i} \tag{120}$$

The direction cosines used for the direction of $-\vec{F}_S$ are therefore

$$d_X = D_X / D \tag{121}$$

$$d_Z = D_Z / D \quad , \tag{122}$$

where

$$D = \sqrt{D_X^2 + D_Z^2} \quad . \tag{123}$$

(Note: D could be used as reasonably as $\overline{D}$ in defining V. Determination of the distance b for Section 2.7.2 by Subroutine WIDTH corresponds to the use of D, except for weighting.) Figure 27 illustrates the unit vector $\hat{d}$ in the direction of $-\vec{F}_S$. Weighting for distribution of F_S to the n segments is in proportion to segment length l_i and to $(-\hat{n}_i \cdot \hat{d})$, the cosine of the angle between $\hat{d}$ and the normal to the segment, i.e., in proportion to the projection of the segment in the direction of $\hat{d}$.* The magnitude of the force on segment "i" in the direction of $-\hat{d}$ (and applied at its midpoint) is therefore

$$f_i = \frac{F_S \, l_i \, (-\hat{n}_i \cdot \hat{d})}{\sum l_i \, (-\hat{n}_i \cdot \hat{d})} \quad , \tag{124}$$

The force vector, then, is

$$\vec{f}_i = \frac{-F_S \, l_i \, (\hat{n}_i \cdot \hat{d})}{\hat{d}_i \cdot \sum l_i \, \hat{n}_i} \, \hat{d} \quad . \tag{125}$$

Finally, the component of $\vec{f}_i$ normal to segment "i" is determined and applied (at the segment midpoint) to the vehicle interior or -- for an occupant profile segment of the secondary profile -- to the body link to which the segment is attached. The component of $\vec{f}_i$ in the direction of $\hat{n}_i$ is

$$f_n^{(i)} = \frac{-F_S \, l_i \, (\hat{n}_i \cdot \hat{d})^2}{\hat{d} \cdot \sum l_i \, \hat{n}_i} \tag{126}$$

---

*The corresponding weighting used for distribution of off-occupant-plane flotation forces (Section 2.9.3) is simply l_i. Here, the projection of this length is used instead since only normal components -- not tangential components -- of slap force are applied to the segments.

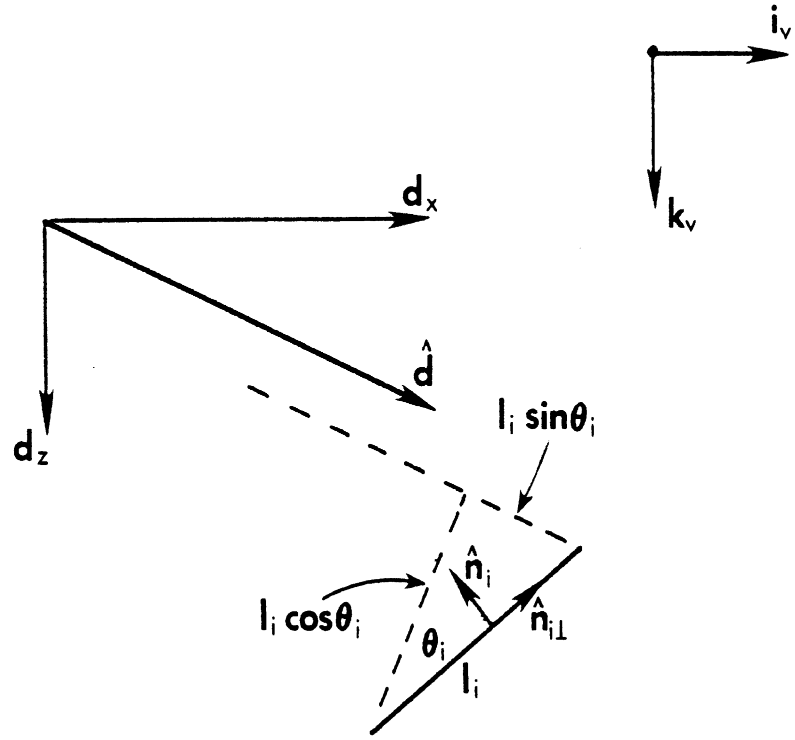

Figure 27. Distribution of the Bag Slap Force

and the applied slap force vector is

$$\vec{f} = f_n^{(i)} \hat{n}_i \quad . \tag{127}$$

2.13 Generalized Forces

Sections 2.1 through 2.12 explain the determination of airbag forces which act against the occupant and the vehicle interior. Those which act on the occupant affect the equations of occupant motion directly. It is the purpose of this section to show how these forces are incorporated into the equations of motion.

2.13.1 The Equations of Motion. The Lagrange formulation of the equations of motion for a system of rigid bodies is

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_j} - \frac{\partial T}{\partial q_j} + \frac{\partial V}{\partial q_j} + \frac{\partial D}{\partial \dot{q}_j} = Q_{q_j}, \quad j = 1, \ldots, n \tag{128}$$

where the q_j's are n independent spatial coordinates from which the positions and orientations of the rigid bodies can be determined.* Here, T is the system kinetic energy function, V is the system potential energy, a function of the generalized coordinates alone, D is the dissipation function for velocity-dependent energy losses, and the Q_{q_j}'s are the n generalized forces for external applied forces [13]. The equations 128 are n second-order, ordinary differential equations for the n q_j's, the "generalized coordinates." The formulation given here is used in Volume 1 of the MVMA 2-D CVS manuals, which explains the analytical model exclusive of the Advanced Airbag System Submodel. The MVMA 2-D occupant model has fourteen degrees of freedom, so n is 14. Volume 1 explains various model features which contribute to the generalized forces. In general, all fourteen will be non-zero.

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*Equation 128 differs form the classical form in the presence of the dissipation term and the use of T and V separately instead of the Lagrangian, L=T-V.

In order to introduce the effect of the Advanced Airbag System on the equations of motion, it will be necessary to determine additional contributions to the generalized forces, Q_{q_j}. Further, it should be stated that only these terms in equations 128 will be modified. Since the modeled airbag system has no generalized coordinates of its own, its influence enters only through the airbag forces determined to be acting against contacting surfaces.

2.13.2 The Lagrange Generalized Forces. The generalized force for the coordinate q_j can be determined by equation 129:

$$Q_{q_j} = \sum_{m=1}^{M} \vec{F}^{(m)} \cdot \frac{\partial \vec{r}^{(m)}}{\partial q_j} \quad . \tag{129}$$

Here, the $\vec{F}^{(m)}$ are M applied forces and the $\vec{r}^{(m)}$ are the position vectors from the inertial frame origin to the points of application of the respective force vectors [13]. Figure 28 shows a force vector $\vec{F}^{(m)}$ applied to a rigid body "i" at a position $\vec{r}^{(m)}$.

Sections 2.1 through 1.12 have established the following quantities:

$F_n^{(m)}$, $F_{n_\perp}^{(m)}$	- -	airbag force "m" components on a contact segment fixed to an occupant link, normal to the segment and along the segment
$X_v^{(m)}$, $Z_v^{(m)}$	- -	the coordinates in the vehicle frame of the point of application of the force vector

The M forces determined are pressure forces, occupant-plane flotation forces, off-occupant-plane flotation forces, and slap forces. Their points of application ($X_v^{(m)}$, $Z_v^{(m)}$) are at endpoints of straight-line segments of the secondary profile for occupant-plane flotation forces and at the midpoints of the segments for the other types of forces. From the force components and coordinates above, it is required to

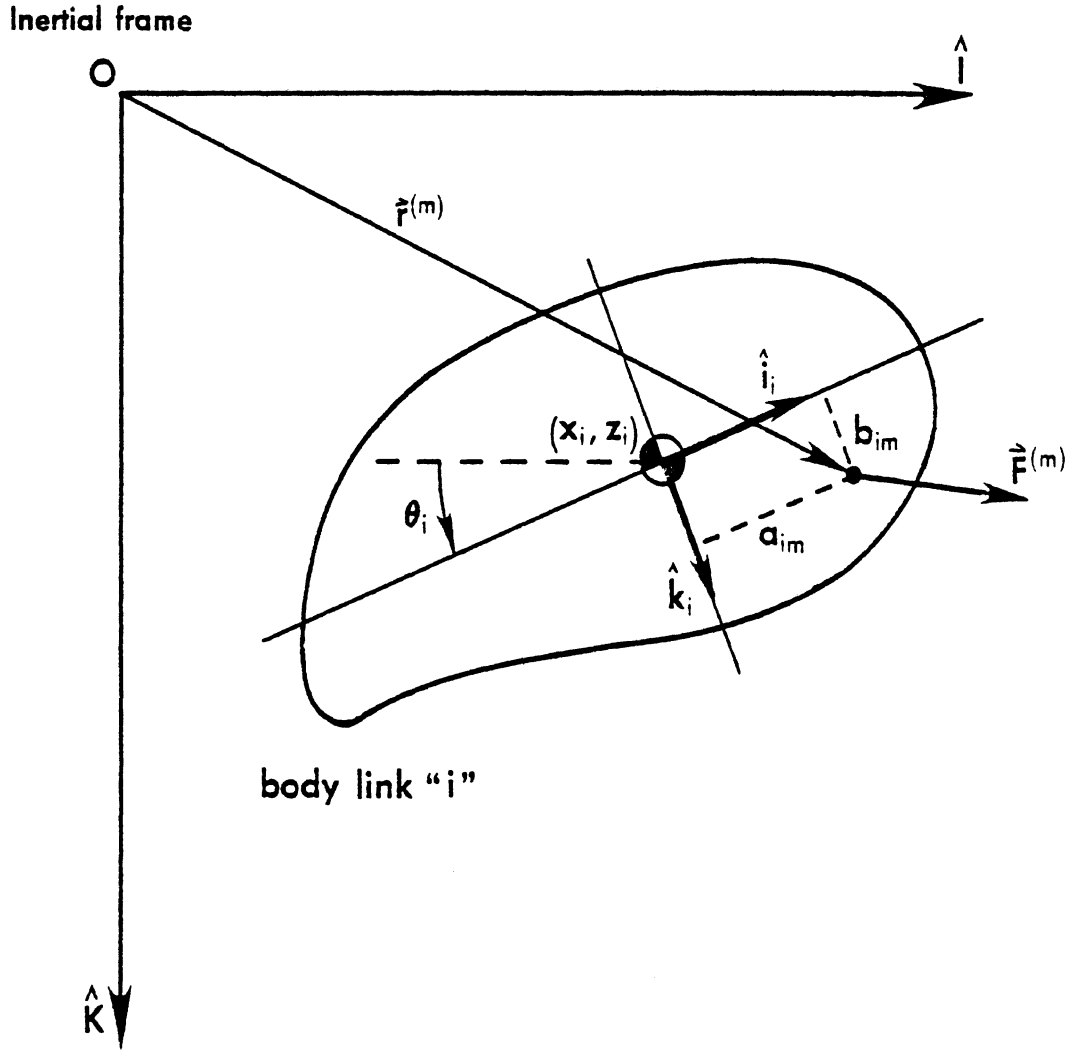

Figure 28. Force "m" Applied to Link "i"

evaluate equation 129 for Q_{q_j}. This will be accomplished by finding $\vec{F}^{(m)}$ and $\vec{r}^{(m)}$ in inertial components.

2.13.2.1 The Position Vector. The position vector $\vec{r}^{(m)}$ will be found first. From Figure 28, $\vec{r}^{(m)}$ may be written as

$$\vec{r}^{(m)} = X_i \hat{I} + Z_i \hat{K} + a_{im} \hat{i}_i + b_{im} \hat{k}_i \quad , \tag{130}$$

where (X_i, Z_i) is the inertial location of the center of mass of link "i" and (a_{im}, b_{im}) are the coordinates in the body-fixed coordinate system of the force application point. Since

$$\hat{i}_i = \cos\theta_i \hat{I} - \sin\theta_i \hat{K} \tag{131}$$

$$\hat{k}_i = \sin\theta_i \hat{I} + \cos\theta_i \hat{K} \quad , \tag{132}$$

equation 130 can be separated into $\hat{I}$- and $\hat{K}$-components as follows:

$$r_x^{(m)} = X_i + a_{im} \cos\theta_i + b_{im} \sin\theta_i \tag{133}$$

$$r_z^{(m)} = Z_i - a_{im} \sin\theta_i + b_{im} \cos\theta_i \quad . \tag{134}$$

Equations 133 and 134 may now be solved for the coordinates a_{im}, b_{im}:

$$a_{im} = (r_x^{(m)} - X_i) \cos\theta_i - (r_z^{(m)} - Z_i) \sin\theta_i \tag{135}$$

$$b_{im} = (r_x^{(m)} - X_i) \sin\theta_i + (r_z^{(m)} - Z_i) \cos\theta_i \,. \tag{136}$$

Next, if the inertial components $r_x^{(m)}$ and $r_z^{(m)}$ can be determined from the known vehicle-relative coordinate values for the point of force application, ($x_v^{(m)}$, $z_v^{(m)}$), then the values a_{im} and b_{im} (equations 135 and 136) can be considered known so that the position vector of equation 130 will be completely determined. This is easily done. These components are simply

$$r_x^{(m)} = X_v + x_v^{(m)} \cos\theta_v + z_v^{(m)} \sin\theta_v \qquad (137)$$

$$r_z^{(m)} = Z_v - x_v^{(m)} \sin\theta_v + z_v^{(m)} \cos\theta_v \; , \qquad (138)$$

where X_v, Z_v, and θ_v are the coordinates of the vehicle frame with respect to the inertial frame.

The quantity $\frac{\partial \vec{r}^{(m)}}{\partial q_j}$ in equation 129 may now be determined. From equation 130, it is

$$\frac{\partial \vec{r}^{(m)}}{\partial q_j} = \frac{\partial X_i}{\partial q_j} \hat{I} + \frac{\partial Z_i}{\partial q_j} \hat{K} + a_{im} \frac{\partial \hat{i}_i}{\partial q_j} + b_{im} \frac{\partial \hat{k}_i}{\partial q_j} \; , \qquad (139)$$

where, from equations 131 and 132,

$$\frac{\partial \hat{i}_i}{\partial q_j} = \left(-\sin\theta_i \hat{I} - \cos\theta_i \hat{K}\right) \delta_{\theta_i, q_j} \qquad (140)$$

$$\frac{\partial \hat{k}_i}{\partial q_j} = \left(\cos\theta_i \hat{I} - \sin\theta_i \hat{K}\right) \delta_{\theta_i, q_j} \qquad (141)$$

and δ_{θ_i, q_j} is the Kronecker delta, unity if q_j is θ_i and zero otherwise.*

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*Note that since $\vec{r}^{(m)}$ is the position of a particle point, a_{im} and b_{im} are constants with respect to q_j-differentiation.

2.13.2.2 The Force Vector. The remaining factor in equation 129 will now be found, i.e., $\vec{F}^{(m)}$. Its components normal and tangential to the contact segment on the body are already known; they are $F_n^{(m)}$ and $F_{n_\perp}^{(m)}$. It is required to resolve the force vector into inertial components so that the dot product in equation 129 can be easily evaluated.

Relative to the segment, we have

$$\vec{F}^{(m)} = F_n^{(m)} \hat{n} + F_{n_\perp}^{(m)} \hat{n}_\perp \quad . \tag{142}$$

But $\hat{n}$ and $\hat{n}_\perp$ are known from equations 54 and 55. Their components in the vehicle frame are g and h from equation 11.

We have, then,

$$\vec{F}^{(m)} = F_n^{(m)} \left[g\,\hat{i}_v + h\,\hat{k}_v \right] + F_{n_\perp}^{(m)} \left[-h\,\hat{i}_v + g\,\hat{k}_v \right] \quad . \tag{143}$$

This result can be resolved into inertial components by eliminating $\hat{i}_v$ and $\hat{k}_v$. The form of equations 131 and 132 applies, so i may be set to v there and we obtain

$$\begin{aligned} \vec{F}^{(m)} = &\left\{ F_n^{(m)} (g \cos\theta_v + h \sin\theta_v) + F_{n_\perp}^{(m)} (-h \cos\theta_v + g \sin\theta_v) \right\} \hat{I} \\ + &\left\{ F_n^{(m)} (-g \sin\theta_v + h \cos\theta_v) + F_{n_\perp}^{(m)} (h \sin\theta_v + g \cos\theta_v) \right\} \hat{K} \quad . \end{aligned} \tag{144}$$

Finally, the dot products of the results of equations 139 and 144 -- summed over all airbag forces on the occupant -- yield the Advanced Airbag System contribution to the generalized force Q_{q_j} for the coordinate q_j.

2.14 Accumulation of Forces on Vehicle Interior Segments

A previously mentioned feature of the Advanced Airbag System Submodel provides the possibility of allowing vehicle interior sections of the airbag system enclosure to undergo a "yielding" motion in response to airbag forces. This feature is discussed in detail in Section 2.16.

Before possible yielding can be investigated, however, the model requires a value for the total airbag force against each potentially yielding vehicle interior segment. Determining these values is a function of Subroutine ADVBAG. Since it is possible for more than one airbag to be in contact simultaneously with a segment, the total bag force must be obtained by summing over all airbags for forces against each segment. Only sections of the secondary profile where the airbag conforms to the vehicle interior profile need be considered since the occupant contact-sensing profile is not allowed to yield to airbag forces. For each straight-line segment of the secondary profile which corresponds to a vehicle-interior segment specified by the user as capable of yielding, all airbag force components normal to the segment are accumulated. In general, the total force against a segment will include pressure forces, slap forces, and components of the occupant-plane and off-occupant-plane flotation forces.

2.15 Incrementing the Index for Airbag Processing

The Advanced Airbag System Submodel allows simulation of multi-bag designs for inflatable restraint device systems. The n-airbag system is discussed in general in Section 2.2.

Each of the n airbags is processed in turn by the model, with Subroutine ADVBAG directing the flow. Section 2.2 explains that because of possible dependencies between the thermodynamics for gas in the various airbags, the order for processing of the airbags is pre-established (by Subroutine SETVLB of the Input Processor). The determination of airbag contacts, thermodynamics, and forces for each bag has been discussed in Sections 2.2 through 2.14. In Figure 1b, the corresponding blocks -- 2 through 14 -- constitute the processing loop for an airbag. Block 15 represents the end of the loop on airbags in Subroutine ADVBAG.

2.16 Vehicle Interior Response to Airbag Forces

As an airbag deploys in a frontal impact and is contacted by the forward-moving occupant, airbag forces of a generally similar magnitude develop on the occupant and the vehicle interior. The forces can be large enough to cause deformation or motion of elements of the occupant compartment. The Advanced Airbag System Submodel allows any desired vehicle-interior line segments to have the potential for yielding as a result of airbag forces against them. Figure 29 illustrates an airbag contacted from one side by the occupant and from the other side by a portion of the vehicle interior. In this example, there are three segments of the vehicle-interior profile capable of undergoing airbag-induced motion. While there are no restrictions regarding which segments may be assigned properties governing potential yielding, it is expected that this model feature will be used primarily for simulating steering column telescoping and windshield blowout, and possibly instrument panel collapse.

In the model described below, yielding of an element of the occupant compartment is treated as a motion. Accordingly, the user assigns an associated mass for each segment which can yield to airbag forces. This type of model is most appropriate, of course, for occupant compartment components which do have a significant inertia and not only a static "material strength." It should be particularly useful for simulating steering column telescoping, the associated mass being simply the mass of the non-fixed portion of the E-A assembly. The masses for the three yielding segments in the illustration are m_1, m_2, and m_3.

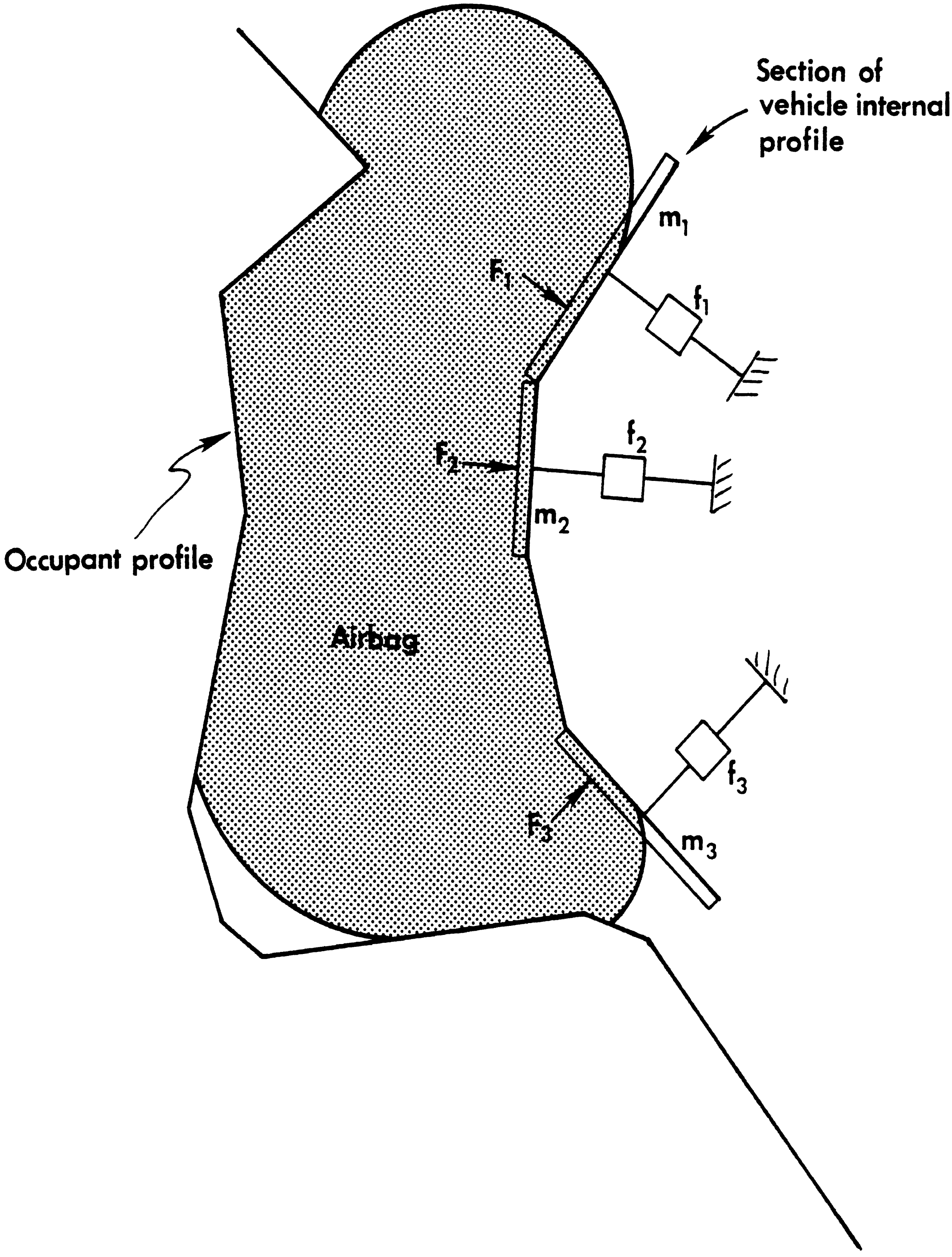


Figure 29. Model for Airbag - Induced Occupant Compartment Deformation

The motion determined for each yielding segment is a displacement along a perpendicular to its length to a position where it is parallel to its initial orientation. In Figure 29, for example, motions would be unrotated displacements in the directions of the illustrated resistive elements, f_i. In addition to the inertia resistance to motion previously mentioned, there are three other types of force resistances which the user can specify. These can all be considered components of f_i. (Subscripts will be omitted in the remainder of this section.) First, a "break-away force," Y, is prescribed; motion will not initiate until the airbag force F exceeds Y. Second, a static displacement-dependent force may be specified. This is simply a tabular force-deflection loading curve, $F_s(\delta)$. It is considered to be for whatever part of the occupant compartment structure would offer static resistance, after breakaway, to displacement of the occupant compartment element represented by the segment of mass m. Third, a velocity-dependent resistance to the motion of mass m is determined from a linear damping coefficient C. Unloading, or "rebound," from maximum displacement can be partial or complete. The unloading is controlled by two additional user inputs for each yielding element, τ and G; unloading occurs over time τ to a permanent deflection of $G\delta_{max}$ where δ_{max} is the displacement at the beginning of unloading.*

The incremental displacement Δx of mass m during the time step Δt is determined in the following manner. First,

$$\Delta x = 0 \qquad \text{for } F < Y . \tag{145}$$

*Straight-line unloading is used, i.e., the user does not specify an R-ratio governing unloading energy.

After airbag forces F have exceeded Y, motion initiates and the yielding element is subject to its own inertia and to displacement-dependent and velocity-dependent forces previously described. Consider motion between two times t_1 and t_2. Where v is velocity, we have

$$\int_{t_1}^{t_2} F_{total}\, dt = \int_{t_1}^{t_2} d(mv) = m(v_2 - v_1)\ . \quad (146)$$

If $t_2 \approx t_1$, this result may be written approximately as

$$\left[F - F_s(x_1) - cv_1\right](t_2 - t_1) = 2m\frac{v_1 + v_2}{2} - 2mv_1\ , \quad (147)$$

where x is displacement. The quantity $(v_1+v_2)/2$ in the right-hand side of equation 147 is the average velocity during t_1 to t_2, which may also be written

$$\frac{v_1 + v_2}{2} = \frac{x_2 - x_1}{t_2 - t_1}\quad . \quad (148)$$

Therefore, if t_2-t_1 is the integration time step Δt and x_2-x_1 is the displacement Δx over time Δt, equations 147 and 148 give

$$\Delta x = v_1\,\Delta t + \frac{1}{2m}\left[F - F_s(x_1) - cv_1\right](\Delta t)^2\ . \quad (149)$$

Loading motion is determined by accumulating Δx from equation 149 to obtain a time-dependent total displacement. x_1 and v_1 are always the displacement and velocity conditions at the preceding time step.

