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COMPUTER SIMULATION OF AN AIRBAG-RESTRAINED PASSENGER IN IMPACT SIMULATOR AND CRASH BARRIER TESTS: DEVELOPMENT OF AN IMPROVED PROCEDURE FOR USING A HYGE SLED

Final Report

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16. Abstract

The primary goal of the research described was to establish, by way of computer simulations, an improved procedure for using an Impact Simulator (HYGE sled) to obtain estimates of dummy responses that would occur in full-scale vehicle crash (barrier) tests. The MVMA 2-D CVS Q-FEM Airbag Model was used for all simulations. Impact Simulator tests, a vehicle crash test, and all computer simulations were for a right front-seat passenger in a Chrysler preprototype, S-body vehicle with a midmount passenger-airbag system.

The vehicle crash test produced no important deformations of the occupant compartment, and the X-acceleration crash pulse of the vehicle crash test was reasonably well replicated in HYGE sled tests. The primary differences between Hybrid 3 dummy responses in the vehicle crash test and sled tests were for head A-P acceleration. The time history of that acceleration component is significantly broader and lower in magnitude in the vehicle crash test than in the sled tests. In computer simulations of Hybrid 3 dummy responses in sled tests with various kinds of simulated modifications, the only modification found capable of producing this type of difference in head acceleration response was addition of time-varying pitching motion of the occupant compartment like that which occurs in vehicle crash tests--but not in sled tests. Predicted chest accelerations are improved somewhat as well, and predicted femur loads are good.

The primary finding of the study is that, for the specific type of crash examined, time-varying pitch angle of the occupant compartment is the most important determinant of the differences between occupant motions in an Impact Simulator test and a vehicle crash test. It is, therefore, of particular importance to simulate the pitching motion of the occupant compartment of the vehicle crash test in Impact Simulator tests if they are to be used in place of vehicle crash tests. It is speculated that even with belt restraints, and even in vehicle crashes that do have important occupant-compartment intrusions, time-varying pitching may be very important. A citation is included of a reference that describes test rig designs that provide time-varying pitching in HYGE sled tests.

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COMPUTER SIMULATION OF AN AIRBAG-RESTRAINED PASSENGER IN IMPACT SIMULATOR AND CRASH BARRIER TESTS: DEVELOPMENT OF AN IMPROVED PROCEDURE FOR USING A HYGE SLED

1.0 BACKGROUND

The primary goal of the research described here is to establish, by way of computer simulations, an improved procedure for using an Impact Simulator (HYGE sled) to obtain estimates of dummy responses that would occur in full-scale vehicle crash tests. The MVMA 2-D CVS Q-FEM Airbag Model (Bowman, 1979; Bowman and Bennett, 1988) was used for all simulations. Impact Simulator tests, a vehicle crash test, and all computer simulations were for a right front-seat passenger in a Chrysler preprototype, S-body vehicle with a midmount passenger-airbag system. The general conclusions reached in the study are likely valid, however, for other types of frontal crash tests as well. [Note: References to the Chrysler preprototype, S-body will be made, hereafter, simply as "S-body."]

Dummy responses can differ significantly between a vehicle crash test and an Impact Simulator test supposedly having the same crash pulse. There are several reasons that differences result. One is that the X-acceleration pulse of the Impact Simulator test is not always a good replication of the pulse from the vehicle crash test. Second, an Impact Simulator test does not reproduce pitching motion that occurs in a vehicle crash. Third, in some instances the primary reason for differences is that occupant-compartment panels can move in a crash test whereas in an Impact Simulator test, panels do not move. There are two significant factors: a) In a crash test, because of occupant-compartment intrusion, a panel may not be in its design position at the time it is struck by some part of the dummy. b) A panel may have nonzero velocity with respect to the occupant compartment at the time of contact with the dummy, i.e., it may actually strike the dummy as well as being struck *by* the dummy. The first factor can be accounted for by establishing guidelines for use of nondesign positions for panels in Impact Simulator tests. The second factor certainly cannot be accounted for in any direct, practical way in Impact Simulator tests.[1] Finally, floorpan buckling can occur in vehicle crash tests, with concomitant upward or downward motion of the occupant's seat.

[1] It may be possible to compensate for nonzero panel velocities at impact with the dummy by further adjustment of fixed panel positions, but this seems unlikely since experience from simulation work has shown that typical nonzero velocity panel impacts can have very significant effects on dummy response. Thus, it is not probable that satisfactory vehicle crash simulation by an Impact Simulator test or by a computer simulation of an Impact Simulator test can be accomplished if panel motion has not ceased before contact with the occupant occurs.

2.0 APPROACH AND METHODS

By determining, for a computer simulation of occupant response in an Impact Simulator, the modifications that will give us the best simulation of response in a vehicle crash test, we establish the best manner in which to modify a laboratory Impact Simulator test. It must be kept in mind, however, that not all modifications that can be made in input data sets can be so easily made, if at all, in laboratory tests. Practicality of the corresponding test procedure therefore becomes an important consideration in the simulations, although, for the purpose of establishing mechanisms for particular characteristics of occupant response, computer simulations can still be used in an investigative role.

The most logical way in which to conduct the simulation study described here would probably have been to mimic a corresponding experimental study that could be conducted--with considerably greater difficulty--with vehicle crash and Impact Simulator tests: viz., to first simulate (or conduct) a vehicle crash test and then try to replicate it with a computer simulation (or actual test) of a modified, Impact Simulator test. In fact, however, the test data for the vehicle crash test of this study were not provided until a number of months after the Impact Simulator test data were provided, so the simulations were conducted in reverse order. That is, computer simulations of the Impact Simulator tests were done first. The first series of simulations established a reasonable baseline for computer prediction of Impact Simulator tests; a second series of simulations then investigated possible ways in which the Impact Simulator simulations might be modified to obtain a reasonable baseline simulation for the vehicle crash test. Here, and throughout this report, the term "baseline" implies a computer simulation that replicates an experimental test with good accuracy and upon which a parameter variation study may be reasonably based.

2.1 Data Provided

The data used in the simulations were a mixture of measured, estimated, and assumed data. Data provided by Chrysler are described briefly here. All airbag-system data provided were for one type of airbag--specifically, a midmount passenger bag of one basic shape.

- Vehicle interior dimensions for the S-body vehicle were provided together with mechanical properties for some parts of the occupant compartment, such as the force-deflection curve for the IP.

- Hybrid 3 dummy initial position values were given.

- A time-sequence of profiles for a freely deploying airbag were provided in the form of digitized data. These data

were described as having been derived from sketches and not directly from film. It was thought, however, that times, sizes, and shapes were all reasonably accurate.

- The dimensions of the airbag were given, together with a value for its full volume (6 cu ft), which was said to be accurate to within 10 percent.

- At different times during the study three different mass influx time histories for the airbag system used in the tests were provided. The third one was the one described eventually as the correct one.

- Two different temperature-vs-time histories for source gas were provided. The second, accompanying the third mass influx rate time history, was described as the correct one.

- A pressure-vs-time history for a freely deploying airbag was given in plotted form.

- The airbag was described as being without deflation vents. Gas loss was through porous fabric. Data were provided for two types of fabric, one of high porosity and one of low porosity. A "medium porosity" fabric was said to be the best to use; therefore, values half way between the high and low porosity data were used in the simulations.

- Test data were provided from two Impact Simulator tests, which were said to be "identical." These were tests IS11144 and IS11145. The corresponding vehicle crash test data were from test VC04240. All tests were nominally for delta-V's of 35 mph. Data from tests consisted of crash pulses and occupant responses. The vehicle interior, occupant, and airbag system in the Impact Simulator and vehicle crash tests were described as having been made as nearly identical as possible. Data initially provided were not all filtered, but final provided data used in this simulation study were filtered at 100 Hz (Channel Frequency Class 60, corner frequency 100 Hz). Crash pulse data were used as input to the computer simulations. Occupant response data were used for comparison with computer simulation results. For the simulation work the time history data provided for tests IS11144 and IS11145 were averaged, point by point, to establish a single Impact Simulator "test"--"test IS11144/45."

- Occupant response data provided did not include head angle as a function of time. Instead, for Impact Simulator tests, two angle-vs-time curves estimated from film were described by Chrysler in a telephone conversation. Since the two curves were considerably different, both were plotted with the computer simulation results from the Impact Simulator simulations.

2.2 Other Data, Assumed and Estimated

Data described above as "provided" cannot all be considered to be *measured* data. It is clear from the descriptions of the data that much of it must be considered *estimated*. Data in addition to those described above are required as input to the MVMA 2-D model; all of these data must be considered to have estimated or assumed values. They are described briefly below.

- The "standard" Hybrid 3 dummy data set for the MVMA 2-D model was used. Values in the data set are for size, inertial, and mechanical properties of the dummy. Most values in the data set were determined by General Motors, the developers of the dummy, but no value in the data set can be said with certainty to be *the* correct value.

- Representative mechanical property data were used for some parts of the S-body vehicle interior, such as the toepan, where data were not provided by Chrysler.

- It was concluded from computer simulations that vehicle pitching must have been an important determinant of occupant dynamics in the vehicle crash test. (This will be discussed later.) However, neither vehicle pitch angle nor any time histories from which it could be derived were included in data provided for test VC04240. Data found in the literature for a 35-mph barrier crash were therefore used in some of the vehicle crash simulations. They are assumed to be representative.

3.0 COMPUTER SIMULATIONS

A series of simulations of Impact Simulator test IS11144/45 resulted in two baseline simulations, given the names "IS1" and "IS2". The two baseline simulation data sets were used as the basis for all subsequent simulations, which were made for the purpose of identifying important factors in the simulation of a (barrier) vehicle crash. The IS1 and IS2 simulations both predict laboratory occupant responses reasonably well. Neither, however, is satisfactory in all regards, and it was unknown which data set, when modified for factors important in barrier crashes, would lead to the best replication of vehicle crash test VC04240. A series of simulations based on each of the two Impact Simulator baselines was therefore run. IS1 and IS2 differ in only one input parameter, viz., a quantity called V3, which has a direct relationship to overall stiffness of the airbag.[1] The value of V3 for IS1 is 2,500 cu in and the value for IS2 is 2,000 cu in. Smaller values of V3 correspond to greater airbag stiffnesses. There is greater tendency for the airbag to collapse, i.e., bottom out, for IS1 than for IS2. Full volume for the airbag in all data sets was 9,331 cu in.

The IS1 and IS2 simulation results, and all others, will be discussed in the next section. However, typical plots are illustrated immediately following, in Figures 1 and 2. These example plots are from IS1 and IS2; they are the (translational) kinematic responses of the head. Simulation results for all IS runs are plotted together with experimental, IS11144/45 results.

Table 1 identifies all final simulations by data set name and a brief description. The descriptions (in parentheses), but not the data set names, are printed in the heading of each page of plotted simulation output.

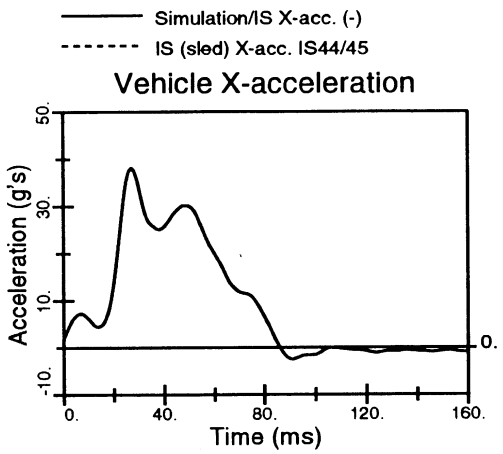
[1] Specifically, V3 is the volume at the break point of a bilinear relationship for "taut volume" as a function of average airbag penetration by the occupant. Taut volume can be described as follows: After the occupant contacts the airbag, bag forces can result even if the thermodynamic volume has not reached the geometric full-bag volume. The occupant profile at any instant of time provides a geometric constraint on airbag shape and "full" volume. We may consider a static situation in which a bag is not fully inflated and yet is made just taut by quasi-statically increasing occupant penetration (averaged over occupant surfaces) to some value δ. Alternatively, and equivalently, we may consider quasi-statically increasing the amount of gas in the bag while holding the occupant position fixed at a penetration δ until the bag becomes just taut. Taut volume is thus established as a function of δ. The value at δ=0 is just the geometric full-bag volume, and the value at δ equal to the airbag diameter is V3.

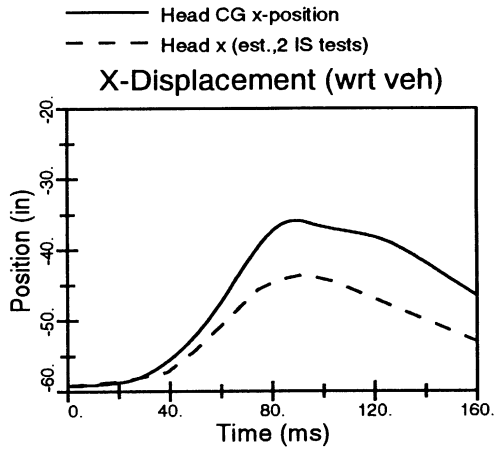
MVMA 2-D CVS Quasi-Finite Element Airbag Model

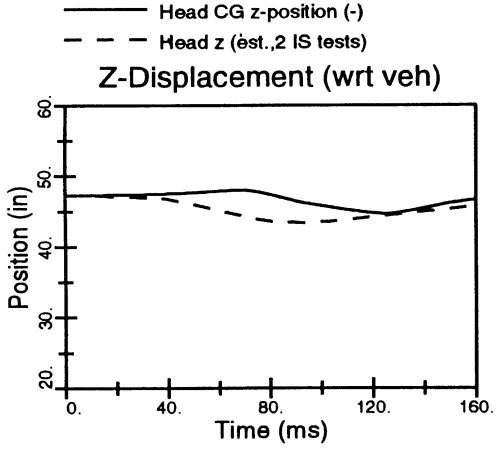
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

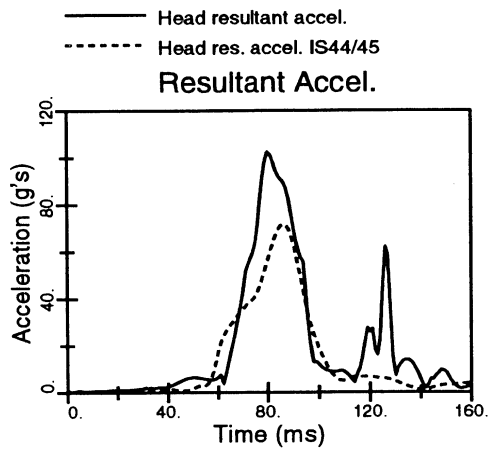
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

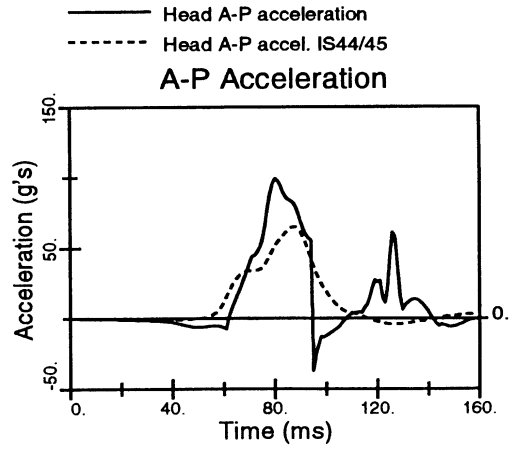
HEAD KINEMATIC RESPONSE











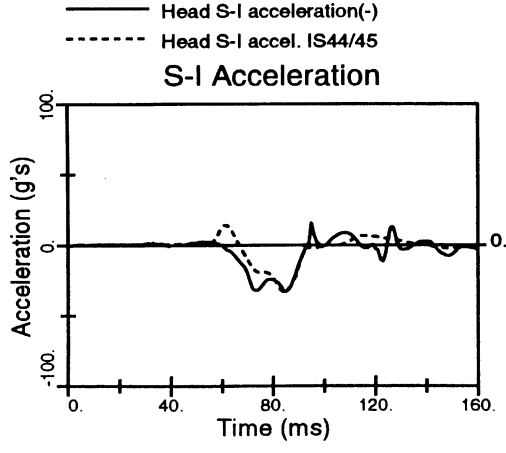


Figure 1.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

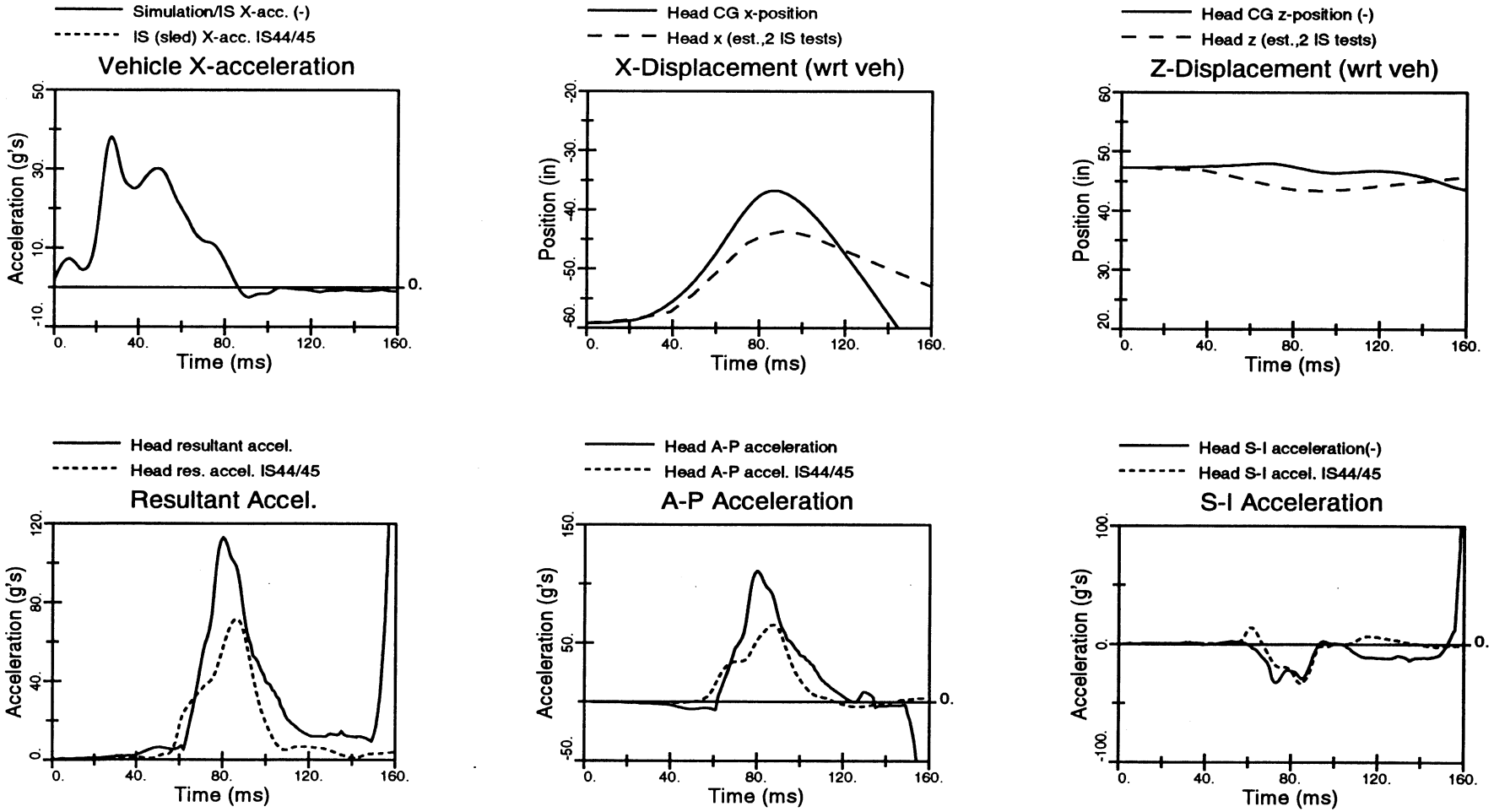


Figure 2.

TABLE 1. Key to MVMA 2-D Simulations

IS baseline
- IS1 (baseline #1: IS)
- IS2 (baseline #2: IS)

VC baseline
- VC1 (baseline #1: VC)
- VC2 (baseline #2: VC)

VC without vehicle pitch
- VC1_0THV (VC #1 without vehicle pitch)
- VC2_0THV (VC #2 without vehicle pitch)

IS with VC x-acceleration
- IS1_VCX (IS #1 with VC X-acceleration)
- IS2_VCX (IS #2 with VC X-acceleration)

IS with VC pitch acceleration
- IS1_THVT (IS #1 with VC pitch acceleration)
- IS2_THVT (IS #2 with VC pitch acceleration)

IS with fixed, nonzero vehicle pitch angle
- IS1_5THV (IS #1 with fixed, 5-degree pitch angle)
- IS2_5THV (IS #2 with fixed, 5-degree pitch angle)

IS with fixed, nonzero vehicle pitch angle
- IS1_9THV (IS #1 with fixed, 9-degree pitch angle)
- IS2_9THV (IS #2 with fixed, 9-degree pitch angle)

IS with VC x-acceleration and fixed vehicle pitch angle
- IS1_VCX5 (IS #1 w. VC X-accel and fixed, 5-deg pitch)
- IS2_VCX5 (IS #2 w. VC X-accel and fixed, 5-deg pitch)

IS with VC x-acceleration and fixed vehicle pitch angle
- IS1_VCX9 (IS #1 w. VC X-accel and fixed, 9-deg pitch)
- IS2_VCX9 (IS #2 w. VC X-accel and fixed, 9-deg pitch)

IS with rearward IP intrusion
- IS1_INTR (IS #1 with occupant surfaces 2" forward)
- IS2_INTR (IS #2 with occupant surfaces 2" forward)

IS with buckled floor
- IS1_BUKL (IS #1 with 3" lower seat, static)
- IS2_BUKL (IS #2 with 3" lower seat, static)

4.0 SIMULATION RESULTS

4.1 The IS Baseline Simulations

The IS1 and IS2 baseline simulation results are shown in Figure 5 (eight pages) and Figure 6 (eight pages). [These figures follow Section 4.2.] Simulation results are plotted together with experimental results (IS11144/45) for all simulation variables for which experimental data are available. These IS1 and IS2 plots are also included in full in the Appendix, where all plots for all simulations of Table 1 may be found.

IS1 (Figure 5) is for the softer airbag and IS2 (Figure 6) is for the stiffer airbag, as described in Section 3.0. A clear consequence of this difference in the data sets may be seen in the upper center plot of the first page of each set of plots. Specifically, the head X-displacements show a greater amount of rebound from the airbag for IS2 than for IS1. Evidence of greater rebound may also be seen in the plot for head resultant acceleration (lower left) for IS2. There, the spike near the end of the curve, beginning at about 150 ms, results from the head striking the seat headrest following rebound from the airbag. In IS1 the peak near 120-130 ms is associated with head angular acceleration and flexion torque in the neck that occur following chest rebound from the airbag.

Examination of all plots for both IS1 and IS2 shows that there is excellent agreement between experiment and simulation with regard to timing (phase) of occupant responses. Specifically, the available experimental data are for head X- and Z-displacements; head resultant, A-P, and S-I accelerations; chest resultant, A-P, and S-I accelerations; pelvis resultant, A-P, and S-I accelerations;[1] and averaged left-and-right femur loads. Simulation response curve shapes are in good agreement with experimental results. Simulation peak magnitudes are in less good agreement with experimental peaks, with differences in magnitudes generally in the 25-50 percent range. (Simulation magnitudes are consistently larger than experimental magnitudes.) Overall, however, simulation responses for both baselines, IS1 and IS2, can be considered reasonably good. This assessment is valid partly in view of the fact that many inputs are known only in approximation, as discussed in Sections 2.1 and 2.2. It should be noted, further, that in *any* parameter variation study, absolute magnitudes of response are less important than the relative magnitudes for the various simulations. Specifically, in this instance, this means the VC (vehicle crash) computer simulation responses relative to the IS computer simulation responses; these comparisons are discussed below.

[1] For the pelvis, inertial X- and Z-components of acceleration were plotted for the simulations since it is unknown how A-P and S-I components were defined in the laboratory tests.

4.2 The VC Baseline Simulations

A possibly exhaustive list of mechanisms that can account for differences in occupant response in laboratory Impact Simulator tests and vehicle crash tests is given in Section 1.0. One or more of those mechanisms is anticipated to be a factor in observed differences between Chrysler tests IS11144/45 and VC04240. A comparison of the occupant responses for IS11144/45 and VC04240 is shown in Figure 4 (eight pages, following this section). It may be seen that even without modification of the Impact Simulator experiment, results match vehicle crash experimental responses reasonably well except for head A-P acceleration and pelvis S-I acceleration. (The difference in resultant head accelerations is explained almost fully by the difference in the A-P components.) Of these two, prediction of head acceleration is certainly the more important. "Correction" of head translational acceleration in the Impact Simulator tests --with possible concomitant improvement of other responses (or, at least, no degradation of those responses)--is therefore the goal of IS and VC computer simulations in this study. It should be noted in particular that in the Impact Simulator tests, the head resultant and A-P acceleration responses are narrow (≈50 ms) and high--about 75 G's. This is greatly different from the head response in the vehicle crash test, viz., a broad (≈100 ms), plateau-like response of less than 25 G's average magnitude. With regard to computer prediction of head acceleration response, then, the goal will be to produce--in vehicle crash simulations--a broad pulse that has a magnitude of about a third the magnitude of the head acceleration in the Impact Simulator tests.

The obvious first approach to improving the degree to which IS results match VC results is to make the HYGE X-acceleration pulse agree more closely with the vehicle crash pulse--exactly, if possible. Therefore, the first "VC" data sets run were nothing more than the IS1 and IS2 baseline data sets with the IS11144/45 crash pulse replaced by the VC04240 crash pulse. The vehicle pitch angle in these simulations was identically zero, as in the Impact Simulator tests and baseline computer simulations. Therefore, the VC data sets were named VC1_0THV and VC2_0THV, where "0" and "THV" indicate a value of zero for θ_V, the vehicle pitch angle. The results of these simulations are in Figures 9 and 10 (in the Appendix). There is no improvement over IS1 and IS2 in the degree to which responses match the experimental VC04240 dummy responses. Indeed, a comparison with Figures 5 and 6 shows that VC1_0THV and VC2_0THV results are negligibly different from the IS1 and IS2 results; that is to say that differences in the X-acceleration pulses no greater than seen in the upper left graph on the first page of Figure 4 may possibly be safely ignored in Impact Simulator experiments.

In order to examine the importance of time-varying vehicle pitch angle it was desired to make vehicle crash simulations like VC1_0THV and VC2_0THV except with the actual vehicle pitch-angle time history in addition to the actual X-acceleration time

history. It was found, however, that time histories from which vehicle pitch angle could be derived were not included among the channels of data provided for test VC04240. Data were not available for pitch angle, pitch angle velocity, or pitch angle acceleration. Further, translational data were available only in the form of accelerations, and while both X- and Z-acceleration data for "LEFT FRONT SILL" and "RIGHT FRONT SILL" were available (channels 7-10) and also X-acceleration data for "LEFT REAR SILL" and "RIGHT REAR SILL" (channels 11,12), no Z-acceleration data were available for the "rear sill" accelerometer locations. (Nor were locations in vehicle coordinates of the accelerometer mounts immediately available.) Since the requisite experimental data from test VC04240 were not available, data assumed to be representative were found in the literature (Berge, et al., 1985). Specifically, pitching motion data--angle vs. time--for a 35-mph barrier crash of a Volvo 760 were used. The vehicle pitch time history is shown in Figure 3, which was extracted from the identified reference[1]. Maximum pitch angle is 6.1 deg (back end up). In order to properly specify constrained, vehicle pitch-related motion to the MVMA 2-D model, use was also made of data in the paper for time-varying vertical displacement of three points surrounding the center of gravity of the vehicle.

The data sets constructed *by adding the described vehicle pitch data* to VC1_0THV and VC2_0THV were found to yield *the best simulations of test VC04240 determined in this study.* They were therefore named VC1 and VC2 and are *the vehicle crash simulation baselines*, which correspond to IS1 and IS2, the Impact Simulator baselines. Simulations that investigated other candidate factors for explaining the large difference between head acceleration response in the vehicle crash test and the Impact Simulator tests are discussed in Section 4.3.

The simulation results for VC1 and VC2 are shown in Figures 7 and 8. For both baselines the head bottoms out just before its forward motion is stopped by the airbag, and spikes corresponding to head-IP contact are seen at about 120 ms. This spike is reduced in the case of the stiffer airbag (simulation VC2). Without changes in values for airbag-system parameters thought to be "knowns," this bottoming out against the IP in the VC simulations cannot be prevented, but it is certain that only relatively small revisions of "known values" would be required to prevent IP contact since peak head-IP forces, particularly for VC2, are small. It is apparent that the head did not bottom out against the IP in vehicle crash test VC04240 since there is no significant spike at 120 ms for the head resultant acceleration. The head A-P acceleration response through 100 ms for both VC1 and VC2 matches experimental response reasonably well in an average sense, i.e., if simulation results are smoothed. The

[1]Berge, S.; Lundell, B.; Nilsson, M. 1985. Simulation of vehicle pitch in sled testing. Volvo Car Corporation, Goeteborg, Sweden. 5 p. Field Accidents: Data Collection, Analysis, Methodologies, and Crash Injury Reconstructions. Warrendale, SAE, Feb 1985. Pp. 127-131. Report No. SAE 850098.

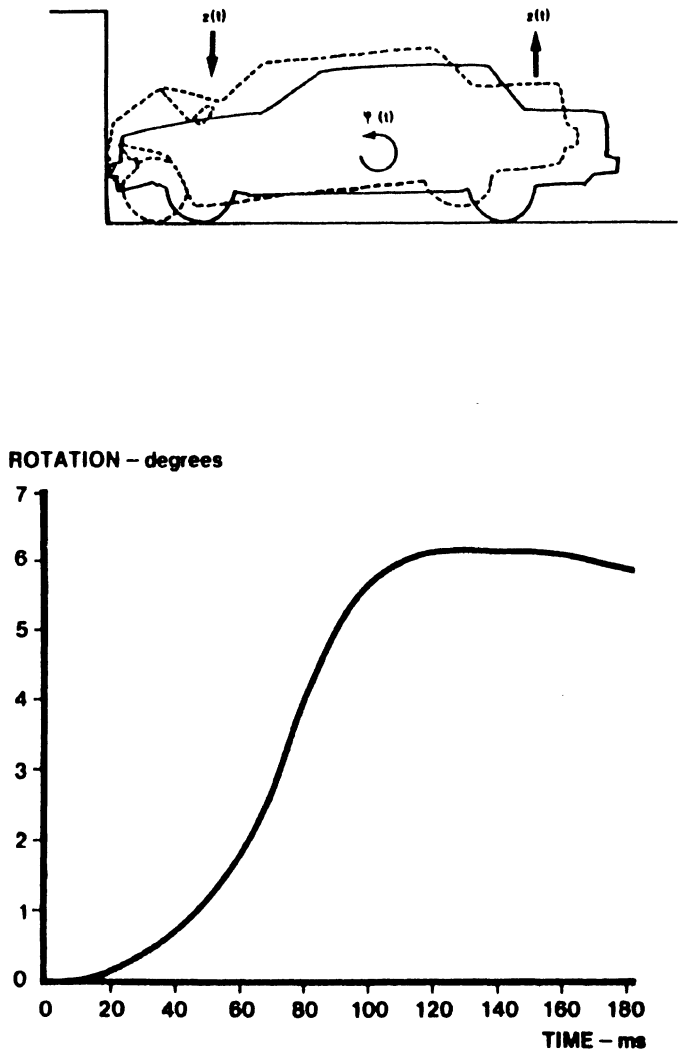
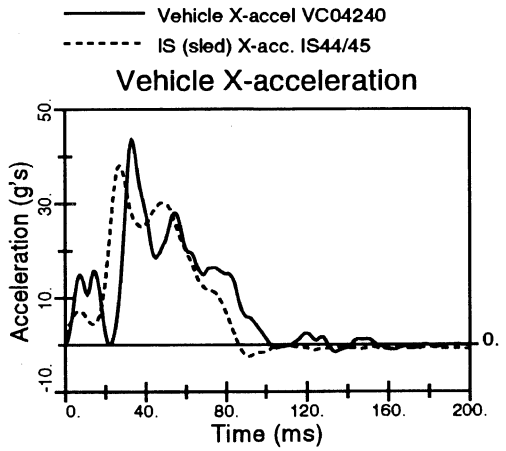


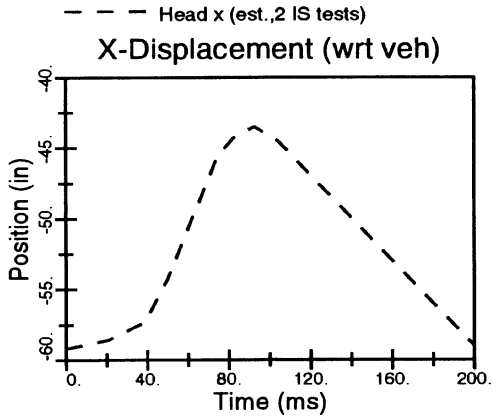
Figure 3. Time-varying pitch angle for occupant compartment of a Volvo 760 in a 35-mph barrier crash (from Berge, et al., 1985)

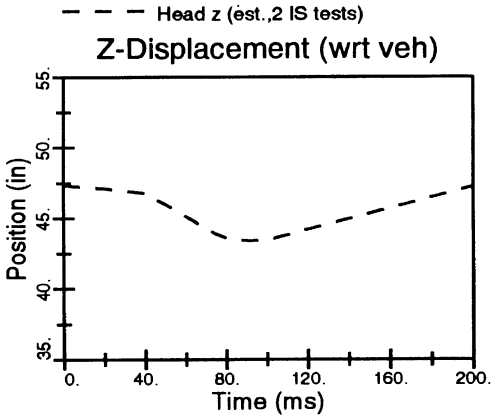
great degree of improvement that results from introducing vehicle pitching motion is seen clearly in both head and chest acceleration responses. Chest acceleration responses, while good in VC1_0THV and VC2_0THV (Figures 9 and 10 in the Appendix), are improved substantially, with error relative to experimental response being roughly 10-15 percent instead of 50-75 percent. Head resultant accelerations through 100 ms (prior to bottoming out at 120 ms) are still in disagreement with crash test VC04240 results--too high by 50-75 percent--but they are *much* improved in both magnitude and shape in comparison with the VC1_0THV and VC2_0THV results, where values are on the order of 250 percent too large. That is, inclusion of time-varying vehicle pitch angle produces approximately a four- to five-fold improvement in head resultant acceleration response and yields errors versus experimental data much more like errors in the IS baseline simulations (25-50 percent, high). Thus, on a relative basis, the vehicle crash baseline simulations, VC1 and VC2, are of about the same quality as the Impact Simulator baseline simulations, IS1 and IS2. This may indicate that there is not great likelihood, without changing values of "knowns," as discussed previously with regard to IS1 and IS2, that it will be possible to greatly improve upon VC1 and VC2.

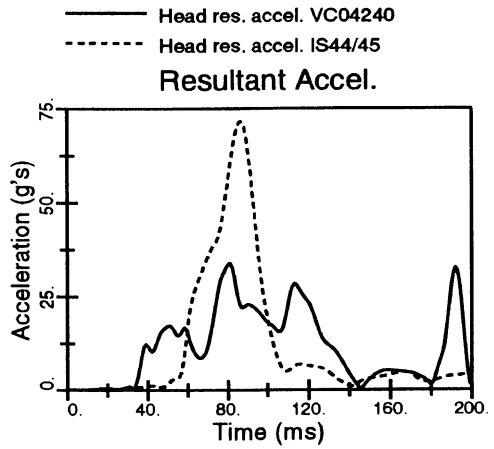
[Section 4.3 begins on page 54.]

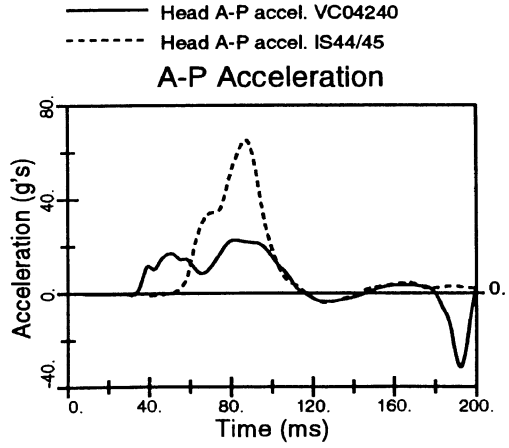
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HEAD KINEMATIC RESPONSE











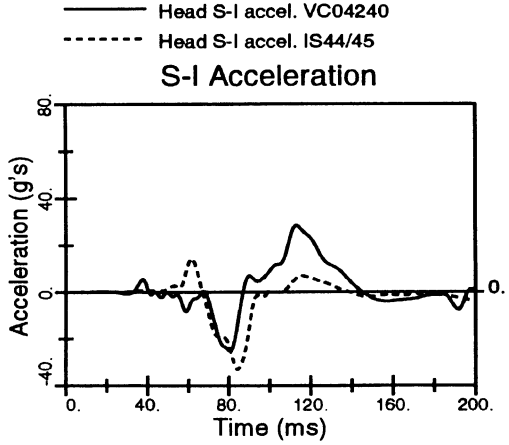
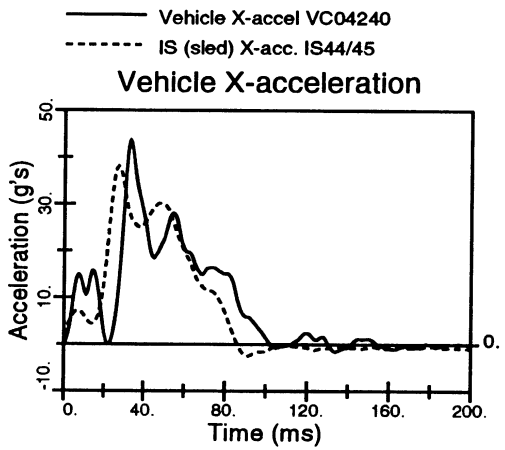
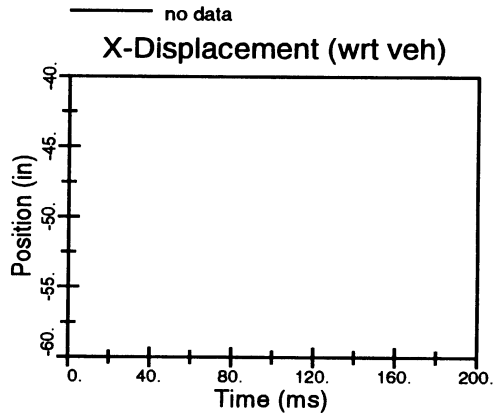
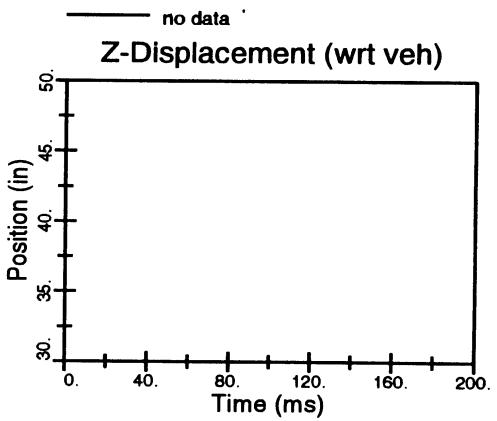


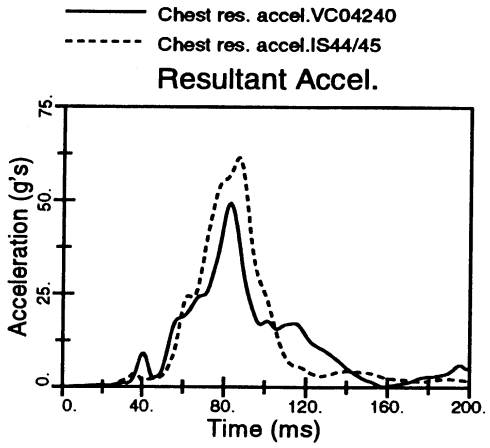
Figure 4.

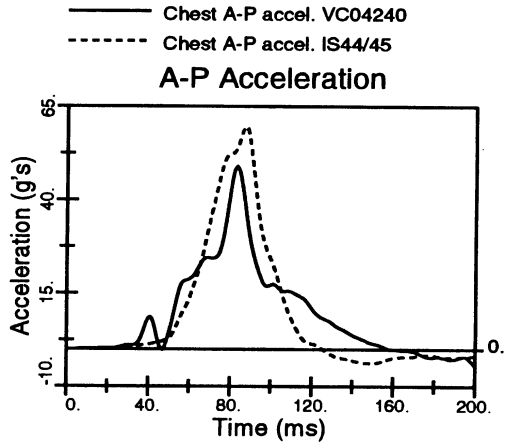
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
CHEST KINEMATIC RESPONSE











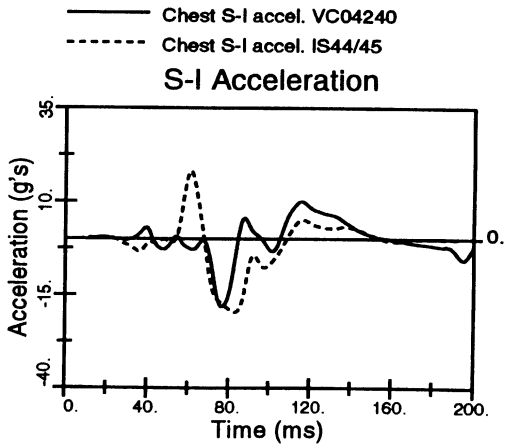
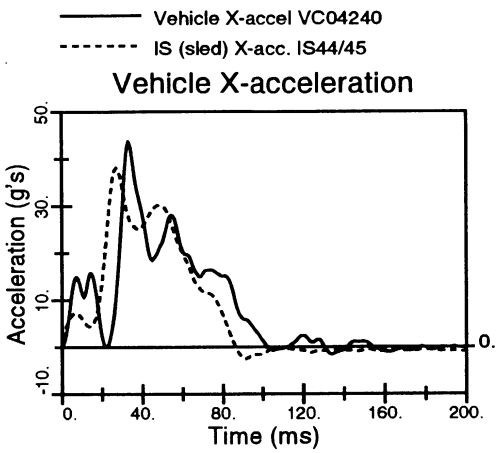
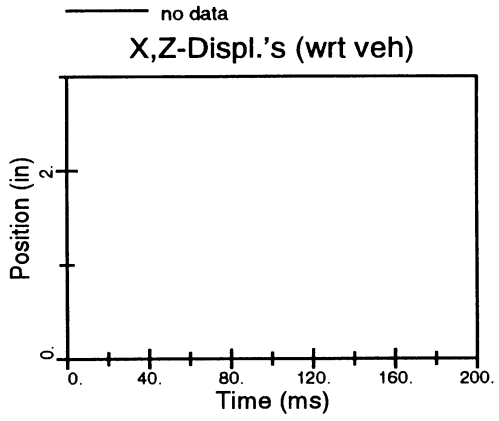
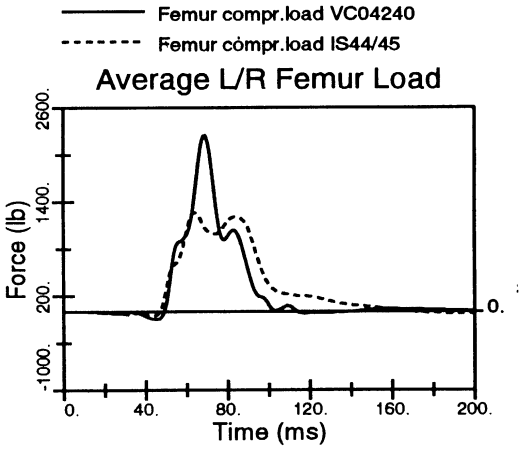


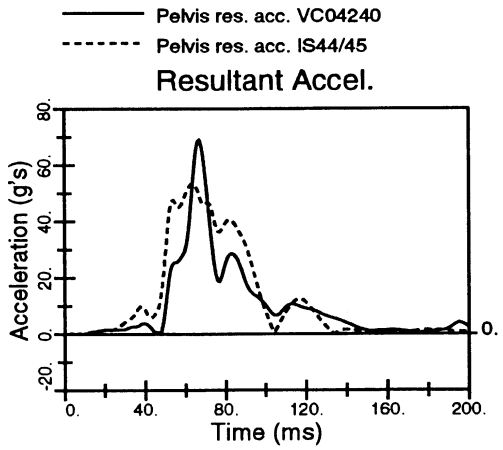
Figure 4.

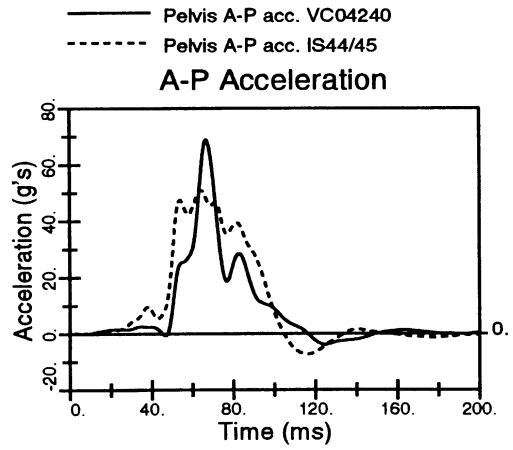
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HIP KINEMATIC RESPONSE / FEMUR LOAD











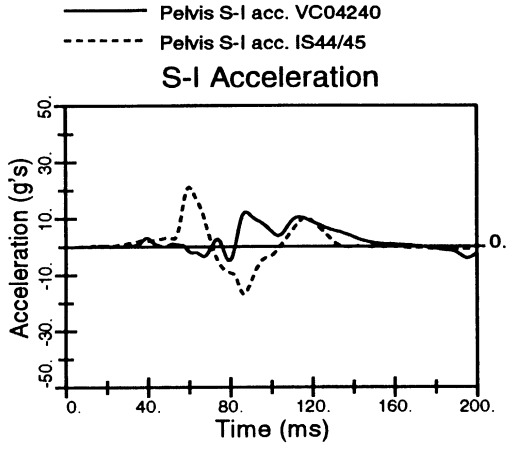


Figure 4.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HEAD ANGULAR RESPONSE / OTHER RESPONSES

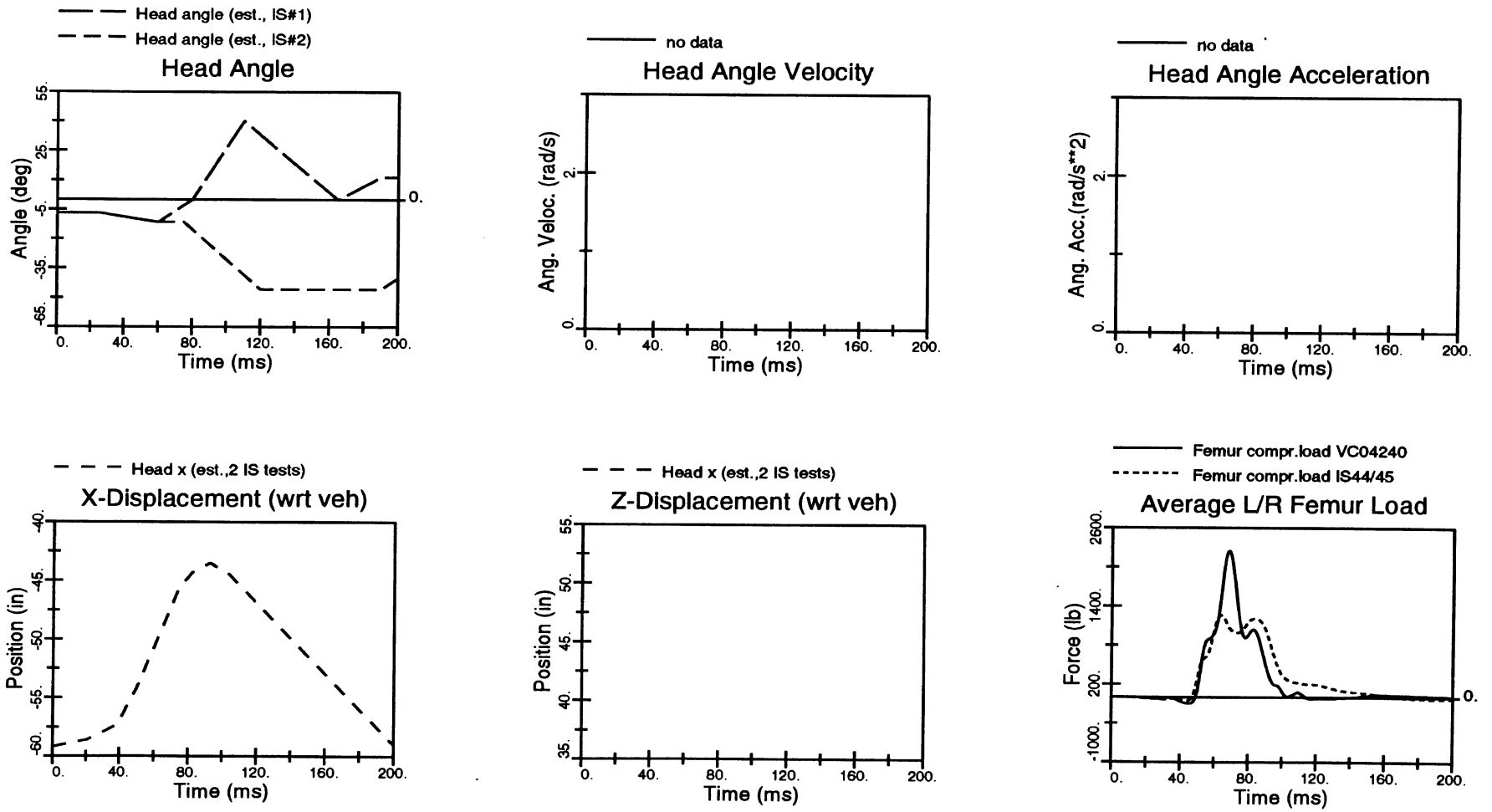
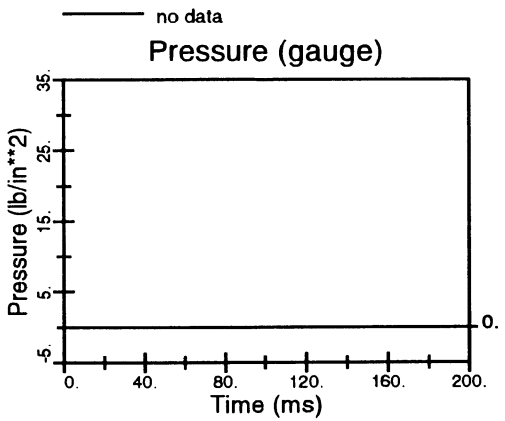
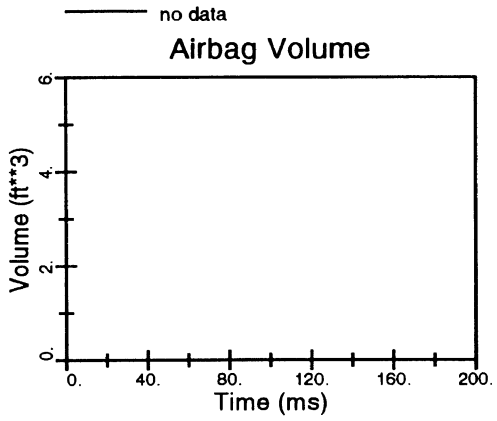
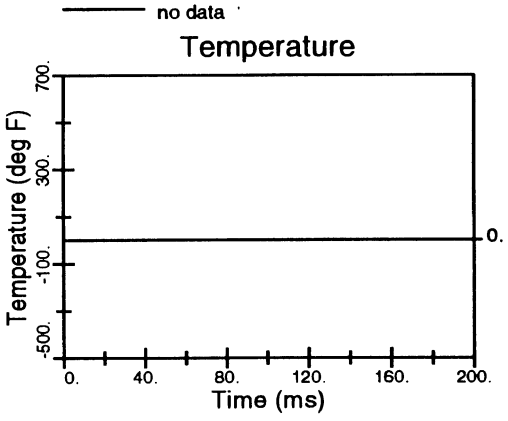


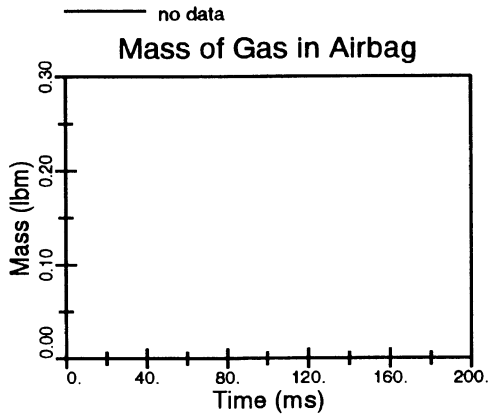
Figure 4.

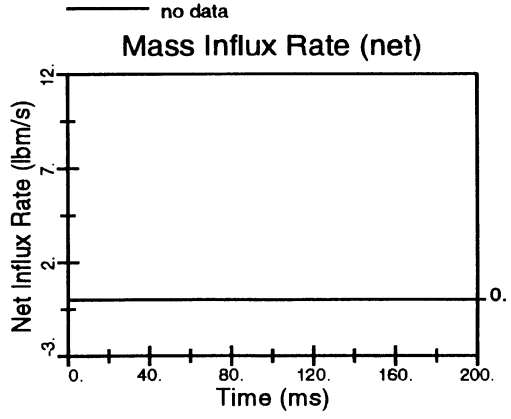
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
THERMODYNAMIC VARIABLES











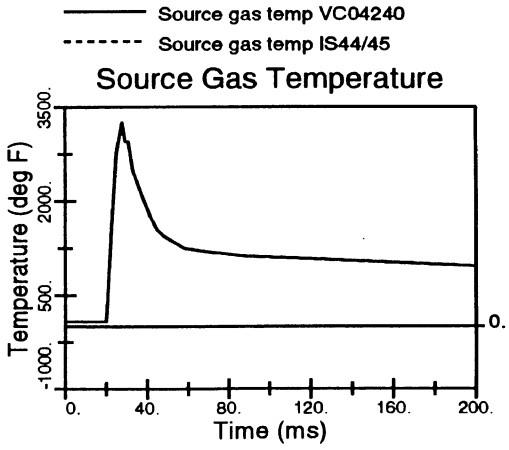


Figure 4.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
AIRBAG MASS INFLUX/OUTFLUX

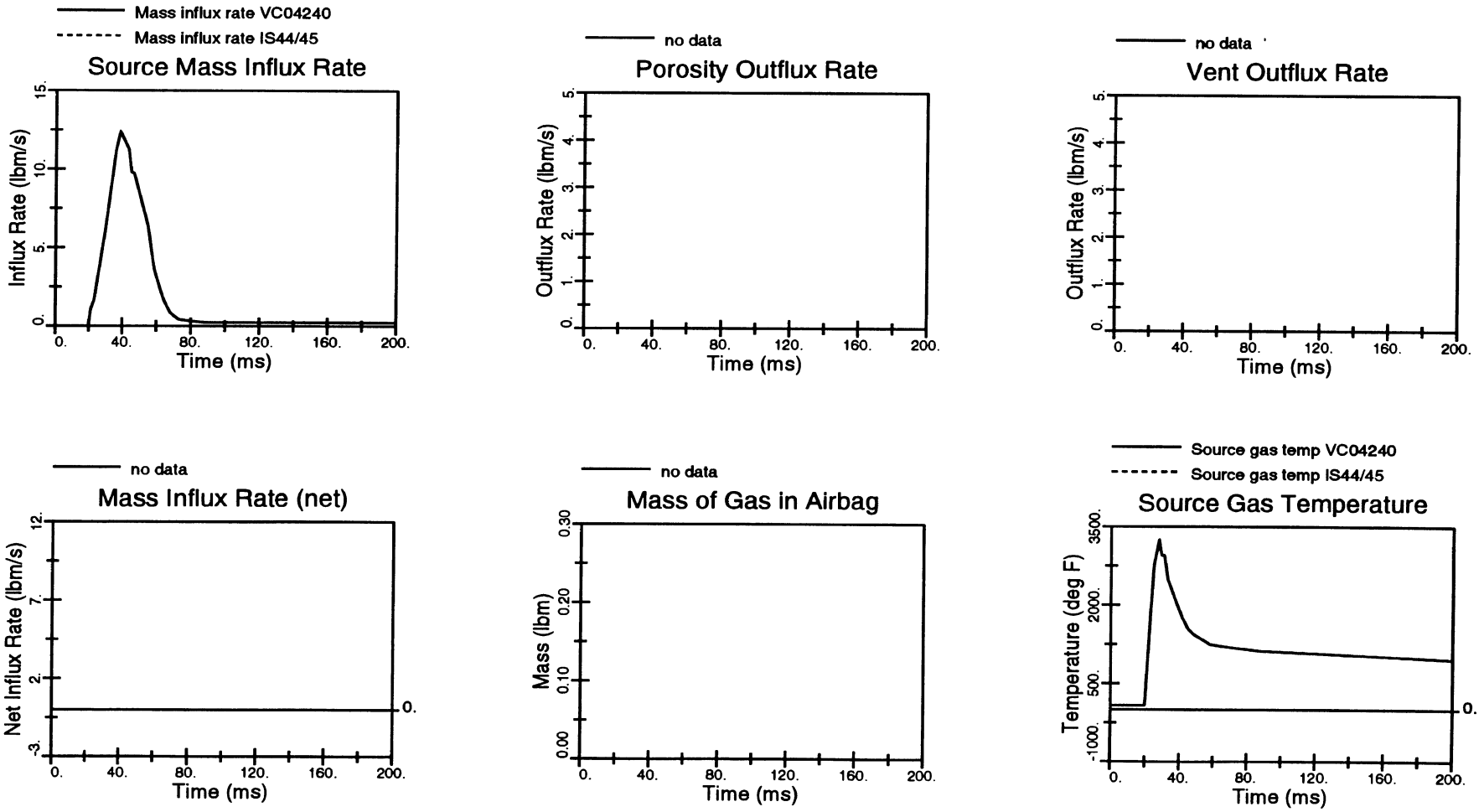
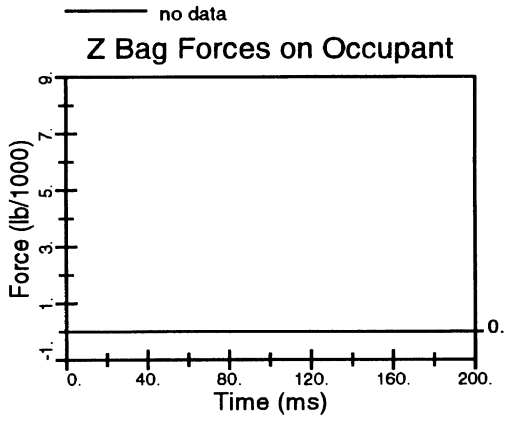
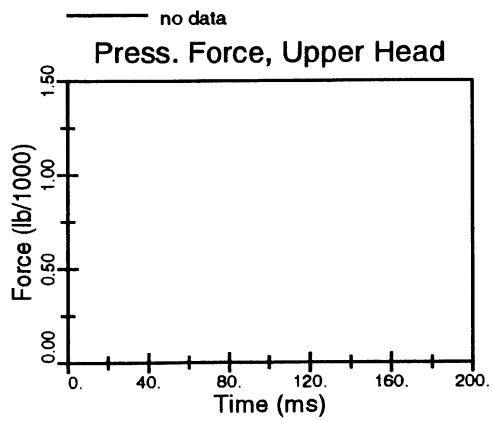
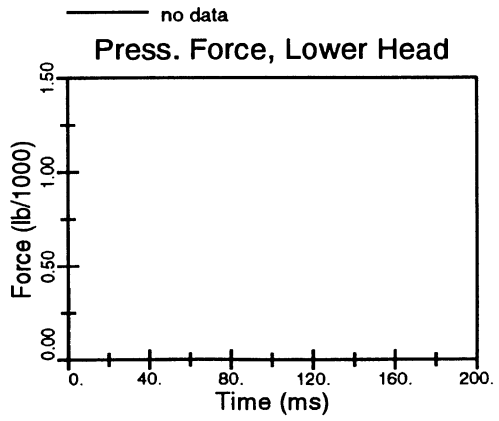


Figure 4.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
AIRBAG FORCES (SUMMARY)







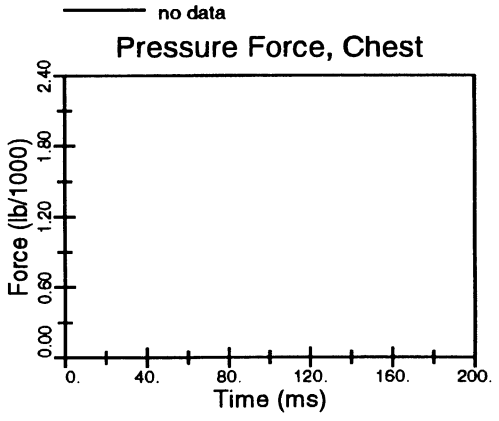
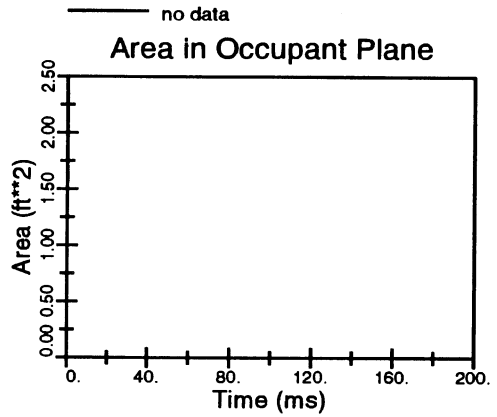
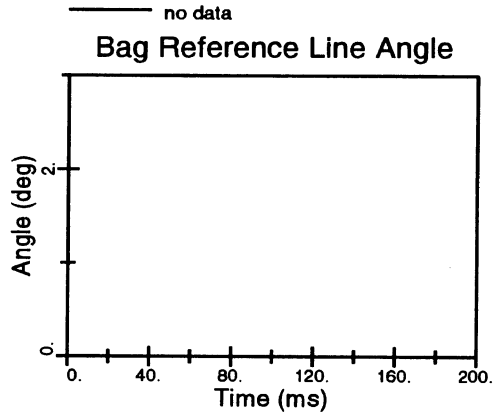
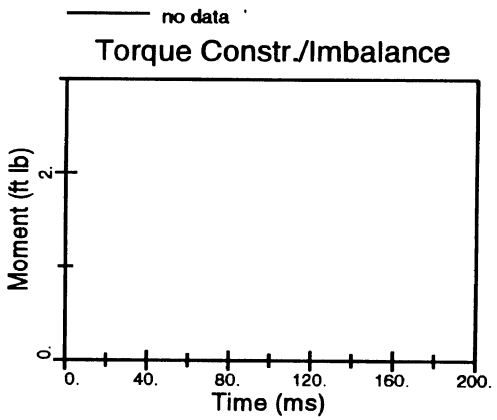


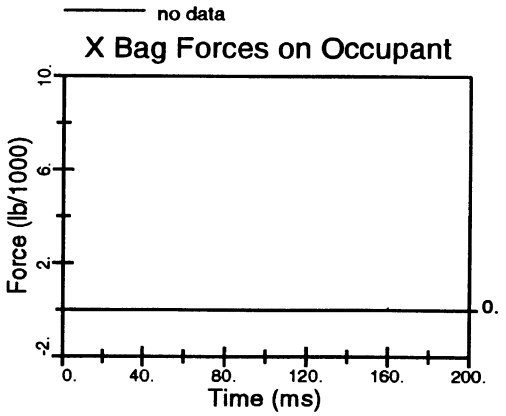
Figure 4.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
MISCELLANEOUS AIRBAG RESPONSE VARIABLES









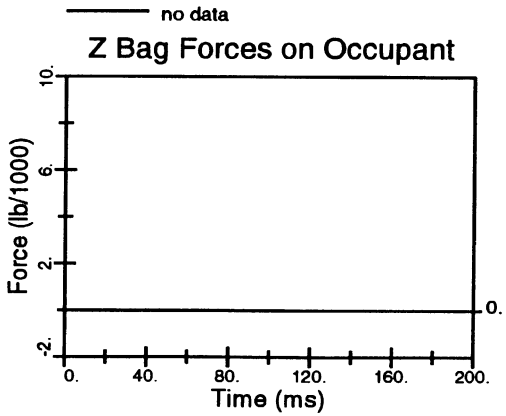


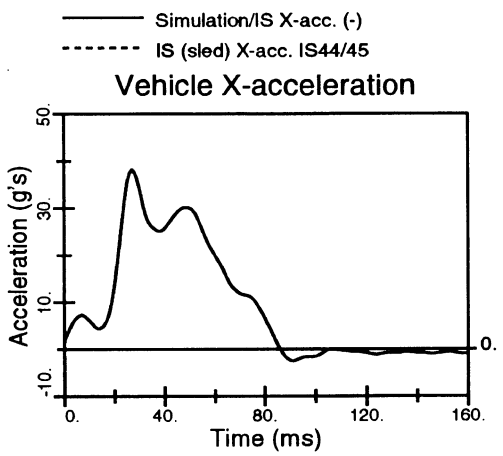
Figure 4.

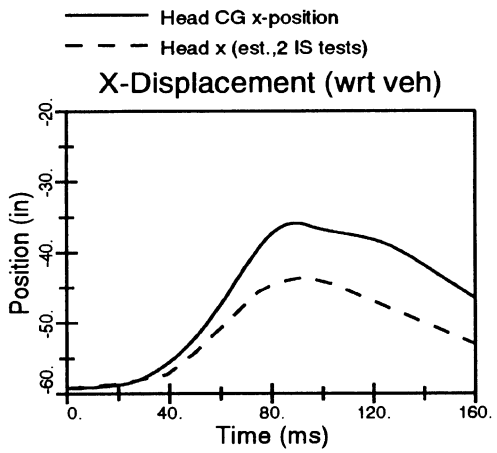
MVMA 2-D CVS Quasi-Finite Element Airbag Model

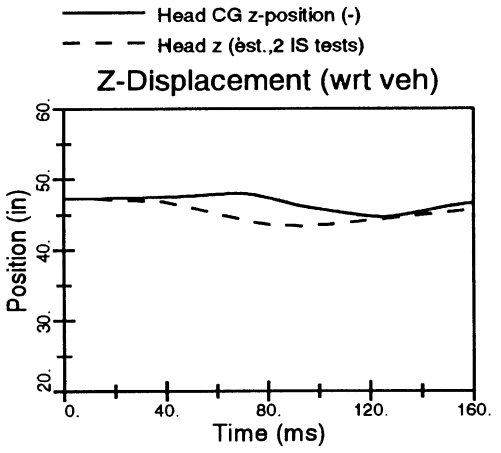
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

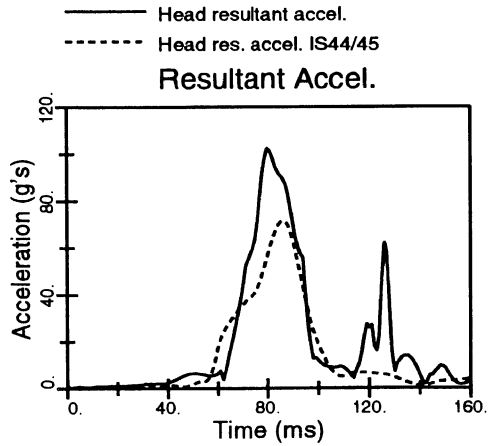
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

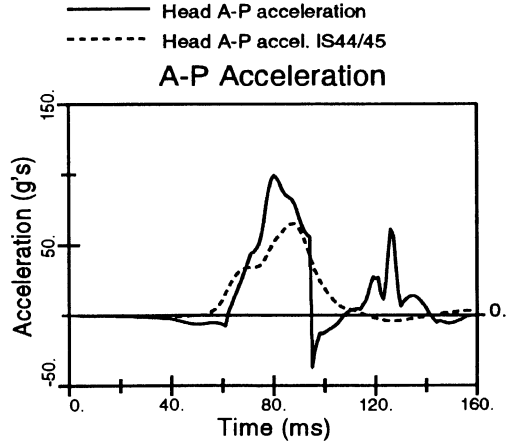
HEAD KINEMATIC RESPONSE











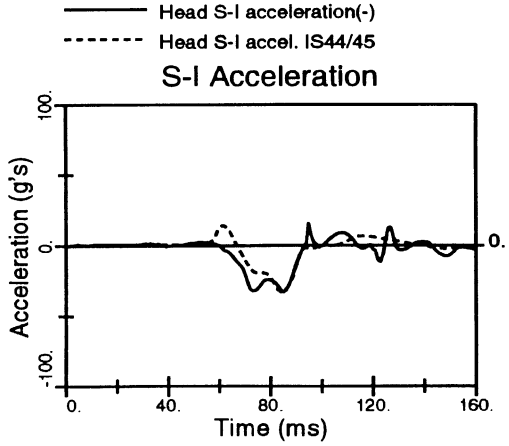


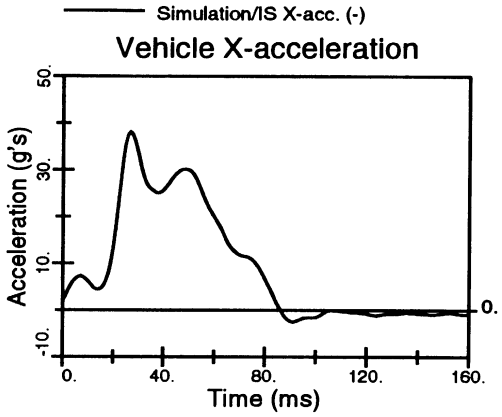
Figure 5.

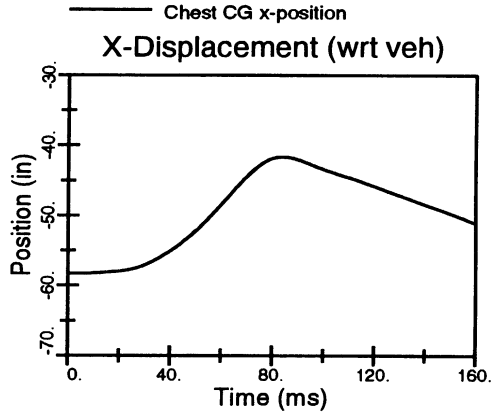
MVMA 2-D CVS Quasi-Finite Element Airbag Model

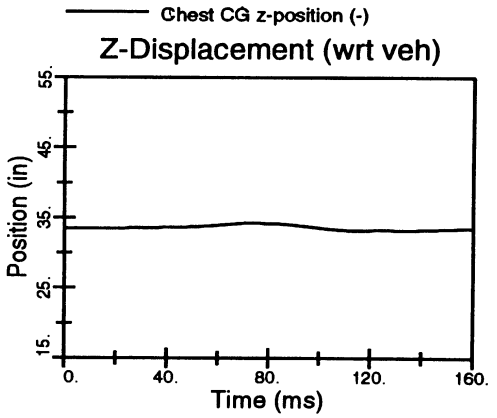
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

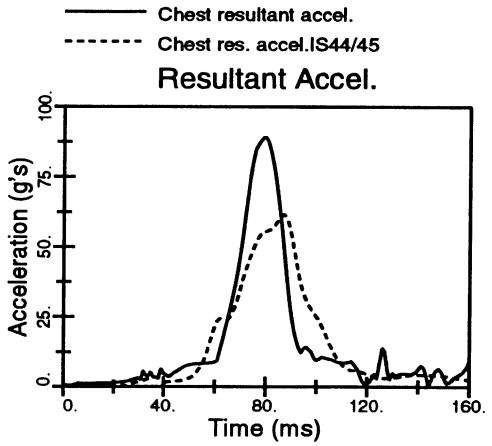
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

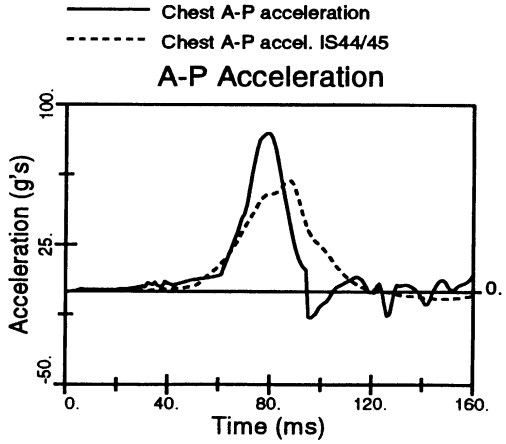
CHEST KINEMATIC RESPONSE











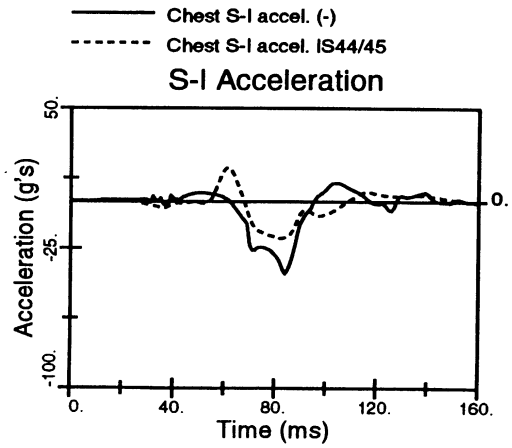


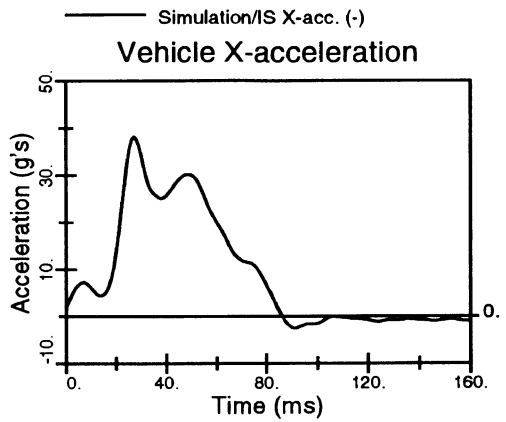
Figure 5.

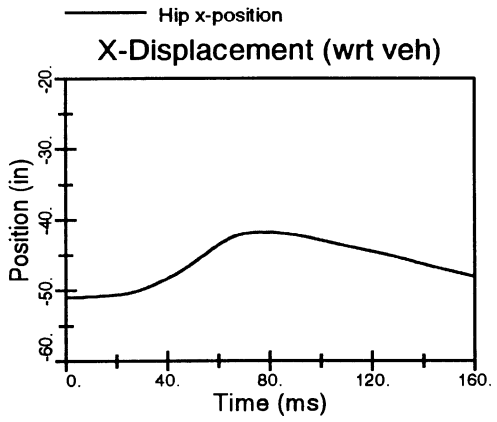
MVMA 2-D CVS Quasi-Finite Element Airbag Model

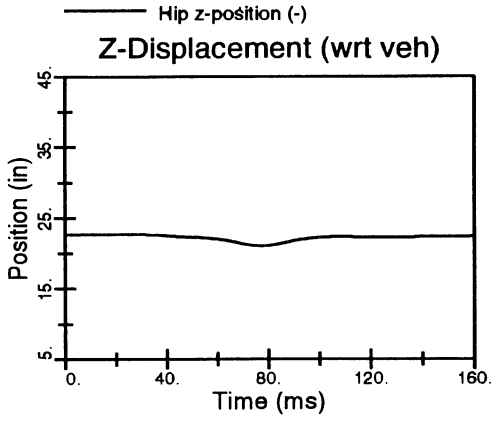
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

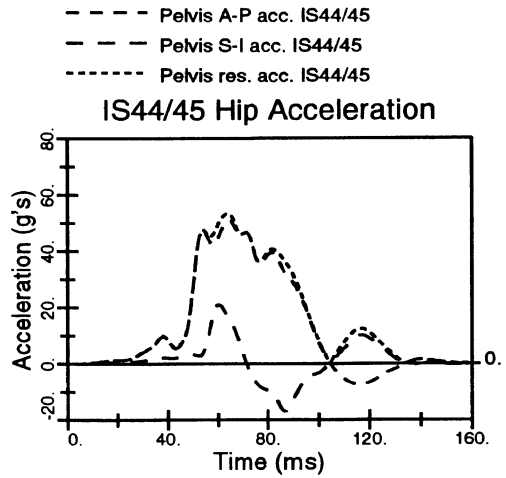
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

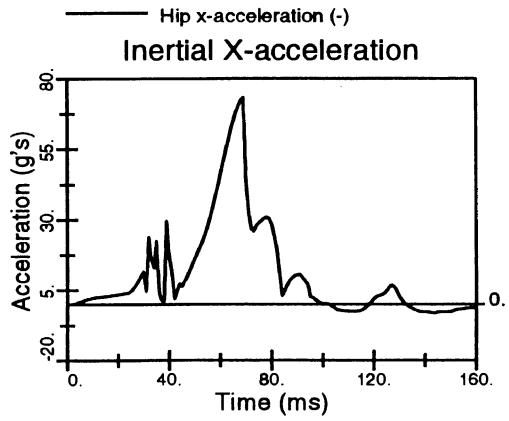
HIP KINEMATIC RESPONSE











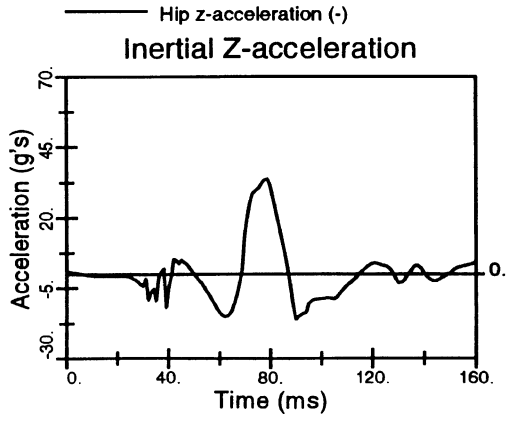


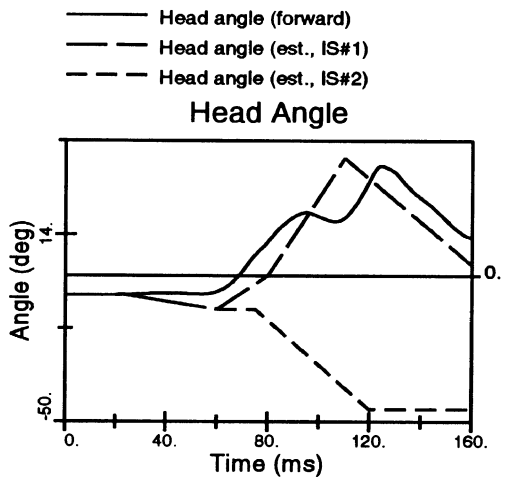
Figure 5.

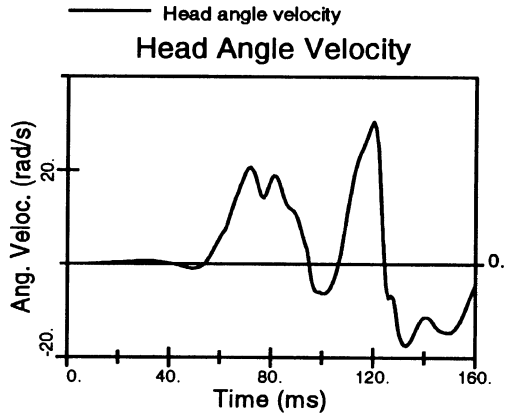
MVMA 2-D CVS Quasi-Finite Element Airbag Model

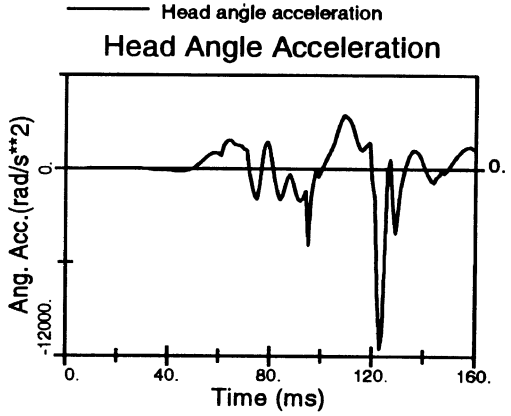
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

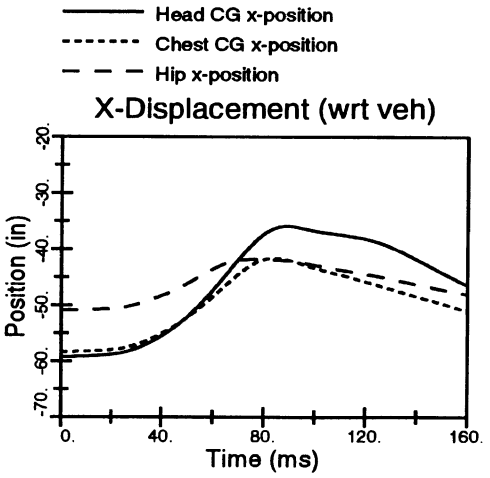
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

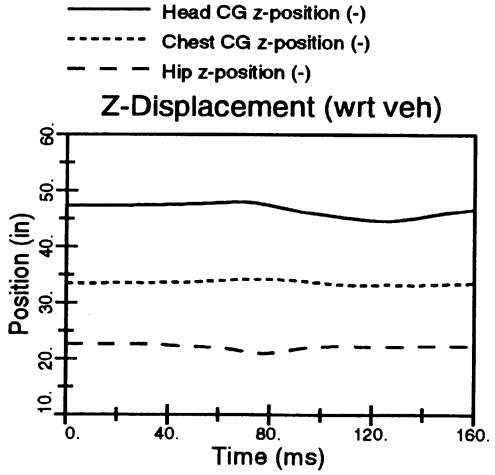
HEAD ANGULAR RESPONSE / OTHER RESPONSES











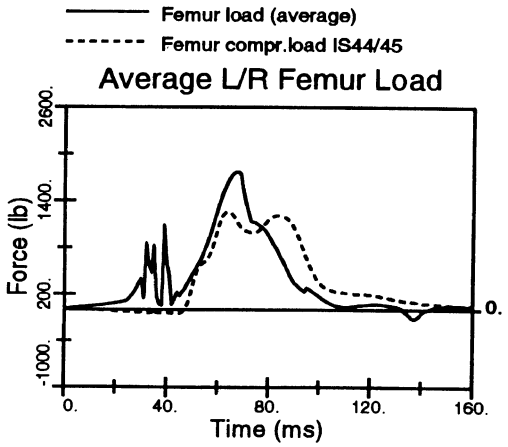


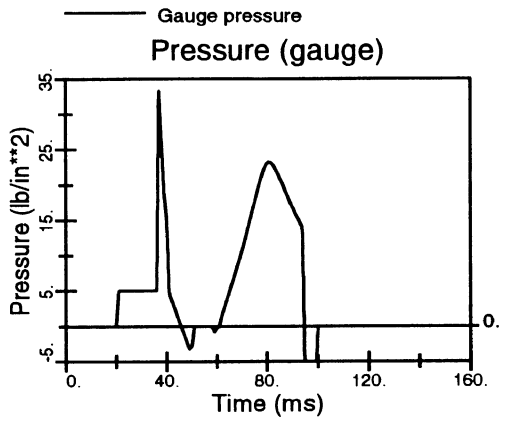
Figure 5.

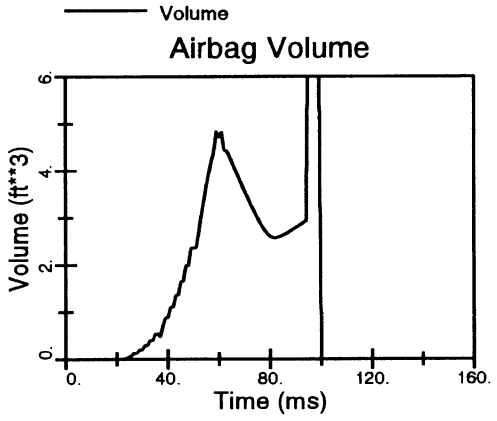
MVMA 2-D CVS Quasi-Finite Element Airbag Model

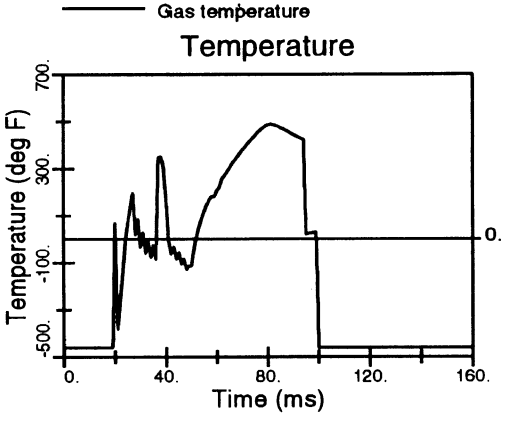
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

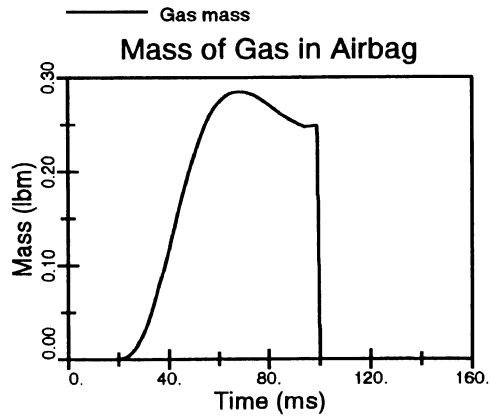
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

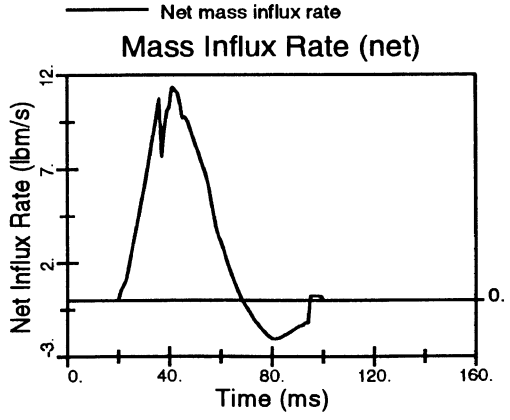
THERMODYNAMIC VARIABLES











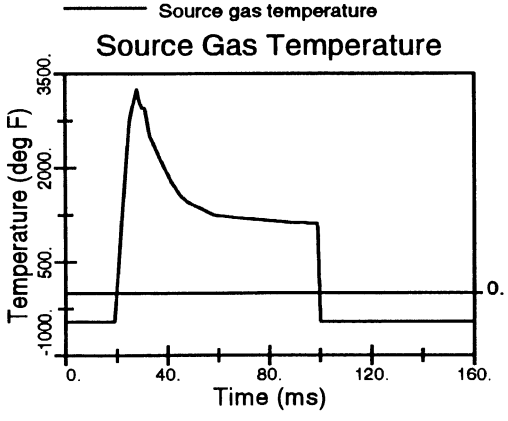


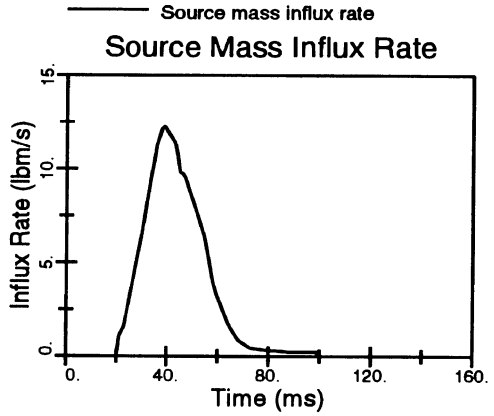
Figure 5.

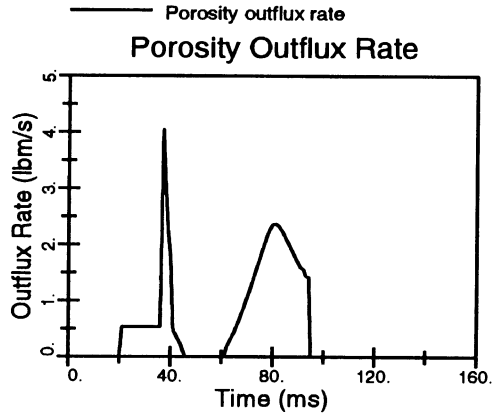
MVMA 2-D CVS Quasi-Finite Element Airbag Model

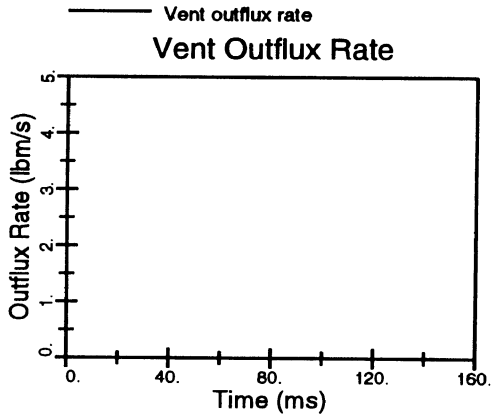
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

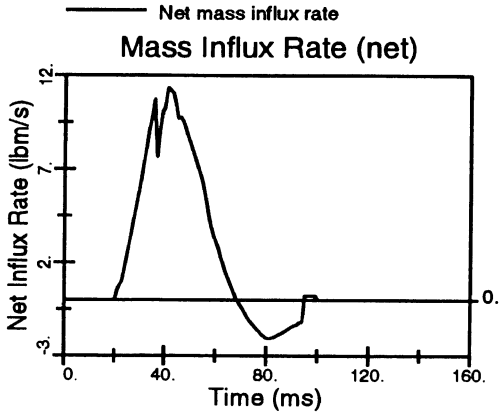
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

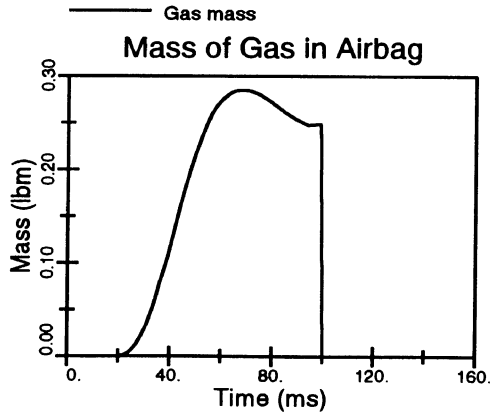
AIRBAG MASS INFLUX/OUTFLUX











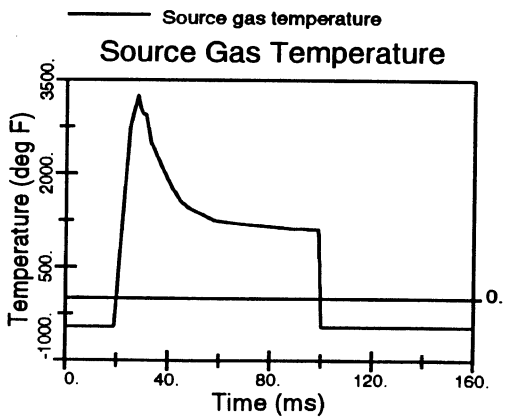


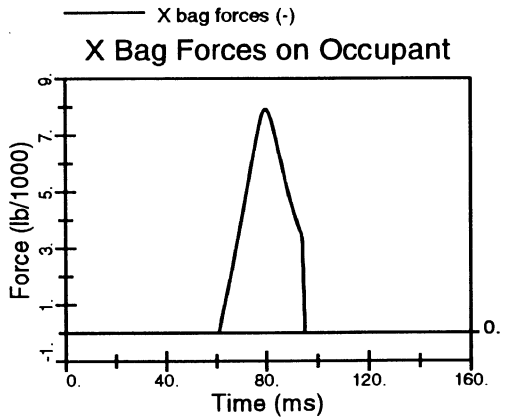
Figure 5.

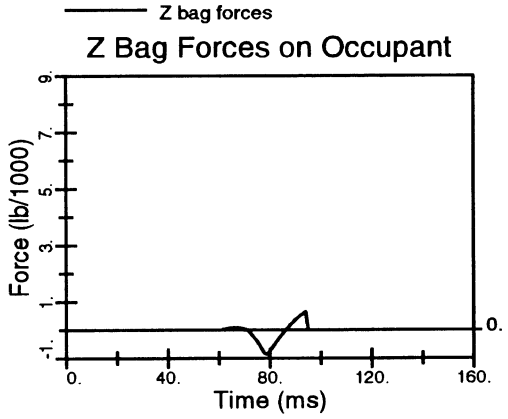
MVMA 2-D CVS Quasi-Finite Element Airbag Model

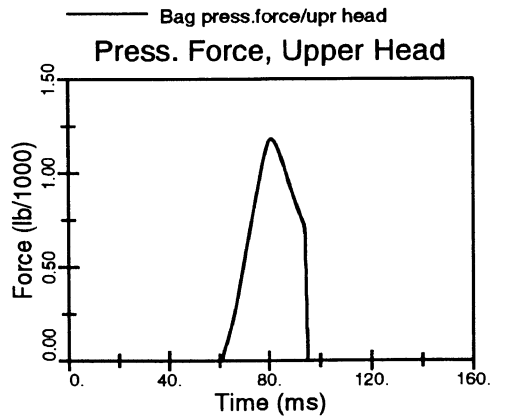
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

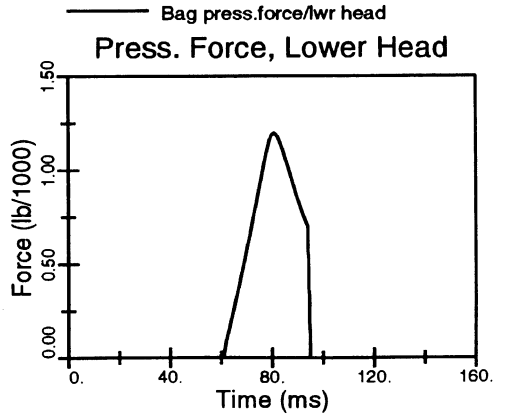
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









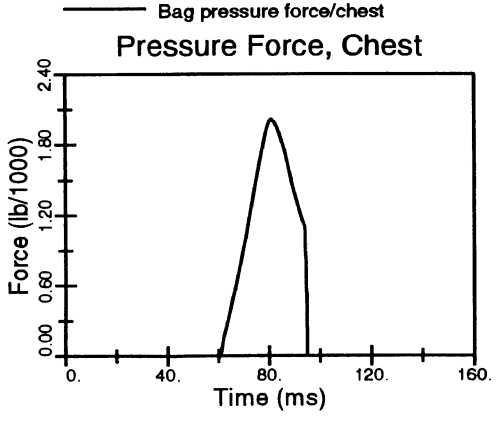


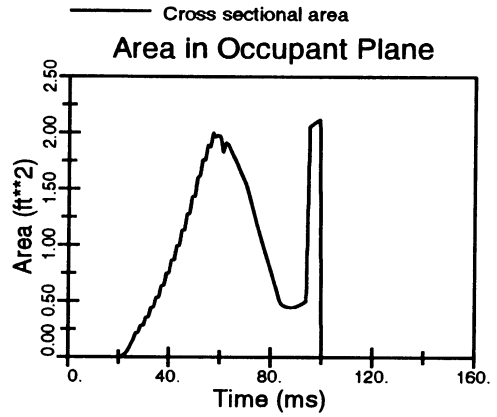
Figure 5.

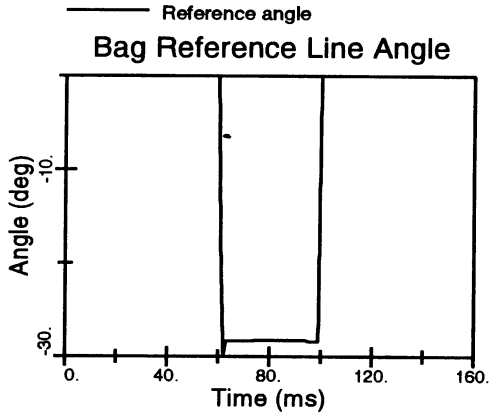
MVMA 2-D CVS Quasi-Finite Element Airbag Model

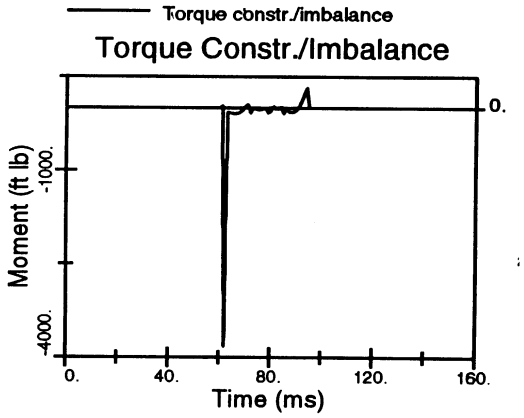
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

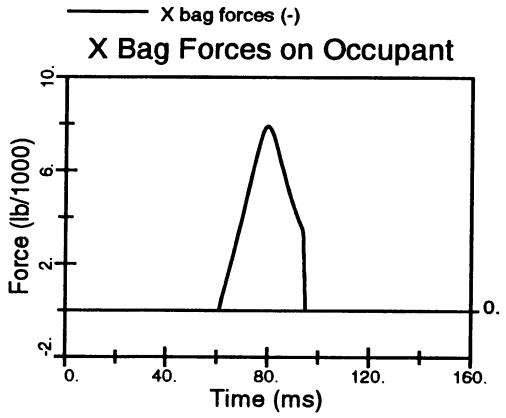
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









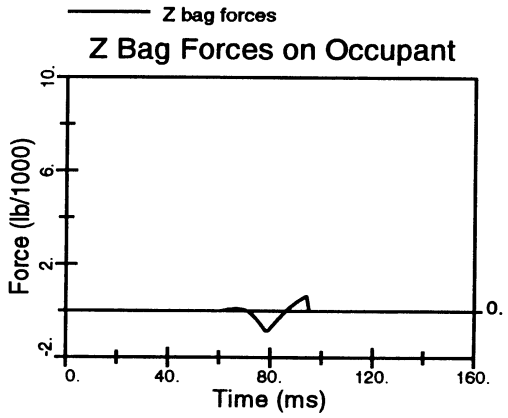


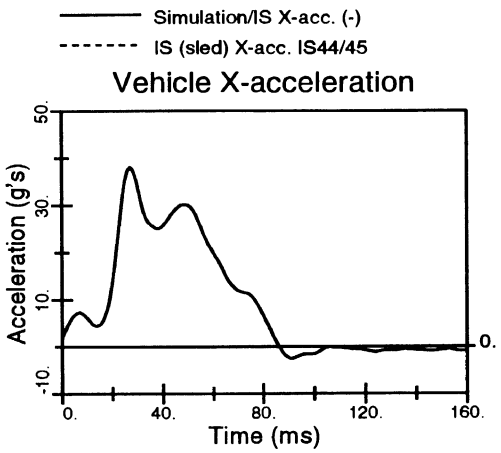
Figure 5.

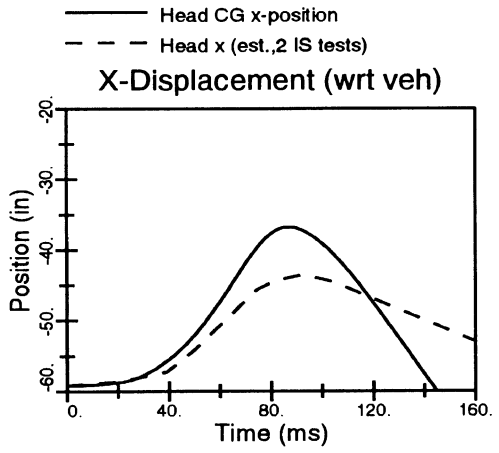
MVMA 2-D CVS Quasi-Finite Element Airbag Model

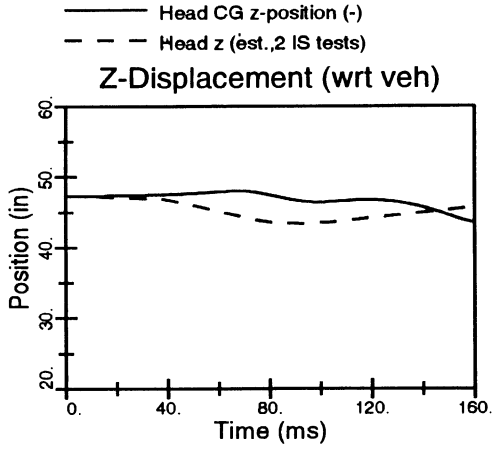
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

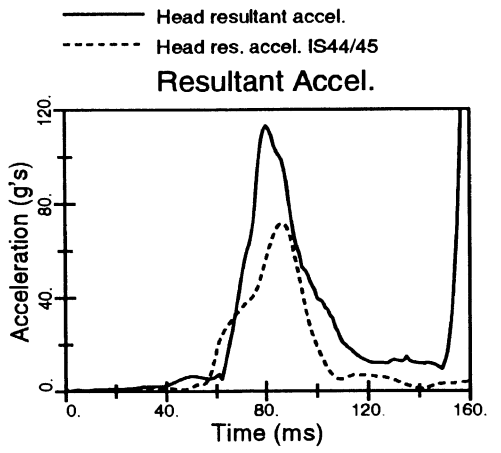
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

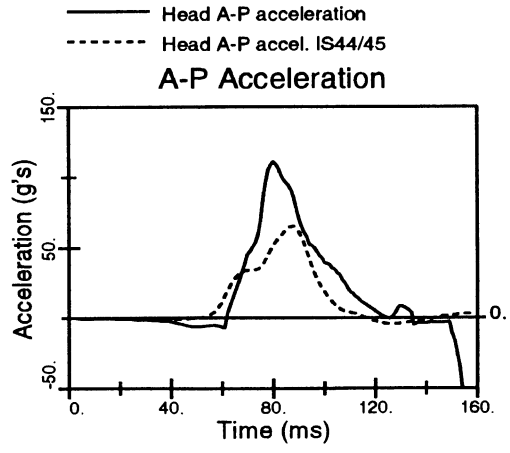
HEAD KINEMATIC RESPONSE











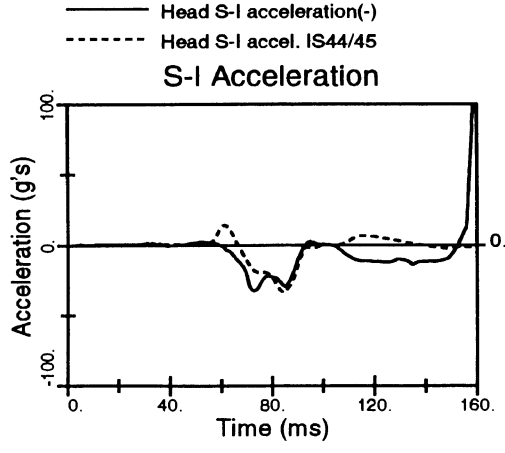


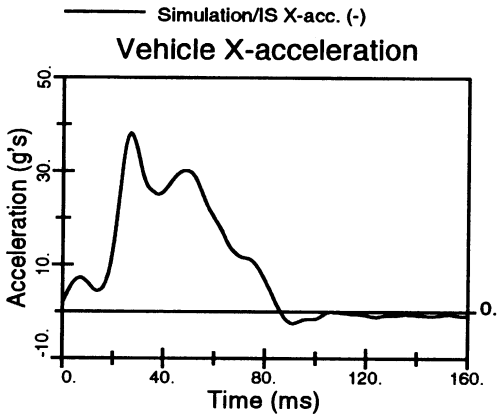
Figure 6.

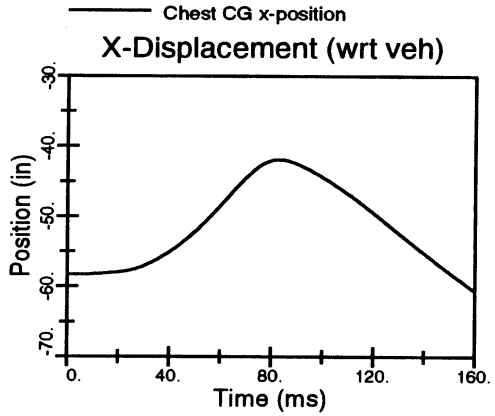
MVMA 2-D CVS Quasi-Finite Element Airbag Model

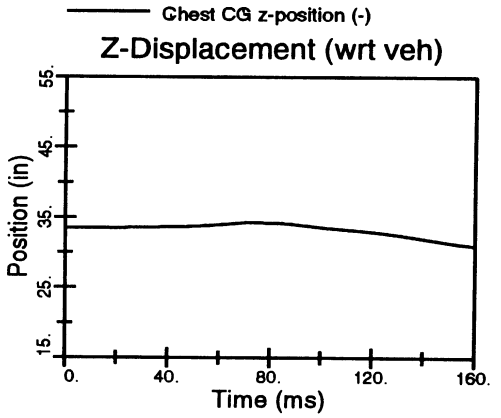
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

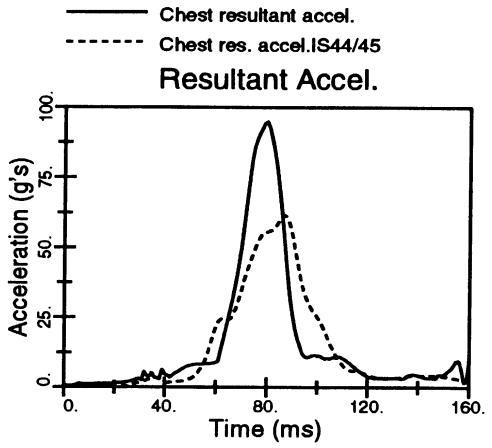
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

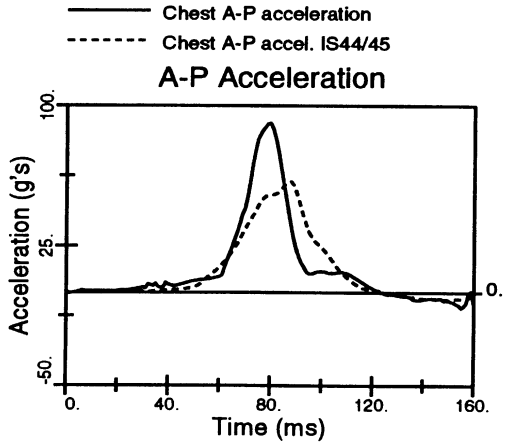
CHEST KINEMATIC RESPONSE











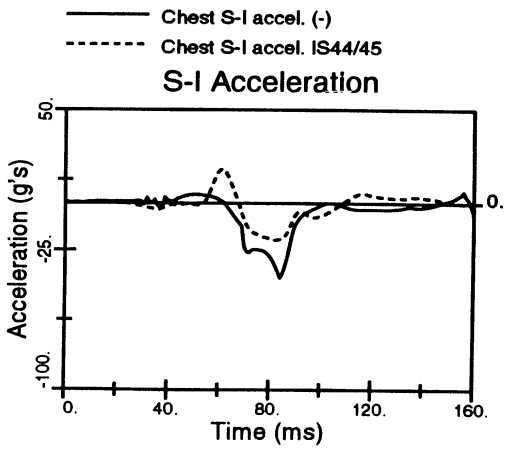


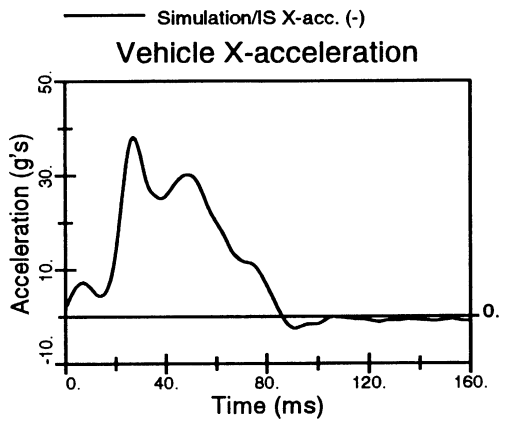
Figure 6.

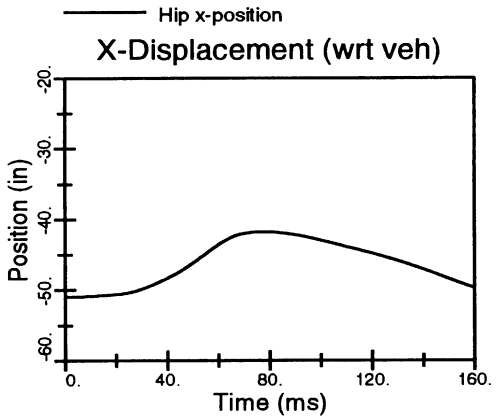
MVMA 2-D CVS Quasi-Finite Element Airbag Model

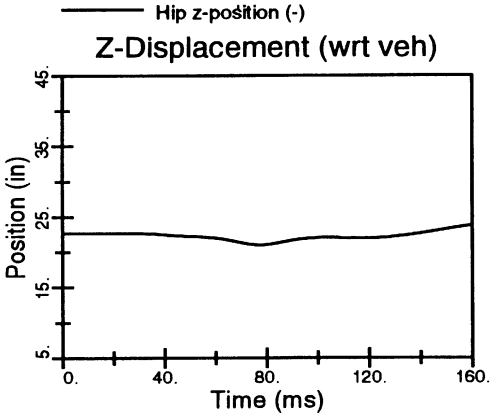
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

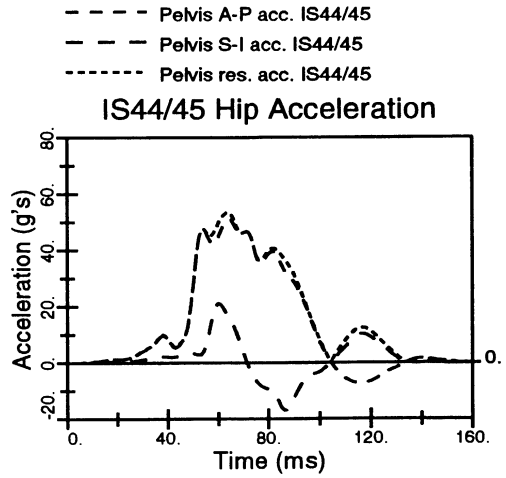
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

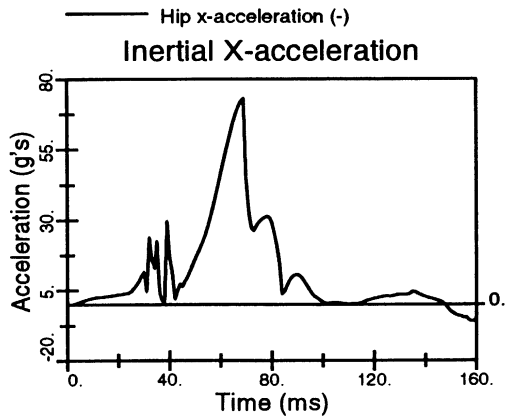
HIP KINEMATIC RESPONSE











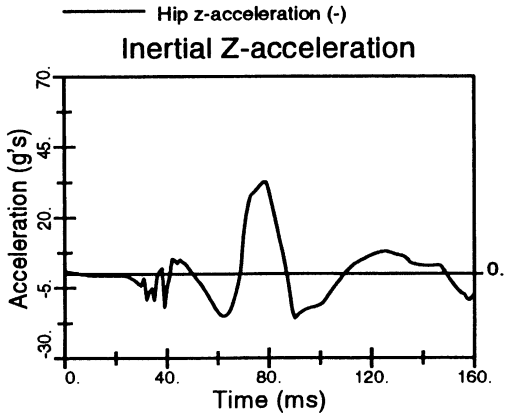


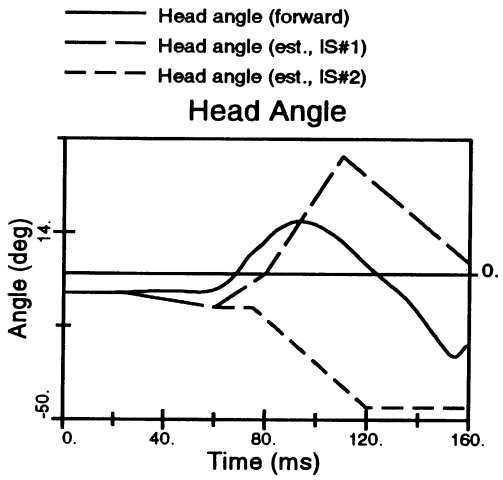
Figure 6.

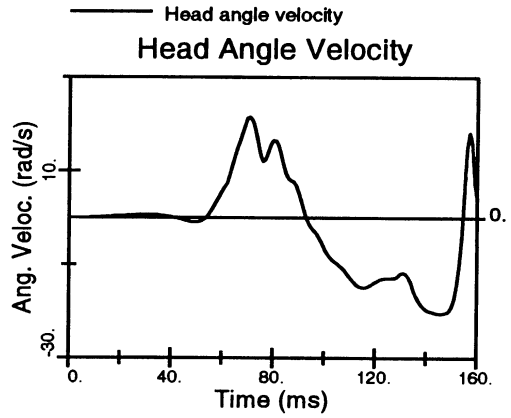
MVMA 2-D CVS Quasi-Finite Element Airbag Model

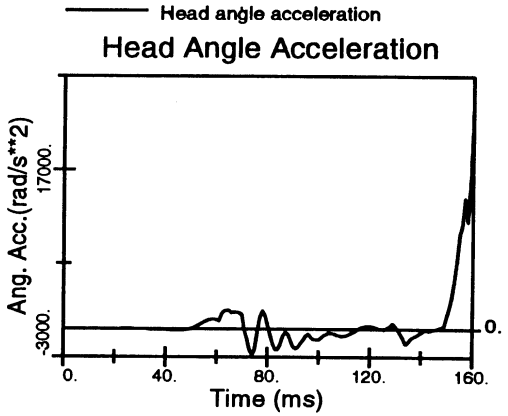
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

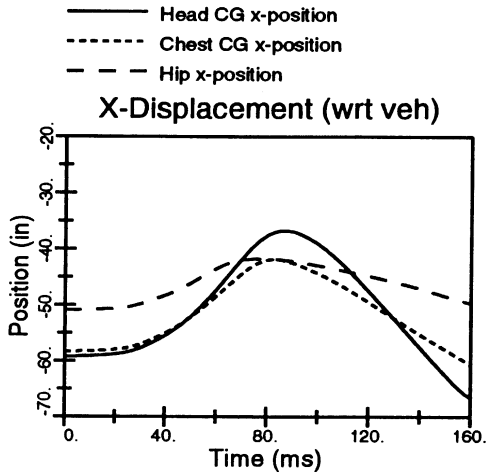
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

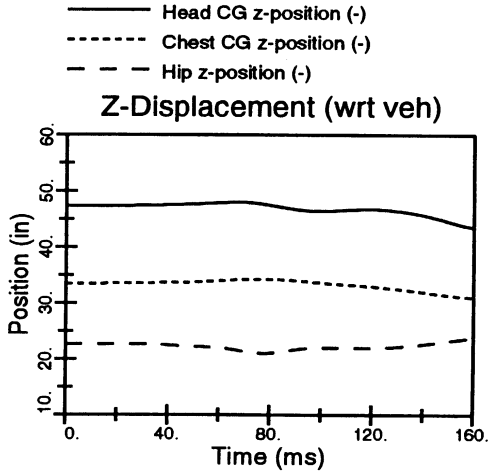
HEAD ANGULAR RESPONSE / OTHER RESPONSES











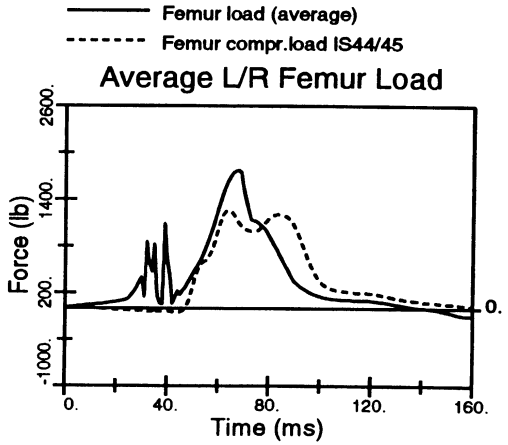


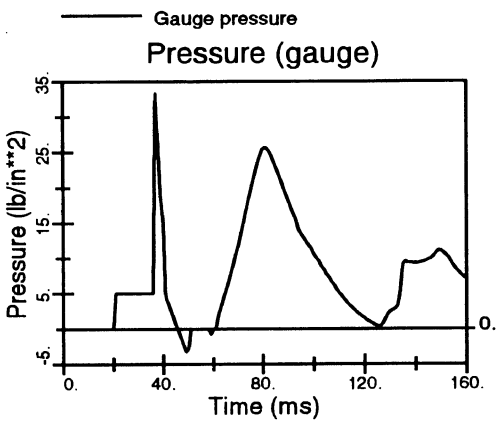
Figure 6.

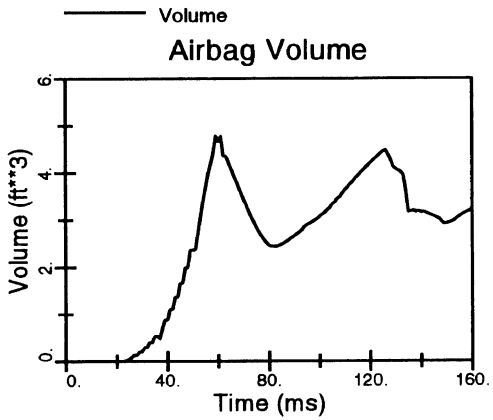
MVMA 2-D CVS Quasi-Finite Element Airbag Model

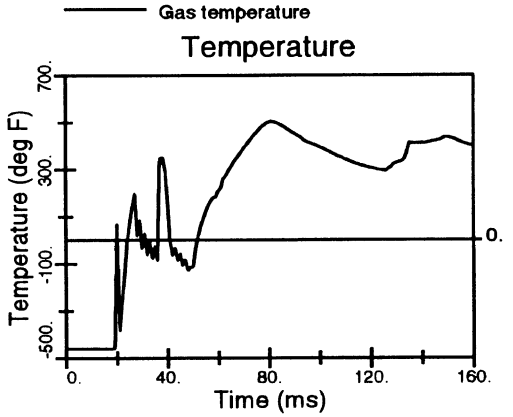
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

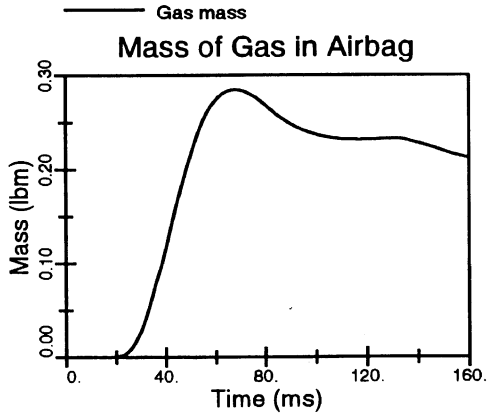
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

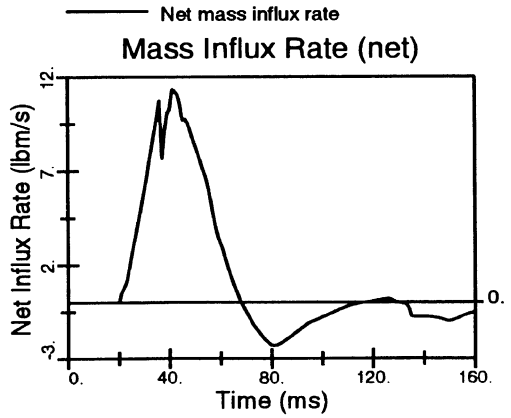
THERMODYNAMIC VARIABLES











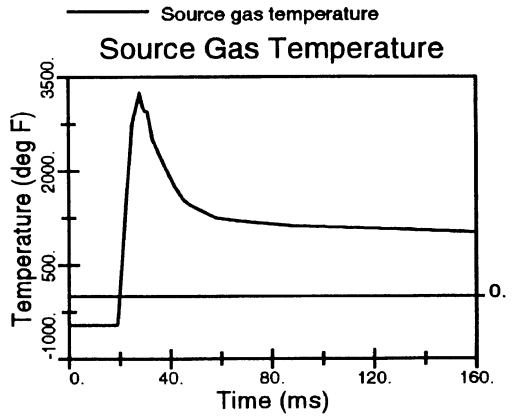


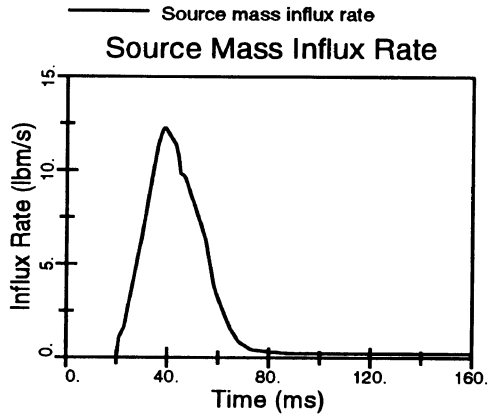
Figure 6.

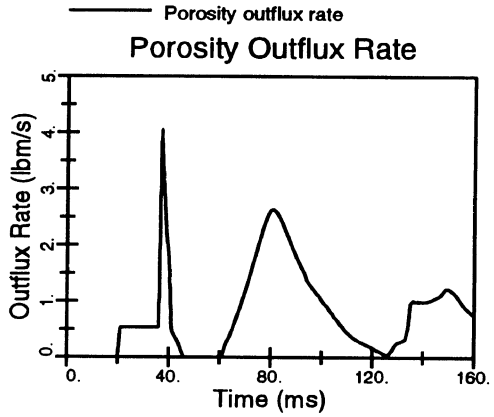
MVMA 2-D CVS Quasi-Finite Element Airbag Model

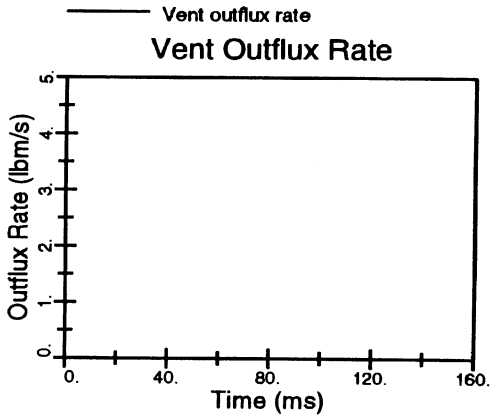
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

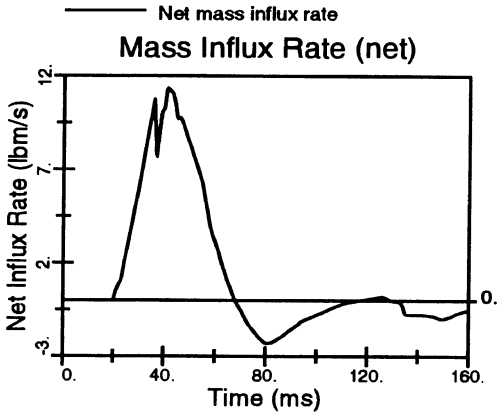
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

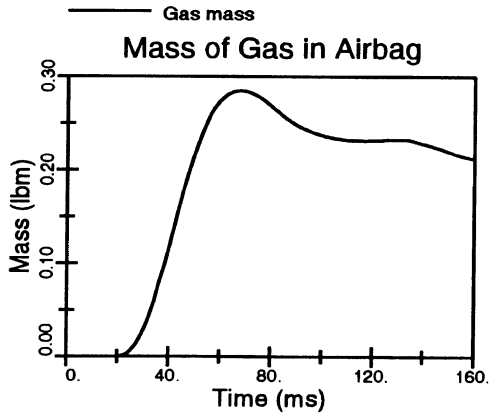
AIRBAG MASS INFLUX/OUTFLUX











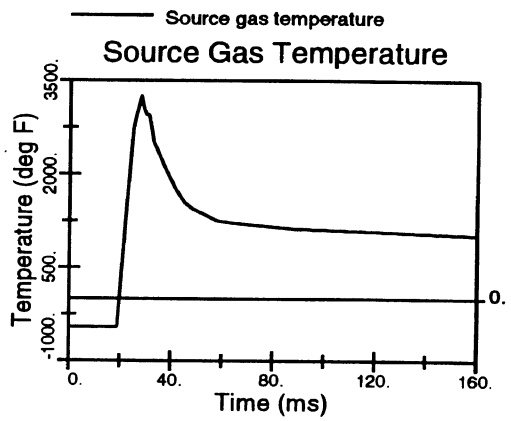


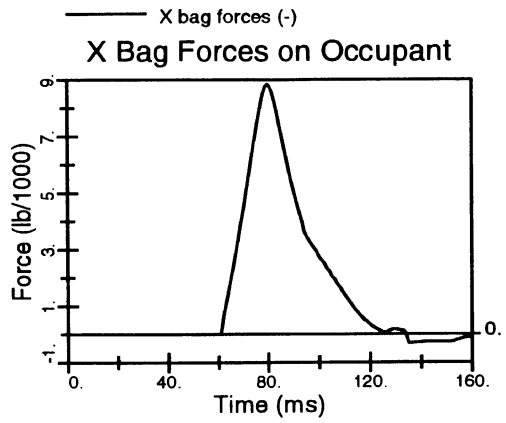
Figure 6.

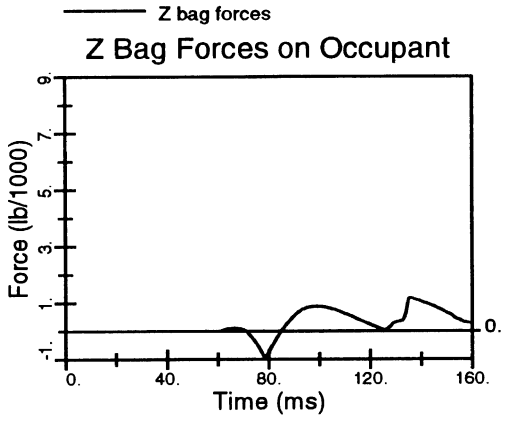
MVMA 2-D CVS Quasi-Finite Element Airbag Model

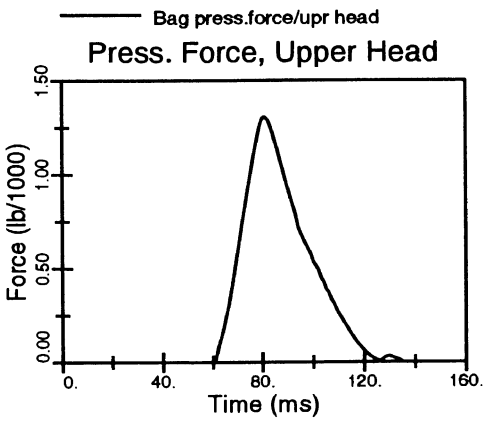
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

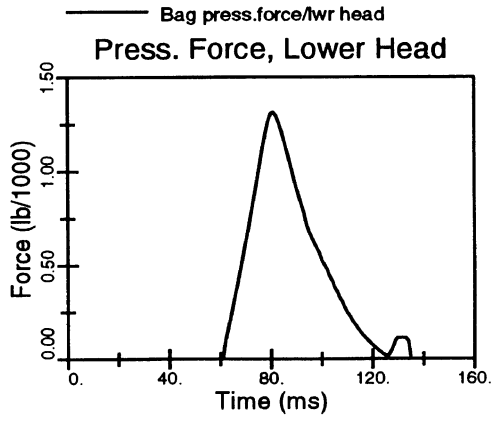
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









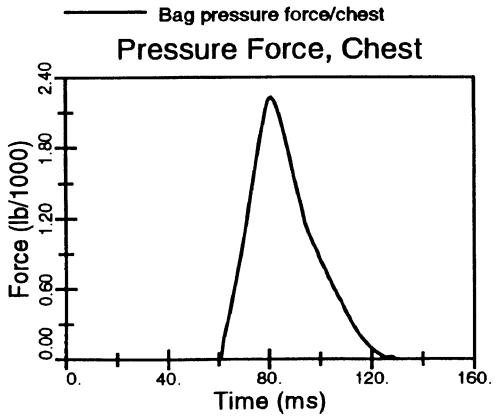


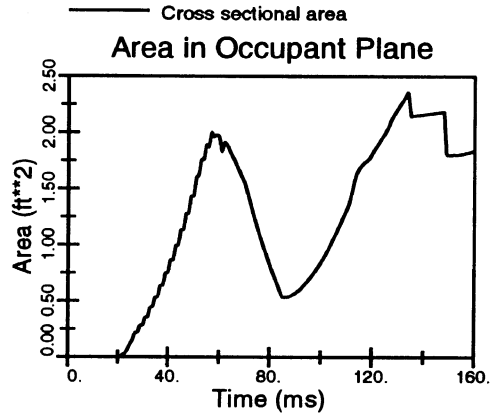
Figure 6.

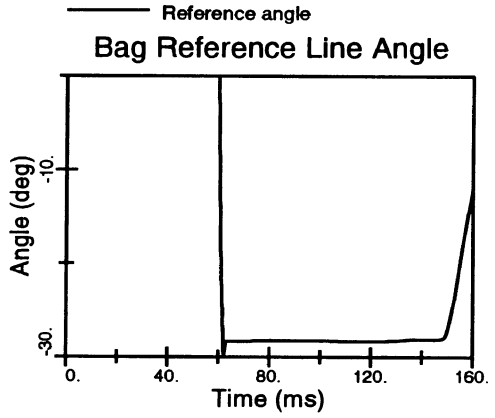
MVMA 2-D CVS Quasi-Finite Element Airbag Model

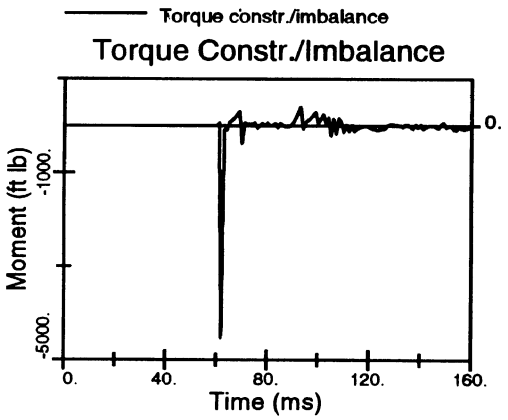
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

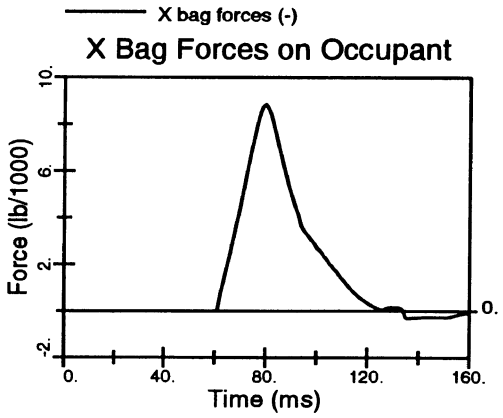
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









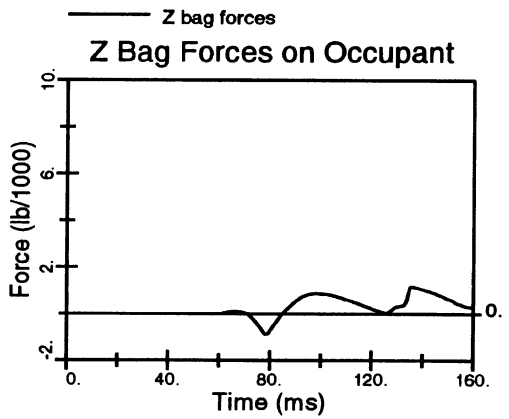


Figure 6.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

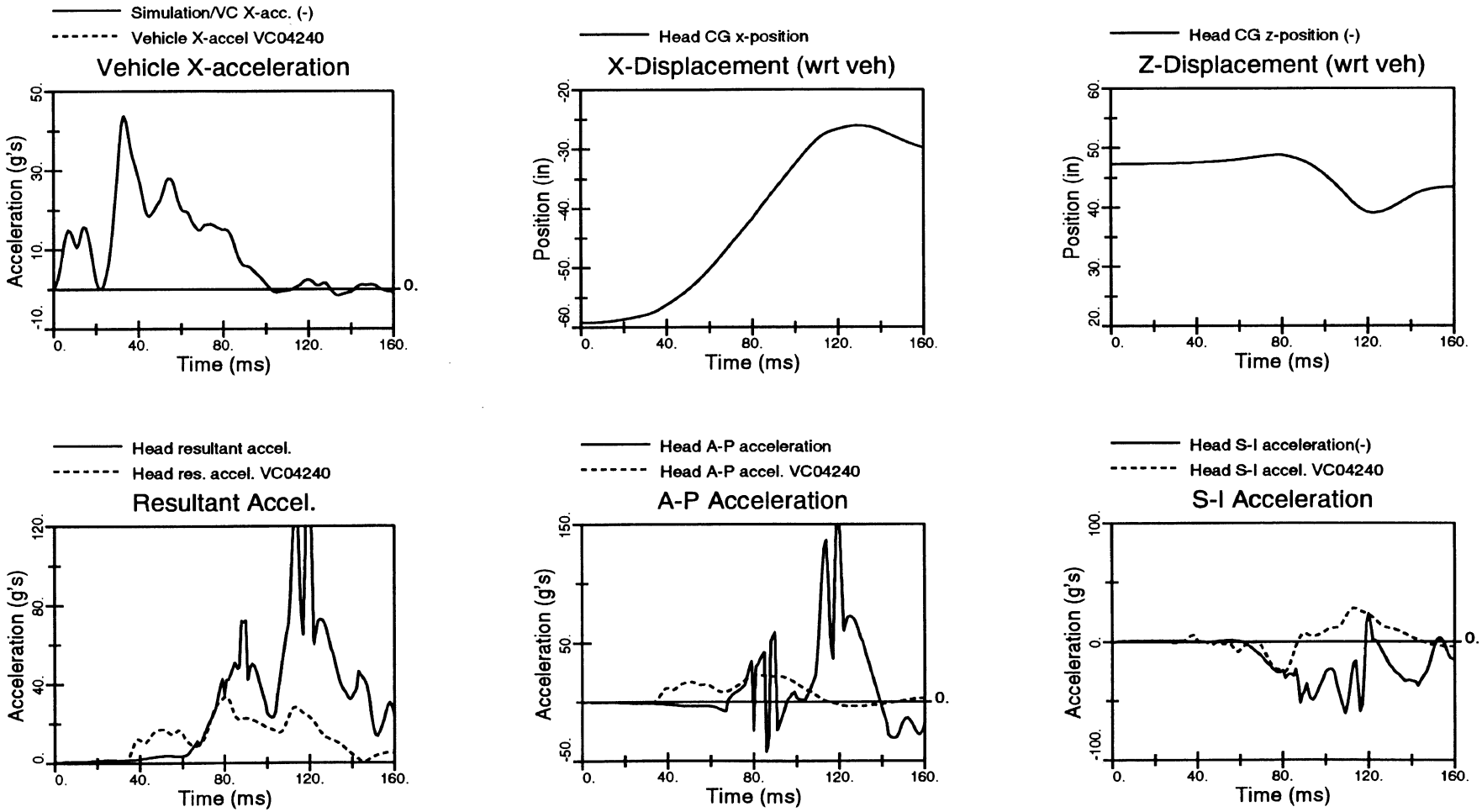


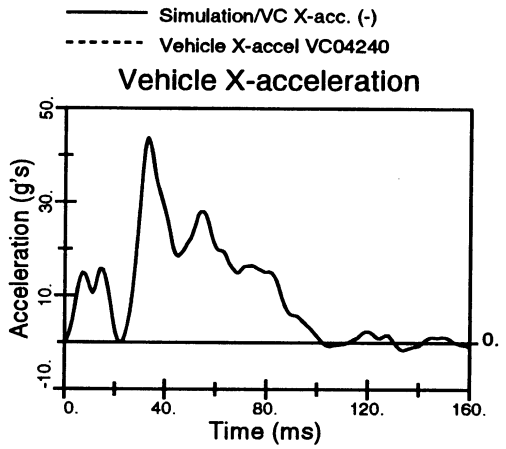
Figure 7.

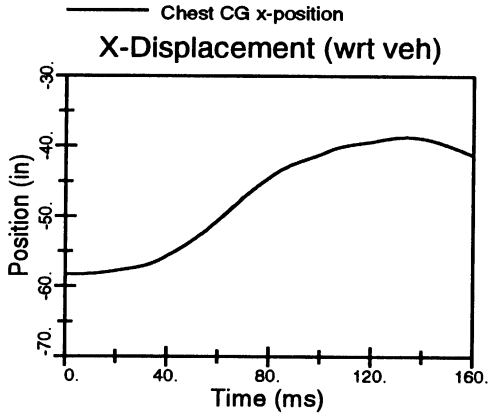
MVMA 2-D CVS Quasi-Finite Element Airbag Model

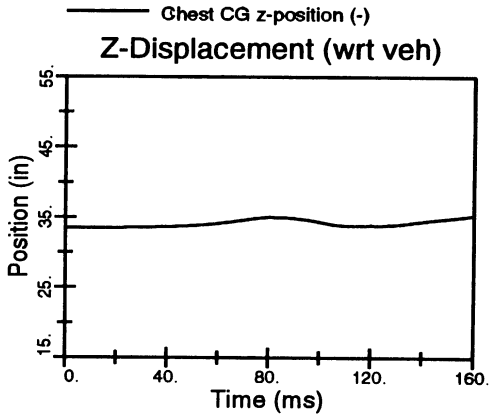
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

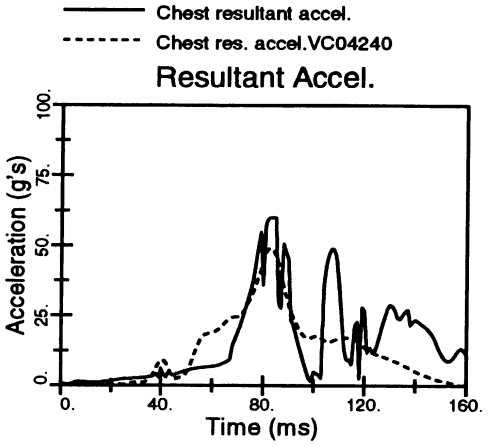
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

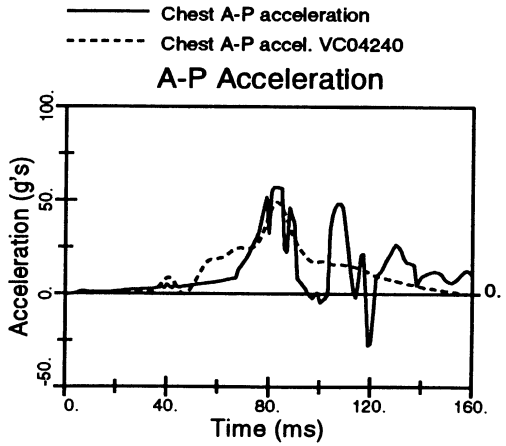
CHEST KINEMATIC RESPONSE











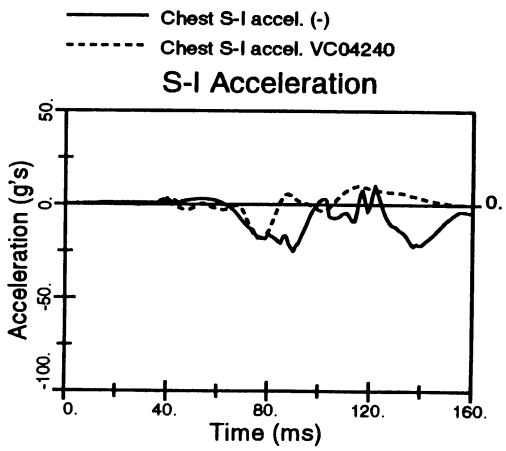


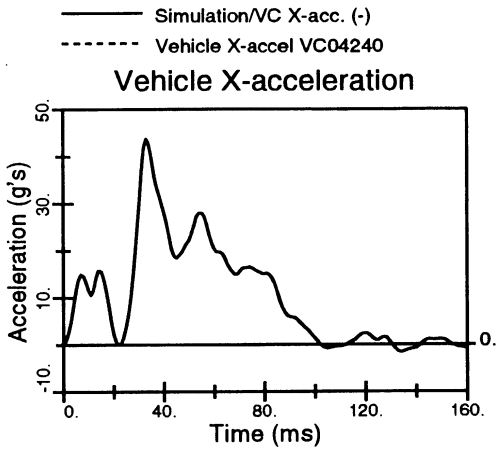
Figure 7.

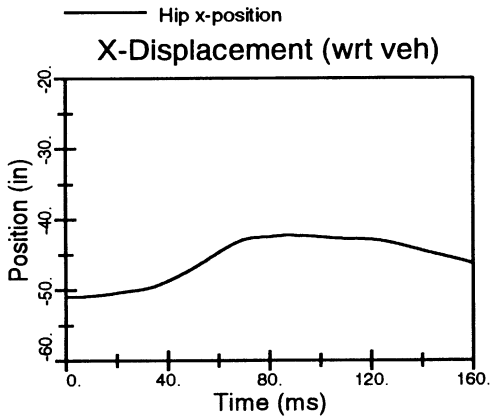
MVMA 2-D CVS Quasi-Finite Element Airbag Model

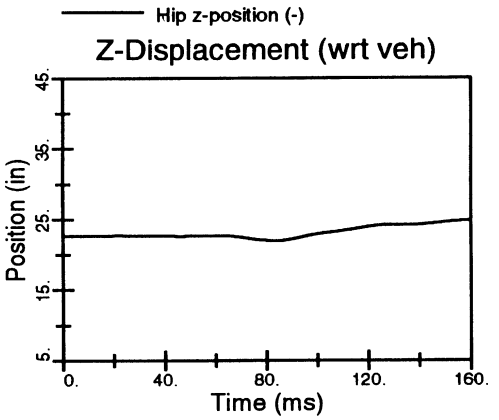
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

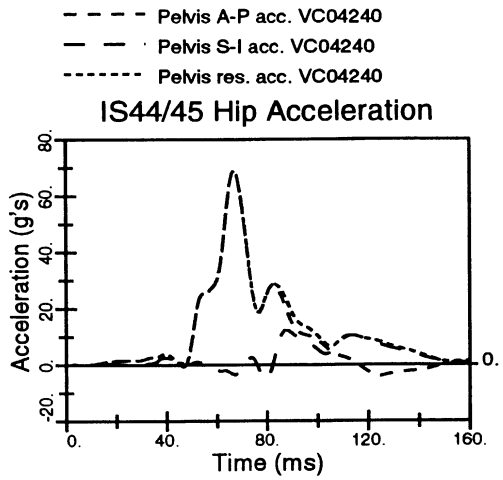
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

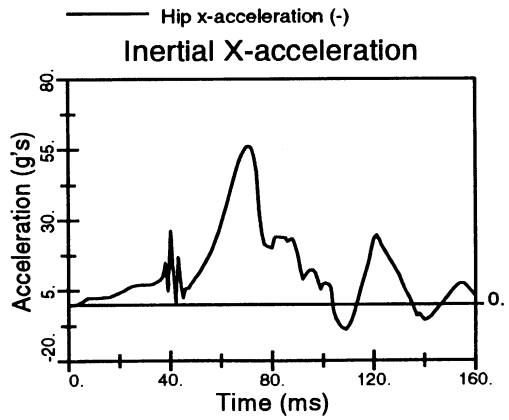
HIP KINEMATIC RESPONSE











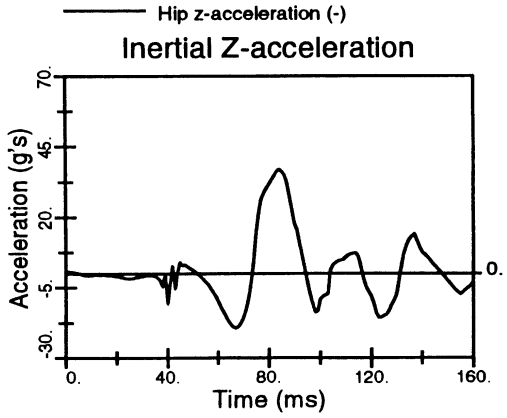


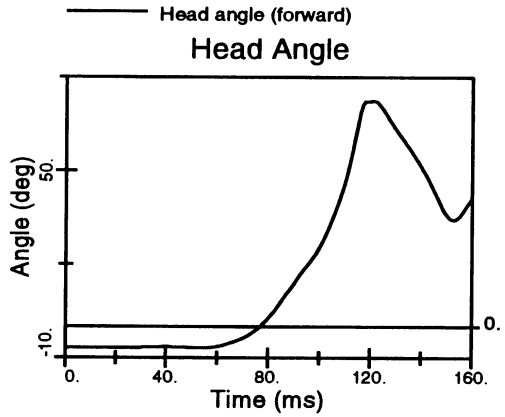
Figure 7.

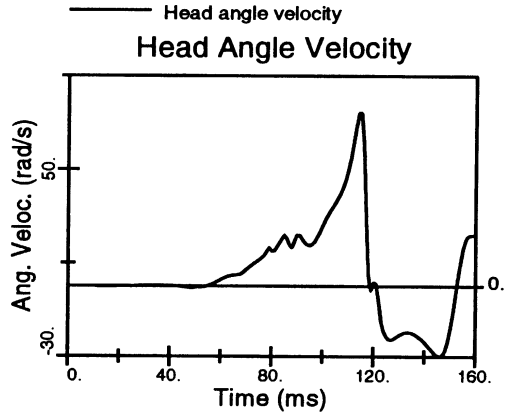
MVMA 2-D CVS Quasi-Finite Element Airbag Model

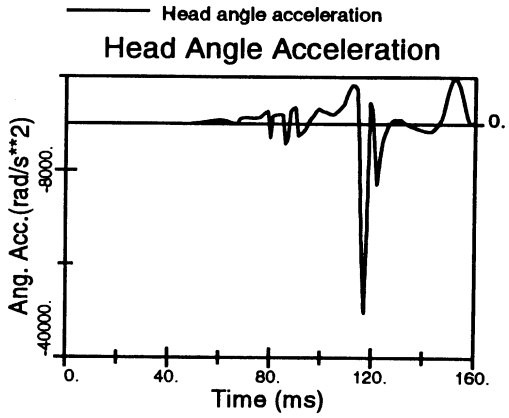
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

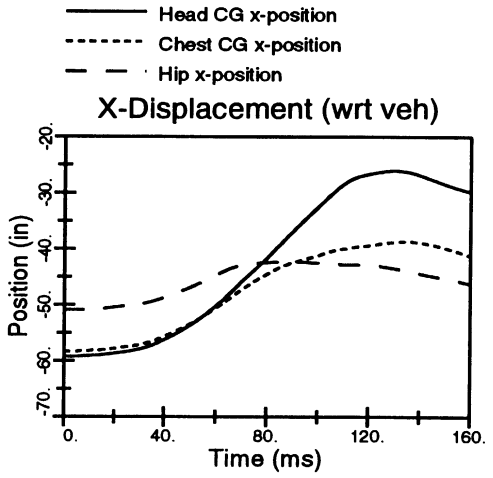
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

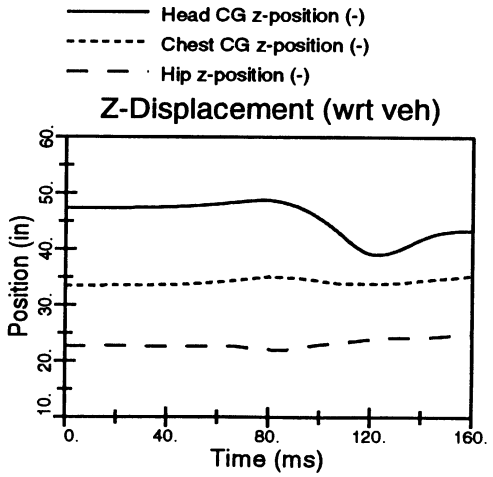
HEAD ANGULAR RESPONSE / OTHER RESPONSES











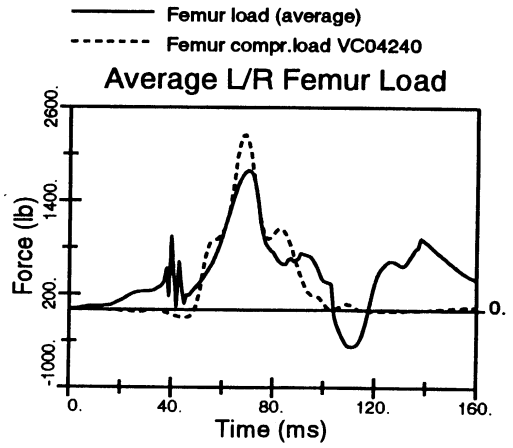


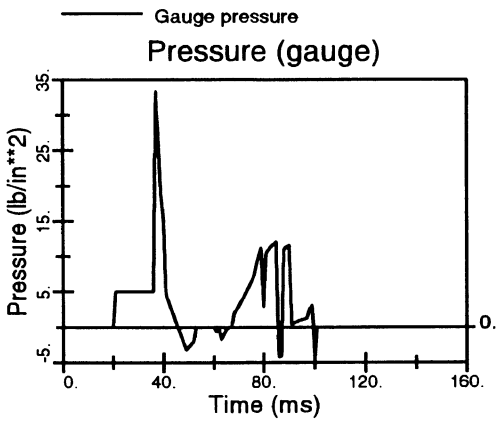
Figure 7.

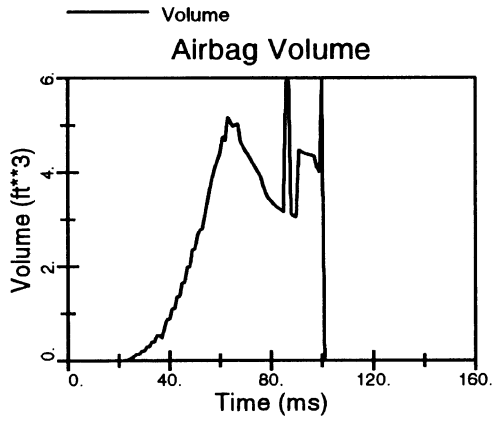
MVMA 2-D CVS Quasi-Finite Element Airbag Model

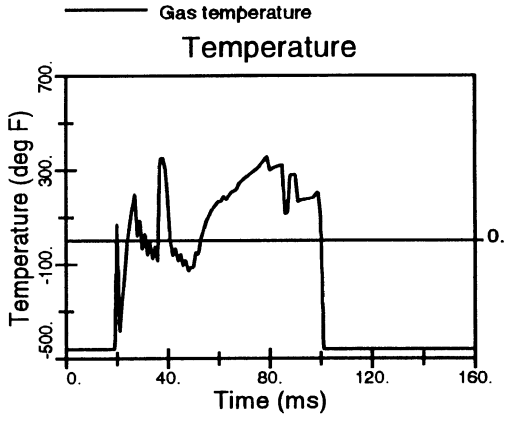
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

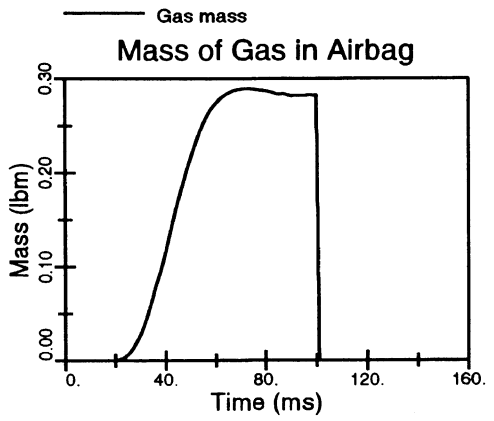
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

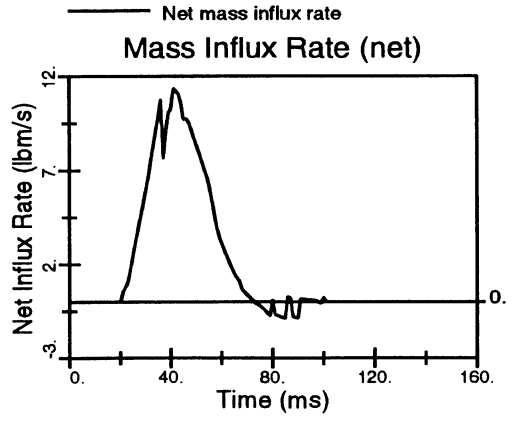
THERMODYNAMIC VARIABLES











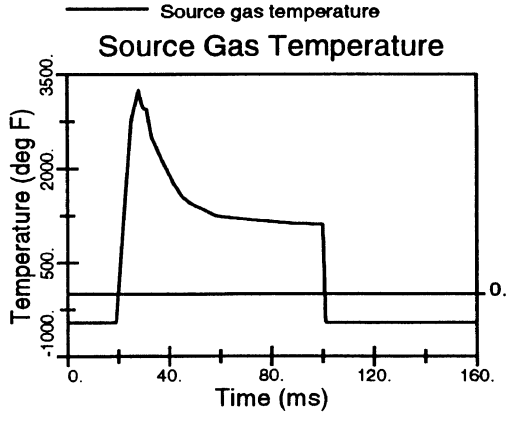


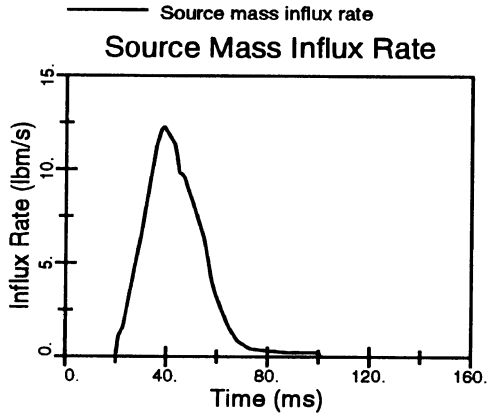
Figure 7.

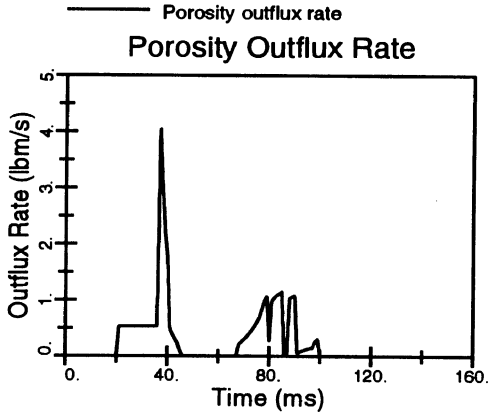
MVMA 2-D CVS Quasi-Finite Element Airbag Model

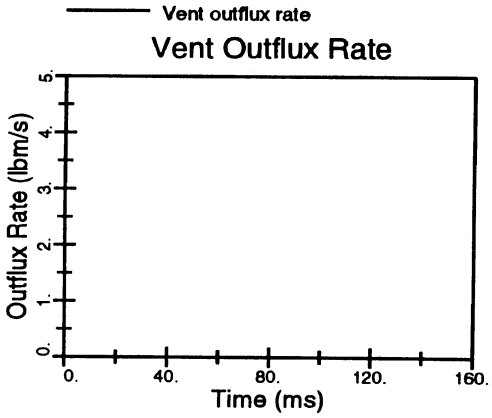
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

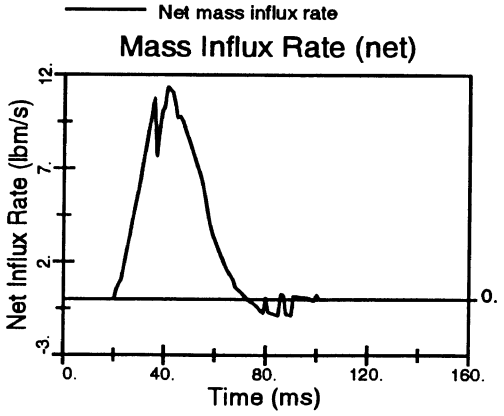
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

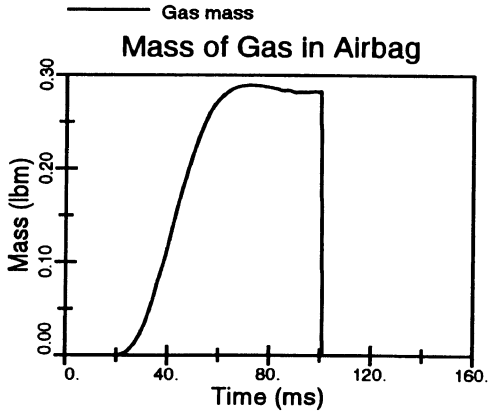
AIRBAG MASS INFLUX/OUTFLUX











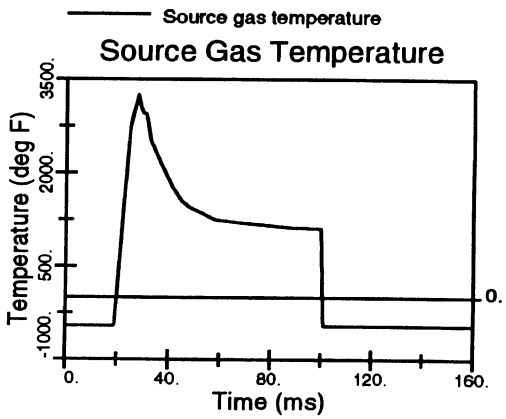


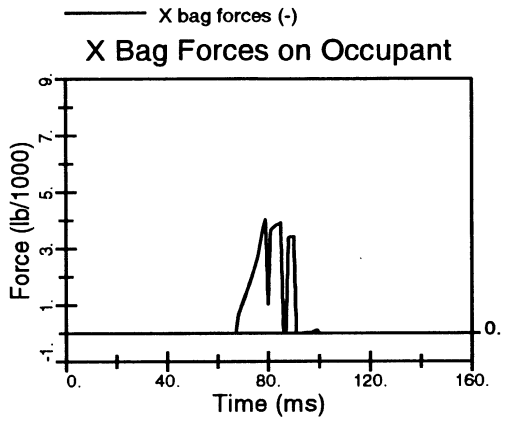
Figure 7.

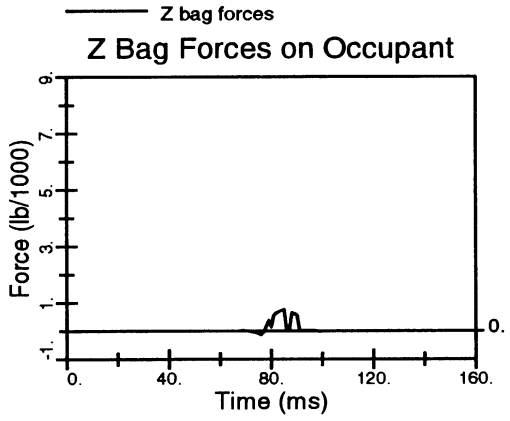
MVMA 2-D CVS Quasi-Finite Element Airbag Model

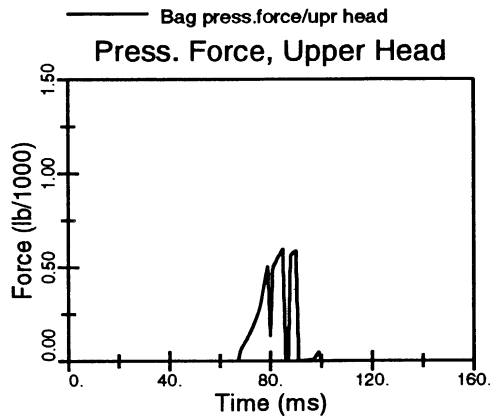
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

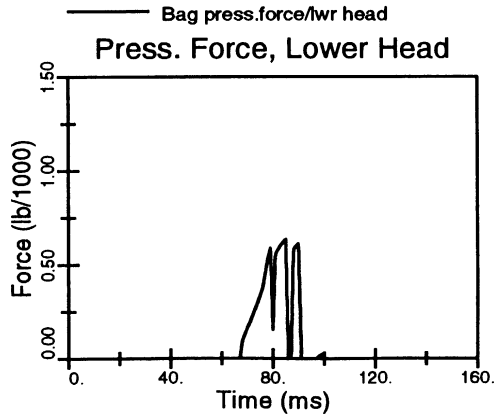
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









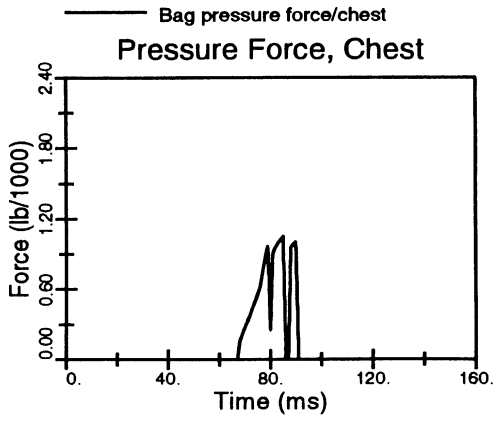


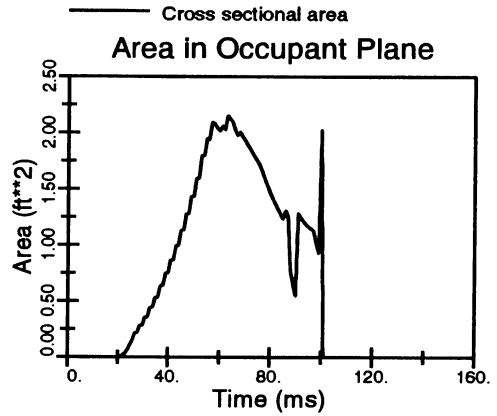
Figure 7.

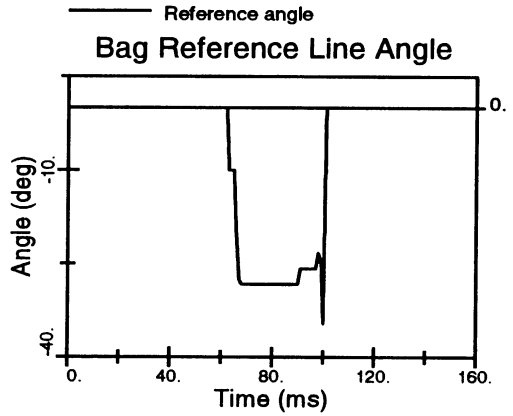
MVMA 2-D CVS Quasi-Finite Element Airbag Model

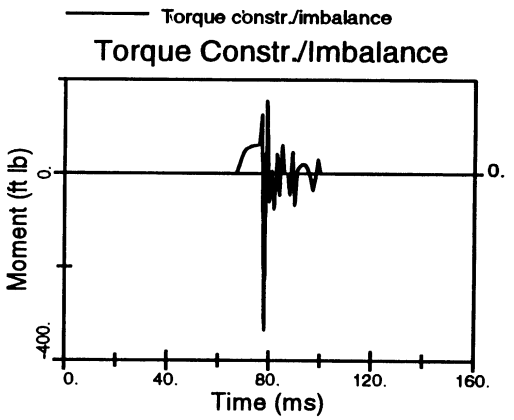
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES







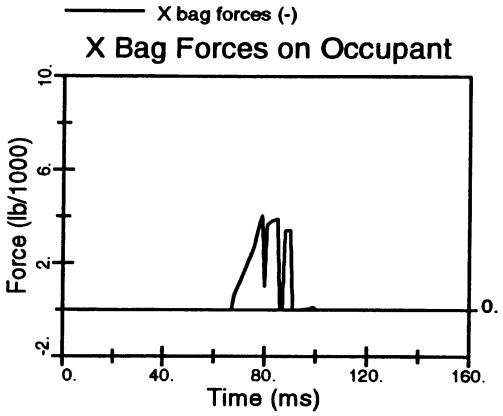


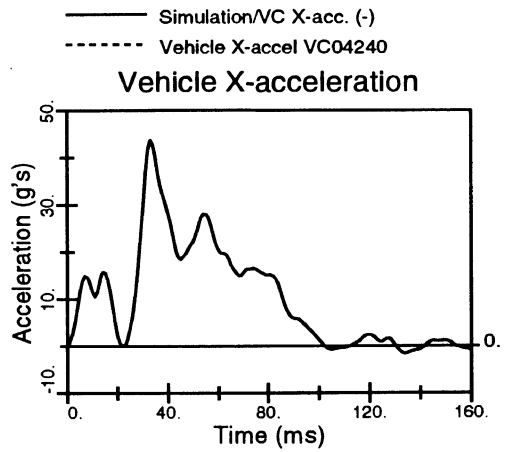
Figure 7.

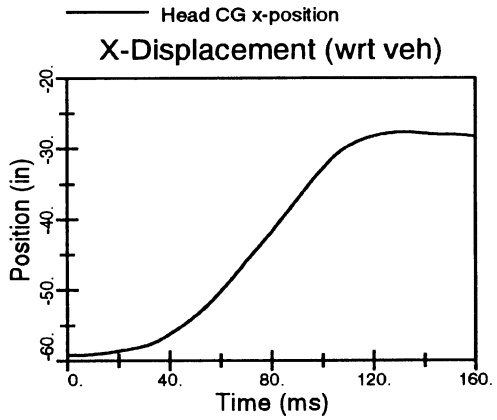
MVMA 2-D CVS Quasi-Finite Element Airbag Model

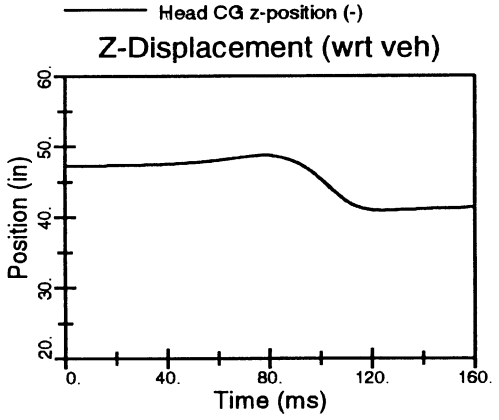
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

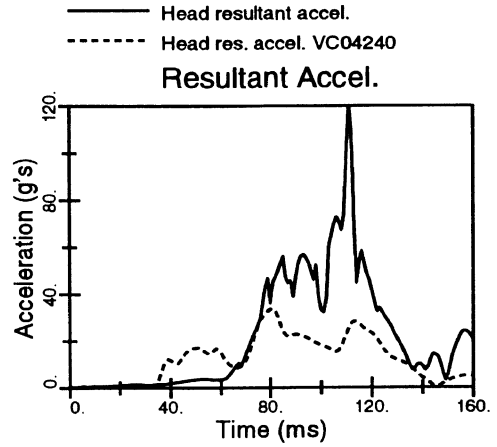
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

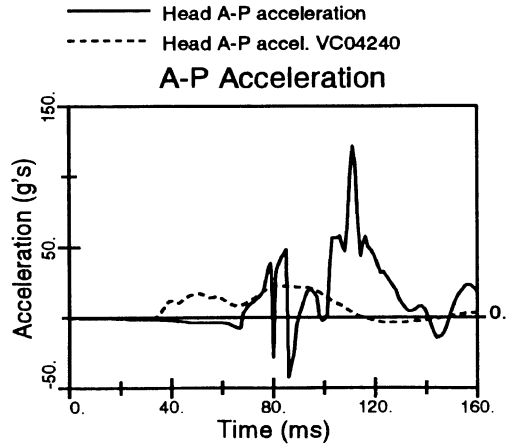
HEAD KINEMATIC RESPONSE











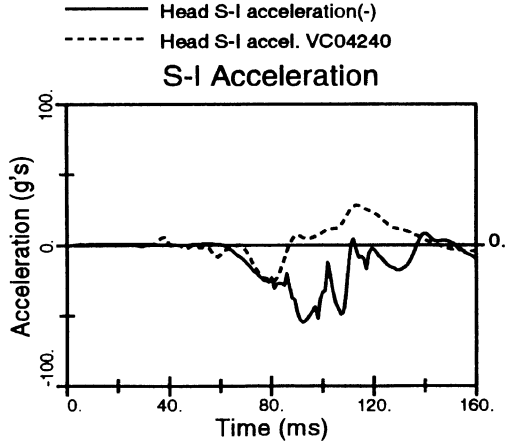


Figure 8.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

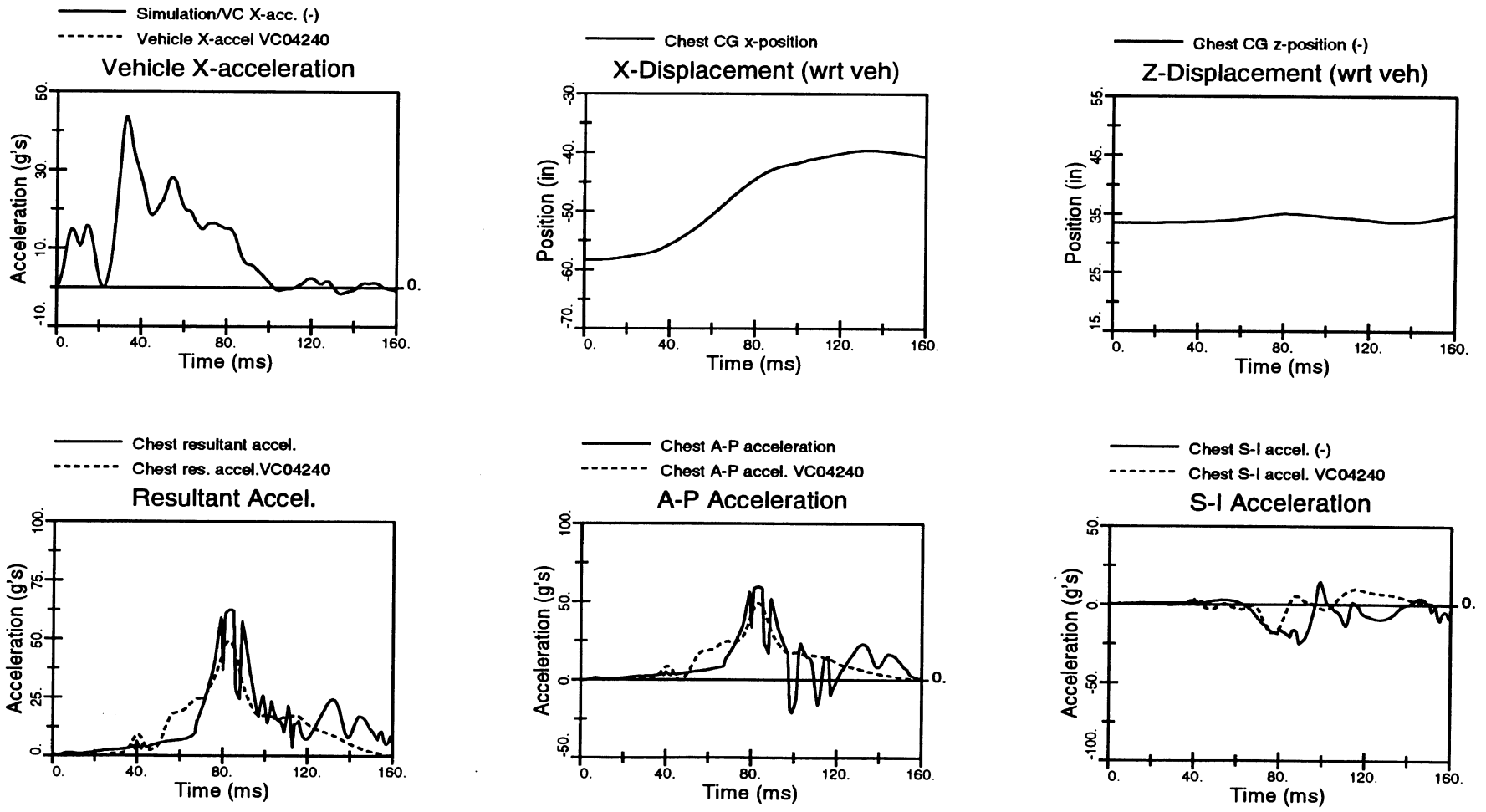


Figure 8.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

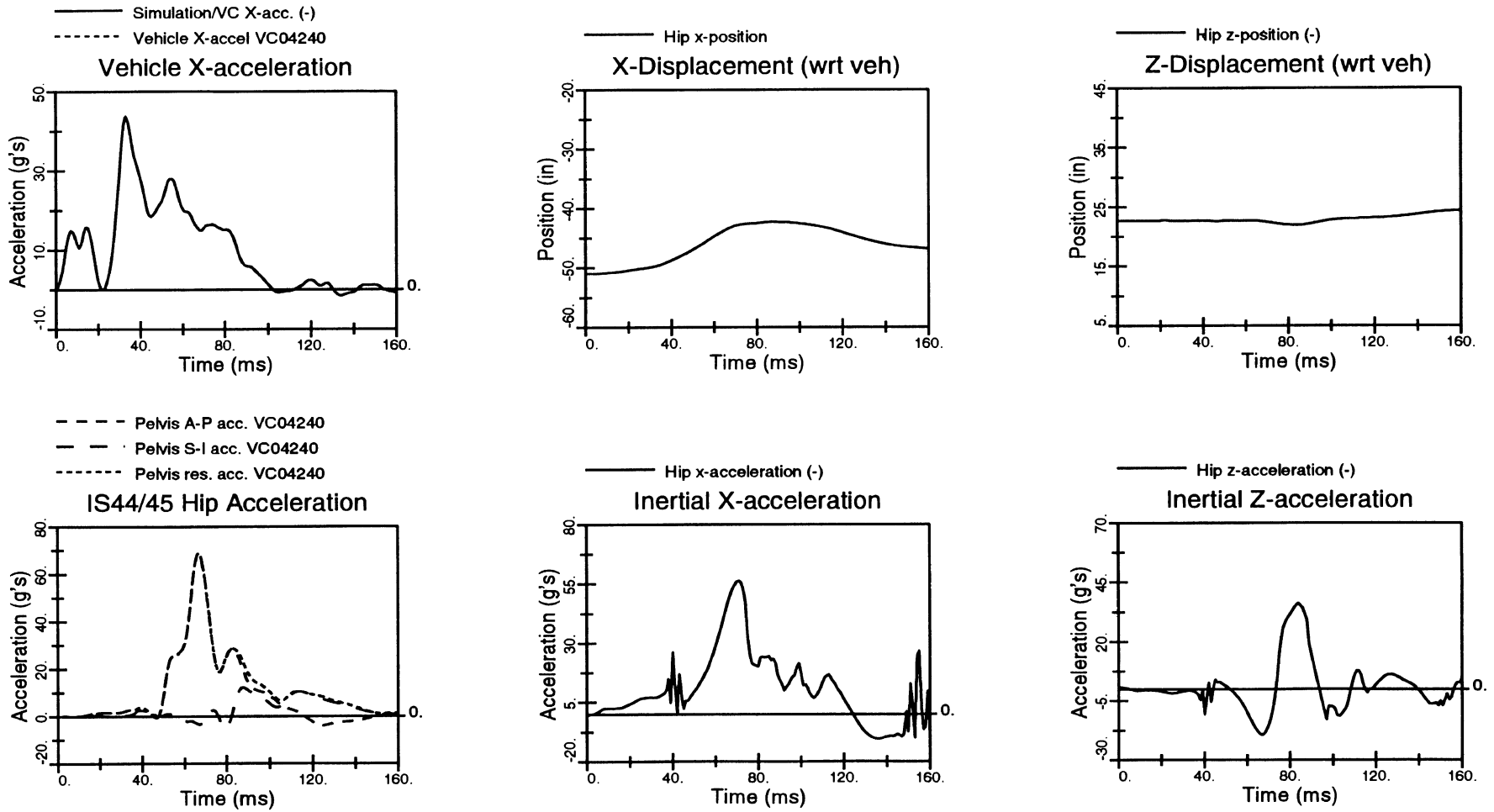


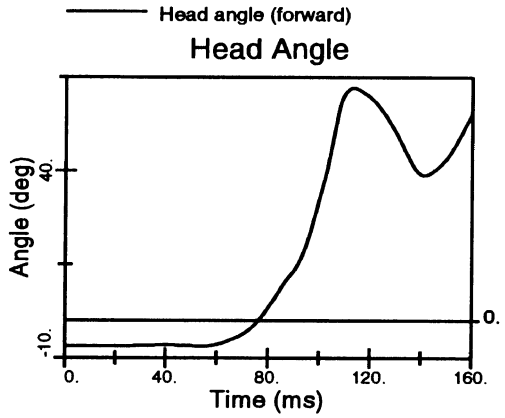
Figure 8.