During unloading, the current deflection is calculated as

$$x_2 = \delta_{max} - \frac{\delta_{max}(1-G)}{\tau}(t - t_t),\quad 0 < t - t_t \leq \tau. \quad (150)$$

Here, t_t is the "turnaround time," i.e., the time at which maximum displacement was reached, viz., the time at which Δx from equation 149 first became negative. After unloading is complete at time τ, the displacement of the segment remains constant at the fraction of maximum displacement specified by the user:

$$x_2 \equiv G\,\delta_{max}\ , \qquad t \geq t_t + \tau\ . \tag{151}$$

Motions determined for yielding segments will affect possible interactions between the segments and occupant ellipses. Should a segment be displaced because of airbag forces, an occupant ellipse which pushes through the airbag (or goes around) to a position where it would have contacted the segment in its unyielded position will not contact the segment until it moves an additional distance in the direction of segment displacement.

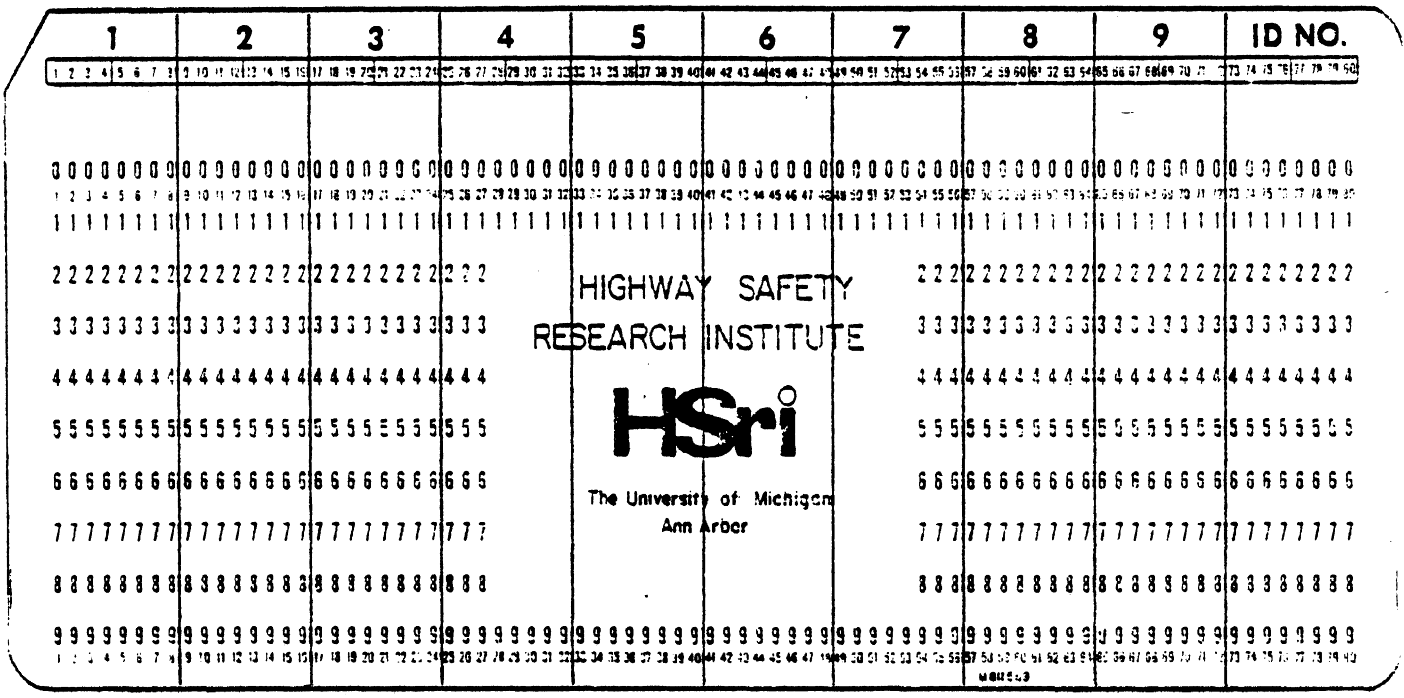
3.0 USERS' GUIDE

This section of the report contains a description of the data required to operate the MVMA 2-D CVS model with the inclusion of the Advanced Airbag System Submodel. Table 1 is a listing of all types of data needed for the submodel. Table 2 describes input data card layouts. These tables should be considered supplements to Tables 6 and 7 of Volume 2 of the three-volume set of report manuals for the MVMA 2-D CVS model [7], which must be referenced as well as this report in order to prepare data decks for Advanced Airbag System simulations.

3.1 Description of Input Data Cards

Two data decks are required for computer simulations made with the MVMA 2-D model. Each data deck consists of a series of eighty-character lines which will be called "cards" in this discussion. The first data deck is read by the input processor, and the cards are identified by numbers 100 through 1000 in columns 78-80 or 77-80. Primarily, these cards contain data which describe the crash event, the occupant, the vehicle interior, and the restraint systems. For simulations involving the Advanced Airbag System, this data deck will include a number of cards specific to the Advanced Airbag System submodel. These are Cards 112 and 113 and Cards 910 through 929. The second data deck is read by the output processor. Each card is identified by a number 1001 through 1600 in columns 77-80. These cards contain data which control printout and the use of post-processors discussed in a section of Volume 3. For Advanced Airbag System simulations, Card 1001 or Cards 1001 and 1002 must specify desired airbag output categories selected from Categories 51 through 62 unless the cards are defaulted. In general, data cards can be in any order within a data deck. Cards which control model options not used for a particular simulation need not be present. Also, as explained in Volume 2 of the MVMA 2-D manuals, various quantities can be defaulted to constants stored within the program by omitting their cards frcm the data deck(s). The only Advanced Airbag System cards which can be defaulted are Cards 112, 113, 911, and 912.

Each card consists of ten fields. (See Figure 30.) The tenth field is reserved for the previously mentioned card identification number. The first nine fields, consisting of eight columns each, are data fields. Thus, up to nine numbers may be required per card although most cards make use of a smaller number of fields. Numerical data must be specified in either F, E, or D format, examples of which are given with Figure 30. Blanks in numeric fields are treated as zeros by most computer systems, so E- and D-format numbers must be right-adjusted within data fields. Alphanumeric data are required on some cards; blanks within an alphanumeric field will not be ignored since a blank is a legitimate alphanumeric character.



Acceptable data formats

F	E	D
123.4	1.234E2	1.234D2

Figure 30. A Data Card

3.2 Input Data Quantities

Numerous data quantities must be specified in the data deck in order to use the Advanced Airbag System submodel. Much information about these quantities is included with the card layouts on pages of Table 2. In addition to "Definition" of the quantities required in the data fields for a card, most pages of this table have several "NOTES" which explain in more detail the quantities required in various fields or which otherwise clarify the use of the card. The user should refer to Section 2 of this manual, which explains the analytical model, for more complete definitions of model parameters for which values must be specified in the data deck.

The "Units" column for each card layout in Table 2 indicates the necessary units for all dimensional input quantities. Units required for metric system usage of the model are in parentheses, and units for English system usage are without parentheses. Table 3 gives conversion constants relating physical quantities expressed in metric and English systems of units. It is included here for the convenience of users who may have source data in one system but wish to prepare their data decks for simulations in the other system.

TABLE 1 SUMMARY OF REQUIRED INPUT DATA CARDS FOR ADVANCED AIRBAG MODEL

I.D.	Card Content	Number of Cards
102	Simulation controls	1
112,113	Stored output specifications	2
900	Airbag System Subtitle	1
910	Advanced airbag system controls	1
---	Vehicle enclosure segment names	1 for each segment
911	Inflation gas properties	1
912	Convergence epsilons and iteration limits	1
913-915	Occupant contact reference points for airbag contact	3
916	Airbag constants	1 for each airbag
917	Interior bag names	1 for each airbag immediately inside another bag
918	Deflation vents	1 for each deflation vent
919	Bag slap parameters	1 for each airbag with bag slap potential
920	Enclosure segments for bag slap	1 for each allowed (or disallowed) bag slap interaction
921	Airbag table names	1 for each airbag

TABLE 1 SUMMARY OF REQUIRED INPUT DATA CARDS FOR ADVANCED AIRBAG MODEL (continued)

I.D.	Card Content	Number of Cards
922	V vs. A for cross-section of bag contact	1 for each point on tabular curve with P/T constant
923	Mass influx rate vs. time	1 for each point on tabular curve
924	Source gas temperature vs. time	1 for each point on tab- ular curve (needed only if constant value not specified)
925	Fabric porosity vs. pressure differential	1 for each point on tabular curve
926	Bag profile controls	1 for each time in history of profiles of expanding air- bag (for each bag)
---	Bag profile points	Several cards, 4 airbag profile vertex points per card
927	Deformable enclosure segment names	1 for each such segment for each airbag
928	Deformable enclosure segment properties	1 for each segment
929	Deformable segment loading curve	1 for each point on tabular curve
1001, 1002	Category selection and ordering specification	1 or 2

TABLE 2 INPUT DATA

SIMULATION CONTROLS (CARD 2)

Field	Name of Quantity	Units	Description	Defaults
1	NBELT		Switch = 0. no belts = 1. standard (MODROS) lap belt, no shoulder harness (BELT) = 2. standard (MODROS) lap belt plus shoulder harness (BELT) = 3. advanced belt system (BELT2)	0.
2	NBAG		Switch = 0. airbag interaction not desired = 1. simple airbag model (AIRBAG) = 2. advanced airbag model (ADVBAG)	0.
3	NSTCOL		Switch = 0. steering column interaction not desired ≠ 0. steering column interaction desired	0.
4	LHIB		Switch = 0., Ellipse-ellipse contacts on 106 cards are allowable 1., Ellipse-ellipse contacts on 106 cards are inhibited	0.
5	KHIB		Switch = 0., Ellipse-region contacts on 106 cards are allowable 1., Ellipse-region contacts on 106 cards are inhibited	1.
6	ILL		Switch = 0., Ellipse-ellipse contacts can occur 1., Global control to override LHIB.No ellipse-ellipse contacts are allowed despite LHIB and 106 cards.	1.
7	FNU	in/sec (m/sec)	Length of scaling ramp to insure friction force continuity	10. .254
8	EPSINV		Relative error tolerance for singularity in matrix inversion step	.000001
9	MX	min.	Execution CPU Time Limit	5.

Note -- This card layout supercedes the one for Card 102 in Volume 2 of the MVMA 2-D CVS manuals.

Card 102

TABLE 2 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 6)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	Category 51		Switch = 0., Store advanced airbag system thermodynamic variables. 1., Inhibit.	0.
2	Category 52		Switch = 0., Store pressure forces on body. 1., Inhibit.	0.
3	Category 53		Switch = 0., Store occupant-plane normal flotation forces. 1., Inhibit.	0.
4	Category 54		Switch = 0., Store occupant-plane tangential flotation forces. 1., Inhibit.	0.
5	Category 55		Switch = 0., Store off-occupant plane normal flotation forces. 1., Inhibit.	0.
6	Category 56		Switch = 0., Store off-occupant plane tangential flotation forces. 1., Inhibit.	0.
7	Category 57		Switch = 0., Store bag slap forces on body. 1., Inhibit.	0.
8	Category 58		Switch = 0., Store airbag equilibrium and contact conditions. 1., Inhibit.	0.
9	Category 59		Switch = 0., Store airbag-deformable segment motions. 1., Inhibit.	0.

NOTE: Use Cards 1001 and 1002 to specify desired printed output.

Card 112

TABLE 2 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 7)
(3 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	Category 60		Switch = 0., Store total bag forces on body. 1., Inhibit.	0.
2	Category 61		Switch = 0., Store total inertial x-component bag forces. 1., Inhibit.	0.
3	Category 62		Switch = 0., Store total inertial z-component bag forces. 1., Inhibit.	0.

NOTE: Use Cards 1001 and 1002 to specify desired printed output

Card 113

TABLE 2 INPUT DATA

AIRBAG SYSTEM SUBTITLE
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1-3	STITLE (31 - 35)		Run subtitle for Airbag Restraint System Input Block Centered in columns 1-17

NOTE: See note on Card 800

Card 900

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM CONTROLS
(5 Fields of 8)

Field	Name of Quantity	Units	Definition
1	NBAGS		Number of Airbags
2	NENCV		Number of vehicle interior enclosure segments
3	NABOVE		Number of vehicle interior enclosure segments above attachment point for airbag number 1 (must be at least one)
4-5			Name assigned to airbag number 1 (see note 1)

NOTES:

1. Airbag number 1, identified in fields 4-5, cannot be inside any other bag.
2. The number of airbags must be no greater than 20.
3. This card must be followed by "NENCV" unnumbered cards, one for each vehicle interior enclosure segment. Each segment must be one named on a 409 - Card, and the "NENCV" segments must be connected, one to another, at their endpoints. The first card following Card 910 must be for the "lowest" in line (~ floor), or most clockwise. The NENCV-th must be for the highest in line (~ roofheader), or most counterclockwise.

Card 910

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM VEHICLE ENCLOSURE SEGMENTS
(2 Fields of 8)

Field	Name of Quantity	Units	Definition
1 - 2			Contact segment name from 409 -Card of segment included in airbag "enclosure"

NOTE:
"NENCV" unnumbered cards follow Card 910. See note on Card 910.

(follows Card 910)

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM INFLATION GAS PROPERTIES
(7 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	RGAS	ft lb / lbm F° (joules / lg C°)	Gas constant for inflation [or 0.]	55.15 (296.7)
2	MOLEWT	–	Molecular weight (average) for inflation gas [or 0.]	28.02
3	GAMMG	–	Ratio of specific heats for inflation gas	1.4
4	CPG	BTU / lbm °F (joules / gm °C)	Specific heat at constant pressure	0.25 (1.0465)
5	PATM	lb / in^2 (N / cm^2)	Pressure of external medium (atmosphere)	14.7 (10.135)
6	TATM	°F (°C)	Temperature of external medium (atmosphere)	68. (20.)
7	RHEAD	in (cm)	Head radius for airbag contacts	5. (12.7)

NOTE:

Field 1 or Field 2 is needed, not both. Enter a "0." (or blank) in the field not used. If non-zero fields are present in both fields, Field 2 will be used.

Card 911

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM CONVERGENCE EPSILONS AND ITERATION LIMITS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	EPSP	$\frac{lb}{in^2}$ $\left(\frac{N}{cm^2}\right)$	Convergence epsilon for testing pressure in pressure-volume iteration	.1 (.068948)
2	EPSM	lb in (N-m)	Convergence epsilon for testing unbalanced moment on bag in bag position iteration	50. 5.6492
3	EP1	in^2 (cm^2)	Distance-squared epsilon for distinguishing between cases of 1) real (small) difference between two distances and 2) an apparent difference due to roundoff	.0005 (.0032258)
4	EP2	in^2 (cm^2)	Distance-squared epsilon for distinguishing between cases of 1) non-coincident (but near) points and 2) coincident points made "non-coincident" by roundoff	.0001 .00064516
5	EP3	in (cm)	X- (or Z-) position epsilon for determining if two straight-line segments interact	.000001 (.00000254)
6	EP4	in (cm)	X- (or Z-) position epsilon for distinguishing between cases of 1) non-coincident (but near) points and 2) coincident points made "non-coincident" by roundoff	.001 (.00254)
7	DMIN	in (cm)	Minimum allowed chord length for arc (bulge) of bag in occupant plane; smaller arcs are replaced by the chord	.3 (.762)
8	ITPMAX	-	Maximum number of iterations allowed for each bag at each time for pressure and volume determination	10.
9	ITMMAX	-	Maximum number of iterations allowed for each bag at each time for adjustment of bag position for moment balance (2. or 3.)	3.

Card 912

TABLE 2 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 1)
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(1), ξ_1	inches(cm)	Distance along centerline from reference joint (see card 915) to contact reference point 1.
2	ZETAI(1), ζ_1	inches(cm)	Distance perpendicular to centerline from reference joint (see card 915) to contact reference point 1.
3	CSI(2), ξ_2	inches(cm)	See Field 1 (Reference Point 2)
4	ZETAI(2), ζ_2	inches(cm)	See Field 2 (Reference Point 2)
5	CSI(3), ξ_3	inches(cm)	(Not used.)
6	ZETAI(3), ζ_3	inches(cm)	(Not used.)
7	CSI(4), ξ_4	inches(cm)	See Field 1 (Reference Point 4)
8	ZETAI(4), ζ_4	inches(cm)	See Field 2 (Reference Point 4)

NOTE: See figures on Cards 914 and 915.

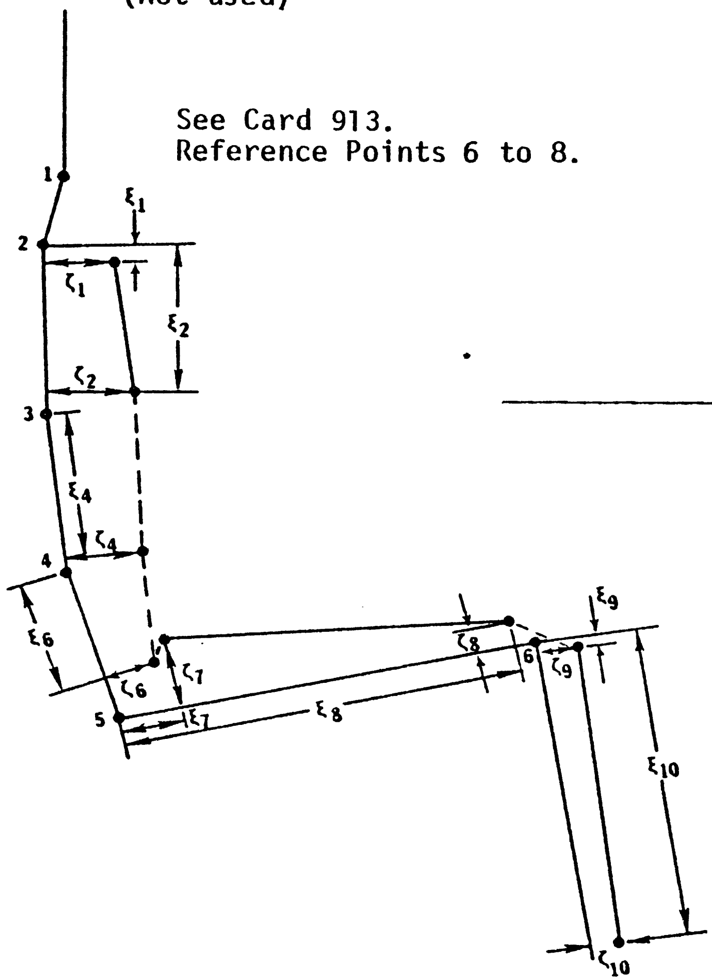
Card 913

TABLE 2 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 2)
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(5), ξ_5	inches (cm)	(Not used)
2	ZETAI(5), ζ_5	inches (cm)	(Not used)
3	CSI(6), ξ_6	inches (cm)	See Card 913. Reference Points 6 to 8.
4	ZETAI(6), ζ_6	inches (cm)	
5	CSI(7), ξ_7	inches (cm)	
6	ZETAI(7), ζ_7	inches (cm)	
7	CSI(8), ξ_8	inches (cm)	
8	ZETAI(8), ζ_8	inches (cm)	

NOTE: Also see figures on Card 915.



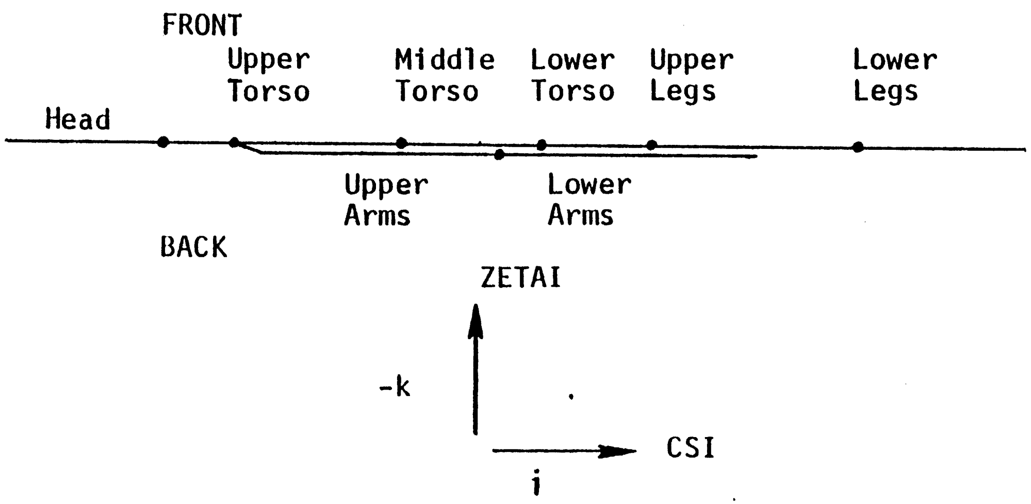
Card 914

TABLE 2 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 3)
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(9), ξ_9	inches (cm)	See Card 913 Reference Points 9 and 10
2	ZETAI(9), ζ_9	inches (cm)	
3	CSI(10), ξ_{10}	inches (cm)	
4	ZETAI(10), ζ_{10}	inches (cm)	

NOTE: Also see figure on Card 914.



Reference Point	Definition	Reference Joint
1	Top of Chest Line	Neck
2	Bottom of Chest Line	Neck
3	Top of Gut Line	Upper Torso
4	Bottom of Gut Line	Upper Torso
5	Top of Pelvis Line	Lower Torso
6	Bottom of Pelvis Line	Lower Torso
7	Top of Upper Leg Line	Hip
8	Bottom of Upper Leg Line	Hip
9	Top of Lower Leg Line	Knee
10	Bottom of Lower Leg Line	Knee

Card 915

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM AIRBAG CONSTANTS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3	WBAG	in (cm)	Side-to-side width of deflated bag
4	SURFCE	ft^2 (m^2)	Total surface area of porous fabric (or negative surface area - see Note 1)
5	TBGFR	msec	Bag fire time
6	T_S	^oF (^oC)	Constant source gas temperature (see note 2)
7		$\frac{deg}{in\ lb}$ $\left(\frac{deg}{N\text{-}m}\right)$ or deg	Bag equilibrium adjustment parameter: compliance for initial θ-adjustment of bag if negative, angle adjustment if positive (+15. is suggested)
8			Number of vehicle interior segments between bag #1 attachment point and attachment point for this bag. (Attachments must be at endpoints of vehicle interior segments of the enclosure.) Number should be positive if counterclockwise from bag # 1 and negative if clockwise. If this airbag is bag # 1, the number entered here will be 0.

NOTES:

1. If the bag is constructed such that none (or little) of the porous venting surface will be in contact with the occupant or vehicle interior surfaces, enter the negative of the porous surface area in Field 4.

2. Field 6 is needed only if no table for source gas temperature vs. time is included for this airbag in the data set.

Card 916

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM INTERIOR BAGS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Name of one of the airbags immediately inside this bag

NOTES:

1. Omit 917-Cards if there are no airbags immediately inside.
2. There can be up to twenty airbags total, but no string of successively nested bags can be greater than five bags in length.

Card 917

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFLATION VENTS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3		in^2 (cm^2)	Area of one of the deflation vents (membranes) for this bag
4		$\frac{lbs}{in^2}$ ($\frac{N}{cm^2}$)	Pressure differential necessary to burst membrane

NOTE:

Use one 918-Card for each deflation vent (omit cards if no vents).

Card 918

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG SLAP PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3	BMASS	lbm (kg)	Bag/gas mass for bag slap
4	FLUIDK	$\frac{lb}{in}$ $\left(\frac{N}{cm}\right)$	Fluid k for bag-slap 4-parameter viscoelastic model
5	FLUIDC	$\frac{lb\ sec}{in}$ $\left(\frac{N\text{-}sec}{cm}\right)$	Fluid c for bag-slap 4-parameter viscoelastic model
6	SOLIDK	$\frac{lb}{in}$ $\left(\frac{N}{cm}\right)$	Solid k for bag-slap 4-parameter viscoelastic model
7	SOLIDC	$\frac{lb\ sec}{in}$ $\left(\frac{N\text{-}sec}{cm}\right)$	Solid c for bag-slap 4-parameter viscoelastic model
8	VFACTR	-	Velocity factor
9			Switch which indicates whether specified enclosure segments (Cards 920) are allowed or disallowed for bag slap interaction with this bag: 0. if all are allowed (no 920-Cards needed), -1. if allowed are specified, 1. if disallowed are specified.

NOTE:

Field 8 (VFACTR) is reasonably from 1. to 2. VFACTR = 1. means that the leading surface of the deploying bag moves with constant velocity from "fire" time until contact; VFACTR = 2. means it moves with constant acceleration. Values between 1. and 2. indicate intermediate conditions.

NOTE:

Omit card if no slap forces are desired from this bag.

Card 919

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM ENCLOSURE SEGMENTS FOR BAG SLAP
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Enclosure segment name allowed or disallowed for bag slap interaction with this bag. See Notes and Card 919.

NOTES:

1. Cards 920 are unneeded if field 9 of Card 919 for this bag is 0 or if Card 919 for this bag is absent.

2. The enclosure segment name in fields 3 and 4 may be either one of the vehicle-interior enclosure segment names on the unnumbered cards following Card 910 or it may be an occupant body element name. Allowed entries for body element names are as follows, where "b" indicates "blank" and all names begin in column 17: HEAD, CHEST, MIDSECTION, PELVIS, UPPERbLEG, KNEE, LOWERbLEG.

3. The bag slap model may perform better if segments allowed for bag slap interaction are restricted to the body element names listed in Note 2, i.e., if no vehicle-interior enclosure segments are allowed for interaction.

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM TABLE NAMES
(6 Fields of 8)

Field	Names of Quantity	Units	Definition
1-2			Name assigned to airbag
3			Name assigned to collective V vs. A tables for this bag ($\frac{P}{T}$ is constant for each tabular curve)
4			Name assigned to table for mass influx rate vs. t
5			Name assigned to table for source gas temperatures vs. t (blank if none)
6			Name assigned to table for bag porosity vs. pressure differential (blank if none)

NOTES:

1. There must be one 921-Card for each airbag.
2. Names in fields 3-6 may be used for more than one bag.
3. Tables are entered with cards indicated:

Card 921 Field	Card for Table Entries
3	922
4	923
5	924
6	925

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM V vs. A FOR CROSS-SECTION OF BAG CONTACT
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to collective V vs. A tables for an airbag
2		$\frac{lb}{in^2 R^\circ} \left(\frac{N}{cm^2 K^\circ}\right)$	Constant P/T value for a tabular curve, V= V(A)
3		ft^2 (m^2)	Area A of cross-section of airbag in occupant plane
4		ft^3 (m^3)	Airbag volume, V

NOTES:

1. Use one card for each point on a tabular curve.

2. At least two V vs. A curves along which P/T is constant must be defined for each airbag. At least two points must be specified to define each curve (one being for A = 0.). There must therefore be at least four 922-Cards for each airbag unless the same collective V vs. A tables name (field 1) is used for more than one bag.