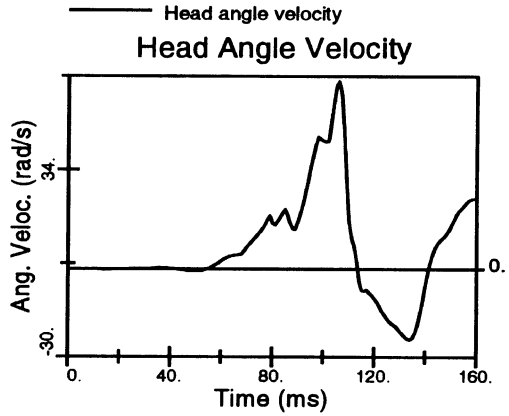
MVMA 2-D CVS Quasi-Finite Element Airbag Model

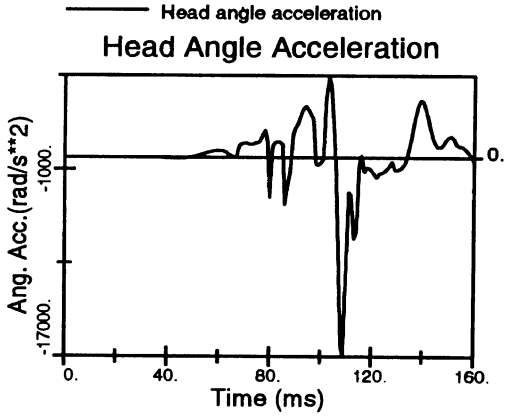
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

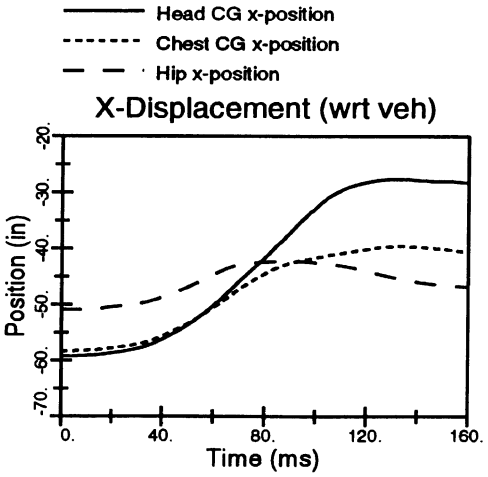
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

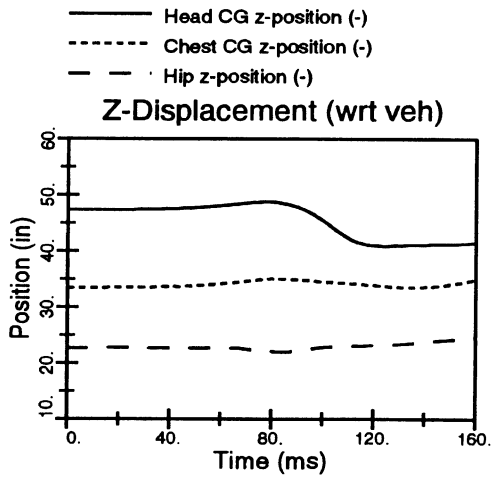
HEAD ANGULAR RESPONSE / OTHER RESPONSES











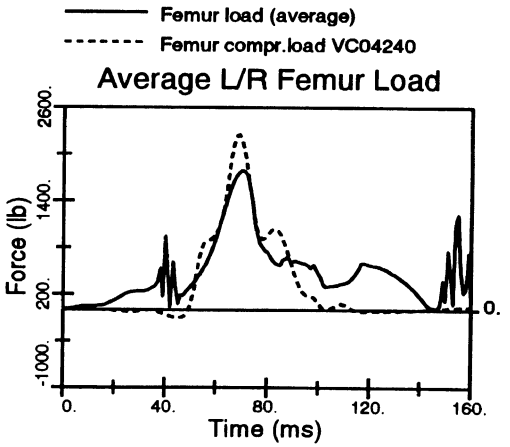


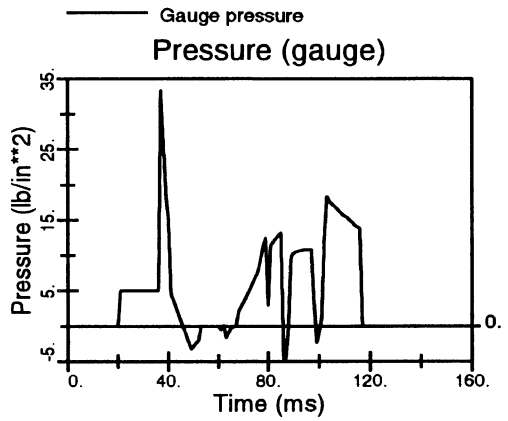
Figure 8.

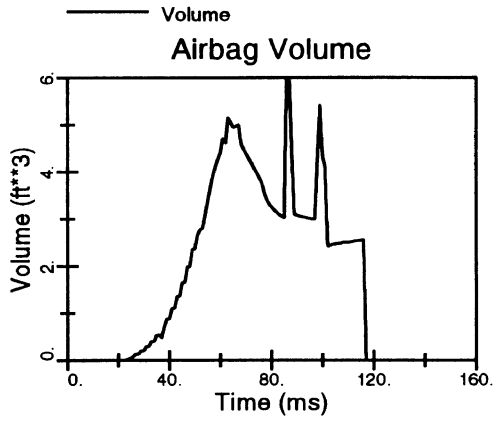
MVMA 2-D CVS Quasi-Finite Element Airbag Model

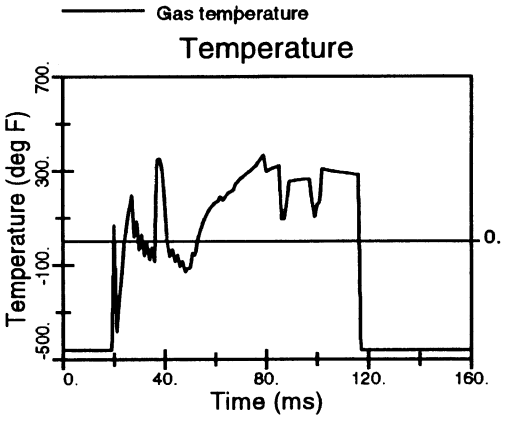
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

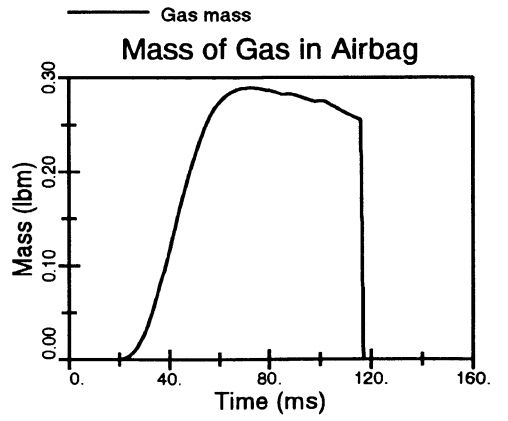
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

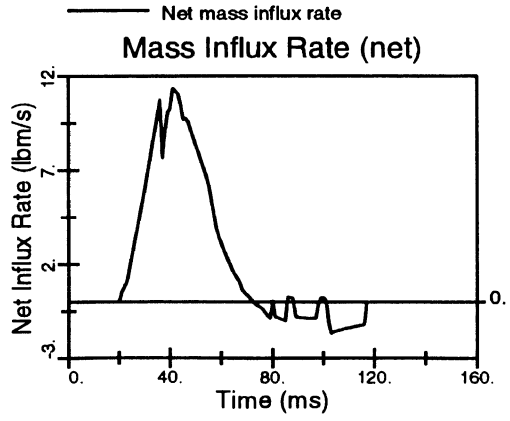
THERMODYNAMIC VARIABLES











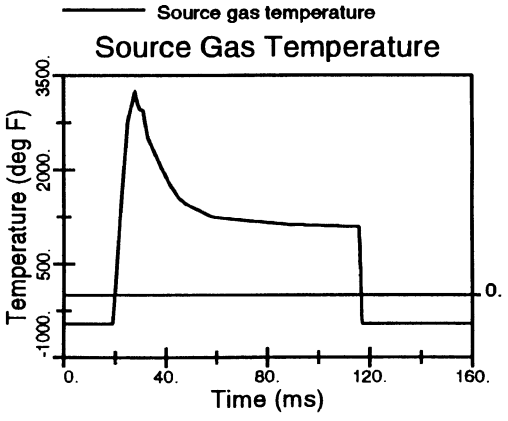


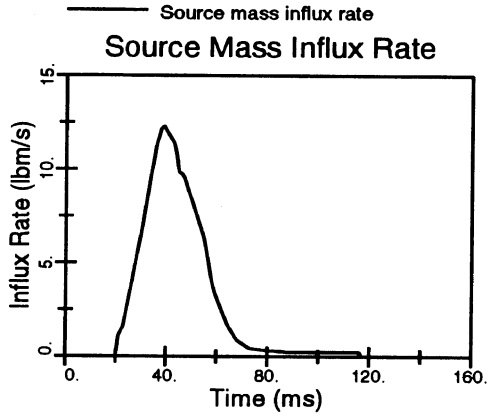
Figure 8.

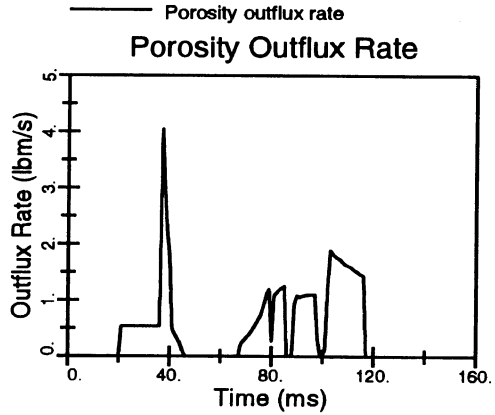
MVMA 2-D CVS Quasi-Finite Element Airbag Model

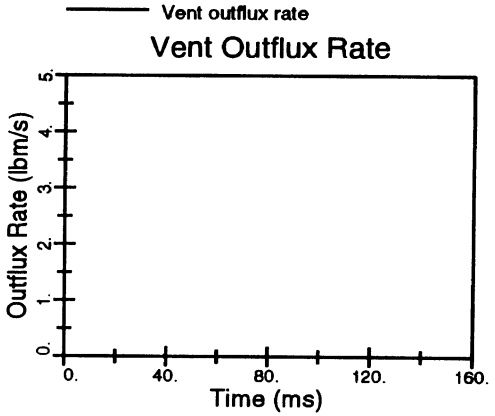
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

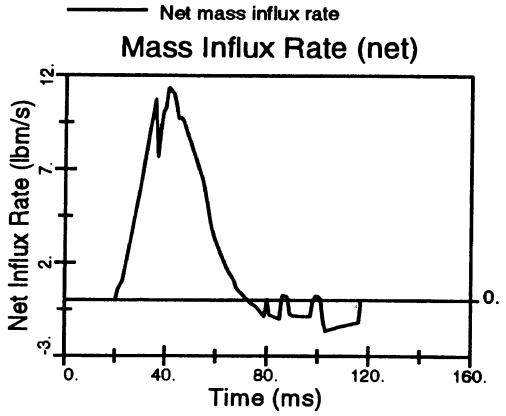
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

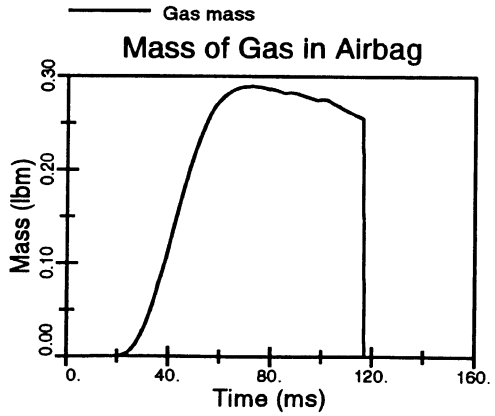
AIRBAG MASS INFLUX/OUTFLUX











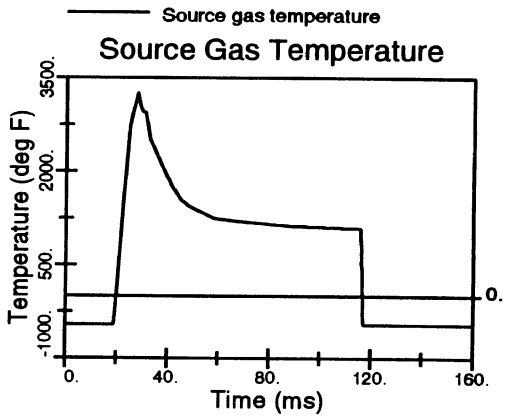


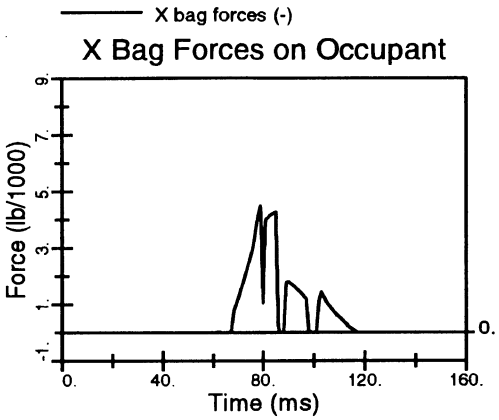
Figure 8.

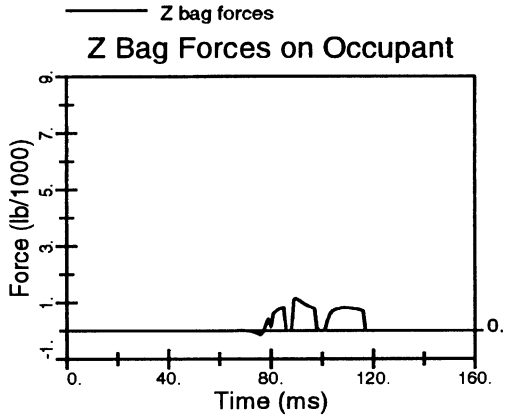
MVMA 2-D CVS Quasi-Finite Element Airbag Model

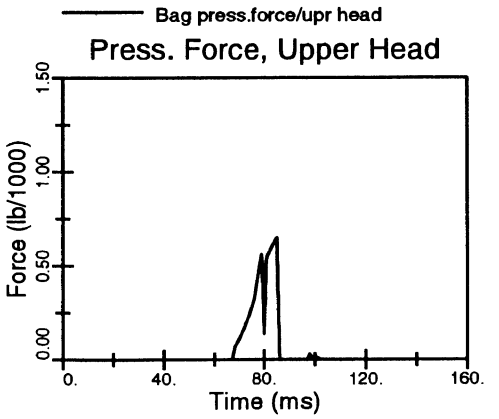
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

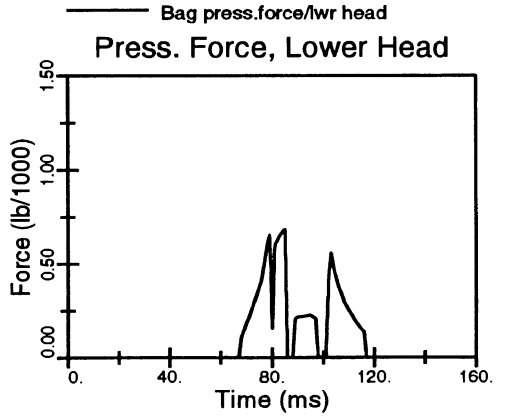
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









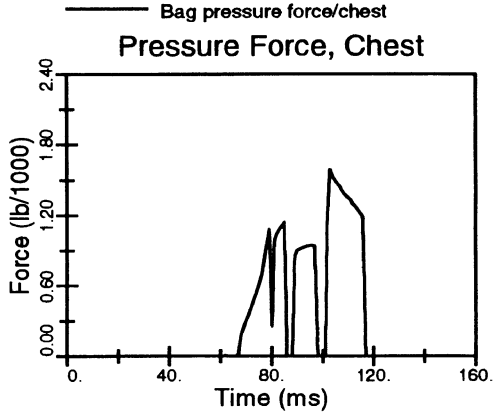


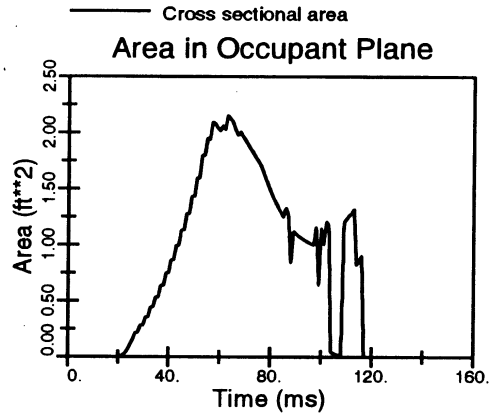
Figure 8.

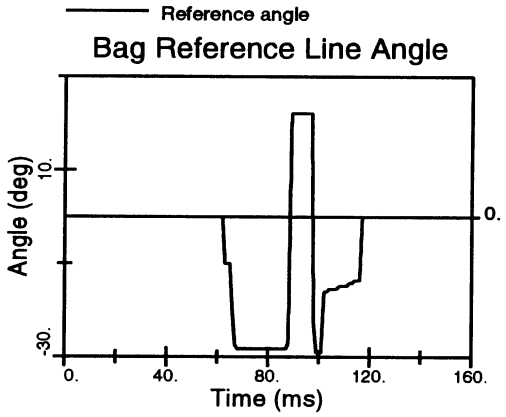
MVMA 2-D CVS Quasi-Finite Element Airbag Model

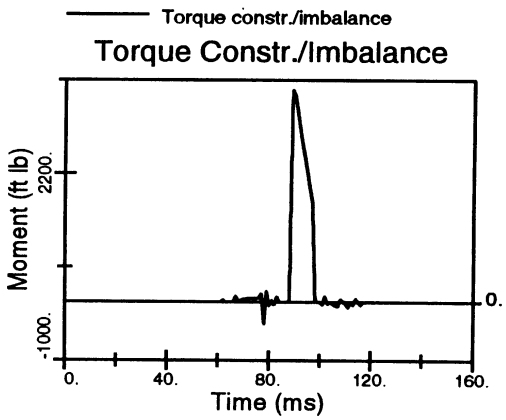
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

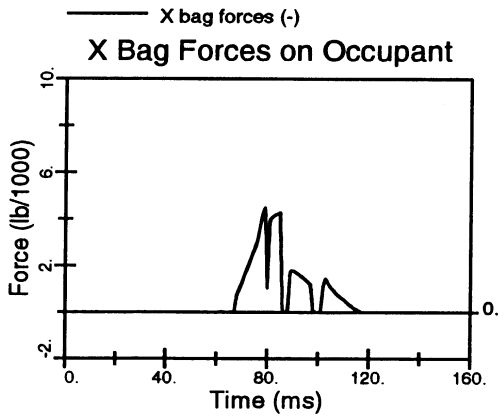
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









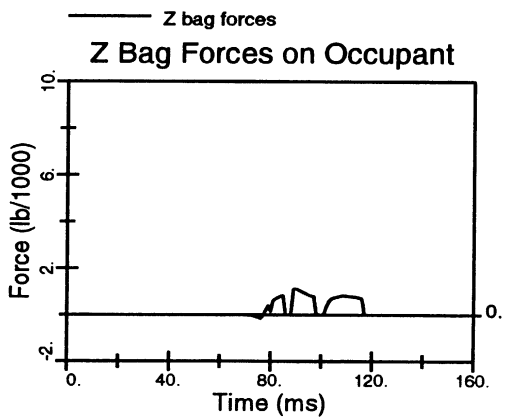


Figure 8.

4.3 Other simulations: replication of vehicle crash test results with an impact simulator

The important *preliminary* conclusion has been reached that, for at least one type of vehicle crash test, a modification of primary importance in an Impact Simulator test intended to replicate vehicle crash tests is introduction of *time-varying*, occupant-compartment pitching motion similar to that of the vehicle crash. While such a modification is possible (discussed later), it is more difficult than *fixed, static* modifications and is thus less desirable. If it can be established, however, that no fixed modification is a reasonable equivalent of time-varying pitching--at least with regard to effect on occupant dynamics--then the preliminary conclusion becomes a firm one: accommodation for time-varying, occupant-compartment pitching must be made.

It must be noted here that, while there is strong indication that normal amounts of vehicle pitching will always importantly affect occupant response, pitching may not be of overriding importance--or even of greatest importance--in vehicle crashes in which there are occupant-compartment intrusions or other factors discussed in Section 1.0. In test VC04240, however, there is good evidence from simulations discussed below that factors other than vehicle pitching motion were not of significance--either because they did not occur or simply because their effects were small.

The simulations described below were all made for the purpose of investigating the degree to which static modifications in Impact Simulator tests like IS11144/45 could improve agreement with vehicle crash tests like VC04240. These simulations are therefore all parametrically varied versions of the IS simulation baselines, IS1 and IS2. All figures for these simulations may be found in the Appendix. When examining these figures (11 to 26) for the purpose of assessing improvement (if any) in simulation head response relative to the experimental *vehicle crash results* (VC04240), it must be kept in mind that the experimental data plotted there (dashed lines) are from *Impact Simulator tests.* The experimental, head resultant acceleration pulse in the vehicle crash test is much broader, with a width of about 100 ms, and much lower, at about 25 G's average magnitude--about a third the magnitude of the plotted IS11144/45 response. This was discussed earlier and may be seen in Figure 4, which compares experimental vehicle crash and Impact Simulator results. Chest response in the vehicle crash test is not greatly different from chest response in the Impact Simulator tests.

4.3.1 IS with VC X-acceleration. Simulation data sets IS1_VCX and IS2_VCX are the same as IS1 and IS2 except that they have the X-acceleration crash pulse from VC04240 instead of from IS11144/45. (These data sets are thus, in fact, identical to VC1_0THV and VC2_0THV.) The results are negligibly different from the IS1 and IS2 results. (See Figures 11 and 12.) These simulations thus establish the validity of using the IS11144/45

X-acceleration pulse in all simulations in which there is no accompanying vehicle pitching.

4.3.2 IS with VC pitch acceleration. Simulation data sets IS1_THVT and IS2_THVT are the same as IS1 and IS2 except that they have the same occupant-compartment pitching motion as the VC1 and VC2 baselines. They are also the same as VC1 and VC2 except that they have the IS11144/45 X-acceleration pulse. While differing from VC1 and VC2 in only this way, the simulation results (Figures 13 and 14) are not in as good agreement with VC04240 crash test results as are the results for VC1 and VC2, discussed above in Section 4.2 and shown in Figures 7 and 8. These simulations thus illustrate that if full advantage is to be taken of the improvement that can be derived from adding time-varying occupant-compartment pitching motion to an Impact Simulator, it is important to reproduce the actual vehicle crash X-acceleration pulse as closely as possible in the HYGE test. The match should be better than the match between the X-acceleration curves for IS11144/45 and VC04240, i.e., the curves in the upper left graph of Figure 4. The primary difference between the curves is a phase shift of about 5 ms. (The IS11144/45 curve is early.) Improving alignment by revising metering pin parameters can be accomplished easily. (Firing the airbag 5 ms earlier would have the same effect in the absence of occupant-compartment pitching.)

4.3.3 IS with fixed, nonzero vehicle pitch angle. The degree to which Impact Simulator experiments might be made to approximate vehicle crash tests more closely by introducing a fixed, nonzero pitch angle for the occupant compartment on the sled was investigated by runs for data sets IS1_5THV, IS2_5THV, IS1_9THV, and IS2_9THV. The first two of these are the same as the IS baseline data sets except that a fixed pitch angle of 5 deg (back end up) is specified. The second two are for a pitch angle of 9 deg. Values of 5 and 9 deg were selected based on consideration of the maximum pitch value of 6.1 deg for the Volvo data used in VC1 and VC2. (See Section 4.2 and Figure 3.) The results of these simulations, in Figures 15 to 18, show no tendency toward improvement of agreement with crash test VC04240 results. While *time-varying* pitch angle in VC1 and VC2 causes substantial and needed reduction of head A-P and resultant acceleration and improvement of chest accelerations, for example, the introduction of the *fixed* pitch angles of 5 and 9 deg causes an increase in responses.

Since the runs for data sets IS1_THVT and IS2_THVT (Section 4.3.2) show that replacing a zero pitch angle with a time-varying pitch angle is not of benefit unless a good X-acceleration pulse is used, it might be the case that the runs discussed here for fixed pitch angles could be improved by using additionally the actual X-acceleration pulse from vehicle crash test VC04240. This was investigated in runs for data sets IS1_VCX5, IS2_VCX5, IS1_VCX9, and IS2_VCX9. The results, shown in Figures 19 to 22, are very little different from the results for IS1_5THV, IS2_5THV,

IS1_9THV, and IS2_9THV--just as was the case for zero pitch angle; i.e., improving the X-acceleration pulse does not help if the nonzero vehicle pitch angle is fixed.

4.3.4 IS with rearward IP intrusion. Another potential cause of differences between occupant responses in vehicle crash tests and Impact Simulator tests is intrusion of occupant-compartment surfaces in the vehicle crash test. Normally no attempt is made to represent displacement of such surfaces in the Impact Simulator test unless it is known that the intruding surfaces in the vehicle crash come to rest before interacting with the occupant. Occupant-compartment surfaces in Impact Simulator tests IS11144 and IS11145 were in their undisplaced positions. It is not known whether there were important rearward intrusions in vehicle crash VC04240; evidence from simulations indicates there were not. The VC04240 femur loads are accurately predicted in the VC1 and VC2 baseline runs and others, and it may therefore be assumed that there was no significant intrusion of either the knee bolster or the toepan. The greatest difference between VC04240 responses and simulation responses was for the head (A-P acceleration). Therefore, the possibility of rearward intrusion of higher parts of the instrument panel was investigated in simulations with data sets IS1_INTR and IS2_INTR. These are the same as the baseline data sets IS1 and IS2 except that the airbag and IP are nearer to the occupant's chest by 2 inches. The most appropriate way to accomplish this in the data set is by causing the IP to move 2 inches rearward, but model constraints make this impossible when an airbag is "attached" to the surfaces. Approximately the same effect was accomplished by displacing the chest surfaces of the occupant--not the occupant itself--forward by 2 inches. Simulation results are shown in Figures 23 and 24. Results are not greatly different from the IS1 and IS2 results; i.e., representation of a modest amount of intrusion of the upper and middle IP does not improve the degree of agreement between vehicle crash test VC04240 results and computer simulations for the Impact Simulator. An implication is that there was no such intrusion in test VC04240.

4.3.5 IS with buckled floor. Buckling of the floorpan, with resulting upward or downward motion of the seat, can cause occupant response in a vehicle crash test to be different from that in an Impact Simulator test. The direction of buckling would depend on structural characteristics of the vehicle, but it is unlikely that upward buckling occurred in test VC04240. If it had, there would very likely have been head contact with the roof header, which is not indicated by the VC04240 head acceleration time histories. Upward buckling of the floorpan was not studied in any simulations. The effect of possible downward buckling was investigated in runs for data sets IS1_BUKL and IS2_BUKL. These data sets are the same as IS1 and IS2 except that the seat drops by 3 inches from its initial position relative to the vehicle coordinate frame. Simulation results are shown in Figures 25 and 26. Of simulations other than the VC1 and VC2 baselines (Figures 7 and 8), in which both vehicle pitching and the actual vehicle

crash X-acceleration are used, these simulations produce the best agreement with the experimental VC04240 data. In particular, head and chest acceleration responses are reduced relative to the Impact Simulator baseline simulations IS1 and IS2 (Figures 5 and 6), as desired. However, neither magnitude nor shape of either the head response or chest response curves match the *vehicle crash* experimental results as well as do the VC1 and VC2 results. Also, femur loads are much less good in these simulations. It should be possible to cause the seat to drop away by 2 or 3 inches in an Impact Simulator test, but downward buckling of the floorpan probably did not occur in test VC04240.

5.0 SUMMARY AND CONCLUSIONS

The primary goal of the research described in this report was to establish, by means of computer simulations, an improved procedure for using an Impact Simulator (HYGE sled) to predict dummy responses that would occur in full-scale, vehicle crash tests. By determining, for a computer simulation of occupant response in an Impact Simulator, the modifications that will give us the best simulation of response in a vehicle crash test, we establish the best manner in which to modify a laboratory Impact Simulator test. This approach is valid provided that a good baseline simulation of the experimental Impact Simulator test is accomplished.

The specific tests studied were for a Chrysler S-body vehicle and occupant compartment. The frontal crash pulses had velocity changes of nominally 35 mph and peak accelerations of approximately 40 G's. The experimental data used were for the right front-seat passenger, a Hybrid 3 dummy, which interacted with a midmount passenger airbag. The dummy was not restrained additionally by belts, although a knee bolster was present. Data from two Impact Simulator tests and a vehicle crash test were available, as were data describing the airbag system. All simulation work in the study was conducted with the MVMA 2-D CVS Q-FEM Airbag Model.

The primary finding of this study is that--*for the specific type of crash examined*--time-varying pitch angle of the occupant compartment is the most important determinant of the differences between occupant motions in an Impact Simulator test and a vehicle crash test. It is of great importance to simulate the pitching motion of the occupant compartment of the vehicle crash test in the Impact Simulator test. Further, in the presence of pitching in an Impact Simulator test, it will be important, as well, to match the X- and Z-motions of the occupant compartment in the vehicle crash test as closely as possible. The X-motion can be matched by accurately reproducing the longitudinal acceleration from the vehicle crash test. Matching the Z-motion is accomplished by providing the proper center of rotation for the pitching motion.

Several alternative modifications of the Impact Simulator experiment were investigated by means of simulations. Those simulations show, however, that no modification except a time-varying pitch angle will greatly improve the degree to which Impact Simulator results are made to agree with vehicle crash test results. Factors tested in simulations and found not to be helpful included fixed, occupant-compartment pitch angles and rearward IP intrusion. Simulation of downward buckling of the floorpan produced mixed results, viz., some (smaller) improvements but also some detrimental effects. It was clear from the vehicle crash data that no significant amount of toepan intrusion or upward buckling of the floorpan occurred, so those factors were not studied. The effect of making the HYGE crash

pulse identical to the vehicle crash longitudinal acceleration was also examined; it was found not to be an important factor in the absence of time-varying pitch angle.

A great improvement from introducing vehicle pitching motion is seen clearly in both head and chest acceleration responses. Chest acceleration responses, while good even without inclusion of pitching, are improved substantially, but the greatest improvement is in head accelerations. There is improvement in both magnitude and shape in comparison with simulations that do not include pitching, where peak head accelerations (without IP contact) are on the order of 250 percent too large compared with the vehicle crash dummy responses. With inclusion of pitching, head accelerations are still too high by 50-75 percent, but this represents a four- to five-fold improvement. Further, inclusion of pitching yields head-acceleration errors versus experimental data much more like the errors in the Impact Simulator baseline computer simulations, which are 25-50 percent (high). Thus, on a relative basis, the "vehicle crash" simulations, i.e., with pitching, are of about the same quality as the Impact Simulator simulation baselines. No other modification tested produced improvement of nearly this magnitude.

The results of this study suggest that it is important to consider vehicle pitching in design of airbag systems. It may be said, however, that design on the basis of results from Impact Simulator tests that do not provide pitching will be conservative since normal, "back end up" pitching in a frontal crash can be expected to reduce chest and, especially, head accelerations.

At least two different methods have been tested at HYGE sled facilities for providing time-varying occupant-compartment pitching in sled tests. One method makes use of hydraulic cylinders at the corners of the test rig. A second method uses supplemental rails that guide an angular motion of the test rig as the sled moves along the track. Information pertinent to these methods is in the paper by Berge, et al. (1985). A copy of that paper accompanies this report.

It does not seem unlikely that similar conclusions regarding the importance of pitching would result from a simulation study of belt-restrained occupants in Impact Simulator and vehicle crash tests. Such a study is recommended.

It should be emphasized, however, that in some types of crashes, differences in pitching motion may not have the overriding importance found in this study. The vehicle crash of this particular study apparently did not have any significant rearward intrusions of IP or toepan. It is a fact, however, that occupant interaction with a displaced or moving vehicle-interior surface can have a large consequence with respect to occupant forces and accelerations. Development of guidelines for accounting for that type of effect in Impact Simulator tests could be done in a study such as the one herein reported if the

vehicle crash data were for a test that had such vehicle-interior intrusion. Similarly, floorpan buckling, which was apparently absent in the vehicle crash in this study, is known to be of particular significance in some types of crash tests; guidelines for accounting for effects related to floorpan buckling, too, could be developed in a simulation study.

Additional simulations of the specific Impact Simulator and vehicle crash tests of this study might be useful for the purpose of refining results relevant to two parameters. One is the pitch-angle time history, which should be derived from pertinent VC04240 test data if such data exist (rather than using data from the literature). The second is velocity change. The velocity change for the VC04240 vehicle crash pulse is 34.75 mph while the velocity change for the averaged IS11144 and IS11145 Impact Simulator tests is 33.23 mph; the effects of the difference in magnitude separate from phase were not examined in this study.

Finally, it should be noted that the computer simulation results of this study confirm experimental findings that show that, for the specific type of crash examined, Impact Simulator experiments without pitching provide a more severe test of a restraint-system design than does a vehicle crash experiment.

LIST OF REFERENCES

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Bowman, B. M. 1979. MVMA two-dimensional crash victim simulation - advanced airbag-system submodel. Final report. Highway Safety Research Institute, Ann Arbor, Mich. 286 p. Sponsor: General Motors Corporation, Research Laboratories, Biomedical Sciences Department, Warren, Mich. Report No. UM-HSRI-79-51.

Bowman, B. M.; Bennett, R. O. 1988. MVMA two-dimensional crash victim simulation, version 6. Volumes 1, 2, and 3. Final report. Michigan University, Ann Arbor, Transportation Research Institute. 210 p. Sponsor: Motor Vehicle Manufacturers Association, Detroit, Mich. Report No. UMTRI-88-23-1,2,3.

APPENDIX

Simulation Plots

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

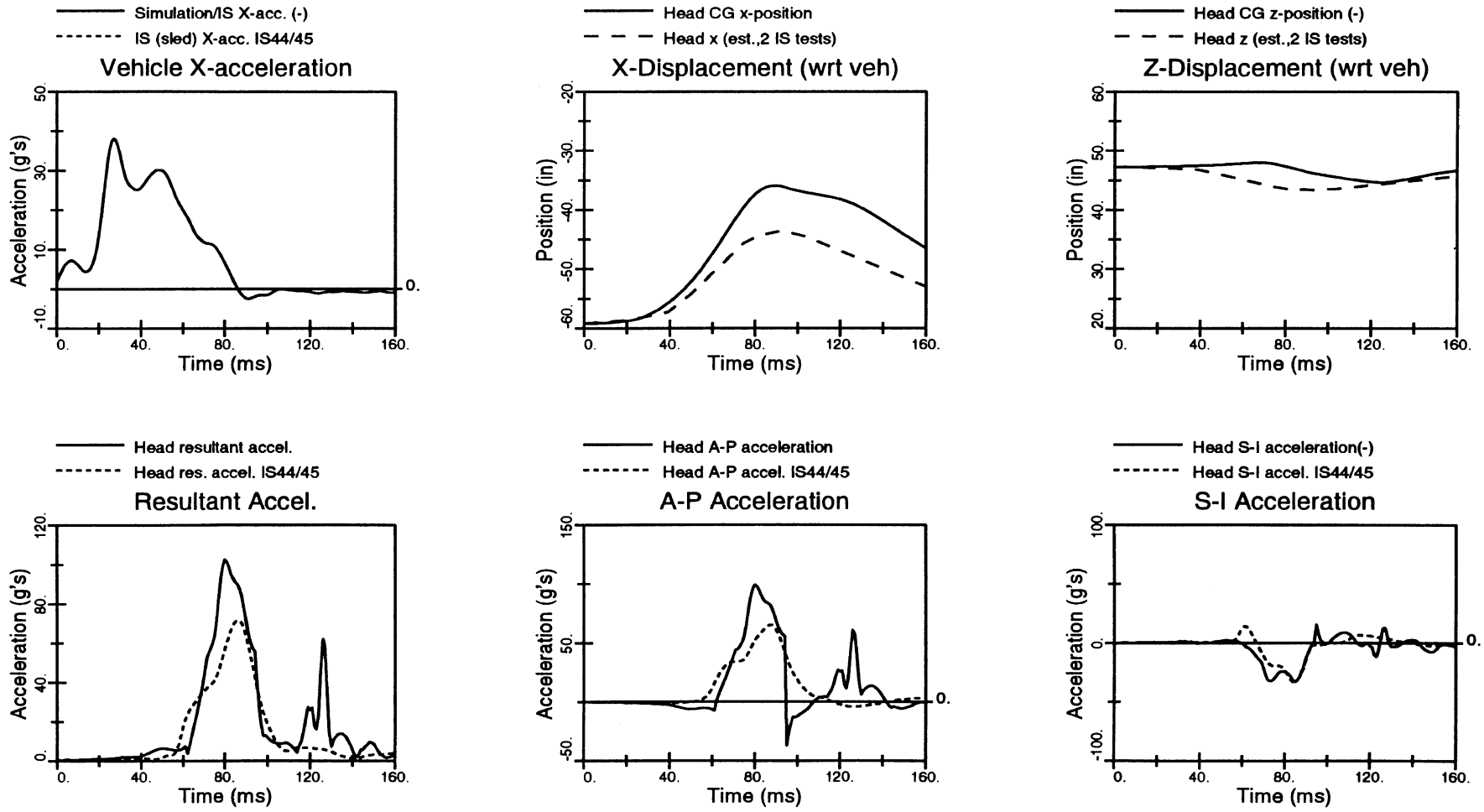


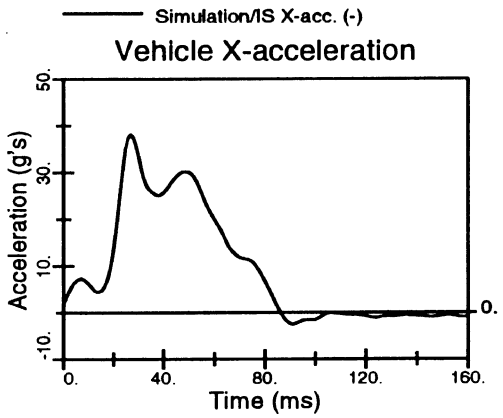
Figure 5.

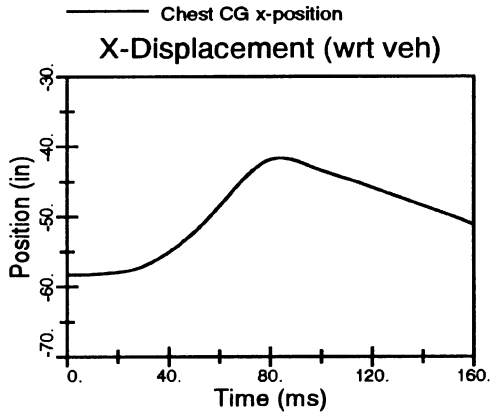
MVMA 2-D CVS Quasi-Finite Element Airbag Model

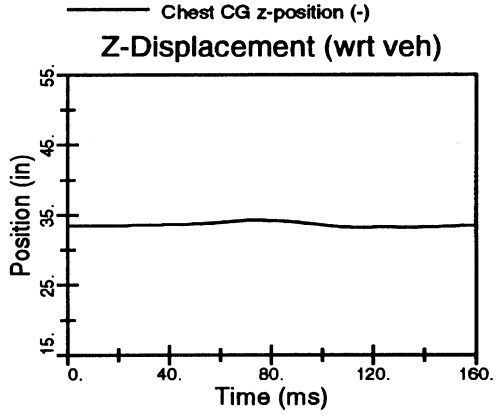
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

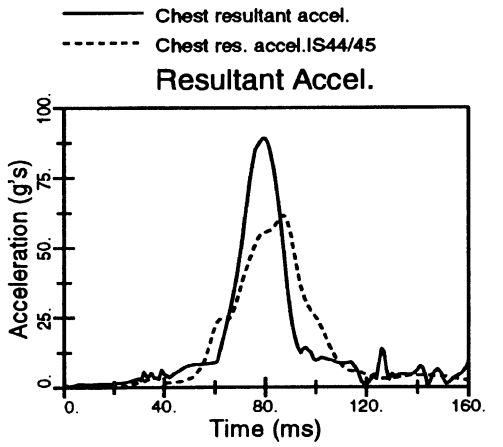
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

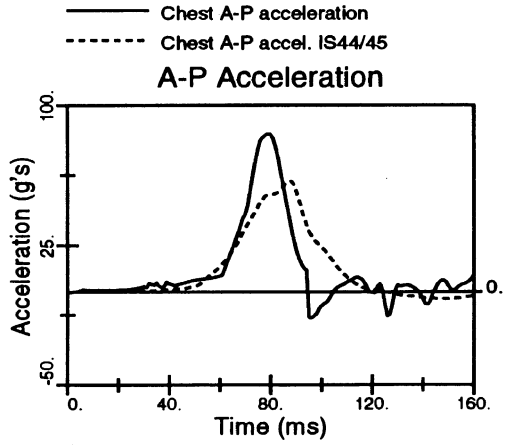
CHEST KINEMATIC RESPONSE











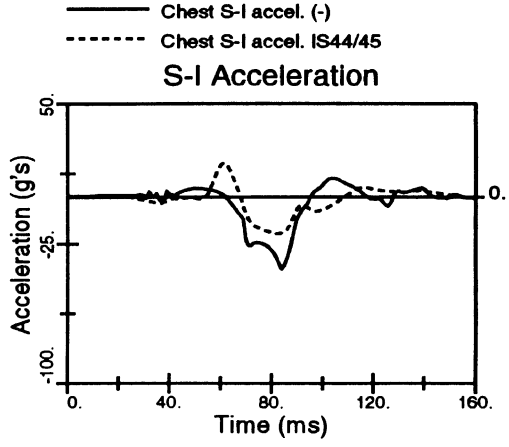


Figure 5.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

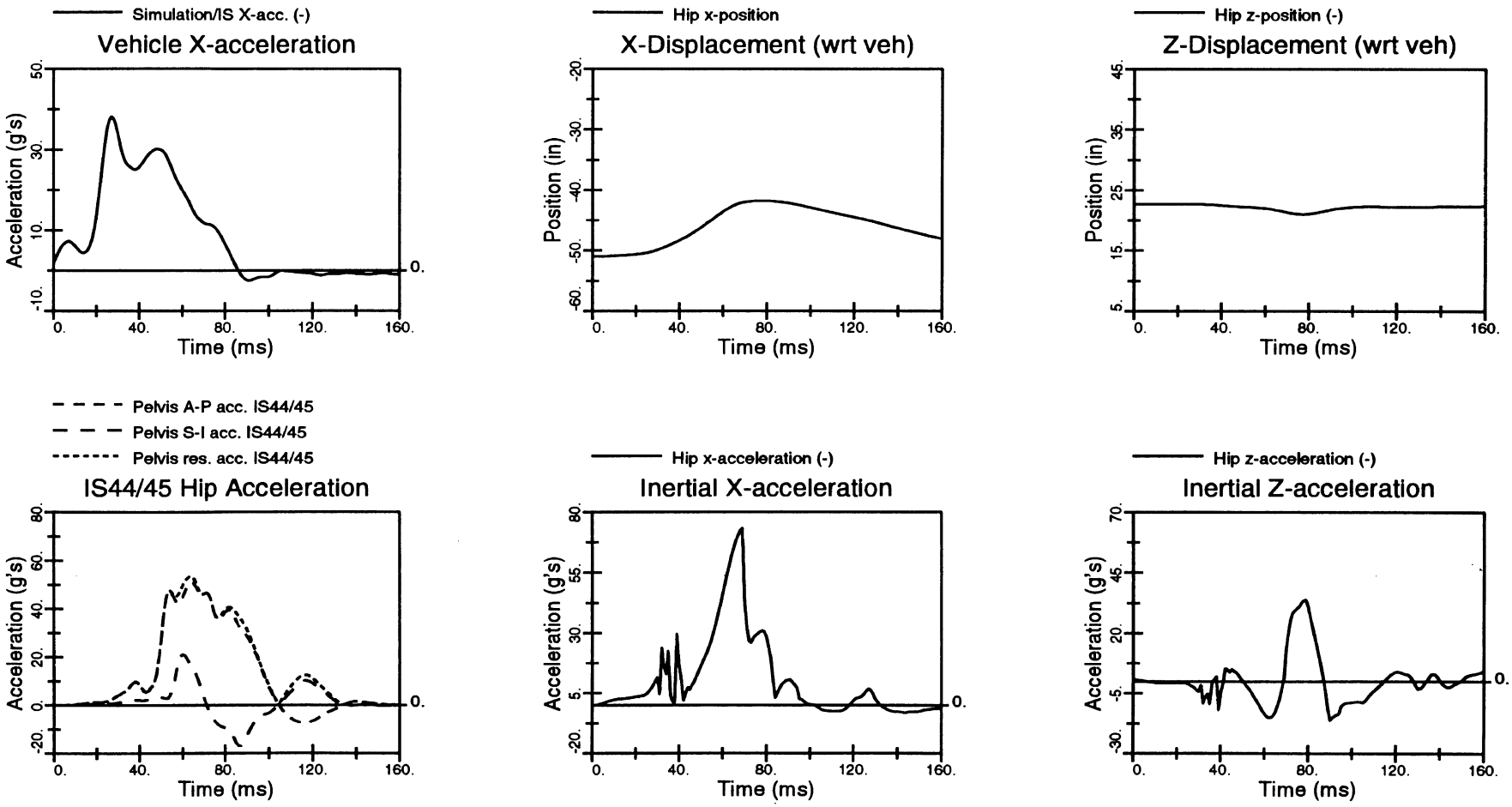


Figure 5.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

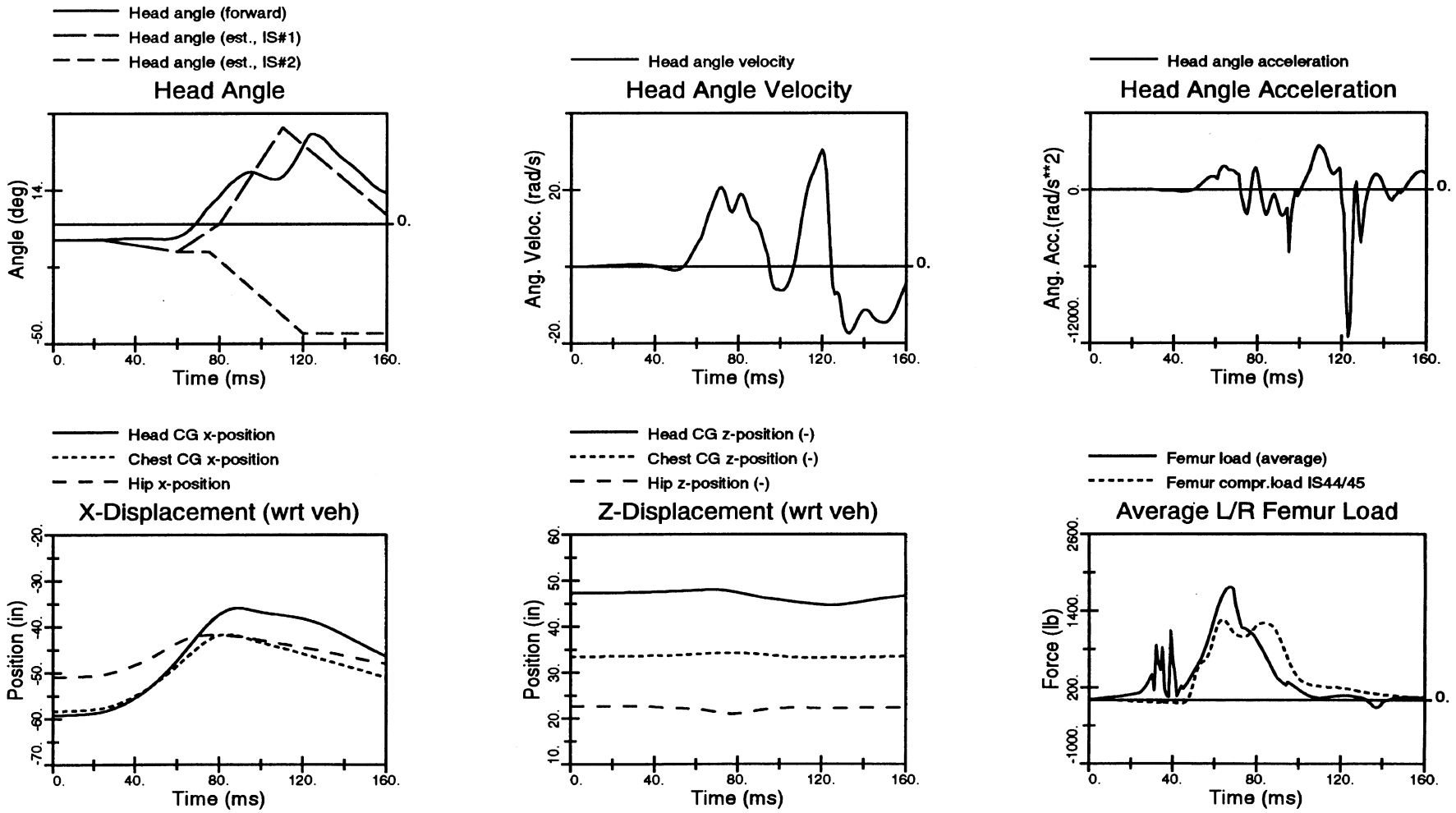


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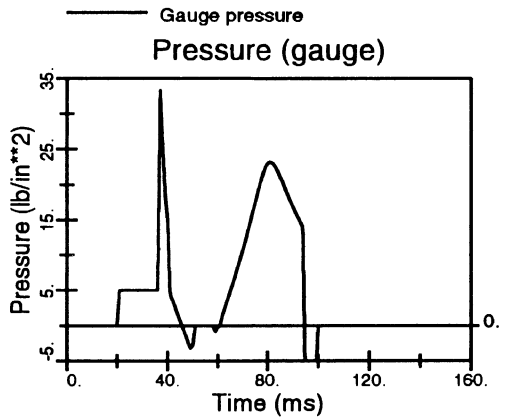
Figure 5.

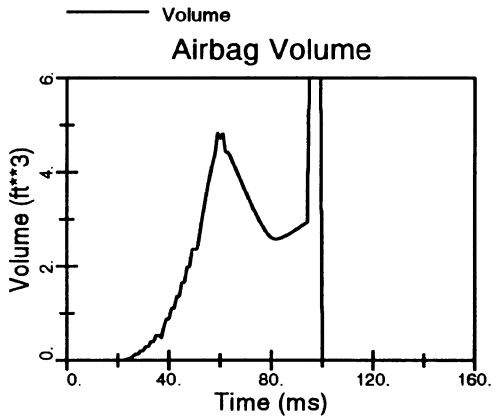
MVMA 2-D CVS Quasi-Finite Element Airbag Model

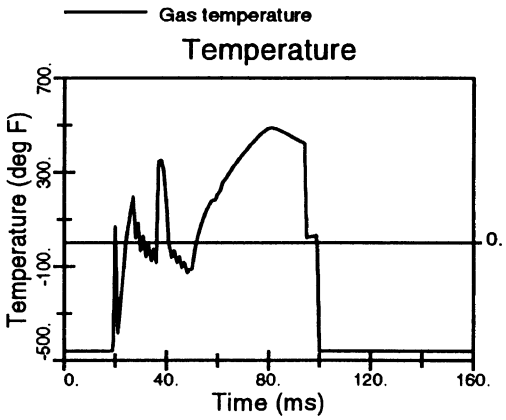
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

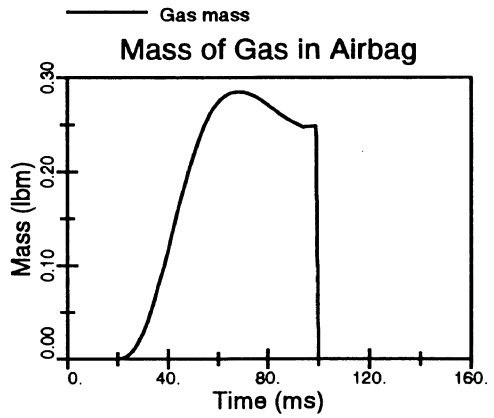
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

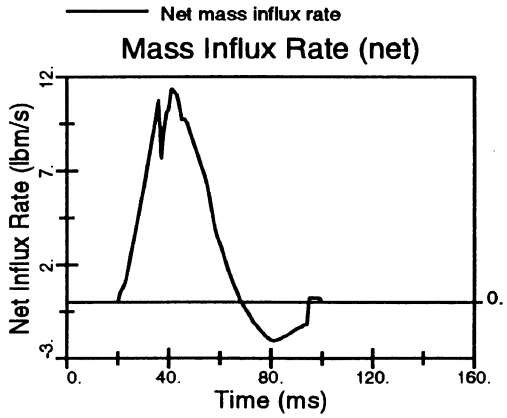
THERMODYNAMIC VARIABLES











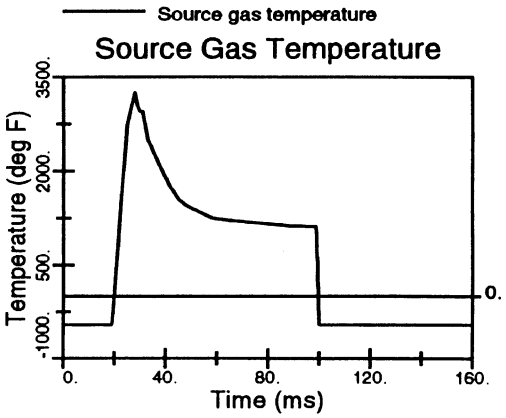


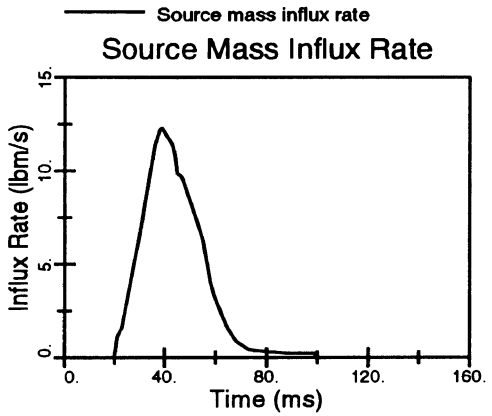
Figure 5.

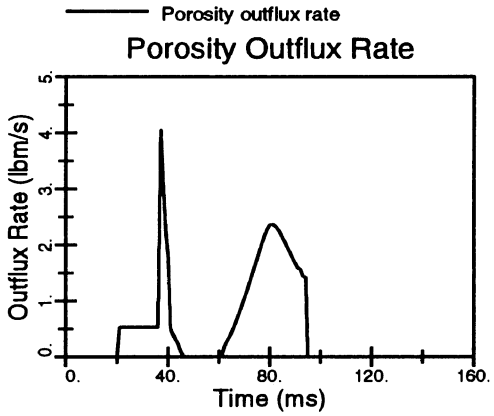
MVMA 2-D CVS Quasi-Finite Element Airbag Model

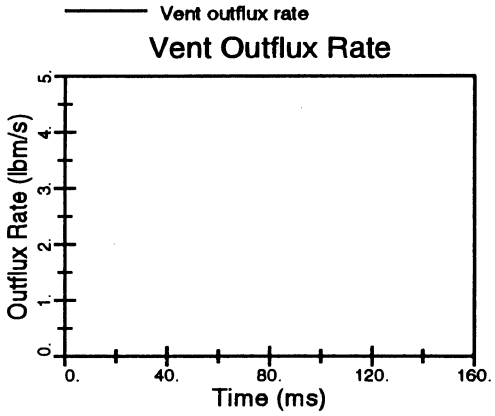
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

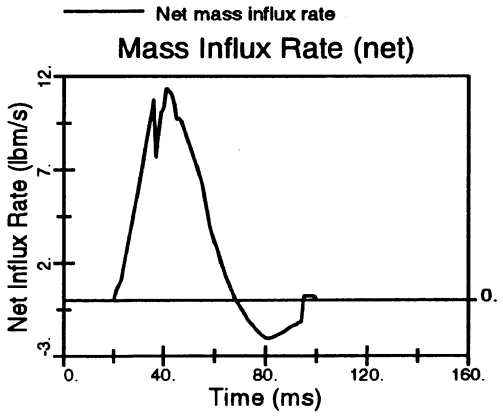
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

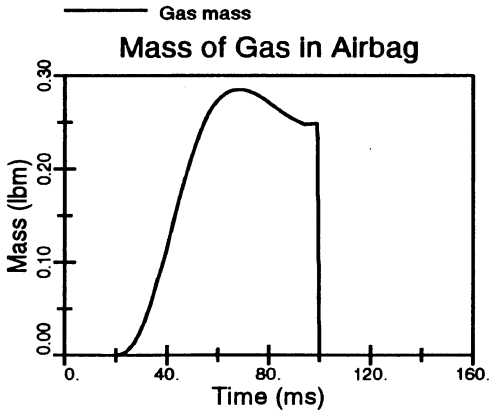
AIRBAG MASS INFLUX/OUTFLUX











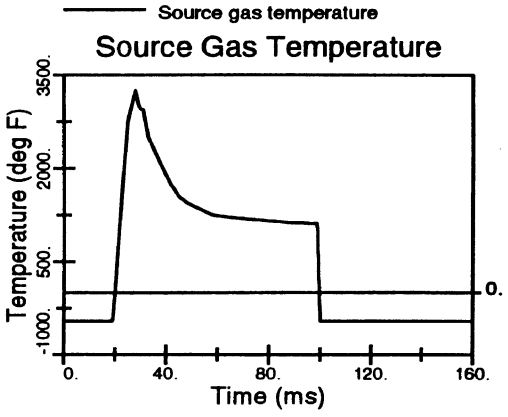


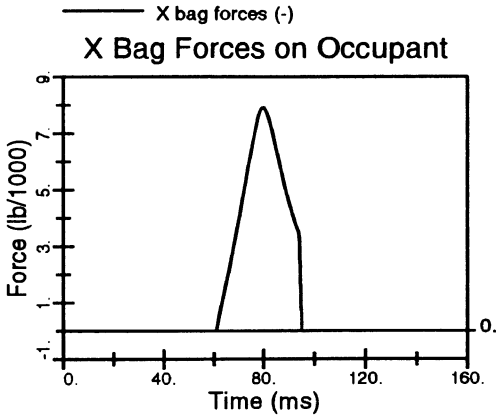
Figure 5.

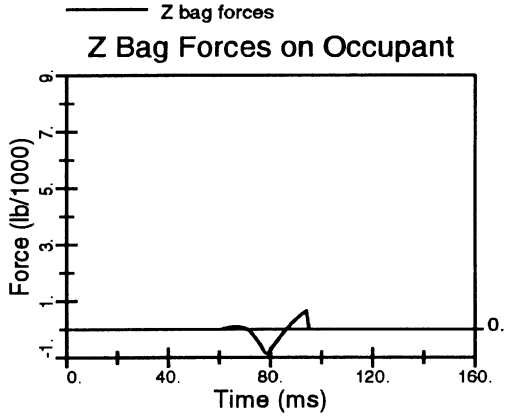
MVMA 2-D CVS Quasi-Finite Element Airbag Model

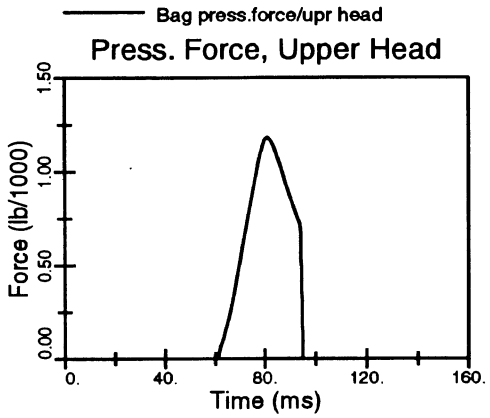
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

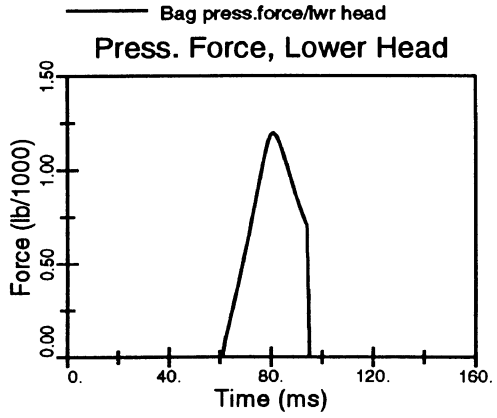
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









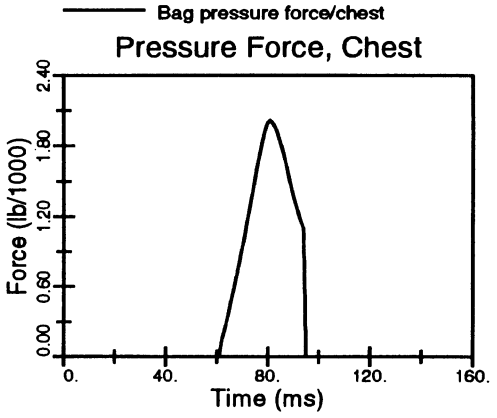


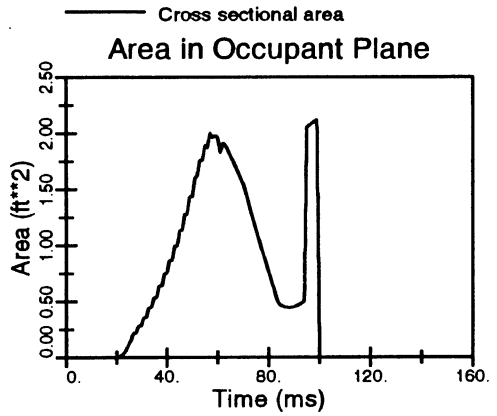
Figure 5.

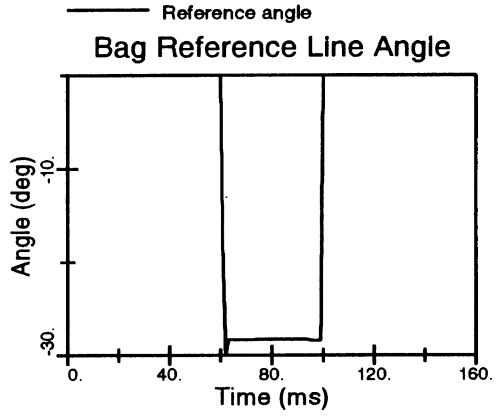
MVMA 2-D CVS Quasi-Finite Element Airbag Model

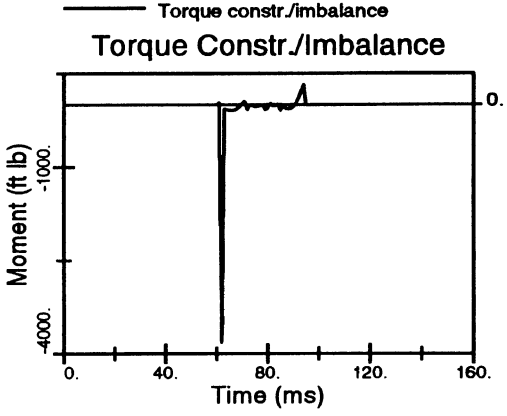
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #1 , Tests IS11144/45

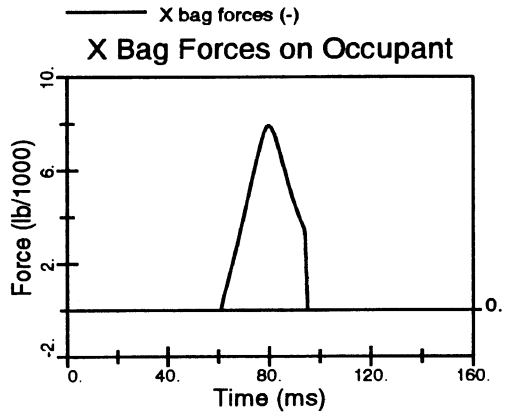
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









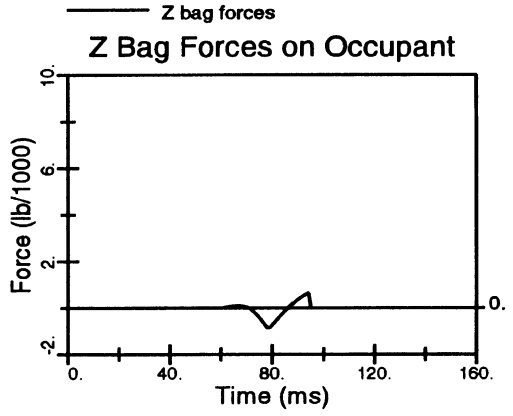


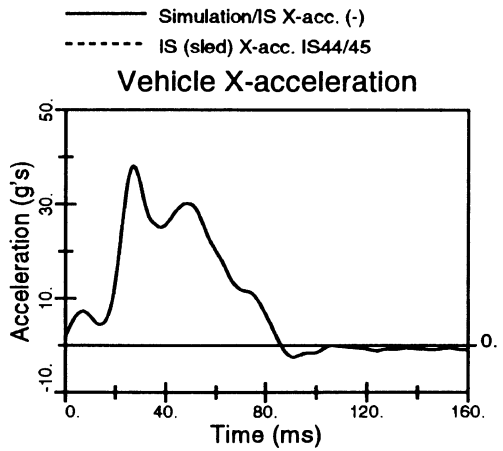
Figure 5.

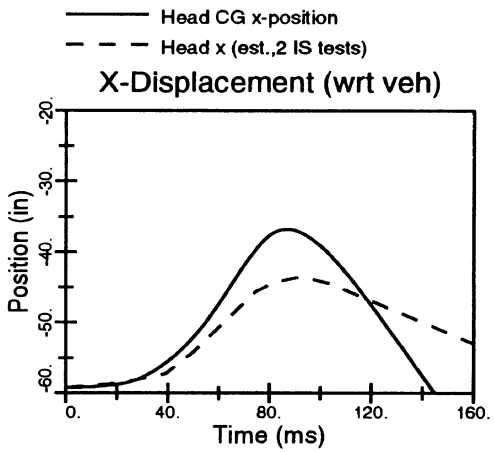
MVMA 2-D CVS Quasi-Finite Element Airbag Model

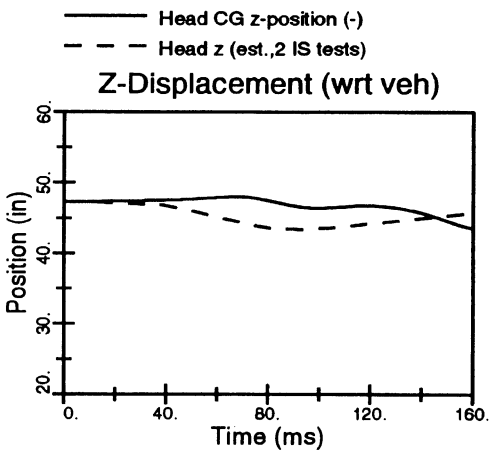
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

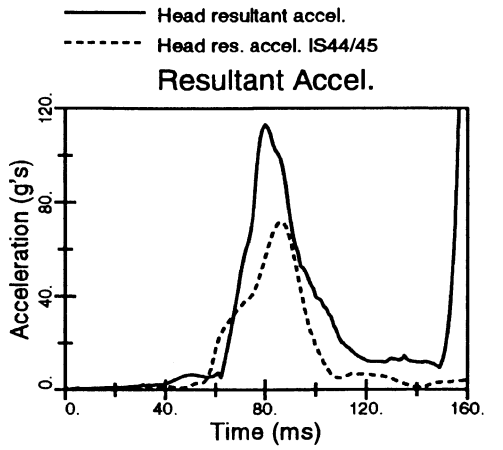
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

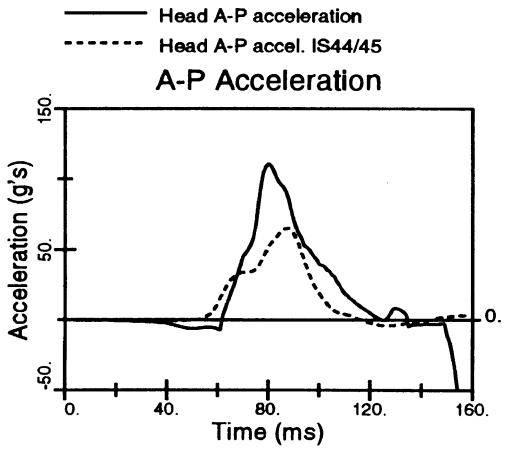
HEAD KINEMATIC RESPONSE











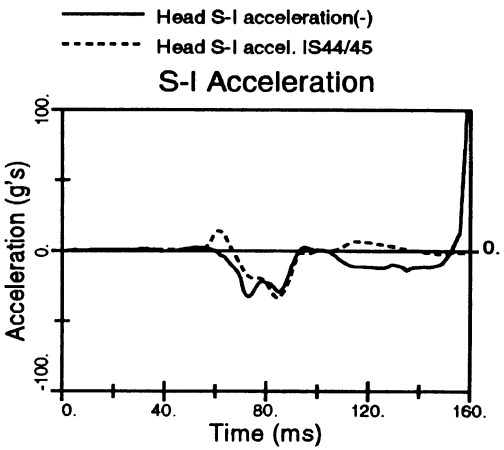


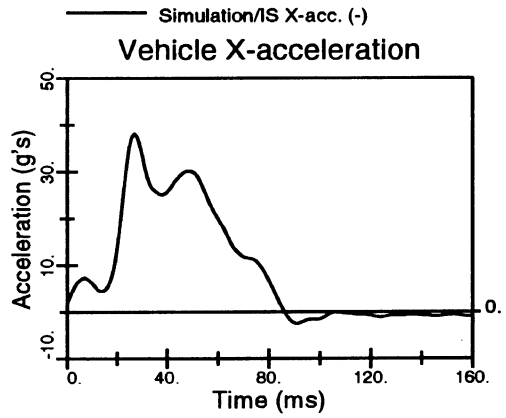
Figure 6.

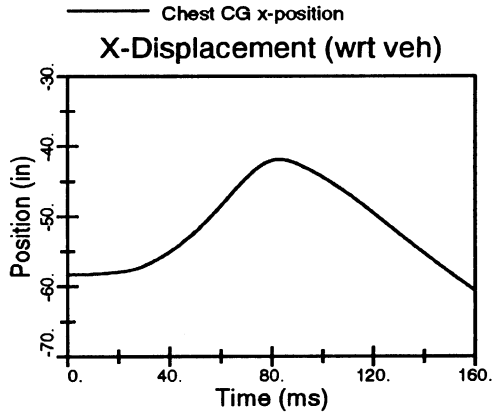
MVMA 2-D CVS Quasi-Finite Element Airbag Model

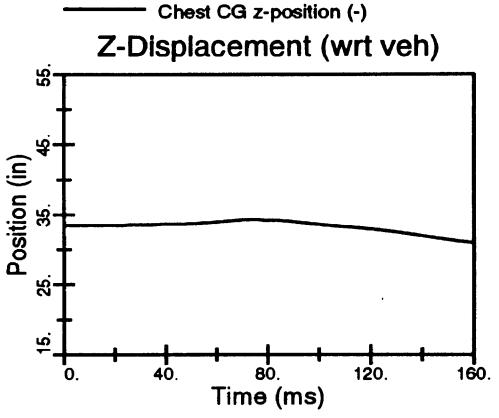
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

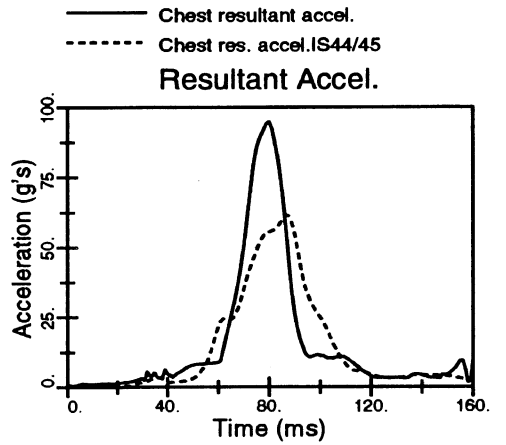
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

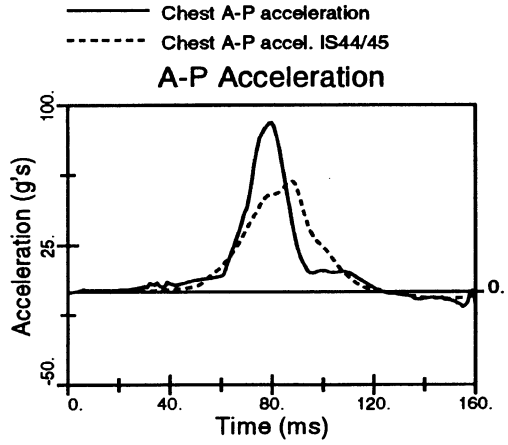
CHEST KINEMATIC RESPONSE











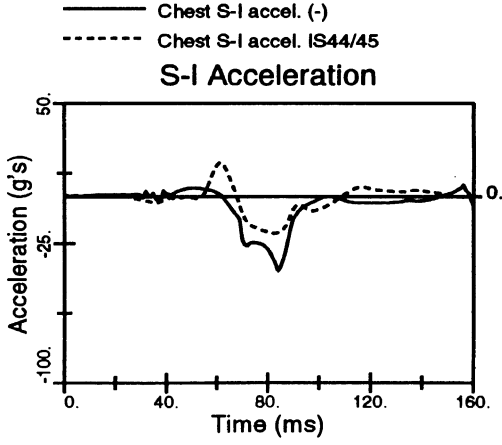


Figure 6.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

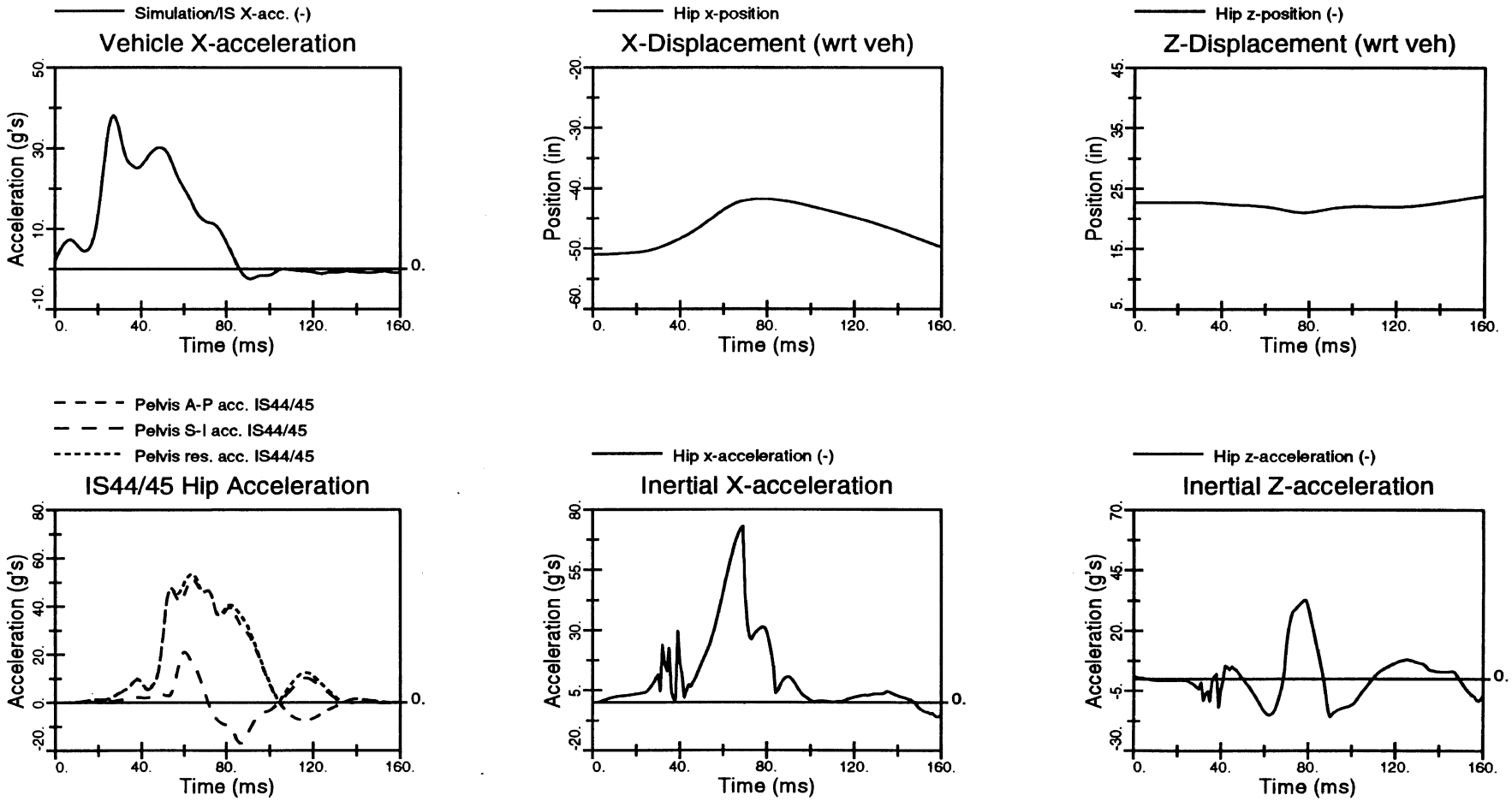


Figure 6.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

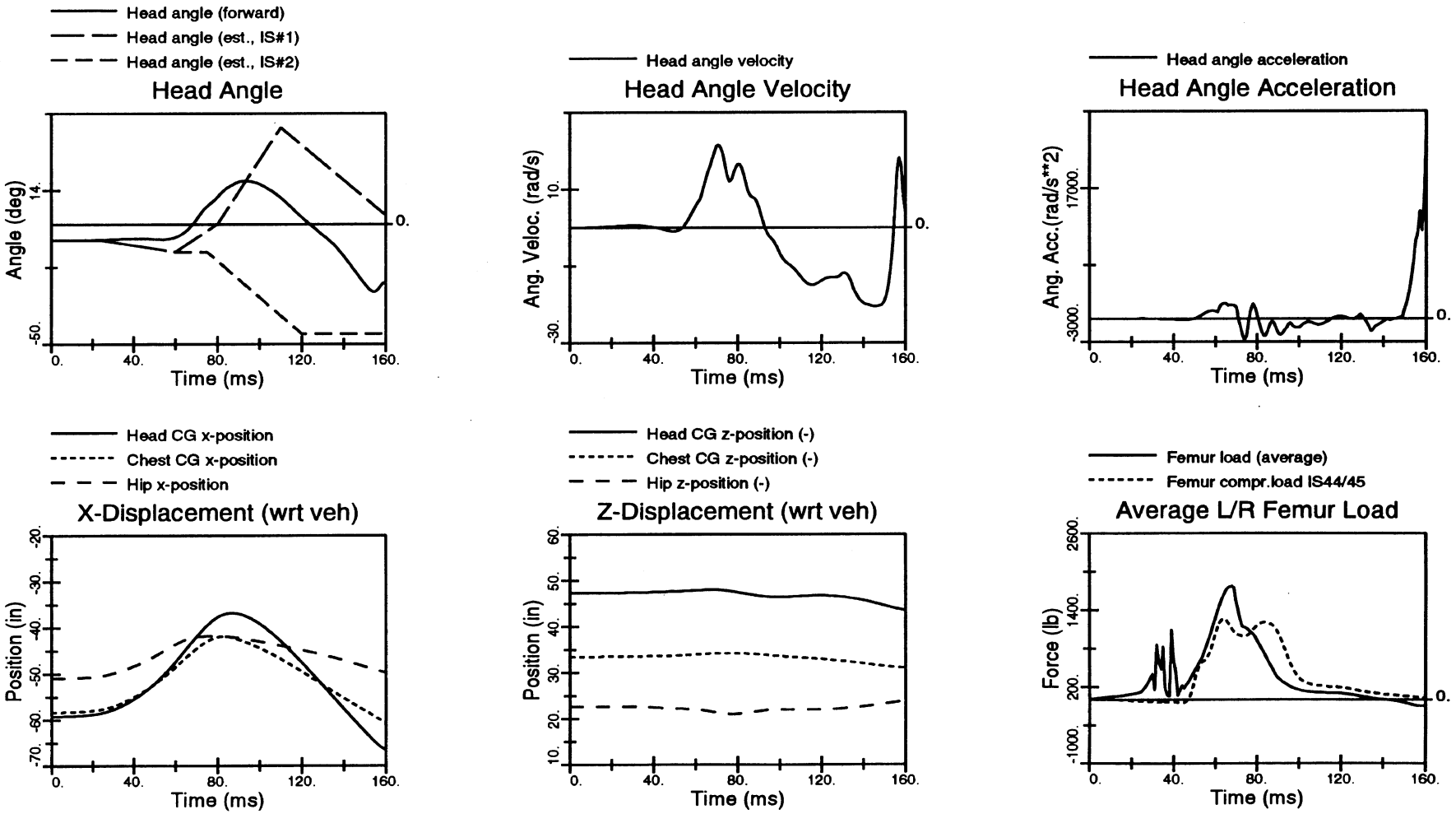


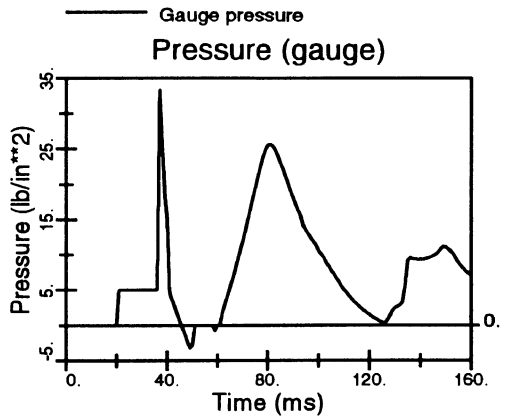
Figure 6.

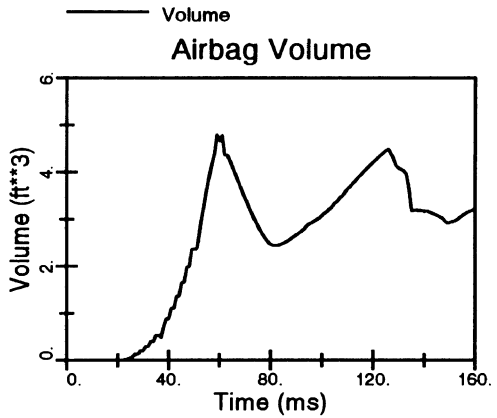
MVMA 2-D CVS Quasi-Finite Element Airbag Model

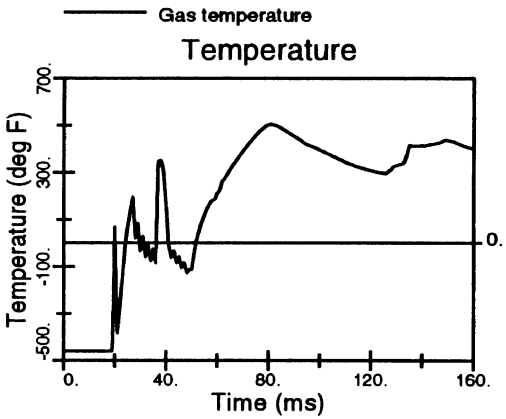
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

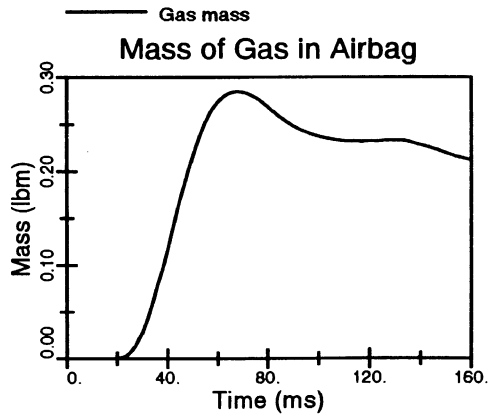
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

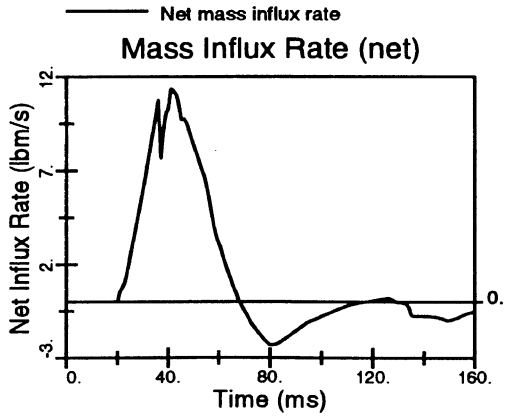
THERMODYNAMIC VARIABLES











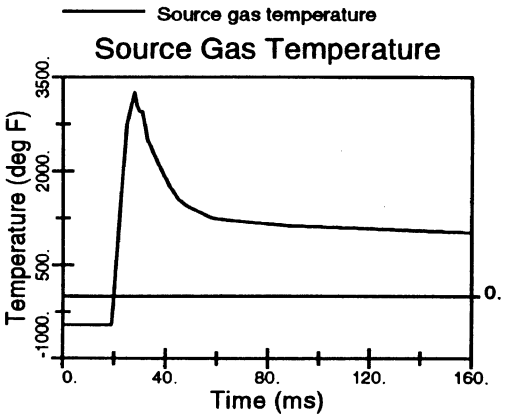


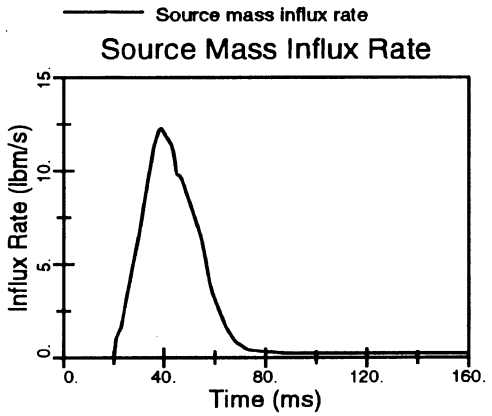
Figure 6.