Card 922

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM MASS INFLUX RATE VS. TIME
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for mass influx rate vs. t for an airbag
2		msec	Time relative to "fire" time (i.e., 0. at t = TBGFR)
3	MNDOT	$\frac{lbm}{sec}$ $\left(\frac{kg}{sec}\right)$	Mass influx rate for primary-source inflation gas

NOTES:

1. Mass influx table must be defined.
2. Use one card for each point in table.

Card 923

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM SOURCE GAS TEMPERATURE VS. TIME
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for source gas temperature vs. t for an airbag
2		msec	Time relative to "fire" time (i.e., 0. at t = TBGFR)
3		°F (°C)	Source gas temperature

NOTES:

1. Omit 924-Cards if no source gas temperature table.
2. Use one card for each point in table.

Card 924

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG FABRIC POROSITY VS. PRESSURE DIFFERENTIAL
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for porosity vs. pressure differential for an airbag
2		$\frac{lb}{in^2}$ ($\frac{N}{cm^2}$)	Pressure differential
3		$ft^3/ft^2/min$ ($m^3/m^2/min$)	Porosity (volume of gas at atmospheric temperature and pressure which will pass through unit area of bag fabric in unit time)

NOTES:

1. Omit 925-Cards if no porosity table.
2. Use one card for each point in table.

Card 925

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG PROFILE CONTROLS
(5 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3			Time relative to "fire" time (i.e., 0. at t = TBGFR)
4	NPPTS		Number of points specified on bag profile
5	NREF		Point number of a reference point, counting counter-clockwise from bag attachment point = 1. (see Note 3)

NOTES:

1. At least one 926-Card must included for each airbag.

2. Point number 1 is the bag attachment point. This point (coordinates entered on the first following unnumbered card) must be at least slightly inside the enclosure (Card 910).

3. One particular material point, called the "reference point," must be present in each profile for the expanding bag. NREF should be in the range [1/4 NPPTS, 3/4 NPPTS] if possible, and as near the center as possible. Since NPPTS is not necessarily the same for each profile, NREF will not necessarily be the same either.

4. This card is followed by a block of unnumbered cards. The block consists of as many cards as necessary to give x and z coordinates of the NPPTS successive points on the bag profile (4 points, i.e., 4 coordinate pairs per card). For each bag, 926-Cards with their blocks of unnumbered cards must appear in the data deck in order of increasing time for profiles of the expanding bag.

Card 926

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG PROFILE POINTS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	x_i	in (cm)	x- and z- coordinates of points on airbag profile, relative to an axis system located at the bag attachment point and parallel to the vehicle-fixed coordinate system
2	z_i	in (cm)	
3	x_{i+1}	in (cm)	
4	z_{i+1}	in (cm)	
5	x_{i+2}	in (cm)	
6	z_{i+2}	in (cm)	
7	x_{i+3}	in (cm)	
8	z_{i+3}	in (cm)	

NOTE:

See notes on Card 926.

(follows Card 926)

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE ENCLOSURE SEGMENTS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Name of an enclosure segment which can deform (yield) in response to contact by this bag (see Note)

NOTES:

1. Omit 927-Cards if no deformations from contacts by this bag.

2. Fields 3-4 contain the name of a vehicle-interior enclosure segment. It will be the name on one of the unnumbered cards which follow Card 910.

Card 927

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE ENCLOSURE SEGMENT PROPERTIES

(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name of airbag-deformable enclosure segment (See Note 1)
3			Name assigned to tabular static force-deflection curve (See Note 2)
4	m	lbm (kg)	Effective inertial resistance (mass) of segment (greater than 0.)
5	Y	lb (N)	Bag force required to cause initial movement of segment
6	C	$\frac{\text{lb in}}{\text{sec}}$ $\left(\frac{\text{N cm}}{\text{sec}}\right)$	Viscous damping coefficient
7	G	-	G - ratio for segment displacements
8	τ	msec	Segment rebound duration time ($\neq$ 0.) from maximum displacement

NOTES:

1. Fields 1-2 must contain a vehicle-interior enclosure segment name which appears on an unnumbered card following the 910-Card . Also, see Card 927.
2. The static curve name in field 3 must be different from names appearing on 225-, 407-, 708-, and 816-Cards.
3. Omit 928-Cards for vehicle-interior enclosure segments not named on any 927-Card.

Card 928

TABLE 2 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE SEGMENT LOADING CURVE DATA
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to static curve for airbag-deformable segment (See Card 928, field 3)
2		in (cm)	Deflection
3		lb (N)	Force

NOTES:

1. Use one card for each point for tabular curve.
2. Tabular static force-deflection curve must start at (0., 0.).

Card 929

TABLE 2 INPUT DATA

CATEGORY SELECTION AND ORDERING SPECIFICATION
(Free Format, Columns 1-72)

Specifications are made by using a string of intermixed entries which are either individual listings ("a" below) or contiguous range listings ("b" below) ordered as desired.

(a) "NN," where NN is a one or two digit number in the range 0 to 55 with or without leading zeroes. The comma appears literally for punctuation.

(b) "NN-NN," where NN is as above and the hyphen appears for punctuation. The first number may be larger or smaller than the second.

NOTES

1. Blanks are ignored
2. If card 1001 and 1002 are both missing or blank, the default cards below are used.
3. If card 1001 has -1bb (b=blank) in first four columns, the default ordering is used minus printout of input data summary (category 0).
4. Cols. 1 to 72 of Card 1002 are treated as 73 to 144 of Card 1001.
5. The comma is not necessary in the last specification on the two cards.
6. See Card 1001, 1002 writeup in Section 3.2 of Volume 2.

DEFAULTS

1001	0,1,46-48,10-14,21,22,37,5,38,49,50,15,23-26,2-4,18-20,51-62,33-36,
1002	30-32,16,27-29,39,17,40,6-9,45

Cards 1001, 1002

Note -- This card layout supercedes the one for Cards 1001/1002 in Volume 2 of the MVMA 2-D CVS manuals.

METRIC/ENGLISH SYSTEM CONVERSION CONSTANTS

PHYSICAL QUANTITY	CONVERSION RELATION
Length	1 in. = 2.54 cm*
Length	1 ft. = .3048 m*
Length	39.370075 in. = 1 m
Force	1 lb. = 4.4482216 N
Mass	1 lbm = .45359237 kg*
Mass	1 lb-sec^2/in. = 175.12684 kg
Mass	1 slug = 14.593903 kg.
Moment of Inertia	1 lb-sec^2-in = 0.11298483 kg-m^2
Torque	1 lb-in = 0.11298483 N-m
Energy	1 in-lb = 0.11298483 N-m
Linear Spring Coefficient	1 lb/in. = 1.7512684 N/cm
Second Order Coefficient	1 lb/in^2 = 0.68947573 N/cm^2
Third Order Coefficient	1 lb/in^3 = 0.27144714 N/cm^3
Fourth Order Coefficient	1 lb/in^4 = 0.10686895 N/cm^4
Fifth Order Coefficient	1 lb/in^5 = 0.042074390 N/cm^5
Sixth Order Coefficient	1 lb/in^6 = 0.016564721 N/cm^6
Pressure	1 lb/in^2 = 0.68947573 N/cm^2
Pressure	1 atm. = 14.696 lb/in^2 = 1.0132535 x 10^5 N/m^2
Gas Constant	1 ft-lb/(1bm °F) = 5.38032 Joules/(kg °C)
Specific Heat	1 BTU/lb-°F = 1 kg-cal/kg-°C = 4.1868 Joules/gm-°C*
Earth Standard Gravity	1 E.S.G. = 9.80665 m/sec^2* = 32.174049 ft/sec^2 = 386.08858 in/sec^2

* Exact conversion

Table 3 . Metric/English System Conversion Constants

3.3 Description of Normal Output

There are twelve standard output categories for printout of advanced airbag system submodel results. These are categories 51 through 62 in Table 4. As with all other standard output categories, in order to obtain printout of a category the model user must set appropriate switches in the data decks for the Input and Output Processors (or default the pertinent data cards). Switches in the Input Processor data deck for advanced airbag system categories are on Cards 112 and 113; they cause results to be stored (or not stored) on a binary file for possible later printing. In the Output Processor data deck, Cards 1001 and 1002 may be used for requesting that stored results actually be printed.

Table 4 is a complete list of categories of output which may be obtained in a run of the MVMA 2-D CVS. Following Table 4 are twelve pages which illustrate the printout from each of the twelve advanced airbag system categories. Printouts of Categories 51 through 58 from an actual simulation (if requested) are repeated for each airbag included in the data set. Category 59 printout occurs once for each vehicle interior enclosure segment which is allowed to yield, or deform, in response to airbag contact. There are nine printouts of Category 60, one for each of the nine body contact-sensing line segments previously illustrated in Figure 2 and defined by the user on Cards 911 and 913 through 915. Categories 61 and 62 summarize total x- and z-component airbag forces on the occupant and therefore occur only once for each run.

As with other categories, units for airbag dimensional quantities - whether the run is with English system data or metric system data - are printed either in the category heading or in column headings. Page number and category number are generated automatically in the upper right-hand corner of each page.

Table 5 lists the twelve categories and 118 output variables together with category number and column number. This table supplements Table 114 of Volume 3.

Category Number	Description
0	Formatted Printout of Input Quantities
1	Vehicle Response
2	Real Line Region Parameters
3	Real Line Region Individual Line Segment Movement
4	Contact Forces Including Occupant-Vehicle, Occupant-Belt, Occupant-Occupant
5	Neck Reaction Forces
6	Unfiltered Body Accelerations (Head, Chest, Pelvis)
7	Filtered Body Accelerations (Head, Chest, Pelvis)
8	Unfiltered Severity Indices
9	Filtered Severity Indices
10	Body Link Angles
11	Body Link Angular Velocities
12	Body Link Angular Accelerations
13	Body Joint Coordinates
14	Body Joint Velocities
15	Body Joint Torques
16	Body Joint Absorbed Energies
17	Body Kinetic Energies
18	Airbag Variables
19	Airbag Contact Forces
20	Airbag Center of Mass Forces and Moments
21	Neck Joint Coordinates
22	Shoulder Joint Coordinates
23	Joint Torque Elastic Components
24	Joint Torque Joint-Stop Components
25	Joint Torque Friction Components
26	Joint Torque Viscosity Components
27	Joint Absorbed Energy Joint Stop Components
28	Joint Absorbed Energy Friction Components
29	Joint Absorbed Energy Viscosity Components
30	Center of Mass X-Component Forces
31	Center of Mass Z-Component Forces

Table 4 List of Output Categories

Category Number	Description
32	Center of Mass Resultant Moments
33	Steering Column Coordinates
34	Steering Column Generalized Coordinates
35	Steering Column Forces and Moments
36	Forces and Moments on Body Due to Steering Column
37	Neck and Shoulder Forces
38	Muscle Tension Forces
39	Muscle Tension Energy Absorption
40	Femur and Tibia Accelerations and Loads
41	Joint Relative Angle Comparisons Against Upper and Lower Test Values
42	Standard List of Quantities to be Compared Against Test Values
43	Individual Type A Comparisons
44	Individual Type B Comparisons
45	Printer-Plots of Stick Figures
46	Head Center-of-Gravity Motion
47	Chest Center-of-Gravity Motion
48	Hip Motion
49	Joint Relative Angles
50	Joint Relative Angle Velocities
51	Advanced Airbag System Thermodynamic Variables
52	Pressure Forces on Body (AAS*)
53	Occupant-Plane Normal Flotation Forces (AAS)
54	Occupant-Plane Tangential Flotation Forces (AAS)
55	Off-Occupant-Plane Normal Flotation Forces (AAS)
56	Off-Occupant-Plane Normal Flotation Forces (AAS)
57	Bag Slap Forces on Body (AAS)
58	Airbag Equilibrium and Contact Conditions (AAS)
59	Airbag-Deformable Segment Motions (AAS)
60	Total Bag Forces on Body (AAS)
61	Total Inertial X-Component Bag Forces (AAS)
62	Total Inertial Z-Component Bag Forces (AAS)

Table 4 List of Output Categories

*AAS = Advanced Airbag System

THERMODYNAMIC VARIABLES
FROM AIRBAG BAG #3

TIME (MSEC)	PRESSURE GAUGE (N/CM**2)	PRESSURE ABSOLUTE (N/CM**2)	GAS TEMP. (DEG C)	VOLUME NET (M**3)	VOLUME TOTAL (M**3)	GAS MASS (KG)	MASS INFLUX RATE SOURCE (KG/SEC)	MASS INFLUX RATE INTERIOR BAGS (KG/SEC)	MASS OUTFLUX RATE VENTS (KG/SEC)	MASS OUTFLUX RATE POROUS FABRIC (KG/SEC)	NET MASS INFLUX RATE (KG/SEC)	SOURCE GAS TEMP. (DEG C)
0.0	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
5.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
10.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
15.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
20.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
25.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
30.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
35.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
40.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
45.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
50.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
55.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
60.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
65.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
70.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
75.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
80.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
85.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
90.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
95.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
100.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
105.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
110.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
115.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
120.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
125.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
130.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
135.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
140.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
145.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
150.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
155.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
160.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
165.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
170.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
175.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
180.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
185.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
190.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
195.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--
200.00	---.--	---.--	----.--	---.--	---.--	--.--	----.--	----.--	----.--	----.--	-----.--	----.--

PRESSURE FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--

OCCUPANT-PLANE FLOTATION FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3
[NORMAL COMPONENT]

	HEAD				PELVIS		UPPER		LOWER
TIME	UPPER	LOWER	CHEST	MIDSECTION	UPPER	LOWER	LEG	KNEE	LEG
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--

OCCUPANT-PLANE FLOTATION FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3
[TANGENTIAL COMPONENT]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--

OFF-OCCUPANT-PLANE FLOTATION FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3
[NORMAL COMPONENT]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--

OFF-OCCUPANT-PLANE FLOTATION FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3
[TANGENTIAL COMPONENT]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--

SLAP FORCES (N)
ON BODY CONTACT SEGMENTS
FROM AIRBAG BAG #3
[NORMAL COMPONENT]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG	RATIO OF FLUID COMPONENT TO TOTAL SLAP FORCE
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	-.---

EQUILIBRIUM AND CONTACT CONDITIONS
FOR AIRBAG BAG #3

TIME (MSEC)	SUM OF INERTIAL FORCES ON OCCUPANT X (N)	Z (N)	MOMENT IMBALANCE (N M)	REF. ANGLE (DEG)	ATTACH.PT. IN VEH.COORD. X (CM)	Z (CM)	AREA IN OCCUP. PLANE (M**2)	CONTACT WIDTH ACROSS VEH.FRONT (CM)	OCCUP.(AVG.) (CM)	NO.SEG. CONTACTED OCCUP.	VEH.INT.	NO.SEG. IN BAG PROFILE
0.0	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
5.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
10.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
15.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
20.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
25.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
30.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
35.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
40.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
45.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
50.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
55.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
60.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
65.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
70.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
75.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
80.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
85.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
90.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
95.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
100.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
105.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
110.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
115.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
120.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
125.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
130.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
135.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
140.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
145.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
150.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
155.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
160.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
165.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
170.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
175.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
180.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
185.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
190.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
195.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---
200.00	------.--	------.--	------.-	----.-	----.--	----.--	--.---	---.--	---.--	---	---	---

FORCES ON AND MOTIONS OF
VEHICLE-INTERIOR ENCLOSURE SEGMENT WINDSHIELD
DUE TO AIRBAG CONTACTS

TIME (MSEC)	TOTAL FORCE FROM ALL AIRBAGS (N)	TOTAL YIELD DISPLACEMENT (CM)	YIELD MOTION VELOCITY (CM/SEC)	RESISTANCE TO YIELD MOTION STATIC-FORCE (N)	VELOCITY-DEPEND. (N)	INERTIAL (N)
0.0	------.--	---.--	----.--	------.--	------.--	------.--
5.00	------.--	---.--	----.--	------.--	------.--	------.--
10.00	------.--	---.--	----.--	------.--	------.--	------.--
15.00	------.--	---.--	----.--	------.--	------.--	------.--
20.00	------.--	---.--	----.--	------.--	------.--	------.--
25.00	------.--	---.--	----.--	------.--	------.--	------.--
30.00	------.--	---.--	----.--	------.--	------.--	------.--
35.00	------.--	---.--	----.--	------.--	------.--	------.--
40.00	------.--	---.--	----.--	------.--	------.--	------.--
45.00	------.--	---.--	----.--	------.--	------.--	------.--
50.00	------.--	---.--	----.--	------.--	------.--	------.--
55.00	------.--	---.--	----.--	------.--	------.--	------.--
60.00	------.--	---.--	----.--	------.--	------.--	------.--
65.00	------.--	---.--	----.--	------.--	------.--	------.--
70.00	------.--	---.--	----.--	------.--	------.--	------.--
75.00	------.--	---.--	----.--	------.--	------.--	------.--
80.00	------.--	---.--	----.--	------.--	------.--	------.--
85.00	------.--	---.--	----.--	------.--	------.--	------.--
90.00	------.--	---.--	----.--	------.--	------.--	------.--
95.00	------.--	---.--	----.--	------.--	------.--	------.--
100.00	------.--	---.--	----.--	------.--	------.--	------.--
105.00	------.--	---.--	----.--	------.--	------.--	------.--
110.00	------.--	---.--	----.--	------.--	------.--	------.--
115.00	------.--	---.--	----.--	------.--	------.--	------.--
120.00	------.--	---.--	----.--	------.--	------.--	------.--
125.00	------.--	---.--	----.--	------.--	------.--	------.--
130.00	------.--	---.--	----.--	------.--	------.--	------.--
135.00	------.--	---.--	----.--	------.--	------.--	------.--
140.00	------.--	---.--	----.--	------.--	------.--	------.--
145.00	------.--	---.--	----.--	------.--	------.--	------.--
150.00	------.--	---.--	----.--	------.--	------.--	------.--
155.00	------.--	---.--	----.--	------.--	------.--	------.--
160.00	------.--	---.--	----.--	------.--	------.--	------.--
165.00	------.--	---.--	----.--	------.--	------.--	------.--
170.00	------.--	---.--	----.--	------.--	------.--	------.--
175.00	------.--	---.--	----.--	------.--	------.--	------.--
180.00	------.--	---.--	----.--	------.--	------.--	------.--
185.00	------.--	---.--	----.--	------.--	------.--	------.--
190.00	------.--	---.--	----.--	------.--	------.--	------.--
195.00	------.--	---.--	----.--	------.--	------.--	------.--
200.00	------.--	---.--	----.--	------.--	------.--	------.--

TOTAL AIRBAG FORCES (N)
ON BODY CONTACT SEGMENT UPPER LEG

TIME	PRESSURE FORCE	FLOTATION FORCE (NORMAL) OCCUP-PLANE	FLOTATION FORCE (NORMAL) OFF-OCCUP-PLANE	SLAP FORCE	FLOTATION FORCE (TANGENTIAL) OCCUP-PLANE	FLOTATION FORCE (TANGENTIAL) OFF-OCCUP-PLANE	TOTAL FORCE NORMAL	TOTAL FORCE TANGENTIAL	CONTACT LINE ANGLE (DEG)	BODY LINK ANGLE (DEG)	NO. BAGS IN CONTACT
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	----.-	----.-	--

TOTAL AIRBAG FORCES (N)
ON BODY CONTACT SEGMENTS
[INERTIAL X-COMPONENTS]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG	TOT.FORCE ON OCCUP.	NO.BAGS CONTACTING OCCUP.
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---

TOTAL AIRBAG FORCES (N)
ON BODY CONTACT SEGMENTS
[INERTIAL Z-COMPONENTS]

TIME	HEAD UPPER	HEAD LOWER	CHEST	MIDSECTION	PELVIS UPPER	PELVIS LOWER	UPPER LEG	KNEE	LOWER LEG	TOT. FORCE ON OCCUP.	NO. BAGS CONTACTING OCCUP.
0.0	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
5.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
10.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
15.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
20.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
25.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
30.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
35.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
40.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
45.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
50.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
55.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
60.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
65.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
70.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
75.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
80.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
85.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
90.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
95.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
100.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
105.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
110.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
115.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
120.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
125.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
130.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
135.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
140.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
145.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
150.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
155.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
160.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
165.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
170.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
175.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
180.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
185.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
190.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
195.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---
200.00	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	------.--	---

TABLE 5 .* OUTPUT VARIABLES AND THEIR SPECIFICATIONS

QUANTITY DESCRIPTION		CATG. NO.	COL. NO.
Airbag thermodynamics	- gauge pressure	51	1
	- absolute pressure	51	2
	- gas temperature	51	3
	- net volume	51	4
	- total volume	51	5
	- gas mass	51	6
	- mass influx rate from source	51	7
	- mass influx rate from internal bags	51	8
	- mass outflux rate through vents	51	9
	- mass outflux rate through porous fabric	51	10
	- net mass influx	51	11
	- source gas temperature	51	12
Pressure forces	- on upper head segment	52	1
	- on lower head segment	52	2
	- on chest	52	3
	- on midsection	52	4
	- on upper pelvis segment	52	5
	- on lower pelvis segment	52	6
	- on upper leg segment	52	7
	- on knee	52	8
	- on lower leg segment	52	9
Occupant-plane normal flotation forces -			
	- on upper head segment	53	1
	- on lower head segment	53	2
	- on chest	53	3
	- on midsection	53	4
	- on upper pelvis segment	53	5
	- on lower pelvis segment	53	6
	- on upper leg segment	53	7
	- on knee	53	8
	- on lower leg segment	53	9
Occupant-plane tangential flotation forces-			
	- on upper head segment	54	1
	- on lower head segment	54	2
	- on chest	54	3
	- on midsection	54	4
	- on upper pelvis segment	54	5
	- on lower pelvis segment	54	6
	- on upper leg segment	54	7
	- on knee	54	8
	- on lower leg segment	54	9

* This table supplements Table 114 of Volume 3.

TABLE 5 . OUTPUT VARIABLES AND THEIR SPECIFICATIONS (continued)

QUANTITY DESCRIPTION		CATG. NO.	COL. NO.
Off-occupant-plane normal flotation forces -			
	- on upper head segment	55	1
	- on lower head segment	55	2
	- on chest	55	3
	- on midsection	55	4
	- on upper pelvis segment	55	5
	- on lower pelvis segment	55	6
	- on upper leg segment	55	7
	- on knee	55	8
	- on lower leg segment	55	9
Off-occupant-plane tangential flotation forces -			
	- on upper head segment	56	1
	- on lower head segment	56	2
	- on chest	56	3
	- on midsection	56	4
	- on upper pelvis segment	56	5
	- on lower pelvis segment	56	6
	- on upper leg segment	56	7
	- on knee	56	8
	- on lower leg segment	56	9
Bag slap forces	- on upper head segment	57	1
	- on lower head segment	57	2
	- on chest	57	3
	- on midsection	57	4
	- on upper pelvis segment	57	5
	- on lower pelvis segment	57	6
	- on upper leg	57	7
	- on knee	57	8
	- on lower leg	57	9
	- ratio of fluid component to total bag slap force	57	10
Airbag equilibrium and contact conditions -			
	- sum of inertial x-forces on occupant	58	1
	- sum of inertial z-forces on occupant	58	2
	- moment imbalance on airbag	58	3
	- airbag reference angle	58	4
	- attachment point x	58	5
	- attachment point z	58	6
	- cross-sectioned area in occupant plane	58	7
	- contact width across front of vehicle	58	8
	- average contact width across occupant	58	9
	- no. of occupant segments contacted	58	10
	- no. of vehicle interior segments contacted	58	11
	- no. of segments in airbag profile	58	12

TABLE 5. OUTPUT VARIABLES AND THEIR SPECIFICATIONS (continued)

QUANTITY DESCRIPTION	CATG. NO.	COL. NO.
Airbag-deformable segment motions -		
- total force on segment	59	1
- total yield displacement	59	2
- yield motion velocity	59	3
- static force resistance	59	4
- velocity-dependent resistance	59	5
- inertia resistance to yield motion	59	6
Total bag forces on body contact segment -		
- total pressure force	60	1
- total occupant-plane normal flotation force	60	2
- total off-occupant-plane normal flotation force	60	3
- total slap force	60	4
- total occupant-plane tangential flotation force	60	5
- total off-occupant-plane tangential flotation force	60	6
- total normal force	60	7
- total headward tangential force	60	8
- occupant contact segment angle in vehicle frame	60	9
- link angle for contact segment	60	10
- number of airbags in contact with segment	60	11
Total inertial x-component bag forces -		
- on upper head segment	61	1
- on lower head segment	61	2
- on chest	61	3
- on midsection	61	4
- on upper pelvis segment	61	5
- on lower pelvis segment	61	6
- on upper leg	61	7
- on knee	61	8
- on lower leg	61	9
- on occupant, total	61	10
- number of bags in contact with occupant	61	11
Total inertial z-component bag forces -		
- on upper head segment	62	1
- on lower head segment	62	2
- on chest	62	3
- on midsection	62	4
- on upper pelvis segment	62	5
- on lower pelvis segment	62	6
- on upper leg	62	7
- on knee	62	8
- on lower leg	62	9
- on occupant, total	62	10
- number of bags in contact with occupant	62	11

4.0 DETAILED PROGRAM INFORMATION -- A PROGRAMMER'S GUIDE

This section supplements Volume 3 of the report manuals [7]. Volume 3 describes the computer model in detail. The program (for Version 3) is organized into three separate processors which are run successively. These are called, respectively, the Input Processor, the Execution Processor, and the Output Processor. For convenience, they are referred to by the names IN, GO, AND OUT.* Communication between the processors is through use of four external files or data sets. Volume 3 describes each processor in terms of program organization and flow, auxiliary program output, organization of storage for program variables, and binary output formats. The same type of information is included in this section relative to the Advanced Airbag System Submodel routines.

With regard to program organization and flow, there are two types of tables and one figure for each of the three processors. The figure is a flow diagram.** In the case of IN, the figure is a complete flow diagram for the processor. In the cases of GO and OUT, however, the flow diagram does not describe the entire flow beginning with the main program. For example, for GO (Figure 32) the illustrated flow branches from subroutines DAUX and ADVBAG since, although many Version 3 subroutines have modifications relating to the Advanced Airbag System submodel, all new routines occur after DAUX in the flow. The flow diagrams for GO and OUT should be used together with the flow diagram(s) in Volume 3. The

*Version 4 has five processors, which include IN, GO, and OUT, and also an Input Pre-Processor (INP) and an Output Pre-Processor (OUTP). INP and IN of Version 4 together perform all functions of IN of Version 3 and OUTP plus OUT correspond to OUT of Version 3.

**Flow diagrams: Figures 31, 32, and 33 for IN, GO, and OUT.

first of the tables mentioned for each processor describes the organization and function of each subroutine separately. These tables have the titles "Subprogram Specifications and Appearances" (for IN, GO, and OUT).* For each subprogram, there is a description of its function, a list of common blocks occurring, lists of subprograms called by and calling the subprogram, and references to tables which describe auxiliary output from the subprogram. A second table, titled "Labeled Common Descriptions," lists all common block names occurring in the processor, describes their content, and indicates the subprograms which use each common.**

With regard to auxiliary program output, there is a table for each processor which describes WARNING and FATAL ERROR messages which can be printed out. These tables are titled "'Appended' Error Messages" (from IN, GO, and OUT).*** Error messages in these tables are identified by EAn, where n is an integer, and references to these identifiers are included in the "Subprogram Specifications" tables.**** These tables do not include all error messages which could result from an advanced airbag system simulation with the MVMA 2-D model. None of the error

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*Subprogram Specifications and Appearances: Tables 6, 33, and 54 for IN, GO, and OUT.

**Labeled Common Descriptions: Tables 7, 34, and 55 for IN, GO, and OUT.

***"Appended" Error Messages: Tables 32, 53, and 56 for IN, GO, and OUT.

****Debug printout relative to the Advanced Airbag System Submodel is available only from Subroutine PROFLE. The debug block numbers are DB145 through DB165, as indicated by Table 33, and they include printout for three levels of detail. Debug switch number 4 is used to obtain this printout. This manual does not include tables corresponding to Tables 90 through 94 in Volume 3, which describe the debug printout.

messages which can be printed by Version 4, and are therefore in an error message table in Volume 3, are repeated here. These tables are therefore to be used together with those in Volume 3. There are two types of error messages occurring here: 1) ones relating to the Advanced Airbag System and 2) ones which are present in Version 3 but are absent in Version 4 and will therefore not be found in Volume 3.

Storage for program variables for the Advanced Airbag System Submodel is organized similarly to storage for the rest of the model. That is, most storage is "packed" into large integer and real arrays, with location information for different types of quantities being kept in multi-level dictionaries in the integer arrays. The manner in which this is done is fully explained in Volume 3; here, only the packing tables relating to Advanced Airbag System Submodel storage for IN, GO, and OUT are included.* These tables, together with some indicating how array dimensions are established, are presented in the following without further comment.

Binary output formats are described by Tables 30 and 31. Table 30, "Indexed Binary Output Data Set on Logical Device NU from IN," replaces Table 47 in Volume 3. Table 31, "Binary Record Lengths for Categories," replaces Table 48 in Volume 3.

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*One modification to Version 3/Version 4 packing not mentioned outside of this footnote is the addition of an entry 23 to the STOMAT section of Table 70. It is: "Global permanent deformation." It is used by Subroutine COLAPS.

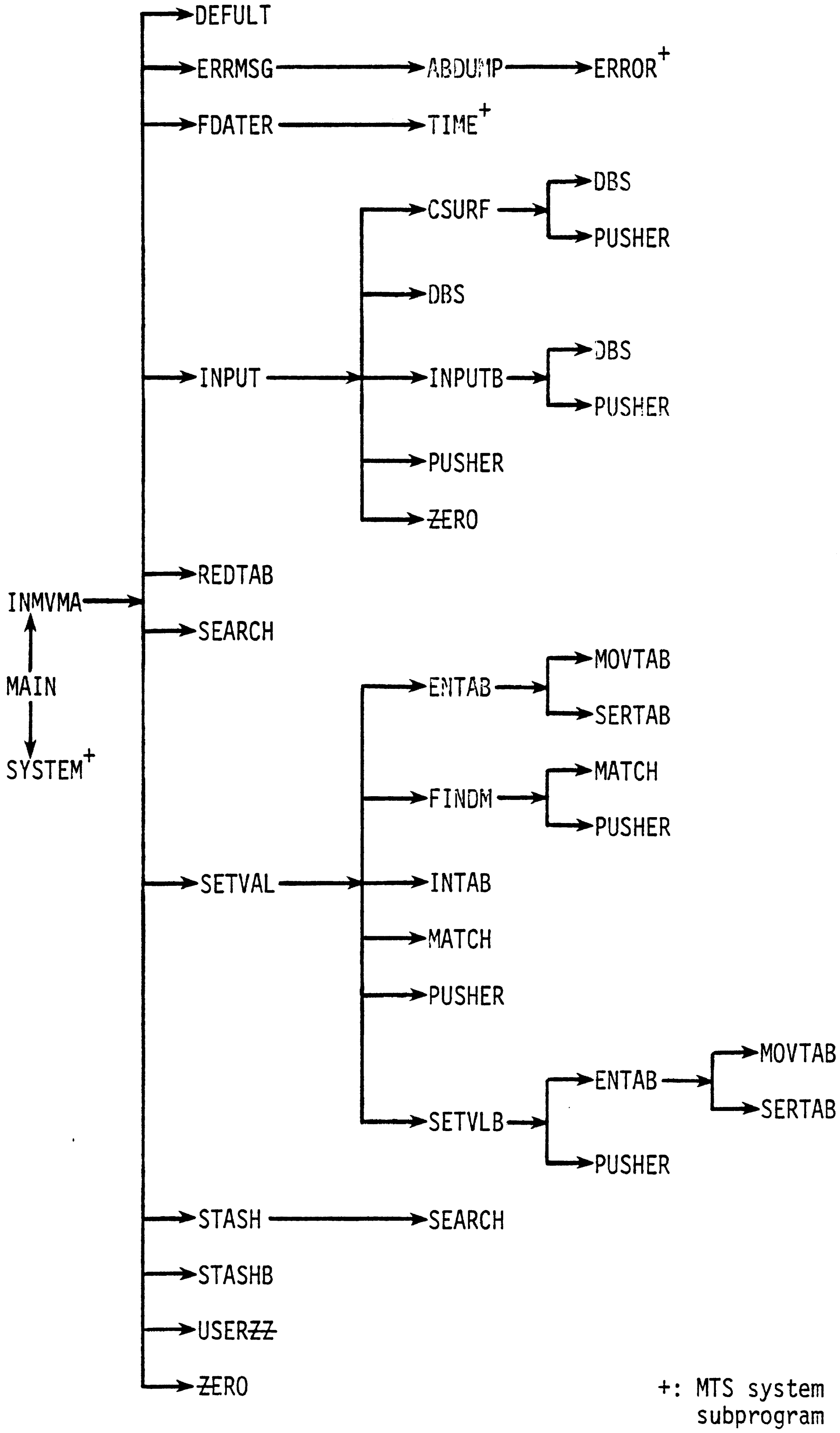

Figure 31. Calling Structure for the Input Processor (IN)

Table 6. Subprogram Specifications and Appearances for IN

Number[1]	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called[2]	Subprograms Calling	Special Output[3]
1	ABDUMP	Error return to system.	NONE	ERROR+	ERRMSG	NONE
2	BLKDTA	Predefines input data card default values.	PACK	NONE	NONE	NONE
3	CSURF	Packs information on individual material property cards into preliminary binary tables.	DATA NAMES PACK	DBS PUSHER	INPUT	NONE
4	DBS	Converts information in A-format into binary format for arithmetic use.	DUM	LAND+ SIOC+	CSURF,INPUT, INPUTB	EA1
5	DEFULT	Checks inputted information and supplies specified values for missing cards.	BAGMD PACKB DATA REST DUM SRH NAMES TAB PACK TABLES	NONE	INMVMA	NONE
6	ENTAB	Enters a single new point into a table.	TAB ZERR	MOVTAB SERTAB MAXO ABS,IABS	SETVAL SETVLB	E1 -E2
7	ERRMSG	Prints most of fatal error comments made for this model.	NONE	ABDUMP	INMVMA	E3 -E10 EA2 -EA3

[1] (n) - subprogram not occurring in Version 4

[2] cccccc+ - MTS system subprogram (routine may require modification by local user)

[3] En - error message from IN (Version 4, Table 51)
EAn - error message from IN ("Appended" Table)
EPn - error message from INP (Version 4, Table 23)

Table 6. Subprogram Specification and Appearances for IN (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
8	FDATER	Obtains month, day, year, and time of current run.	NONE	TIME+	INMVMA	NONE
9	FINDM	Find or fill in material property storage given a name of a material.	PACK	MATCH PUSHER	SETVAL	NONE
10	INMVMA	Controls initialization, reading input, and writing binary file.	BAGMD DATA DUM NAMES NAMESB PACK PACKB REST SRH TAB TABLES ZERR ZR	DEFULT ERRMSG FDATER INPUT REDTAB SEARCH SETVAL STASH STASHB USERZZ ZERO ABS AINT AMAX1 MOD	MAIN	E11 -E17 EA4
11	INPUT	Reads input data deck and controls input packing for later recovery.	BAGMD DATA NAMES PACK PACKB REST TABLES	CSURF DBS INPUTB PUSHER ZERO	INMVMA	EP1 E20 EA5
(12)	INPUTB	Performs same function as INPUT for advanced airbag system cards (112, 113, and 910-929).	DATA NAMESB PACKB	DBS PUSHER ABS	INPUT	NONE
13	INTAB	Sort tables into order and then compute slope and intercept for each of the linear segments of each table.	TAB	IABS	SETVAL	NONE

Table 6. Subprogram Specification and Appearances for IN (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
14	MAIN	Calls INMVMA and returns to system.	NONE	INMVMA, SYSTEM+	NONE	NONE
15	MATCH	Match inputted name against names stored and return location if match is found.	NAMES PACK	NONE	FINDM SETVAL	NONE
16	MOVTAB	Move table entries around to make room for a new table entry.	TAB	IABS ISIGN	ENTAB	E19
17	PUSHER	Adjusts stored indices to compensate for a new entry added in the middle of the packing table.	PACK PACKB	NONE	CSURF FINDM INPUT INPUTB SETVAL SETVLB	E29
(18)	REDTAB	Initialize all tables to zero and set size parameters.	TAB	NONE	INMVMA	NONE
19	SEARCH	Determines beginning and ending record number for next binary output record.	SRH	MAXO	INMVMA STASH	E30
20	SERTAB	Searches for the table entry corresponding to a particular argument in tables.	TAB	ABS AMOD IABS ISIGN	ENTAB	NONE
21	SETVAL	Set input values into the appropriate places for execution and recover input information from input packing and carry out final packing execution.	DATA REST NAMES TAB PACK ZERR PACKB	ENTAB FINDM INTAB MATCH PUSHER SETVLB ABS AMAX1	INMVMA	E31 -E35 E37

Table 6. Subprogram Specification and Appearances for IN (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
(22)	SETVLB	Performs same function as SETVAL for advanced airbag system packing arrays.	BAGMD DATA NAMES NAMESB PACK PACKB TAB ZERR	ENTAB PUSHER	SETVAL	EA6 -EA31
23	STASH	Handles the writing of tables which require multiple records.	SRH	SEARCH	INMVMA	E40
(24)	STASHB	Performs same function as STASH for advanced airbag system tables with multiple records.	NONE	MINO	INMVMA	EA32
25	USERZZ	Returns job name in EBCD.	NONE	NONE	INMVMA	NONE
26	ZERO	Sets zero into a number of consecutive locations.	NONE	NONE	INMVMA INPUT	NONE

TABLE 7. LABELED COMMON DESCRIPTIONS FOR IN

Number	Common Name	Subprograms Which Use	Description
1	BAGMD	DEFULT, INMVMA, INPUT, SETVLB	Temporary storage.
2	DATA	CSURF, DEFULT, INMVMA, INPUT, INPUTB, SETVAL, SETVLB	Temporary storage for input quantities until put in their proper place.
3	DUM	DBS, DEFULT, INMVMA	Temporary storage.
4	NAMES	CSURF, DEFULT, INMVMA, INPUT, MATCH, SETVAL, SETVLB	Title storage and number of ellipses, regions, and line segments.
5	NAMESB	INMVMA, INPUTB, SETVLB	Airbag names.
6	PACK	BLKDTA, CSURF, DEFULT, FINDM, INMVMA, INPUT, MATCH, PUSHER, SETVAL, SETVLB	Storage for packing arrays and their lengths.
7	PACKB	DEFULT, INMVMA, INPUT, INPUTB, PUSHER, SETVAL, SETVLB	Storage for airbag packing arrays and their lengths.
8	REST	DEFULT, INMVMA, INPUT, SETVAL	Control information used in packing and unpacking of various tables.
9	SRH	DEFULT, INMVMA, SEARCH, STASH	Binary output file writing controls.
10	TAB	DEFULT, ENTAB, INMVMA, INTAB, MOVTAB, REDTAB, SERTAB, SETVAL, SETVLB.	Table lengths and parameters.
11	TABLES	DEFULT, INMVMA, INPUT	Vehicle acceleration table points.
12	ZERR	ENTAB, INMVMA, SETVAL, SETVLB	Error switch.
13	ZR	INMVMA, SETVAL	Joint stop activity indices.

TABLE 8. ARRAY DIMENSION SYMBOLS FOR "IN"

Symbol	Description	Current Estimate
NBAGS	Number of airbags.	5
NENCV	Number of vehicle interior enclosure segments.	15
A	Number of points in V vs. A tabular curves, total for all bags.	200
B	Number of bag profiles, total for all bags and all times.	100
C	Number of points in bag profiles, total for all bags and all times.	2000
M	Number of points in mass influx rate tables, total.	100
P	Number of points in porosity tables, total.	50
S	Number of segments allowed and disallowed for bag slap, total.	50
T	Number of points in source gas temperature tables, total.	50
V	Number of deflation vents, total.	15
X	Number of allowed interactions for yielding enclosure segments, total.	25
Y	Number of enclosure segments which can yield to airbag forces.	10
Z	Number of points in static force curves for yielding enclosure segments	100

TABLE 9. ARRAY DIMENSION RELATIONSHIPS FOR "IN"

Number	Dimension Relationship	Array Name	Length Name	Length Value
1	4(NENCV+2NBAGS-1) + 2V + 7NBAGS + 4(S+2NBAGS) + 5A + 4(M+T+P) + 3B + 2C + 4X + 11Y + 4Z	STOACB	LENSCB	7111
2	6(19NBAGS-3+V+S+A+M+T+P+B+X+Y+Z)	KACB	LENKCB	4320

TABLE 10. THE STANDARD AREA FOR INPUT STORAGE IN THE KACB ARRAY

Index	Description
1-15	Total number of entries (cards) of code i in KACB (k_i, i = 1,...,15)

(Note: The STANDARD AREA is followed by GENERAL KACB ENTRIES in blocks of 4, occurring in whatever order the data cards occur.)

TABLE 11. THE TYPICAL GENERAL KACB ENTRY FOR INPUT STORAGE

Relative Index	Description
1 (IKB)	Code for STOACB entry (ICODE) 1 if enclosure segment name entry, length = 4*NENCV 2 if airbag constants entry, length = 6 3 if interior bag entry, length = 4 4 if deflation vent entry, length = 2 5 if bag slap entry, length = 7 6 if enclosure segment allowed/dis-allowed entry, length = 4 7 if table names entry, length = 8 8 if V vs. A table entry, length = 5 9 if mass influx rate table entry, length = 4 10 if source gas temperature table entry, length = 4 11 if porosity table entry, length = 4 12 if profile information entry, length = 2*NPPTS + 3 13 if deformable-segment name entry, length = 4 14 if deformable-segment information entry, length = 11 15 if deformable-segment static force table entry, length = 4
2	Beginning index in STOACB (IA)
3	Airbag name number (beginning index in KBAGNM) if code = 2 - 7, 12, or 13; 0 otherwise (IBAGNM)
4	Card identification number (NO)

TABLE 12. THE TYPICAL ENTRY FOR INPUT STORAGE IN THE KACB ARRAY

Relative Index	Description
1 (JKB) to k_1	Code 1 STOACB beginning indices
$k_1 + 1$ to $k_1 + k_2$	Code 2 STOACB beginning indices
$1 + k_1 + k_2$ to $\sum_{i=1}^{3} k_i$	Code 3 STOACB beginning indices
⋮	⋮
$1 + \sum_{i=1}^{14} k_i$ to $\sum_{i=1}^{15} k_i$	Code 15 STOACB beginning indices

Note: k_i = KACB(i) = total number of cards of code i in data deck. In SETVLB, during processing for codes 1, 8, 9, 10, 11, 14, and 15, the entire entry for the code is used since these codes do not relate to a specific bag. During processing for codes 2-7, 12, and 13, which relate to a specific bag, the available space indicated above for the code is only partially filled for processing for each bag whenever the data deck includes specifications for more than one bag.

TABLE 13. THE TYPICAL ENCLOSURE SEGMENT NAME ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-4	First enclosure segment name (16)	(following 910-card)
5-8	Second enclosure segment name (16)	
.	.	
.	.	
.	.	
.	.	
.	.	
4-NENCV-3 to 4 NENCV	NENCV-th enclosure segment name (16)	

Note: Code 1 entry, unnumbered cards following Card 910.

TABLE 14. THE TYPICAL AIRBAG CONSTANTS ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1	WBAG	916-3
2	SURFACE	916-4
3	TBGFR	916-5
4	Constant source gas temperature	916-6
5	Bag equilibrium adjustment parameter	916-7
6	No. of segments away from bag #1 attachment, pos. counterclockwise	916-8

Note: Code 2 entry, for airbag; card 916.

TABLE 15. THE TYPICAL INTERIOR BAG ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-4	Name of airbag immediately inside (16)	917-3,4

Note: Code 3 entry, for airbag; card 917.

TABLE 16. THE TYPICAL DEFLATION VENT ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1	Deflation vent area	918-3
2	Burst pressure differential	918-4

Note: Code 4 entry, for airbag; card 918.

TABLE 17. THE TYPICAL BAG SLAP ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1	BMASS	919-3
2	FLUIDK	919-4
3	FLUIDC	919-5
4	SOLIDK	919-6
5	SOLIDC	919-7
6	VFACTR	919-8
7	Enclosure segment inhibition switch	919-9

Note: Code 5 entry, for airbag; Card 919.

TABLE 18. THE TYPICAL ENCLOSURE SEGMENT ALLOWED/DISALLOWED ENTRY FOR BAG SLAP IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-4	Name of enclosure segment allowed or disallowed for bag slap interaction (16)	920-3,4

Note: Code 6 entry, for airbag; card 920.

TABLE 19. THE TYPICAL TABLE NAMES ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name for collective V vs. A tables (8)	921-3
3-4	Name for mass influx rate vs. t table (8)	921-4
5-6	Name for source gas temperature vs. t table (8)	921-5
7-8	Name for bag porosity vs. pressure differential table (8)	921-6

Note: Code 7 entry, for airbag; Card 921.

TABLE 20. THE TYPICAL V VS. A TABLE ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name for collective V vs. A tables (8)	922-1
3	P/T	922-2
4	Area A (or table no. in SETVLB)	922-3
5	Volume V	922-4

Note: Code 8 entry, Card 922.

TABLE 21. THE TYPICAL MASS INFLUX RATE TABLE ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name of mass influx rate table (8)	923-1
3	Time	923-2
4	MNDOT	923-3

Note: Code 9 entry, Card 923.

TABLE 22. THE TYPICAL SOURCE GAS TEMPERATURE TABLE ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name of source gas temperature table (8)	924-1
3	Time	924-2
4	Temperature	924-3

Note: Code 10 entry, Card 924.

TABLE 23. THE TYPICAL POROSITY TABLE ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name of porosity table (8)	925-1
3	Pressure differential	925-2
4	Porosity	925-3

Note: Code 11 entry, Card 925.

TABLE 24. THE TYPICAL PROFILE INFORMATION ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1	Time	926-3
2	Number of points defining bag profile (NPPTS)	926-4
3	NREF	926-5
4	$X_1 = X_A$	(following card 926)
5	$Ƶ_1 = Ƶ_A$	
6	X_2	
7	$Ƶ_2$	
.	.	
.	.	
.	.	
.	.	
.	.	
2 NPPTS + 2	X_{NPPTS}	
2 NPPTS + 3	$Ƶ_{NPPTS}$	

Note: Code 12 entry, for airbag; card 926 and following unnumbered cards.

TABLE 25. THE TYPICAL DEFORMABLE-SEGMENT NAME ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-4	Name of enclosure segment which can deform in response to bag contact (16)	927-3,4

Note: Code 13 entry, for airbag; Card 927.

TABLE 26. THE TYPICAL DEFORMABLE-SEGMENT INFORMATION ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-4	Name of airbag-deformable enclosure segment (16)	928-1,2
5-6	Name of tabular static force-deflection curve (8)	928-3
7	m	928-4
8	Y	928-5
9	c	928-6
10	G	928-7
11	τ	928-8

Note: Code 14 entry, Card 928.

TABLE 27. THE TYPICAL DEFORMABLE-SEGMENT STATIC FORCE TABLE ENTRY IN STOACB FOR INPUT

Relative Index	Description	MVMA Input Card
1-2	Name of static force table (8)	929-1
3	Deflection	929-2
4	Force	929-3

Note: Code 15 entry, Card 929.

TABLE 28. DESCRIPTION OF DATAB(I,K) IN "IN"

K	I	Unused Columns	MVMA Card Fields
1	1-3	4-9	910,1-3
2	1-7	8-9	911,1-7
3	1-9		912,1-9
4	1-8	9	913,1-8
5	1-8	9	914,1-8
6	1-4	5-9	915,1-4
7	1-9		112,1-9
8	1-3	4-9	113,1-3

Note: Complements Table 16 in Volume 3 of MVMA 2-D CVS manuals.

TABLE 29. DESCRIPTION OF IFAULT(K) IN "IN" FOR ADVANCED AIRBAG SYSTEM CARDS

K	MVMA CARDS
86	910
87	911
88	912
89	913
90	914
91	915
92	112
93	113

Note: Supplements Table 17 in Volume 3 of MVMA 2-D CVS manuals.

TABLE 30.* INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU FROM IN

Record Number**	Contents
INSX + 1	NBELT, (1,2) NBAG, (2,2) NELLS NLINES NREGNS NTIMES NACTUL NINTAC ICBEG(1) . . . . ICBEG(12)
INSX + 2	ICBEG (13) . . . . ICBEG(32) NOTE: ICBEG(1) and (5) - (40): Beginning record number of category (γ_{n-1}) ICBEG(2): Logical device number for sequential accel. output (MU) ICBEG(3): Logical device number for direct access interaction output (MV) ICBEG(4): Beginning record number of INTACT table 1-4 is set negative if corresponding category not wanted; 5-40 is set 0 if corresponding category not wanted.
INSX + 3	HTITLE(1) . . . HTITLE(18) TTITLE(1) TTITLE(2)
INSX + 4	STITLE(1) . . . STITLE(20)
INSX + 5	STITLE(21) . . . STITLE(35) TTITLE(3) . . . TTITLE(7) Note: TTITLE(1)-(3): Date TTITLE(4)-(5): Time TTITLE(6)-(7): Job Name
INSX + 6	ICBEG(33) . . . ICBEG(40) MTIMES KPTIMS TB(5,1) TF (6,1) DT (7,1) PTINC (8,1) PLINC (9,1) NSTCOL (3,2) MKSSWT IUSEM IUSEK IPREP
INSX + 7	LHIB,(4,2) KHIB,(5,2) ILL,(6,2) EPSINV,(8,2) MX,(9,2) DSTEPX,(1,3) DSTEPN,(2,3) FORLIM,(3,3) HARDCN,(4,3) LIMCNT,(5,3) TPC,(6,3) EPSFAC,(7,3) BETELP,(8,3) GAMELP,(9,3) NUMTAB LIMTAB NUMENT LIMENT LENMAT LENKON
INSX + 8	EDEPS,(4,1) XH,(1,22) XHD,(2,22) ZH,(3,22) ZHD,(4,22) ELN,(5,22) ELND,(6,22) XS,(1,21) XSD,(2, 21) ZS,(3, 21) ZSD,(4,21) THETA(1-9),(1-9,20)
INSX + 9	XV,(1,24) XVD,(2,28) ZV,(3,24) ZVD,(4,24) THV,(5,24) THVD,(6,24) AA,(7,24) C,(8,24) VM, (9,24) THDI(1-9), (1-9,46) AH,(1,19) AC,(2,19)
INSX + 10	HEAD(1-3), (2-4,38) FLJI(2-8), (1-7,6) ASH, (8,6) FLI(1-8), (1-8,7) NP
INSX + 11	AMUS(1-11,1),(1,48-58) FMI(1-8), (1-8,8) EM9, (9,8)

*Note: This table replaces Table 47 in Volume 3 of MVMA 2-D CVS manuals.