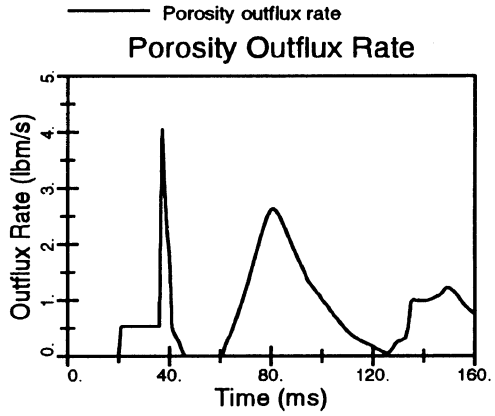
MVMA 2-D CVS Quasi-Finite Element Airbag Model

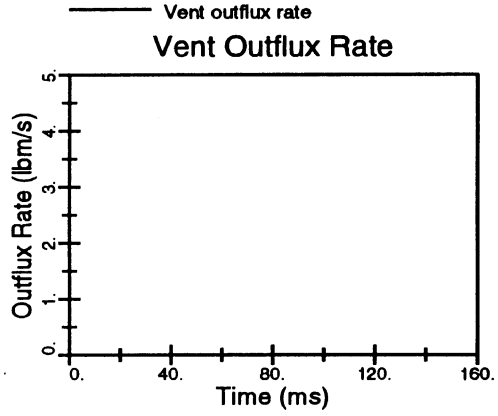
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

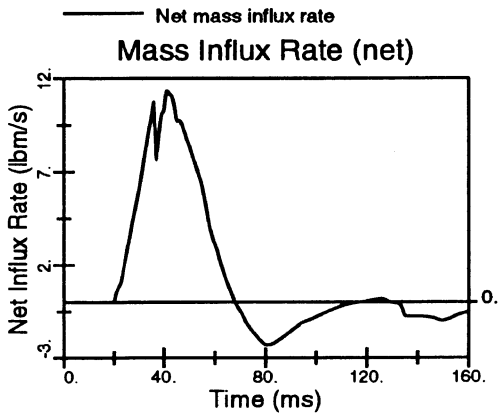
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

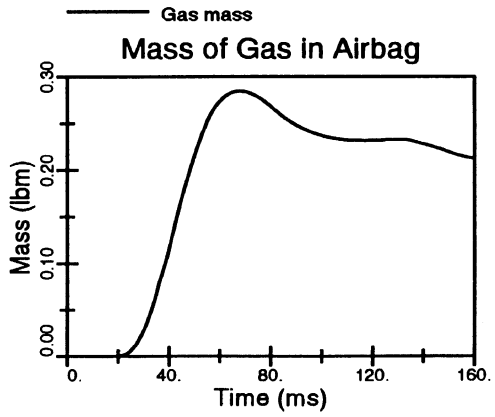
AIRBAG MASS INFLUX/OUTFLUX











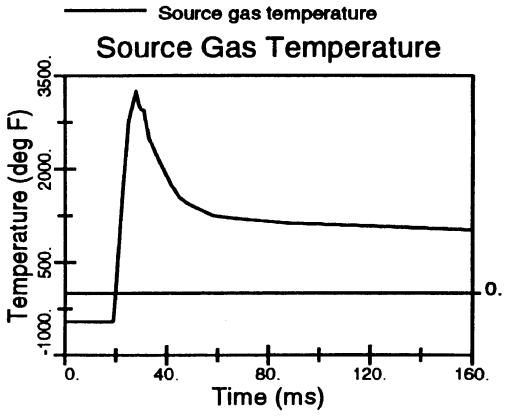


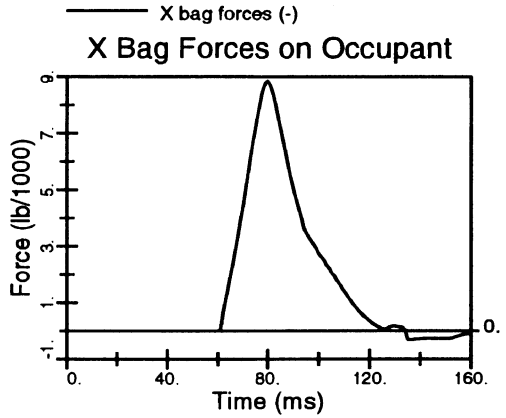
Figure 6.

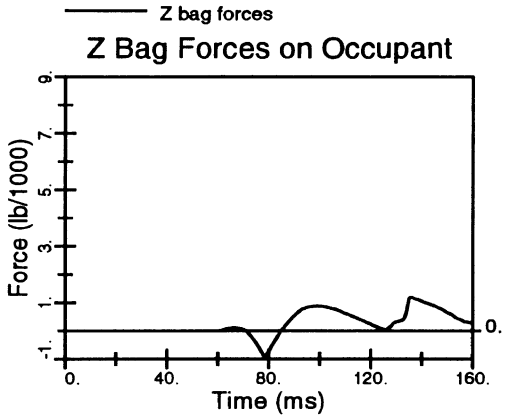
MVMA 2-D CVS Quasi-Finite Element Airbag Model

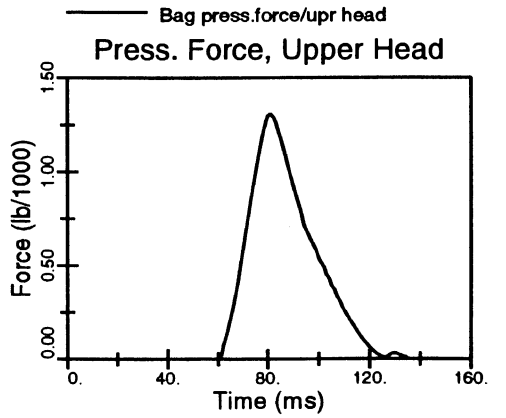
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

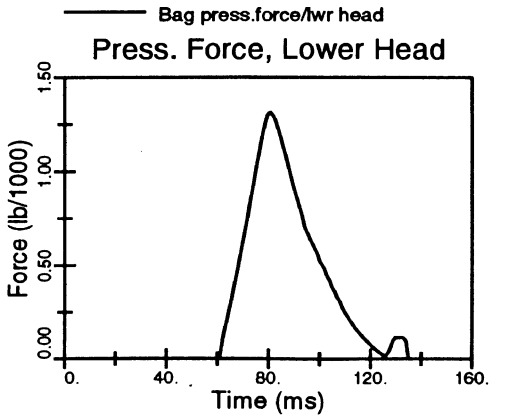
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









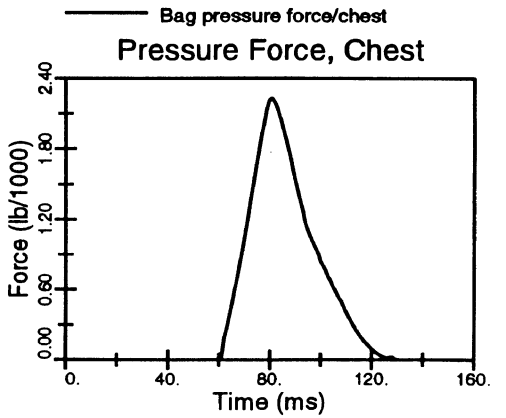


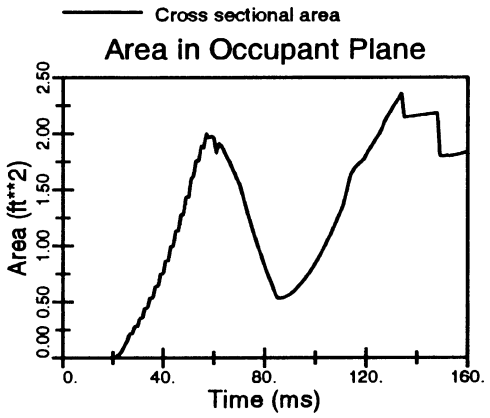
Figure 6.

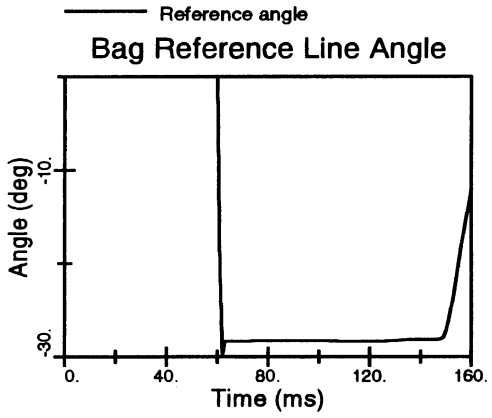
MVMA 2-D CVS Quasi-Finite Element Airbag Model

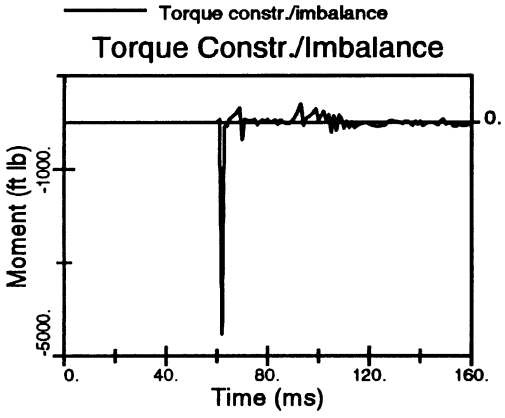
UMTRI Preliminary S-Body IS Test Simulation / IS baseline #2 , Tests IS11144/45

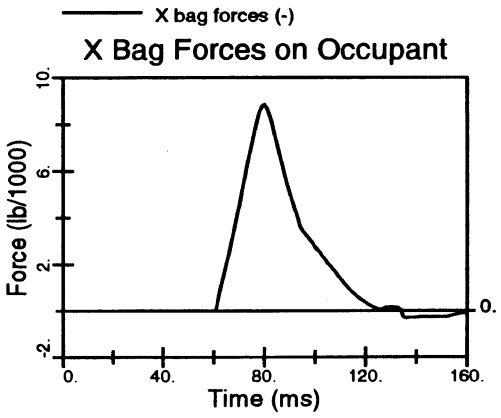
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









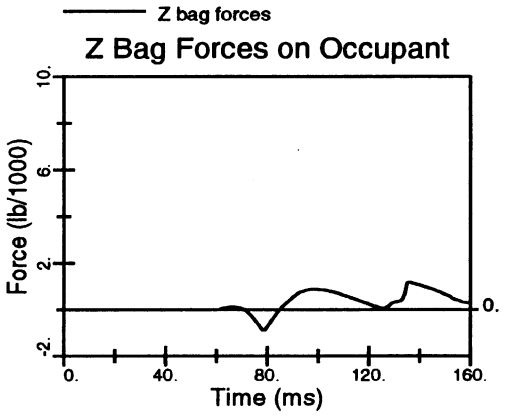


Figure 6.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

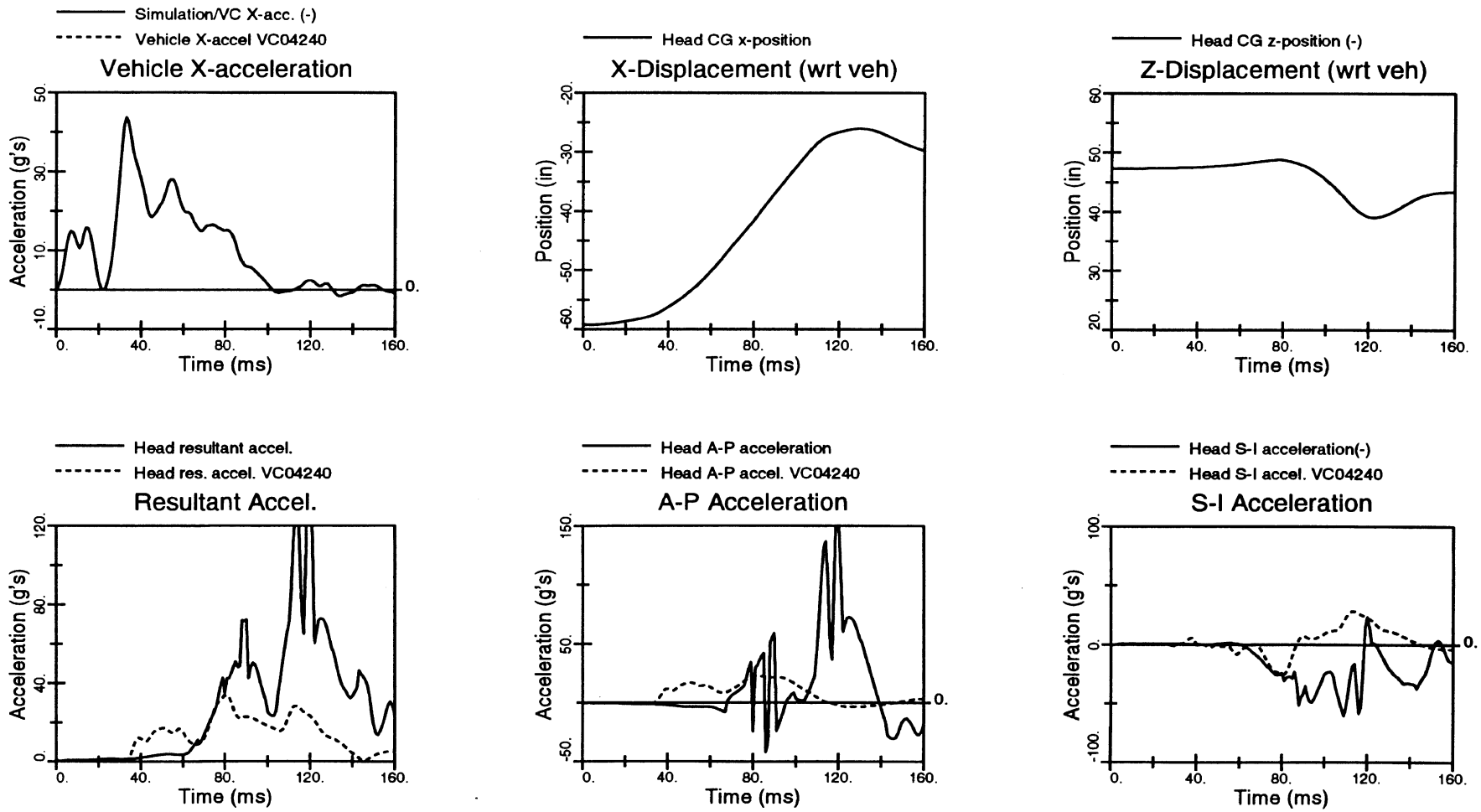


Figure 7.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

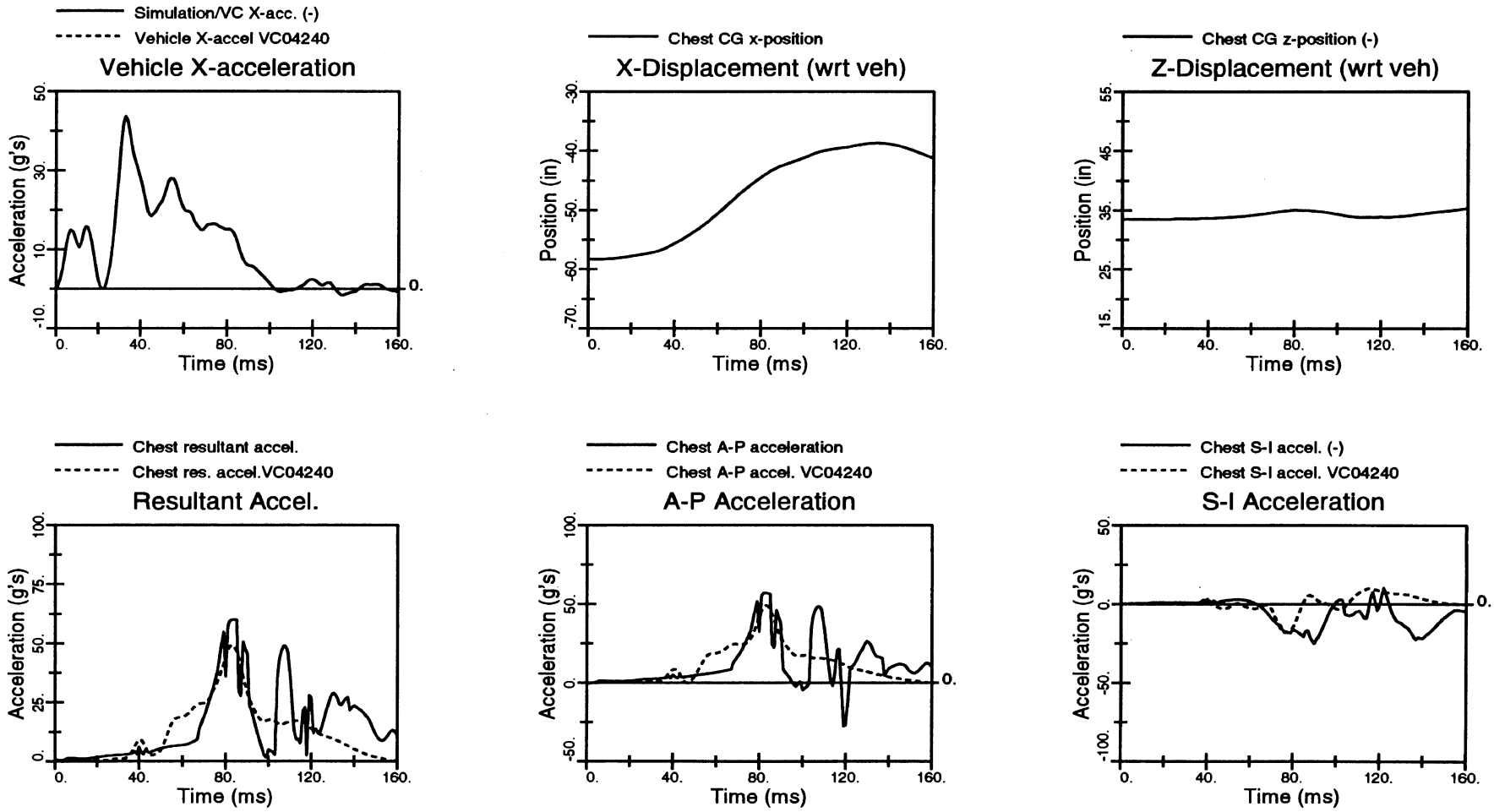


Figure 7.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

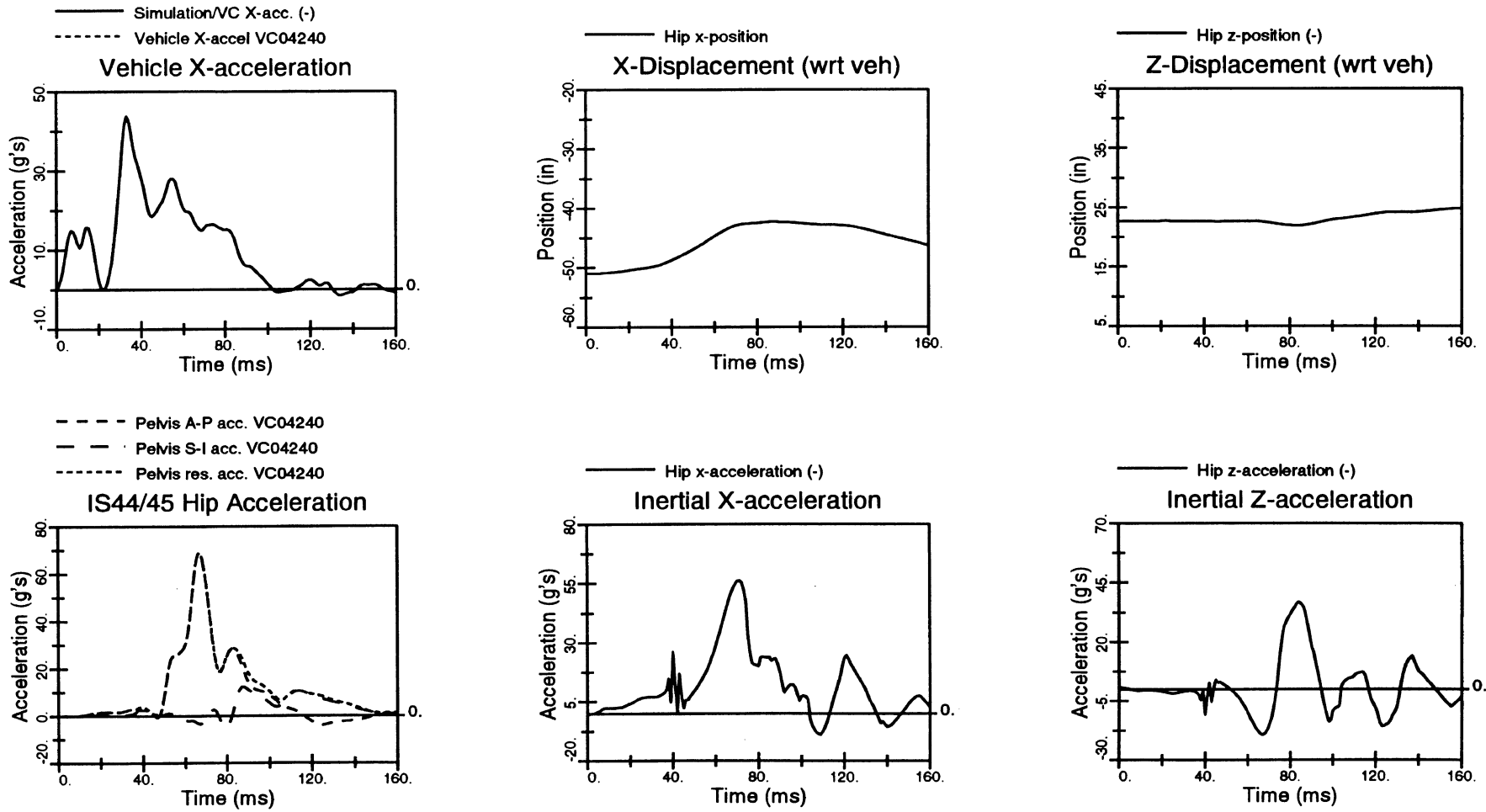


Figure 7.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

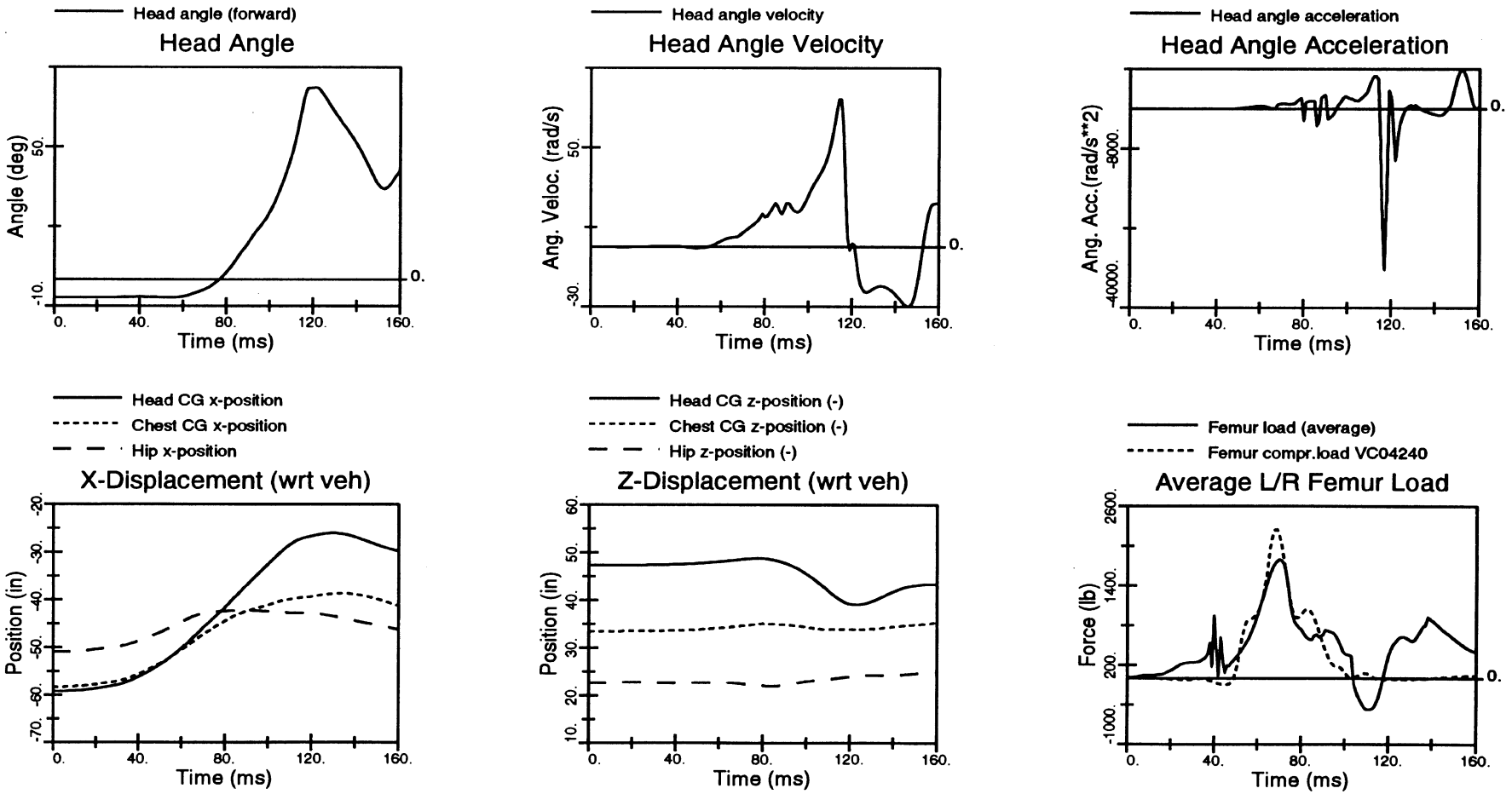


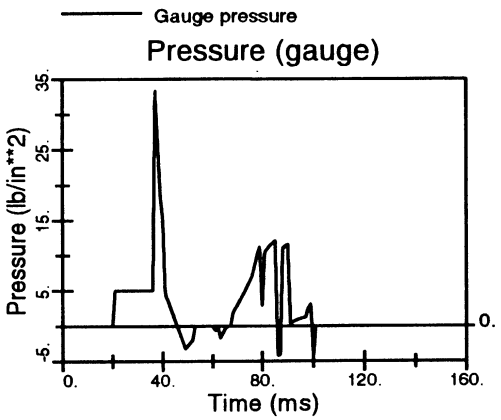
Figure 7.

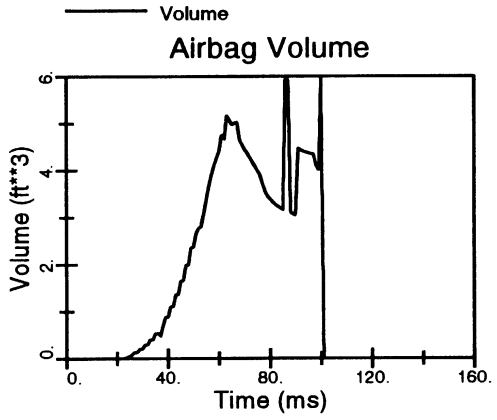
MVMA 2-D CVS Quasi-Finite Element Airbag Model

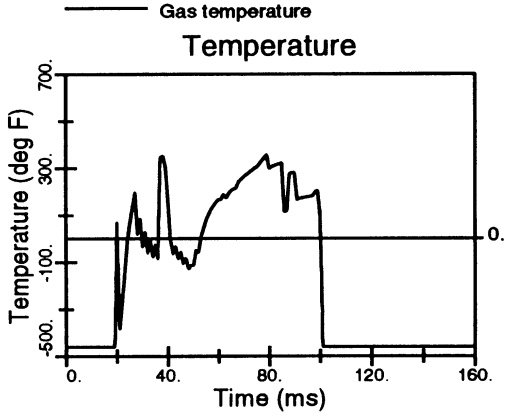
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

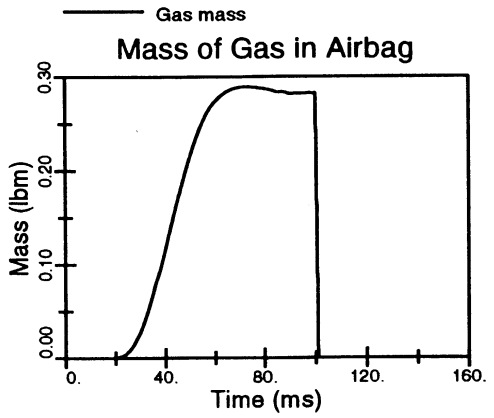
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

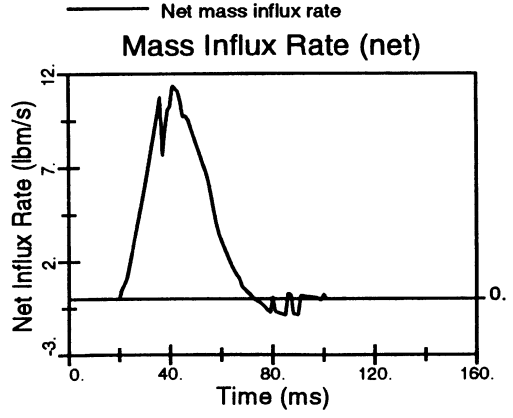
THERMODYNAMIC VARIABLES

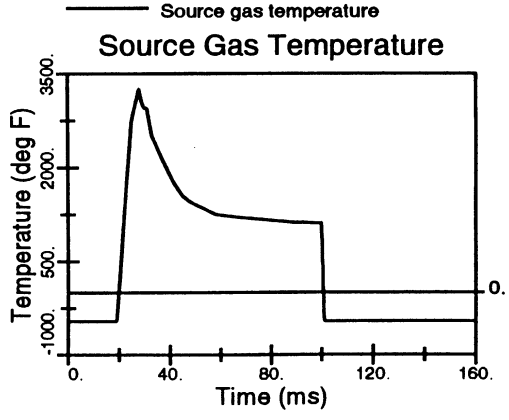












A-22

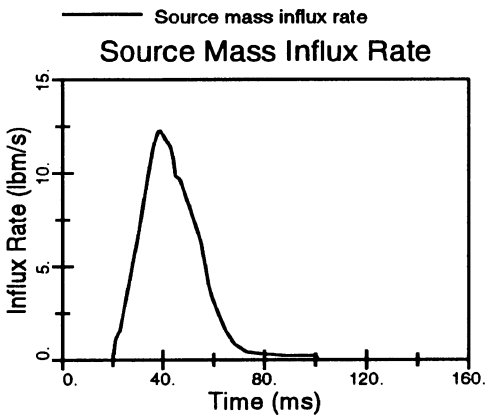
Figure 7.

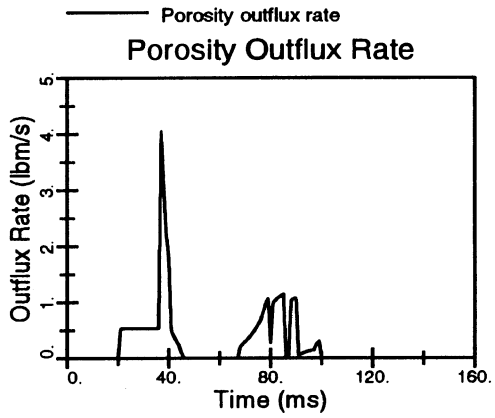
MVMA 2-D CVS Quasi-Finite Element Airbag Model

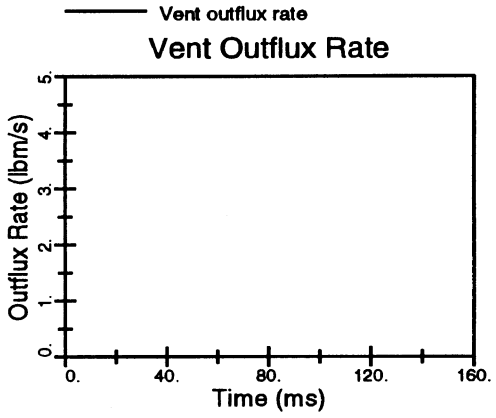
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

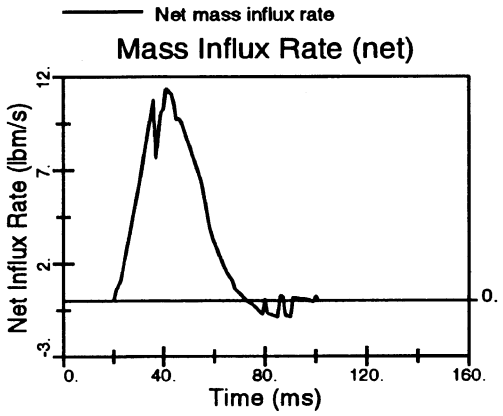
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

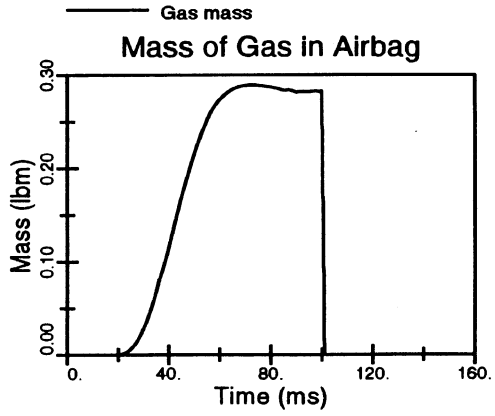
AIRBAG MASS INFLUX/OUTFLUX











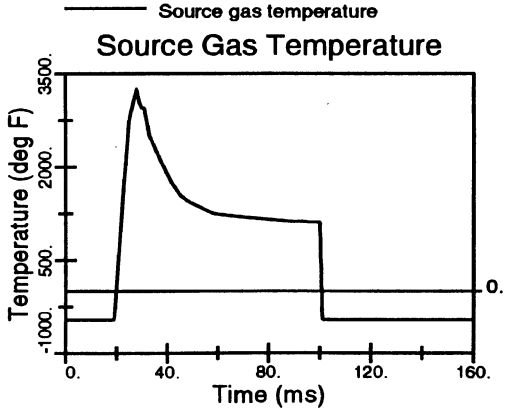


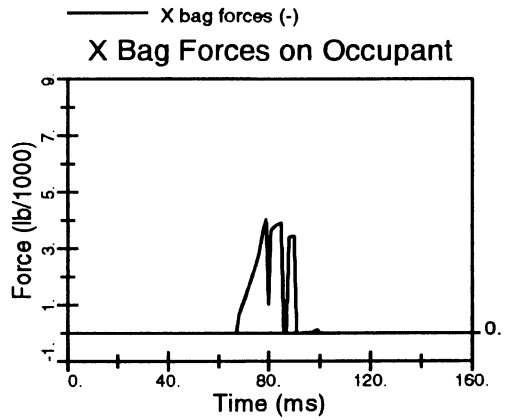
Figure 7.

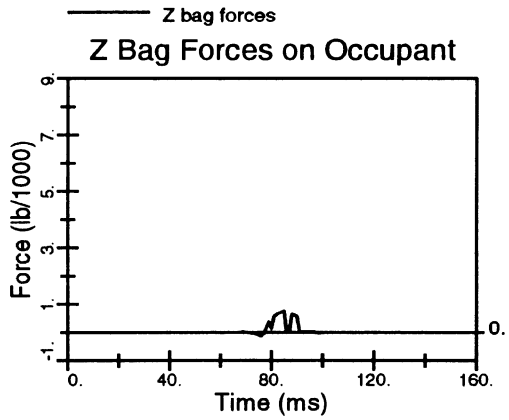
MVMA 2-D CVS Quasi-Finite Element Airbag Model

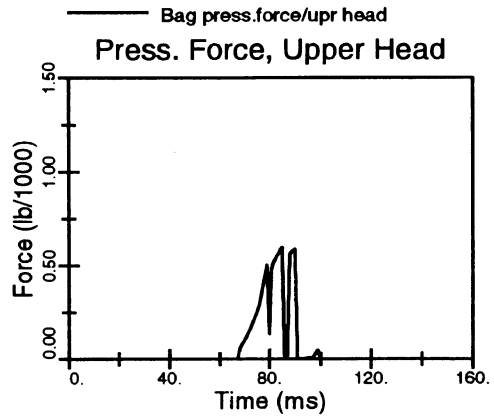
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

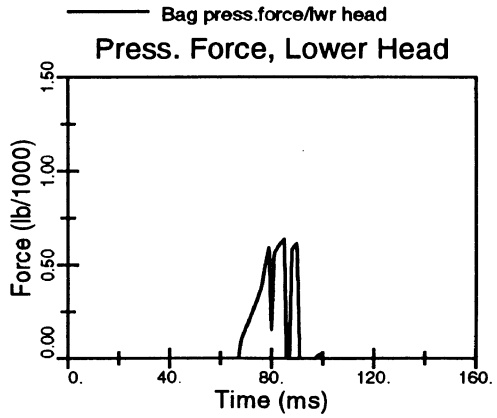
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









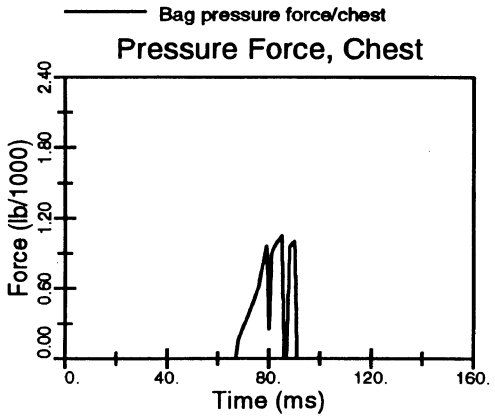


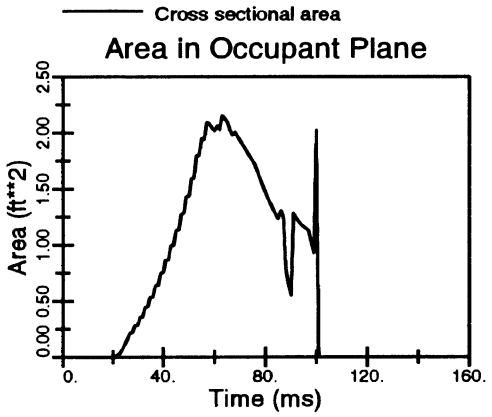
Figure 7.

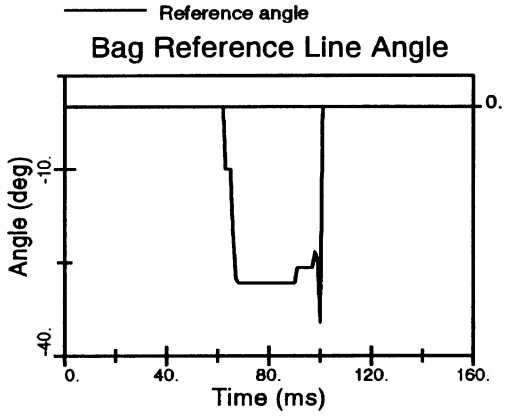
MVMA 2-D CVS Quasi-Finite Element Airbag Model

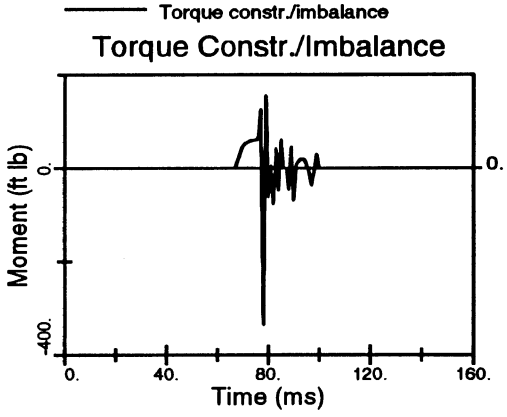
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #1 , Test VC04240

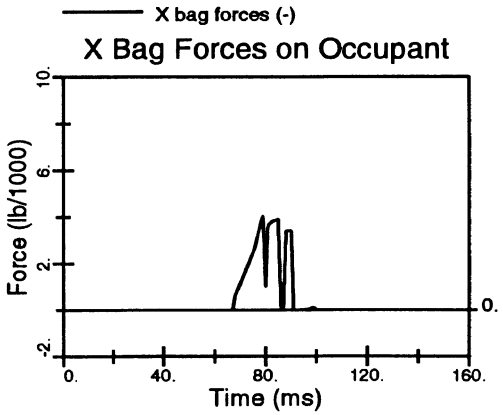
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









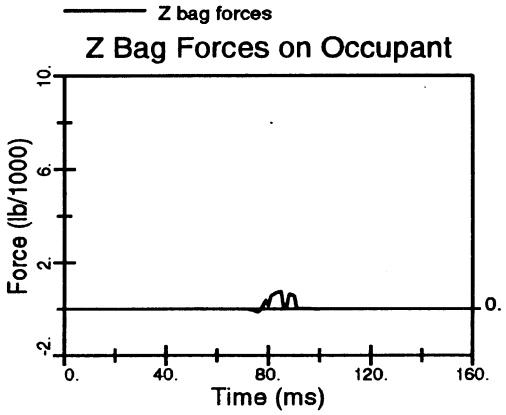


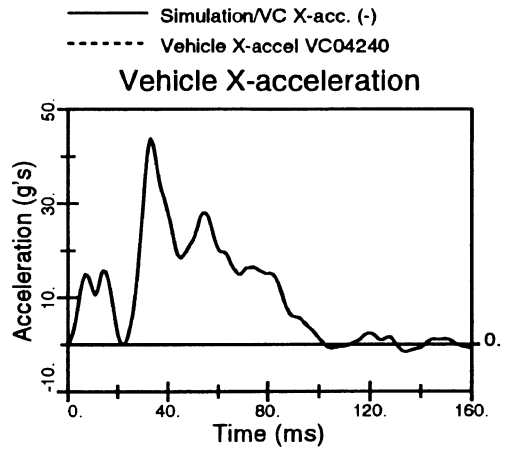
Figure 7.

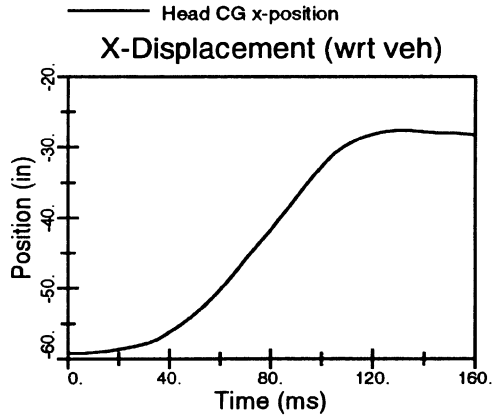
MVMA 2-D CVS Quasi-Finite Element Airbag Model

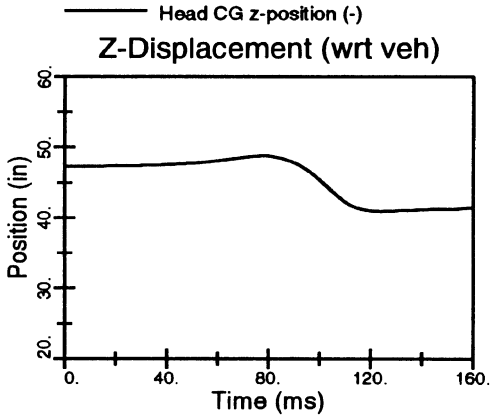
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

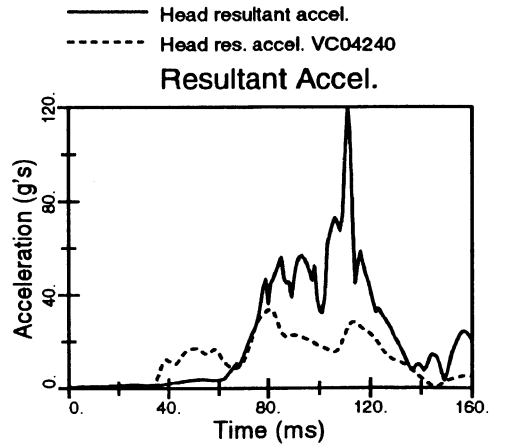
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

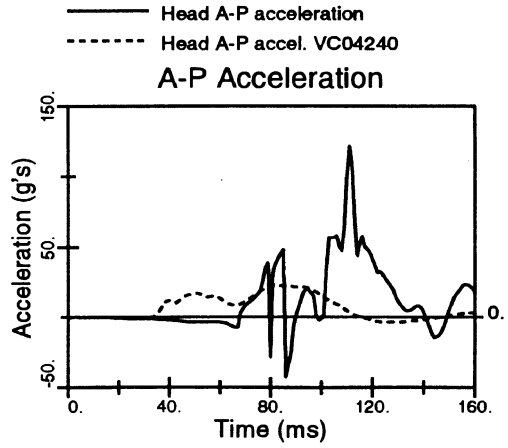
HEAD KINEMATIC RESPONSE











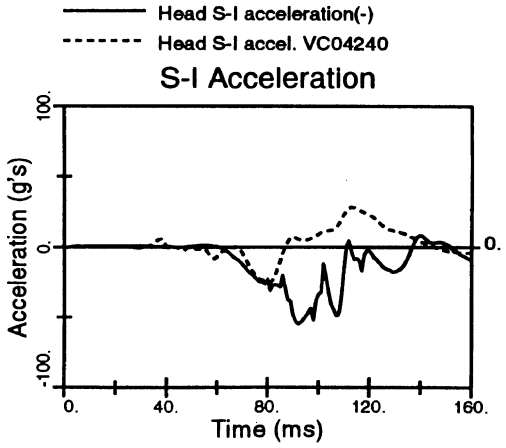


Figure 8.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

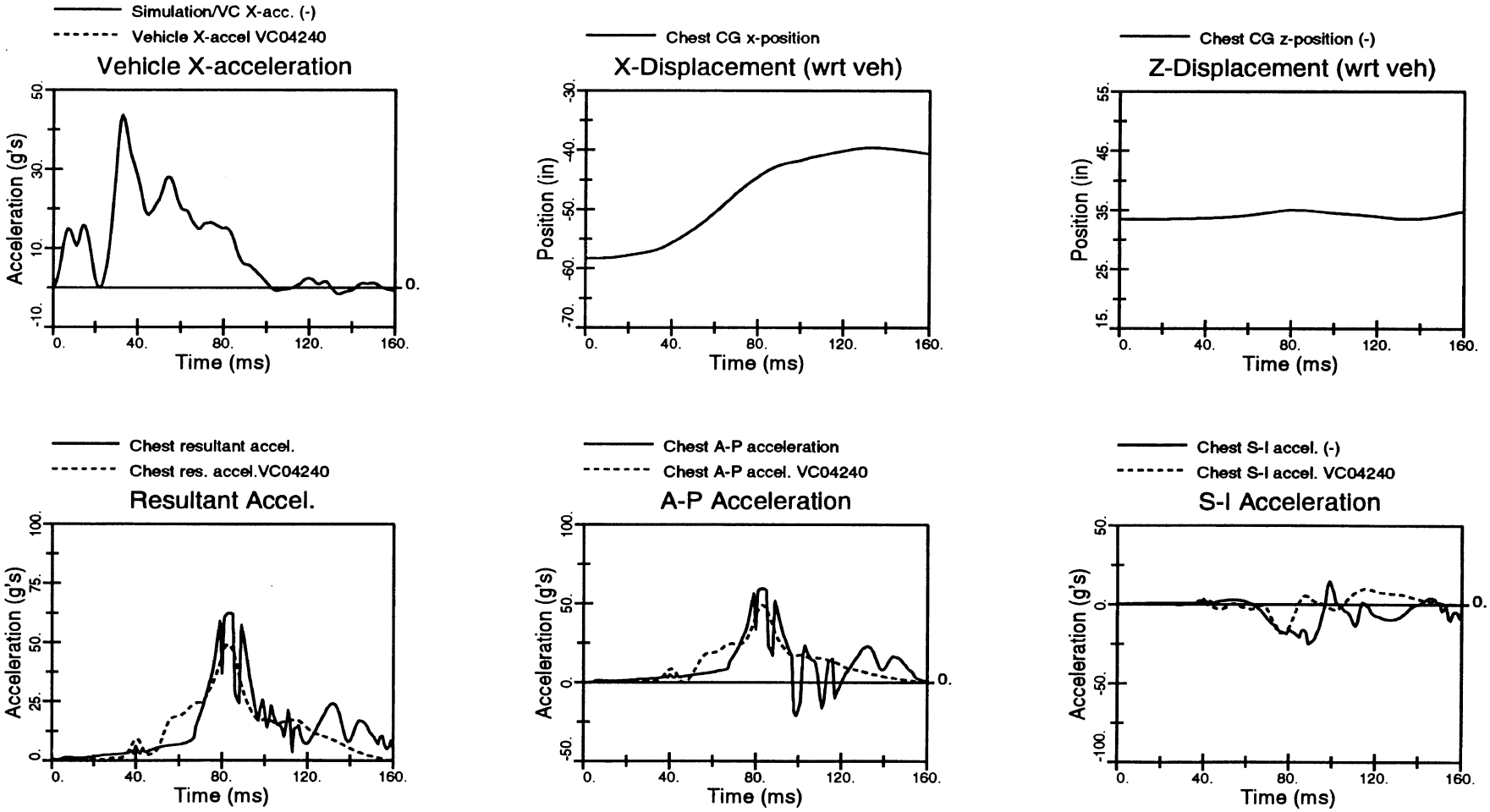


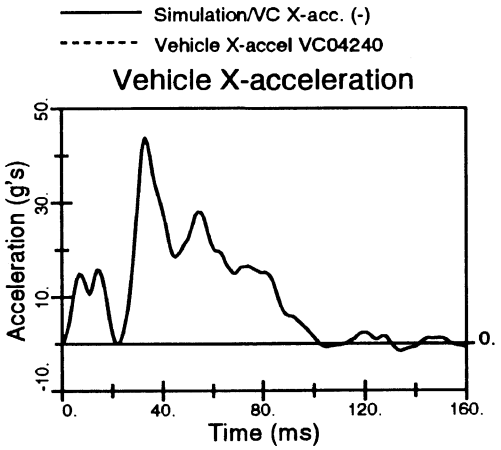
Figure 8.

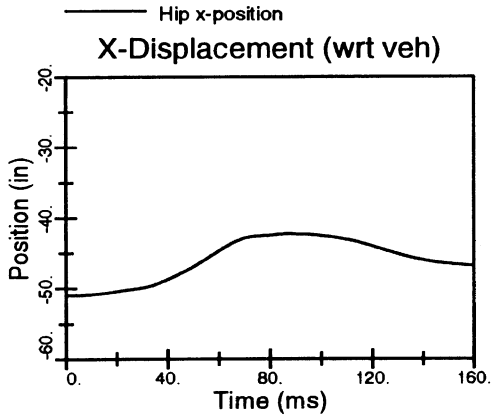
MVMA 2-D CVS Quasi-Finite Element Airbag Model

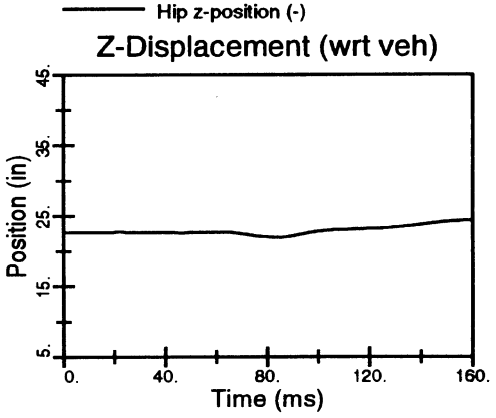
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

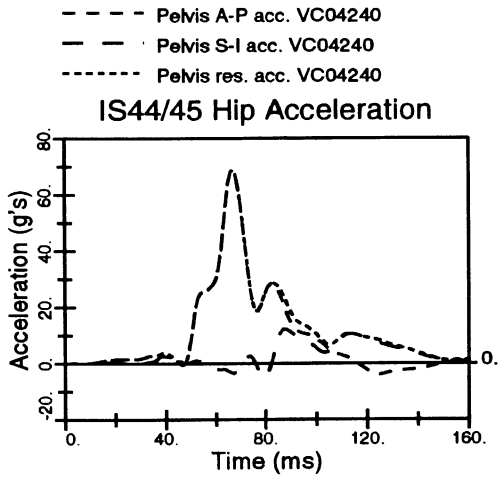
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

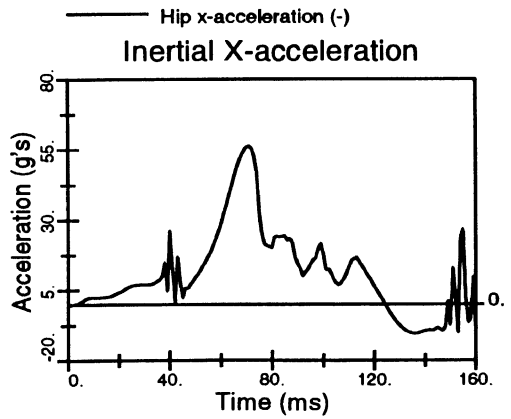
HIP KINEMATIC RESPONSE











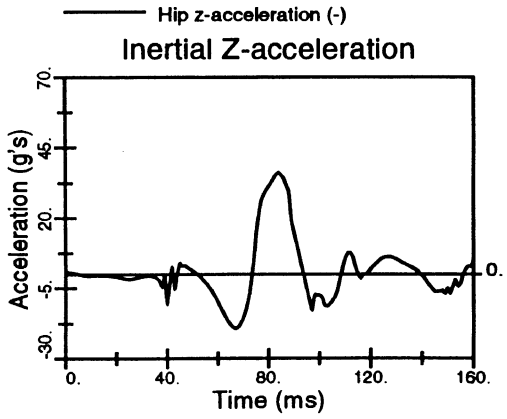


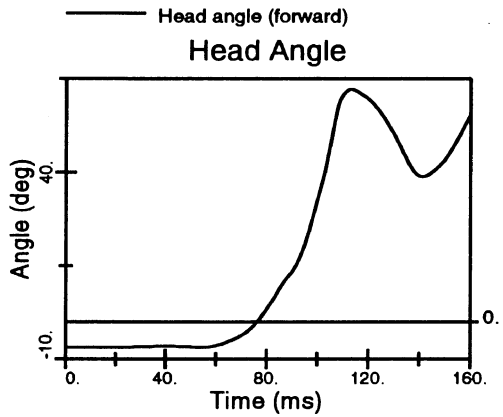
Figure 8.

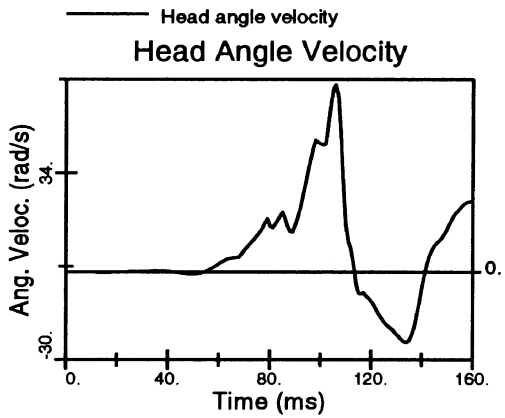
MVMA 2-D CVS Quasi-Finite Element Airbag Model

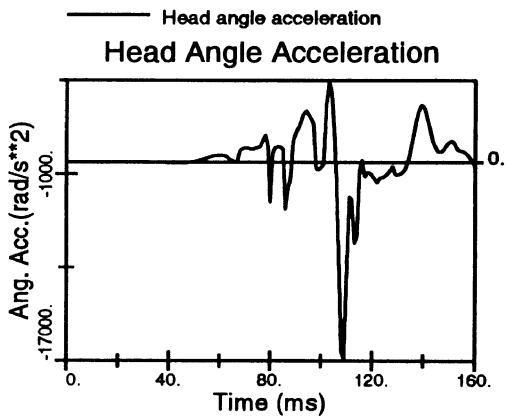
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

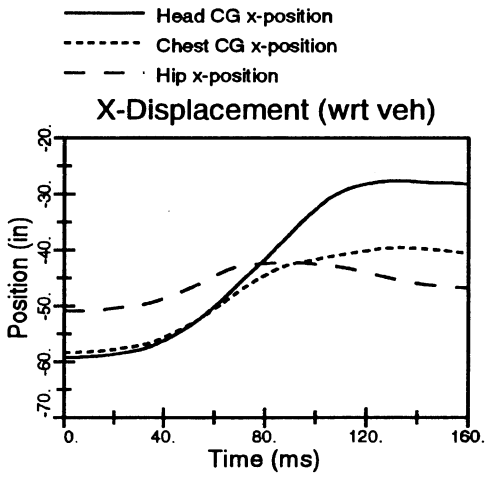
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

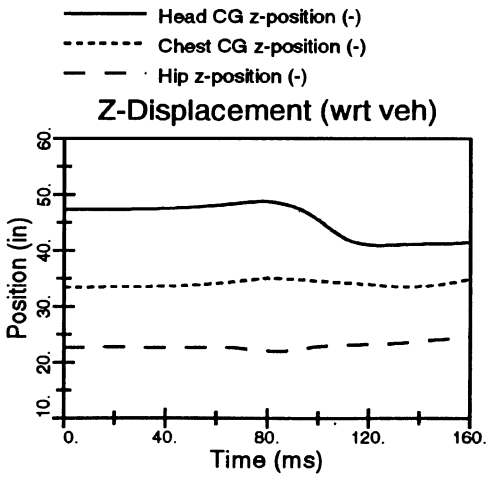
HEAD ANGULAR RESPONSE / OTHER RESPONSES











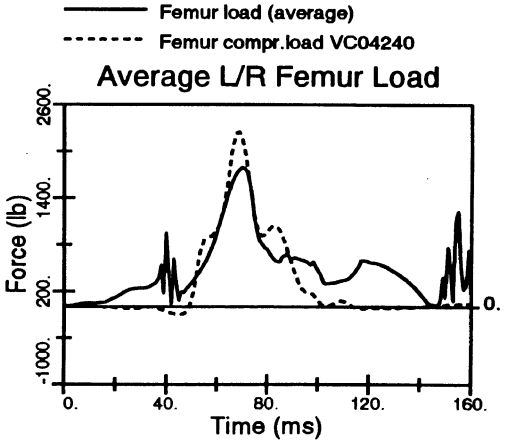


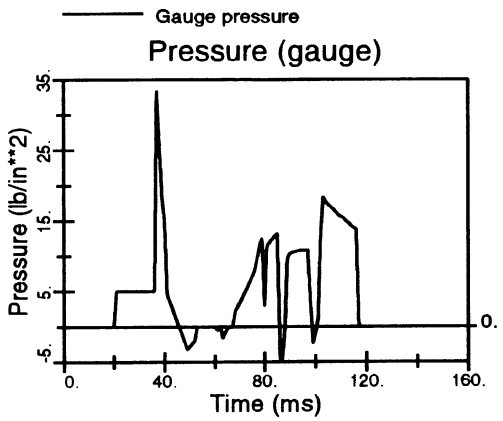
Figure 8.

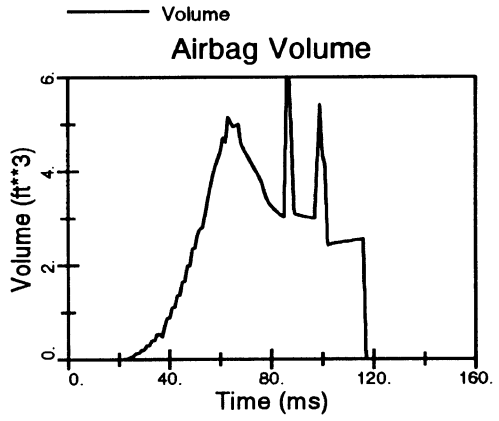
MVMA 2-D CVS Quasi-Finite Element Airbag Model

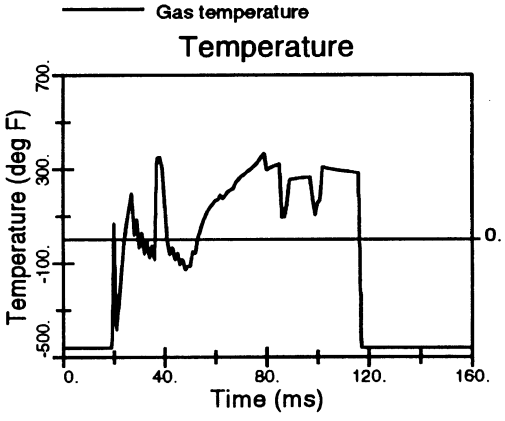
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

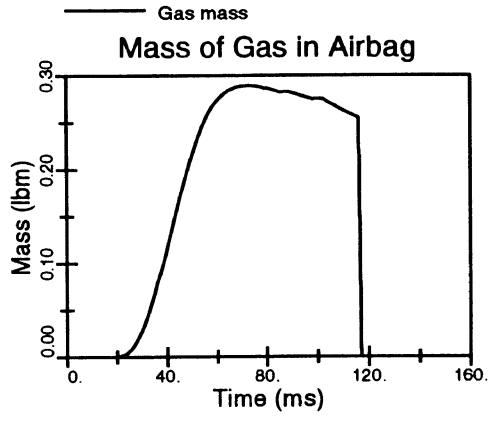
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

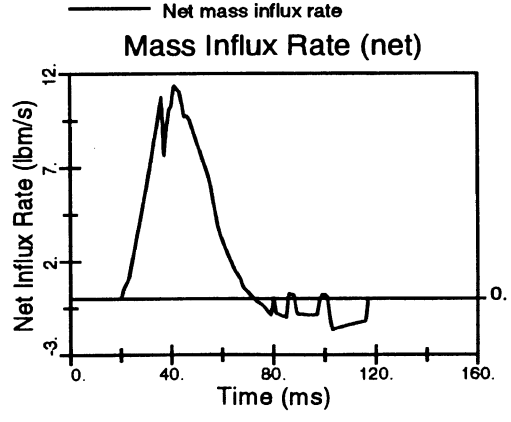
THERMODYNAMIC VARIABLES











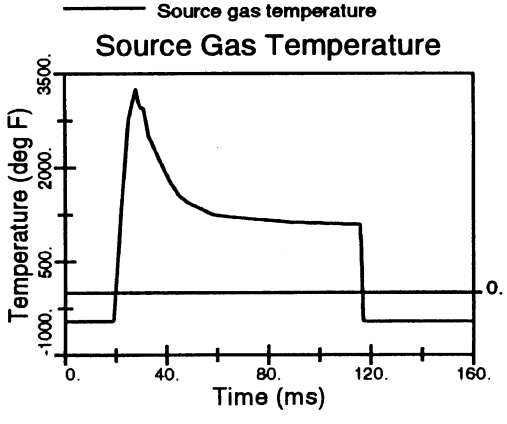


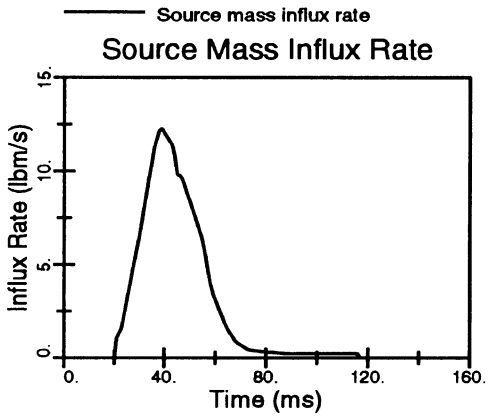
Figure 8.

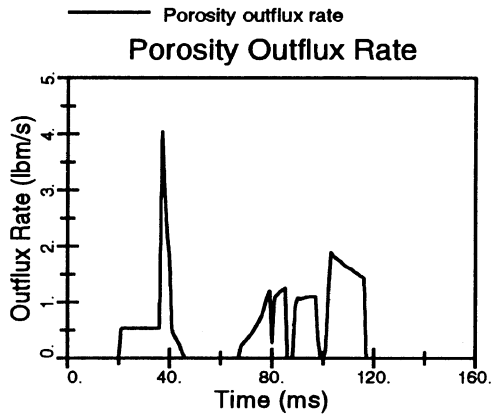
MVMA 2-D CVS Quasi-Finite Element Airbag Model

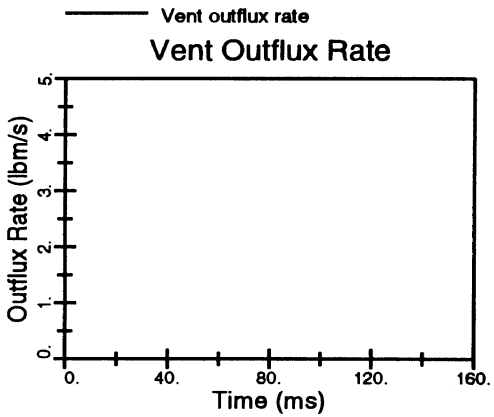
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

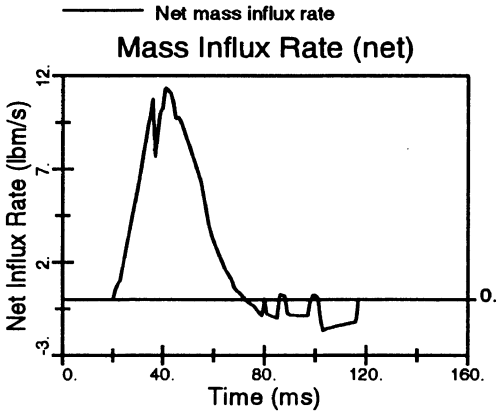
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

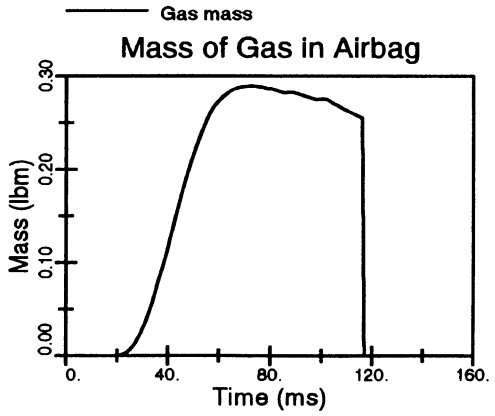
AIRBAG MASS INFLUX/OUTFLUX











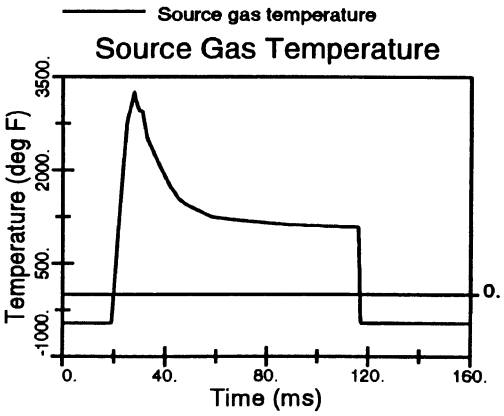


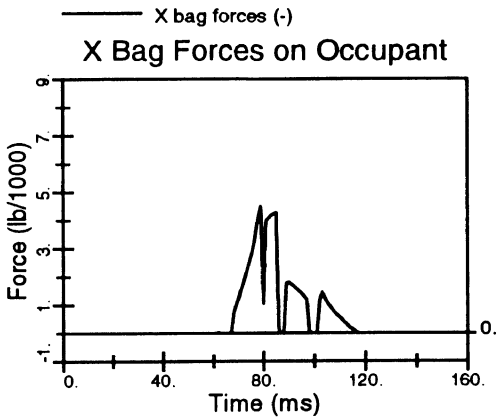
Figure 8.

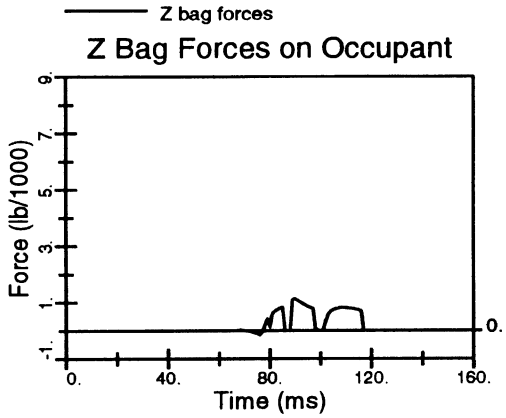
MVMA 2-D CVS Quasi-Finite Element Airbag Model

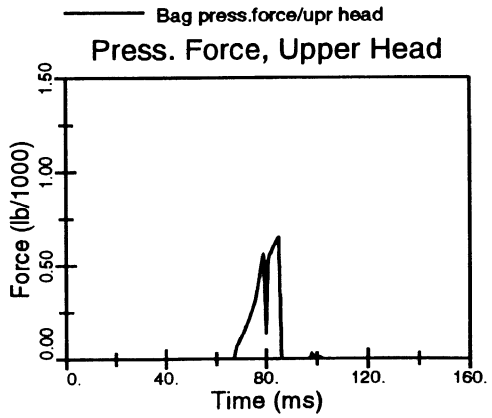
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

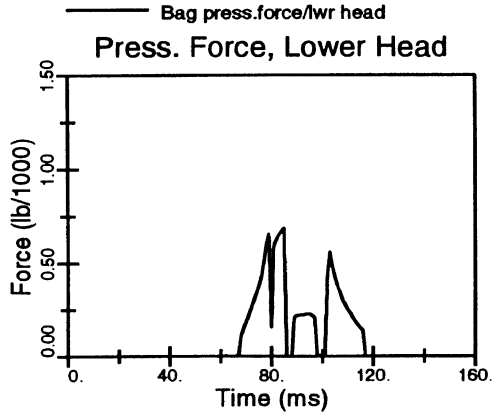
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









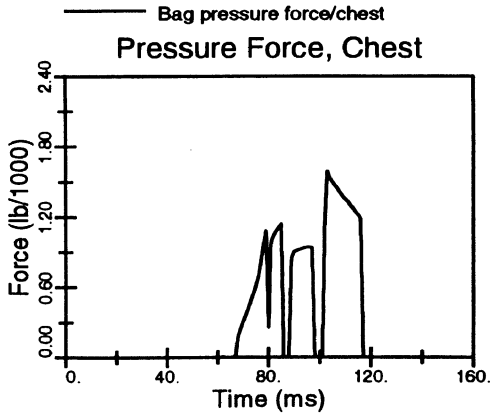


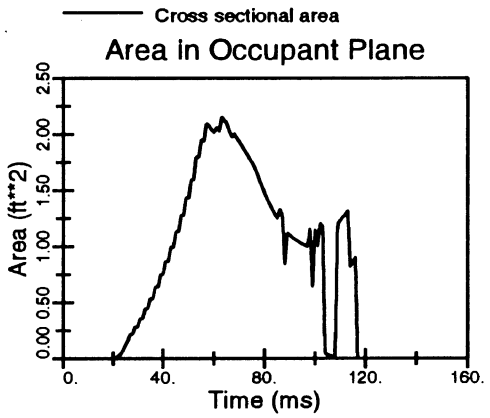
Figure 8.

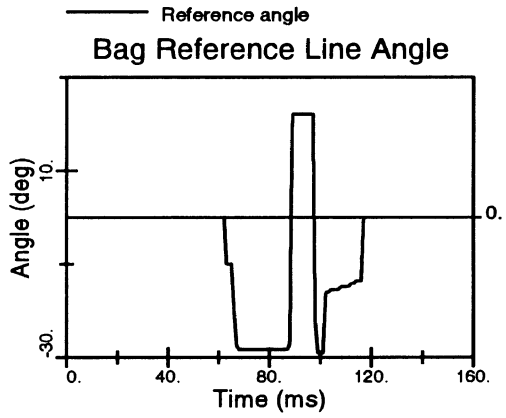
MVMA 2-D CVS Quasi-Finite Element Airbag Model

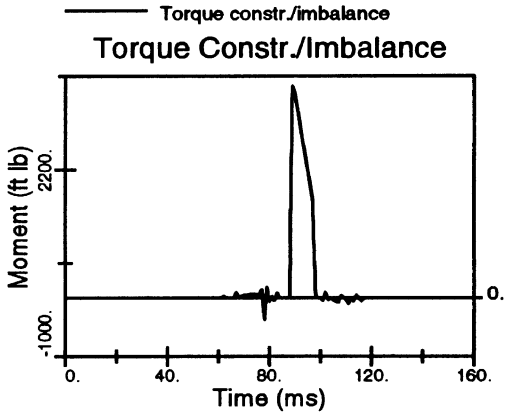
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC baseline #2 , Test VC04240

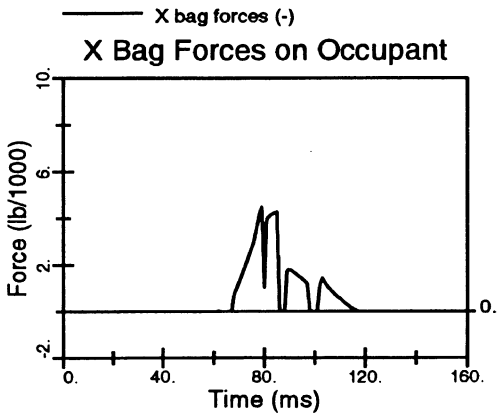
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









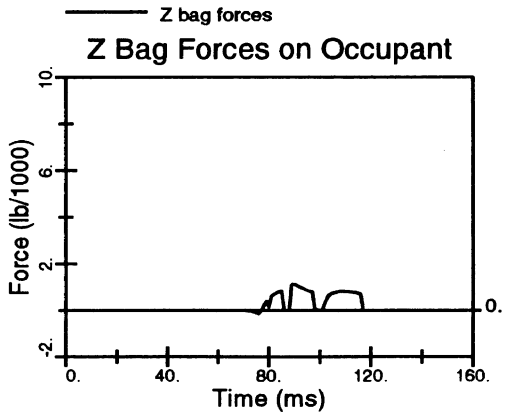


Figure 8.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

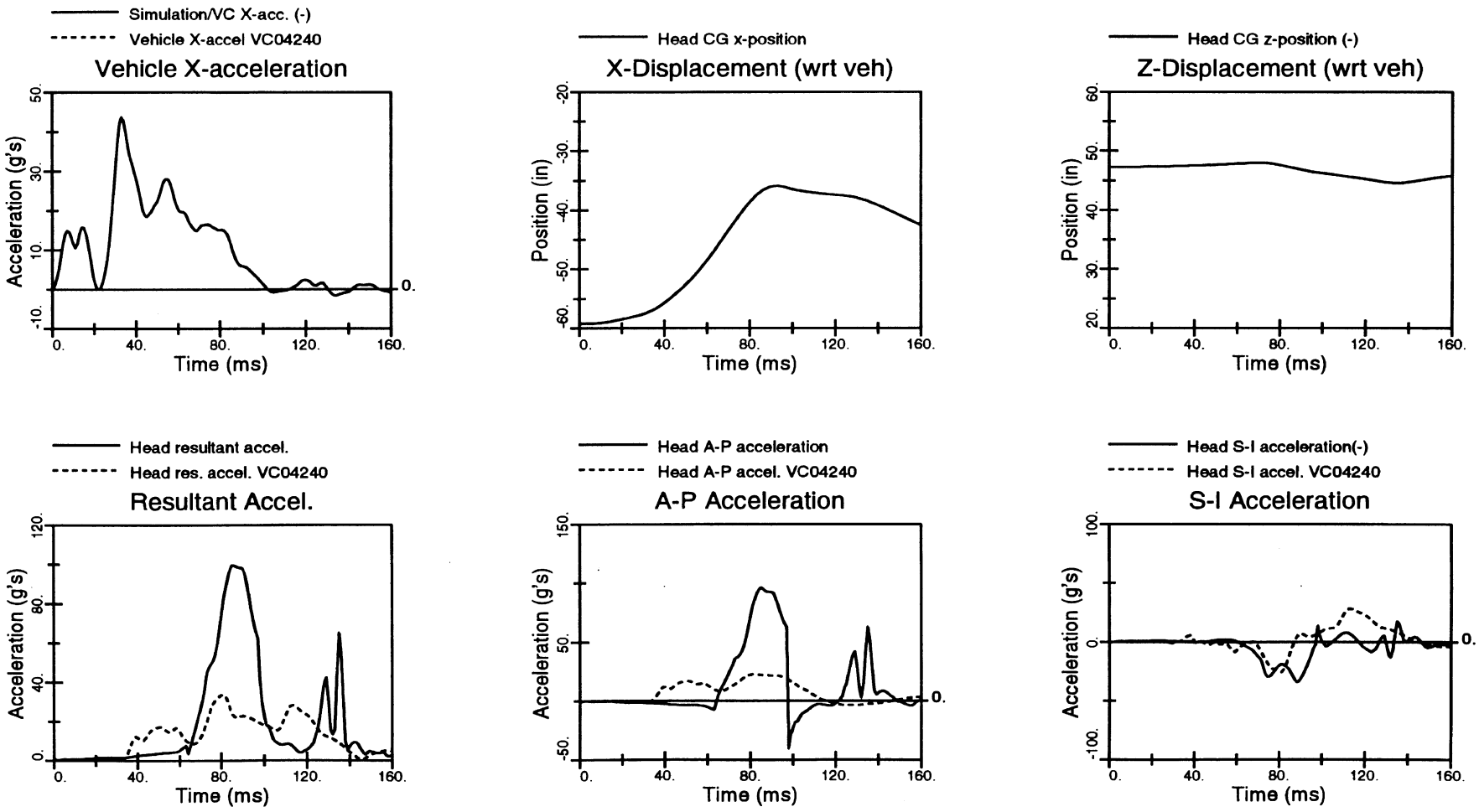


Figure 9.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

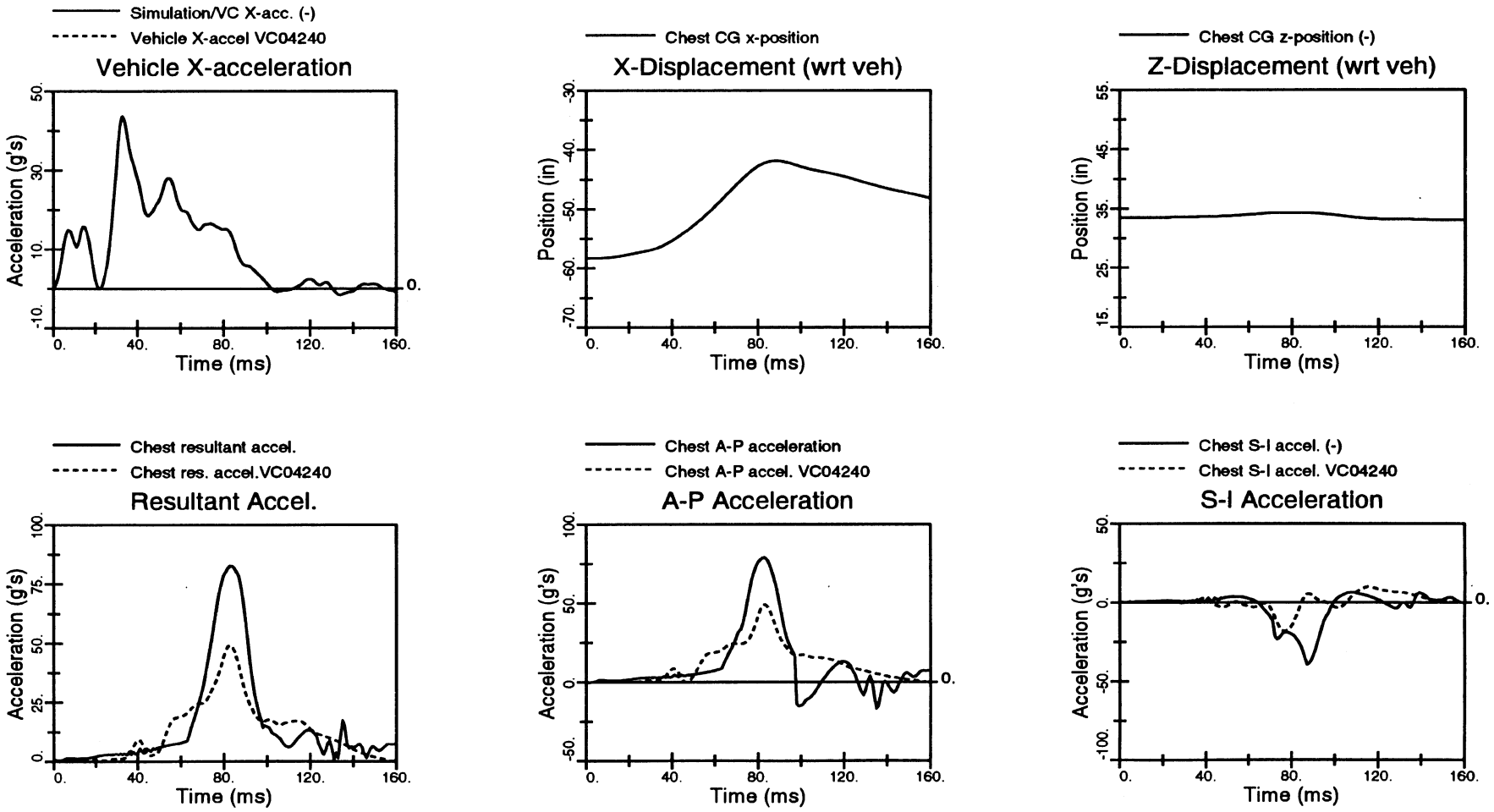


Figure 9.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

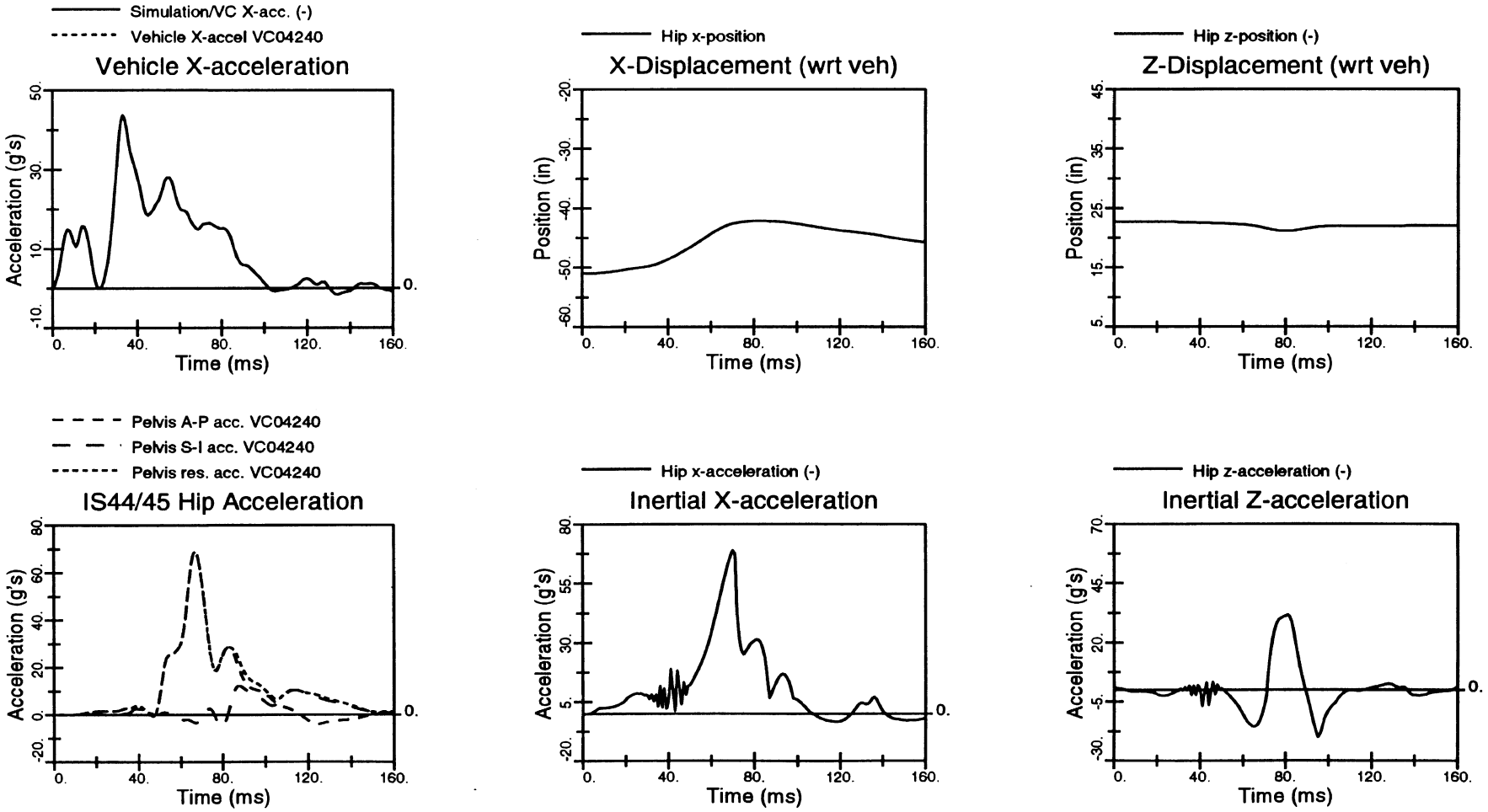


Figure 9.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

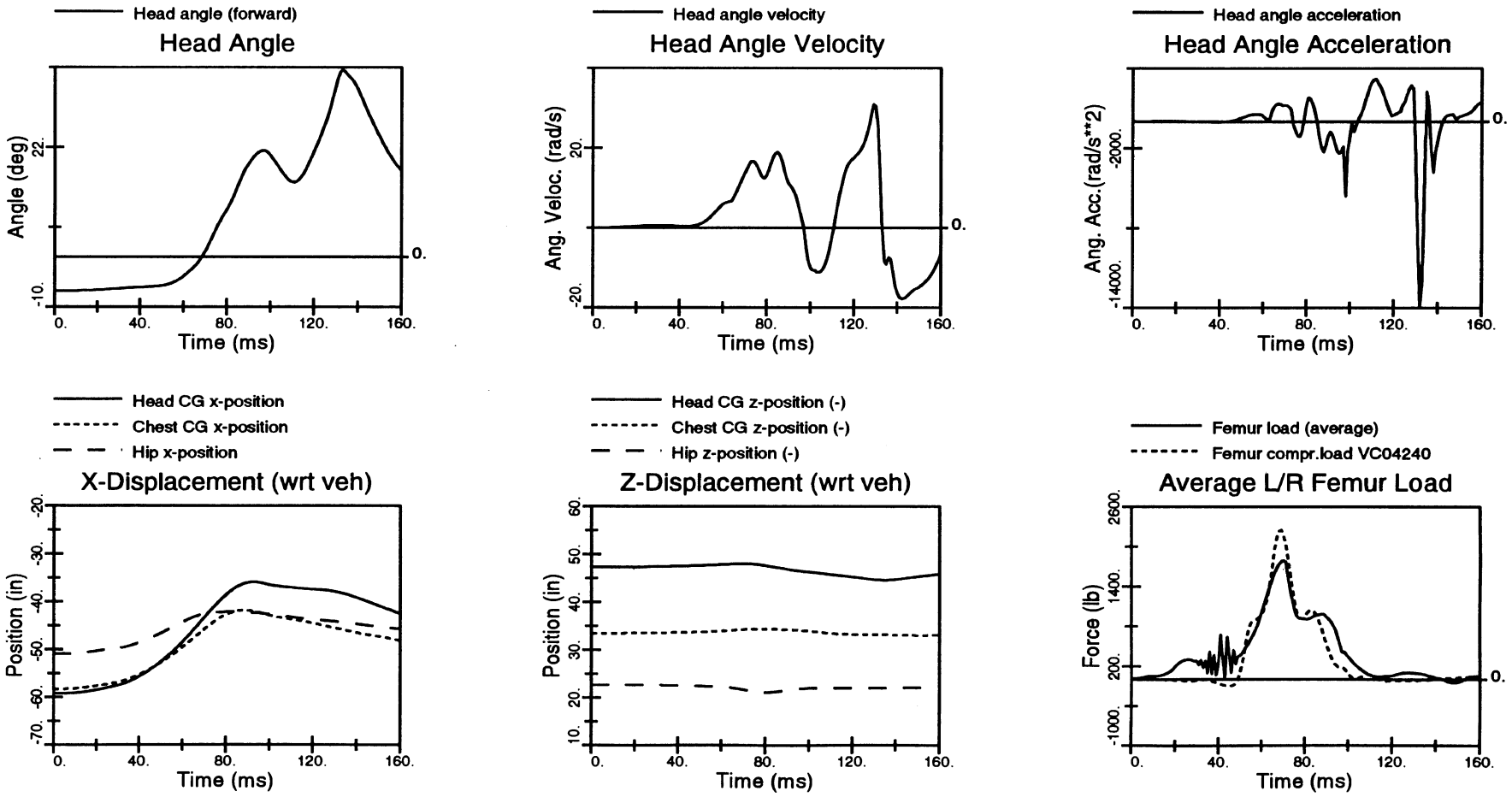


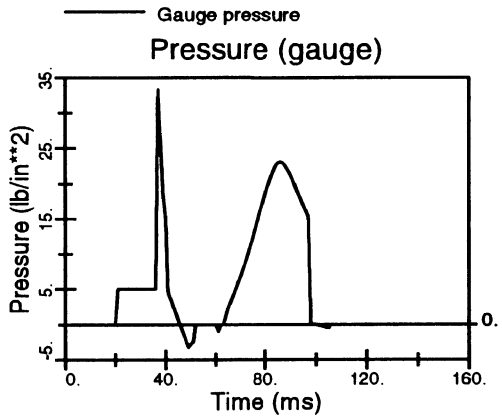
Figure 9.

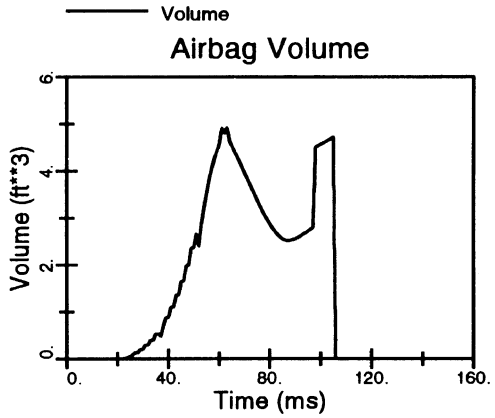
MVMA 2-D CVS Quasi-Finite Element Airbag Model

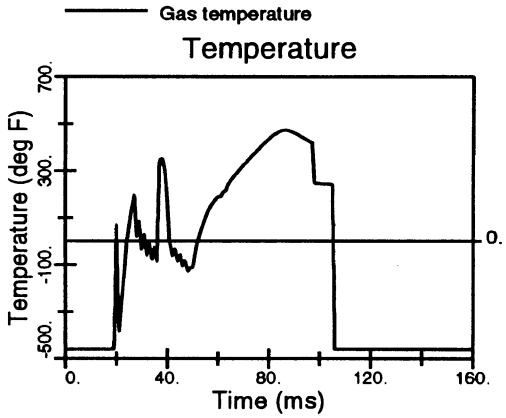
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

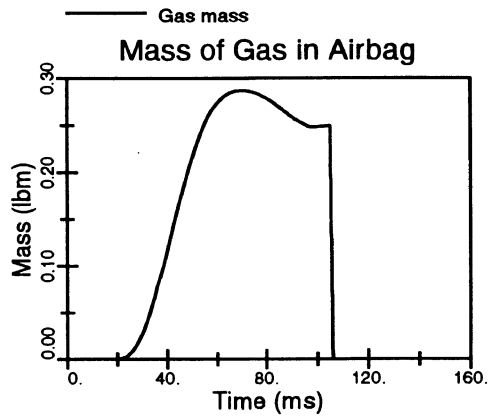
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

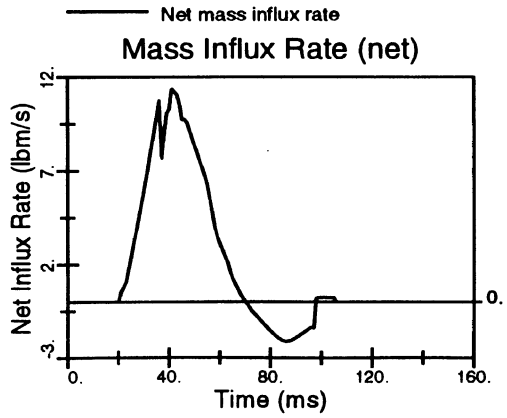
THERMODYNAMIC VARIABLES











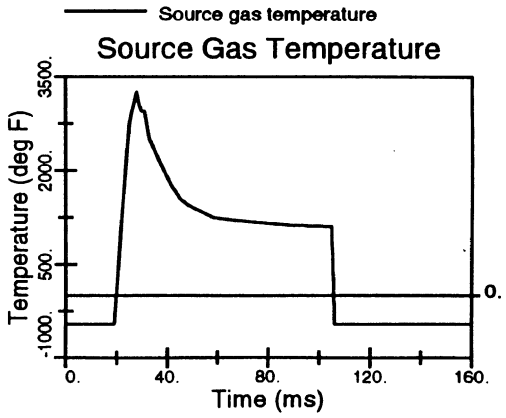


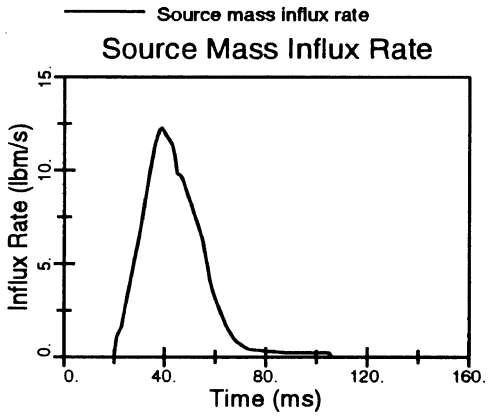
Figure 9.

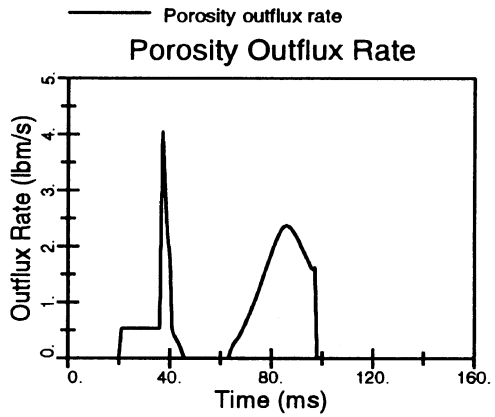
MVMA 2-D CVS Quasi-Finite Element Airbag Model

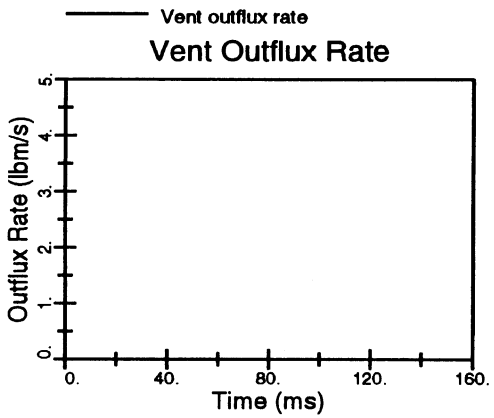
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

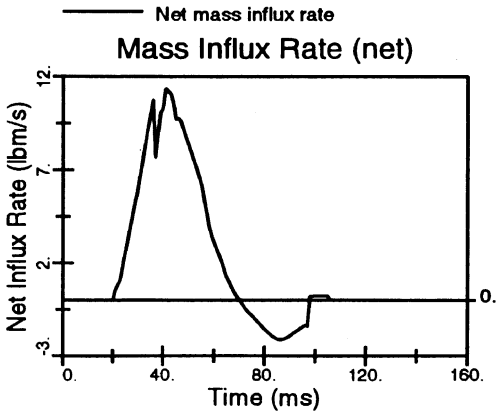
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

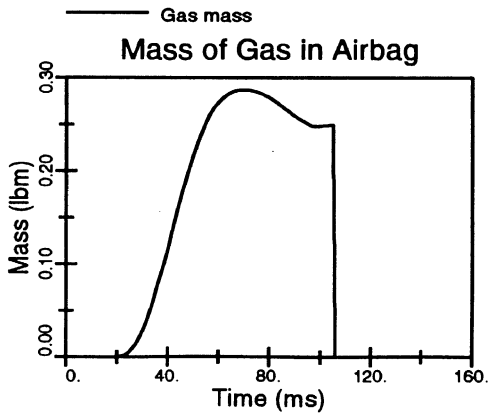
AIRBAG MASS INFLUX/OUTFLUX











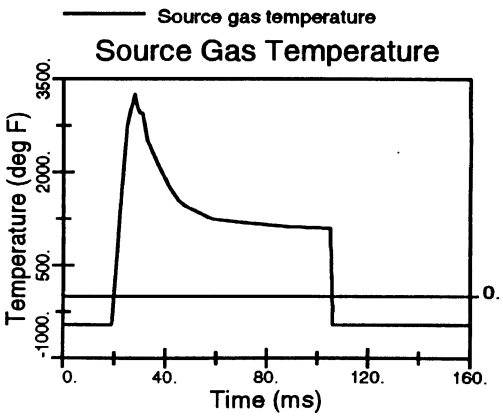


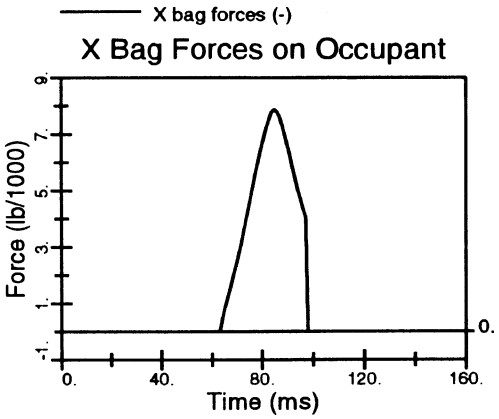
Figure 9.

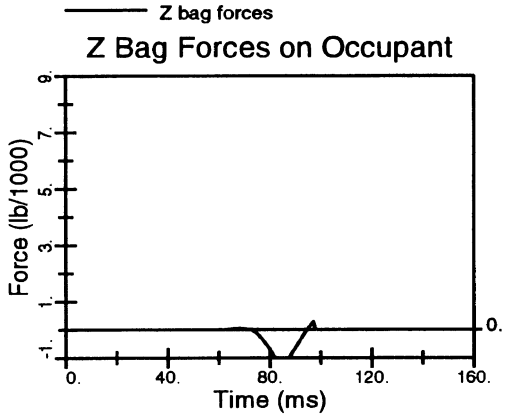
MVMA 2-D CVS Quasi-Finite Element Airbag Model

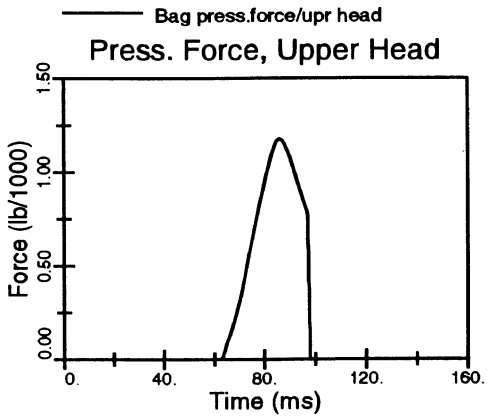
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

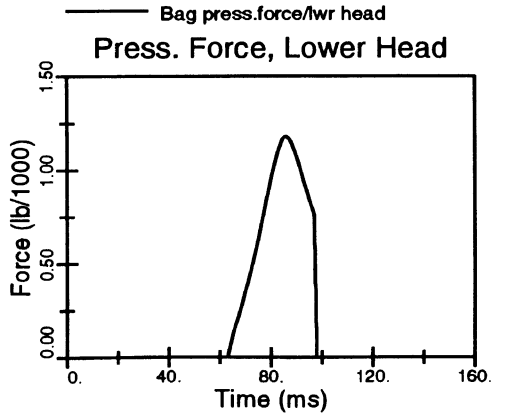
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









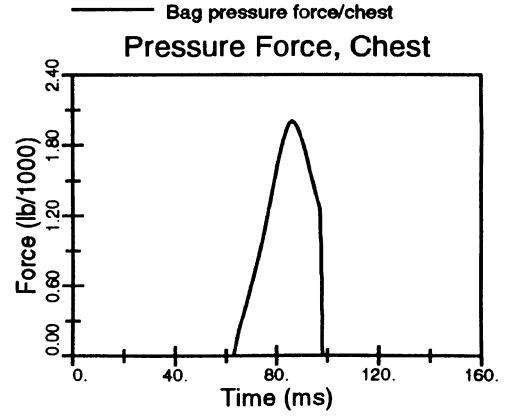


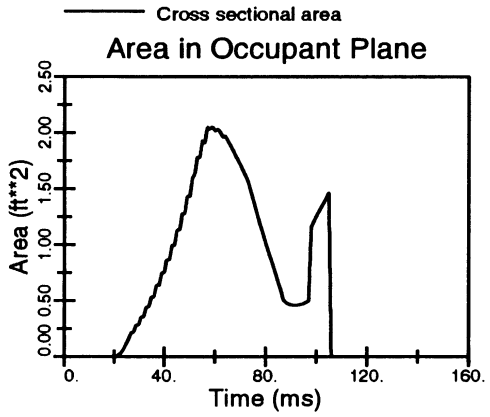
Figure 9.

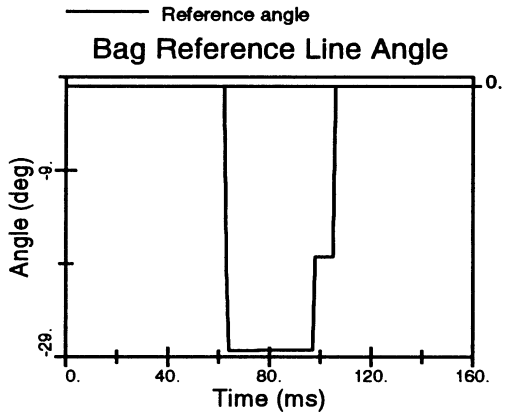
MVMA 2-D CVS Quasi-Finite Element Airbag Model

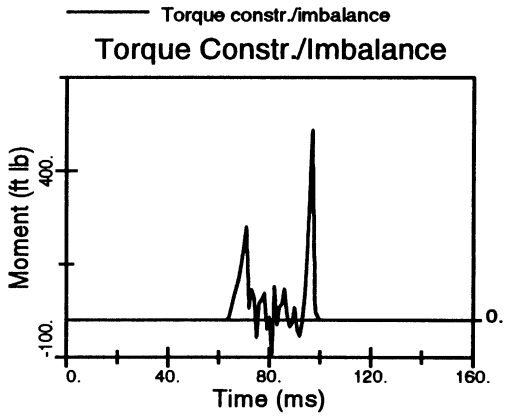
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #1 without vehicle pitch , Test VC04240

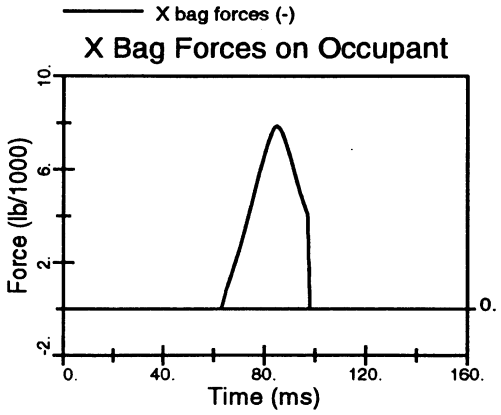
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









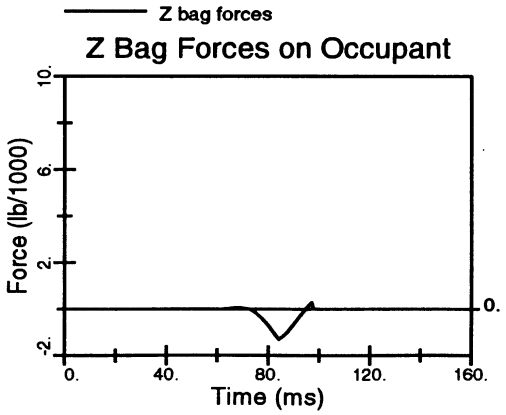


Figure 9.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

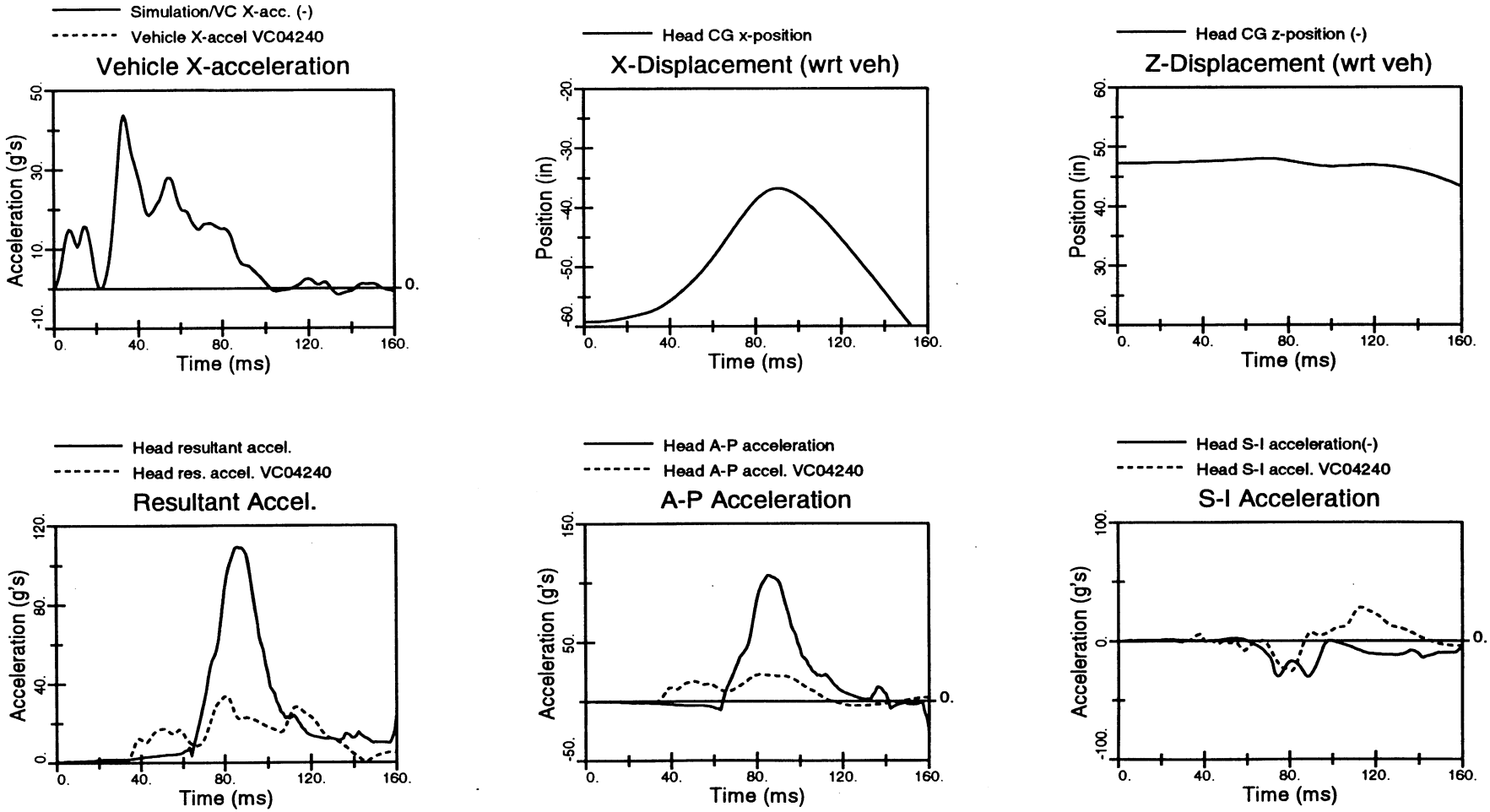


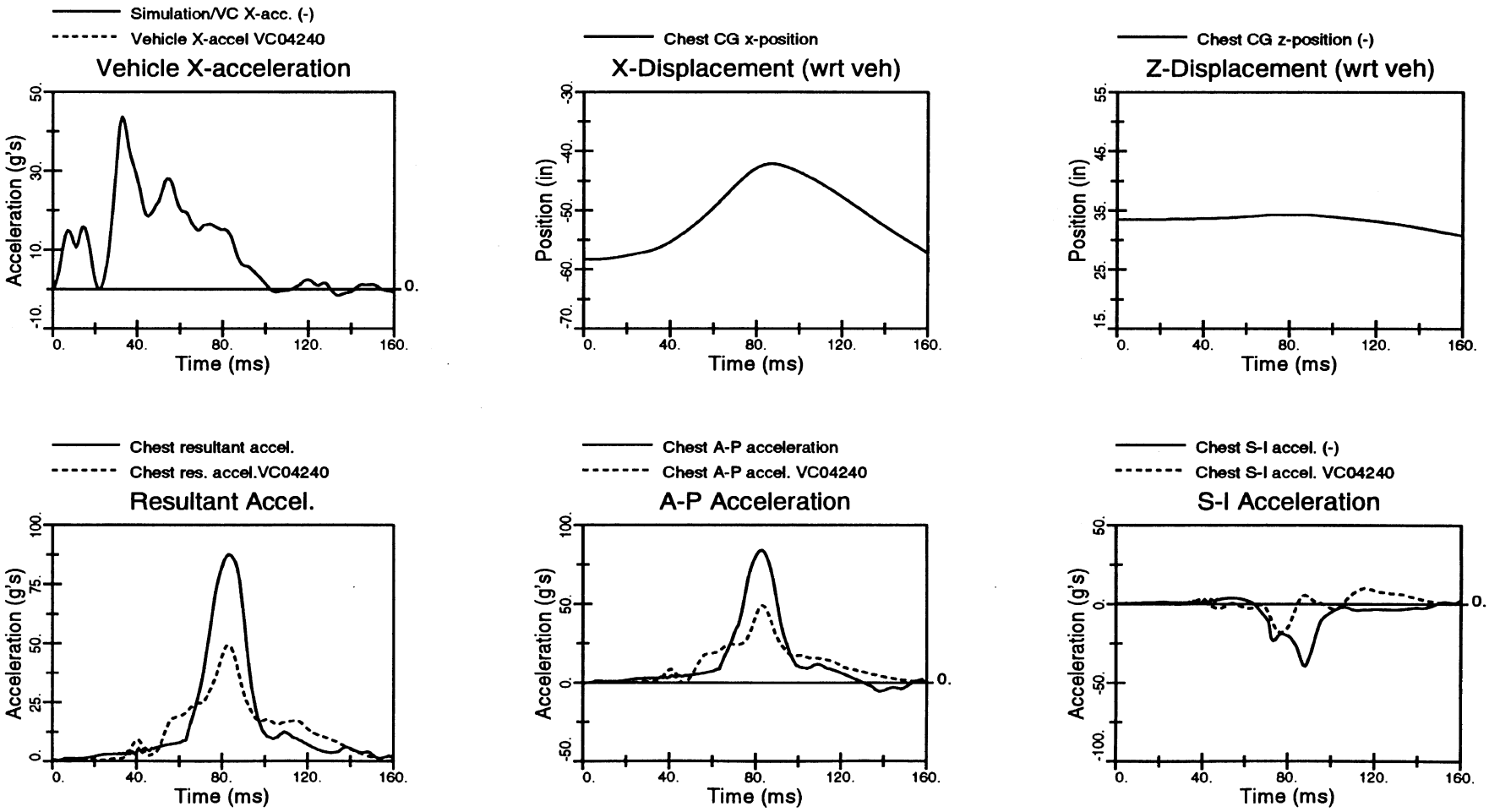
Figure 10.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE



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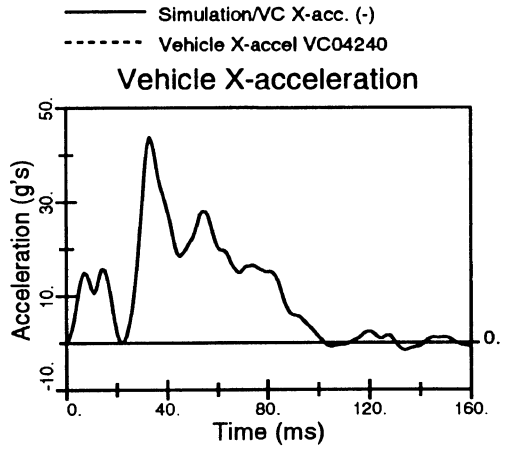
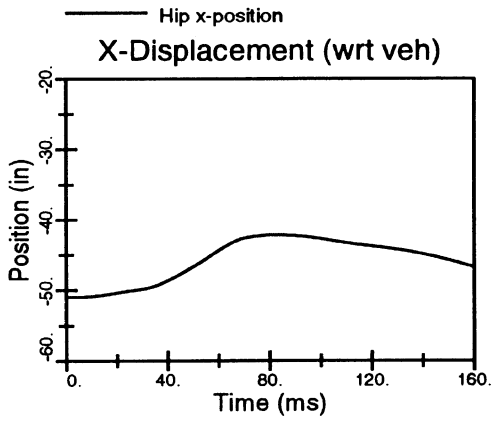
MVMA 2-D CVS Quasi-Finite Element Airbag Model

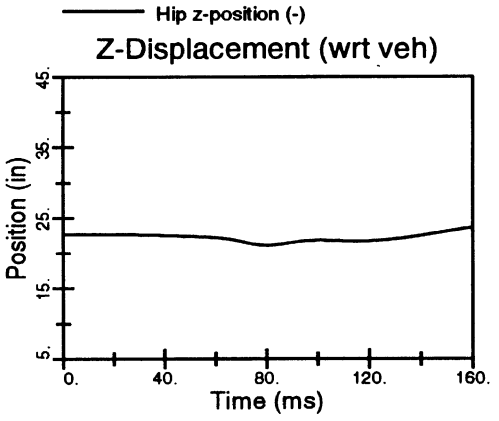
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

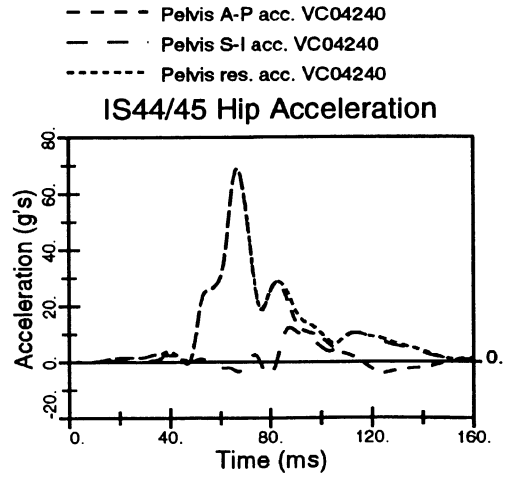
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

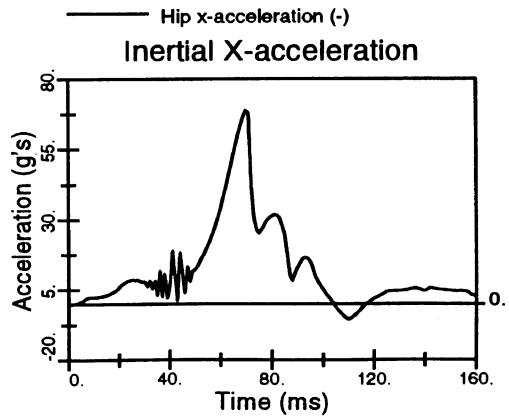
HIP KINEMATIC RESPONSE











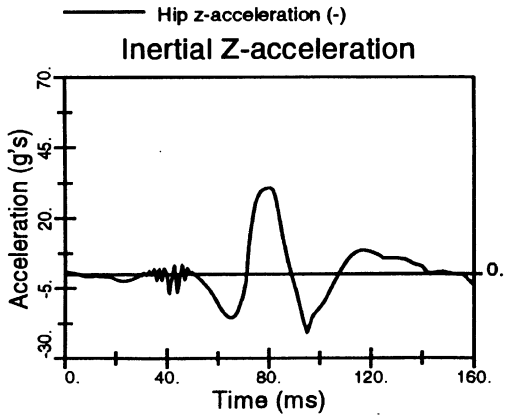


Figure 10.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

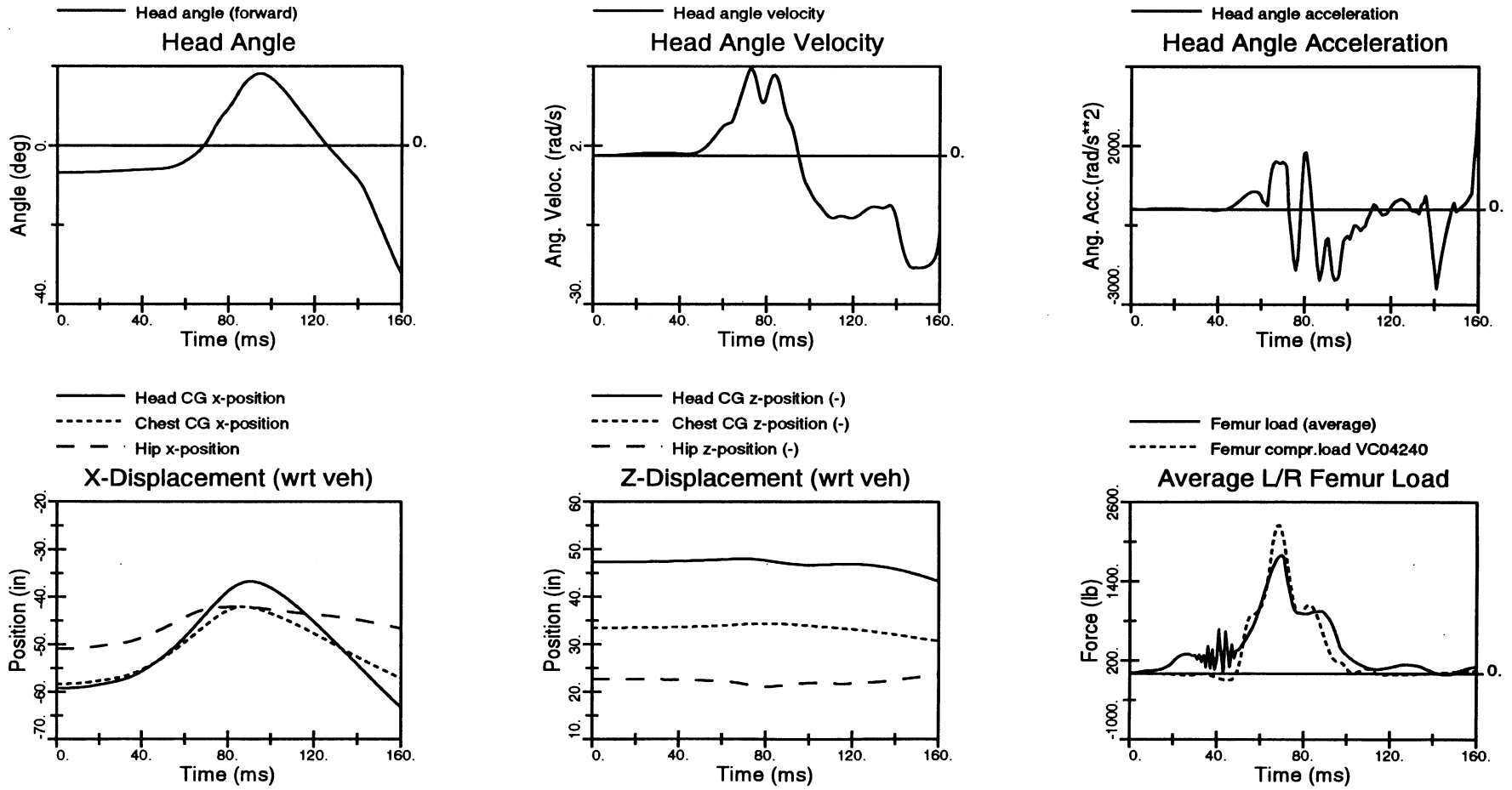


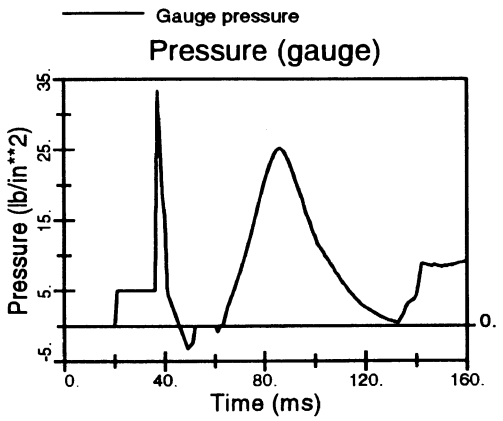
Figure 10.

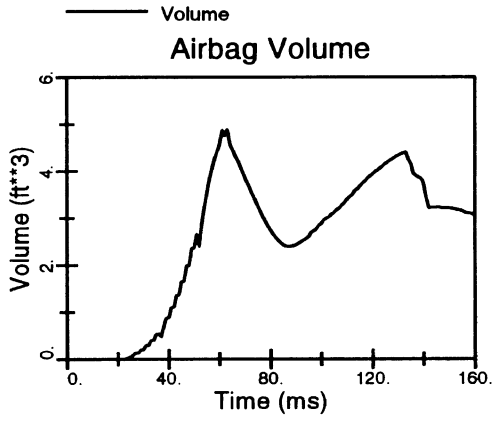
MVMA 2-D CVS Quasi-Finite Element Airbag Model

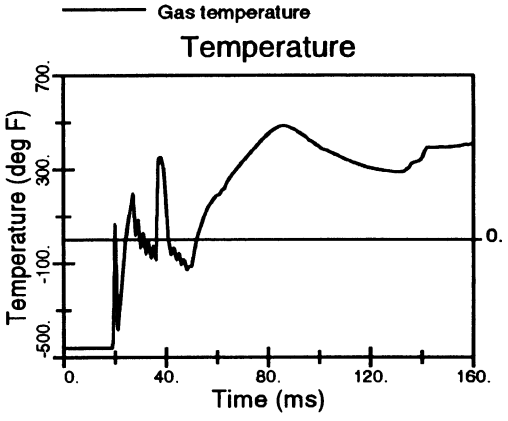
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

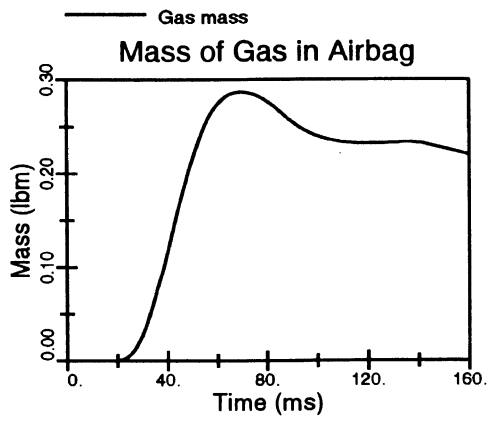
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

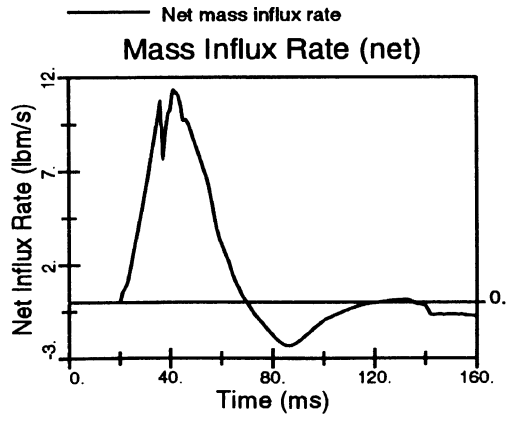
THERMODYNAMIC VARIABLES











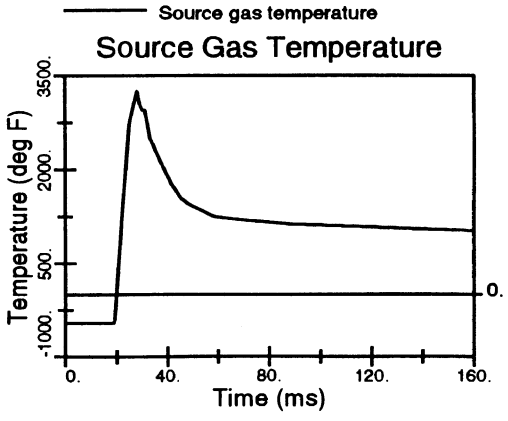


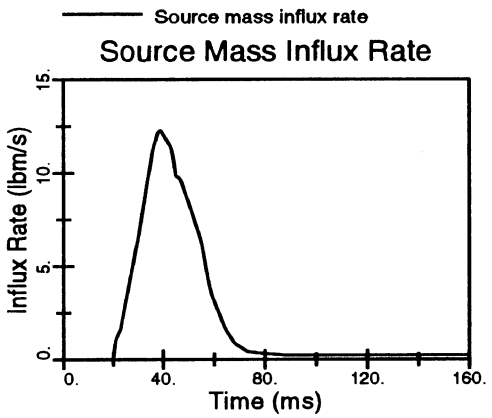
Figure 10.

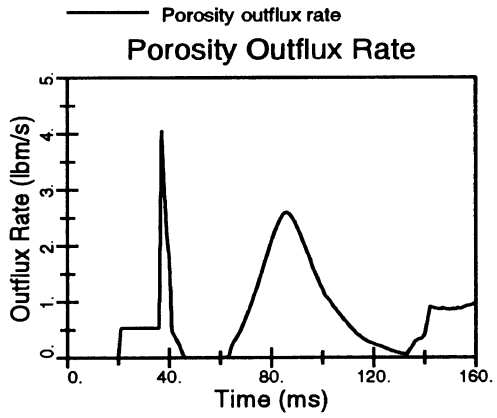
MVMA 2-D CVS Quasi-Finite Element Airbag Model

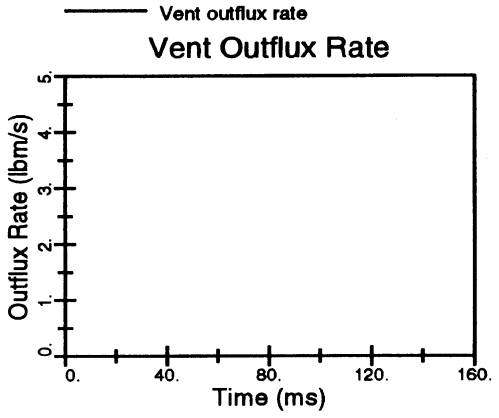
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

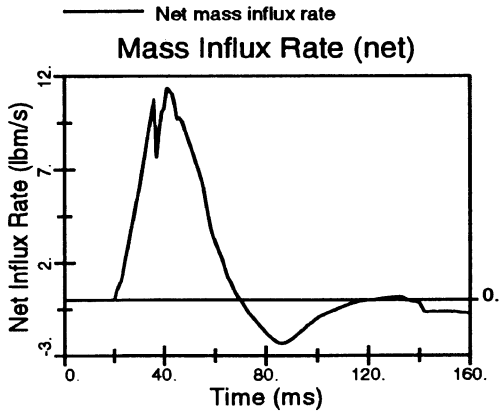
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

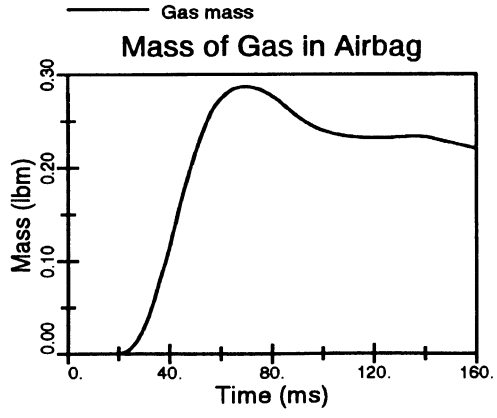
AIRBAG MASS INFLUX/OUTFLUX











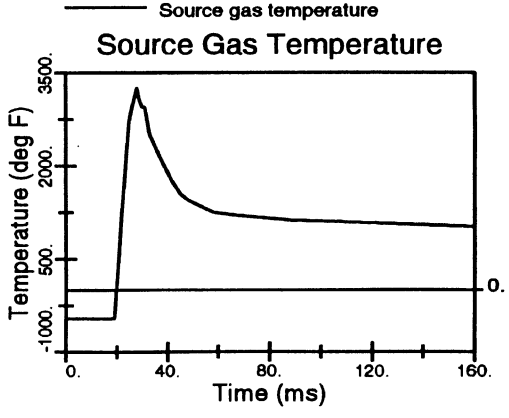


Figure 10.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)

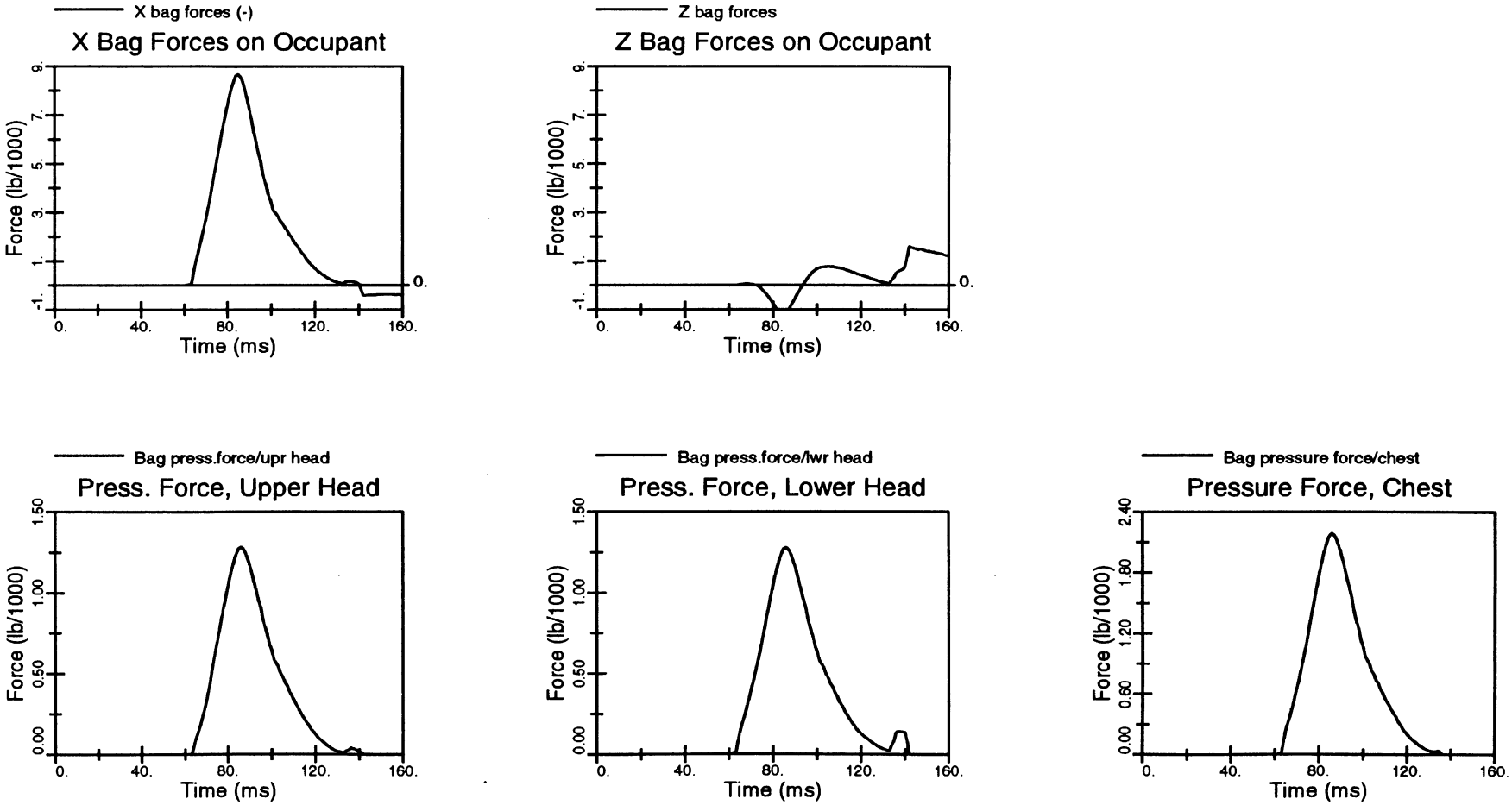


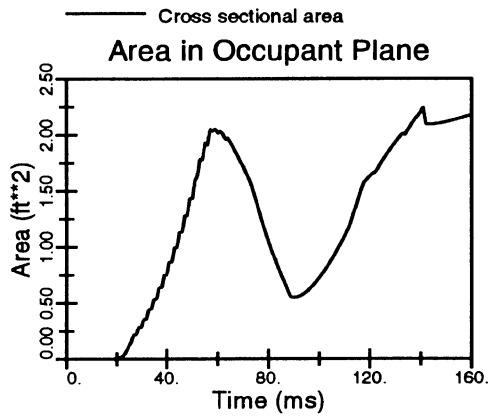
Figure 10.

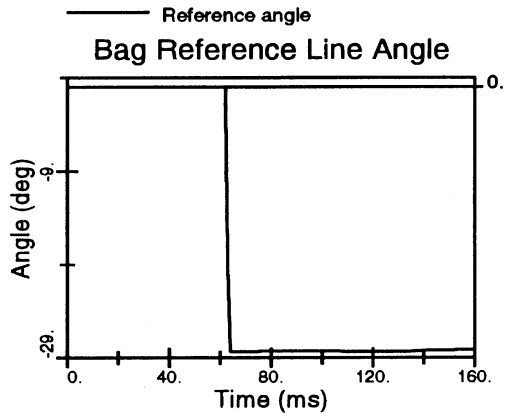
MVMA 2-D CVS Quasi-Finite Element Airbag Model

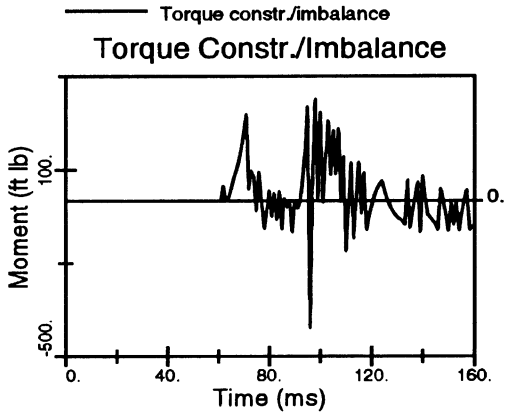
UMTRI Preliminary S-Body Vehicle Crash Test Simulation / VC #2 without vehicle pitch , Test VC04240

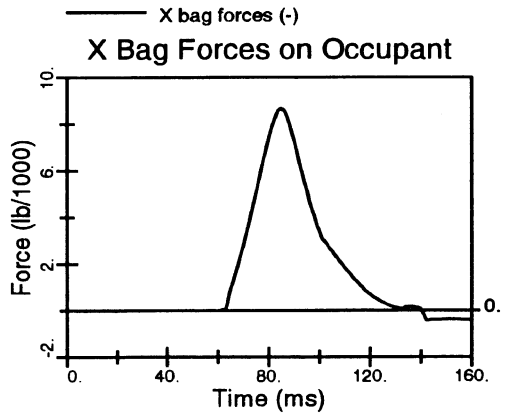
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









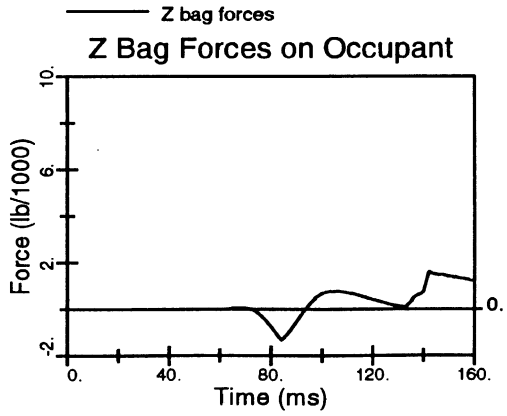


Figure 10.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

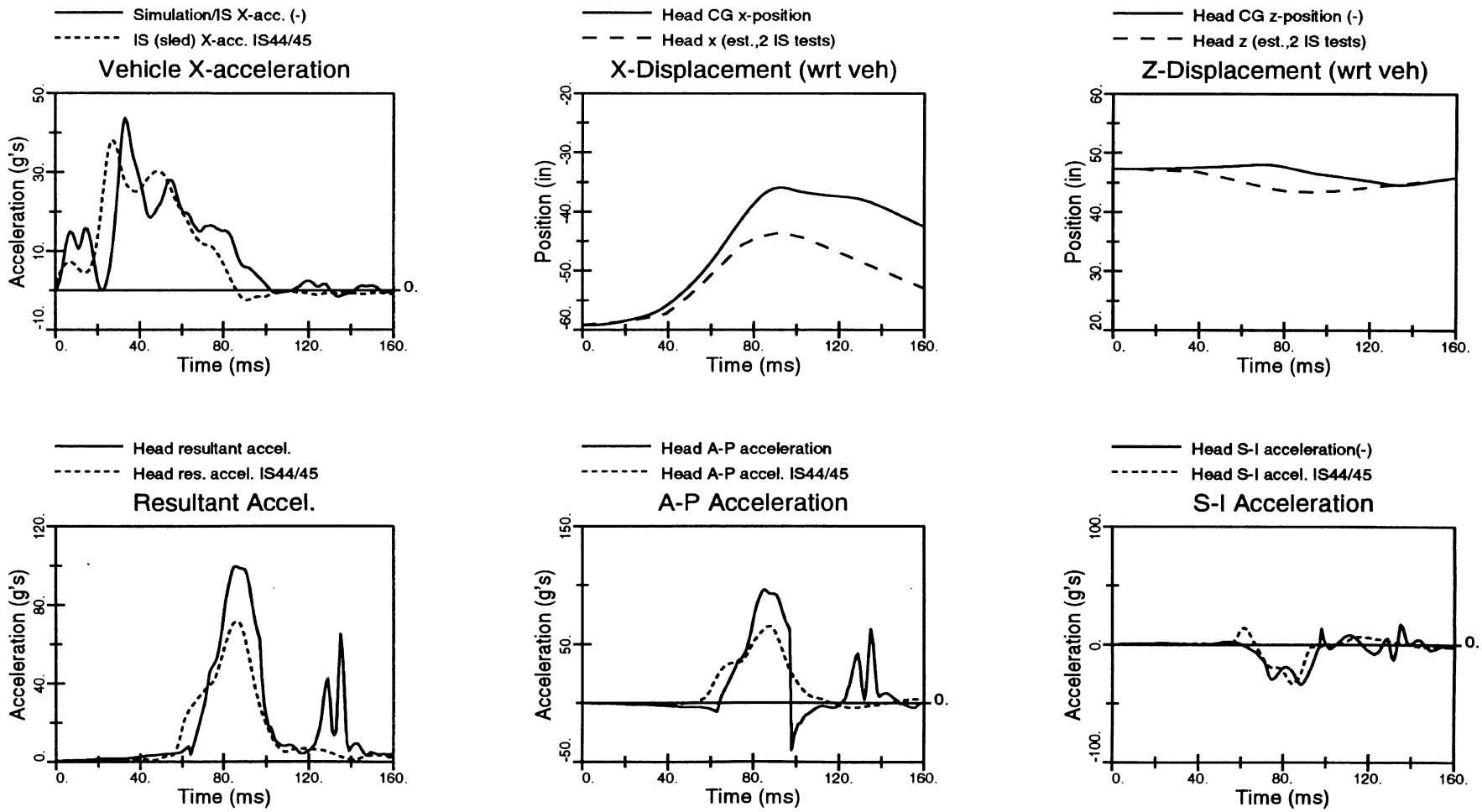


Figure 11.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

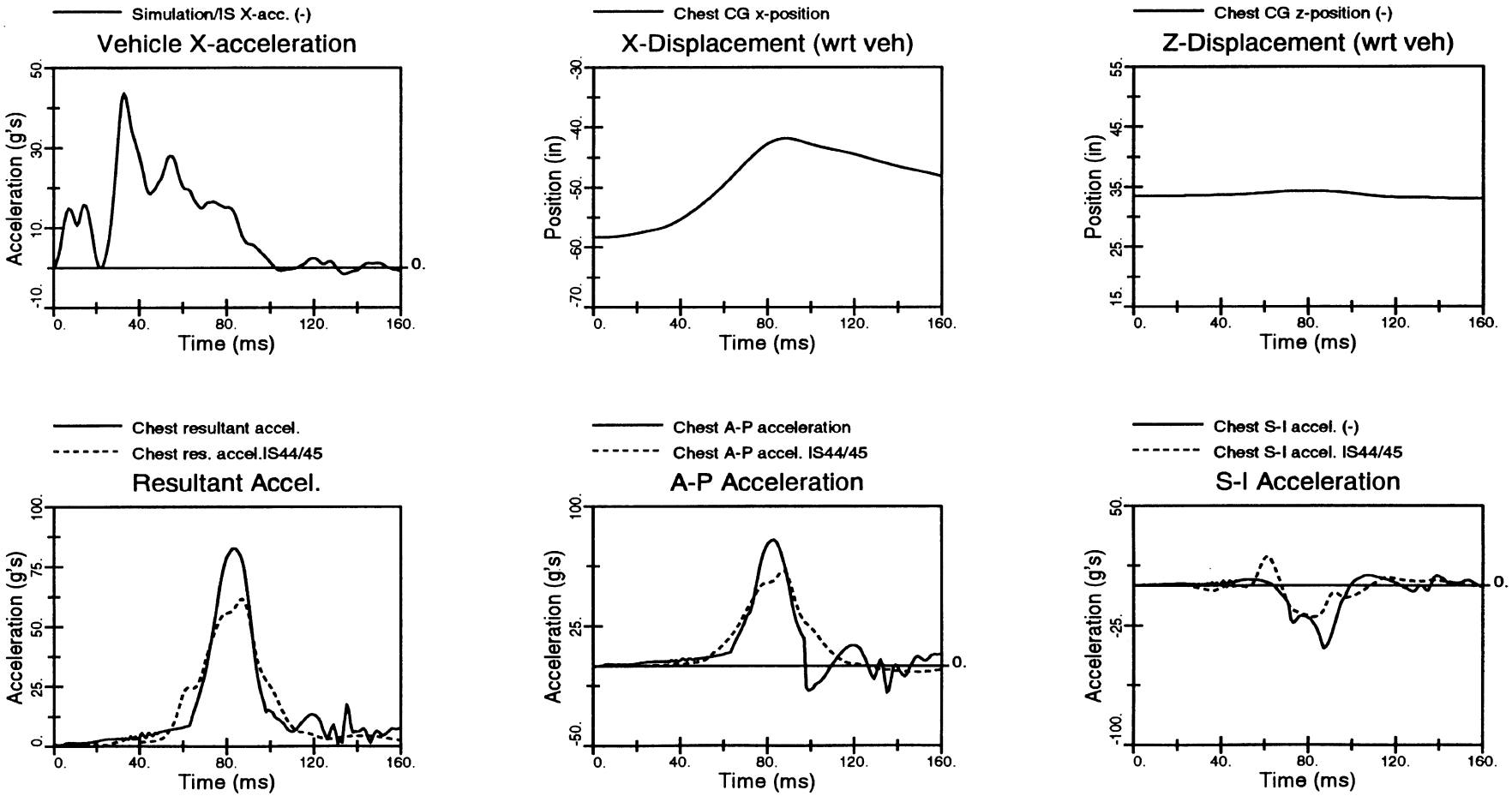


Figure 11.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

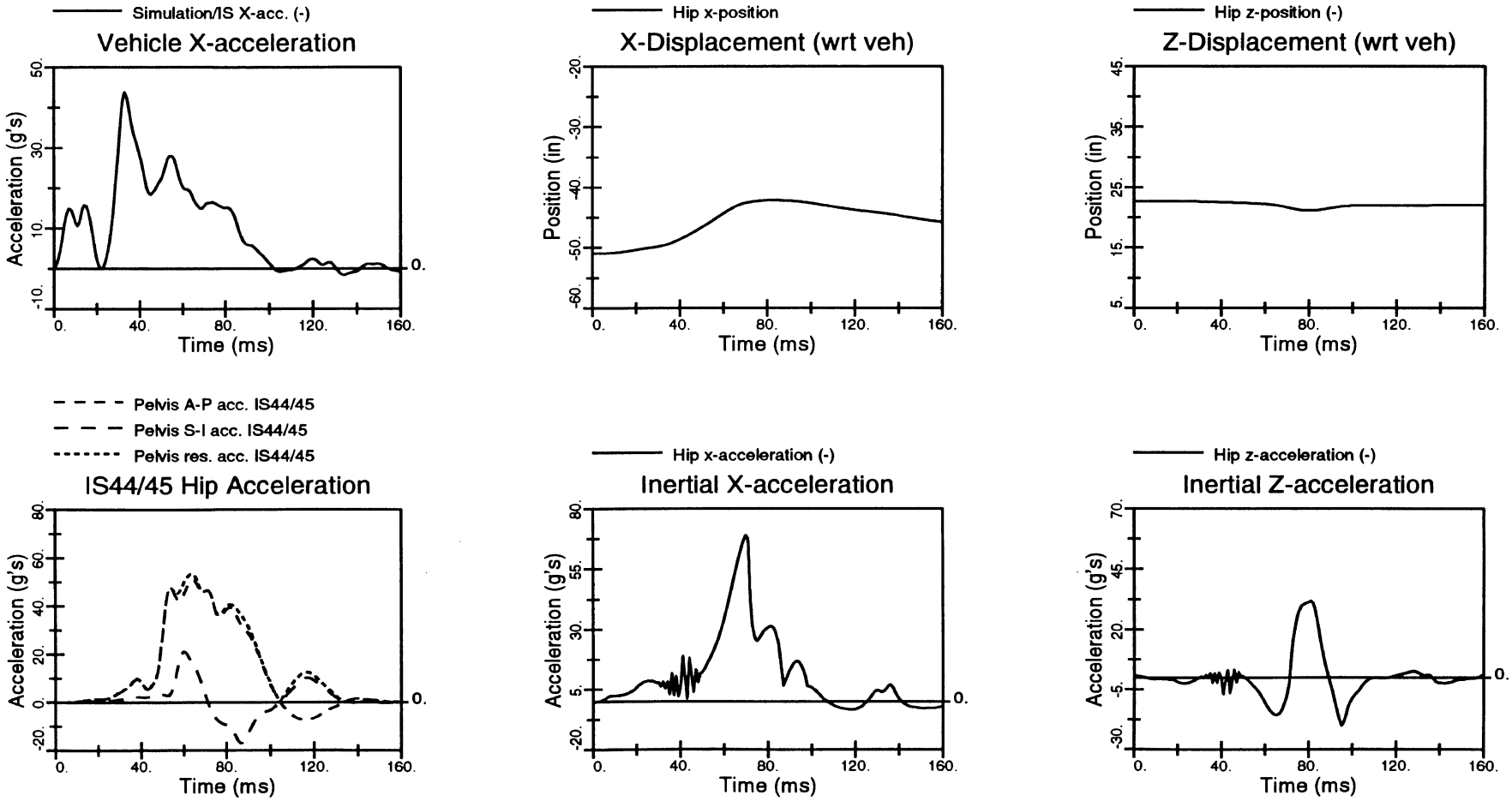


Figure 11.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

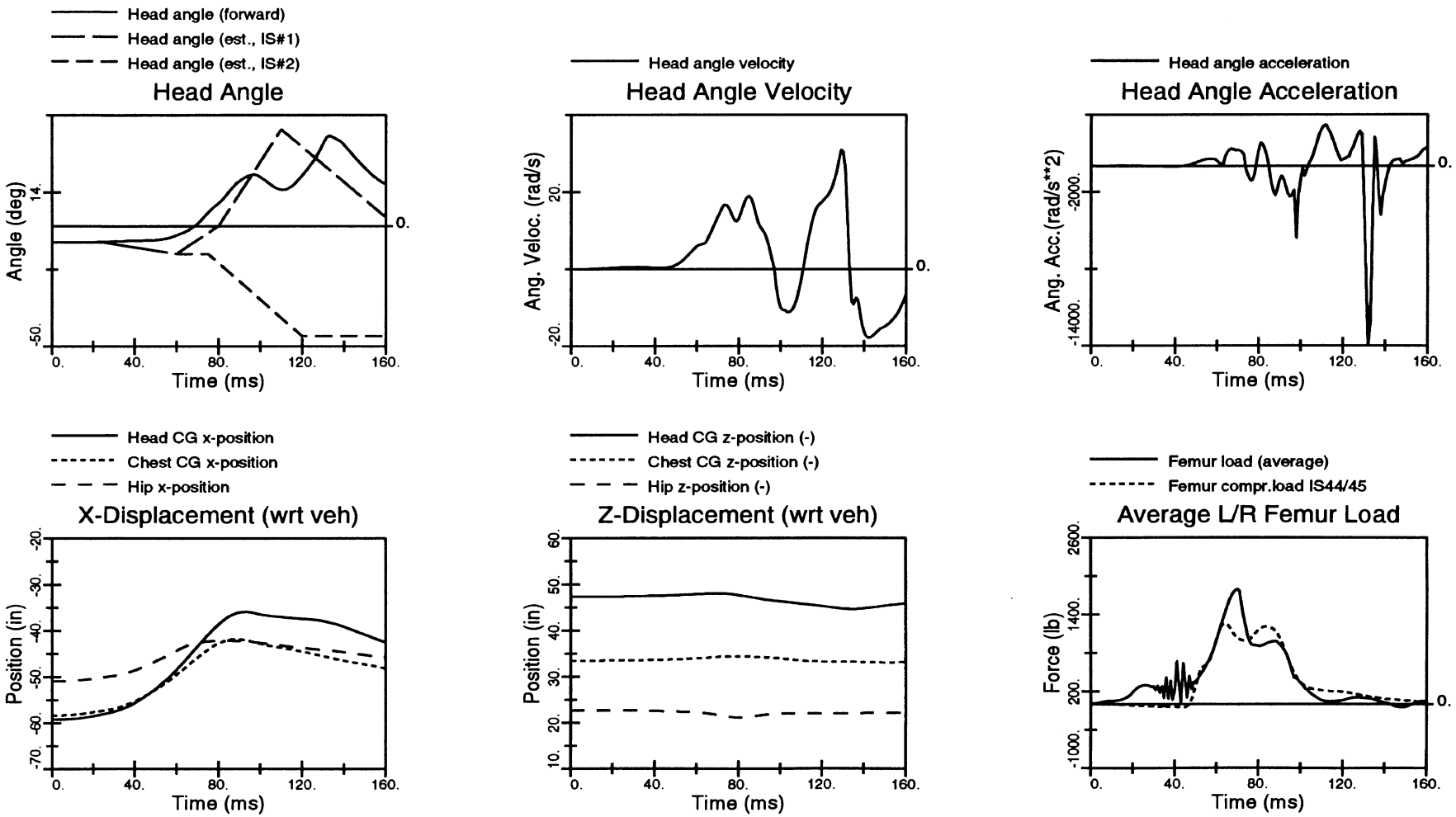


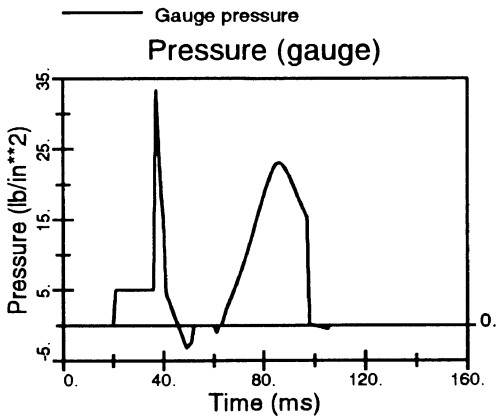
Figure 11.

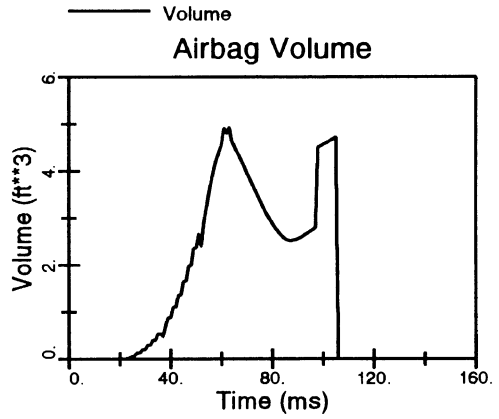
MVMA 2-D CVS Quasi-Finite Element Airbag Model

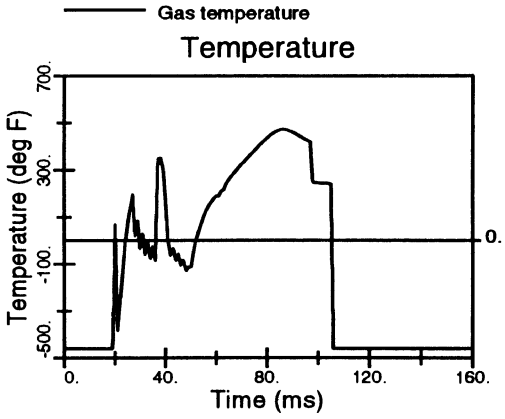
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

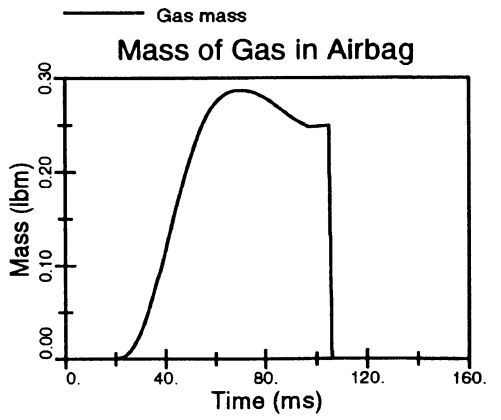
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

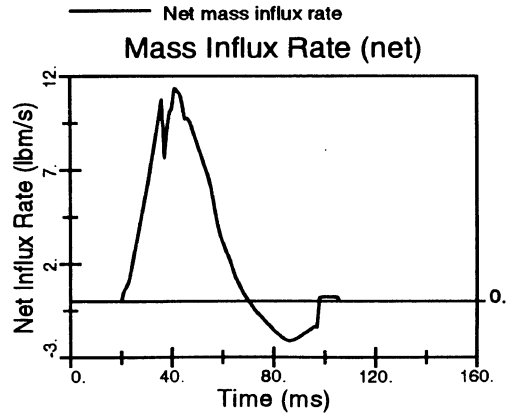
THERMODYNAMIC VARIABLES











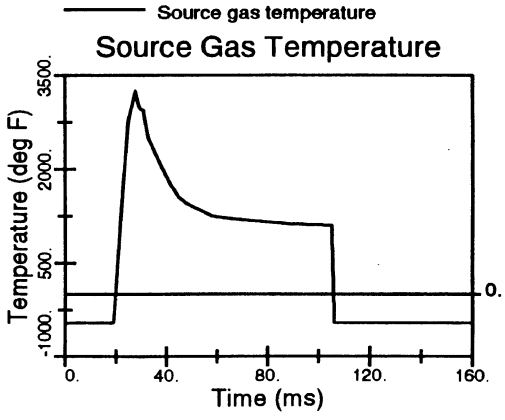


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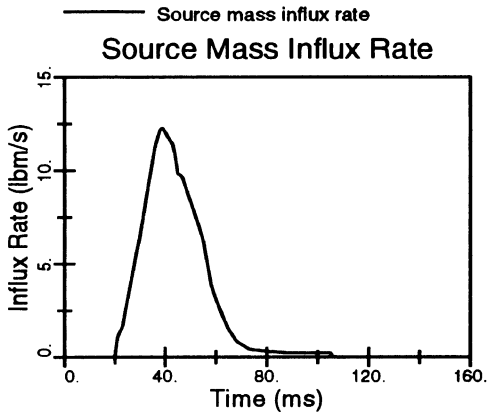
Figure 11.

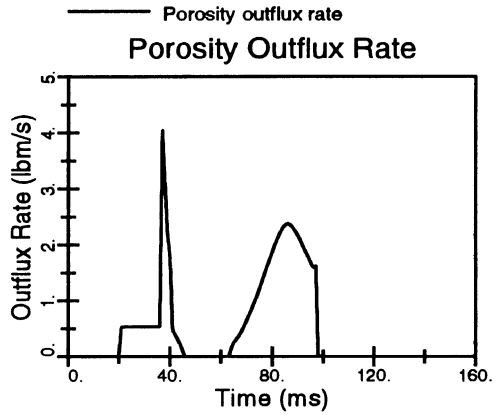
MVMA 2-D CVS Quasi-Finite Element Airbag Model

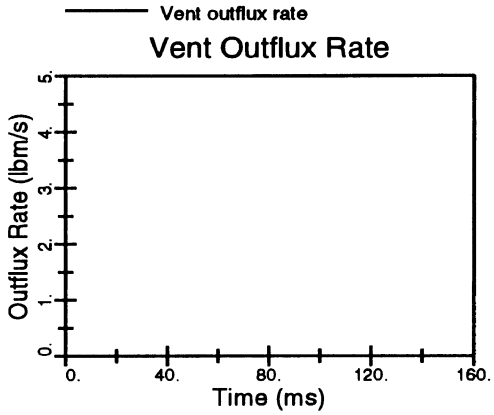
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

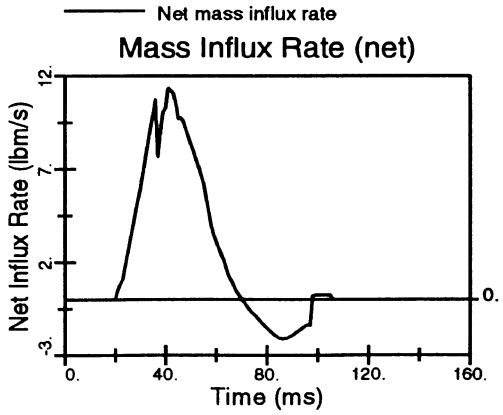
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

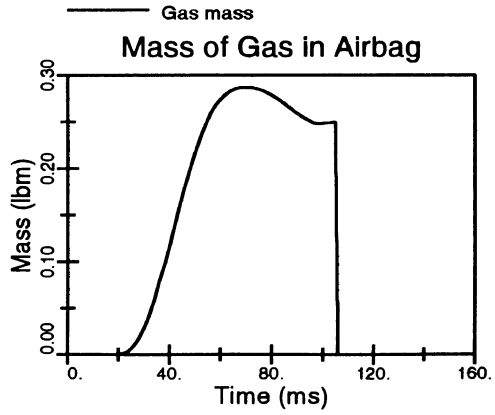
AIRBAG MASS INFLUX/OUTFLUX











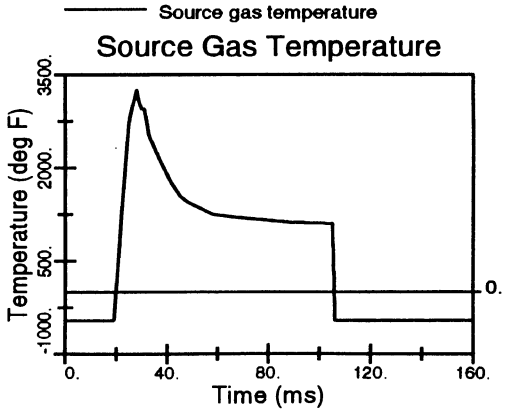


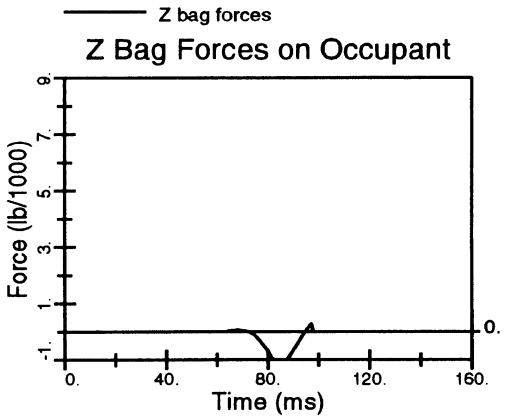
Figure 11.

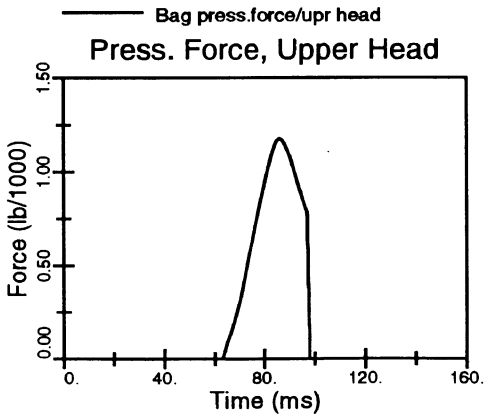
MVMA 2-D CVS Quasi-Finite Element Airbag Model

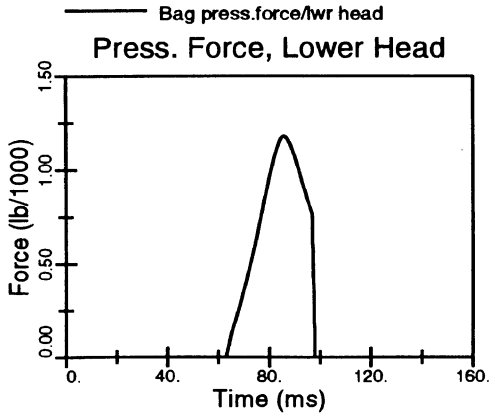
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







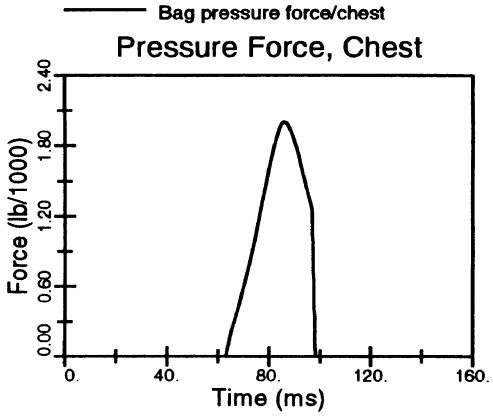


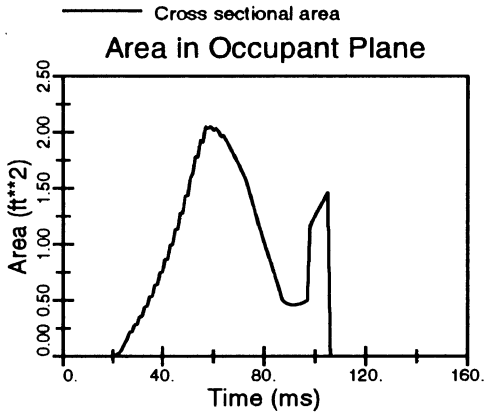
Figure 11.

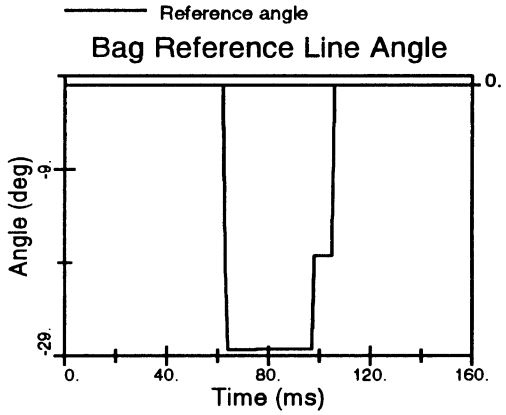
MVMA 2-D CVS Quasi-Finite Element Airbag Model

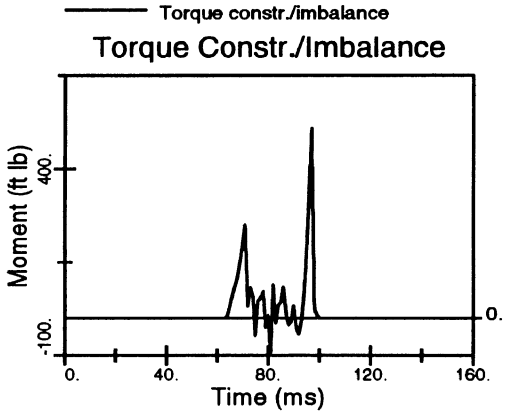
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration , Tests IS11144/45

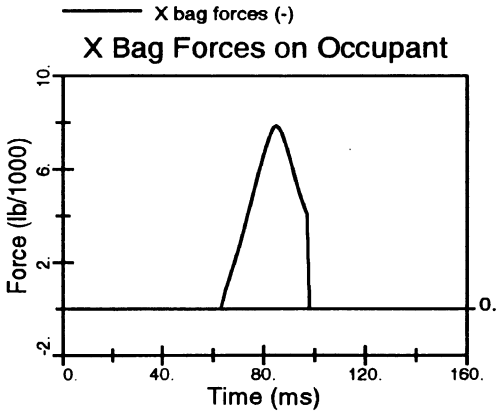
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









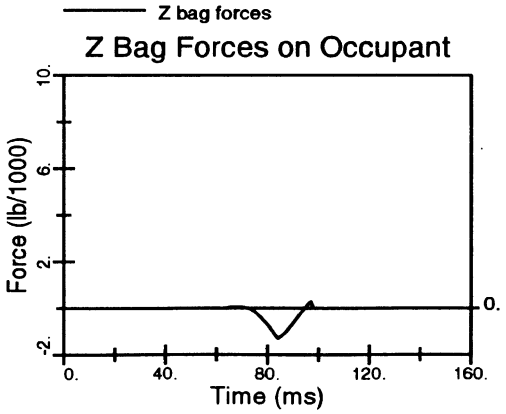


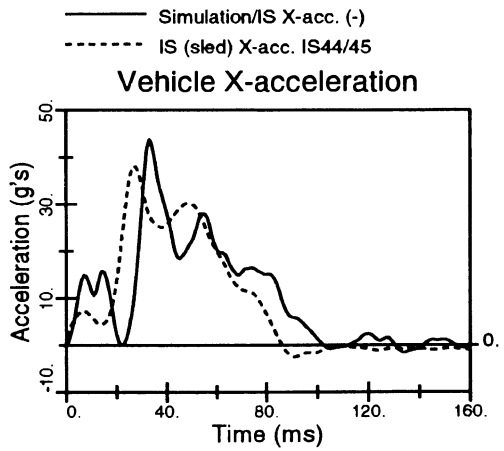
Figure 11.