**Note: INSX = 0.

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number	Contents
INSX + 12	AMUS(1-11, 2), (2,48-58) FI(1-8), (1-8,9) ALF, (9,7)
INSX + 13	AMUS(1-11,3), (3,48-58) THROI(1-8), (1-8,18) BSH, (9,6)
INSX + 14	TMUS(1-11)(4,48-58) NPTS(1-3) NSTART(1-3) INTOP, (2,1) NNOACC FNU,(7,2)
INSX + 15	KJI(1-12,1), (1, 10-17; 42-45) KJI(1-8,2) (2,10-17)
INSX + 16	KJI(9-12,2), (2,42-45) KJI(1-12,3), (3,10-17; 42-45) CJI(1-4), (4,10-13)
INSX + 17	CJI(5-12), (4,14-17; 42-45) FJI(1-12), (5,10-17;42-45)
INSX + 18	VJI(1-12), (6,10-17;42-45) RJI(1-8), (9,10-17)
INSX + 19	RJI(9-12), (9,42-45) THSI(1-12,1), (7,10-17; 42-45) THSI(1-4,2), (8,10-13)
INSX + 20	THSI(5-12,2), (8,14-17; 42-45) G, (3,1) MUSNAM (3,1-11)
INSX + 21	CMU(1-5,1-4,1) or STOACT (6-25)
INSX + 22	CMU(1-5,5-8,1) or STOACT (26-45)
INSX + 23	CMU(1-5,9-10,1) and CMU(1-5,1-2,2) or STOACT(46-65)
INSX + 24	CMU(1-5,2-6,2) or STOACT(66-85)
INSX + 25	CMU(1-5,7-10,2) or STOACT(86-105)
INSX + 26	CMU(1-5,1-4,3) or STOACT (106-125)
INSX + 27	CMU(1-5,5-8,3) or STOACT(126-145)
INSX + 28	CMU(1-5,9-10,3) or STOACT(146-155) THEX(1-8), (1;3;5;7,4-5) HEX(1), (2,4) EYE9, (9,9)
INSX + 29	HEX(2-8), (2;4;6;8,5) / (4;6;8,4) LEAD(1-12): a_A a_B a_C a_D a_E a_F a_G a_H a_I $\alpha+1$ $\beta+1$ $\gamma+1$ LACCEL
INSX + 30	KONSIS KTABSW(1-3) NUMACC HIC(1-2) KJI(13,1), (1,61) KJI(13,2), (2,61) KJI(13,3), (8,61) CJI(13) (9,61), NCR, FEMSOR, NBAGS (16 long) ICBEG(61), ICBEG(62)
INSX + 31	HICTA(1-2) HICTB(1-2) TMADC(1-16)
INSX + 32	{MUSNAM (3, 12-13) / NFORCE(1-2)}, JFORCE, AF, CF, MJOINT(1-11), AHH, CONDYL, TRAD(9,18) (18 long)
INSX + 33	ICBEG(41)...ICBEG(60)

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number	Contents
	if NBELT = 1 or 2
NCR	XVAI(1-4), (1;3;5;7,23) ZVAI(1-4), (2;4;6;8,23) CSIB1, (4,19) ZETAB1, (5,19) CSIB2,(6,19) ZETAB2, (7,19) CSIB3, (8,19) ZETAB3, (9,19) LBLO, (1,25) DELBL, (2,25) LBTUO, (3,25) DELBTU, (4,25) FBLMAX, (5,25) FBTMAX, (6,25) (Real)
NCR+1	LBTLO, (5,26) DELBTL, (6,26) LBTLA, (7,26) MUR, (8,25) DELTB, (7,25)
	if NBELT = 3
NCR	(((ATTANC (I,K,J), K=1,2), I = 1,2), J = 1,5), (1-4,47-51)
NCR+1	(((ATTANC (I,K,J), K = 1,2), I = 1,2), J = 6,7), (5-8,52-53) SLAK(1-7), (9,47-53) INFLNC, (5,54) MBELT, (6,54) LBTLA, (7,54) YSEP(1-2), (8-9,54)
NCR+2	IPRMT(2-3), (5-6,55) REPS, (7,55) XEPS(1-2), (8-9,55) 2 Spec. Switches (1,59) (2,59) BMUK, (5,56) BMUS, (6,56) ZINFL (7,56) INF(1,2) (8,56) RFSAT, (9,56) AFSAT, (1,60) PERCNT, (2,60) ANCHOR(1-4), (5-8,57) RING(1-2), (9,57), (7,60)
NCR+3	RINGMU(1-2), (8-9,60) REEL(1-3), (5,58), (9,25), (1,38) TLOCK(1-3), (6,58), (1,26), (5,38) ALOCK(1-3), if webbing - (9,62), (9,26), (9,38); if vehicle (7,58), (2,26), (6,38) PLOCK(1-3), (8,58), (3,26), (7,38) VLOCK(1-3), (9,58), (4,26), (8,38) KSA(1-3)
NCR+4	SETFLG(1-2,1-7) KSA(4-7) BFLAG(1-2)

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number	Contents
NOTE:	if NBELT = { 0 then a_A = NCR; 1 or 2 then a_A = NCR+2; 3 then a_A = NCR+5 } NCR currently set to INSX + 34
L1 a_A <u>if steering column</u>	SCMU(4,3), (4,30), (7,59), (4,60), (4,61), (5,30), (8,59), (5,60), (5,61), (6,30), (9,59), (6,60), (6,61) SZETA(1-4) (2,4,6,8;62) SCSI(1-4),(1,3,5,7;62)
a_A +1	HTX11(1-20)
a_A +2	HX11I(1-20)
a_A +3	MATLSC(1-11) SZETAI(1-3), (6,59), (3,60), (3,61) HL, (1,27) HLD, (2,27), HAL1, (3,27) SCENTZ, (4,59)
a_A +4	HALID, (4,27) HAL2, (5,27) HAL2D, (6,27) HH, (7,27) HHD, (8,27) HA(1,28) HRW(2,28) HLOC(3,28) HL1(4,28) HH1(5,28) HS1(6,28) HS2, (7,28) HS5, (8,28) HI1, (1,29) HI2, (2,29) HM1, (3,29) HM2, (4,29) RHOI(1-2), (3,30), (5,59) SCENTX, (3,59)

NOTE: if steering column, $a_B = a_A+5$; if not, $a_B = a_A$

L2 <u>if simple airbag</u>	a_B	INIT, (1,31) BAGANG, (2,31) BAGWTH, (3,31) ERRTOL, (4,31) CNTMAX, (5,31) BAGPER, (6,31) BRSTPR, (7,31) AREADM, (8,31) BGXCOR, (9,31) BGZCOR, (1,32) GASTMP, (2,32) HDWTH, (3,32) SHDWTH, (4,32) TORWTH, (5,32) HIPWTH, (6,32) THIWTH, (7,32) BFRIMP, (8,32) TBGFR, (9,32) RX, (1,33) PEX, (2,33)
	a_B+1	CSI(1-10), (1,3,5,7;39-41) ZETAI(1-10), (2,4,6,8;39-41)-- Note: only 1st two used for 41.
	a_B+2	BTIM(1-20)
	a_B+3	MDOT(1-20)
	a_B+4	TTIM(1-20)
	a_B+5	TEMPS(1-20)
	a_B+6	DELTAP(1-20)
	a_B+7	PERM(1-20)
	a_B+8	GAMMB, (3,33) TAU, (4,33) CP,(5,33) SPSI, (6,33) RHEAD, (7,33) IDPT, (1-2,1-6)

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number	Contents
L2 a_B if advanced airbag	NBAGS, (1,1) NENCV, (2,1) NABOVE, (3,1) RGAS, (1,2) MOLEWT, (2,2) GAMMG, (3,2) CPG, (4,2) PATM, (5,2) TATM, (6,2) RHEADG, (7,2) PEPS, (1,3) EPSM, (2,3) EP1, (3,3) EP2, (4,3) EP3, (5,3) EP4, (6,3) DMIN, (7,3) ITPMAX, (8,3) ITMMAX, (9,3)
a_B+1	(CSI(I),ZETAI(I),I=1,4), (1-8,4) (CSI(J),ZETAI(J),J=5,8), (1-8,5) (CSI(K),ZETAI(K),K=9,10), (1-4,6)
a_B+2	IUSEKG, IUSESG, IUSEKC
$a_{B1} = a_B + 3 + [\frac{IUSEKG + 19}{20}]$ $a_B + 3$ to $a_{B1} - 1$	KBAG( ) 20 to a line
$a_{B2} = a_{B1} + [\frac{IUSESG + 19}{20}]$ a_{B1} to $a_{B2} - 1$	STOBAG( ) 20 to a line
$a_{B3} = a_{B2} + [\frac{IUSEKC + 19}{20}]$ a_{B2} to $a_{B3} - 1$	KENC( ) 20 to a line
$a_{B4} = a_{B3} + [\frac{NBAGS + 1}{2}]$ a_{B3} to $a_{B4} - 1$	Airbag names, KBAGNM (8,20), 2 names to a line

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number		Contents
NOTE:	simple airbag if advanced airbag, neither	$a_C = $ $a_B + 9$ a_{B4} a_B
L3	$a_D = a_C + \left[\frac{IUSEK + 19}{20}\right]$ Records a_C to $a_D - 1$	KCON( ) 20 to a line
L4	$a_E = a_D + \left[\frac{IUSEM + 19}{20}\right]$ Records a_D to $a_E - 1$	STOMAT( ) 20 to a line
L5	$a_F = a_E + \left[\frac{NUMTAB + 4}{5}\right]$ Records a_E to $a_F - 1$	MSTOR(,4) 5 to a line stored on rows

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

Record Number	Contents	
L6 $a_G = a_F + \left[\frac{NUMENT + 19}{5}\right]$ Records a_F to $a_G - 1$	STOR( )	20 to a line
L7 $a_H = a_G + \left[\frac{2 * ITS + 9}{10}\right]$ Records a_G to $a_H - 1$	all TACC( ),then all ACC( )	20 to a line
L8 $a_I = a_H + \left[\frac{NUMTAB + 9}{10}\right]$ Records a_H to $a_I - 1$	NAMTAB (,2) stored on rows	10 to a line
L9 $\alpha = a_I + \left[\frac{NELLS+1}{2}\right]$ Records a_I to $\alpha - 1$	: Ellipse names [KELLNM(8,27) or ELLNAM(8,27)]:	Ellipse A Material A Ellipse B Material B
L10 $\beta = \alpha + \left[\frac{NLINES+4}{5}\right]$ Records α to $\beta - 1$	: Contact line names [KCONAM(4,50)or CONNAM(4,50)]:	Line A Line B Line C Line D Line E
L11 $\gamma = \beta + \left[\frac{NREGNS+1}{2}\right]$ Records β to $\gamma - 1$	: Region names [KREGNM(8,27) or REGNAM(8,27)]:	Region A Material A Region B Material B
L12 $\gamma_0 = \gamma + \left[\frac{NREGNS+3}{4}\right]$ Records γ to $\gamma_0 - 1$	: KREGNS(5,27): Region A Region B Region C Region D	

TABLE 30. INDEXED BINARY OUTPUT DATA SET ON LOGICAL DEVICE NUMBER NU (continued)

	Record Number	Contents
I1	$\gamma_1=\gamma_0$+NTIMES: Records γ_0 to γ_1-1	Entry for category 1 (NTIMES long) [n=1]
I5 to 140 and I46 to I50	$\gamma_n=\gamma_{n-1}$+NTIMES: Records γ_{n-1} to γ_n-1	Entries are possible for categories 5-40 and 46-50 (each NTIMES long).*
I51 to I58	$\gamma_n=\gamma_{n-1}$ +NTIMES*NBAGS Records γ_{n-1} to γ_n-1	Entries are possible for categories 51-58 (each containing NTIMES time points for each of NBAGS airbags in turn.*
I59	$\gamma_n=\gamma_{n-1}$ +NTIMES*KBAG(2) Records γ_{n-1} to γ_n-1	Entry is possible for category 59 containing NTIMES time points for each of KBAG(2) yielding vehicle segments.*
I60	$\gamma_n=\gamma_{n-1}$+9*NTIMES Records γ_{n-1} to γ_n-1	Entry is possible for category 60 containing NTIMES time points for each of 9 body airbag contact segments.*
I61 to I62	$\gamma_n=\gamma_{n-1}$+NTIMES Records γ_{n-1} to γ_n-1	Entries are possible for categories 61 and 62 containing NTIMES time points.*
14	p = n_{max}+1: Records γ_p to γ_p + NINTAC	INTACT table (NINTAC entries)

* n is incremented for each category actually entered.

TABLE 31.* BINARY RECORD LENGTHS FOR OUTPUT CATEGORIES

Category	Record Length
1	10
2	9
3	12
4	1-12 E-L=14 (12 are printed); 13-23 E-E=11; 24-31 8 = 8
5	10
6	9
7	9
8	12
9	12
10	10
11	10
12	10
13	10
14	10
15	9
16	11
17	5
18	7
19	10
20	15
21	10
22	10
23	8
24	8
25	8
26	8
27	9
28	8
29	10
30	9
31	9
32	9
33	12
34	8
35	12

Category	Record Length
36	12
37	10
38	11
39	11
40	7 (5 are printed)
46	9
47	6
48	6
49	8
50	8
51	12
52	9
53	9
54	9
55	9
56	9
57	10
58	12
59	6
60	11
61	11
62	11

Category 4 is special case

Printed Columns	Binary record word position
1	1
2	13
3	2
4	14
5	3
6	4
7	5
8	6
9	7
10	8
11	9
12	10

Category 40 is special case

Printed Columns	Binary record word position
1	7
2	1
3	2
4	5
5	4

*Note: This table replaces Table 48 in Volume 3 of MVMA 2-D CVS manuals.

TABLE 32. "APPENDED" ERROR MESSAGES FOR IN

Number	Message	Condition and Action Required	Subroutine
EA1	INPUT PUNCHING ERROR: VALUE(1) VALUE(2) ERR.POST=ZZZZZZZZ ERR.TYPE=ZZZZZZZZ DS PICT BEG.COL.=XXX CONTL.WORD=ZZZZZZZZ DV(1...2) DV(3...4) ... DV(17...18) /1/AAAAAAAA/9/AAAAAAAA/17/.../65/AAAAAAAA	Correct bad character and rerun.	DBS
EA2	FATAL ERROR--KBAGNM SIZE EXCEEDED (MORE THAN 20 BAGS)	Reduce number of airbags in system.	ERRMSG
EA3	FATAL ERROR--THERE MUST BE NENCV UNNUMBERED CARDS FOLLOWING 910-CARD (NENCV=FIELD 2)	Self-explanatory.	ERRMSG
EA4	FATAL ERROR--TEST EPSILONS AND ITERATION LIMITS ON CARD 912 MUST ALL BE GREATER THAN ZERO.	Self-explanatory.	INMVMA
EA5	NUMBER OF (TIME, DECEL) PAIRS > MAXIMUM ALLOWED, EXCESS PAIRS DELETED	Use maximum of 200 points in each vehicle acceleration time history.	INPUT
EA6	FATAL ERROR--THERE ARE SPECIFICATIONS NBAGS FOR XX AIRBAGS IN THE DATA SET BUT CARD 910 INDICATES THAT THERE SHOULD I BE XX AIRBAGS.	Self-explanatory.	SETVLB
EA7	FATAL ERROR--NUMBER OF VEHICLE INTERIOR ENCLOSURE SEGMENTS ABOVE BAG #1 ATTACHMENT NABOVE IS XXX. IT MUST BE GREATER THAN ZERO. SEE CARD 910.	Self-explanatory.	SETVLB

TABLE 32. "APPENDED" ERROR MESSAGES FOR IN (continued)

Number	Message	Condition and Action Required	Subroutine
EA8	FATAL ERROR--THERE MUST BE EXACTLY ONE 910-CARD.	Self-explanatory.	SETVLB
EA9	FATAL ERROR--EACH AIRBAG MUST BE ASSIGNED V VS. A CURVES FOR AT LEAST TWO DIFFERENT P/T CONSTANTS, EACH CURVE WITH AT LEAST TWO POINTS.	Self-explanatory.	SETVLB
EA10	FATAL ERROR--A MASS INFLUX RATE CURVE WITH AT LEAST TWO POINTS MUST BE PRESCRIBED WITH 923-CARDS FOR EACH AIRBAG.	Self-explanatory.	SETVLB
EA11	FATAL ERROR--THERE ARE NO STATIC FORCE TABLE ENTRIES (CARDS 929) FOR THE SPECIFIED DEFORMABLE ENCLOSURE SEGMENTS (CARDS 928).	Self-explanatory.	SETVLB
EA12	FATAL ERROR--ILLEGAL VEHICLE INTERIOR ENCLOSURE (CONTACT) SEGMENT NAME ON UNNUMBERED CARD FOLLOWING 910-CARD.	Self-explanatory.	SETVLB
EA13	FATAL ERROR--P/T RATIOS FOR VOL. VS. AREA CURVES MUST BE POSITIVE. TABLE table name IS FLAGGED (CARD 922).	Self-explanatory.	SETVLB
EA14	FATAL ERROR--NAME OF AN AIRBAG-DEFORMABLE ENCLOSURE SEGMENT ON 928-CARD (segment name) DOES NOT MATCH ANY OF THE NAMES ON UNNUMBERED CARDS FOLLOWING 910-CARD.	Self-explanatory.	SETVLB
EA15	FATAL ERROR--NAME OF STATIC CURVE (curve name) ON 928-CARD DOES NOT MATCH ANY NAME FOR WHICH SPECIFICATIONS ARE MADE ON 929-CARD.	Self-explanatory.	SETVLB
EA16	FATAL ERROR--THERE MUST BE EXACTLY ONE K XXX-CARD FOR THE AIRBAG NAMED bag name	Self-explanatory.	SETVLB

TABLE 32. "APPENDED" ERROR MESSAGES FOR IN (continued)

Number	Message	Condition and Action Required	Subroutine
EA17	FATAL ERROR--TIME HISTORY PROFILES FOR AIRBAG NAMED bag name MUST BE PRESCRIBED USING 926-CARDS.	Self-explanatory.	SETVLB
EA18	FATAL ERROR--TABLE NAME table name ON A 921-CARD FOR MASS INFLUX RATE (*1*), SOURCE GAS TEMPERATURE (*2*), OR BAG POROSITY (*3*) HAS NO ASSOCIATED 923-, 924-, 925-CARDS WITH KC SPECIFICATIONS. ----- (*X*)	Self-explanatory.	SETVLB
EA19	FATAL ERROR--LOOP STORING P/T IN TEMPS ( ) FAILS, PROBABLE LOGIC ERROR IN SETVLB. list of 7 values	Examine code in SETVLB.	SETVLB
EA20	WARNING--NO SOURCE TEMPERATURE VS. TIME TABLE HAS BEEN SPECIFIED FOR AIRBAG bag name AND THE DEFAULT CONSTANT SOURCE GAS TEMPERATURE ON CARD 916 IS ZERO.	Self-explanatory.	SETVLB
EA21	WARNING--THERE ARE NO DATA SPECIFICATIONS ALLOWING DEFLATION-VENT OR POROUS-FABRIC VENTING OF GAS FROM AIRBAG bag name.	Self-explanatory.	SETVLB
EA22	WARNING--THE DATA DECK INCLUDES 927-CARDS FOR DEFORMABLE ENCLOSURE SEGMENTS FOR AIRBAG bag name BUT DOES NOT INCLUDE 928-CARDS WITH SPECIFICATIONS FOR ALL DEFORMABLE SEGMENTS. THE AFFECTED 927-CARDS ARE IGNORED.	Self-explanatory.	SETVLB
EA23	KBD WARNING--FOR AIRBAG bag name THERE ARE XX 927-CARDS FOR DEFORMABLE SEGMENTS, BUT K1 ONLY XX OF THESE ARE LEGAL.	Self-explanatory.	SETVLB

TABLE 32. "APPENDED" ERROR MESSAGES FOR IN

Number	Message	Condition and Action Required	Subroutine
EA24	FATAL ERROR--PROBABLE LOGIC ERROR IN SETVLB. MORE DEFORMABLE VEHICLE INTERIOR SEGMENTS HAVE BEEN IDENTIFIED FOR AIRBAG bag name THAN ARE INCLUDED IN THE DATA DECK AS 927-CARDS.	Self-explanatory.	SETVLB
EA25	WARNING--THE DATA DECK INCLUDES 927-CARDS FOR DEFORMABLE ENCLOSURE SEGMENTS BUT DOES NOT INCLUDE 928-CARDS WITH SPECIFICATIONS. THE 927-CARDS ARE IGNORED.	Self-explanatory.	SETVLB
EA26	FATAL ERROR--AIRBAG NO. 1 (bag name) IS INSIDE ANOTHER BAG (bag name). SEE NOTE FOR CARD 910.	Self-explanatory.	SETVLB
EA27	FATAL ERROR--AN AIRBAG OF NAME bag name IS INDICATED BY A 917-CARD TO BE INSIDE THE AIRBAG NAMED bag name. ONE OF THESE NAMES IS MISSPELLED ON A 916- OR 917-CARD, OR A 916-CARD IS MISSING.	Self-explanatory.	SETVLB
EA28	FATAL ERROR--SEGMENT NAME segment name ON 920-CARD FOR AIRBAG bag name IS ILLEGAL. SEE NOTES ON CARD (920).	Self-explanatory.	SETVLB
EA29	FATAL ERROR--PROBABLE LOGIC ERROR IN SETVLB FOR CODE 6. NUMBER OF SLAP FORCE ENTRIES LL IN KBAG (=XX) NOT EQUAL TO ABS. VAL. OF NSLAP (NSLAP=XXX).	Self-explanatory.	SETVLB
EA30	FATAL ERROR--PROBABLE LOGIC ERROR IN SETVLB FOR CODE 6. SEGMENT JKC=XXXX FOR BAG SLAP NOT IN JKC LIST IN STANDARD AREA OF KENC.	Self-explanatory.	SETVLB

TABLE 32. "APPENDED" ERROR MESSAGES FOR IN

Number	Message	Condition and Action Required	Subroutine
EA31	FATAL ERROR--THERE IS A NESTING OF BAGS MORE THAN FIVE DEEP. THE KBAG BEGINNING INDICES OF THE FIRST FIVE ARE list of 5 values.	Self-explanatory.	SETVLB
EA32	WARNING--VARIABLE POSITION SECTION PARAMETERS INCONSISTENT--- NCR MCR CUR REC NO RANGE=XXXXXXXXXXXX, NVALS NO. VALUES=XXXXX, NVALPL NO. VALUES PER LINE=XXXXX, NUMR NO. OF RECORDS=XXXXX, I LAST RECORD NO. WRITTEN=XXXXXX, JA JB VAL IND RANGE CUR LINE=XXXXXXXXXXXX	Warning. The LEAD array has not been set up correctly or has been stored over. Program error or machine error.	STASHB

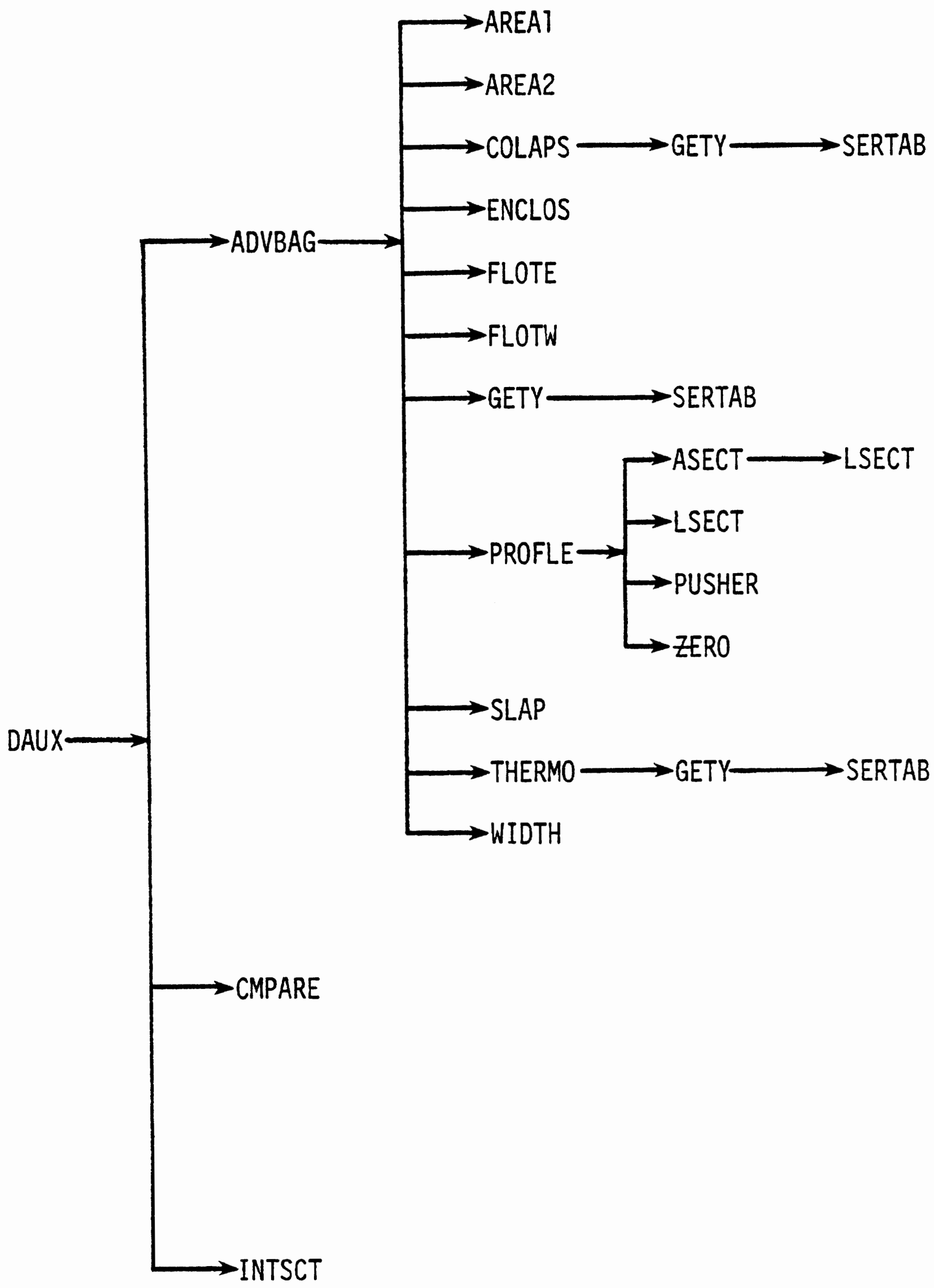

Figure 32. "Appended" Flow for GO

Table 33. Subprogram Specifications and Appearances for GO

Number[1]	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called[2]	Subprograms Calling	Special Output[3]
1	ABDUMP	Makes error return to system with dump.	NONE	ERROR+	EVAL GOMVMA	NONE
2	ABINIT	Determines location of surfaces that can be sensed by airbag. Initializes various constants. Solves gas thermodynamics equations. Reads airbag data from binary tables.	ABAG ARBAG ARBGCM BAGMD CKOUT DBGPTR DJN INTEG IOCNTL MSCON OCCC PACK QV THETA	ABS ATAN2 COS SIN SQRT	AIRBAG	NONE