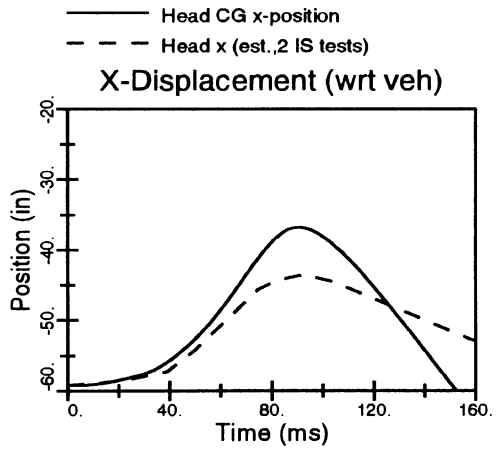
MVMA 2-D CVS Quasi-Finite Element Airbag Model

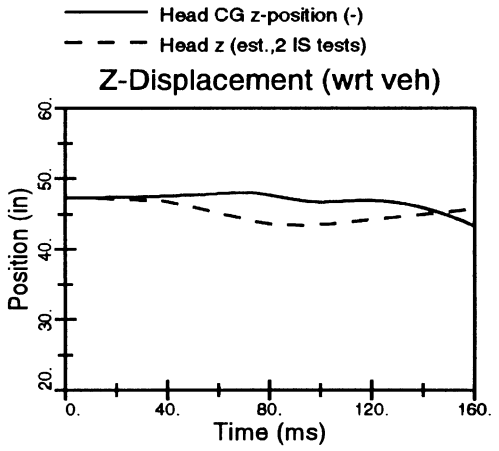
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

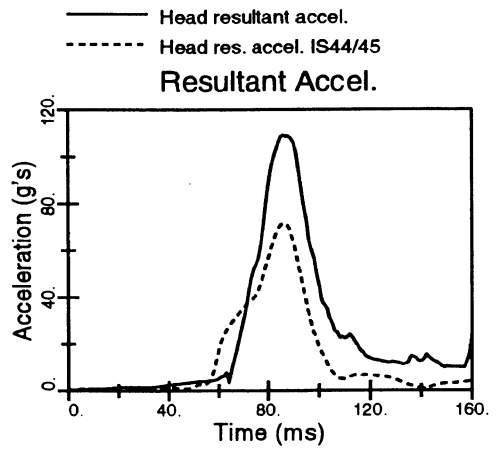
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

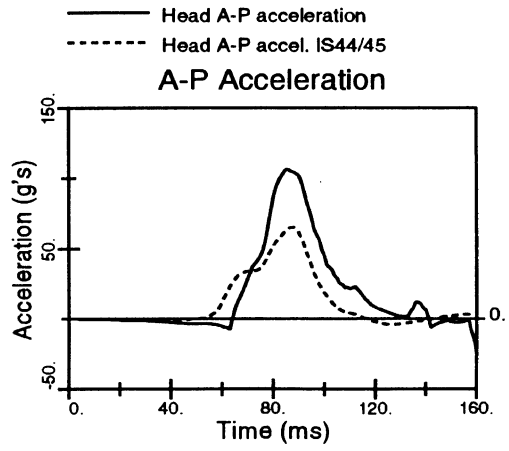
HEAD KINEMATIC RESPONSE











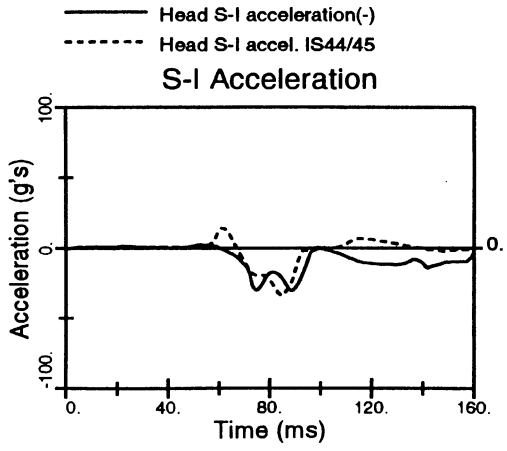


Figure 12.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

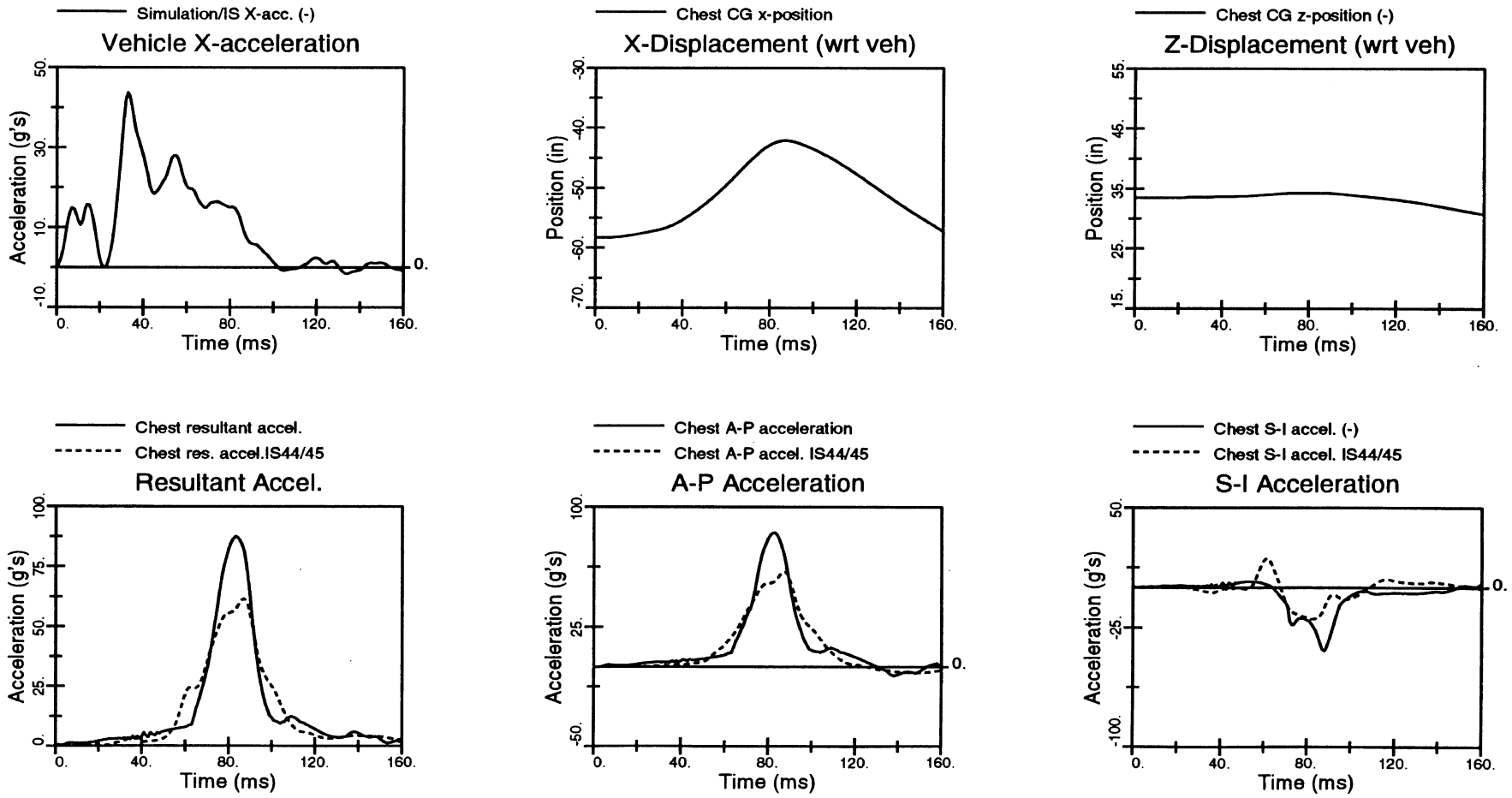


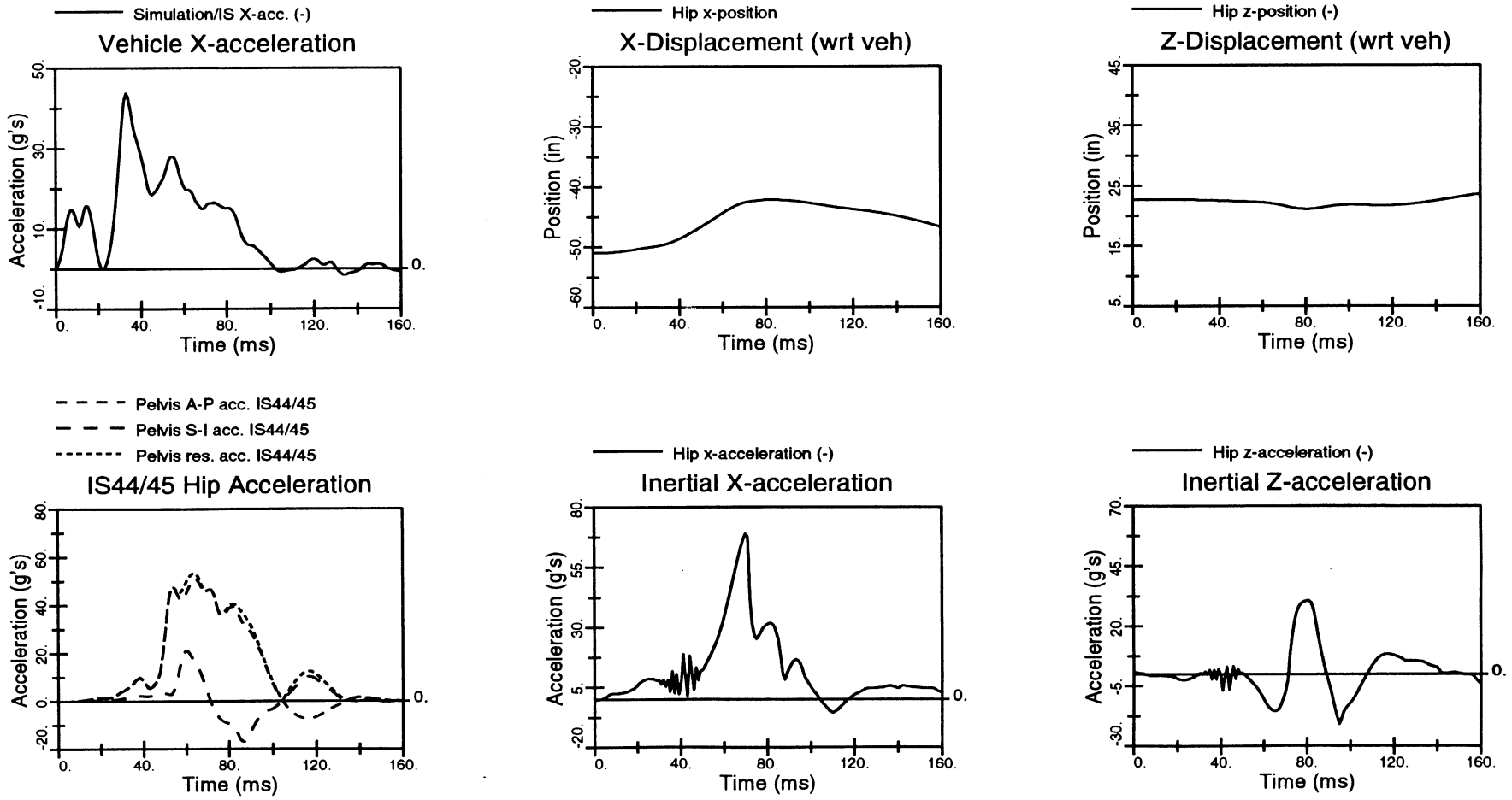
Figure 12.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE



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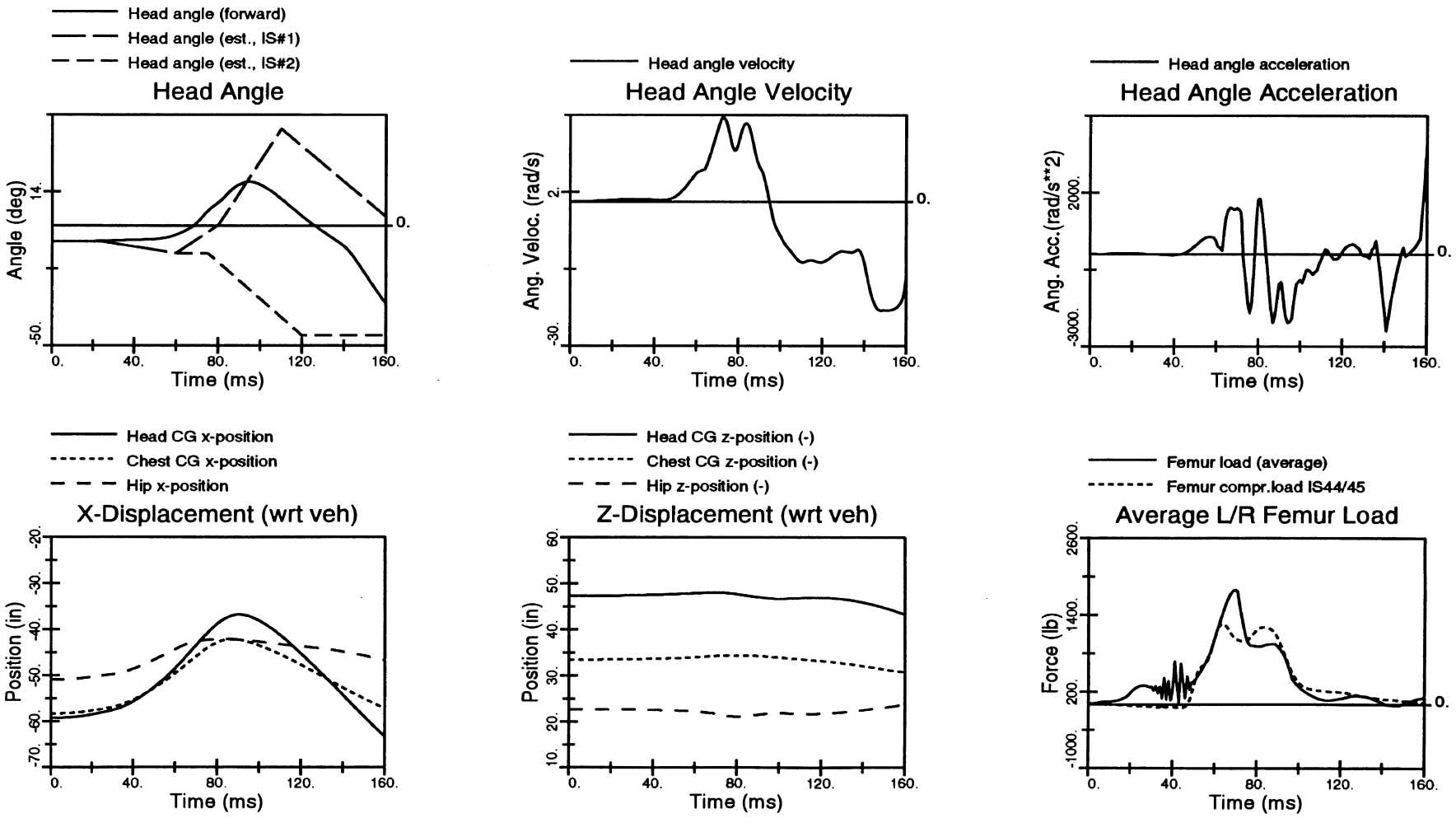
HEAD ANGULAR RESPONSE / OTHER RESPONSES



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MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

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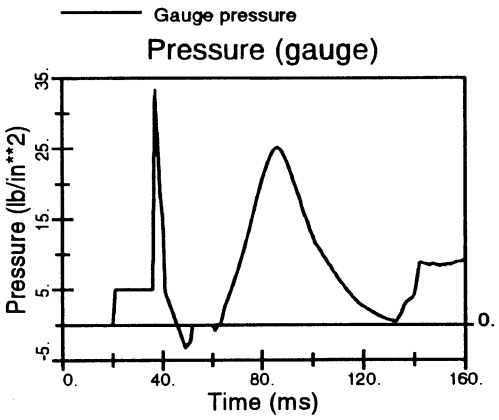
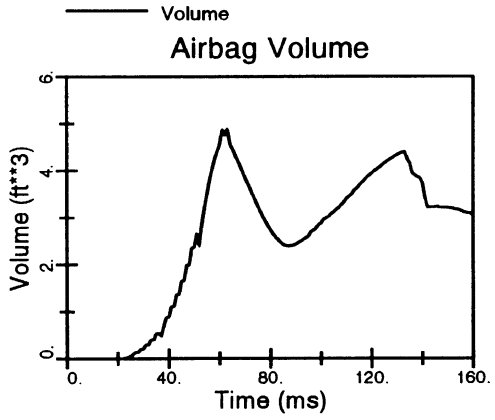
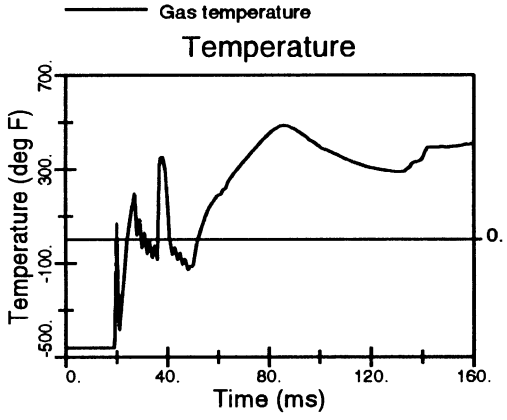
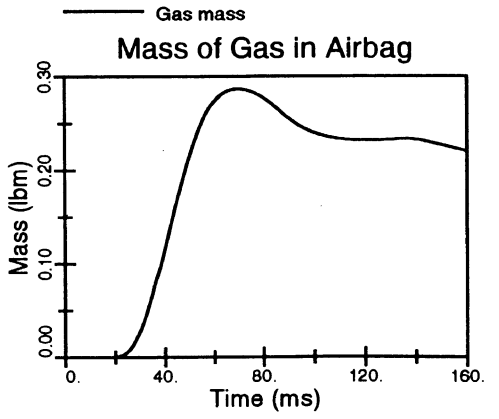
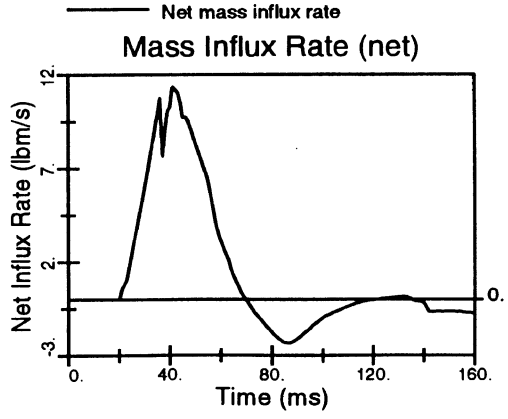
THERMODYNAMIC VARIABLES











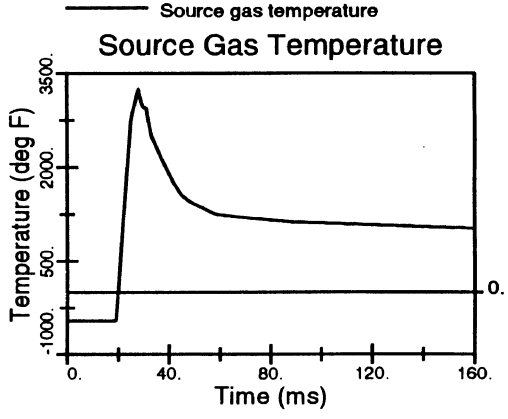


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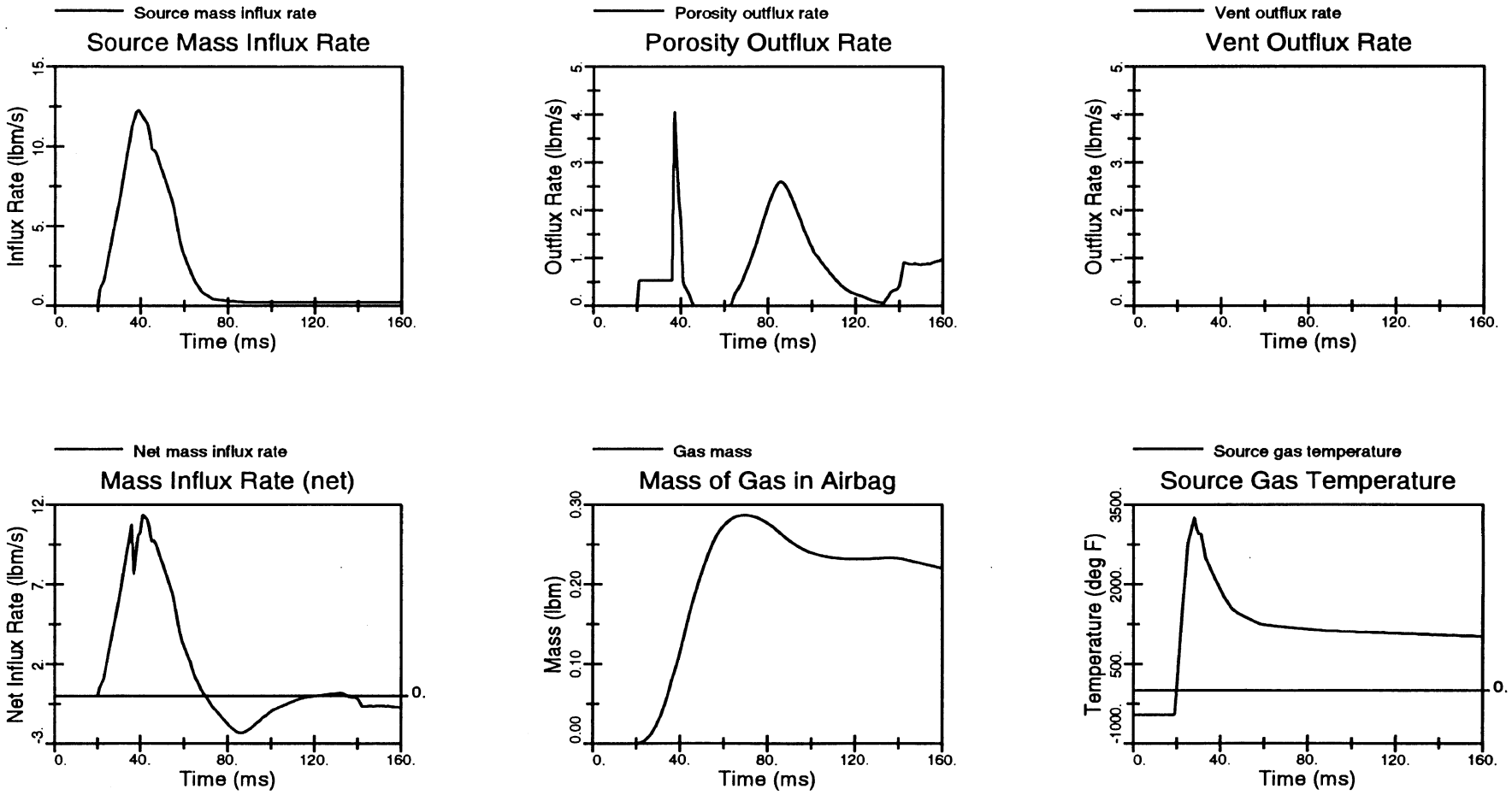
Figure 12.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG MASS INFLUX/OUTFLUX



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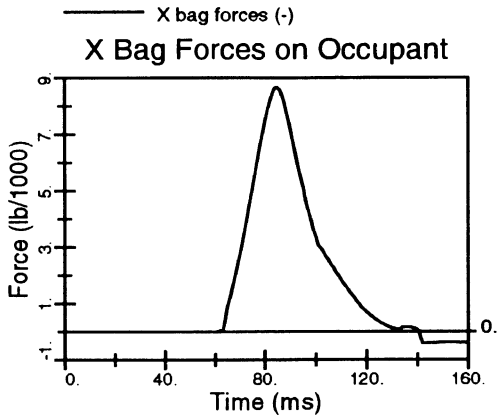
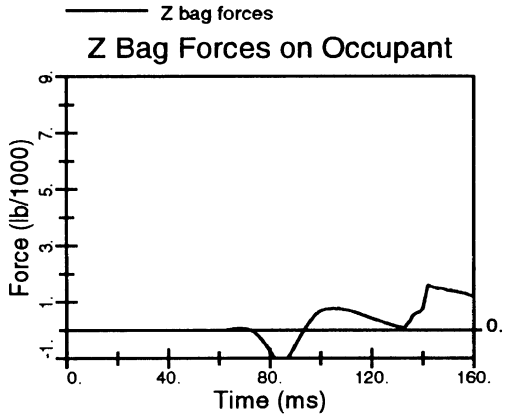
MVMA 2-D CVS Quasi-Finite Element Airbag Model

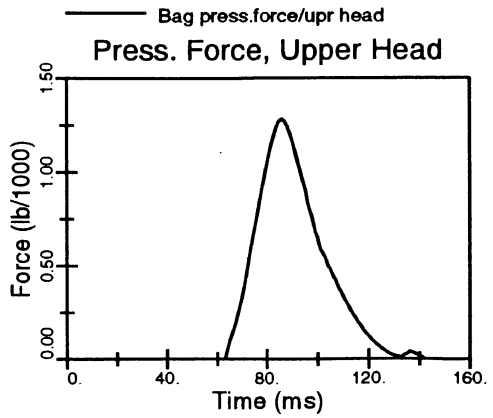
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

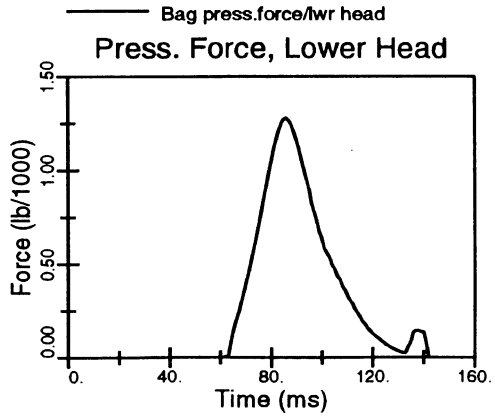
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

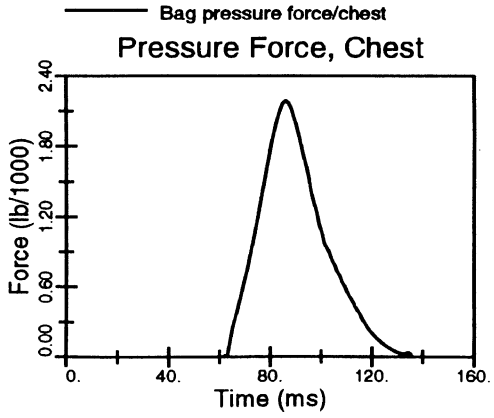
AIRBAG FORCES (SUMMARY)











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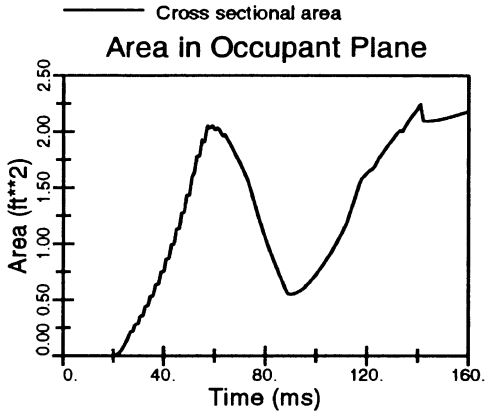
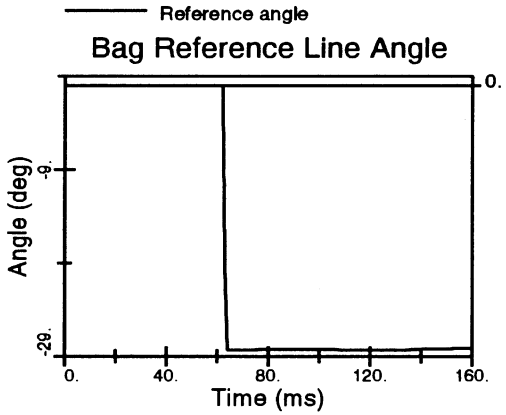
MVMA 2-D CVS Quasi-Finite Element Airbag Model

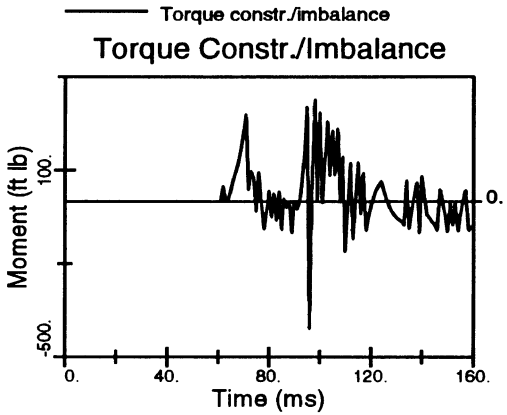
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration , Tests IS11144/45

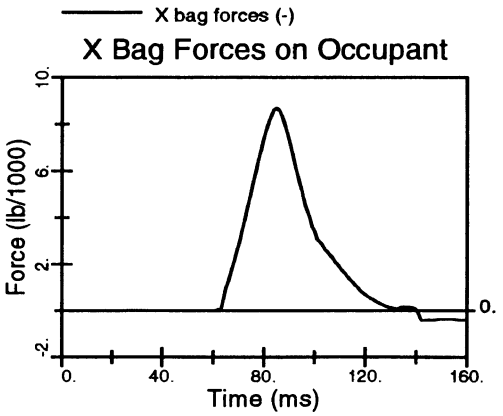
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









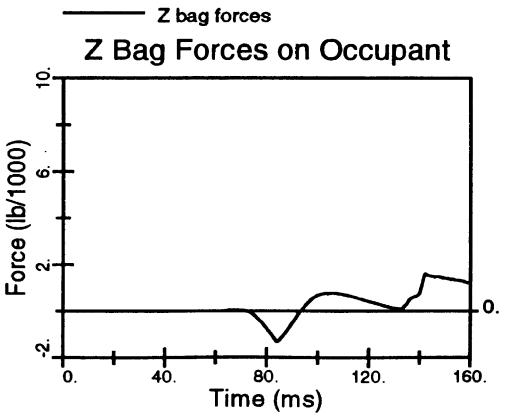


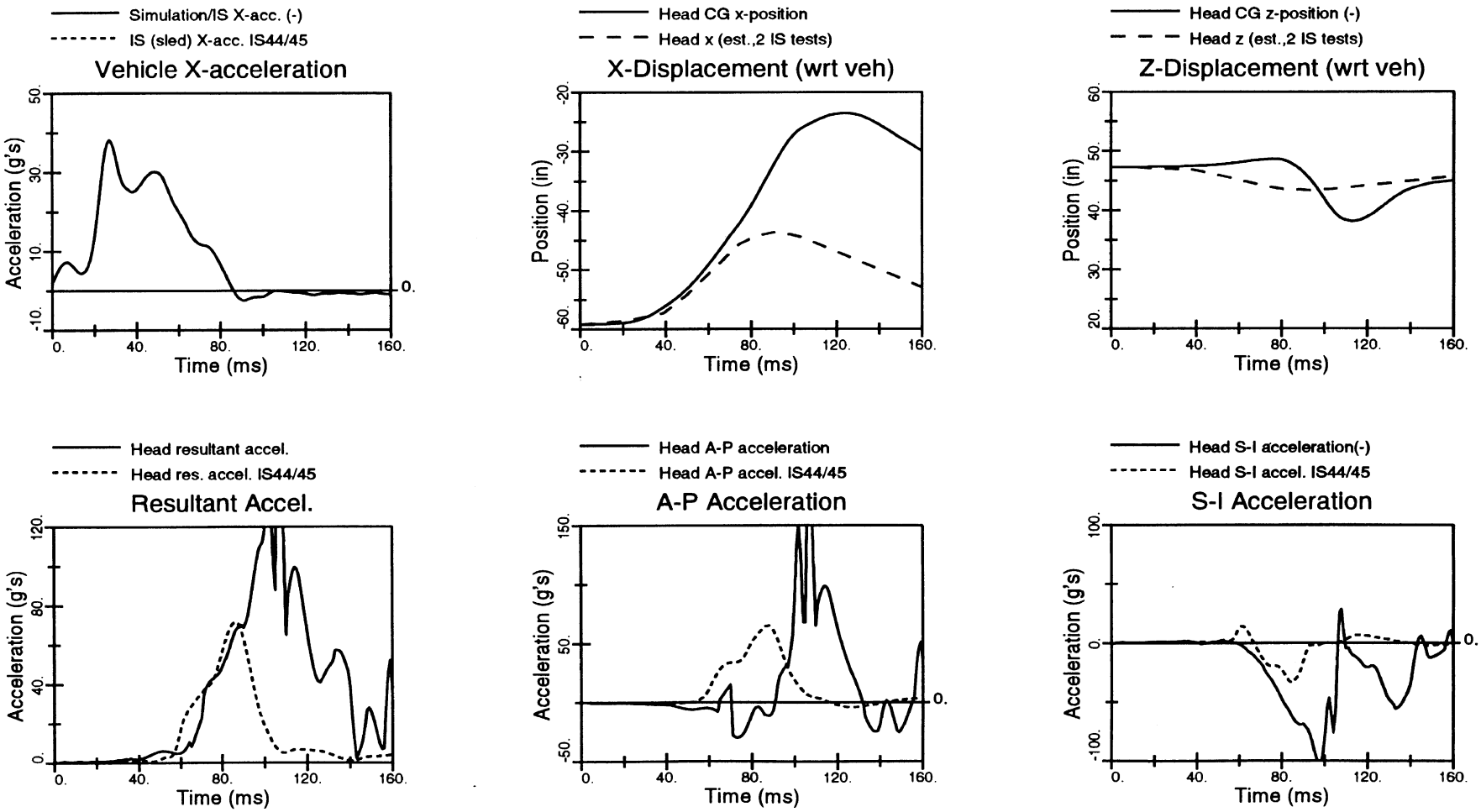
Figure 12.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE



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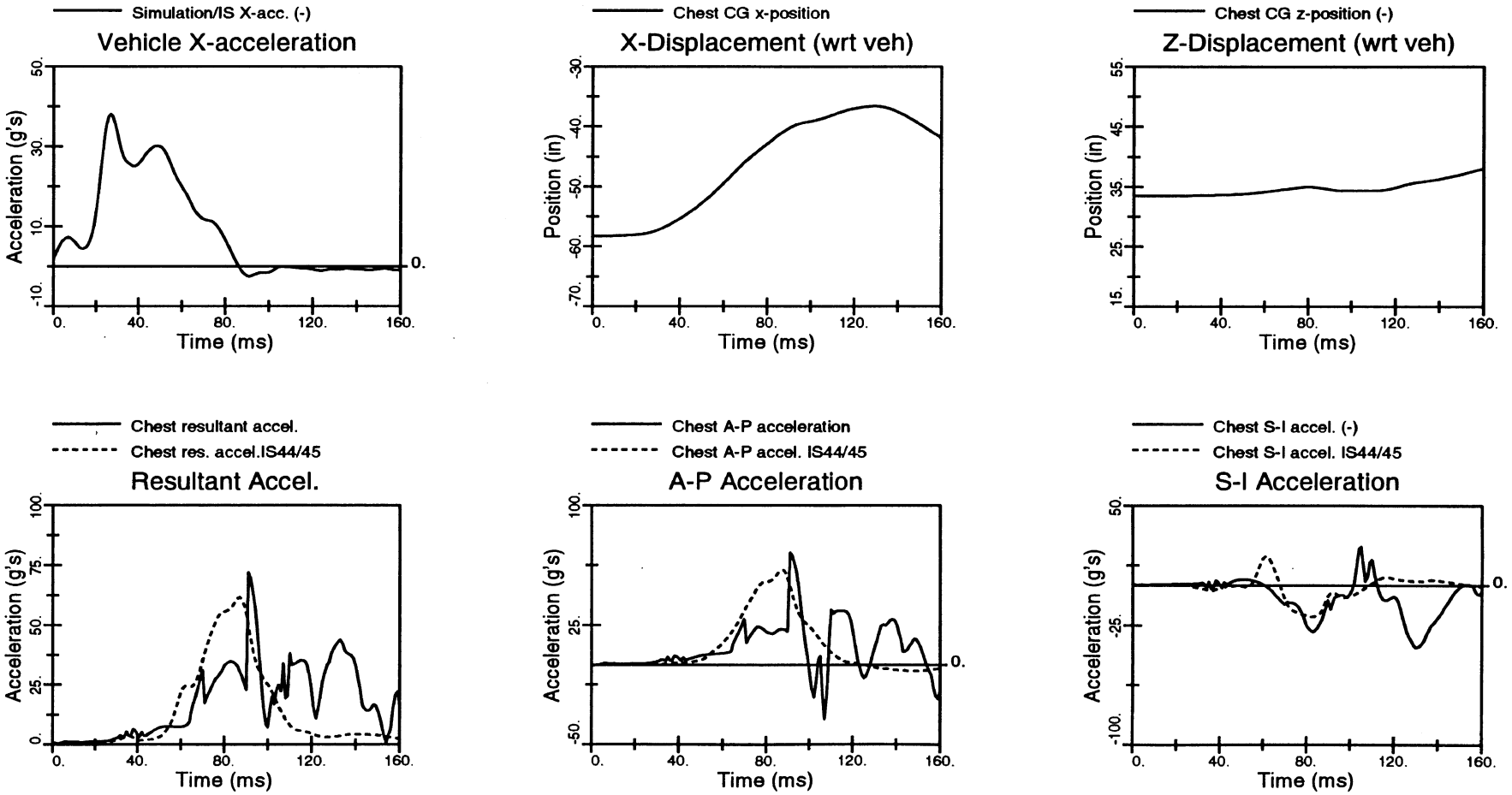
MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE



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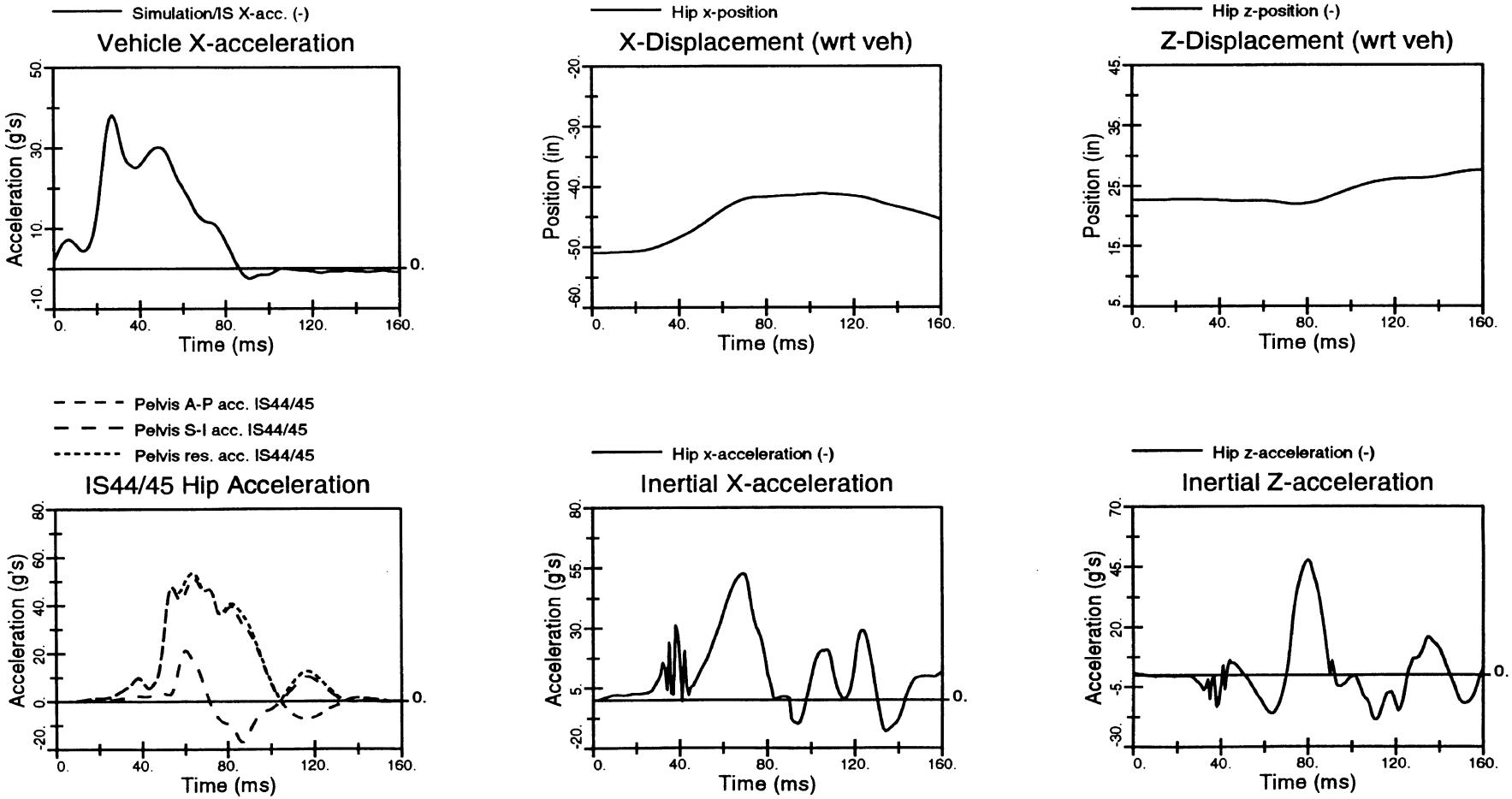
MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE



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MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

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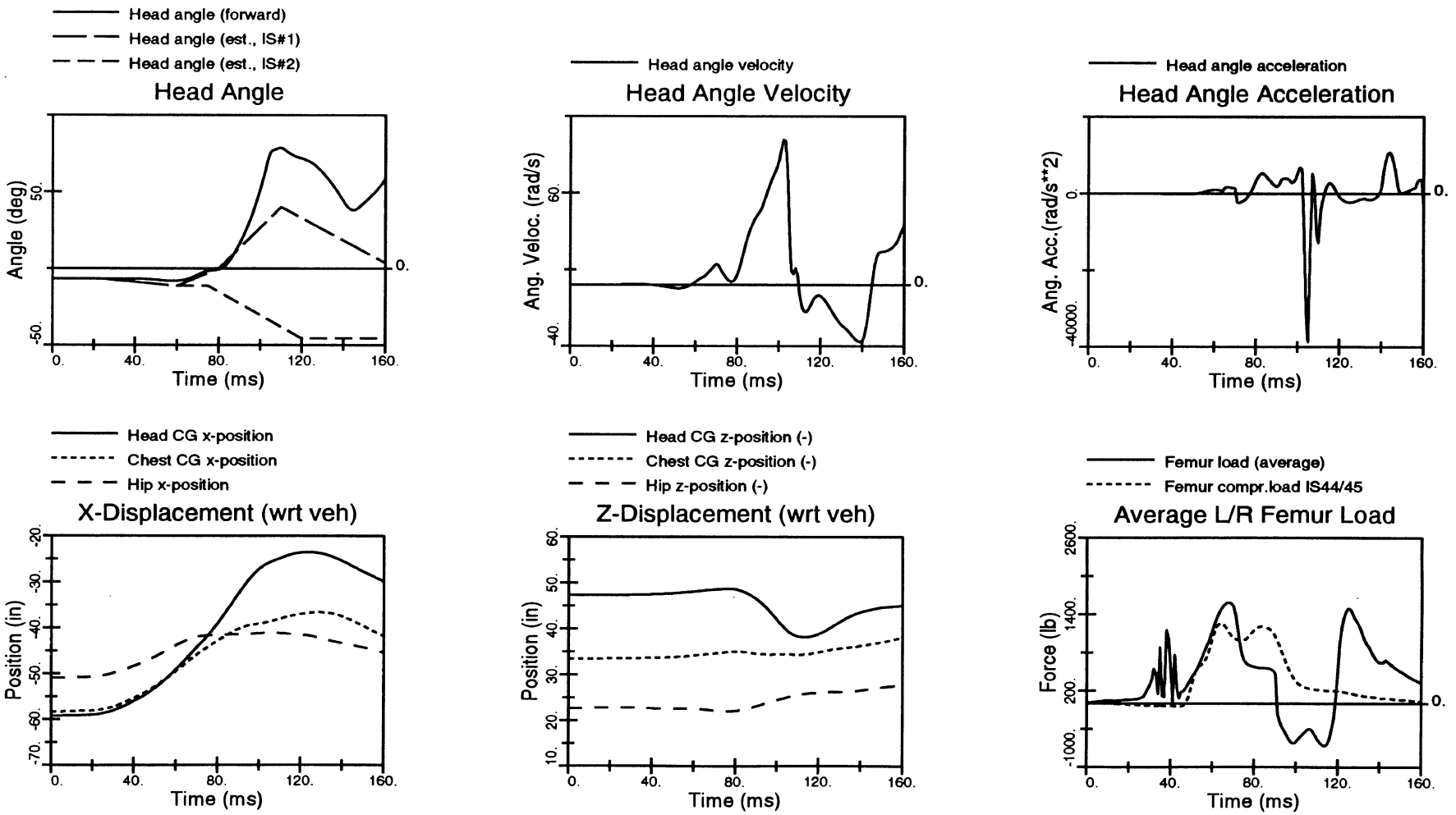


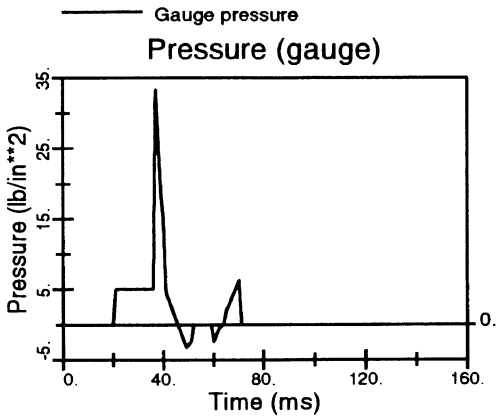
Figure 13.

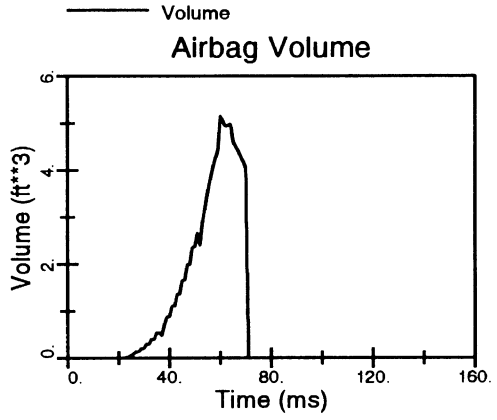
MVMA 2-D CVS Quasi-Finite Element Airbag Model

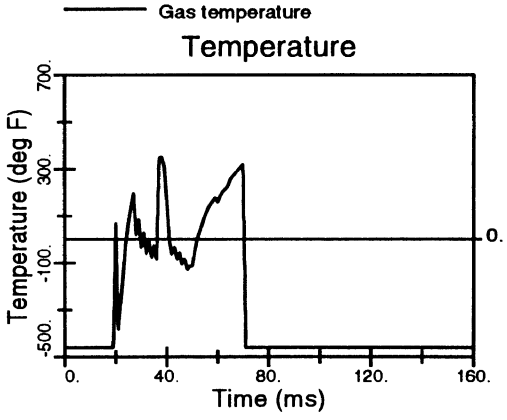
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

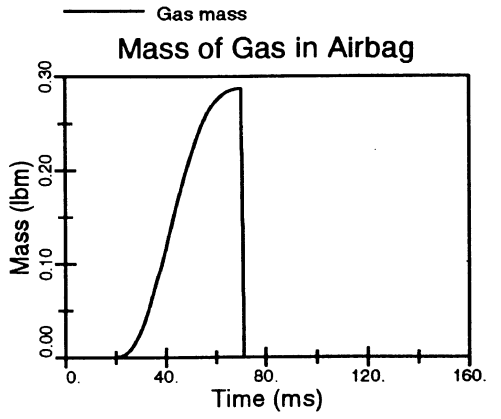
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

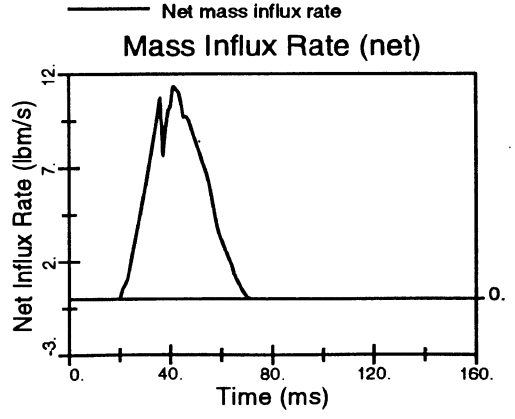
THERMODYNAMIC VARIABLES











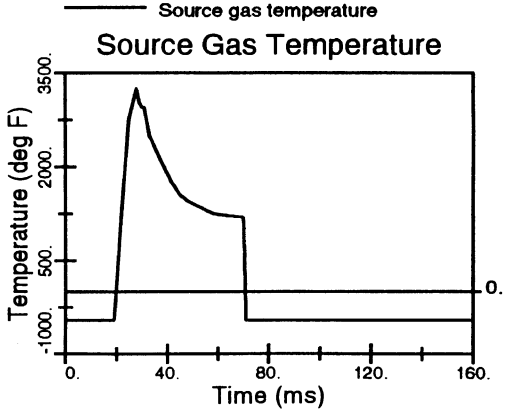


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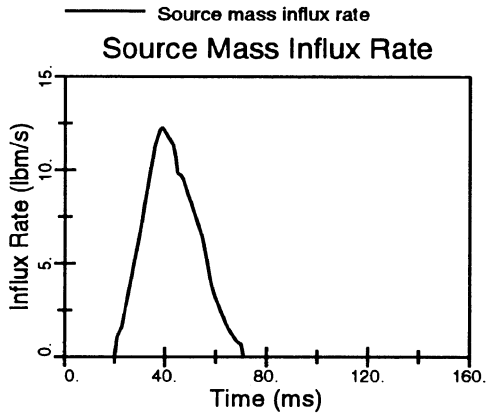
Figure 13.

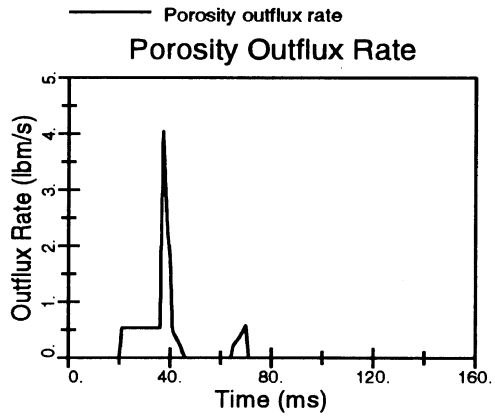
MVMA 2-D CVS Quasi-Finite Element Airbag Model

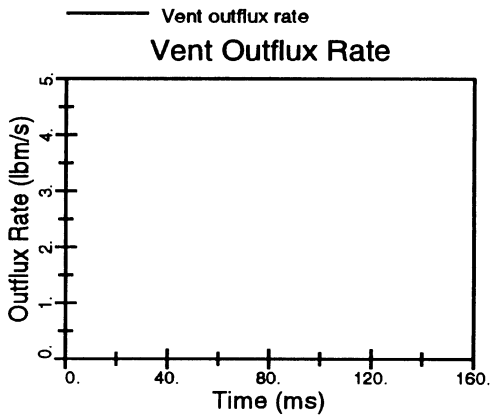
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

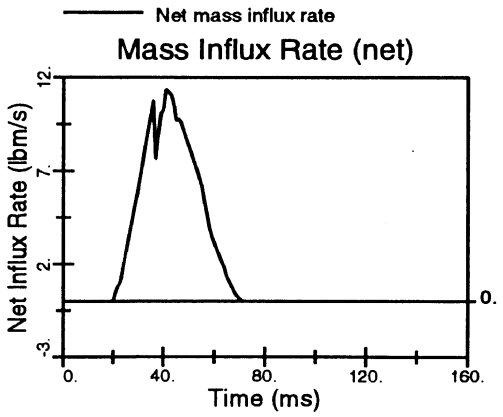
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

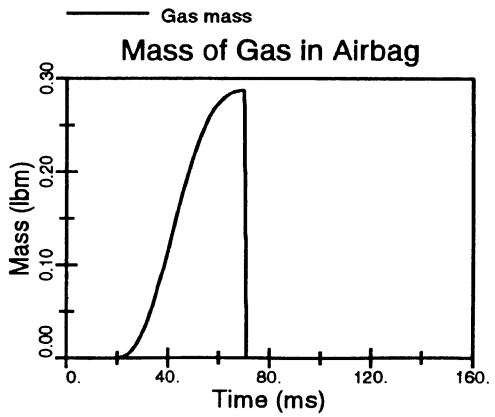
AIRBAG MASS INFLUX/OUTFLUX











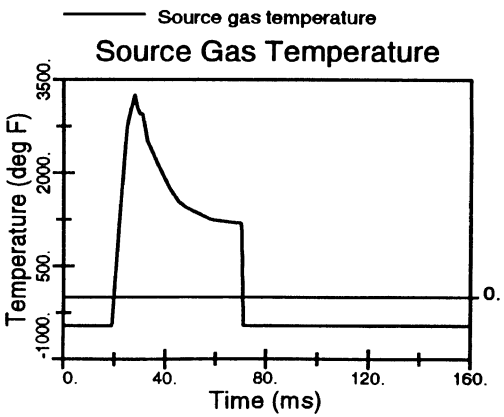


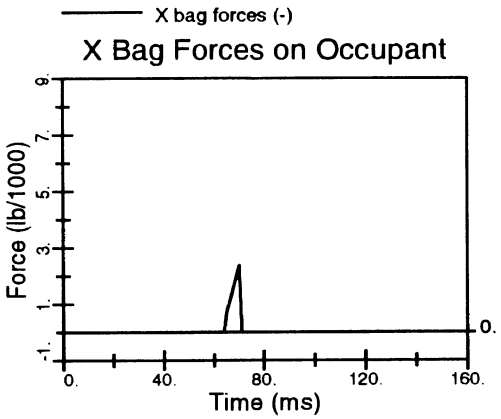
Figure 13.

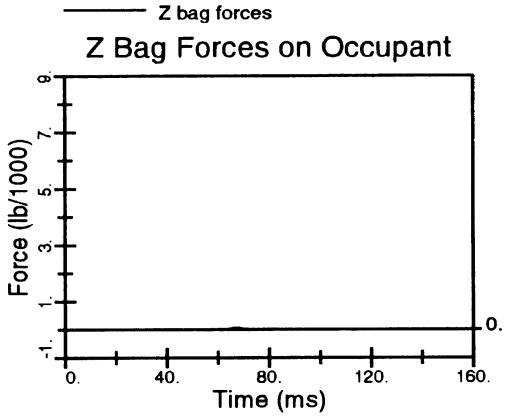
MVMA 2-D CVS Quasi-Finite Element Airbag Model

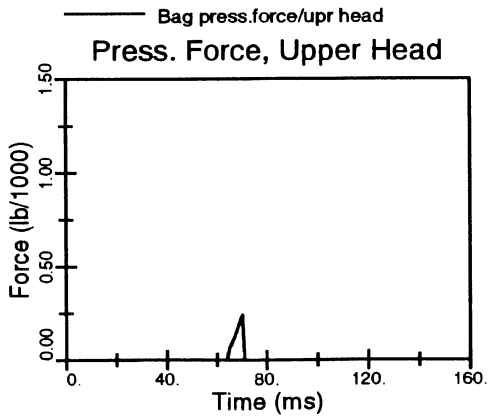
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

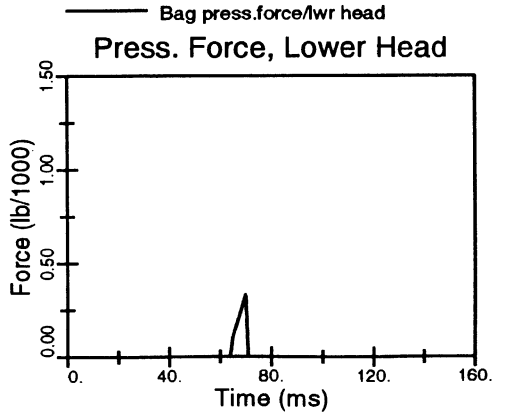
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

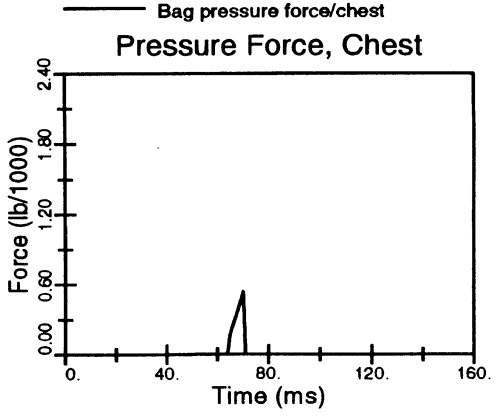
AIRBAG FORCES (SUMMARY)











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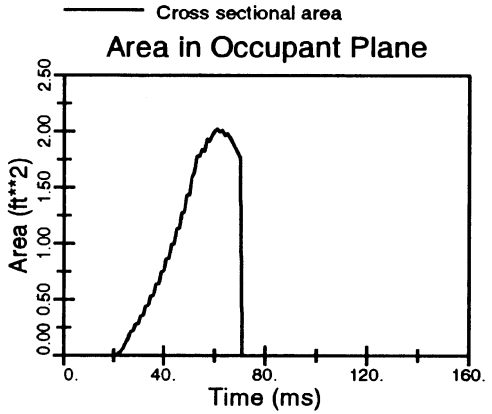
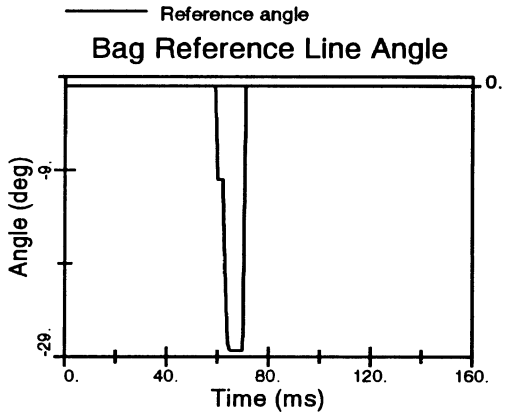
MVMA 2-D CVS Quasi-Finite Element Airbag Model

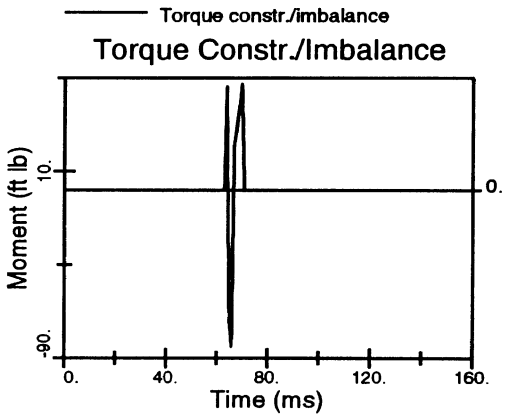
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC pitch acceleration , Tests IS11144/45

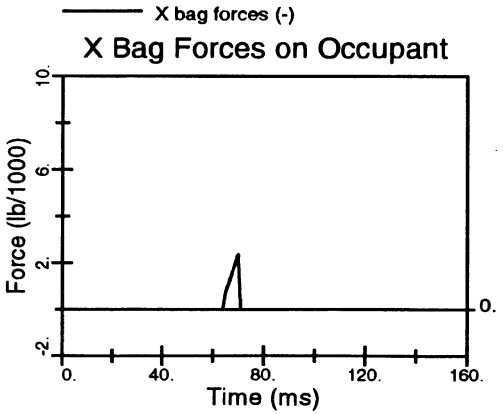
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









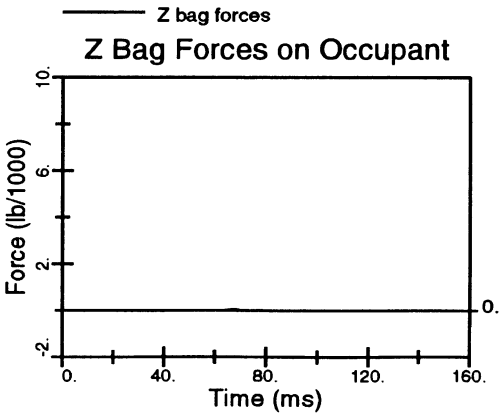


Figure 13.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

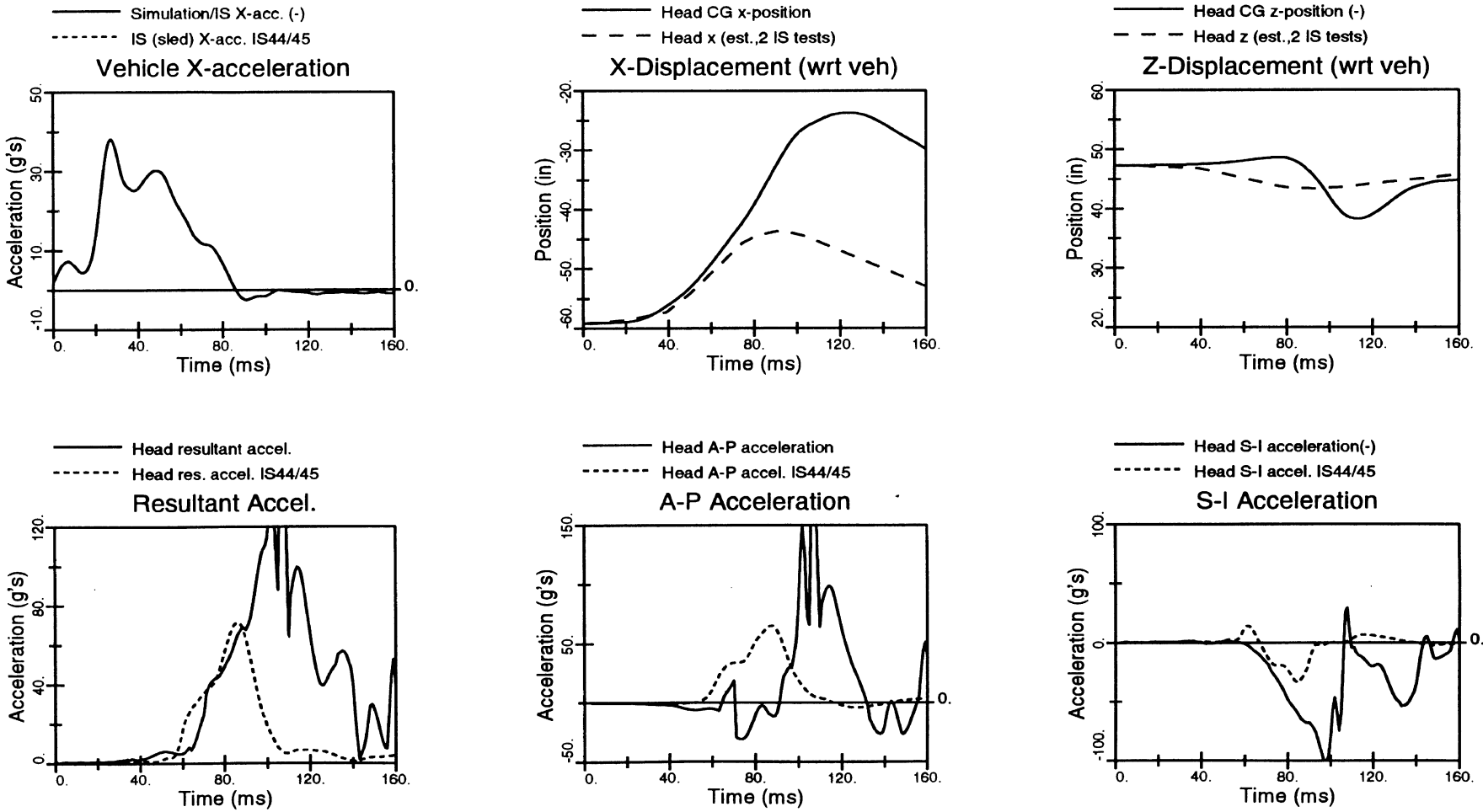


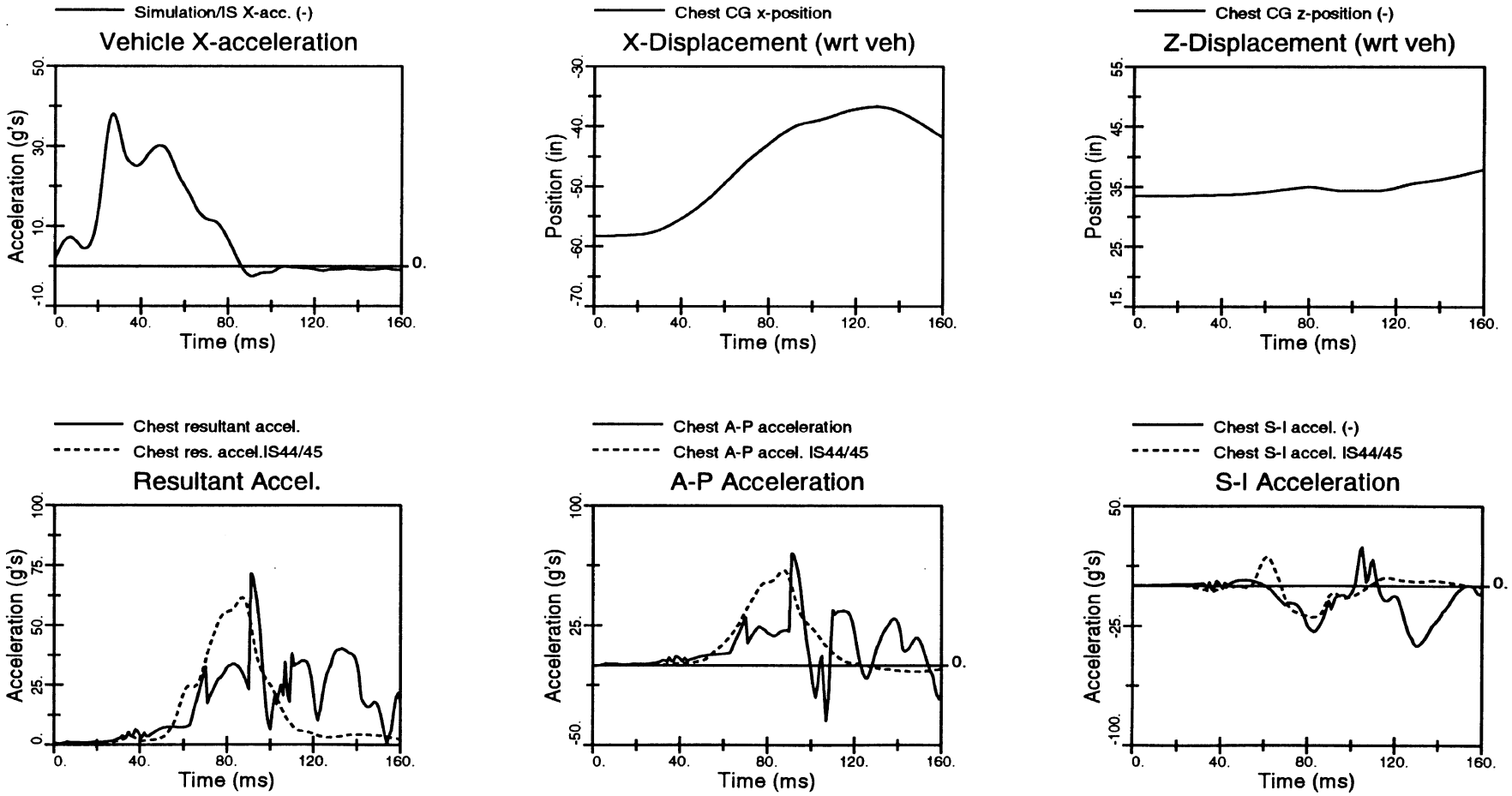
Figure 14.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE



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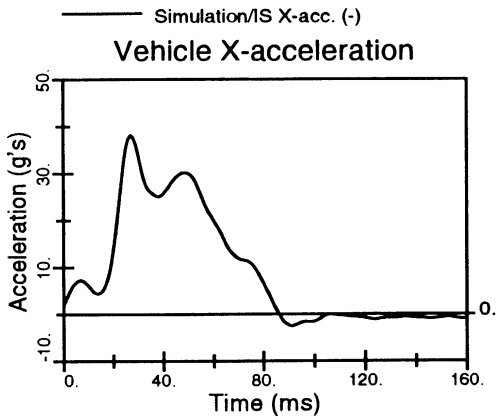
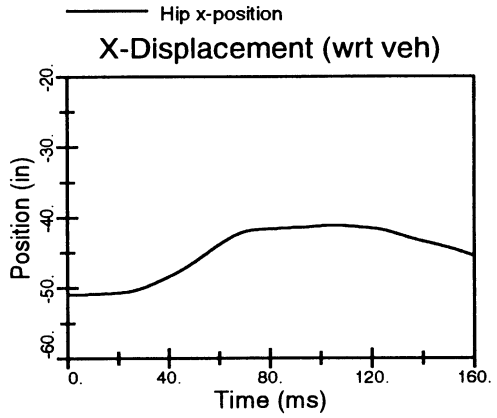
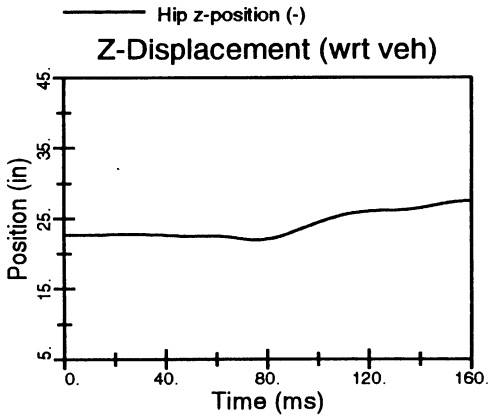
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

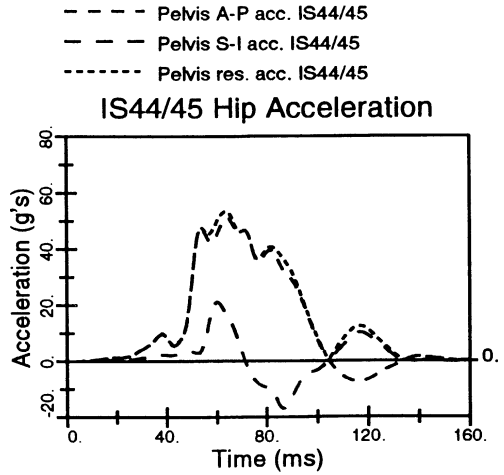
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

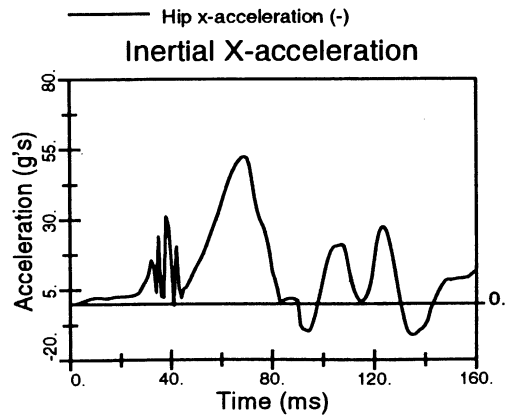
HIP KINEMATIC RESPONSE











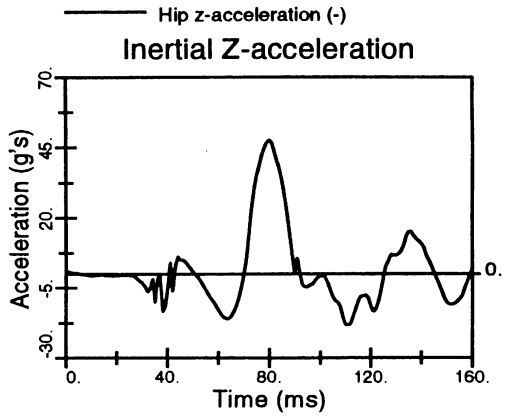


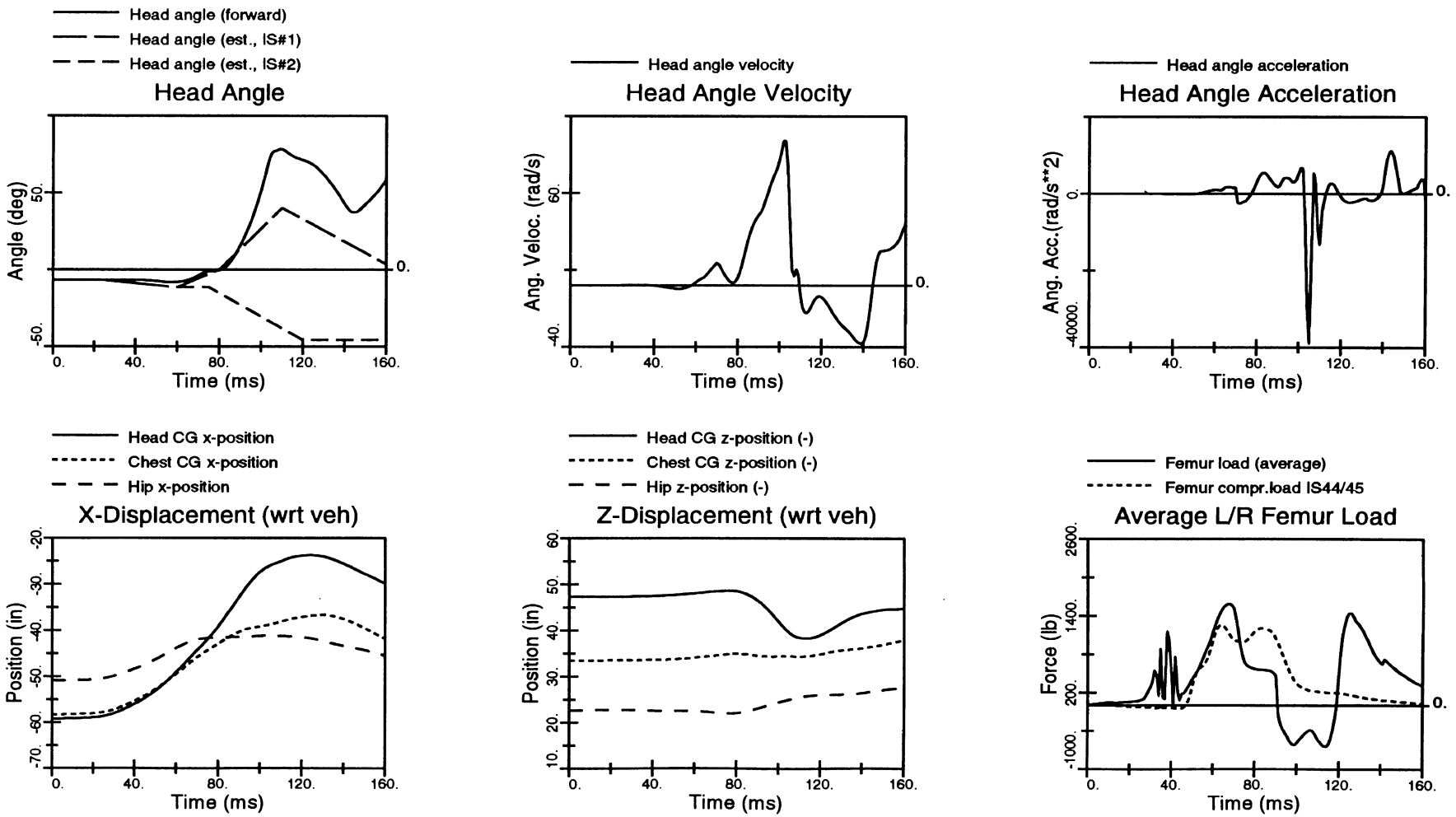
Figure 14.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES



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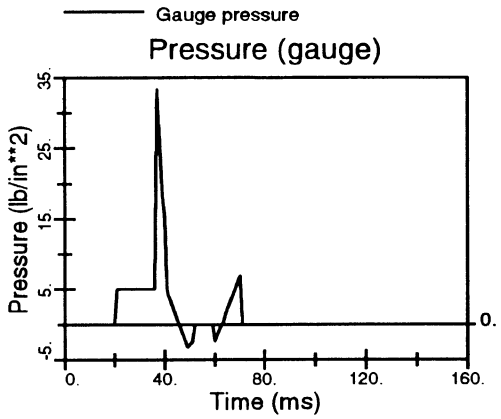

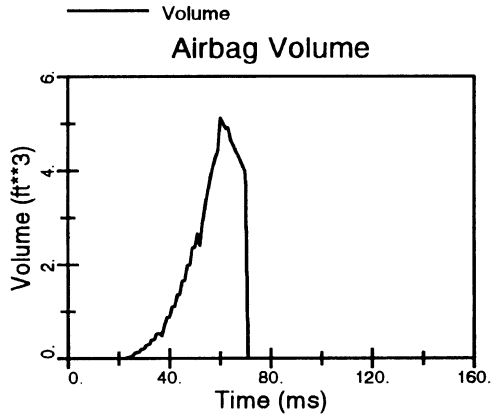

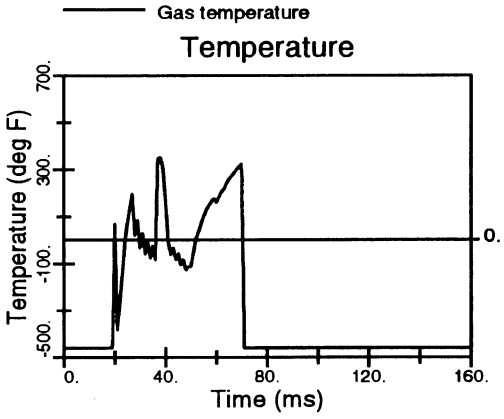

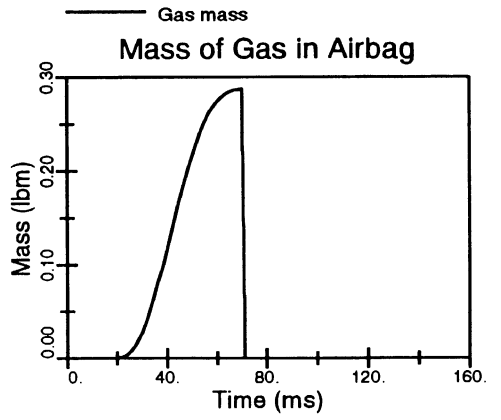

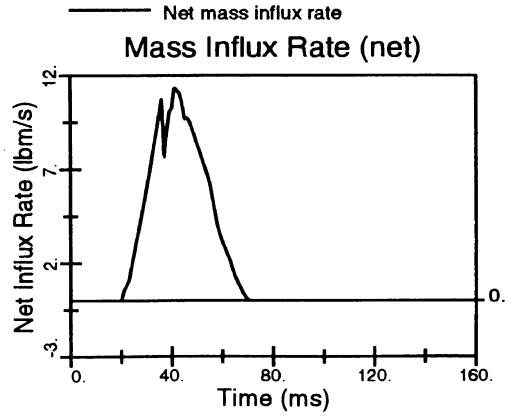

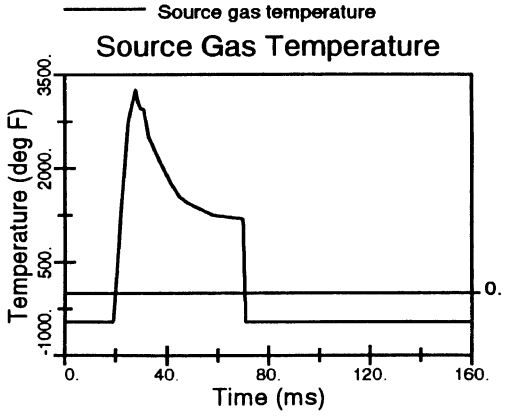

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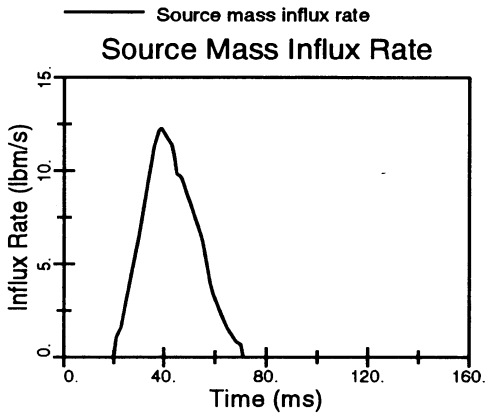
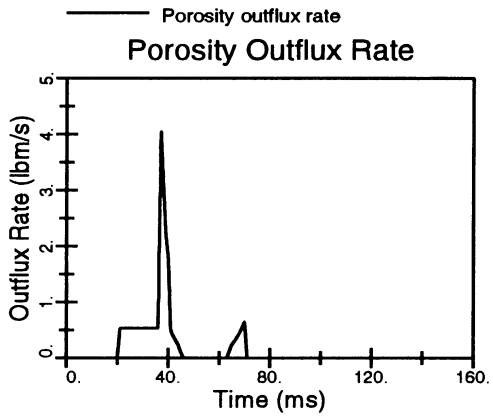
MVMA 2-D CVS Quasi-Finite Element Airbag Model

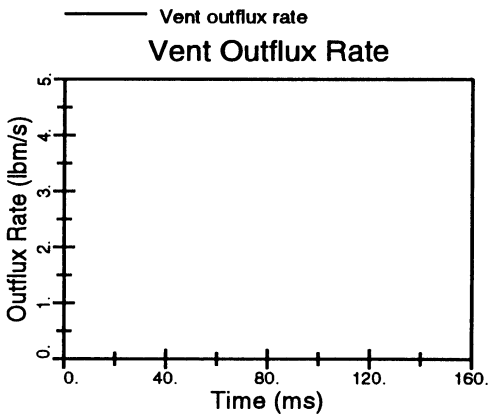
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

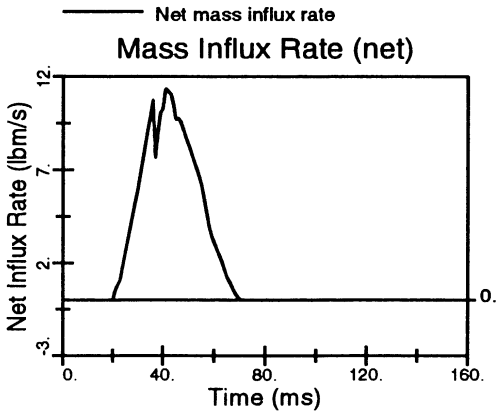
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

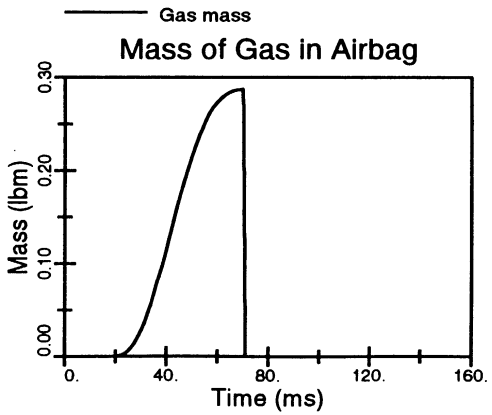
AIRBAG MASS INFLUX/OUTFLUX











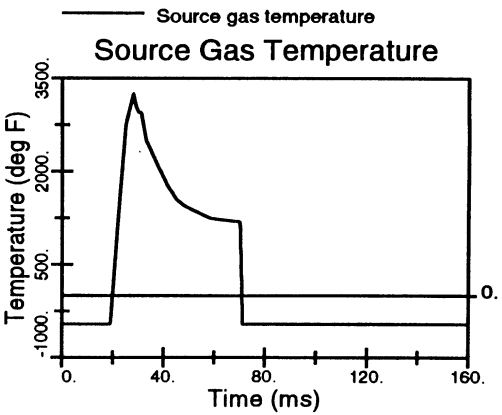


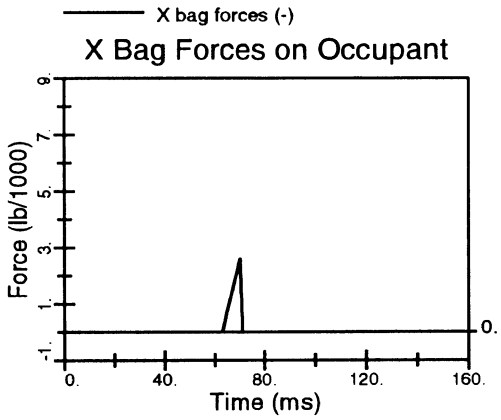
Figure 14.

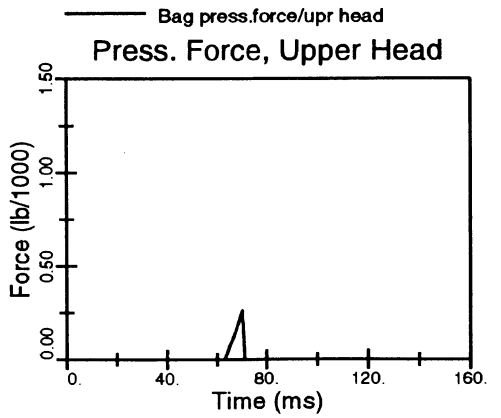
MVMA 2-D CVS Quasi-Finite Element Airbag Model

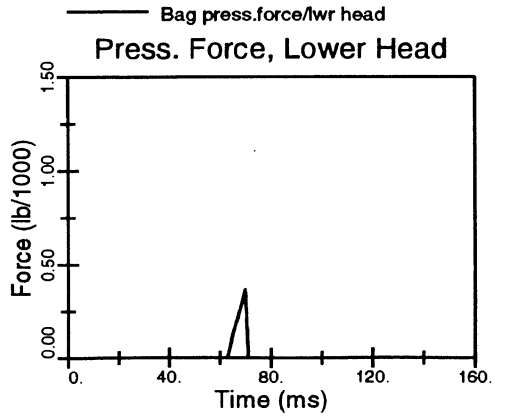
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







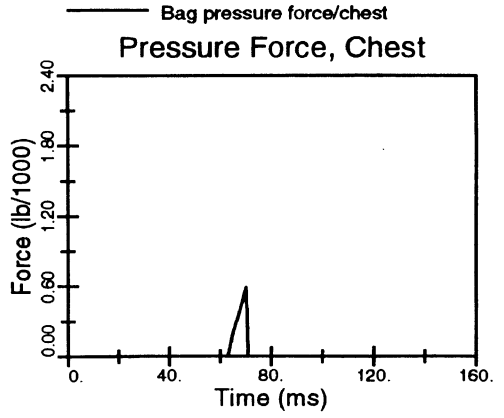


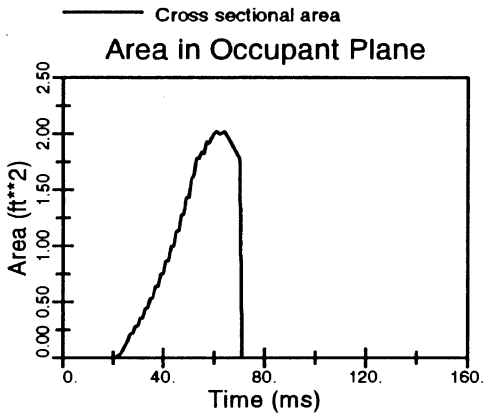
Figure 14.

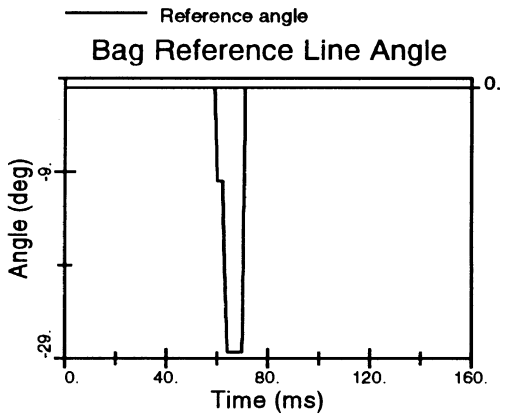
MVMA 2-D CVS Quasi-Finite Element Airbag Model

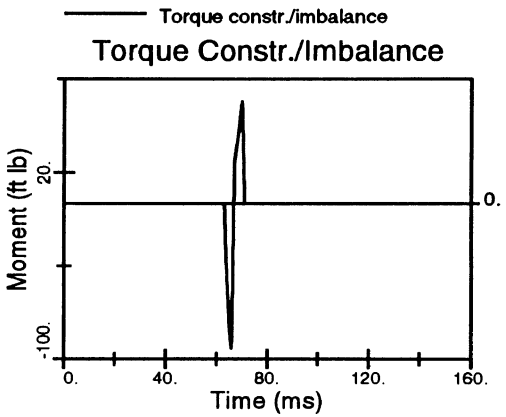
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC pitch acceleration , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES







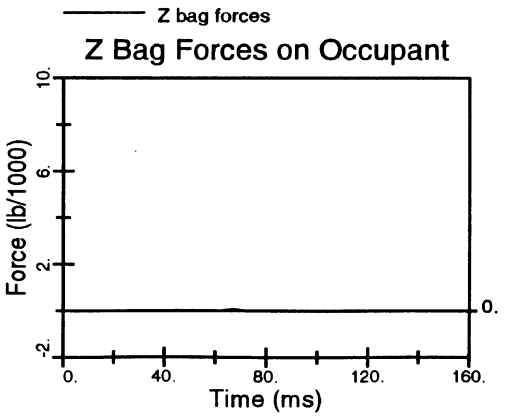


Figure 14.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

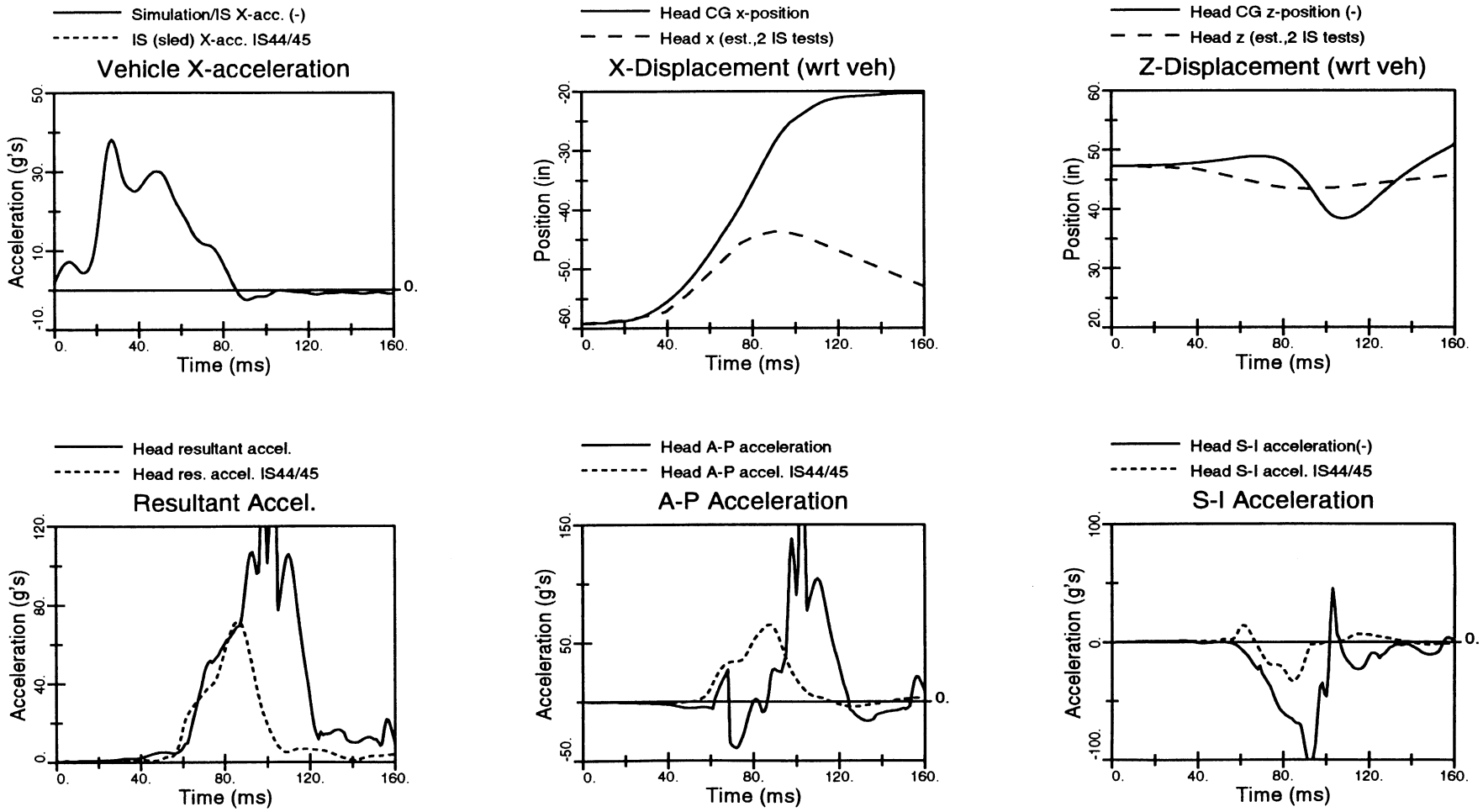


Figure 15.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

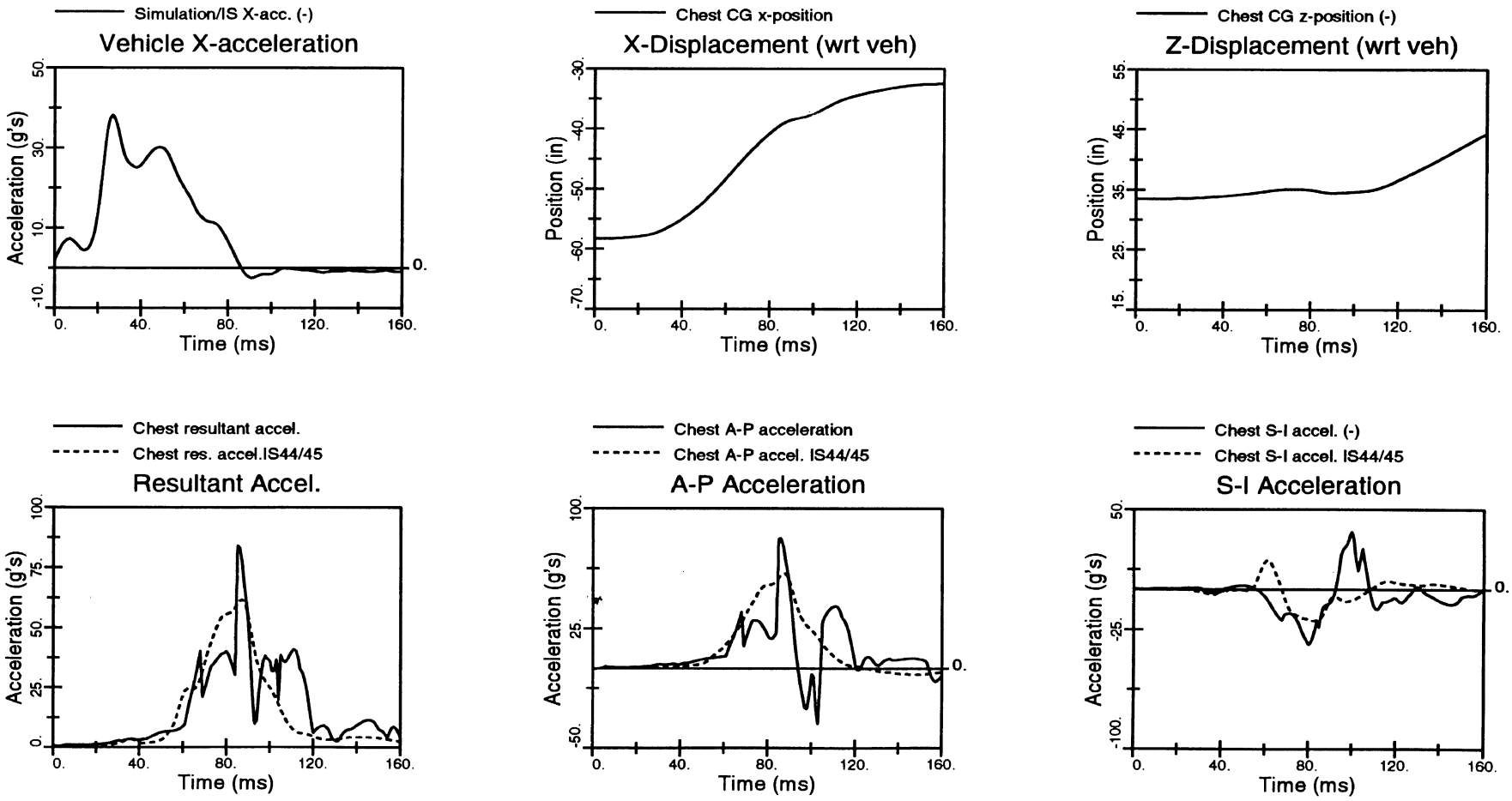


Figure 15.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

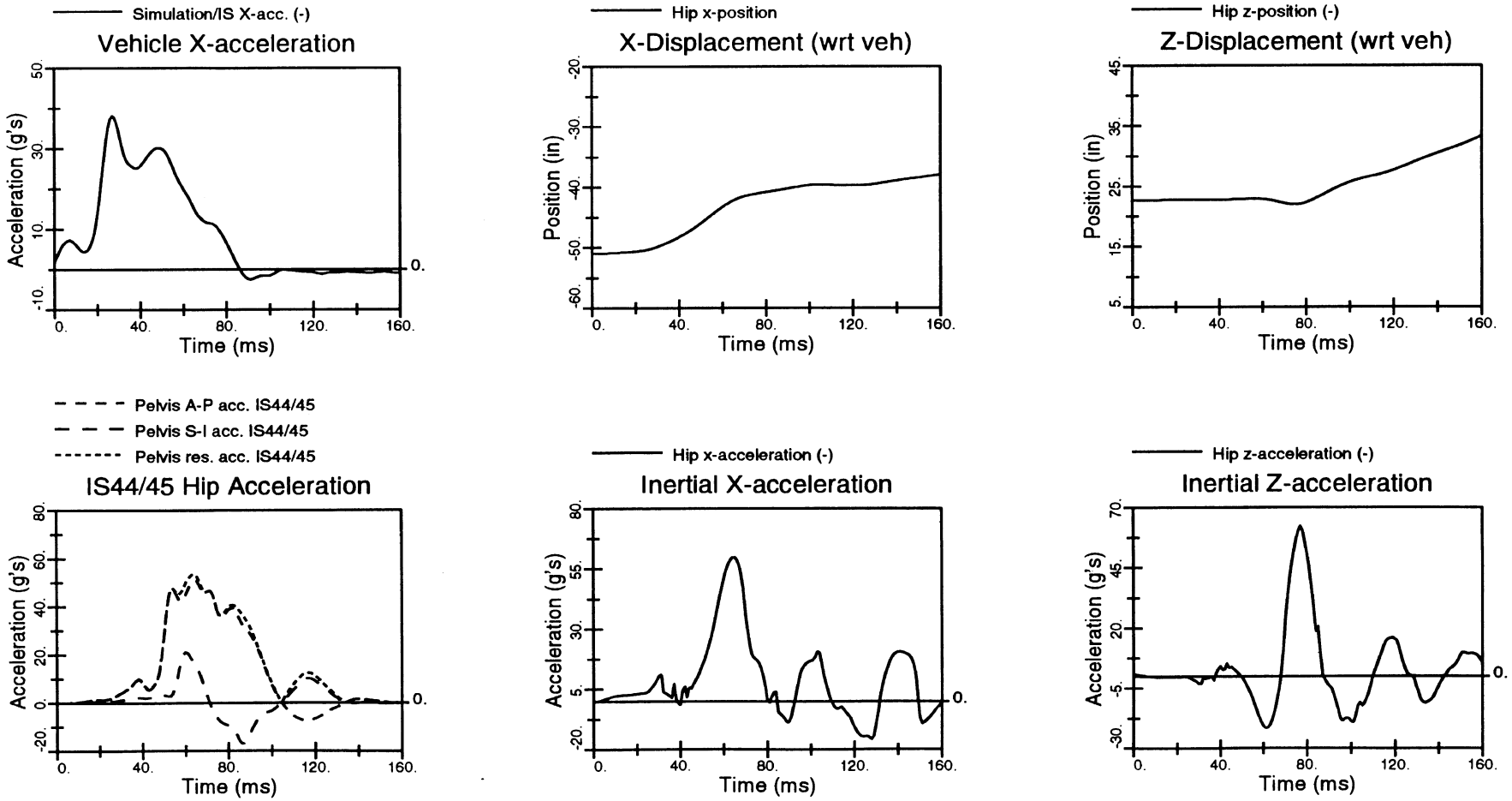


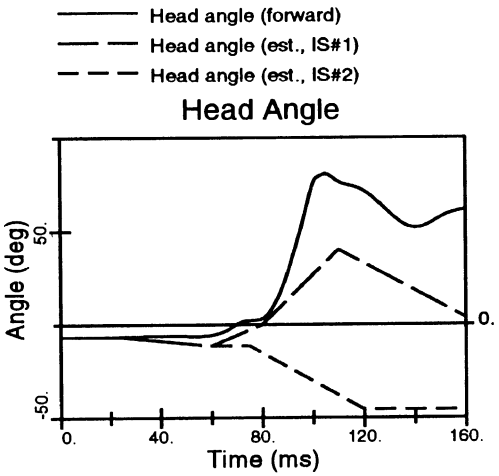
Figure 15.

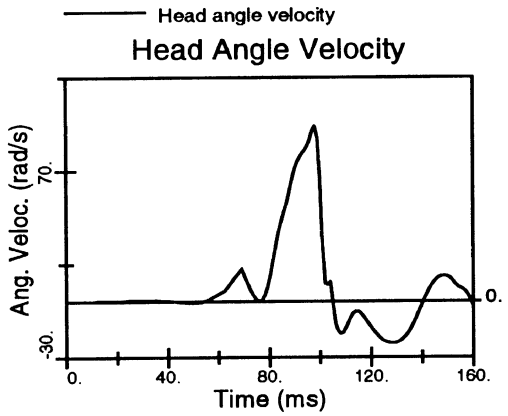
MVMA 2-D CVS Quasi-Finite Element Airbag Model

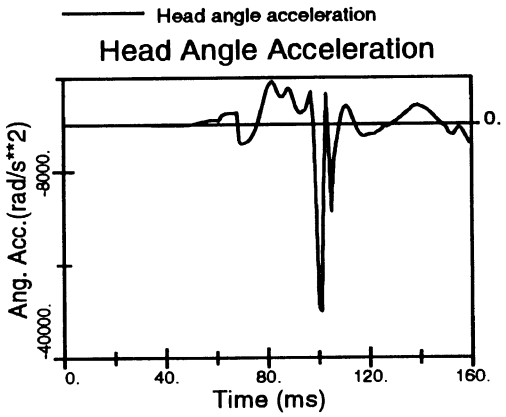
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

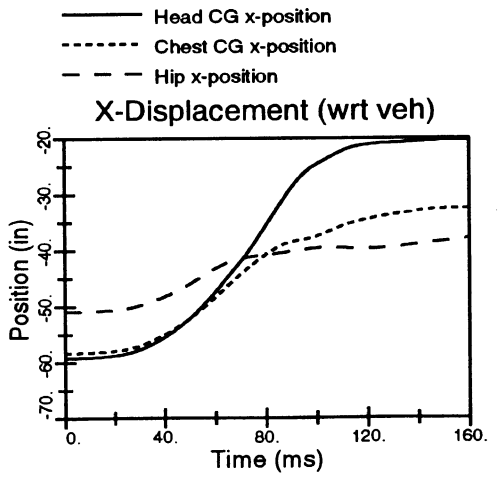
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

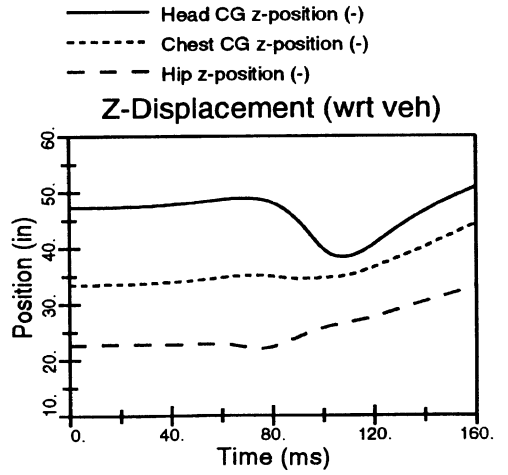
HEAD ANGULAR RESPONSE / OTHER RESPONSES











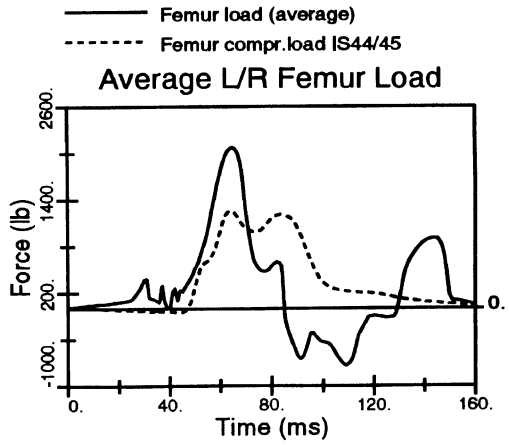


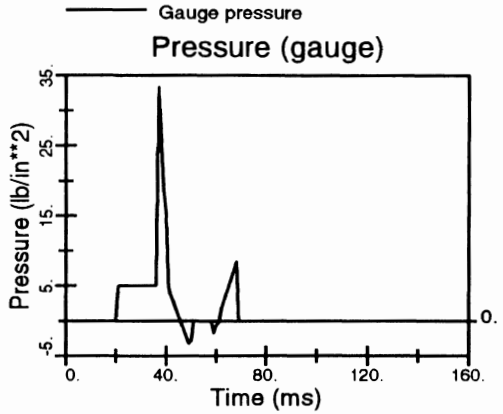
Figure 15.

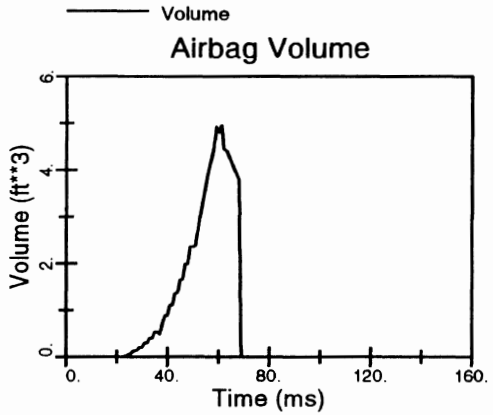
MVMA 2-D CVS Quasi-Finite Element Airbag Model

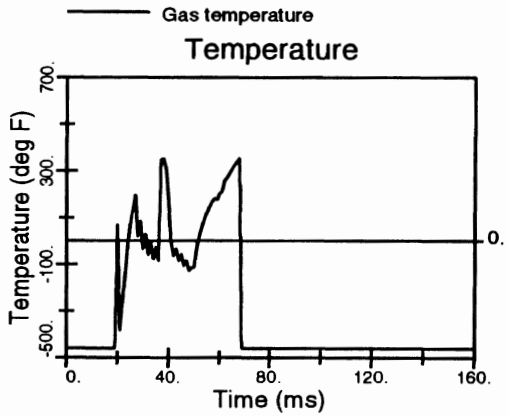
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

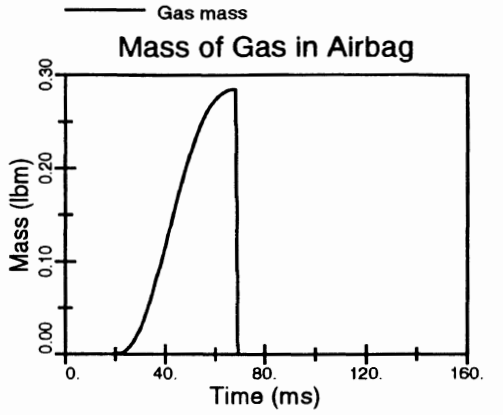
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

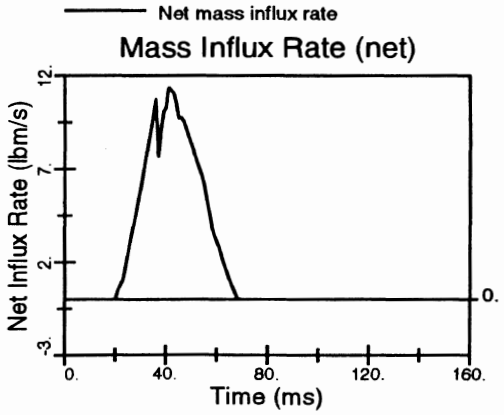
THERMODYNAMIC VARIABLES











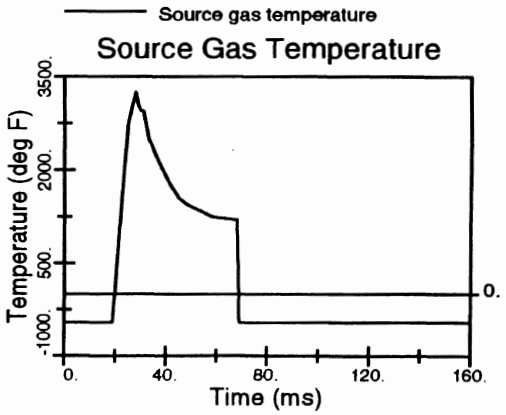


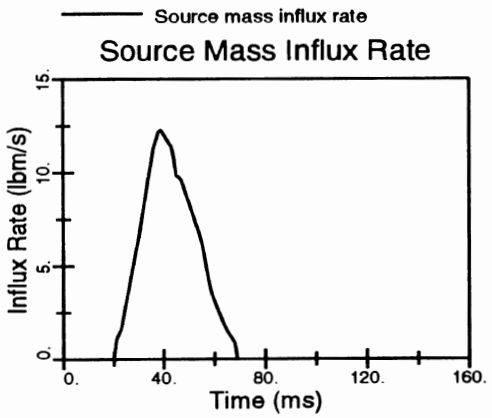
Figure 15.

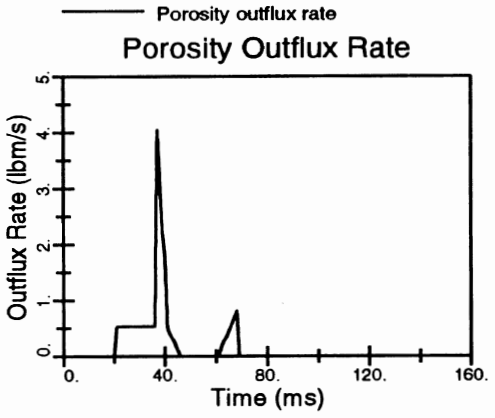
MVMA 2-D CVS Quasi-Finite Element Airbag Model

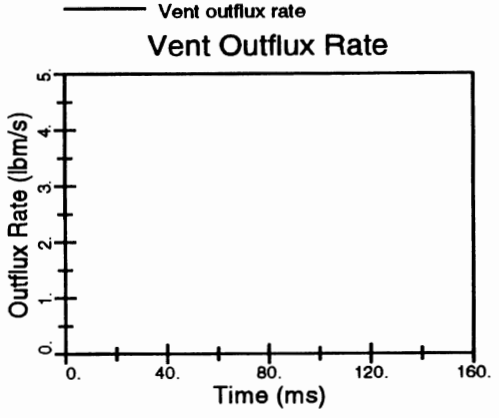
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

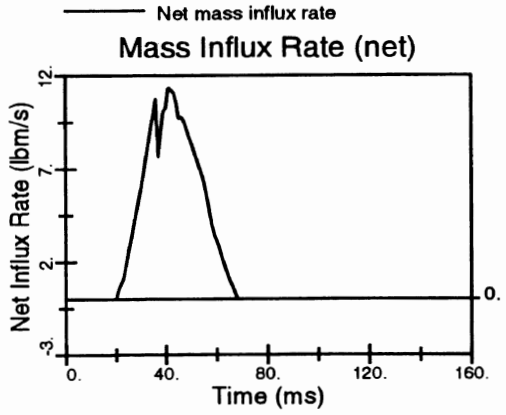
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

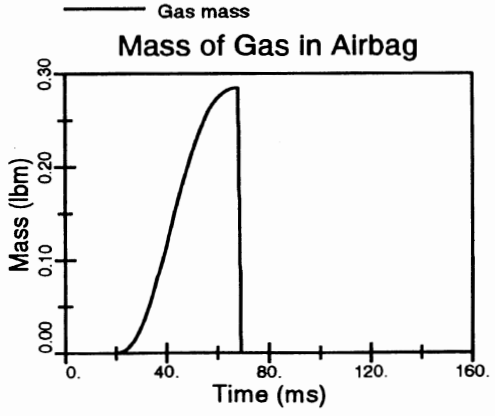
AIRBAG MASS INFLUX/OUTFLUX

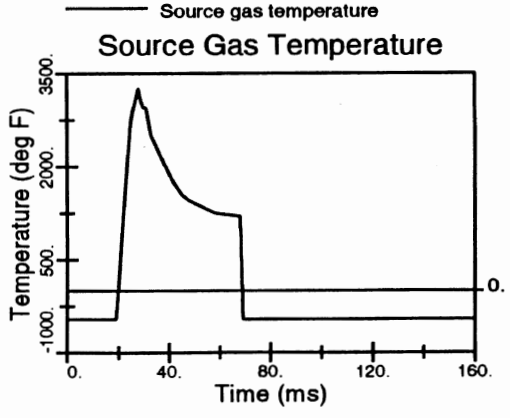












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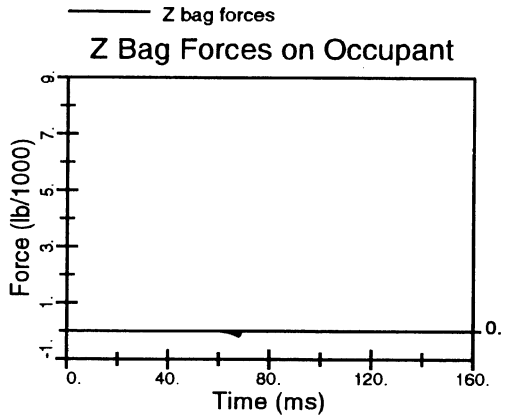
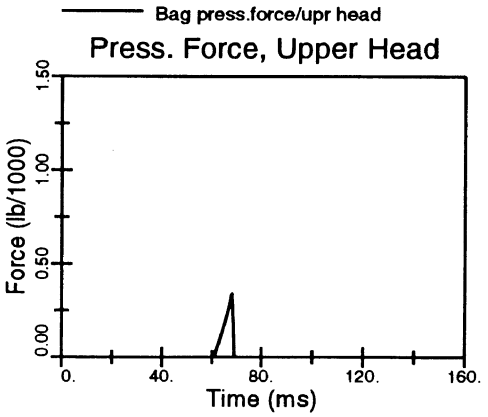
MVMA 2-D CVS Quasi-Finite Element Airbag Model

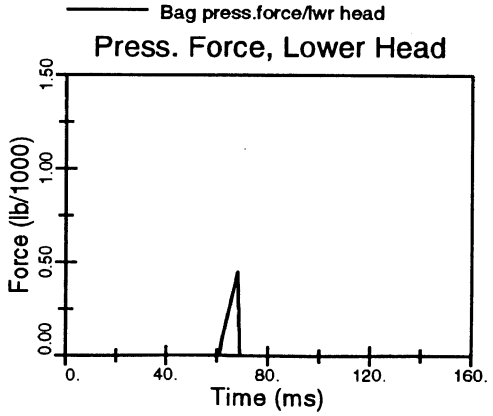
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







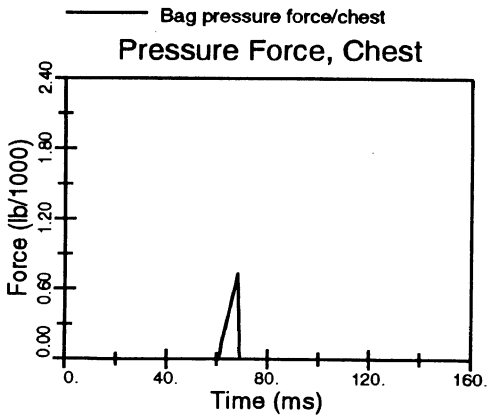


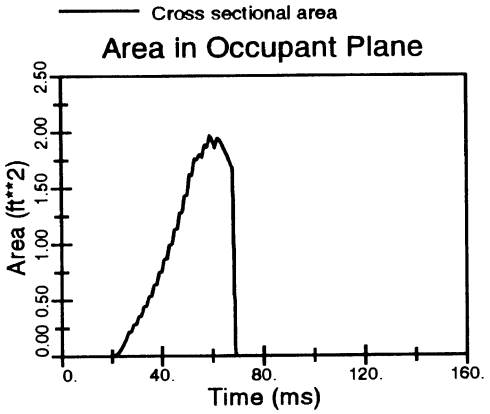
Figure 15.

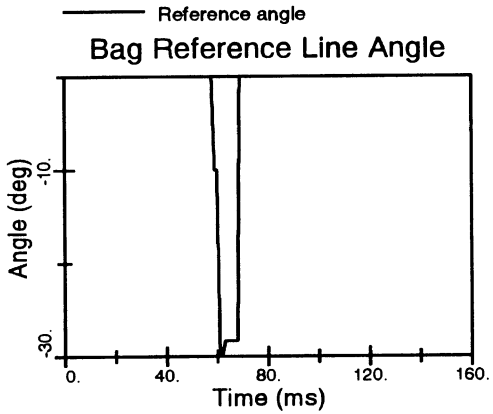
MVMA 2-D CVS Quasi-Finite Element Airbag Model

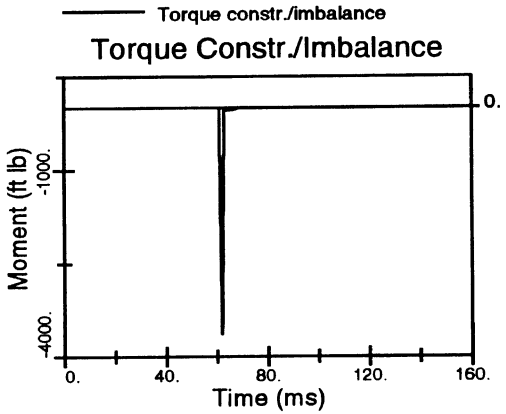
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 5-degree pitch angle , Tests IS11144/45

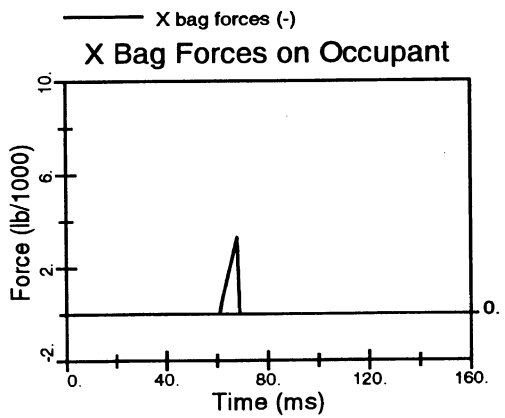
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









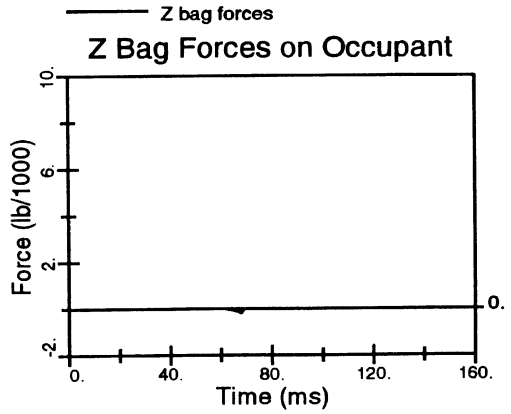


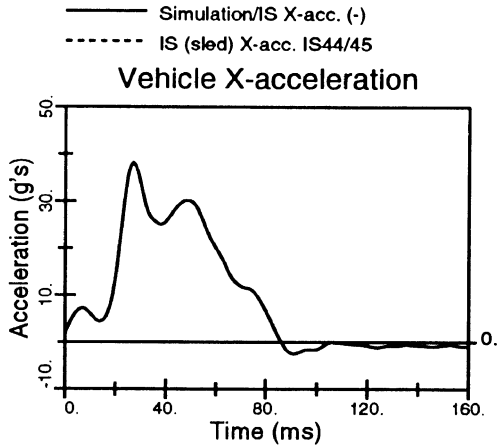
Figure 15.

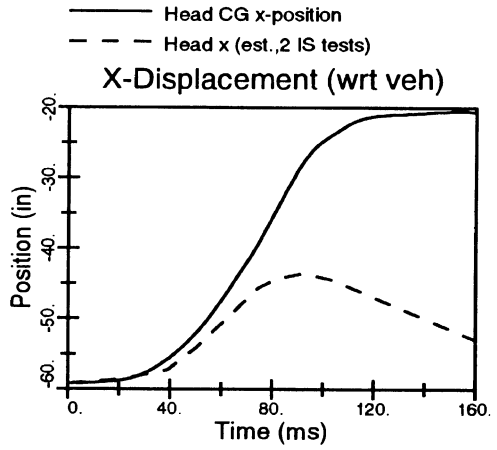
MVMA 2-D CVS Quasi-Finite Element Airbag Model

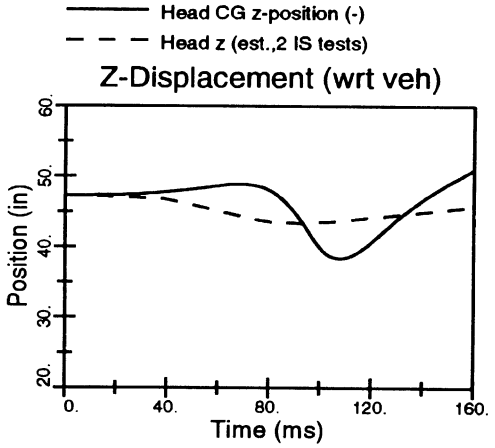
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

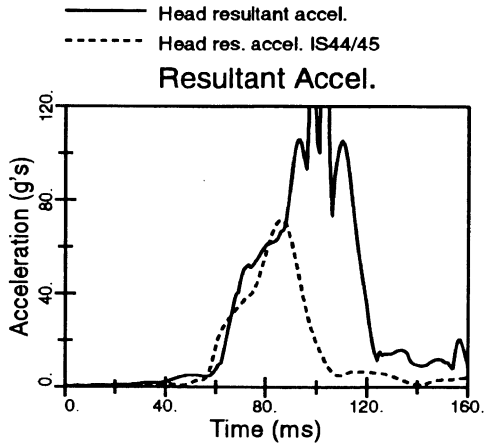
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

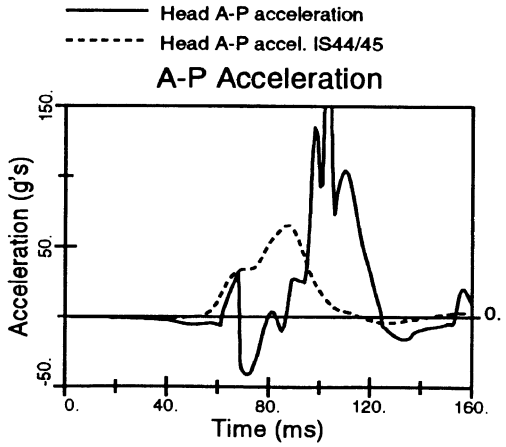
HEAD KINEMATIC RESPONSE











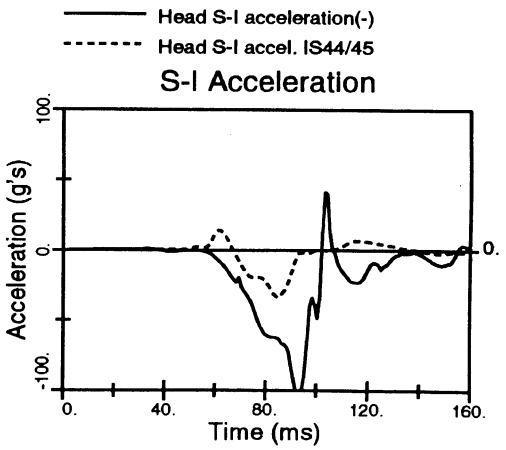


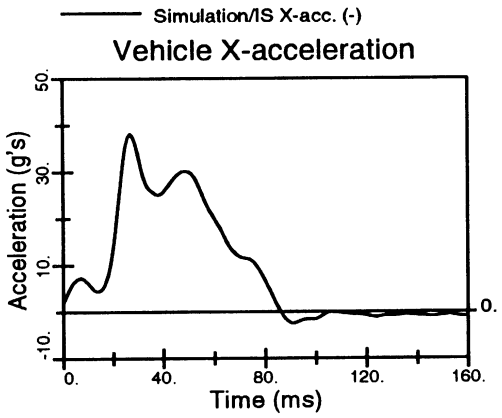
Figure 16.

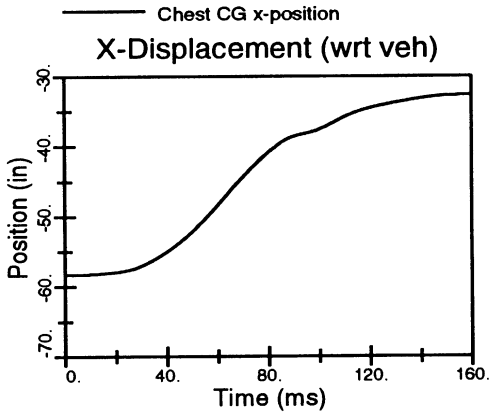
MVMA 2-D CVS Quasi-Finite Element Airbag Model

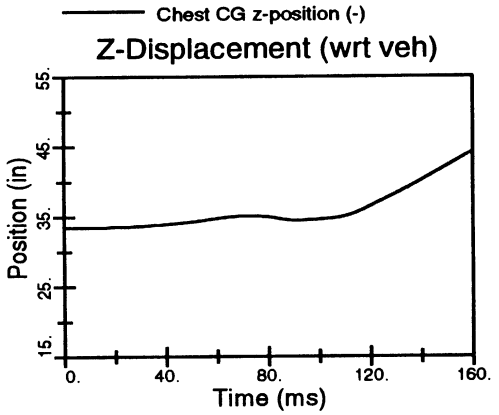
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

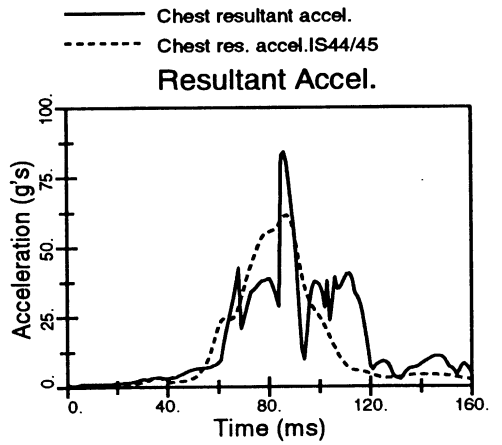
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

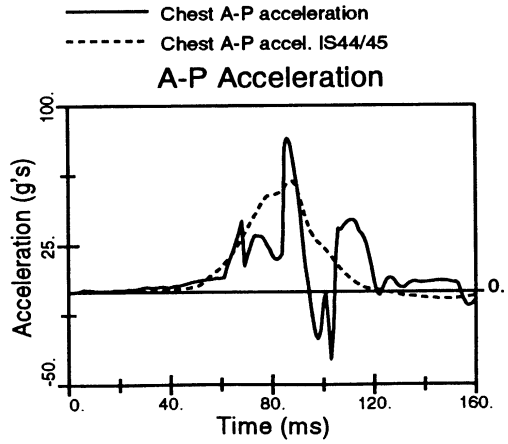
CHEST KINEMATIC RESPONSE











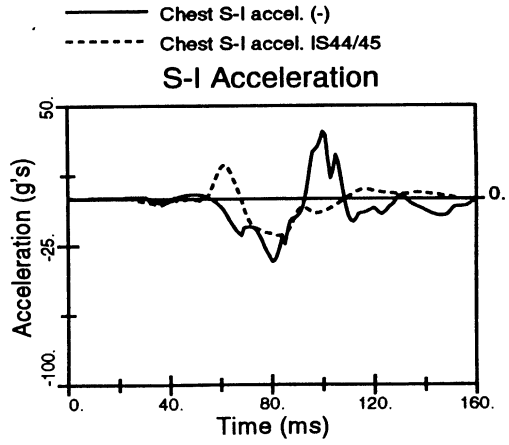


Figure 16.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

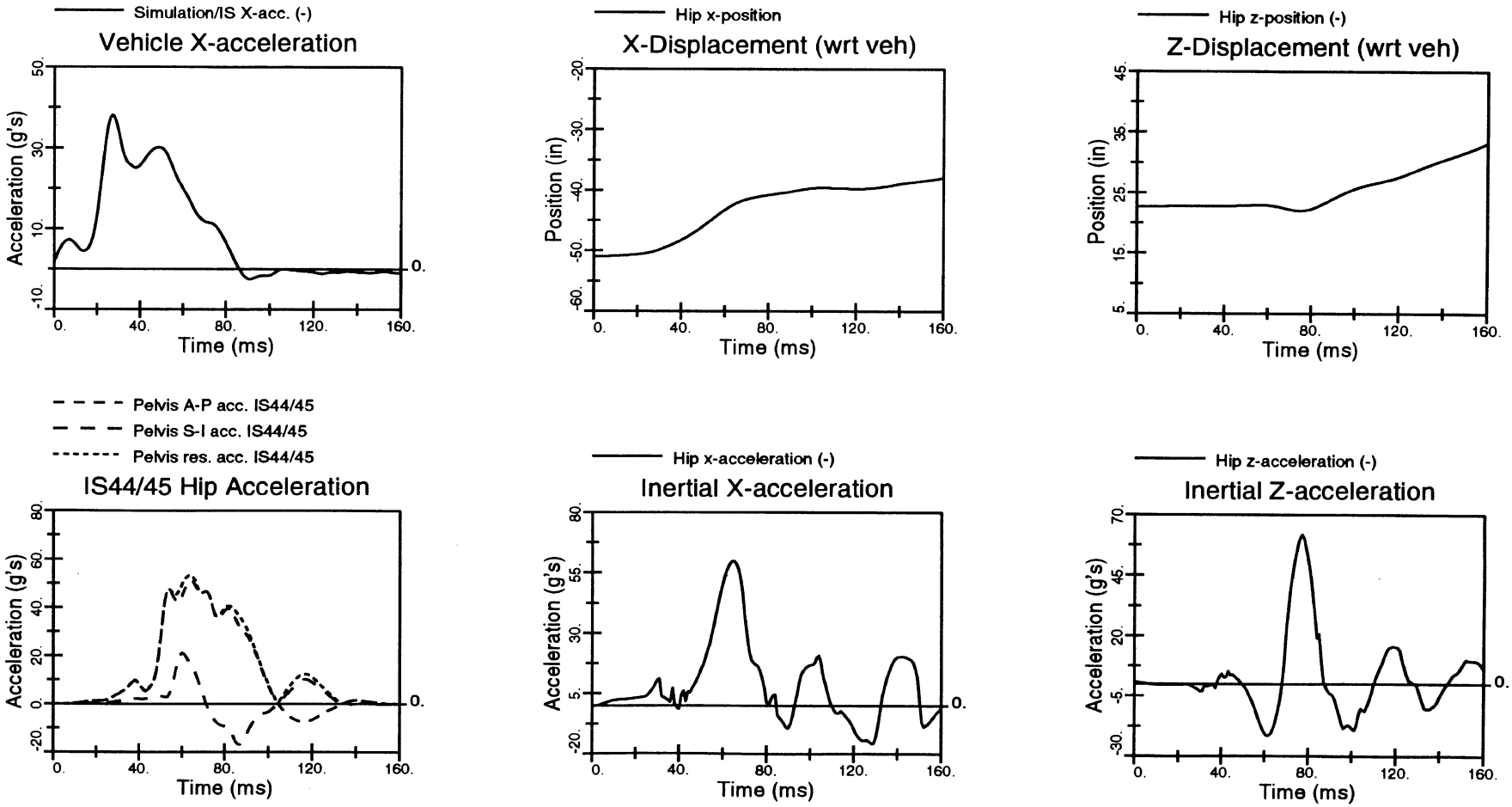


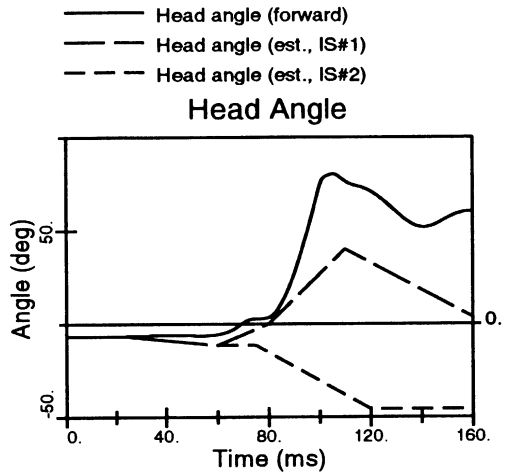
Figure 16.

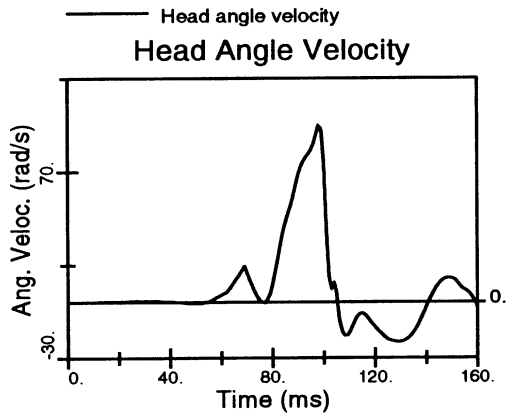
MVMA 2-D CVS Quasi-Finite Element Airbag Model

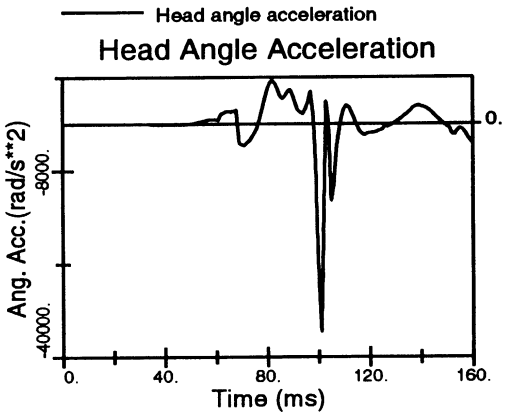
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

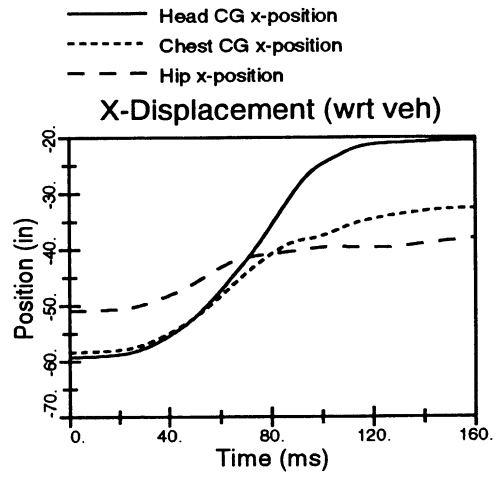
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

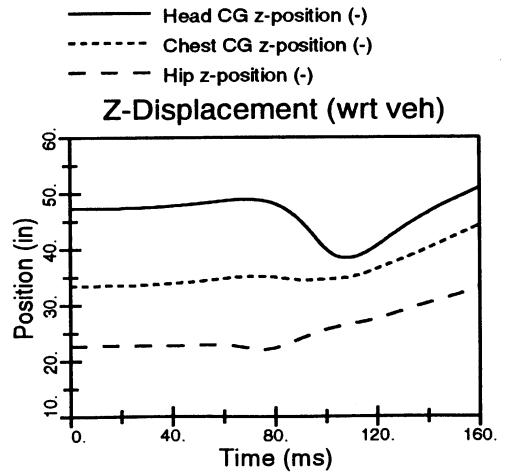
HEAD ANGULAR RESPONSE / OTHER RESPONSES











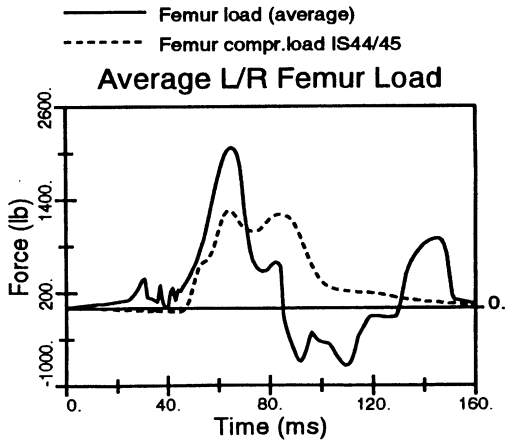


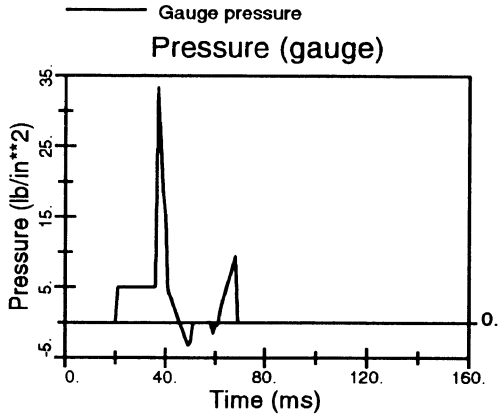
Figure 16.

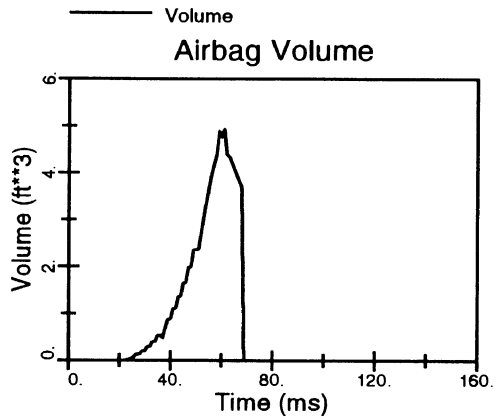
MVMA 2-D CVS Quasi-Finite Element Airbag Model

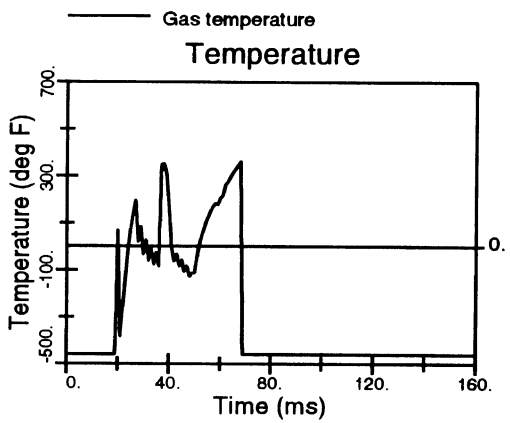
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

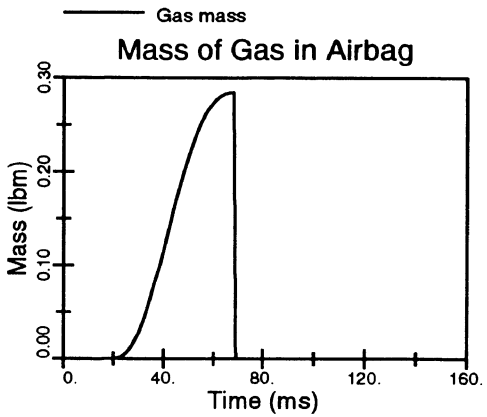
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

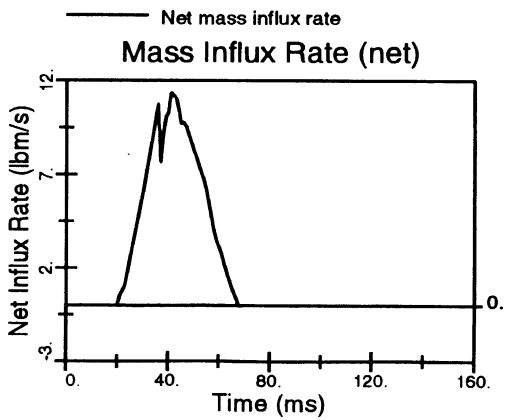
THERMODYNAMIC VARIABLES











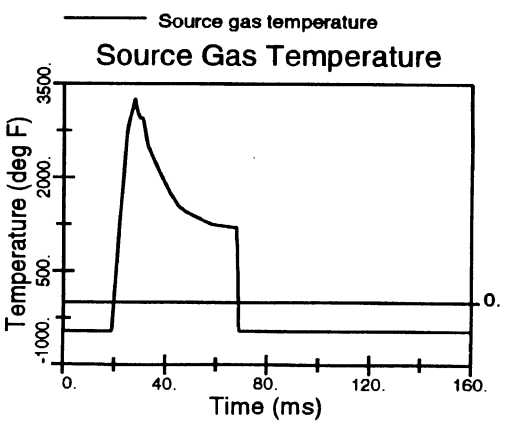


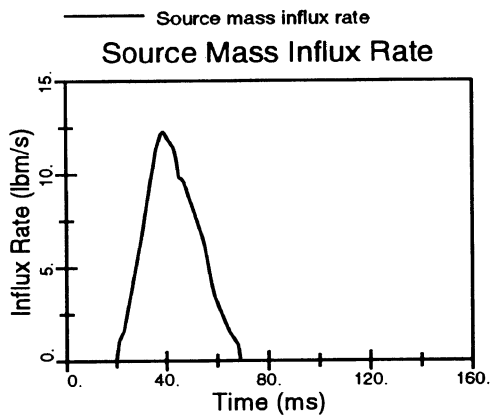
Figure 16.

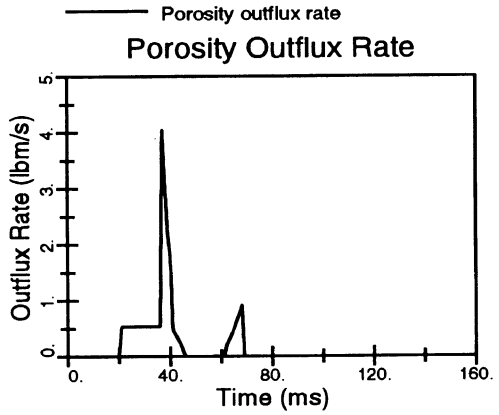
MVMA 2-D CVS Quasi-Finite Element Airbag Model

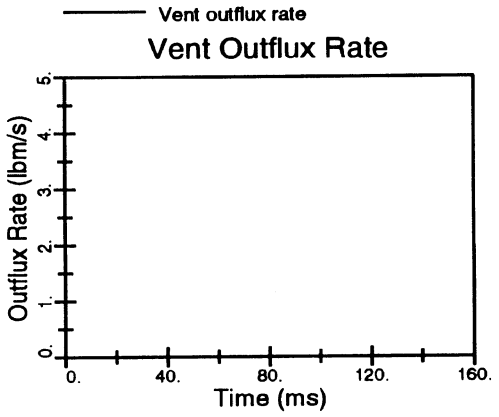
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

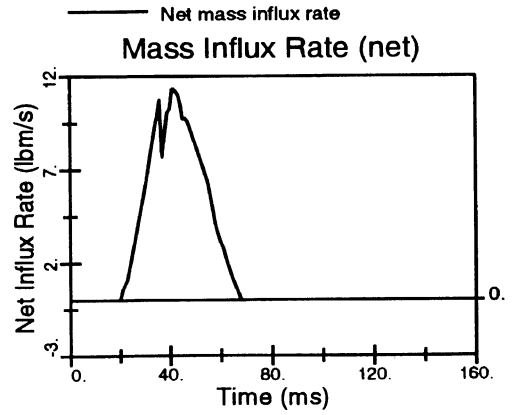
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

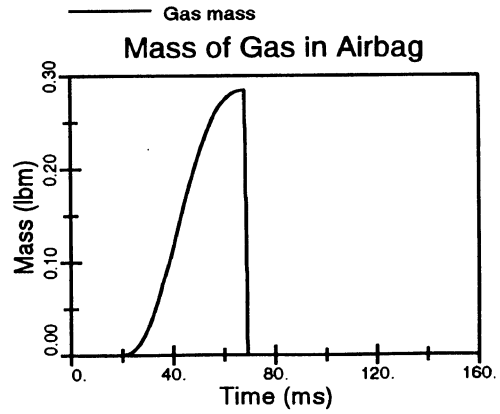
AIRBAG MASS INFLUX/OUTFLUX











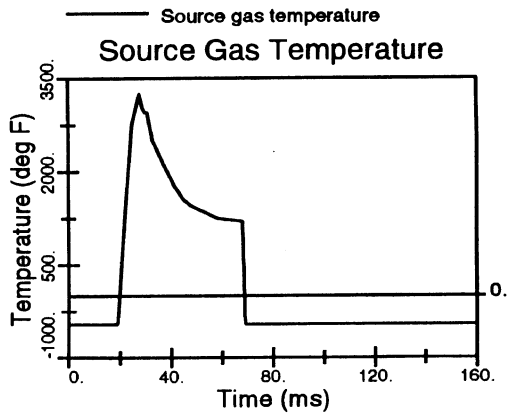


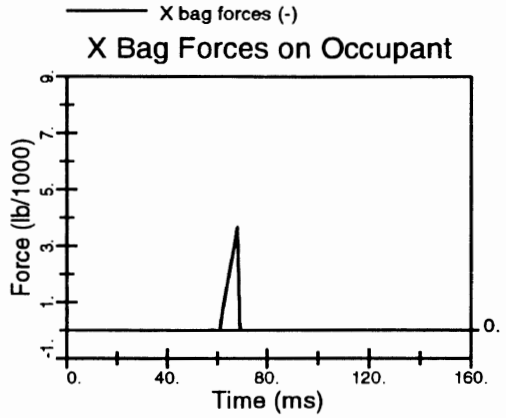
Figure 16.

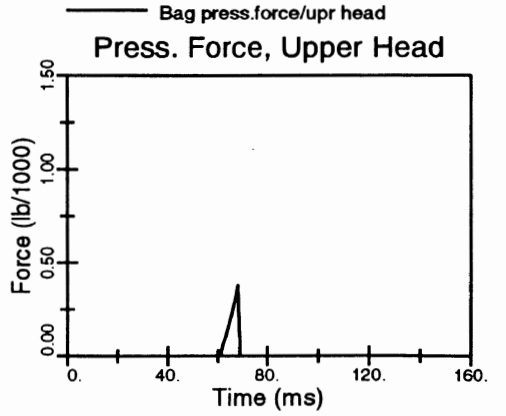
MVMA 2-D CVS Quasi-Finite Element Airbag Model

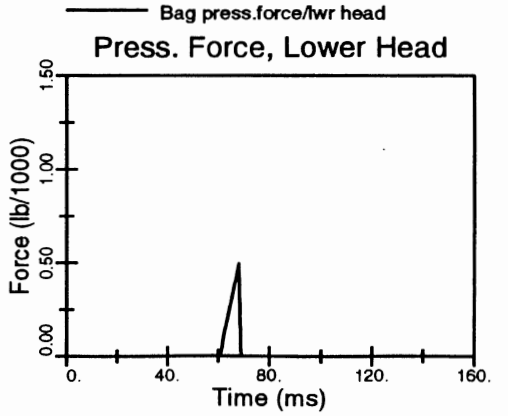
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







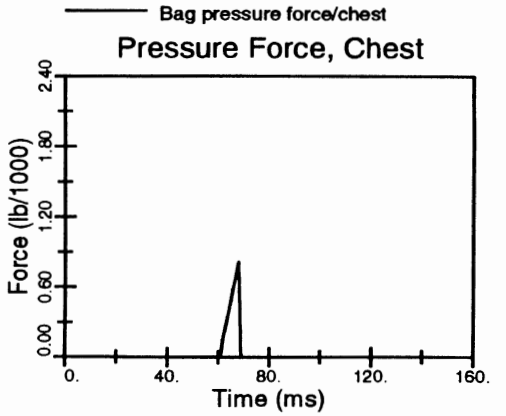


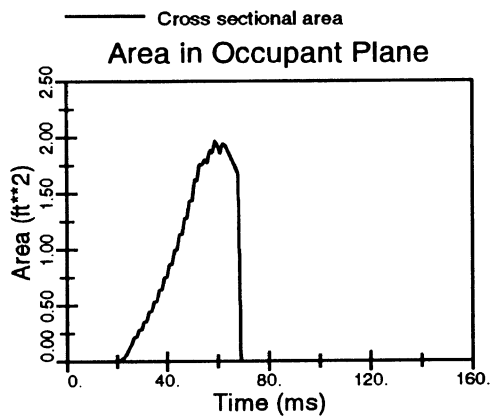
Figure 16.

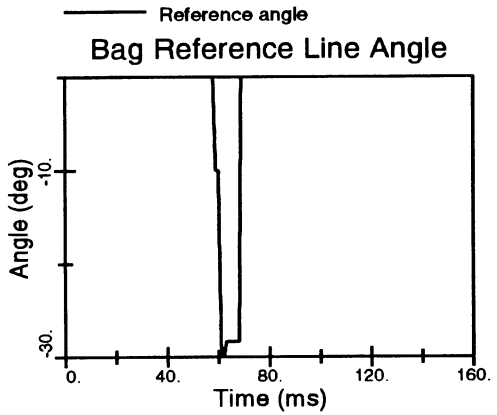
MVMA 2-D CVS Quasi-Finite Element Airbag Model

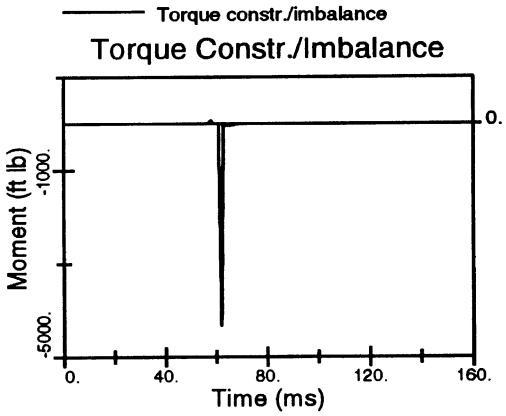
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 5-degree pitch angle , Tests IS11144/45

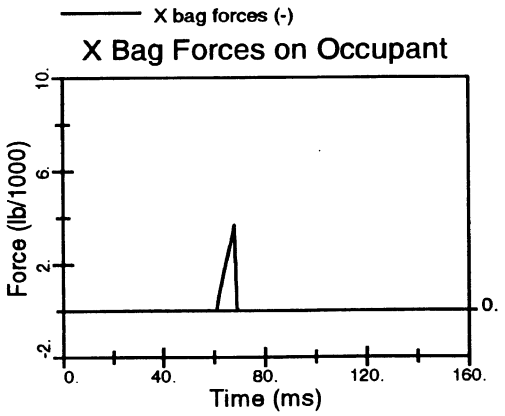
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









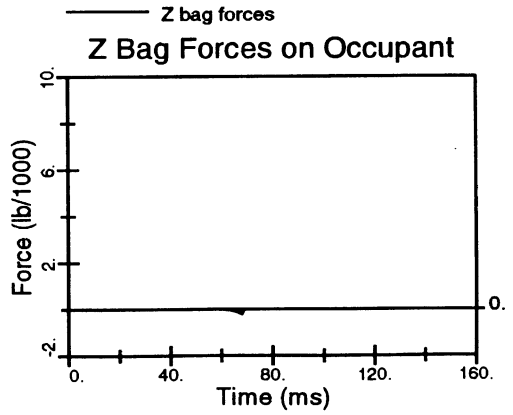


Figure 16.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

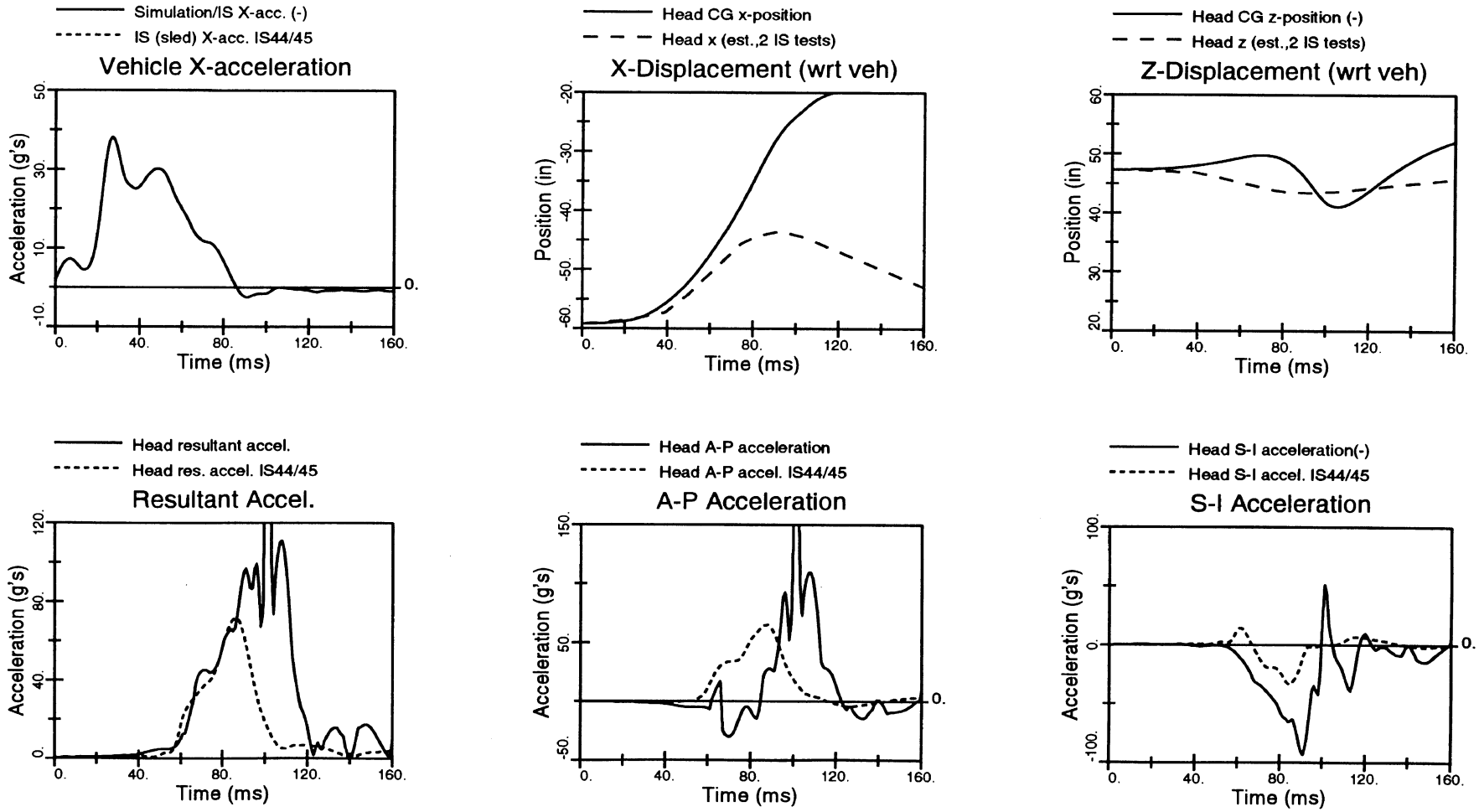


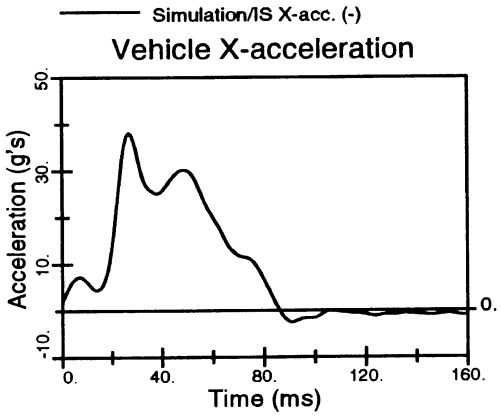
Figure 17.

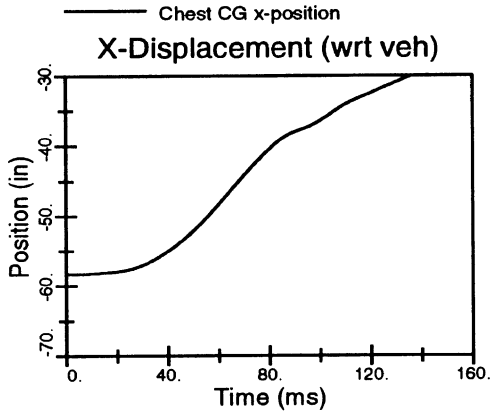
MVMA 2-D CVS Quasi-Finite Element Airbag Model

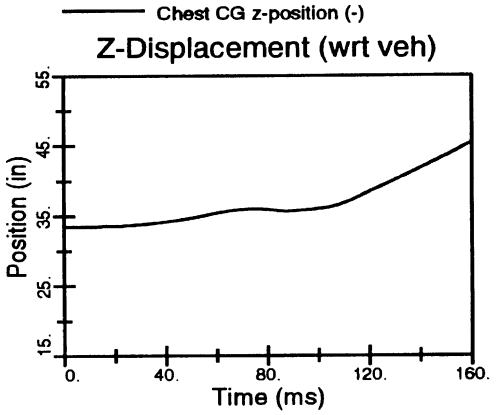
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

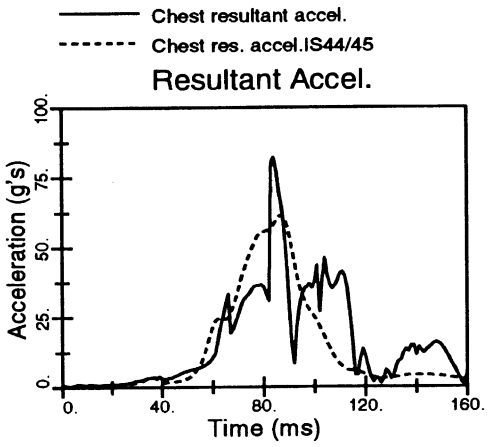
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

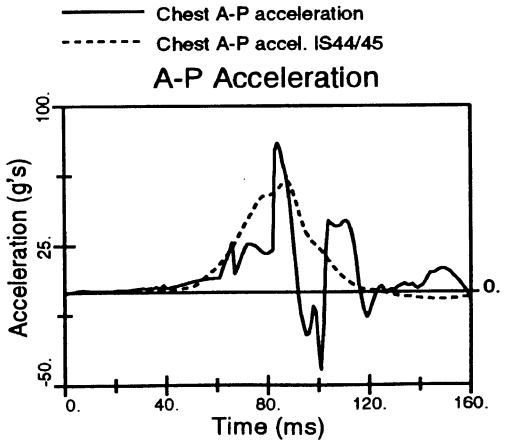
CHEST KINEMATIC RESPONSE

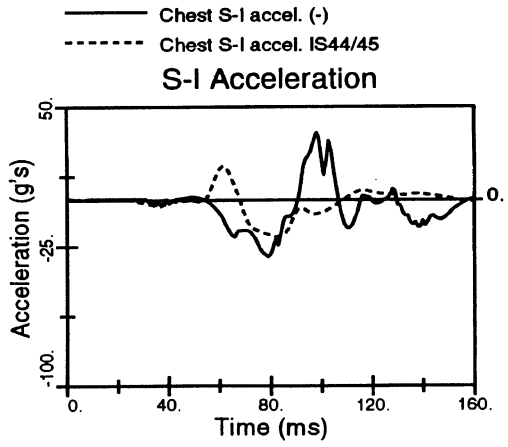












A-99

Figure 17.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

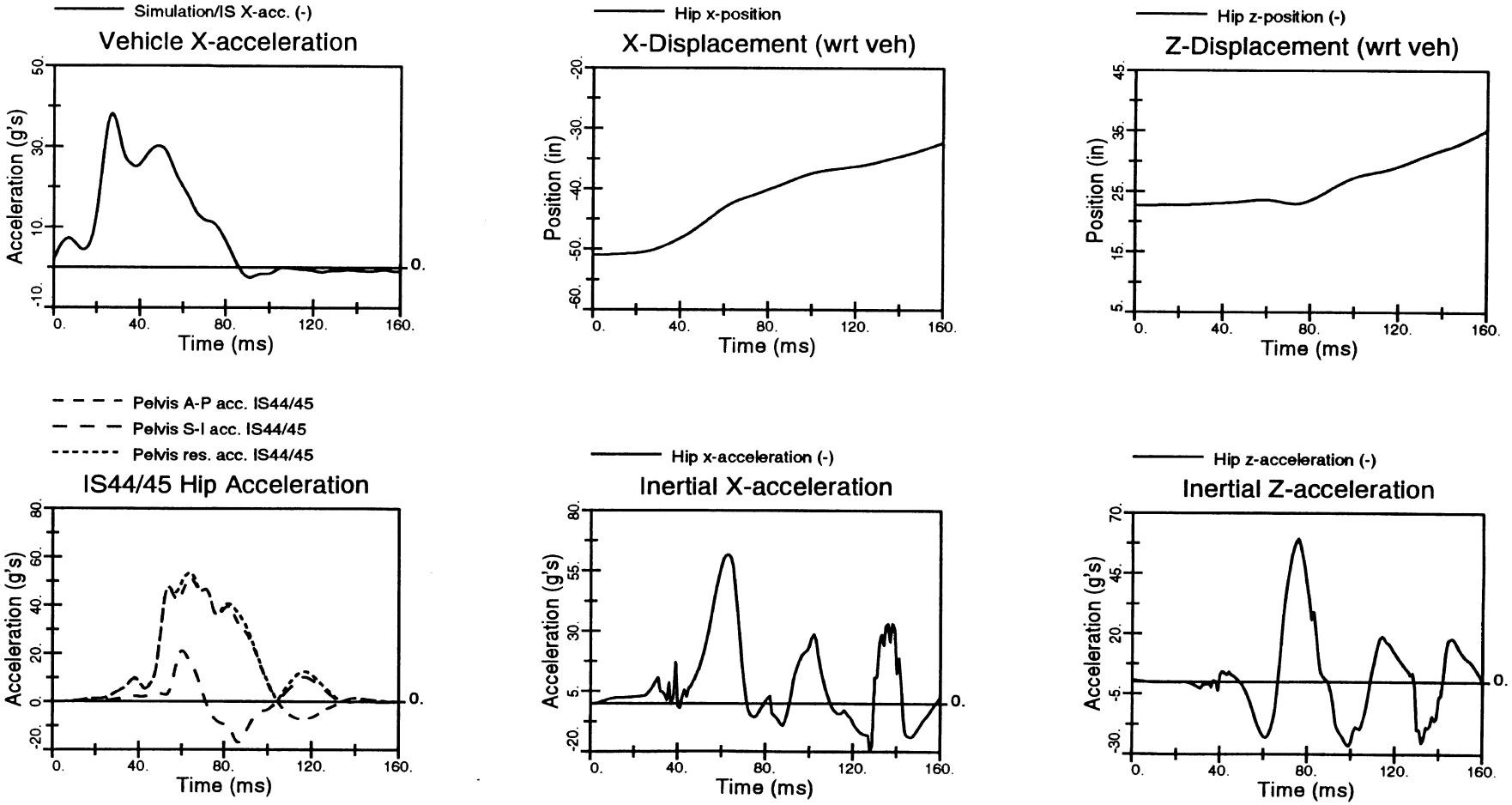


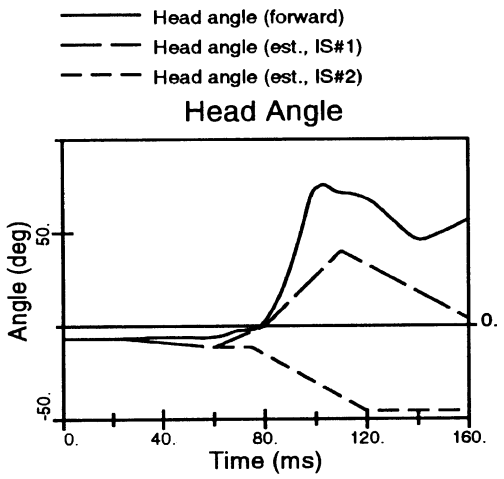
Figure 17.

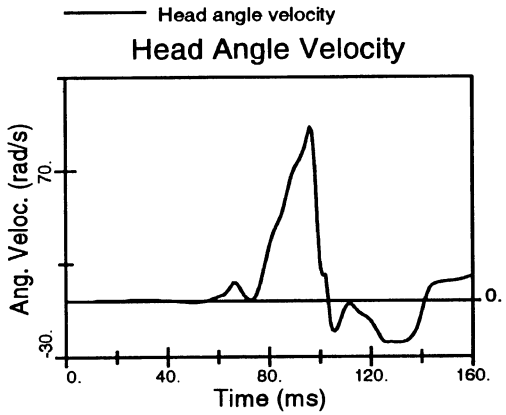
MVMA 2-D CVS Quasi-Finite Element Airbag Model

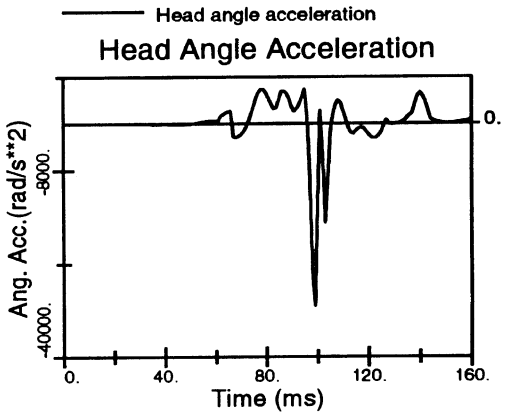
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

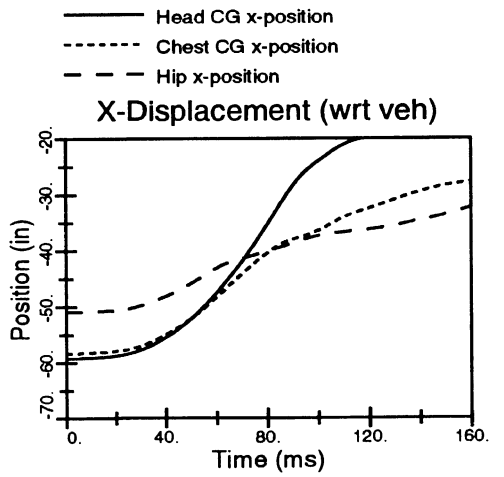
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

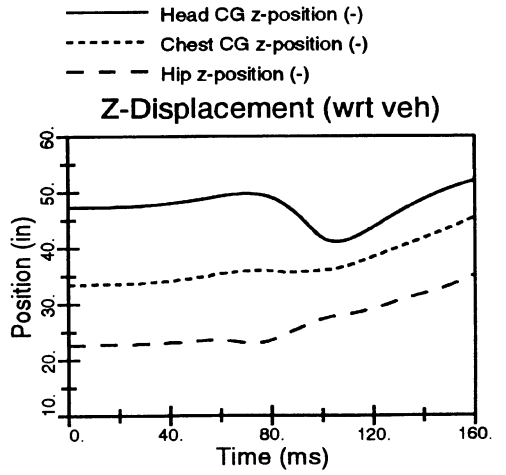
HEAD ANGULAR RESPONSE / OTHER RESPONSES











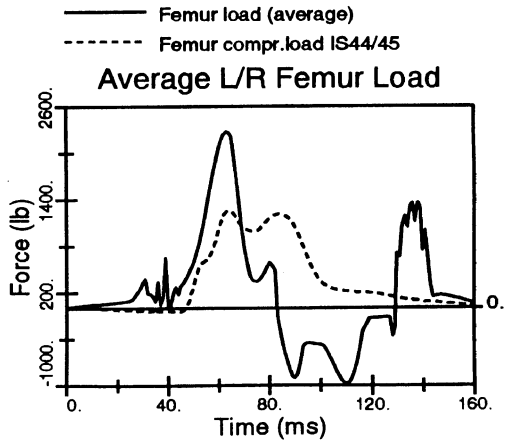


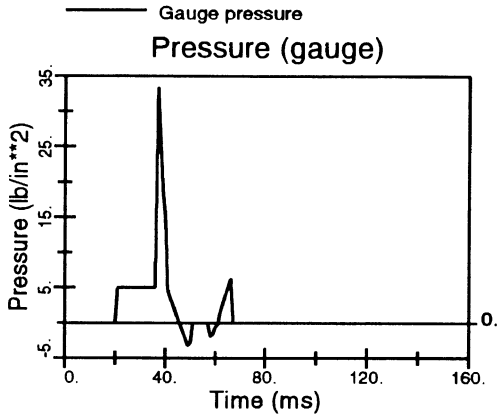
Figure 17.

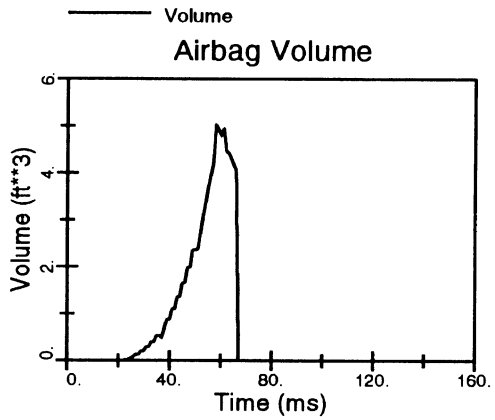
MVMA 2-D CVS Quasi-Finite Element Airbag Model

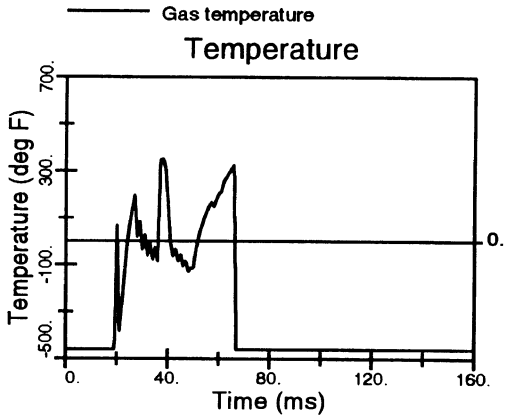
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

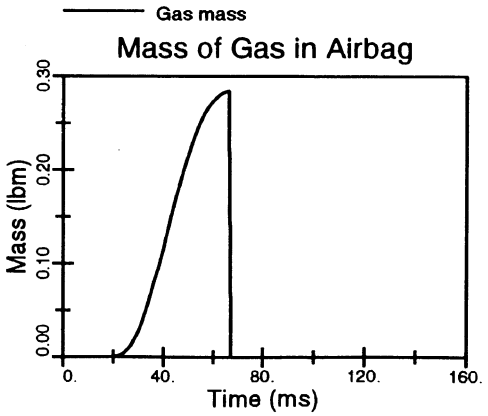
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

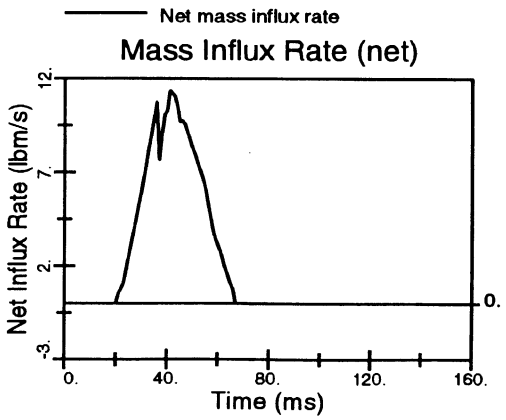
THERMODYNAMIC VARIABLES











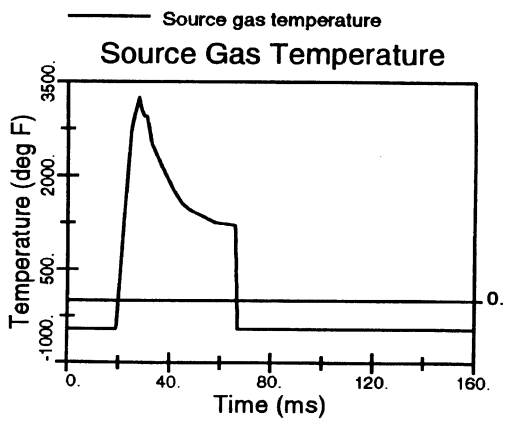


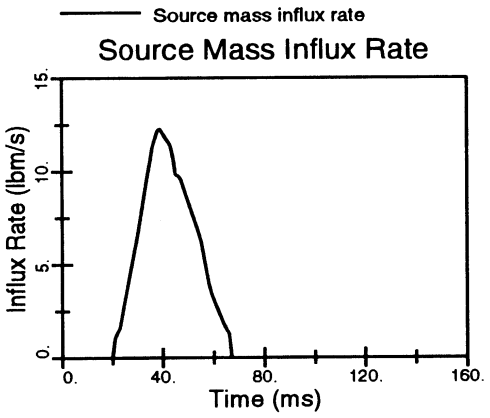
Figure 17.

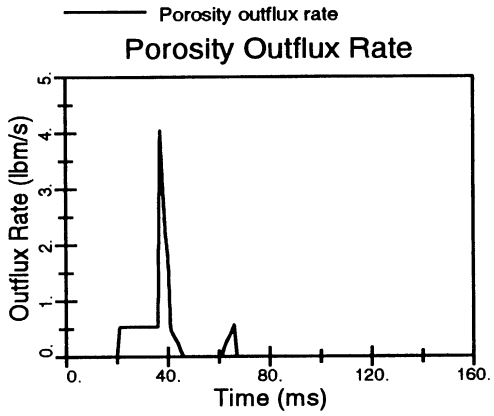
MVMA 2-D CVS Quasi-Finite Element Airbag Model

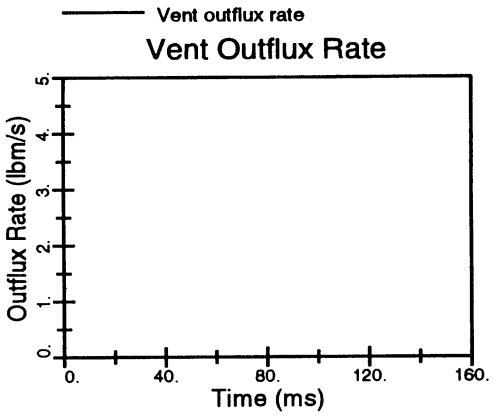
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

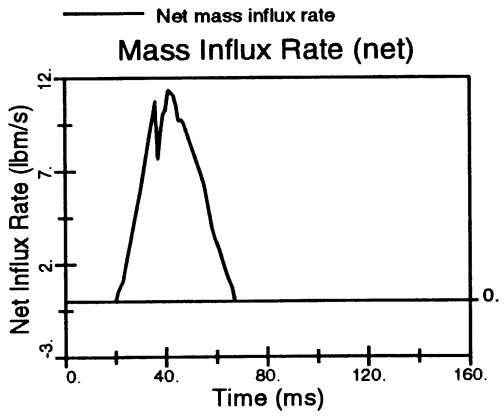
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

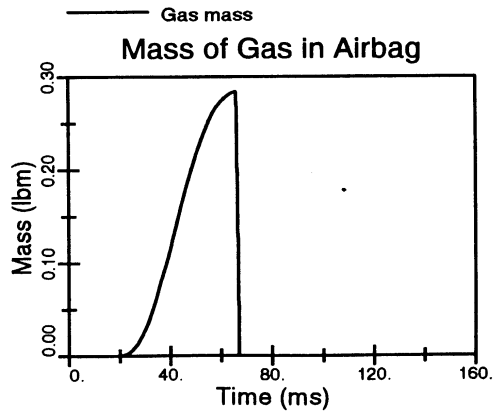
AIRBAG MASS INFLUX/OUTFLUX











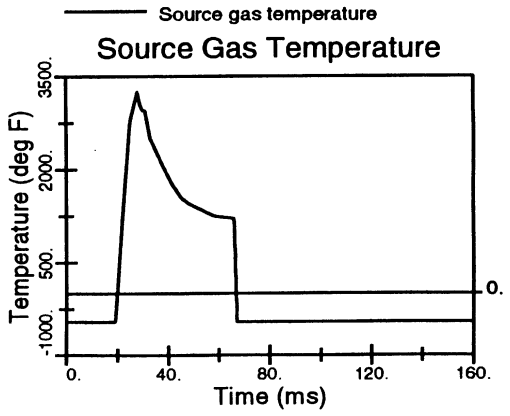


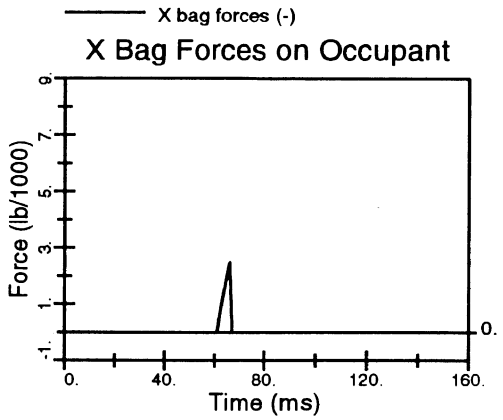
Figure 17.

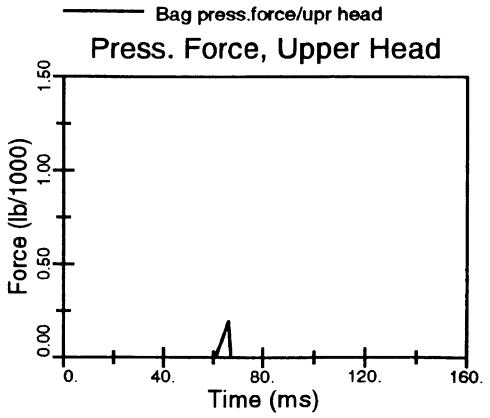
MVMA 2-D CVS Quasi-Finite Element Airbag Model

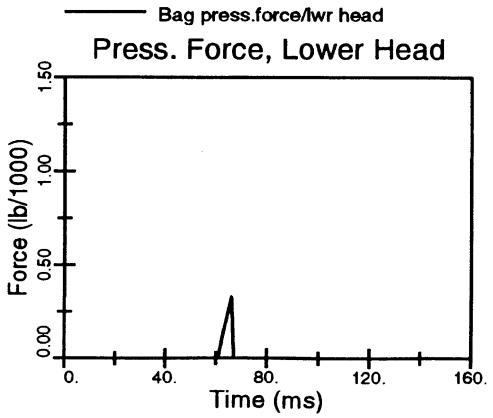
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







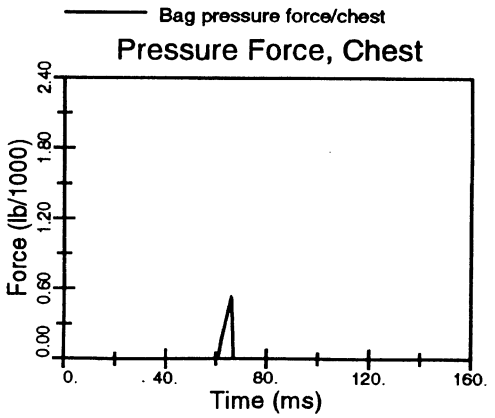


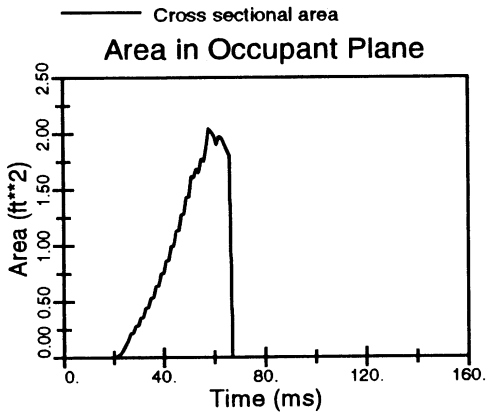
Figure 17.

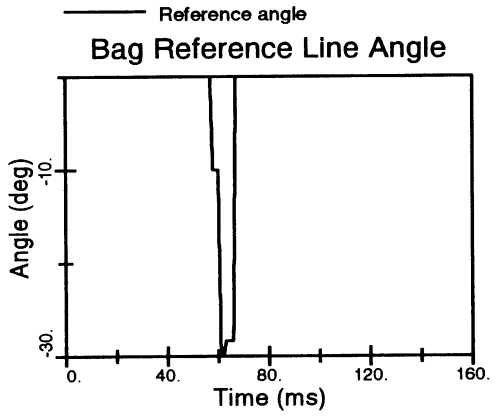
MVMA 2-D CVS Quasi-Finite Element Airbag Model

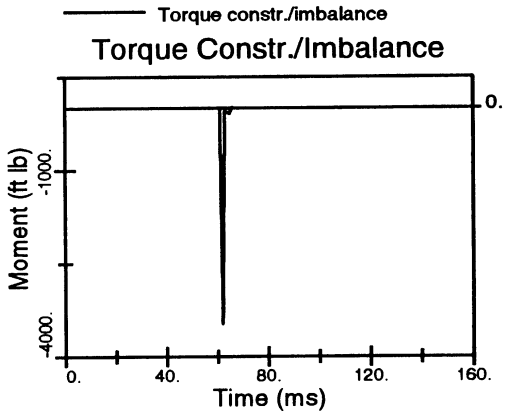
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with fixed, 9-degree pitch angle , Tests IS11144/45

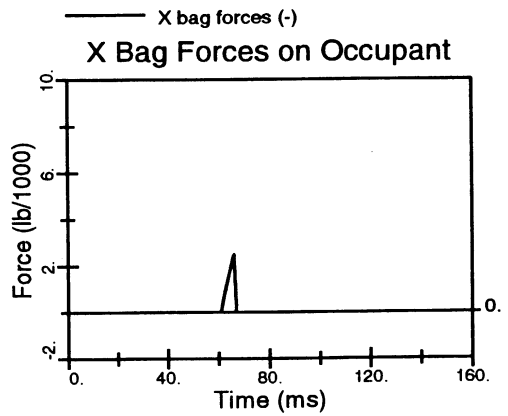
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









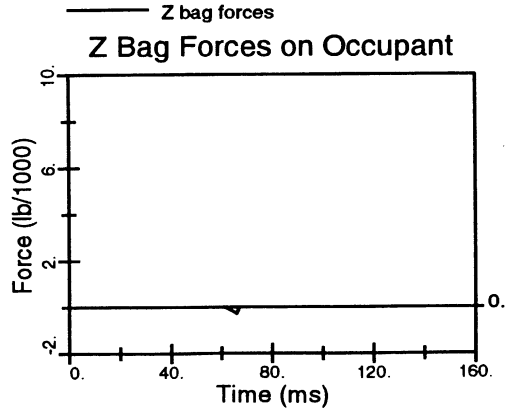


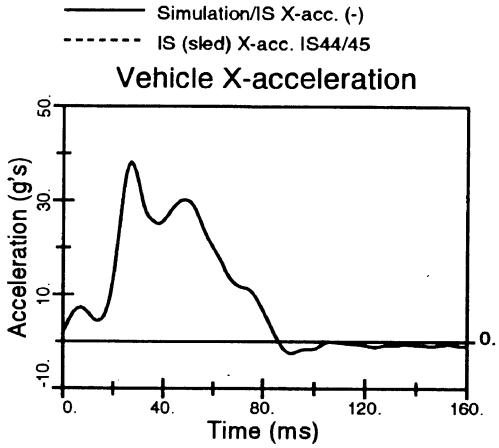
Figure 17.