[1] (n) - subprogram not occurring in Version 4

[2] cccccc+ - MTS system subprogram (routine may require modification by local user)
cccccc* - entry point name

[3] DBn - debug output
En - error message (Version 4, Table 95)
EAn - error message ("Appended" Table)

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
(3)	ADVBAG	Controls the program flow for the advanced airbag system and performs several specific functions of its own, including: A) pressure-volume iteration; B) iterative adjustment of bag position for equilibrium; C) determination of generalized forces; D) determination of movement of vehicle interior segments in response to bag forces. ADVBAG is called only if t is greater than the minimum "fire" time for all airbags.	ADVB CKOUT GAS INTEG ITER PACK QB QV THETA	AREA1 AREA2 COLAPS ENCLOS FLOTE FLOTW GETY PROFLE SLAP THERMO WIDTH ABS SIGN	DAUX	EA1 -EA4
4	AIRBAG	Controls inflatable occupant restraint system submodel flow. Calls BGSHAP if bag is neither full nor in contact with occupant. Calls STFP and VOLCLC if bag is both full and in contact, calls STFV if bag contacts occupant but is not full.	ARBAG ARBGCM CKOUT DBGPTR DJN INTEG IOCNTL MSCON	ABINIT BGSHAP DBUG LSECT STFP STFV VOLCLC COS SIN SQRT	DAUX	NONE
(5)	AREA1	Determines area of a polygon (uncontacted bag)	PACK	NONE	ADVBAG	NONE
(6)	AREA2	Determines area of a closed contour of straight-line segments and circular arcs (contacted bag).	PACK	SIN	ADVBAG	NONE
(7)	ASECT	Determines intersections between straight-line segment and circular arc.	EPSLON PACK	LSECT SQRT	PROFLE	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
8	BELT	Determine belt anchor and reference point coordinates and velocities. Determine forces and moments due to lap belt. Determine geometry and deflection of torso belt straps. Determine forces and moments due to upper torso belt straps. Determine forces and moments due to lower torso belt.	BELTA BELTB BELTC CKOUT INTEG IOCNTL MSCON OCCA OCCD OCCE PACK THETA	LODFEL SETACT AMAX1 ATAN2 COS SIN SQRT	DAUX	DB76 -DB83 DB96 E2 -E4
9	BELT2	Determines belt tensions and generalized forces for Advanced Belt System (see Volume 3).	BELTB BP BQQ BRI BRIP CKOUT INTEG LF MSCON PACK QV THETA	LODFEL RELAX SETACT ABS ATAN2 COS IABS SIGN SIN SQRT	DAUX	DB115 -DB136 E6 EA5
10	BGSHAP	Determines coordinates of 120 points at three degree increments on the circular periphery of the expanding airbag before contact by the occupant.	ARBGCM DBGPTR	ATAN2 COS SIN SQRT	AIRBAG	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
11	BKDATA	Run initialization routine. Sets critical quantities to initialize values.	ABAG ARBAG ARBGCM BAGMD BELTA BELTB BQ CKOUT DBGPTR DJN FORCE INTEG IOCNTL MATRX MSCON NAMES NAMESB OCCF PACK QV STRCOL TABLES	SIN ZERO	GOMVMA	NONE
12	CAVITY	Determines cavity coefficients for the area of contact between an ellipse and a line segment.	CAV	AMAX1 AMIN1 SQRT	MULTI	NONE
(13)	CMPARE	Determines equality or inequality to within an "epsilon."	NONE	ABS	DAUX	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
14	CNTACT	Determines normal and tangential components of force between an ellipse and a contacted line and also generalized forces (see Volume 3).	BQ CART CKOUT CON DUM IOCNTL IT MSCON PACK QQ QV SHDEFL TABLES THETA ZOUT	ELLELL LODFEL MIG MULTI NAMET SETACT SETMIG ABS AMIN1 ATAN2 COS IABS SIGN SIN SQRT	DAUX	DB39 -DB51 DB54 -DB62 DB70 -DB75 E8-E10
(15)	COLAPS	Determines the positions of contact segments which move in response to bag forces.	CKOUT PACK	GETY	ADVBAG	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons		Subprograms Called	Subprograms Calling	Special Output
16	DAUX	Determines generalized accelerations.	ARBAG BELTB BELTC BP BQ BQQ BRI BRIP CART CKOUT DUM FORCE INTEG IT IOCNTL KON MATRX	MSCON OCCD PACK QQ QV STRCOL TABLES THETA THETAP ZOUT ZQB	ADVBAG AIRBAG BELT BELT2 CMPARE CNTACT DEBUG INTSCT JTORQ MATRIX OCCGEO SMSOL STEER COS ABS SIN SQRT	PINT	DB29 -DB32 EA6
17	DBUG	Prints all airbag debug information, always in English system units, if IBUG(4) = 3.	ARBAG ARBGCM CKOUT DBGPTR DJN	NONE		AIRBAG	DB144

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
18	DEBUG	Unpacks hexadecimal control words into sixteen debug switches.	NONE	LAND+ SHFTR+	DAUX GOMVMA	NONE
19	EFFDEF	Determines effective deflection against a trapezoidal cavity.	CAV	NONE	MULTI	NONE
20	ELLELL	Determines forces between contacting ellipses and also generalized forces (see Volume 3).	BQ CKOUT DUM IT PACK QQ QV ZOUT	LODFEL SETACT ABS ATAN2 COS IABS ISIGN SIN SQRT	CNTACT	DB63 -DB69
(21)	ENCLOS	Establishes the geometry of the Advanced Airbag System "enclosure."	ABAG CART CKOUT OCCC PACK QV THETA	NONE	ADVBAG	NONE
22	EOM	Solves equations of motion of steering assembly.	CKOUT INTEG IT MSCON STRCOL	SMSOL	STEER	DB112

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
23	ERRMSG	Prints most of fatal error comments made for this model.	CKOUT DUM	NAMET FLOAT IABS	GOMVMA	E11 -E28
24	EVAL	Compute the force produced given the material properties, deflection and deflection rate for a single interaction.	CKOUT DUM IOCNTL LC LF LP MSCON PACK	ABDUMP GETY NAMET SLOPE ABS AMAX1 AMIN1	LODFEL	DB36 -DB38 DB94 E29 -E33
25	EXTIME	Returns elapsed CPU time after an initiating call.	NONE	NONE	GOMVMA	NONE
(26)	FLOTE	Determines "end" components of flotation forces.	NONE	NONE	ADVBAG	NONE
(27)	FLOTW	Determines "width" components of flotation forces.	ADVB GAS PACK	ATAN2	ADVBAG	EA7
28	FLS	Determines airbag shape and forces on the occupant if the bag is both full and in contact with the occupant.	ABAG ARBAG ARBGCM DBGPTR IOCNTL OCCC QV THETAP	LSECT ATAN2 COS SIN SQRT	STFP STFV	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
29	FMFP	Determines local minimum of a function and corresponding independent variable values.	NONE	ABS AMAX1 SQRT	RELAX	NONE
30	FORCE1	Compute the reaction forces of steering assembly.	CKOUT	LODFEL SETACT ABS SIGN	REACT	E34
31	GETY	Determine correct piecewise linear interval for current abscissa in table and interpolate to current ordinate.	TAB	SERTAB ABS IABS	ADVBAG COLAPS EVAL JTORQ MATRIX THERMO	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
32	GOMVMA	Controls overall solution of the simulation problem.	ARBAG CKOUT INTEG MSCON ZQB	ABDUMP BKDATA DEBUG ERRMSG EXTIME INIT OUTPUT PINT PLTR READIN REPACK UPDATE UPDITL* ABS	MAIN	DB22 -DB25 E35 -E36
33	HDX11	Determines the position and velocity of steering column gear box from a time dependent table.	CKOUT STRCOL TABLES	NONE	STEER	DB114
34	INFL	Determine influence coefficients for x-force or z-force balance at ring. These are the two partial derivatives (for x and z) of $F_k(x)=0$.	BRI BRIP CKOUT PACK	NONE	ZMIN	DB142

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons		Subprograms Called	Subprograms Calling	Special Output
35	INIT	Put input quantities into units needed for execution of model.	ABAG ADVB ARBAG ARBGCM BAGMD BELTA BELTC BP BRI BRIP CON EL EPSLON GAS INTEG IOCNTL ITER JOINT	LD MATRX MSCON MUSCLE NECKON OCCA OCCB OCCC OCCE OCCF PACK STRCOL TAB TABLES THETA ZP ZQ ZR	ABS ATAN2 COS SIGN SIN SQRT	GOMVMA	NONE
36	INTSCT	Accepts center points and radii of two circles as input and returns intersection points.	NONE		SQRT	DAUX	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
37	JTORQ	Compute torques due to body joints.	CKOUT EL INTEG IOCNTL JOINT MUSCLE SHOLDR	GETY LODFEL SETACT SLOPE ABS AMAX1 AMIN1 SIGN	DAUX	DB33 -DB35
38	LODFEL	Carry out the unpacking of material properties for an interaction and manage the shared deflection iteration if any.	BRIP CKOUT IOCNTL LC LD LF LP PACK SHDEFL	EVAL ABS AMAX1 AMIN1 IABS SIGN	BELT BELT2 CNTACT ELLELL FORCE1 JTORQ RSDUAL SFORCE	DB88 -DB91
39	LSECT	Determines intersection, if any, of two line segments.	EPSLON	NONE	AIRBAG ASECT FLS PROFLE STFP	NONE
40	MAIN	Calls GOMVMA and returns to system. Generated by IN with appropriate dimensions.	NONE	GOMVMA SYSTEM+	NONE	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
41	MATRIX	Calculate coefficient matrix and right-hand side vector for system of 14 differential equations.	BELTB BQ BQQ CKOUT DUM FORCE INTEG IOCNTL JOINT MATRX MSCON MUSCLE NECKON OCCA QB QV SHOLDR THETA ZOUT ZP	GETY	DAUX	DB26 DB143
42	MIG	Establishes displaced positions of vehicle interior segments that are allowed to respond to occupant contact forces (see Volume 3).	CART CKOUT IT PACK TABLES	SMSOL ATAN2 COS SIGN SIN	CNTACT	DB9 -DB21 E37
43	MULTI	Directs flow for determination of cavities in line segment contacted by more than one ellipse.	CAV CKOUT	CAVITY EFFDEF ABS AMAX1 AMIN1	CNTACT	DB1 -DB8
44	NAMET	Obtain the name of a material, region, or segment given the KCON beginning index for the corresponding entry.	NAMES PACK	NONE	CNTACT ERRMSG EVAL	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons		Subprograms Called	Subprograms Calling	Special Output
45	OCCGEO	Calculates joint positions, belt reference points, CG positions, rotation matrices, and lever arm factors.	CKOUT DUM INTEG IOCNTL MSCON NECKON OCCA	OCCB OCCC OCCD OCCE QV SHOLDR THETA	ATAN2 SQRT	DAUX	DB27 -DB28 DB93
46	OUTPUT	Write the binary files on logical device numbers seven, eight, and nine for current computed quantities.	ARBAG ARBGCM BELTA CKOUT DBGPTR DJN DUM FORCE INTEG IOCNTL JOINT KON	MSCON NAMES NECKF OCCC OCCF OCCG PACK SHOLDR STRCOL THETA ZP	AINT IABS	GOMVMA	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
(47)	PICKUB	Performs the same function as PICKUP, for advanced airbag system data.	NONE	MINO	READIN	EA8
48	PICKUP	Reads a table from the binary data set on 'NU' which requires multiple records.	IOCNTL	SEARCH	READIN	E38
49	PINT	Solves a system of real ordinary differential equations of the first order using a Runge-Kutta fourth-order method.	CKOUT	DAUX ABS AMAX1 AMIN1 SIGN	GOMVMA	NONE
50	PLTR	Writes a record on binary data set on 'NP' containing plotting quantities.	ARBGCM BRIP CKOUT INTEG IOCNTL MSCON OCCC OCCD PACK QV STRCOL THETA	NONE	GOMVMA	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
(51)	PROFLE	Determines whether user-prescribed airbag profile contacts enclosure, and if so, determines the shape of the cross-section of the bag in the occupant plane as a closed contour of straight-line segments and circular arcs.	CKOUT EPSLON PACK	ASECT LSECT PUSHER ZERO ABS ATAN2 COS IABS SIN SQRT	ADVBAG	DB145 -DB165 EA9 -EA14
52	PULLER	Adjusts stored indices to compensate for an entry removed in the middle of the packing tables.	PACK	NONE	REPACK SETMIG	NONE
53	PUSHER	Adjusts stored indices to compensate for a new entry added in the middle of the packing table.	CKOUT PACK	IABS ISIGN	PROFLE SETACT SETMIG	DB95
54	REACT	Sets the final reaction forces for the steering assembly.	CKOUT INTEG MSCON STRCOL STRO	FORCE1 ABS SQRT	STEER	DB113

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons		Subprograms Called	Subprograms Calling	Special Output
55	READIN	Controls the reading of the input data in binary form produced by "IN".	ABAG ADVB ARBAG BAGMD BELTA BELTC BP BRI BRIP CKOUT CON DUM EL EPSLON GAS INTEG IOCNTL IT ITER	JOINT KON LD MSCON MUSCLE NAMES NAMESB NECKON OCCA OCCB OCCE OCCF PACK STRCOL TAB TABLES ZP ZQ ZR	PICKUB PICKUP SEARCH IABS	GOMVMA	NONE
56	RELAX	Solves a set of N simultaneous nonlinear equations of form $F_i(X)=0$ for the N unknowns, x_j.		ZQA	FMFP ZMIN	BELT2	NONE
57	REPACK	Update the time history entries in the packing tables in preparation for establishing the current time.		CKOUT PACK	PULLER IABS	GOMVMA	DB85 -DB87 DB92

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
58	RSDUAL	Determines "residuals" for x- and z-force balance at slip ring for advanced belt system.	BRI BRIP CKOUT LF PACK	LODFEL SETACT SQRT	ZMIN	DB137 -DB141
59	SEARCH	Finds the read control parameters for the next record present on the binary data set in the variable section.	IOCNTL	NONE	READIN PICKUP	E40
60	SERTAB	Search for the table entry corresponding to a particular argument in tables.	TAB	ABS AMOD IABS ISIGN	SLOPE	NONE
61	SETACT	Find or create the control entry in KACT for a given interaction.	CKOUT PACK STRCOL ZR	PUSHER IABS	BELT BELT2 CNTACT ELLELL FORCE1 JTORQ RSDUAL SFORCE	DB52 -DB53
62	SETMIG	Enter the force and point of application in the KMUG and STOMUG arrays.	CKOUT PACK	PULLER PUSHER	CNTACT	DB84
63	SFORCE	Computes the normal and tangential forces due to the occupant contact with steering column.	CKOUT STRCOL	LODFEL SETACT SIGN	STEER	E41

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
(64)	SLAP	Determines airbag slap forces for advanced airbag system.	CKOUT PACK	IABS SQRT	ADVBAG	NONE
65	SLOPE	Look up the ramp slope in a material property table given a particular argument.	TAB	SERTAB	EVAL JTORQ	NONE
66	SMSOL	Solve matrix equation AX=B for X.	NONE	ABS	DAUX EOM MIG	NONE
67	STEER	Controls overall flow of the steering assembly part. Also determines the position of body segment contact surfaces and the steering assembly contact points.	CKOUT INTEG MSCON OCCC QV STRCOL STRO THETA	EOM HDX11 REACT SFORCE ATAN2 COS SIN SQRT	DAUX	DB101 -DB111
68	STFP	Determines bag shape if full and in contact with occupant by matching an imputted perimeter for a fully inflated bag.	ARBAG ARBGCM CKOUT DBGPTR DJN INTEG THETA	FLS LSECT ABS COS SIN SQRT	AIRBAG	NONE
69	STFV	Determines bag shape if in contact with occupant but not full by matching the volume with the volume of gas thus far supplied by the source.	ARBAG ARBGCM CKOUT DBGPTR DJN INTEG	FLS VOLCLC ABS COS SIN	AIRBAG	NONE

Table 33. Subprogram Specifications and Appearances for GO (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Report
(70)	THERMO	Determines time rates of change of temperature and mass of gas inside airbag.	ADVB CKOUT GAS PACK	GETY ABS SQRT	ADVBAG	NONE
71	UPDATE	Computes kinetic energies and head, chest, and hip Anterior-Posterior and Superior-Inferior accelerations.	CKOUT FORCE INTEG IOCNTL JOINT MSCON MUSCLE NECKON NECKF OCCA OCCB OCCC OCCF OCCG QV SHOLDR THETA	ABS	GOMVMA	NONE
72	VOLCLC	Determines the volume of the deformed section of the airbag.	ARBGCM DBGPTR DJN	NONE	AIRBAG STFV	NONE
(73)	WIDTH	Determines the width of bag contact with the vehicle portion of the enclosure.	ADVB CKOUT IOCNTL PACK	ABS ATAN2	ADVBAG	EA15 -EA17
74	ZERO	Sets zero into a number of consecutive locations for integers.	NONE	NONE	BKDATA PROFLE	NONE
75	ZMIN	Helper routine for FMFP.	ZQA	INFL RSDUAL ABS	FMFP	NONE

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO

Number	Common Name	Subprograms Which Use	Description
1	ABAG	ABINIT, BKDATA, ENCLOS, FLS, INIT, READIN	Quantities relating to location of surfaces sensed by airbag.
2	ADVB	ADVBAG, FLOTW, INIT, READIN, THERMO, WIDTH	Miscellaneous advanced airbag quantities.
3	ARBAG	ABINIT, AIRBAG, BKDATA, DAUX, DBUG, FLS, GOMVMA, INIT, OUTPUT, READIN, STFP, STFV	Simple airbag input quantities.
4	ARBGCM	ABINIT, AIRBAG, BGSHAP, BKDATA, DBUG, FLS, INIT, OUTPUT, PLTR, STFP, STFV, VOLCLC	Simple airbag input quantities together with force components and moments.
5	BAGMD	ABINIT, BKDATA, INIT, READIN	Simple airbag input tables and other quantities.
6	BELTA	BELT, BKDATA, INIT, OUTPUT, READIN	Initial belt lengths, breaking tensions, belt angles, and belt slacks.
7	BELTB	BELT, BELT2, BKDATA, DAUX, MATRIX	Belt moments and force components.
8	BELTC	BELT, DAUX, INIT, READIN	Belt anchors in inertial and vehicle coordinates.
9	BP	BELT2, DAUX, INIT, READIN	Advanced belt system constants.
10	BQ	BKDATA, CNTACT, DAUX, ELLELL, MATRIX	Generalized forces for friction, line-ellipse forces, and ellipse-ellipse forces.
11	BQQ	BELT2, DAUX, MATRIX	Generalized forces from advanced belt system.
12	BRI	BELT2, DAUX, INFL, INIT, READIN, RSDUAL	Advanced belt system forces, deflections, and derivatives.

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO (continued)

Number	Common Name	Subprograms Which Use	Description
13	BRIP	BELT2, DAUX, INFL, INIT, LODFEL, PLTR, READIN, RSDUAL	Attachment, anchor and ring positions and constants for advanced belt system.
14	CART	CNTACT, DAUX, ENCLOS, MIG	Vehicle position, velocity, and acceleration.
15	CAV	CAVITY, EFFDEF, MULTI	Deflections, effective deflections, cavity coefficients, and line and ellipse dimensions.
16	CKOUT	ABINIT, ADVBAG, AIRBAG, BELT, BELT2, BKDATA, CNTACT, COLAPS, DAUX, DBUG ELLELL, ENCLOS, EOM, ERRMSG, EVAL, FORCE1, GOMVMA, HDX11, INFL, JTORQ, LODFEL, MATRIX, MIG, MULTI, OCCGEO, OUTPUT, PINT, PLTR, PROFLE, PUSHER, REACT, READIN, REPACK, RSDUAL SETACT, SETMIG, SFORCE, SLAP, STEER, STFP, STFV, THERMO, UPDATE, WIDTH	Time, auxiliary (debug) printout controls and error message controls.
17	CON	CNTACT, INIT, READIN	Tangential force friction coefficients and cutoff for relative velocity ramp.
18	DBGPTR	ABINIT, AIRBAG, BGSHAP, BKDATA, DBUG, FLS, OUTPUT, STFP, STFV, VOLCLC	Miscellaneous simple airbag quantities.
19	DJN	ABINIT, AIRBAG, BKDATA, DBUG, OUTPUT, STFP, STFV, VOLCLC	Miscellaneous simple airbag quantities.
20	DUM	CNTACT, DAUX, ELLELL, ERRMSG, EVAL MATRIX, OCCGEO, OUTPUT, READIN	Temporary storage.
21	EL	INIT, JTORQ, READIN	Neck and shoulder element location constants.
22	EPSLON	ASECT, INIT, LSECT, PROFLE, READIN	Various convergence test epsilons.

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO (continued)

Number	Common Name	Subprograms Which Use	Description
23	FORCE	BKDATA, DAUX, MATRIX, OUTPUT, UPDATE	Moments and force components at body segment C.G.'s due to airbag, steering column, belts, and contact forces.
24	GAS	ADVBAG, FLOTW, INIT, READIN, THERMO	Inflation gas parameters.
25	INTEG	ABINIT, ADVBAG, AIRBAG, BELT, BELT2, BKDATA, DAUX, EOM, GOMVMA, INIT, JTORQ, MATRIX, OCCGEO, OUTPUT, PLTR, REACT, READIN, STEER, STFP, STFV, UPDATE	Generalized coordinates, velocities, and accelerations together with other integrated quantities.
26	IOCNTL	ABINIT, AIRBAG, BELT, BKDATA, CNTACT, DAUX, EVAL, FLS, INIT, JTORQ, LODFEL, MATRIX, OCCGEO, OUTPUT, PICKUP, PLTR, READIN, SEARCH, UPDATE, WIDTH	Controls for binary file reading and writing together with a few program control constants.
27	IT	CNTACT, DAUX, ELLELL, EOM, MIG, READIN	Global constants.
28	ITER	ADVBAG, INIT, READIN	Convergence test epsilons and iteration count limits.
29	JOINT	INIT, JTORQ, MATRIX, OUTPUT, READIN, UPDATE	Joint parameters, relative joint angles and velocities, and torques.
30	KON	DAUX, OUTPUT, READIN	Controls and temporary storage for limiting debug output to the final evaluation at each time step.
31	LC	EVAL, LODFEL	Load deflection input constants.
32	LD	INIT, LODFEL, READIN	Shared deflection input constants.

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO (continued)

Number	Common Name	Subprograms Which Use	Description
33	LF	BELT2, EVAL, LODFEL, RSDUAL	Tentative new values for load-deflection quantities.
34	LP	EVAL, LODFEL	Current values for load-deflection quantities.
35	MATRX	BKDATA, DAUX, INIT, MATRIX	Mass coefficient matrix and right-hand side, constants, and generalized forces.
36	MSCON	ABINIT, AIRBAG, BELT, BELT2, BKDATA, CNTACT, DAUX, EOM, EVAL, GOMVMA, INIT, MATRIX, OCCGEO, OUTPUT PLTR, REACT, READIN, STEEP, UPDATE	Miscellaneous input constants.
37	MUSCLE	INIT, JTORQ, MATRIX, READIN, UPDATE	Muscle tension parameters.
38	NAMES	OUTPUT, READIN, BKDATA, NAMET	Storage for names of ellipses, regions, and line segments.
39	NAMESB	BKDATA, READIN	Advanced airbag names.
40	NECKF	OUTPUT, UPDATE	Neck reaction force components.
41	NECKON	INIT, MATRIX, OCCGEO, READIN, UPDATE	Mass and inertia constants for neck element.
42	OCCA	BELT, INIT, MATRIX, OCCGEO, READIN, UPDATE	Body segment lengths.
43	OCCB	INIT, OCCGEO, READIN, UPDATE	Body segment masses and moments of inertia.
44	OCCC	ABINIT, ENCLOS, FLS, INIT, OCCGEO, OUTPUT, PLTR, STEER, UPDATE	Joint positions and velocities.
45	OCCD	BELT, DAUX, OCCGEO, PLTR	Inertial position and velocity coordinates of belt attachment points.
46	OCCE	BELT, INIT, OCCGEO, READIN	Position of belt attachment points in body segment coordinates.

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO (continued)

Number	Common Name	Subprograms Which Use	Description
47	OCCF	BKDATA, INIT, OUTPUT, READIN, UPDATE	Dissipated and absorbed energies for joints and accelerometer location coordinates.
48	OCCG	OUTPUT, UPDATE	Kinetic energies and components of head, chest, and hip accelerations.
49	PACK	ABINIT, ADVBAG, AREA1, AREA2, ASECT, BELT, BELT2, BKDATA, CNTACT, COLAPS, DAUX, ELLELL, ENCLOS, EVAL, FLOTW, INFL, INIT, LODFEL, MIG, NAMET, OUTPUT, PLTR, PROFLE, PULLER, PUSHER, READIN, REPACK, RSDUAL, SETACT, SETMIG, SLAP, THERMO, WIDTH	Packing arrays, with their maximum lengths and current usage lengths.
50	QB	ADVBAG, MATRIX	Advanced airbag generalized forces.
51	QQ	CNTACT, DAUX, ELLELL	Generalized velocities.
52	QV	ABINIT, ADVBAG, BELT2, BKDATA, CNTACT, DAUX, ELLELL, ENCLOS, FLS, MATRIX, OCCGEO, PLTR, STEER, UPDATE	Body segment CG positions and rotation matrices, with time derivatives and partials.
53	SHDEFL	CNTACT, LODFEL	Component defl. and rates.
54	SHOLDR	JTORQ, MATRIX, OCCGEO, OUTPUT, UPDATE	Polar coordinates and velocities for shoulder.
55	STRCOL	BKDATA, DAUX, EOM, HDX11, INIT, OUTPUT, PLTR, REACT, READIN, SETACT, SFORCE, STEER	Steering column quantities.
56	STRO	REACT, STEER	Initial length of upper steering column.
57	TAB	GETY, INIT, READIN, SERTAB, SLOPE	Storage for tables of static curves, inertial spike curves, G-ratios, R-ratios, muscle parameters, and stiffness coefficients.

TABLE 34. LABELED COMMON DESCRIPTIONS FOR GO (continued)

Number	Common Name	Subprograms Which Use	Description
58	TABLES	BKDATA, CNTACT, DAUX, HDX11, INIT, MIG, READIN	Tables for vehicle acceleration and miscellaneous purposes.
59	THETA	ABINIT, ADVBAG, BELT, BELT2, CNTACT DAUX, ENCLOS, INIT, MATRIX, OCCGEO, OUTPUT, PLTR, STEER, STFP, UPDATE	Sines and cosines of angles.
60	THETAP	DAUX, FLS	Sine and cosine of head angle.
61	ZOUT	CNTACT, DAUX, ELLELL, MATRIX	Force and moment components at body CG's from contacts.
62	ZP	INIT, MATRIX, OUTPUT, READIN	Head applied force components.
63	ZQ	INIT, READIN	Switch, vehicle angular acceleration in deg/sec^2 or rad/sec^2.
64	ZQA	RELAX, ZMIN	Miscellaneous advanced belt system controls.
65	ZQB	DAUX, GOMVMA	Debug printout parameters.
66	ZR	INIT, READIN, SETACT	Locations in KCON of beginning indices for the joint material properties entries in STOMAT.

TABLE 35. ARRAY DIMENSION SYMBOLS FOR GO

Symbol	Description	Current Estimate
NBAGS	Number of airbags.	5
NENCV	Number of vehicle interior enclosure segments.	15
B	Number of bag profiles, total for all bags and all times.	100
C	Number of points in bag profiles, total for all bags and all times.	2000
K	Number of P/T constant curves for V vs. A, total.	20
S	Number of segments allowed and disallowed for bag slap, total.	50
V	Number of deflation vents, total	15
X	Number of allowed interactions for yielding enclosure segments, total.	25
Y	Number of enclosure segments which can yield to airbag forces.	10

TABLE 36. ARRAY DIMENSION RELATIONSHIPS FOR GO

Number	Dimension Relationship	Array Name	Length Name	Length Value
1	14 + NENCV + 22NBAGS + 4B + K + X + V + 2S + 4Y	KBAG	LENKBG	699
2	33NBAGS + 2V + K + 5B + 2C + 12Y	STOBAG	LENSBG	4835
3	17 + 3NENCV	KENC	LENKNC	107*
4	5(13+NENCV)	STOENC	LENSNC	215*
5	6(13+NENCV)	KINT+	LENKNT	168
6	4(13+NENCV)	STINT+	LENSNT	112
7	3 + 12 (13+NENCV)	KABB++	LENKBB	387**
8	160 (13+NENCV)	STOABB++	LENSBB	2560***
9	79 NBAGS + 6Y + 121	BAGOUT	LENBOT	576

* NENCV taken as 30, not 15.
** NENCV taken as 19, not 15.
*** Result with NENCV = 19 is halved; could be too small.
\+ Dimension based on assumption that NINT, the number of intersections between enclosure and bag profile, is $\leq$ 2NENC = 2(13+NENCV).
++ Dimension based on assumption that the number of segments in the primary and secondary profiles, NPRI and NSEC, are $\leq$ 4NENC = 4(13+NENCV).

TABLE 37. THE STANDARD AREA OF THE KBAG ARRAY

Index	Description
1	Number of airbags (N = NBAGS)
2	Number of contact (enclosure) segments given properties for "deforming" in response to contact by one or more airbags (M = NKFORM)
3 to 2 + N	Beginning index in KBAG of control entries (in order of processing, from inside out) (last entry is bag #1) (KBC)
3 + N to 2 + N + NENC	Beginning index in KBAG of airbag-deformable enclosure segment entries (0 if not deformable by one or more bags) (This NENC-long list is ordered relative to bag no. 1 attachment.)

TABLE 38. TYPICAL ENTRY FOR AIRBAG IN KBAG ARRAY

Relative Index	Description
1(KBC) to 4	Airbag name
5	Beginning index in STOBAG for general entry (ISB)
6	Beginning index in BAGOUT for typical airbag entry (KBAGO)
7	Number of airbags immediately inside (m)
8	Number of times in input time history for bag position (n)
9	Number of tables with constant P/T for volume vs. area (p)
10	Table number for mass influx ($\dot{m}_n$ vs. t)
11	Table number for source gas temp. (T vs. t)
12	Table number for bag porosity vs. pressure differential
13	Number of deflation membranes (k)
14	Beginning index in KBAG for bag slap force entry (ISLF)
15	0 if bag not previously in contact w. enclosure, 1 otherwise
16	Number of airbag-deformable contact segments for this bag (d=NDFORM)
17	Beginning index in KBAG of bag outside, 0 if none
18	Beginning index in STOENC for 1st endpoint of 1st enclosure segment for this bag (ISNC)
19	Current time point number for bag profile history
20	Airbag name number (KBAGNM index)

Note: In packed KBAG, the Table 41 entries precede these entries.

TABLE 38. TYPICAL ENTRY FOR AIRBAG IN KBAG ARRAY (continued)

Relative Index	Description
21 to 20 + ℓ	Not used --ℓ = 0
21 + ℓ to 20 + ℓ + m	Beginning indices in KBAG for bags immediately inside.
21 + ℓ + m to 20 + ℓ + m + n	Beginning index in KBAG for time history entry (ITIME, KBI)
21 + ℓ + m + n to 20 + ℓ + m + n + p	Table numbers for V vs. A tables with constant P/T [in order of increasing values for P/T]
21 + ℓ + m + n + p to 20 + ℓ + m + n + p + d	List of NDFORM (d) enclosure segment numbers, (relative to attachment point for this bag) that can respond to forces from this bag.
21 + ℓ + m + n + p + d to 20 + ℓ + m + n + p + d + h	0 if deflation membrane is not ruptured, 1 if ruptured

TABLE 39. TYPICAL TIME HISTORY ENTRY IN KBAG ARRAY

Relative Index	Description
1 (ITIME)	Number of perimeter points (NPPTS) (equals no. of bag perim. segments NBSEG)
2	Point number of reference point for bag equilibrium (NREF)
3	Beginning index in STOBAG for typical perimeter pts. entry (IPER)

TABLE 40. TYPICAL BAG SLAP FORCE ENTRY IN KBAG ARRAY

Relative Index	Description
1 (ISLF)	Initially, 0 if slap force allowed, -2 if not; later, 1 if slap force nonzero, -1 if zero (ISLAP)
2	Number of enclosure segments for which slap force is not to be considered if ≥ 0; number to be considered if < 0 (NSLAP)
3 to $\lvert NSLAP \rvert + 2$	Enclosure segment numbers (relative to bag #1 attachment) for which slap force is not to be considered if $(2) > 0$, or to be considered if $(2) < 0$

TABLE 41. TYPICAL ENTRY FOR AIRBAG-DEFORMABLE CONTACT SEGMENTS IN KBAG ARRAY

Relative Index	Description
1	Beginning index in STOBAG for airbag-deformable segment section (IST)
2	Beginning index in KCON of line segment section for airbag-deformable segment (JKC)
3	Table number for static force curve
4	0 if never yielded, 1 if loading, -1 if unloading, -2 if unloaded

Note: One entry for each deformable segment, independent of bag.

Note: In packed KBAG, these entries precede the Table 38 entries.

TABLE 42. GENERAL ENTRY FOR AIRBAG IN STOBAG ARRAY

Relative Index	Description
1 (ISB)	Bag pressure, P
2	Bag volume, V_{total}
3	Gas temperature, T
4	Rate of change of temperature, $\dot{T}$
5	Mass of gas in bag, m
6	Exhaust rate, $\dot{m}_{ex}$
7	(unused)
8	Angle θ from horizontal of a line from bag attachment point to reference point on bag periphery (for moment equilibrium)
9	Source gas temp. (constant, used if T vs. t table is absent)
10	m for 4-parameter solid (bag slap)
11	k_{Fluid} for 4-parameter solid (bag slap)
12	K_{Solid} for 4-parameter solid (bag slap)
13	C_{Fluid} for 4-parameter solid (bag slap)
14	C_{Solid} for 4-parameter solid (bag slap)
15	Velocity factor for bag slap (VFACTR)
16	Bag fire time
17	Last $\dot{m}_{ex}$
18	Total volume of bags immediately inside
19	Last T
20	Last m

TABLE 42. GENERAL ENTRY FOR AIRBAG IN STOBAG ARRAY (continued)

Relative Index	Description
21	X-coordinate of bag attachment point (XA)
22	Z-coordinate of bag attachment point (ZA)
23	Fluid component of slap force (FFLUID)
24	Fluid force rate (FFLUDD)
25	Bag-slap X (XSLAP)
26	Bag-slap $\dot{X}$ (XSLAPD)
27	Bag-slap $\dot{X}$ (DXSLAP)
28	Bag-slap $\ddot{X}$ (DXSLPD)
29	Compliance for initial θ adjustment of bag if neg., angle adjustment if positive
30	Full out-of-plane width of flattened bag, WBAG
31	Total surface area, SURFCE
32	Pressure at preceding time step
33	Total volume at preceding time step

TABLE 43. TYPICAL PERIMETER POINTS ENTRY IN THE STOBAG ARRAY

Relative Index	Description
1	Time
2	X_1 for first perimeter point (attachment point = source)
3	Z_1 for first perimeter point
4 (IPER)*	X_1 for rotated bag (same as unrotated X_1)
5	Z_1 for rotated bag (same as unrotated Z_1)
6	X_2 for second perimeter point
7	Z_2 for second perimeter point
.	.
.	.
.	.
.	.
4n - 2	X_n for n^{th} perimeter point
4n - 1	Z_n for n^{th} perimeter point
4n	X_n for rotated bag
4n + 1	Z_n for rotated bag
.	.
.	.
.	.
.	.
4 NPPTS-2	X_{NPPTS} for $NPPTS^{th}$ perimeter point
4 NPPTS-1	Z_{NPPTS} for $NPPTS^{th}$ perimeter point

*IPER points to X_1 (rotated bag) in Subroutine PROFLE and to "Time" (relative index equals 1) in Subroutine SETVLB.

TABLE 43. TYPICAL PERIMETER POINTS ENTRY IN THE STOBAG ARRAY (continued)

Relative Index	Description
4 NPPTS	X_{NPPTS} for rotated bag
4 NPPTS + 1	Z_{NPPTS} for rotated bag
4 NPPTS + 2	$X_{NPPTS + 1}$ = unrotated X_1 (attachment point)
4 NPPTS + 3	$Z_{NPPTS + 2}$ = unrotated Z_1 (attachment point)
4 NPPTS + 4	$X_{NPPTS + 1}$ for rotated bag (same as unrotated)
4 NPPTS + 5	$Z_{NPPTS + 1}$ for rotated bag (same as unrotated)

Note: All coordinates are with respect to axes parallel to the vehicle axes and with origin at the bag attachment point.

TABLE 44. TYPICAL ENTRY FOR AIRBAG-DEFORMABLE CONTACT SEGMENTS IN STOBAG ARRAY

Relative Index	Description
1 (IST)	(unused)
2	Last velocity (v_1)
3	$(\Delta t)^2 / 2m$
4	Yield force for segment (Y)
5	Sum of bag forces on segment (F_b)
6	Resistance force against segment (F_r)
7	Viscous damping coefficient C for $C\dot{x}$, which is added to static force (contributes to F_r)
8	$(1 - G)/\tau$
9	Rebound duration (τ)
10	G-ratio
11	Maximum deformation δ_{max} due to airbag contacts
12	Turnaround time for sequent motion

Note: One entry for each deformable segment, independent of bag.

TABLE 45. STANDARD AREA OF KENC ARRAY FOR ENCLOSURE SEGMENTS

Index	Description
1	Number of enclosure segments (NENC=11+NENCV+2)
2	Number of vehicle interior enclosure segments (NENCV)
3	Number of vehicle interior enclosure segments above attachment point for airbag no. 1 (must be at least one)
4	not used
5 to 4 + NENC	Body segment number if enclosure segment attached to body segment (beginning with first enclosure segment for airbag no. 1); otherwise, 0.
5 + NENC to 4 + NENC + NENCV	Beginning indices in KCON of segment control entry for vehicle interior enclosure segments, beginning at lowest segment (~toeboard)(JKC)
5 + NENC + NENCV to 4 + NENC + 2NENCV	Index in STOMAT (region entry) of inertial x-coord. of 1st endpoint of vehicle interior enclosure segments, beginning at lowest segment (~toeboard) (INDEX)

TABLE 46. STOENC ARRAY FOR ENCLOSURE SEGMENTS

Relative Index		Description
		Note: ISNC points to $X_i = X_{attachment}$ for bag being processed by subroutine ADVBAG. Each bag attachment must be at a vertex of enclosure.
1	X_1	coords. of first endpoint of first segment of enclosure (for bag no. 1)
2	Z_1	
3	X_2	next endpoint of enclosure
4	Z_2	
5	X_3	⋮
6	Z_3	
⋮	⋮	successive endpoints
		⋮
2 NENC - 1	X_{NENC}	NENC[th] endpoint (for bag no. 1)
2 NENC	Z_{NENC}	
2 NENC + 1	X_1	repeated values
2 NENC + 2	Z_1	
⋮	⋮	
4 NENC - 1	X_{NENC}	
4 NENC	Z_{NENC}	
4 NENC + 1 to 5 NENC		Width (out-of-place) of enclosure segment ("infinite" for vehicle segments) (numbered rel. to bag 1 attachment)

TABLE 47. TYPICAL CONTROL ENTRY FOR AIRBAG INTERSECTIONS OF THE KINT ARRAY

Relative Index	Description
1 (IKINT)	Enclosure segment number (rel. to attachment for this bag)
2	(Unused)
3	Switch = { 1 bag segment crosses inside to outside; -1 bag segment crosses outside to inside }

TABLE 48. TYPICAL AIRBAG INTERSECTION ENTRY OF THE STINT ARRAY

Relative Index	Description
1 (ISTINT)	X-coordinate of intersection
2	Z-coordinate of intersection

TABLE 49. THE STANDARD AREA OF THE KABB ARRAY

Index	Description
1 (KBBC=1)	Beginning index in KBAG for this airbag
2	Number of segments for primary profile (NPRI)
3	Number of segments for secondary profile (NSEC)
4 to 3 + NPRI	Beginning indices in STOABB for segments (primary) (ISBB)
4 + NPRI to 3 + 2NPRI	Enclosure segment numbers for straight line sections of primary profile (0 if arc)
4 + 2NPRI to 3 + 2NPRI + NSEC	Beginning indices in STOABB for segments (secondary) (ISBB, IISBB)

TABLE 50. THE TYPICAL SEGMENT ENTRY FOR THE STOABB ARRAY

Relative Index	Description	
1 (ISBB)	Beginning index for this airbag in KABB (KBBC = 1)	
2	X of first endpoint	
3	Z of first endpoint	
4	X of second endpoint	
5	Z of second endpoint	
6	C, curvature switch for segment (>0 for arc, ≤0 for line segment: 0 for unextended; -1 if replacement for small arc; -2 or -3 for extension)	
	<u>Line</u>	<u>Arc</u>
7	length l_i	length S_i
8	center X_i	center of circle h_i (X)
9	center Z_i	center of circle k_i (Z)
10	x-component of unit outward normal to line (g)	x-component of unit outward normal to chord (G)
11	Z-component of unit outward normal to line (h)	Z-component of unit outward normal to chord (H)
12	$\lvert\vec{F}^{(i)}_{pressure}\rvert$	chord length d_i
13	$F^{(i)}_{slap}$	radius r_i
14*	$f^{(i)}_{n}$	angle θ_i
15	Enclosure segment no. rel. to attachment pt. for the bag (nonzero only for C = 0 or C = -2 or C = -3)	sin $(\theta_i/2)$

TABLE 50. THE TYPICAL SEGMENT ENTRY FOR THE STOABB ARRAY (continued)

Relative Index	Description (Line)	(Arc)
16*	$f_{n_\perp}^{(i)}$	$\cos(\theta_i/2)$
17*	$f_n^{(b)}$ (1st endpt.)	α_i
18*	$f_{n_\perp}^{(b)}$ (1st endpt.)	β_i
19*	$f_n^{(a)}$ (2nd endpt.)	(not used)
20*	$f_{n_\perp}^{(a)}$ (2nd endpt.)	(not used)

*NOTE: $f_n^{(i)}$ and $f_{n_\perp}^{(i)}$ are off-occupant-plane force components. $f_n^{(b)}$, $f_{n_\perp}^{(b)}$, $f_n^{(a)}$, and $f_{n_\perp}^{(a)}$ are occupant-plane force components.

TABLE 51. THE STANDARD AREA OF THE BAGOUT ARRAY

Index	Description
1 to 9	Total inertial X-component of forces on 9 segments
10	Total inertial X-component for occupant
11	Number of bags in contact
12 to 20	Total inertial Z-component of forces on 9 segments
21	Total inertial Z-component for occupant
22	Number of bags in contact
23 to 121	Entries of the following layout for each of 9 segments: 0 Total pressure force 1 Total planar normal flotation 2 Total non-planar normal flotation 3 Total slap force 4 Total planar tangential flotation 5 Total non-planar tangential flotation 6 Total normal force 7 Total tangential force 8 Contact line segment angle 9 Body link angle 10 Number of bags in contact
122 to 121+6*KBAG(2)	KBAG(2) entries of layout below for yielding vehicle bag enclosure segments: 0 Total force 1 Total yield displacement 2 Yield motion velocity 3 Static resistance to yielding 4 Rate-dependent resistance to yielding 5 Inertia resistance to yielding

* This layout is for Categories 59-62 in the order 61, 62, 60, 59.

TABLE 52. THE TYPICAL AIRBAG ENTRY OF THE BAGOUT ARRAY

Relative Index	Description
KBAGO	Gauge pressure
KBAGO+1	Absolute pressure
KBAGO+2	Gas temperature
KBAGO+3	Net volume
KBAGO+4	Total volume
KBAGO+5	Gas mass
KBAGO+6	Mass influx rate from source
KBAGO+7	Mass influx rate from internal bags
KBAGO+8	Mass outflux rate through vents
KBAGO+9	Mass outflux rate through porous fabric
KBAGO+10	Net mass influx
KBAGO+11	Source gas temperature
KBAGO+12 thru KBAGO+20	Pressure force on segments (upper head, lower head, chest, midsection, upper pelvis, lower pelvis, upper leg, knee, lower leg)
KBAGO+21 thru KBAGO+29	Planar normal flotation forces for 9 segments
KBAGO+30 thru KBAGO+38	Planar tangential flotation forces for 9 segments
KBAGO+39 thru KBAGO+47	Non-Planar normal flotation forces for 9 segments
KBAGO+48 thru KBAGO+56	Non-Planar tangential flotation forces for 9 segments
KBAGO+57 thru KBAGO+65	Bag Slap forces for 9 segments
KBAGO+66	Ratio of fluid component to total bag slap force
KBAGO+67	Sum of inertial x-forces on occupant
KBAGO+68	Sum of inertial z-forces on occupant
KBAGO+69	Moment imbalance on airbag
KBAGO+70	Airbag reference angle
KBAGO+71	Attachment point X (vehicle coordinates)
KBAGO+72	Attachment point Z (vehicle coordinates)
KBAGO+73	Cross Section area in occupant plane
KBAGO+74	Vehicle contact width
KBAGO+75	Average occupant contact width
KBAGO+76	Number of occupant segments contacted
KBAGO+77	Number of vehicle interior segments contacted
KBAGO+78	Number of segments in airbag profile

TABLE 53. "APPENDED" ERROR MESSAGES FROM GO

Number	Message	Condition and Action Required	Subroutine
EA1	WARNING--AT TIME X.XXXXXX BAG ANGLE EQUILIBRIUM IS NOT ATTAINED FOR BAG bag name. EPSM MOMENT EPSILON IS ±0.XXXXXXE±XX AND SUMM UNBALANCED MOMENT IS ±0.XXXXXXE±XX. list of 25 values	Increase EPSM or increase ITMMAX to 3 (both on Card 912) and rerun. Or examine run for anomalous behavior due to some other problem.	ADVBAG
EA2	FATAL ERROR--AT TIME X.XXXXXX P/T FOR BAG bag name IS OUTSIDE RANGE OF P/T VALUES FOR WHICH VOL VS. AREA TABLES ARE SPECIFIED PT BY USER. FOR ITERATION, P/T= ±0.XXXXXXE±XX STOBAG(IA-T) AND P/T LIMITS ARE ±0.XXXXXXE±XX AND STOBAG(IB) ±0.XXXXXXE±XX. list of 25 values	Add 921-Cards to data deck for broader P/T range.	ADVBAG
EA3	FATAL ERROR--AT TIME X.XXXXXX PRESSURE-VOLUME ITERATION LIMIT IS EXCEEDED FOR BAG bag name. list of 28 values	Increase EPSP and/or ITPMAX on Card 912.	ADVBAG
EA4	FATAL ERROR--AT TIME X.XXXXXX NET VOLUME OF AN EXTERIOR BAG, AIRBAG bag name IS LESS THAN OR EQUAL TO ZERO. list of 25 values	Examine run for anomalous behavior due to some other problem. Consider adequacy of bag profile history.	ADVBAG
EA5	ISA FATAL ERROR--BELT SEGMENT X MUST BE PRESENT FOR THE ANCHOR( )-RING( ) OR OTHER OPTIONS SELECTED.	See Figures 9-7 and 9-8 in Self-Study Guide or Figures 92 and 93 in Volume 2.	BELT2
EA6	FATAL ERROR--LINE SEGMENT segment name IN THE ADVANCED AIRBAG ENCLOSURE DOES NOT JOIN AT AN ENDPOINT TO THE NEXT ENCLOSURE SEGMENT COUNTER-CLOCKWISE.	Examine 409-Cards and unnumbered cards after 910-Card for segment names and 411-Cards for endpoint coordinates.	DAUX

TABLE 53. "APPENDED" ERROR MESSAGES FROM GO (continued)

Number	Message	Condition and Action Required	Subroutine
EA7	FATAL ERROR--MORE THAN 20 BULGES IN AIRBAG SECONDARY PROFILE. IW( ) ARRAY DIMENSION TOO SMALL IN SUBROUTINE FLOTW. KBC=XXXXX	Increase dimension of IW in program or decrease number of vehicle interior segments in enclosure.	FLOTW
EA8	WARNING---VARIABLE POSITION SELECTION PARAMETERS INCONSISTENT--- NCR MCR CUR REC NO RANGE=XXXXXXXXXXXX NVALS NO. VALUES=XXXXX, NO. VALUES PER NVALPL NUMR LINE=XXXXX, NO. OF RECORDS=XXXXX, I LAST RECORD NO. WRITTEN=XXXXXX JA JB VAL IND RANGE CUR LINE=XXXXXXXXXXXX	Warning, the LEAD array or one of the controls is not set up correctly or has been stored over. Program error or machine error.	PICKUB
EA9	FATAL ERROR--KINT OR STINT ARRAY SIZE EXCEEDED--IUSEKT=XXXX IUSEST=XXXX	Increase dimensions.	PROFLE
EA10	FATAL ERROR--KABB OR STOABB ARRAY SIZE EXCEEDED--IK=XXXX IPER=XXXX IUSESB=XXXX	Increase dimensions.	PROFLE
EA11	FATAL ERROR--MXNPRI=4*NENC=XXXX IN SUBROUTINE PROFLE IS NOT LARGE ENOUGH. MUST BE LARGER THAN NPRI=XXXX. CHANGE "MXNPRI=4*NENC" IN CODE AND RECOMPILE	Self-explanatory.	PROFLE

TABLE 53. "APPENDED" ERROR MESSAGES FROM GO (continued)

Number	Message	Condition and Action Required	Subroutine
EA12	WARNING--PERIMETER PROFILE FOR CONTACTED BAG CROSS SECTION IS GREATER THAN AVAILABLE LENGTH OF BAG FABRIC BY R AMOUNT ±0.XXXXE±XX AT TIME X.XXXXX KIX FOR PROFILE XX OF BAG bag name. FREE RELAXATION IS ASSUMED; EFFECTIVE INCREASE S OF BAG PERIMETER IS ±0.XXXXE±XX. Z3= ±0.XXXXE±XX D= ±0.XXXXE±XX SUML= ±0.XXXXE±XX SUMD= ±0.XXXXE±XX PERIM= ±0.XXXXE±XX	Ignore; fixup is consistent with the modeling assumptions for the contact phenomenon. Or consider modifying bag profile history.	PROFLE
EA13	WARNING--ITERATION FOR ARC RADIUS KIX (PROFILE XX) FAILED TO CONVERGE AT TIME X.XXXXX. LAST AND NEXT TO LAST VALUES R X1 WERE ±0.XXXXE±XX ±0.XXXXE±XX. THIS ARC I IS SEGMENT NO.XXX IN THE STOABB ARRAY AND THE CHORD AND ARC LENGTHS D S ARE ±0.XXXXE±XX ±0.XXXXE±XX	Probably unimportant. Iteration limit and epsilon are internally defined and could be changed in code.	PROFLE
EA14	FATAL ERROR--DETERMINATION OF SECONDARY PROFILE FAILS DUE TO INVALID ENCLOSURE SPECIFICATIONS (ENCLOSURE SEGMENTS ARE PROBABLY DISCONNECTED) list of 11 values	Examine 411-cards and KENC packing code in DAUX.	PROFLE

TABLE 53. "APPENDED" ERROR MESSAGES FROM GO (continued)

Number	Message	Condition and Action Required	Subroutine
EA15	WARNING--AT T= X.XXXXX NEGATIVE WEIGHTED AVERAGE OCCUPANT-VEHICLE X-DISTANCE XX B=+0.XXXXXE+XX IS CALCULATED FOR DETERMINATION OF Y-WIDTH OF BAG-VEHICLE B CONTACT. VALUE IS RESET TO X.XXXX . (NENC,NPRI,NSEC,KOUNT,JOUNT,TSA,TSB, WOCC,XVEH,XOCC)= list of 10 values AIRBAG NAME= bag name	Ignore, or examine run for anomalous behavior due to some other problem. Fixup is probably good.	WIDTH
EA16	WARNING--ITERATION FOR BAG-VEHICLE CONTACT WIDTH FAILED TO CONVERGE AT TIME X.XXXXX. LAST AND NEXT TO LAST VALUES FOR X WERE X XX +0.XXXXE+XX +0.XXXXE+XX (WBAG,WOCC,B,WVEH,C,R,S,THDIV2,H)= list of 9 values AIRBAG NAME= bag name	Same as EA13.	WIDTH
EA17	FATAL ERROR--WVEH FROM ITERATION FOR BAG-VEHICLE CONTACT WIDTH IS NEGATIVE AT TIME X.XXXXX. (X,XX,WBAG,WOCC,B,WVEH,C,R,S,THDIV2,H)= list of 11 values AIRBAG NAME= bag name	Check WBAG value on Card 916. Examine Newton's iteration code in WIDTH.	WIDTH

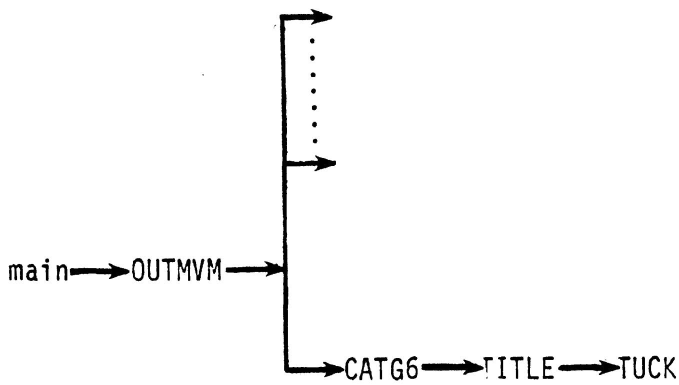

Figure 33. "Appended" Flow for OUT

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT

Number[1]	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called[2]	Subprograms Calling	Special Output[3]
1	BLKDTA	Initialize ordering and name tables.	INDEXX JUNK	NONE	NONE	NONE
2	BRAKUP	Analyze the free format instructions for output control and set up controlling arrays.	NONE	LAND+ LOR+ SHFTL+ SHFTR+ MAXO	OUTMVM	EP1-EP3
3	CATG1	Reads part of binary files on logical device numbers NU and MV and produces printed output for categories one through four.	INDEXX JUNK PREP PRNT	TITLE IABS	OUTMVM	NONE
4	CATG2	Reads part of binary files on logical device number NU and produces printed output for categories five through nine.	JUNK PREP PRNT SI	TITLE	OUTMVM	NONE
5	CATG3	Reads part of binary file on logical device number NU and produces printed output for categories ten through twenty.	JUNK PREP PRNT	TITLE	OUTMVM	NONE
6	CATG4	Reads part of binary file on logical device number NU and produces printed output for categories twenty-three through thirty-nine.	JUNK PREP PRNT	TITLE	OUTMVM	NONE

[1] (n) - subprogram not occurring in Version 4

[2] cccccc+ - MTS system subprogram
(Routine may require modification by local user. See Sec. 4.8.1 of Volume 3.)

[3] En - error message from OUT (Version 4, Table 119)
EAn - error message from OUTP (Version 4, Table 103)
EPn - error message ("Appended" Table)

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
7	CATG5	Reads part of binary file on logical device number NU and produces printed output for categories forty and forty-six through fifty.	JUNK PREP PRNT	TITLE	OUTMVM	NONE
(8)	CATG6	Reads part of binary file on logical device number NU and produces printed output for categories fifty-one through sixty-two.	JUNK PREP PRNT	TITLE	OUTMVM	NONE
9	COMPA	Carries out all requests for type A comparisons.	COMPS INDEXX PREP PRNT	EXCESS FETCH INST TITLE	OUTMVM	NONE
10	COMPB	Carries out all requests for type B comparisons.	COMPS PREP PRNT	DIFFER INST	OUTMVM	E1
11	DBS	GM system routine to convert information in A-format into binary format for arithmetic use.	DUM	LAND+ SIOC+	OUTMVM	EP4
12	DIFFER	Routine which carries out an individual two variable comparison.	INDEXX PREP PRNT	FETCH TITLE	COMPB	NONE
13	DOLIST	Routine which carries out the testing of the standard list.	COMPS INDEXX PREP PRNT SI	EXCESS FETCH INST TITLE ABS	OUTMVM	NONE

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
14	DRAWIT	Routine to print out finished plot page image.	JUNK PREP	TITLE	STYX	NONE
15	ELLIPS	Plot outline of ellipse.	CTYX	SCALE PUT COS SIN	STYX	NONE
16	EXCESS	Routine which carries out an individual one variable high and low test over a range.	PRNT	NONE	COMPA DOLIST TJOINT	NONE
17	FETCH	Routine which obtains a particular time value of a particular variable from binary storage.	INDEXX PREP PRNT	NONE	COMPA DIFFER DOLIST	NONE
18	FILTER	Carries out Martin-Graham filtering of output acceleration data.	NONE	AINT SIN	PRELIM	E2 -E4
19	HIC	Routine which computes the HIC index.	NONE	ABS SQRT	PRELIM	E5
20	IDOUT	Routine which prints a summary of the input quantities.	DUM JUNK PREP PRNT	PICKUP ZBAG ZBELT ZBELTA ZCOLM ZINT1 ZINT2	OUTMVM	NONE

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
21	INDEX	Routine which forms and prints an index of categories and force producers in terms of page numbers.	INDEXX PREP PRNT	NONE	OUTMVM	NONE
22	INST	Routine which determines the control parameters for locating a variable in binary storage and reading it in.	INDEXX PREP PRNT	IABS	COMPA COMPB DOLIST	E6-E7
23	INTSCT	Routine to determine intersection between two circles.	NONE	SQRT	STYX	NONE
24	LINE	Routine to enter a line into the plot image.	NONE	PUT SCALE	STYX	NONE
25	MAIN	Routine which passes control to OUTMVM and then back to the system.	NONE	OUTMVM SYSTEM[+]	NONE	NONE
26	OUTMVM	Controls the overall functioning of the Output Processor.	COMPS CTYX JUNK PREP PRNT SI	BRAKUP CATG1 INDEX CATG2 PICKUP CATG3 PRELIM CATG4 STYX CATG5 TJOINT CATG6 ABS COMPA AMAX1 COMPB AMIN1 DBS IABS DOLIST MAXO IDOUT MINO	MAIN	EP5
27	PICKUP	Reads a table in from binary storage.	PRNT	SEARCH	OUTMVM IDOUT STYX	E12

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
28	PRELIM	Controls the calculation and storage of edited accelerations, filtered accelerations, and various severity indices.	DUM PREP PRNT SI	FILTER HIC SEVIND THRAVG ABS MINO SQRT	OUTMVM	E13 EA1-EA2
29	PUT	Routine to insert a character at a mesh point specified in plot image.	PREP	LAND LOR SHFTR	ELLIPS LINE STYX	NONE
30	SCALE	Routine to obtain the mesh point coordinates from coordinate value for insertion in plot image.	PREP	NONE	ELLIPS LINE STYX	NONE
31	SEARCH	Locates the beginning record number of a table in binary storage.	PRNT	NONE	PICKUP	E16
32	SEVIND	Compute regular GMR SI and Modified GMR SI for output accelerations.	NONE	ABS	PRELIM	NONE
33	STYX	Produces the stick figure printer plots.	COMPS CTYX PREP PRNT	DRAWIT ELLIPS ABS INTSCT AMIN1 LINE ATAN2 PICKUP COS PUT MOD SCALE SIN TITLE SQRT	OUTMVM	NONE
34	THRAVG	Routine to locate peak acceleration and compute three millisecond average.	NONE	ABS MAX1	PRELIM	NONE

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
35	TITLE	Increment page count and print page heading for regular printout page.	PREP	TUCK	CATG1 CATG2 CATG3 CATG4 CATG5 CATG6 COMPA DIFFER DOLIST DRAWIT STYX TJOINT ZBAG ZBELT ZBELTA ZCOLM ZINT1 ZINT2	NONE
36	TJOINT	Routine to carry out the testing of joint relative angles.	COMPS DUM PREP PRNT	EXCESS TITLE ABS	OUTMVM	NONE
37	TUCK	Routine to record page number under identification of category for inclusion in index.	INDEXX	NONE	TITLE	E17
38	ZBAG	Prints inputted values for airbag system.	DUM JUNK PREP PRNT	TITLE MOD	IDOUT	NONE
39	ZBELT	Prints inputted values for simple belt system.	DUM JUNK PREP PRNT	TITLE	IDOUT	NONE

TABLE 54. SUBPROGRAM SPECIFICATIONS AND APPEARANCES FOR OUT (continued)

Number	Subprogram Name	Flow Sequence or Description	Commons	Subprograms Called	Subprograms Calling	Special Output
40	ZBELTA	Prints inputted values for advanced belt system.	DUM JUNK PREP PRNT	TITLE	IDOUT	NONE
41	ZCOLM	Prints inputted values for steering column system.	DUM JUNK PREP PRNT	TITLE MOD	IDOUT	NONE
42	ZINT1	Prints first half of initial conditions and parameters for the vehicle and occupant.	DUM JUNK PREP PRNT	TITLE FLOAT MOD	IDOUT	NONE
43	ZINT2	Second half of ZINT1.	DUM JUNK PREP PRNT	TITLE MOD SQRT	IDOUT	NONE

TABLE 55. LABELED COMMON DESCRIPTIONS FOR OUT

Number	Common Name	Subprograms Which Use	Description
1	COMPS	COMPA, COMPB, DOLIST, OUTMVM, STYX, TJOINT	Contains test values for comparison
2	CTYX	ELLIPS, OUTMVM, STYX	Contains control parameters for stick figure plots.
3	DUM	DBS, IDOUT, PRELIM, TJOINT, ZBAG, ZBELT, ZBELTA, ZCOLM, ZINT1, ZINT2	Temporary storage.
4	INDEXX	BLKDTA, CATG1, COMPA, DIFFER, DOLIST, FETCH, INDEX, INST, TUCK	Contains information to put together the index.
5	JUNK	BLKDTA, CATG1, CATG2, CATG3, CATG4, CATG5, CATG6, DRAWIT, IDOUT OUTMVM, ZBAG, ZBELT, ZBELTA, ZCOLM, ZINT1, ZINT2	Contains units and body part names for formatting in IDOUT.
6	PREP	CATG1, CATG2, CATG3, CATG4, CATG5, CATG6, COMPA, COMPB, DIFFER, DOLIST, DRAWIT, FETCH, IDOUT, INDEX, INST, OUTMVM, PRELIM, PUT, SCALE, STYX, TITLE, TJOINT, ZBAG, ZBELT, ZBELTA, ZCOLM ZINT1, ZINT2	Contains working tables and input tables. The format employed between OUTMVM and PRELIM differs from the rest.
7	PRNT	CATG1, CATG2, CATG3, CATG4, CATG5, CATG6, COMPA, COMPB, DIFFER, DOLIST, EXCESS, FETCH, IDOUT, INDEX, INST, OUTMVM, PICKUP, PRELIM, SEARCH, STYX, TJOINT, ZBAG, ZBELT, ZBELTA, ZCOLM, ZINT1, ZINT2	Contains printout control information and binary file placement tables.
8	SI	CATG2, DOLIST, OUTMVM, PRELIM	Contains special severity indices.

TABLE 56. "APPENDED" ERROR MESSAGES FROM OUT

Number	Message	Condition and Action Required	Subroutine
EA1	TOO MANY TIME POINTS TO DO ALL, LAST T(NUMTRY) TIME PROCESSED IS XXX.XXXXX NUMTRY AND NO. OF POINTS=XXXXX	Warning only. There may be missing acceleration data.	PRELIM
EA2	ABNORMAL INPUT FILE, NUMBER TIME POINTS NREC PROCESSED IS XXXXX AND LAST TIME T(NREC) IS XXX.XXXXX	Warning only. There may be missing acceleration data.	PRELIM

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APPENDIX A

INTERSECTIONS OF A LINE SEGMENT AND A CIRCULAR ARC
(Subroutine ASECT)

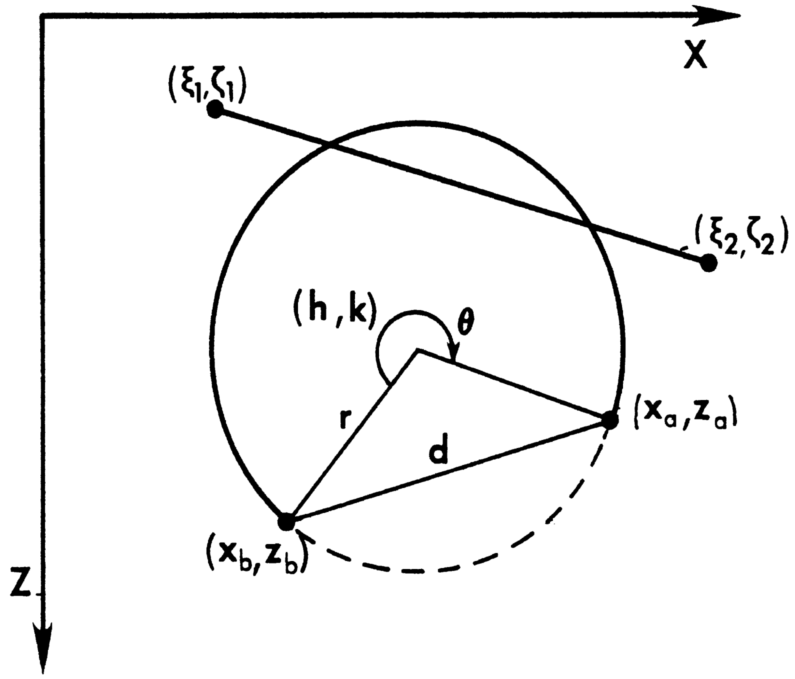

Figure A-1. Line Segment and Circular Arc Coordinates

The figure above shows an arc with endpoints (x_a, z_a) and (x_b, z_b) and a line segment with endpoints (ξ_1, ζ_1) and (ξ_2, ζ_2). It is required to determine the coordinates of intersections that might exist. Several tests are necessary to establish that intersections are actually between the line segment and the arc; these tests are all discussed.

The equations of the circle and extended straight line of which the arc and straight-line segment are parts are as follows:

Circle

$$(x-h)^2 + (z-k)^2 = r^2 \qquad \text{(A.1)}$$

Line

$$z = mx + b, \quad \text{where} \quad m = \frac{\zeta_2 - \zeta_1}{\xi_2 - \xi_1} \qquad \text{(A.2)}$$

$$\text{and} \quad b = \zeta_1 - m\xi_1$$

Case 1: $|m|<\infty$

Provided that the slope of the line is bounded, i.e., $\xi_2-\xi_1\neq 0$, the circle and line will intersect for x equal to the real roots of equation A.3, which is obtained by eliminating z between equations A.1 and A.2.

$$(m^2+1)x^2 + 2\left[m(b-k)-h\right]x + \left[h^2+(b-k)^2-r^2\right] = 0 \qquad \text{(A.3)}$$

Where A, B, and C are the coefficients in equation A.3, the solutions for x are

$$x_{1,2} = \frac{-B \pm \sqrt{B^2-4AC}}{2A} \quad . \qquad \text{(A.4)}$$

There are no intersections between the extended line and the circle if $B^2-4AC<0$. If $B^2-4AC\geq 0$, the x-coordinates of the intersections are $x_{1,2}$. Then,

$$z_{1,2} = m x_{1,2} + b \quad . \qquad \text{(A.5)}$$

Case 2: $|m| = \infty$

If $\xi_2-\xi_1 = 0$, intersections will be at $x_{1,2} = \xi_1$ if they exist at all. The z-coordinates of intersections will be

$$z_{1,2} = k \pm \sqrt{r^2 - (\xi_1 - h)^2} \quad . \qquad \text{(A.6)}$$

If $r^2 - (\xi_1 - h)^2 < 0$, no intersections exist.

Test 1

Now, when intersections are found to occur with the circle, it is necessary to determine that they intersect the bulge and not the inward extension (dashed -- Figure A-1). The intersected line cannot possibly violate the gap space, i.e., it will not intersect the gap chord, d. Therefore, it is sufficient to show that either intersection, say (x_1, z_1), lies on the bulge arc and not on the extension. Consider two cases: $\theta > \pi$, $\theta \leq \pi$.

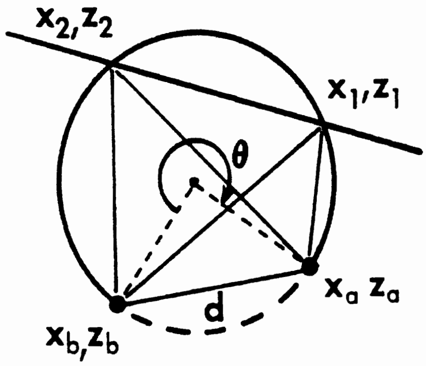

Figure A-2. Segment/ Arc Intersection, $\theta > \pi$

If and only if at least one of the four distances shown is greater than d, the intersections are on the bulge ($\theta > \pi$).

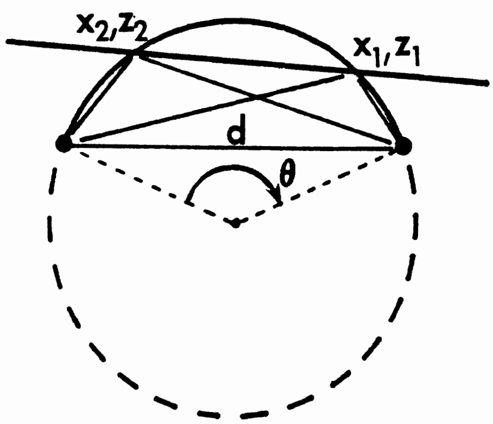

Figure A-3. Segment/ Arc Intersection, $\theta \leq \pi$

If and only if none of the distances shown is greater than d, the intersections are on the bulge ($\theta \leq \pi$).

Test 2

A general algorithm for finding intersections between an arc and a straight-line segment would not require this test, but in the context of determining secondary intersections of the enclosure by arcs of an airbag primary profile (see Section 2.3), it is necessary to discard certain intersections. In particular, by definition of the primary profile, each arc endpoint will lie on a line segment of the enclosure and the arc is therefore intersected by the line. This intersection is not of interest.

Clearly, Test 2 is necessary only when one of the dashed-line distances shown in Figure A-2 or A-3 is zero for this means that the line segment is one of the two in the enclosure which connect to the arc at its endpoints. If one of the distances is zero, then we have one of the two cases illustrated below:

Case I:

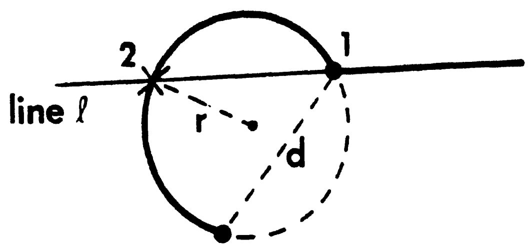

Figure A-4.
Acceptance/Rejection of Intersections: Case I

Case II:

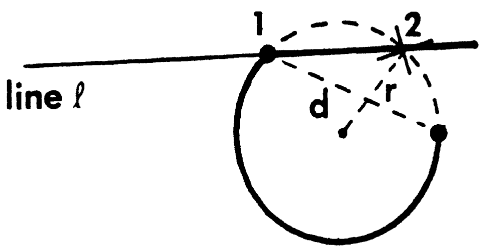

Figure A-5
Acceptance/Rejection of Intersections: Case II

Bold solid lines indicate parts of the primary profile. Light solid lines indicate parts of the enclosure which are not included in the primary profile. Point 1 will be a discarded intersection for each case. For Case II, Point 2 is also discarded, and there are no intersections between the arc and line 1 as far as Subroutine PROFLE is concerned. For Case I, however, the intersection at Point 2 is accepted (as long as it satisfies Test 3), and the line segment will be extended from Point 1 to Point 2 for inclusion in the secondary profile. Arc c of Figure 5 and segment b' of Figure 6 illustrate Case I, and arc d and segment a of Figure 5 illustrate Case II.

The method used to accept or reject the Point 2 intersection, i.e., to distinguish between Case I and Case II, is explained below. First, determine the equation of the straight line which includes Point 2 and the center of the circle of the arc. Call the segment from Point 2 to the center "segment r." Next, determine the equation of the line including the endpoints of the arc and call the chord "segment d." Then determine whether the straight-line segments r and d intersect. There are two cases to consider: $\theta>\pi$ and $\theta\leq\pi$. If $\theta>\pi$ (as illustrated for Cases I and II above), then intersection of segments r and d indicates that Point 2 must be rejected; it is accepted if there is no intersection. If $\theta\leq\pi$ (not illustrated), then the reversed conclusions will be true, i.e., intersection of r and d indicates acceptance of Point 2.

Test 3

One final test must be made in order to establish intersection of the arc and the straight-line segment. It is supposed at this point that Test 1 has been satisfied so that candidate intersection points are known to lie on the arc and not on its circular extension and that Test 2 is satisfied as well. Each candidate intersection point lies on the line containing the straight-line segment of interest, but it is now necessary to determine for each candidate point whether it actually lies within the endpoints of the line segment.

The parametric equations for the line are

$$x = \xi_1 + (\xi_2 - \xi_1)s \qquad (A.7)$$

$$z = \zeta_1 + (\zeta_2 - \zeta_1)s \quad . \qquad (A.8)$$

Here, the parameter s approaches 0 as (x, z) approaches (ξ_1, ζ_1) and s approaches 1 as (x, z) approaches (ξ_2, ζ_2), the two endpoints of the segment. There will in general be two intersections with the line. For each intersection point, determine s:

$$s_{1,2} = \frac{x_{1,2} - \xi_1}{\xi_2 - \xi_1} \qquad (A.9)$$

or use

$$s_{1,2} = \frac{z_{1,2} - \zeta_1}{\zeta_2 - \zeta_1} \qquad \text{if} \quad \xi_2 = \xi_1 \quad (|m| = \infty). \qquad (A.10)$$

If $0 \leq s_1 \leq 1$ and $0 \leq s_2 \leq 1$, then both intersections are on the segment. If neither s_j lies in [0, 1], then the arc does not intersect the segment, i.e., both intersections are instead on an extension of the line segment. If only one s_j lies in [0, 1], then the segment terminates inside the circle. If $(\xi_1-h)^2 + (\zeta_1-k)^2 - r^2 < 0$, then the (ξ_1,ζ_1) -endpoint is within the circle. If this expression is greater than or equal to 0, then the (ξ_2,ζ_2) endpoint is within the circle.

APPENDIX B

CALCULATION OF THE GAS CONSTANT

Let V be the volume of a n moles of a gas at pressure P and absolute temperature T. It is found that for <u>all</u> gases, if the ratio PV/nT is plotted against P for T held constant, the curve for <u>each</u> value of T approaches the same limiting value for the ratio as P approaches zero. This limit is called the "universal gas constant" and is denoted by R_n. Its value is

$$R_n \;=\; 8.3149 \times 10^3 \text{ joules/"kg-mole"-°K} \tag{B.1}$$

where a "kilogram mole" is the mass of gas equal to its molecular weight in kilograms [14]. At low pressures, therefore, we can write -- for all gases --

$$PV = nR_nT \quad . \tag{B.2}$$

Suppose that the molecular weight of a gas is known and that it is desired to find the gas constant appropriate for use in a formulation in which mass m replaces moles n. Where $PV = mR_mT$, we have

$$R_m \;=\; R \;=\; \frac{8.3149 \times 10^3 \text{ joules}}{\text{M.W. kg °K}} \quad ; \tag{B.3}$$

here, M.W. is the molecular weight. In the equations of Sections 2.5 and 2.6, the subscript "m" is dropped and the mass-based gas constant is called simply R. The mass used in the thermodynamics equations in

English system units is "lbm." Since 0.45359237 kg = 1.0 lbm, 1.0 joules = 0.737562143 ft-lb, and 1.0 °K = 1.8 °R, equation (B.3) is equivalent to the following in English system units:

$$R = \frac{1.5454 \times 10^3}{M.W.} \frac{ft\ lb}{lbm\ ^\circ R} \tag{B.4}$$

APPENDIX C

EQUIVALENCE OF TWO VISCOELASTIC MODELS

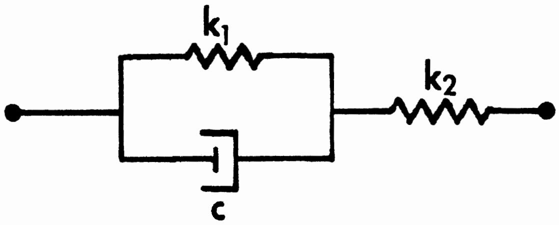

Figure C-1. Three-Parameter Solid

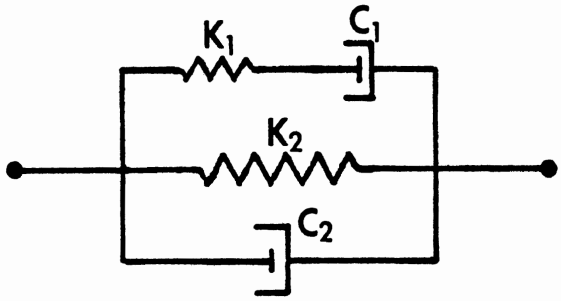

Figure C-2. Four-Parameter Solid

The four-parameter solid model in Figure C-2 and used in Section 2.12 in the bag slap model can be used to represent the three-parameter model shown in Figure C-1. The relationships between the viscoelastic coefficients are given below [15].

$$K_1 = \frac{k_2^2}{k_1 + k_2} \tag{C.1}$$

$$C_1 = c\left(\frac{k_2}{k_1 + k_2}\right)^2 \tag{C.2}$$

$$K_2 = \frac{k_1 k_2}{k_1 + k_2} \tag{C.3}$$

$$C_2 = 0 \tag{C.4}$$