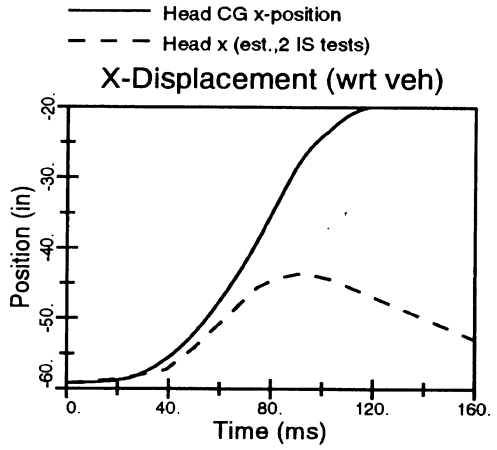
MVMA 2-D CVS Quasi-Finite Element Airbag Model

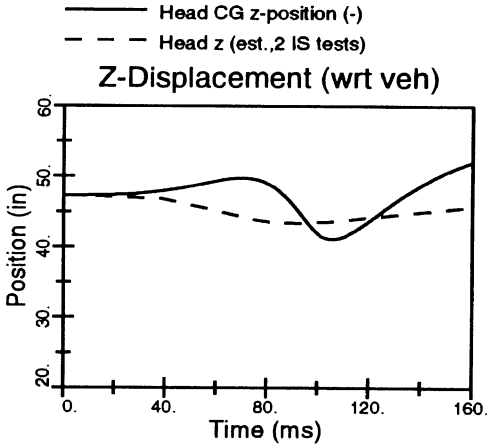
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

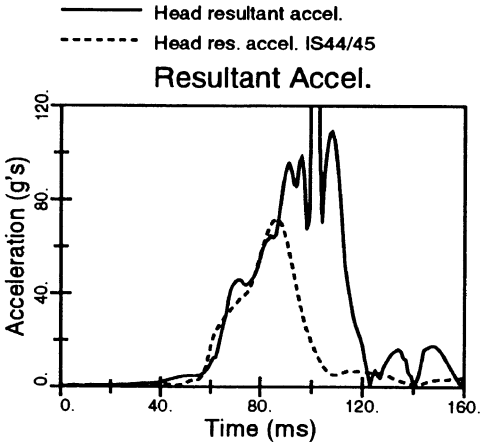
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

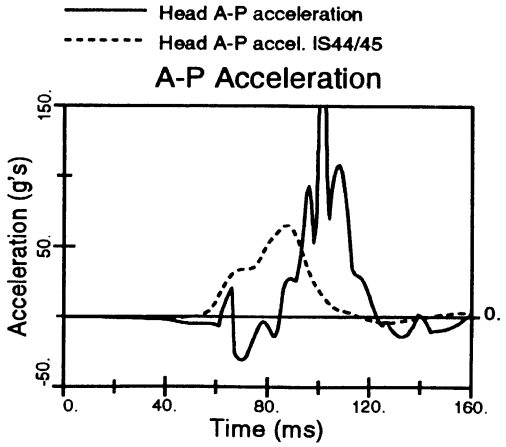
HEAD KINEMATIC RESPONSE











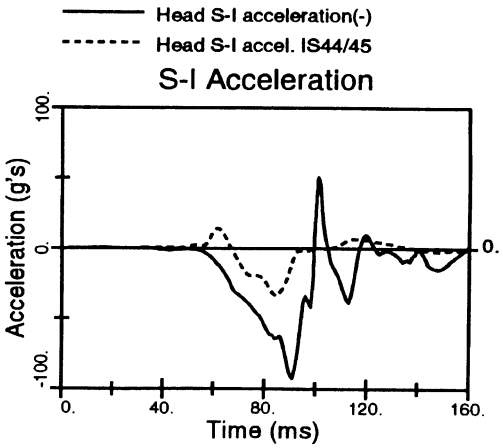


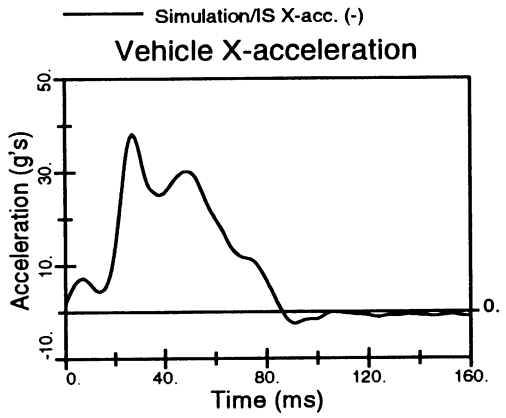
Figure 18.

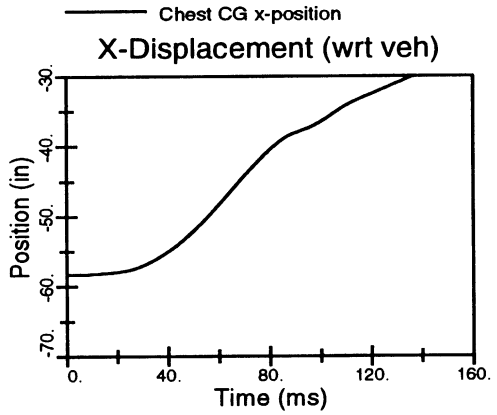
MVMA 2-D CVS Quasi-Finite Element Airbag Model

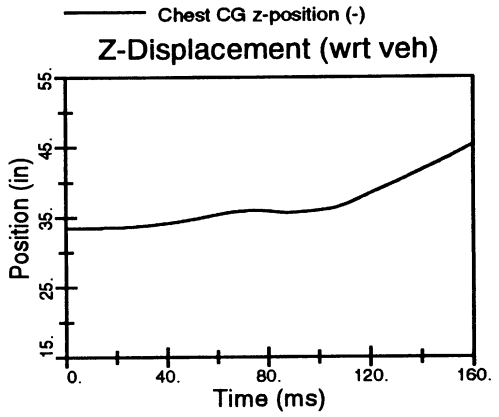
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

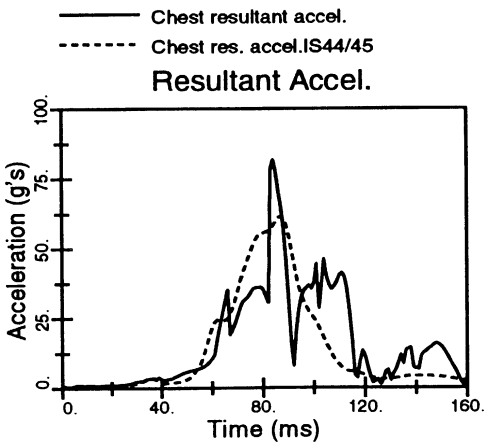
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

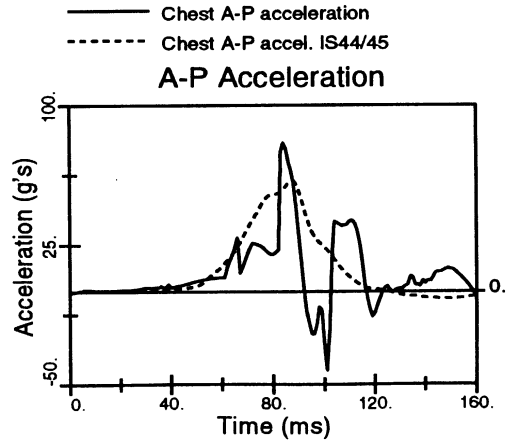
CHEST KINEMATIC RESPONSE











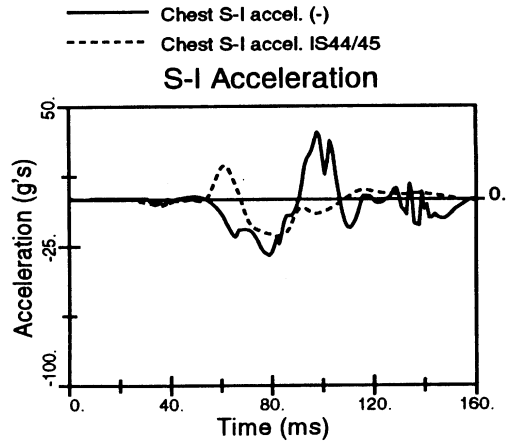


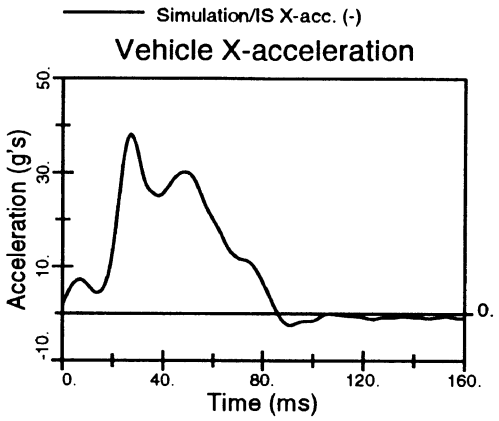
Figure 18.

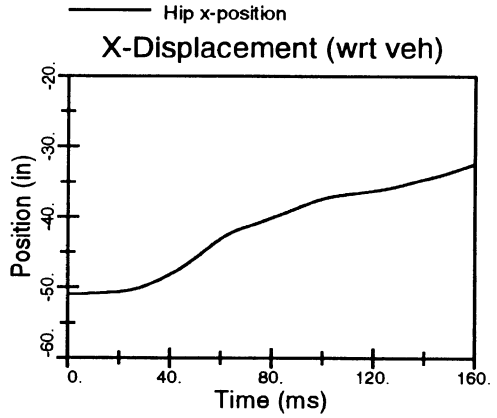
MVMA 2-D CVS Quasi-Finite Element Airbag Model

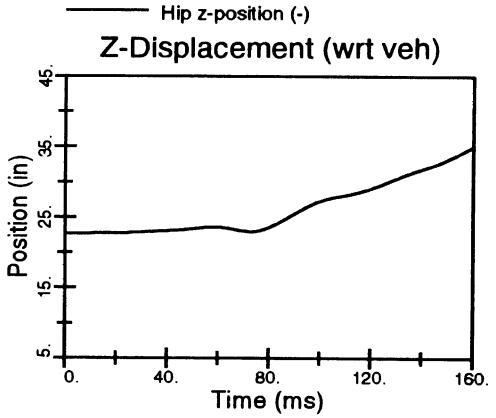
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

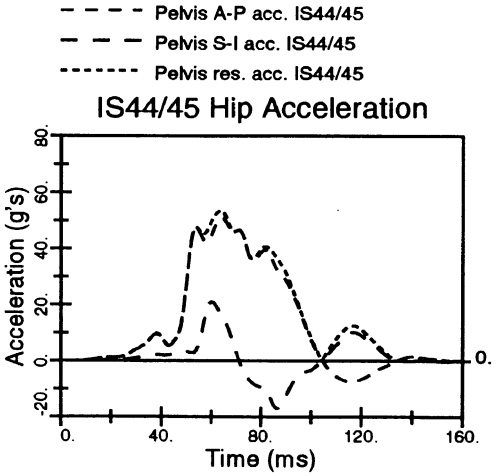
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

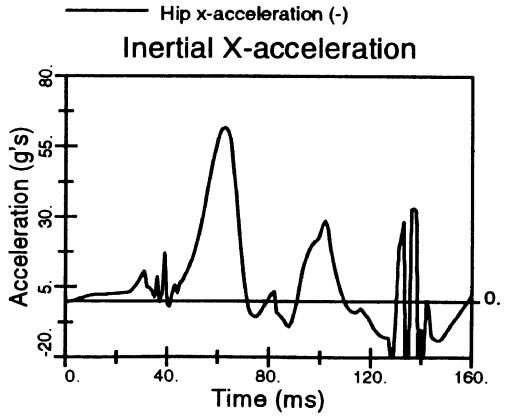
HIP KINEMATIC RESPONSE











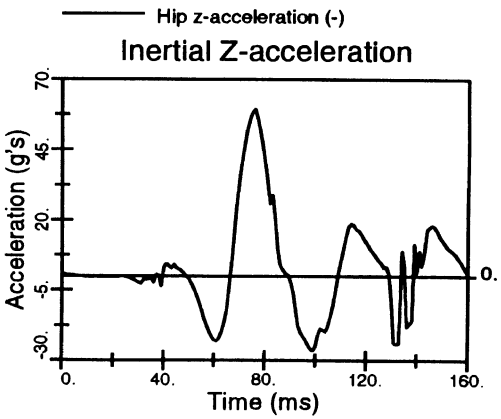


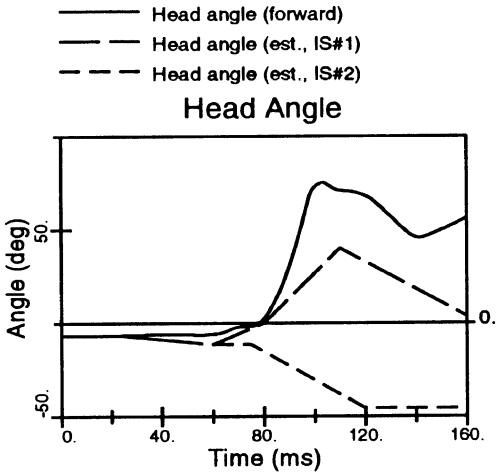
Figure 18.

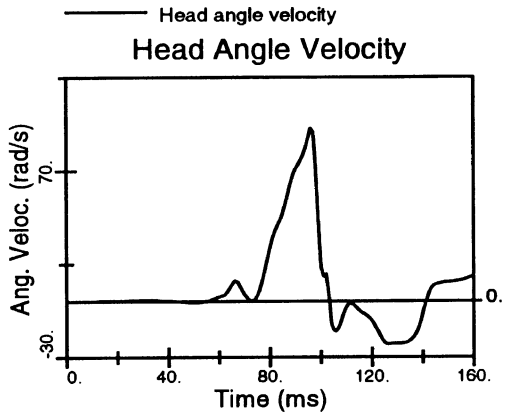
MVMA 2-D CVS Quasi-Finite Element Airbag Model

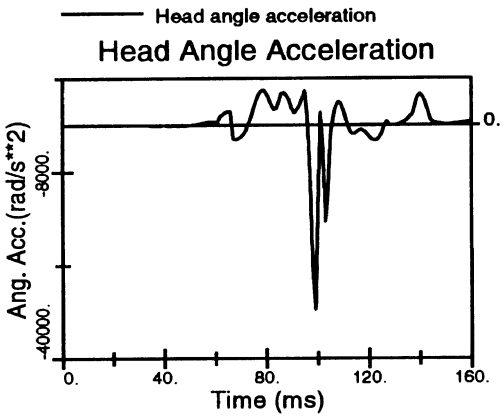
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

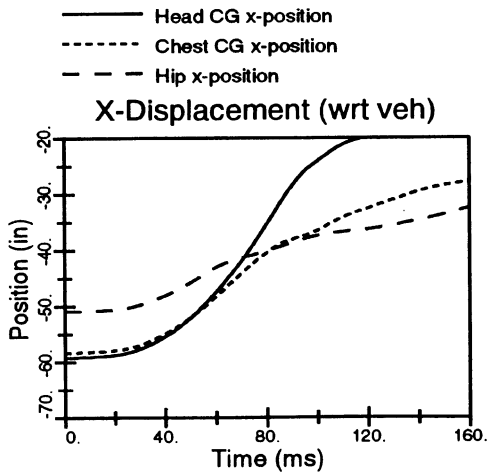
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

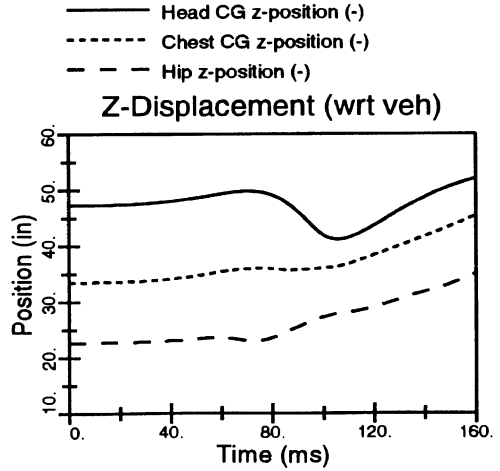
HEAD ANGULAR RESPONSE / OTHER RESPONSES











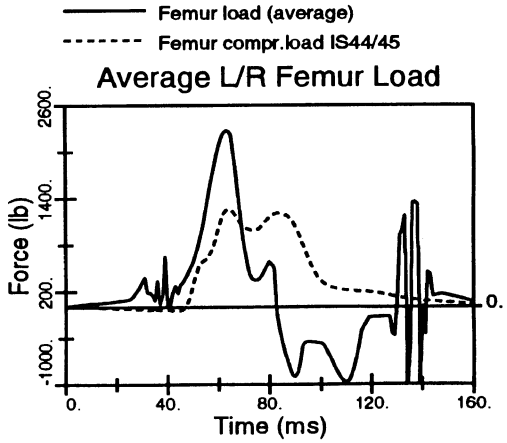


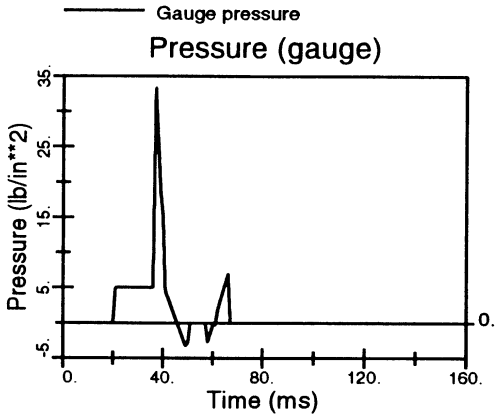
Figure 18.

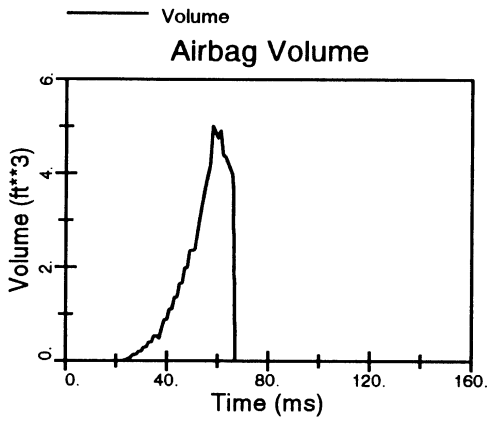
MVMA 2-D CVS Quasi-Finite Element Airbag Model

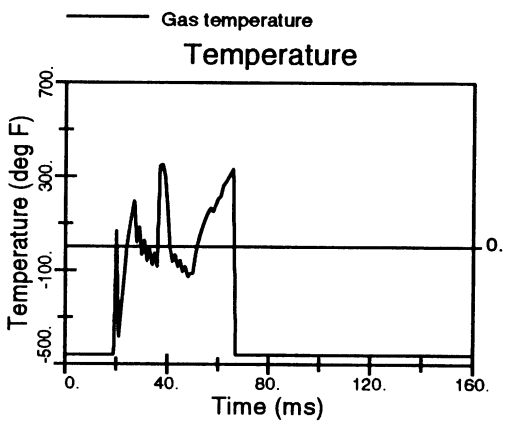
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

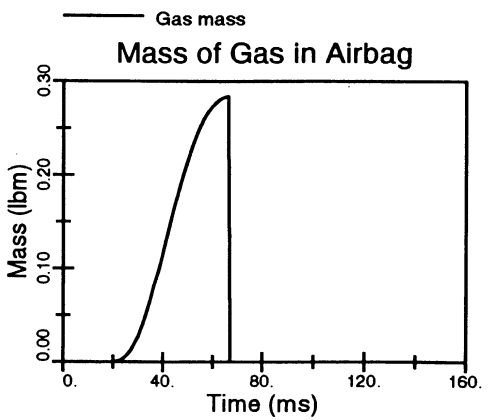
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

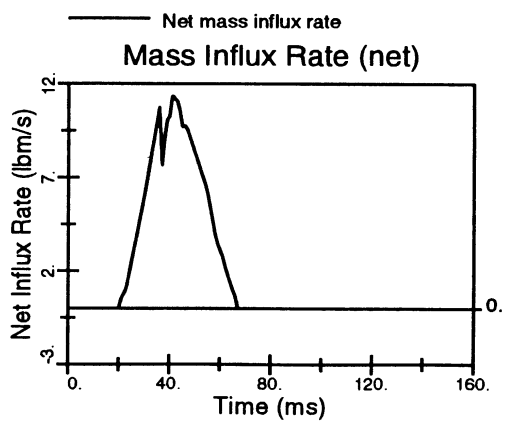
THERMODYNAMIC VARIABLES











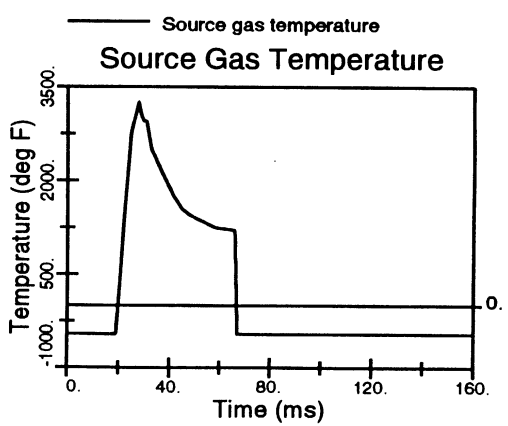


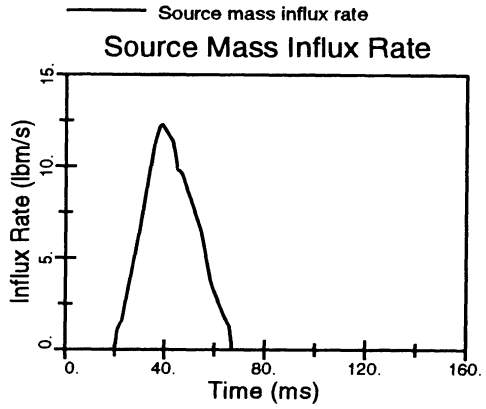
Figure 18.

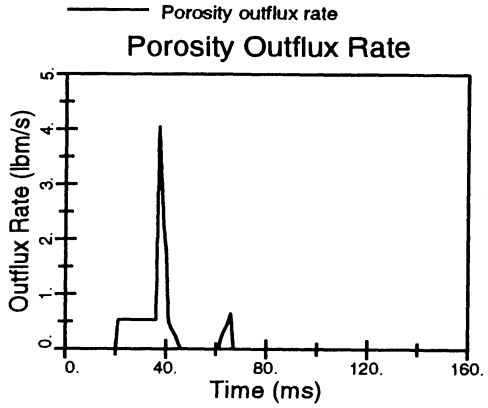
MVMA 2-D CVS Quasi-Finite Element Airbag Model

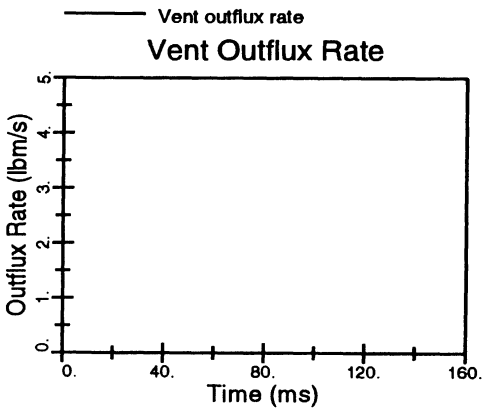
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

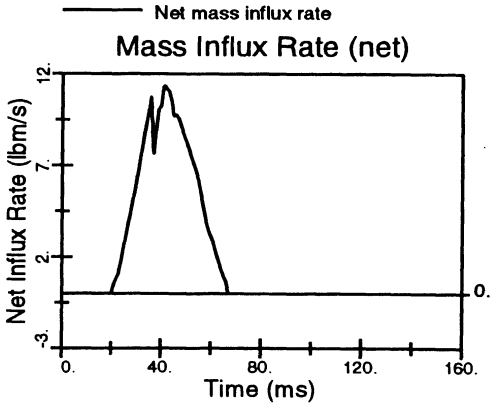
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

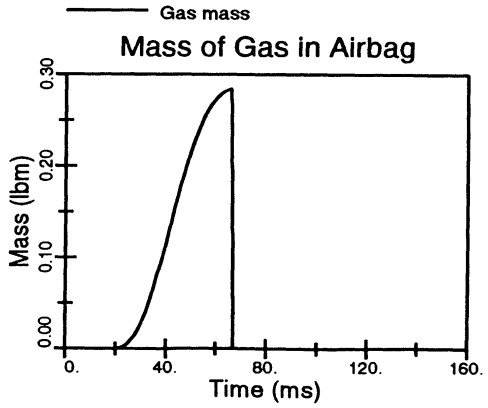
AIRBAG MASS INFLUX/OUTFLUX











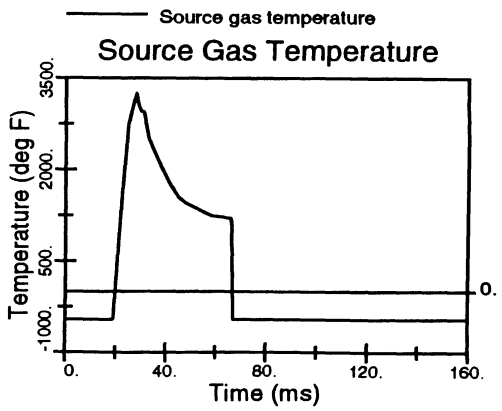


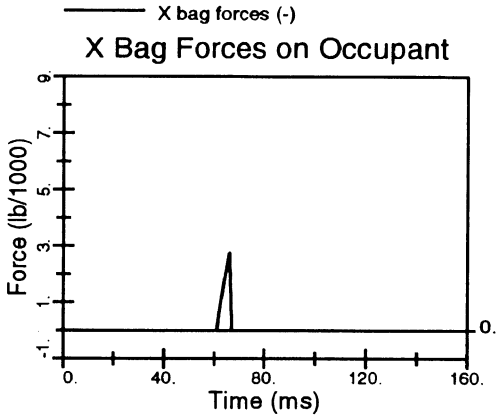
Figure 18.

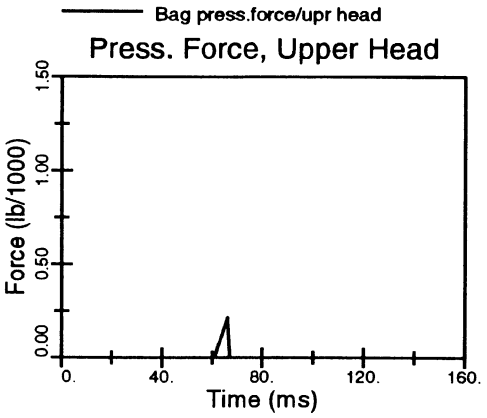
MVMA 2-D CVS Quasi-Finite Element Airbag Model

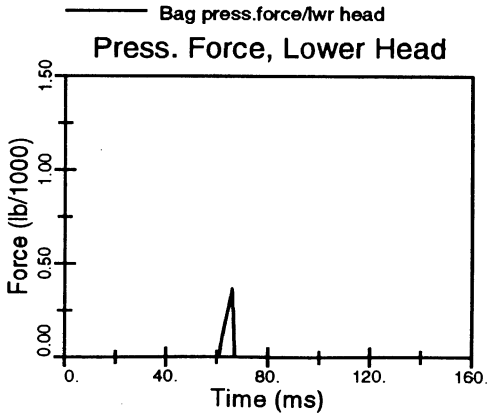
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







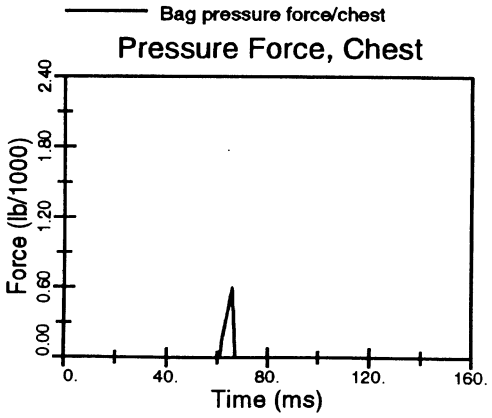


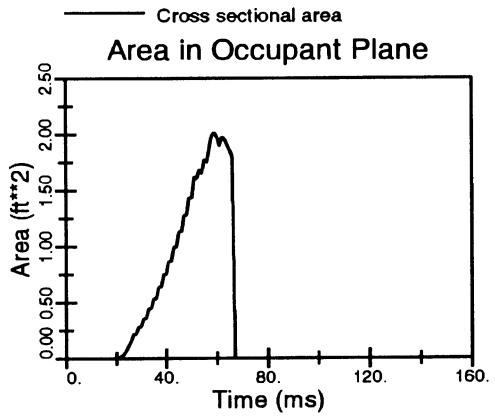
Figure 18.

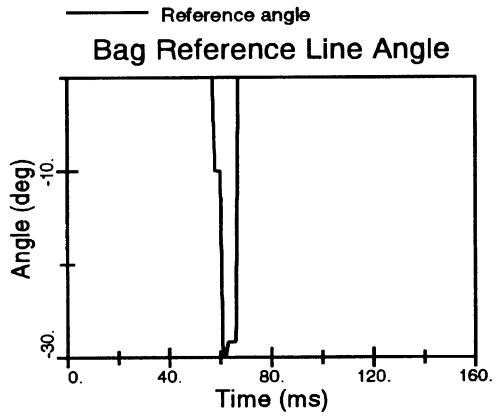
MVMA 2-D CVS Quasi-Finite Element Airbag Model

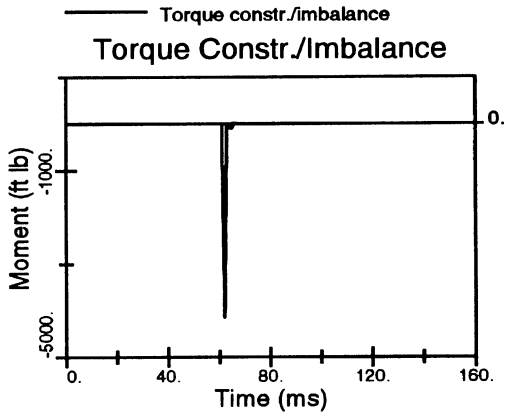
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with fixed, 9-degree pitch angle , Tests IS11144/45

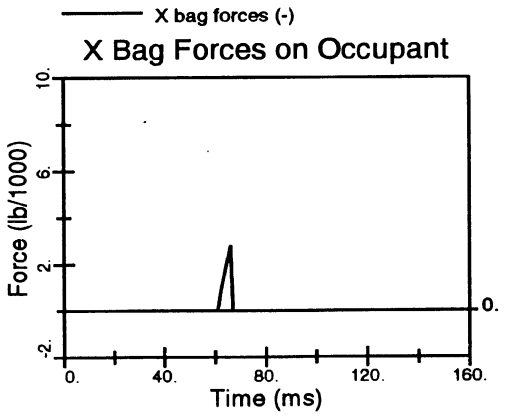
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









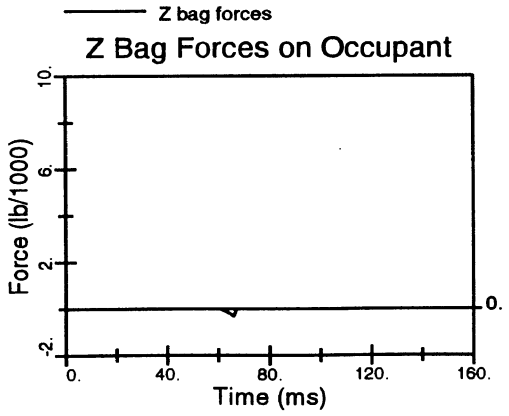


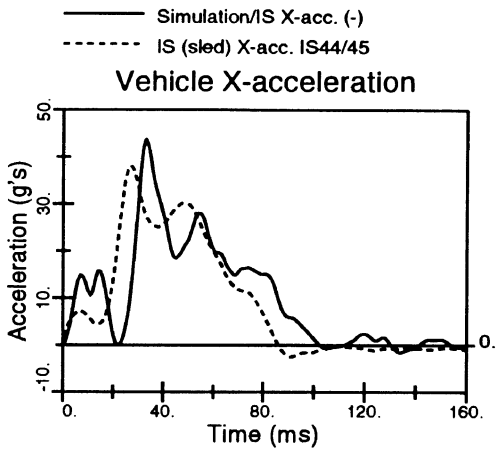
Figure 18.

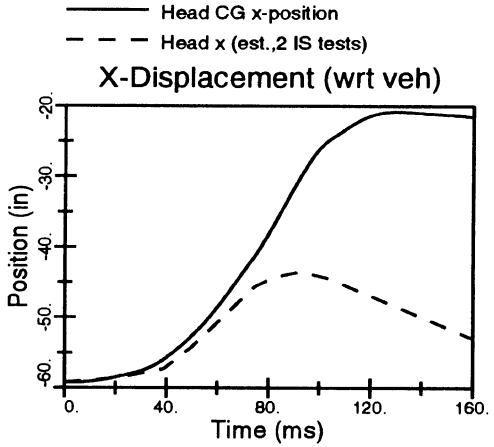
MVMA 2-D CVS Quasi-Finite Element Airbag Model

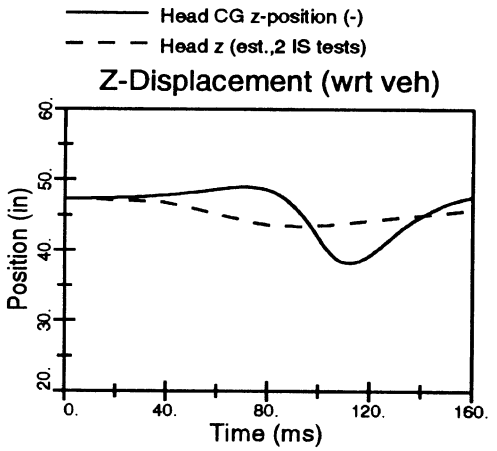
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

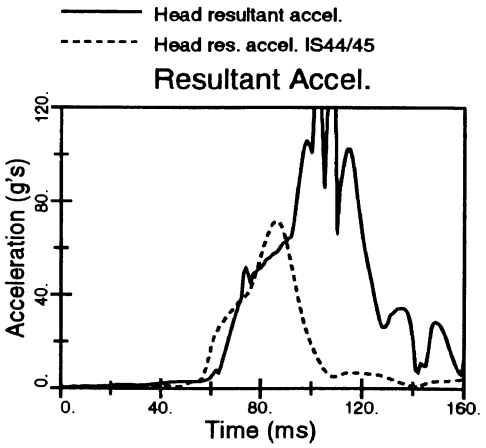
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

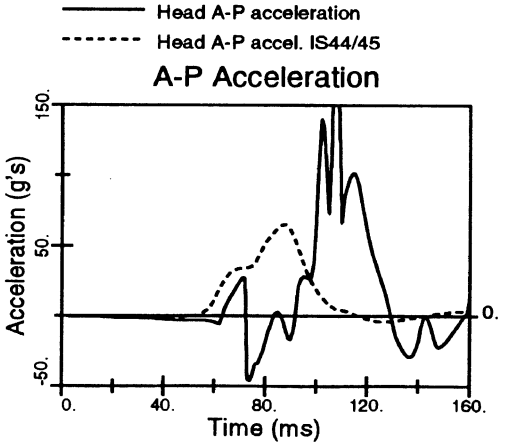
HEAD KINEMATIC RESPONSE











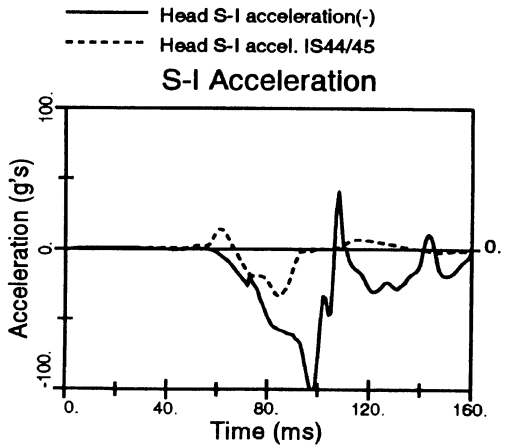


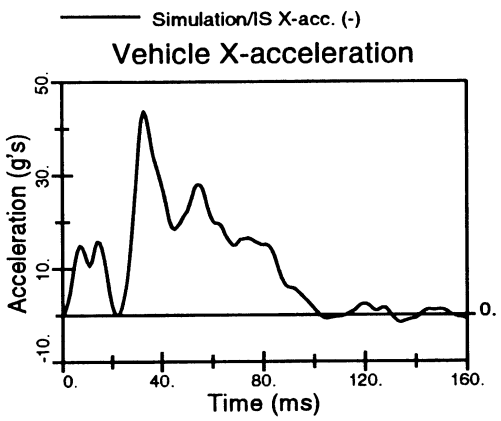
Figure 19.

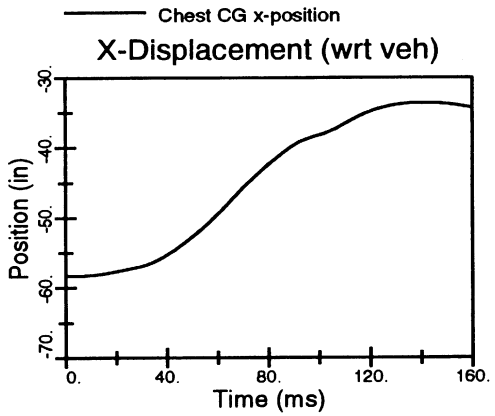
MVMA 2-D CVS Quasi-Finite Element Airbag Model

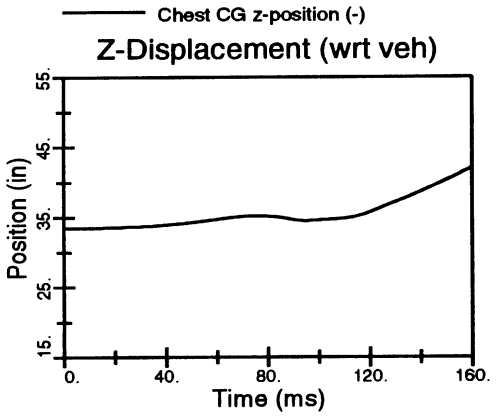
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

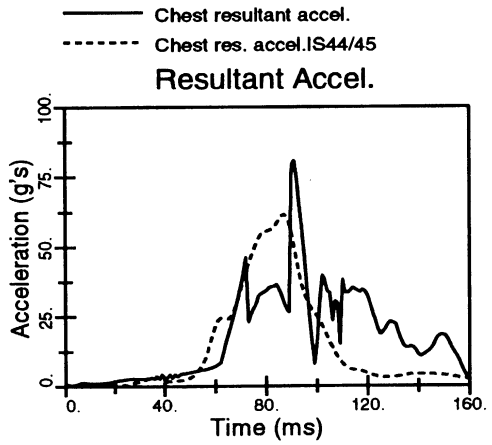
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

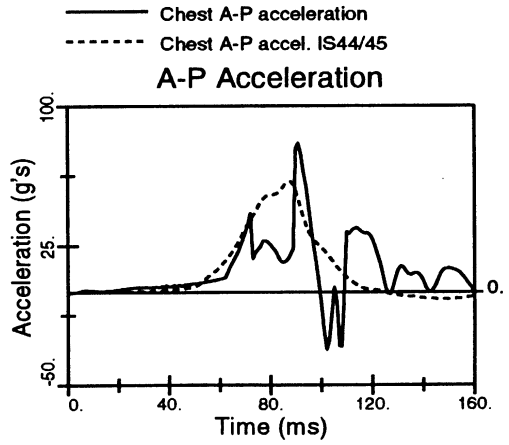
CHEST KINEMATIC RESPONSE











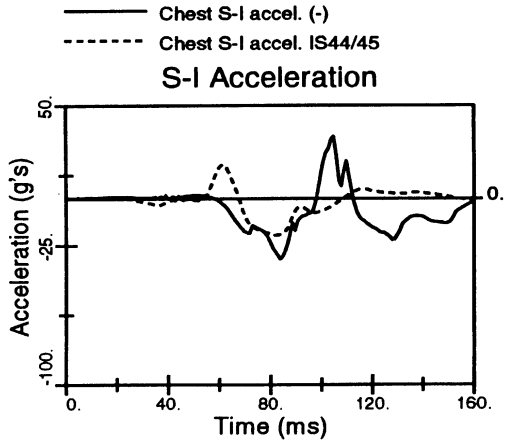


Figure 19.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

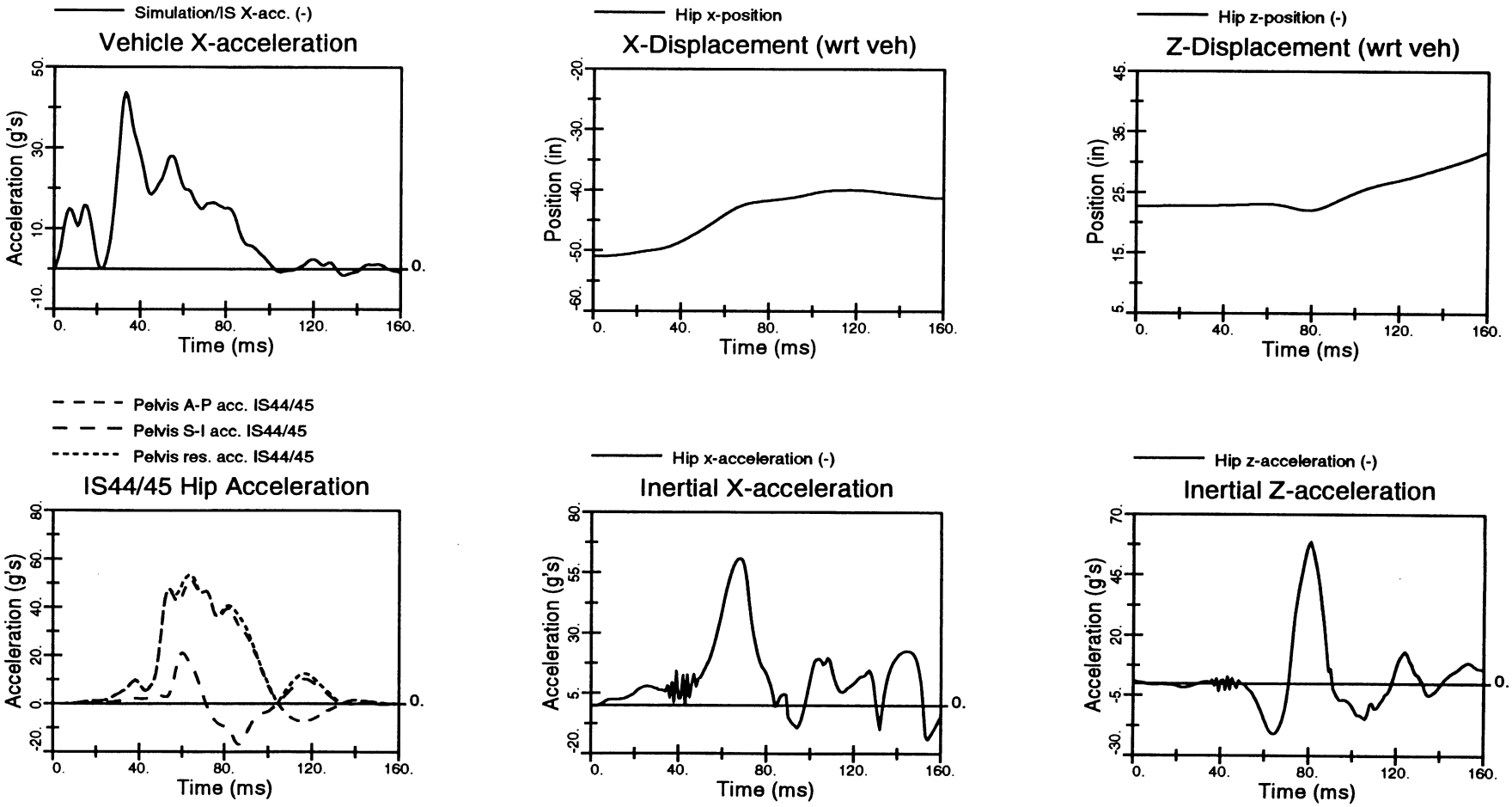


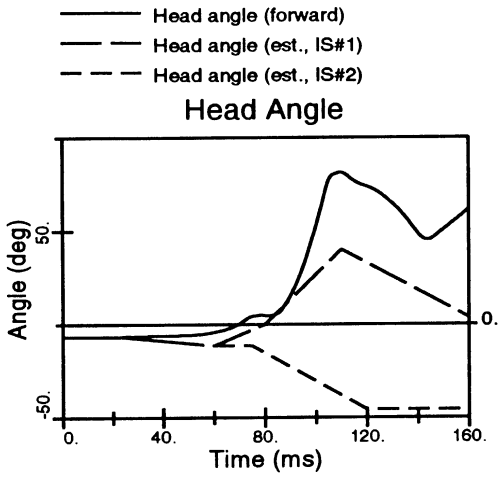
Figure 19.

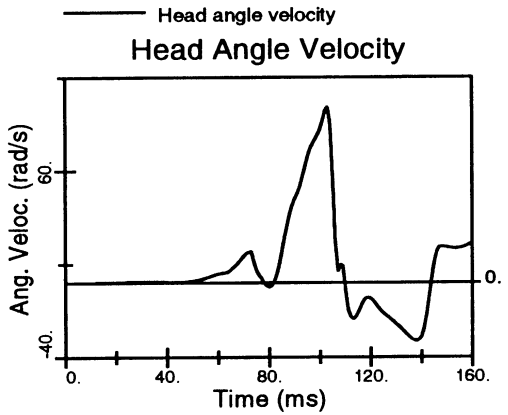
MVMA 2-D CVS Quasi-Finite Element Airbag Model

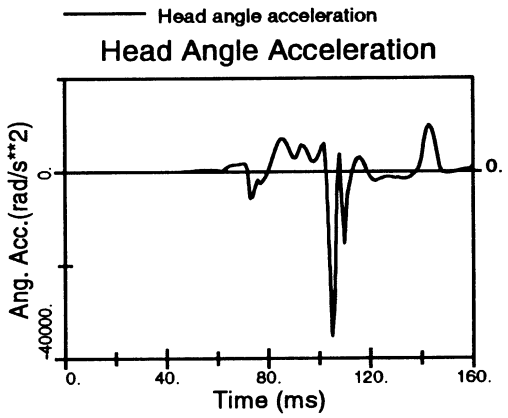
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

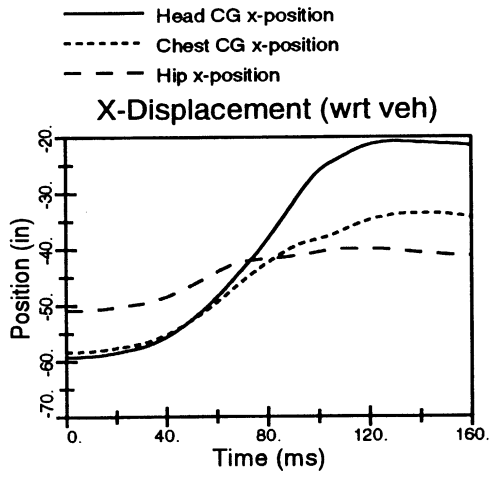
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

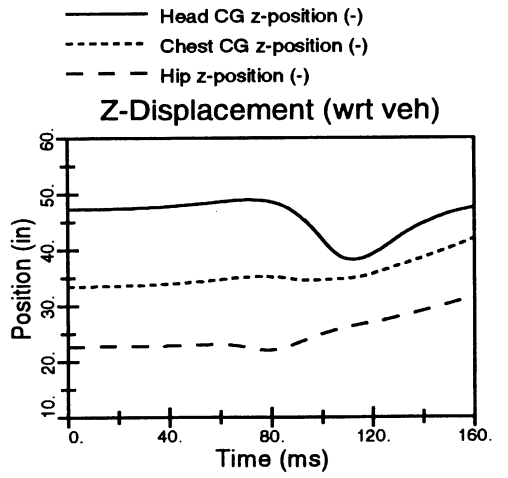
HEAD ANGULAR RESPONSE / OTHER RESPONSES











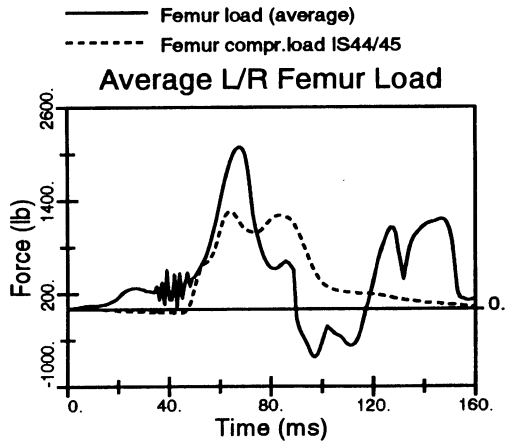


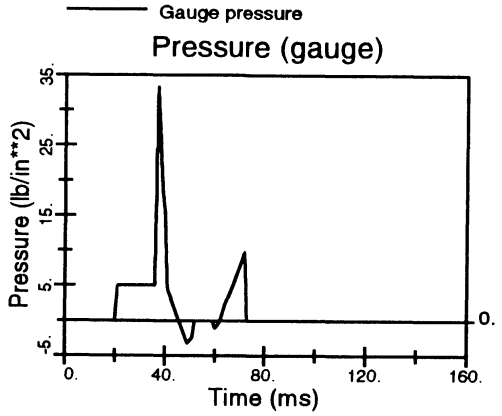
Figure 19.

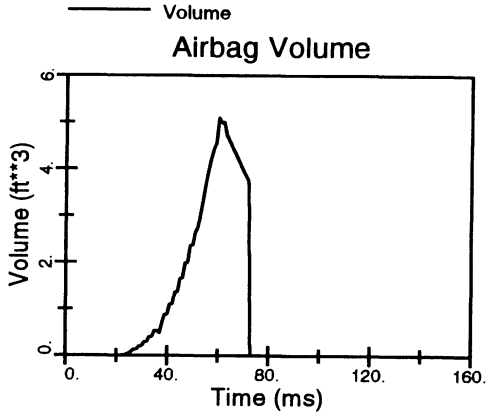
MVMA 2-D CVS Quasi-Finite Element Airbag Model

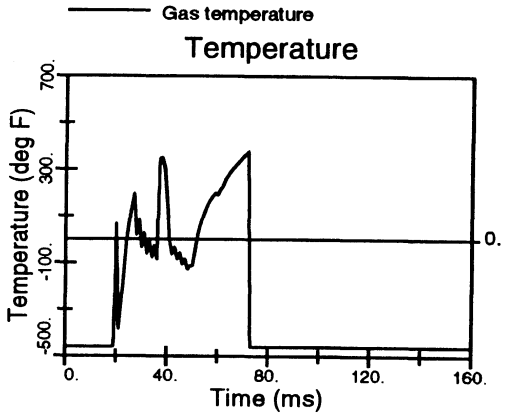
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

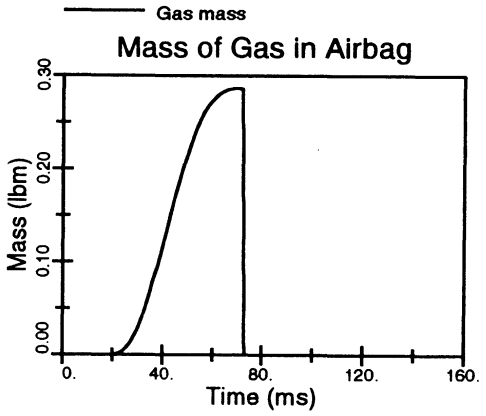
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

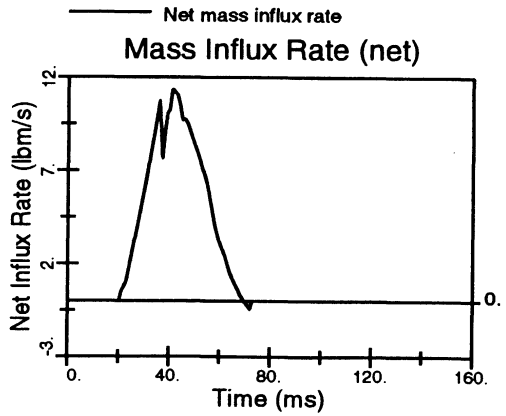
THERMODYNAMIC VARIABLES











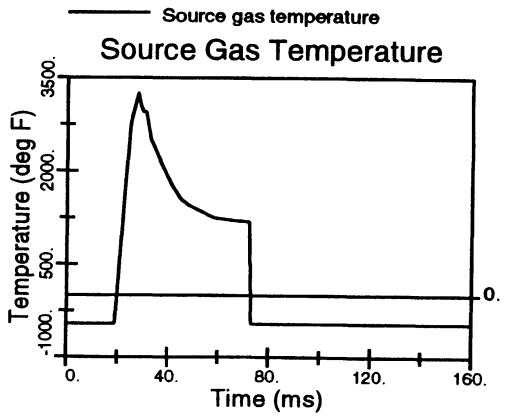


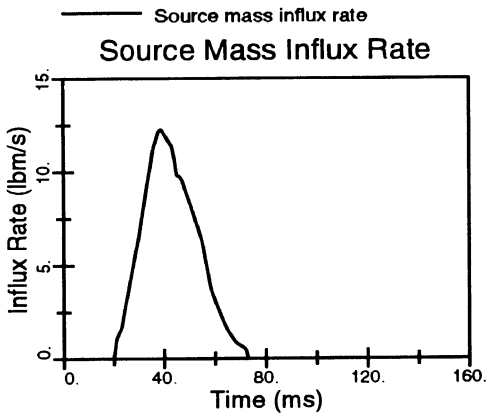
Figure 19.

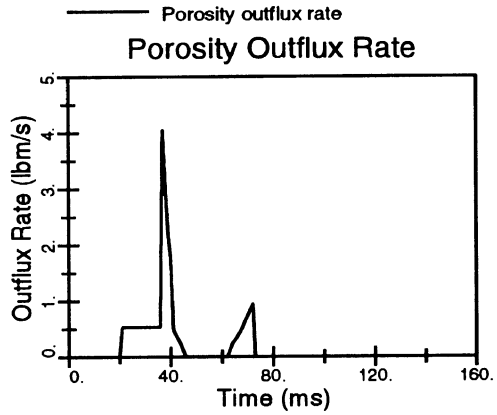
MVMA 2-D CVS Quasi-Finite Element Airbag Model

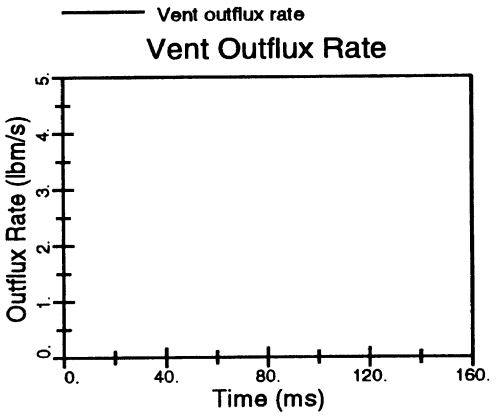
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

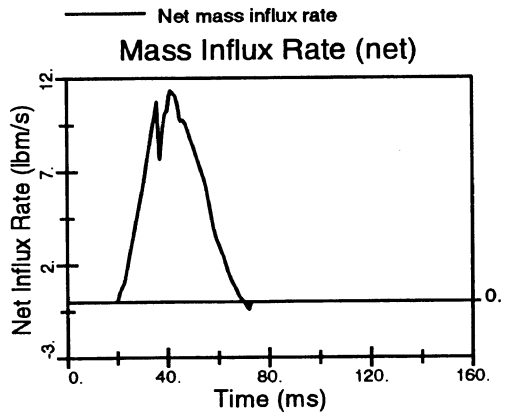
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

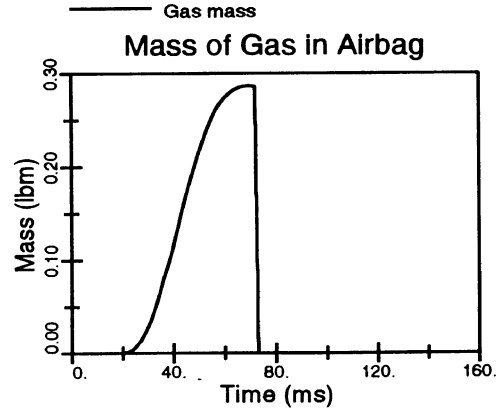
AIRBAG MASS INFLUX/OUTFLUX











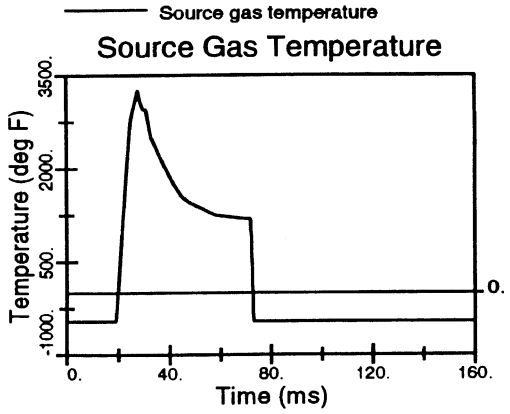


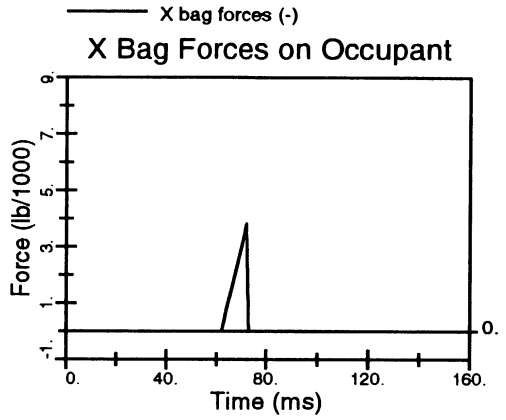
Figure 19.

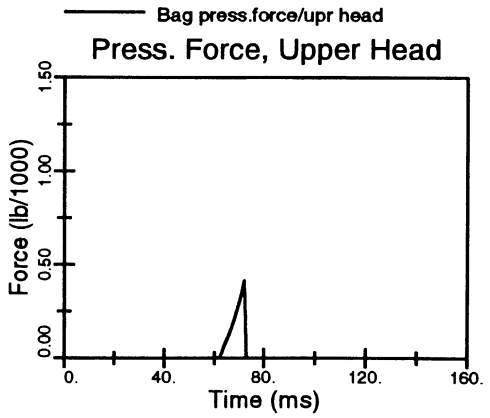
MVMA 2-D CVS Quasi-Finite Element Airbag Model

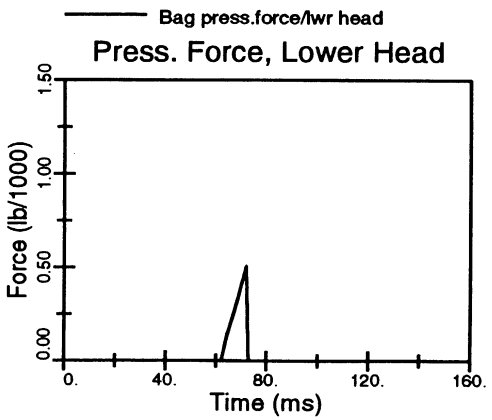
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







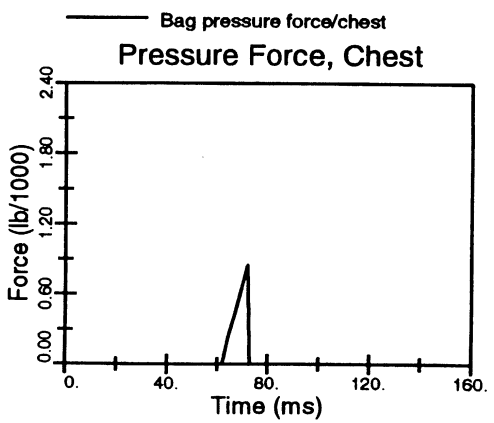


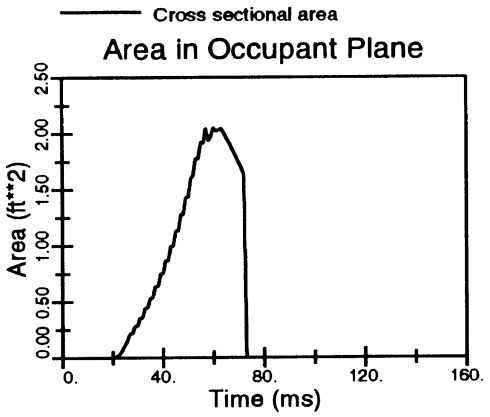
Figure 19.

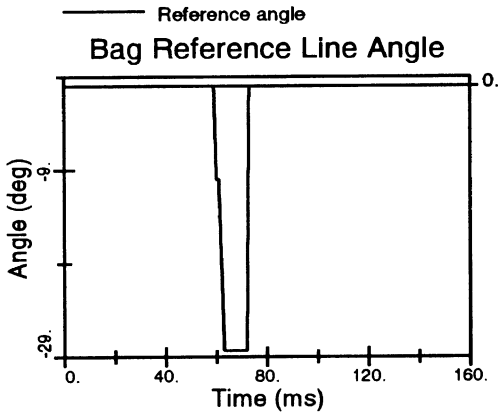
MVMA 2-D CVS Quasi-Finite Element Airbag Model

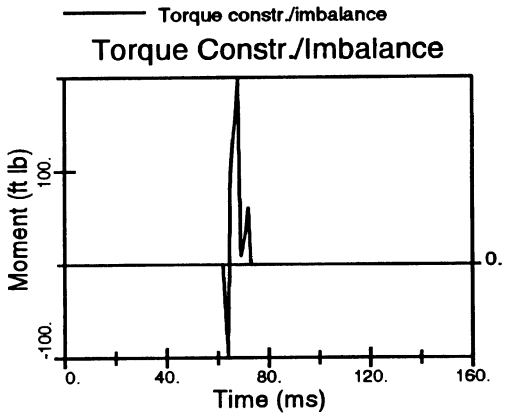
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES







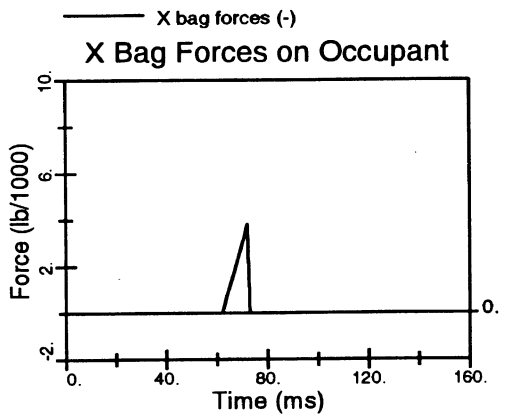


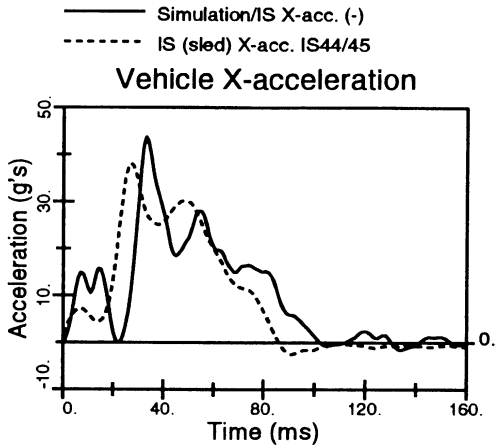
Figure 19.

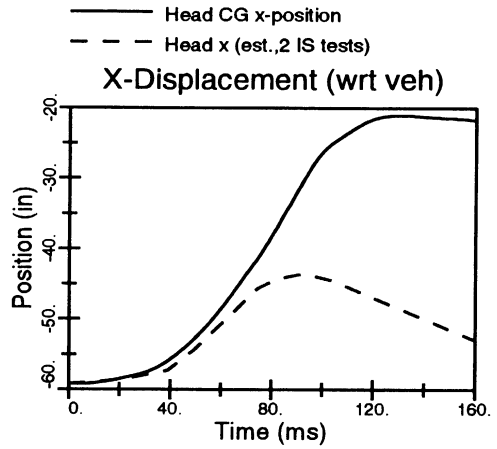
MVMA 2-D CVS Quasi-Finite Element Airbag Model

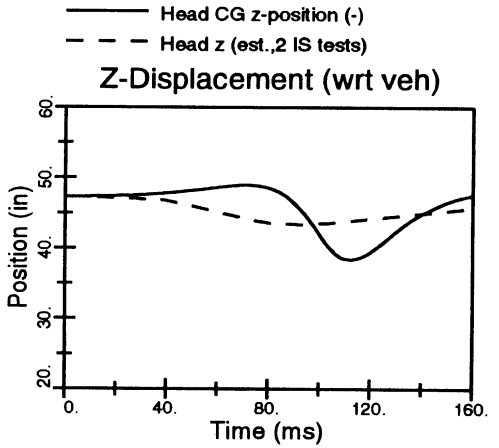
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

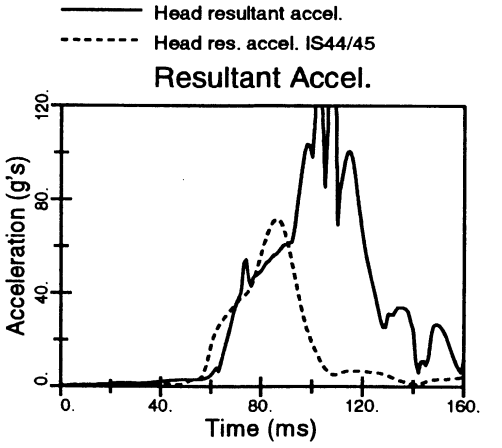
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

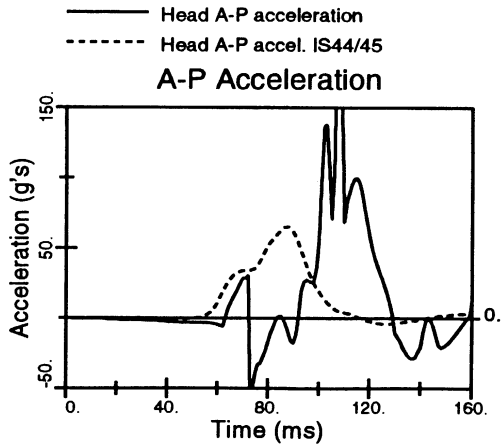
HEAD KINEMATIC RESPONSE











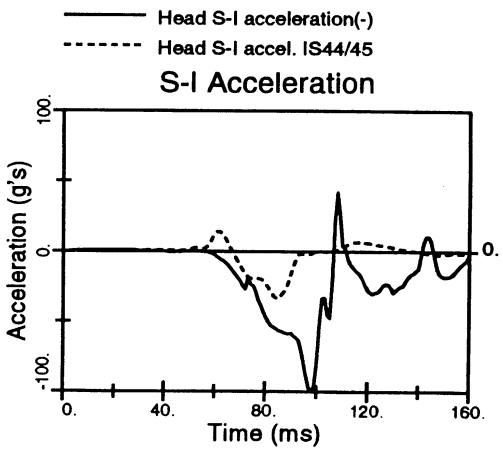


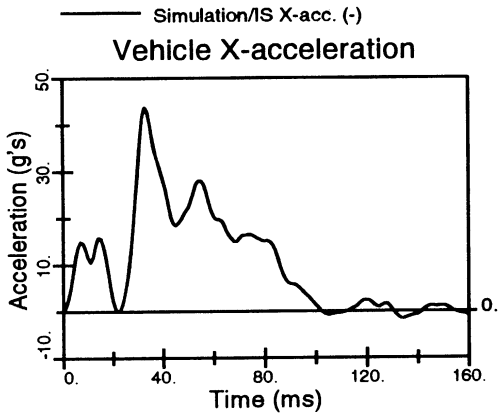
Figure 20.

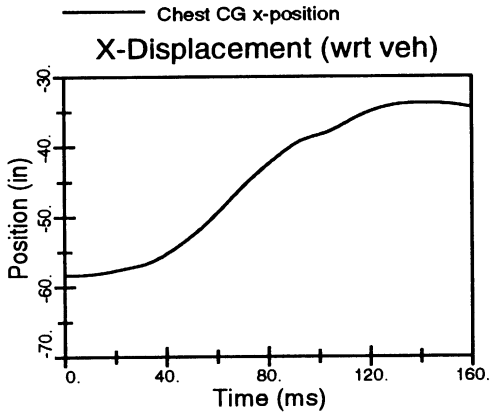
MVMA 2-D CVS Quasi-Finite Element Airbag Model

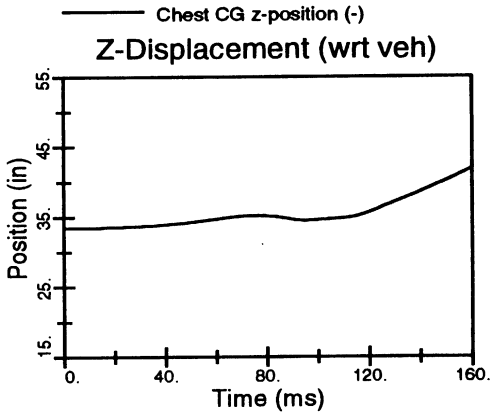
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

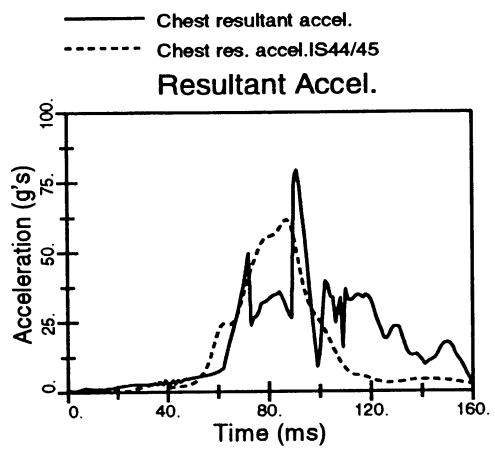
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

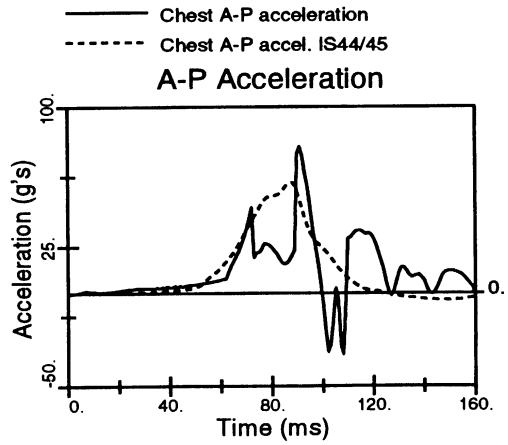
CHEST KINEMATIC RESPONSE











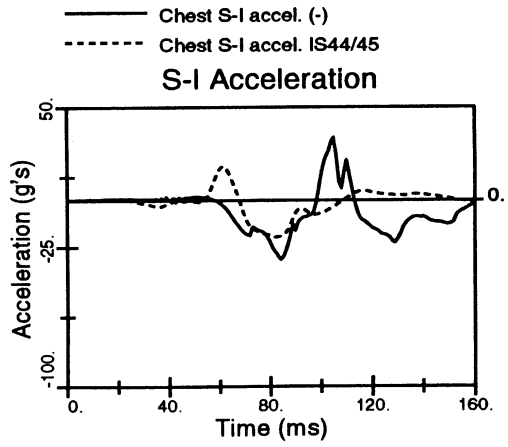


Figure 20.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

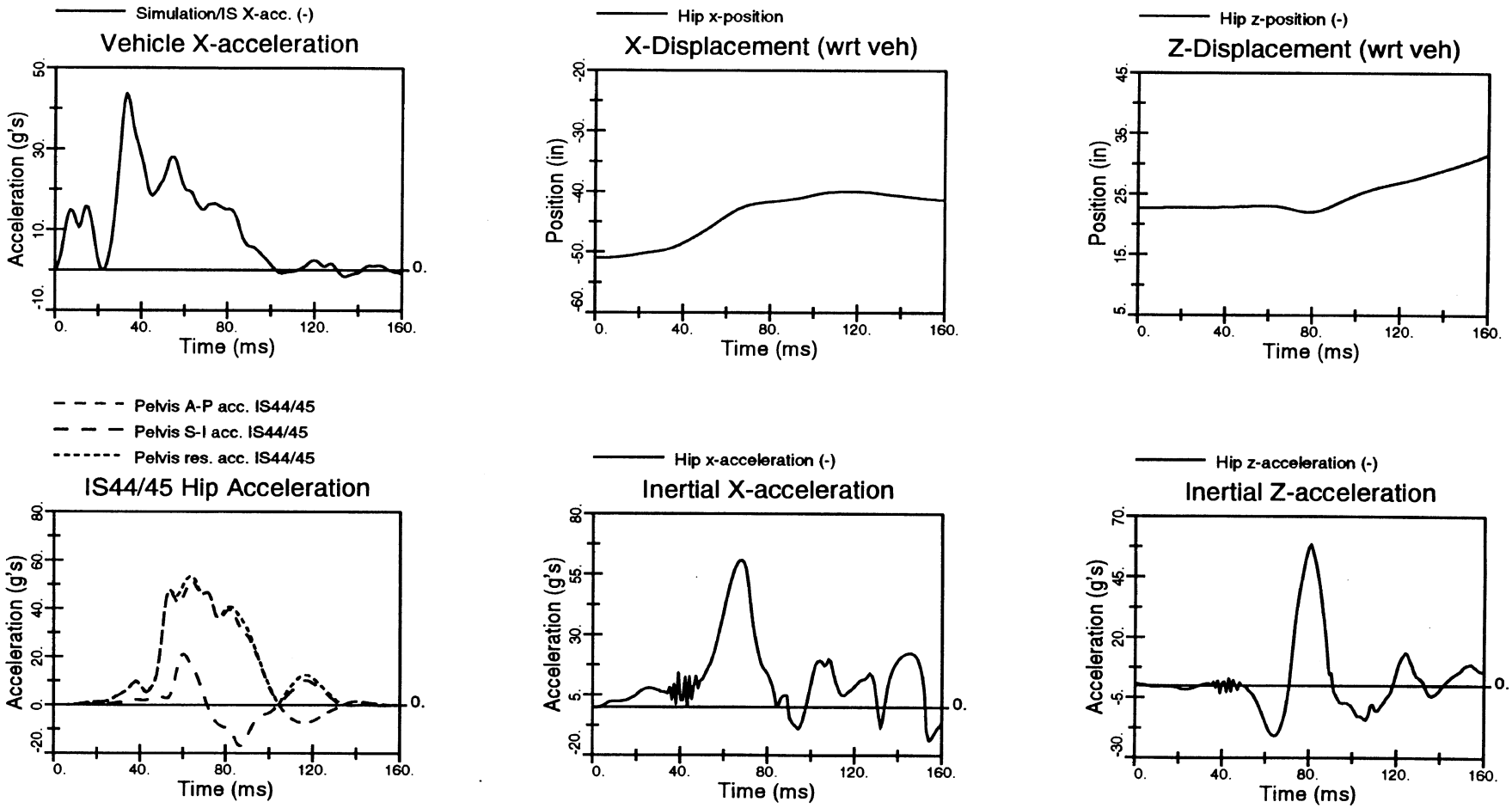


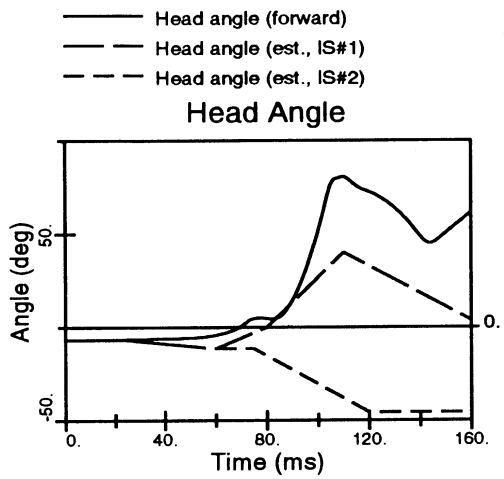
Figure 20.

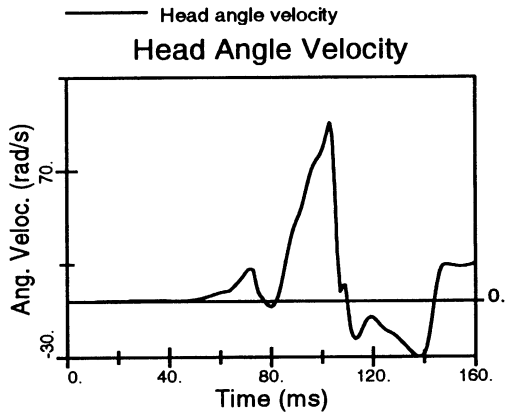
MVMA 2-D CVS Quasi-Finite Element Airbag Model

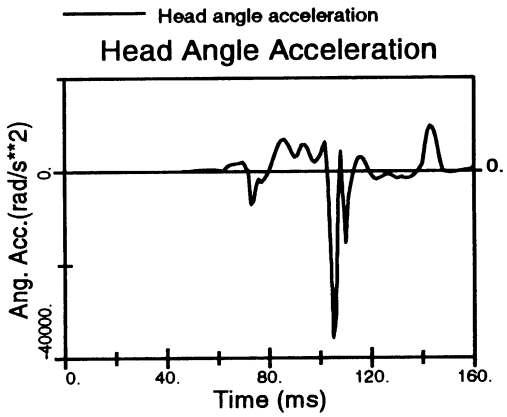
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

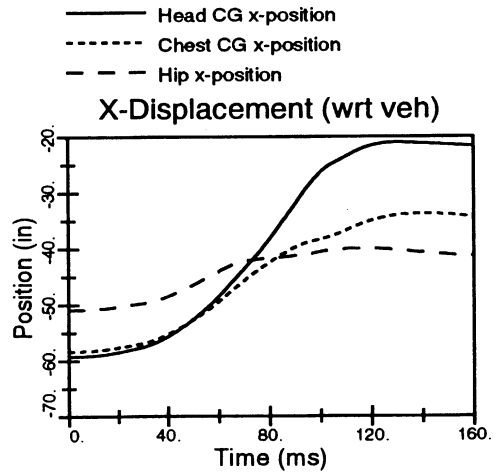
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

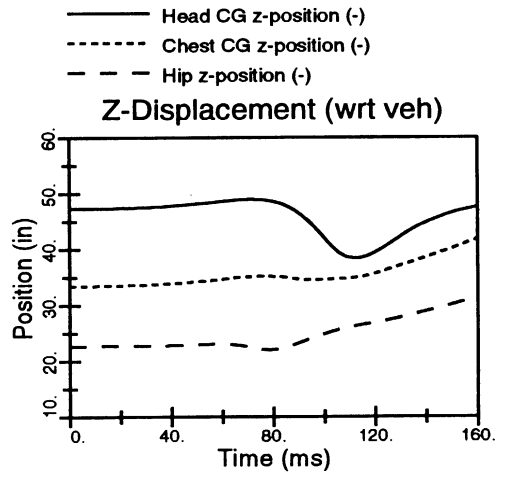
HEAD ANGULAR RESPONSE / OTHER RESPONSES











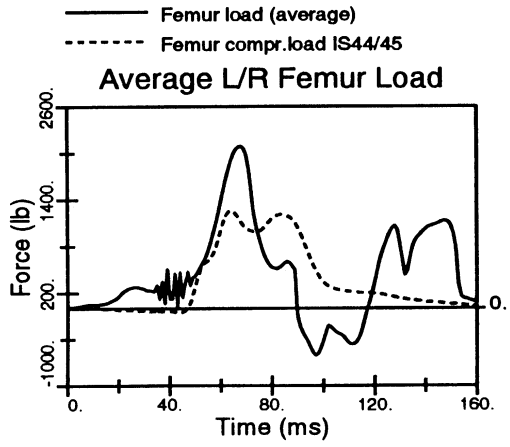


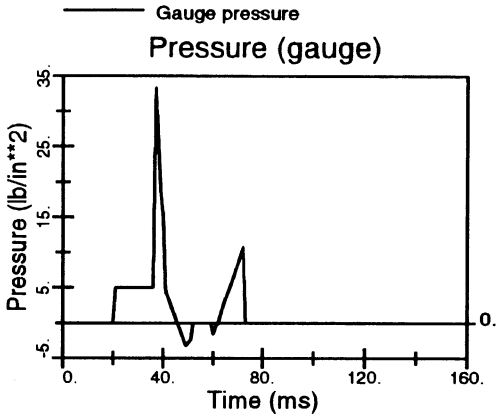
Figure 20.

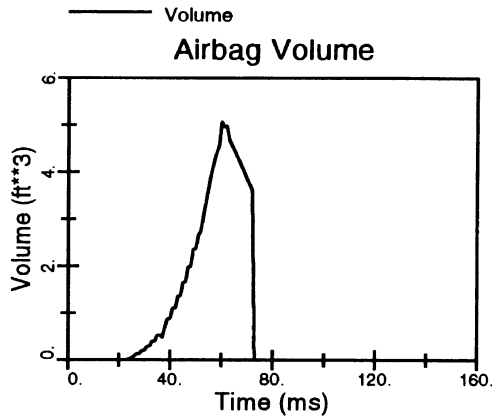
MVMA 2-D CVS Quasi-Finite Element Airbag Model

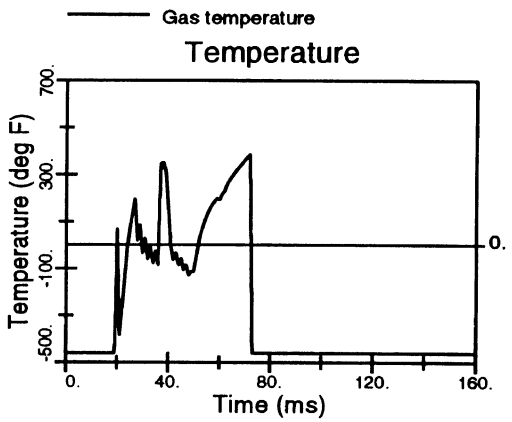
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

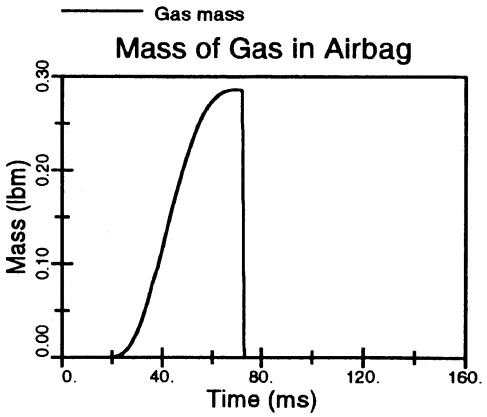
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

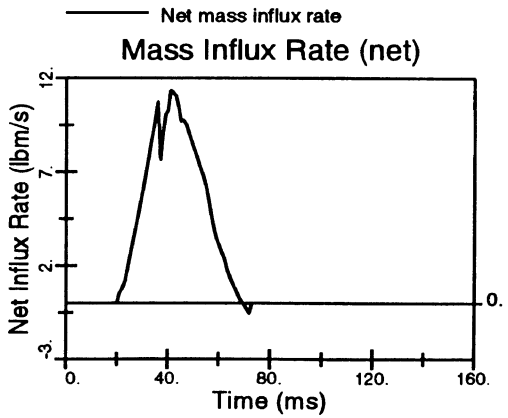
THERMODYNAMIC VARIABLES











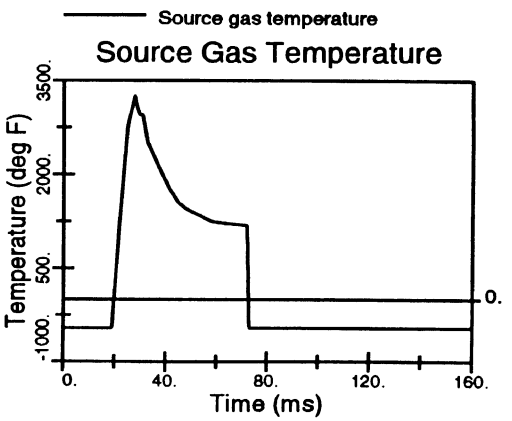


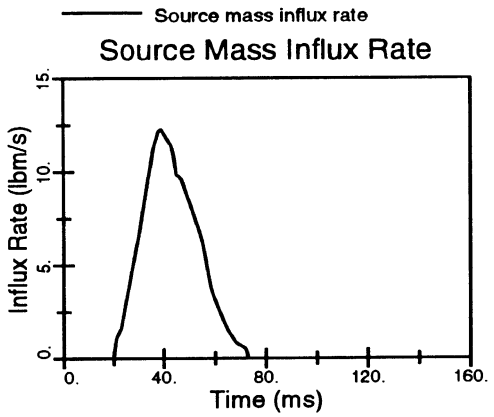
Figure 20.

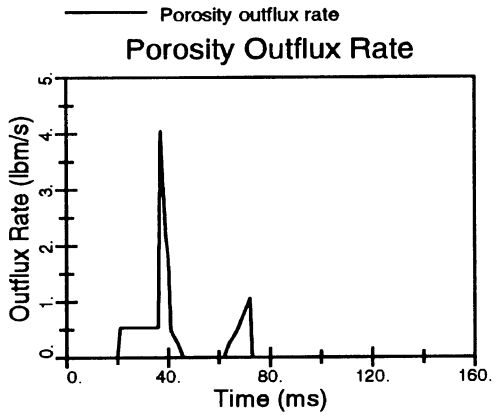
MVMA 2-D CVS Quasi-Finite Element Airbag Model

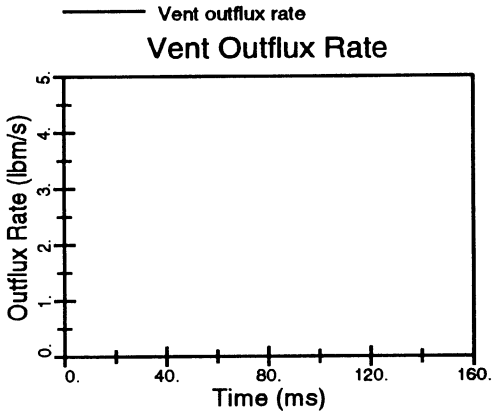
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

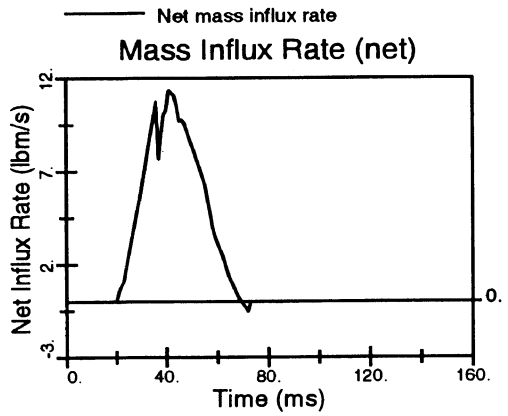
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

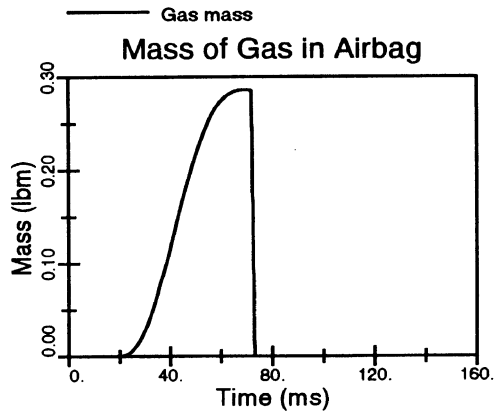
AIRBAG MASS INFLUX/OUTFLUX











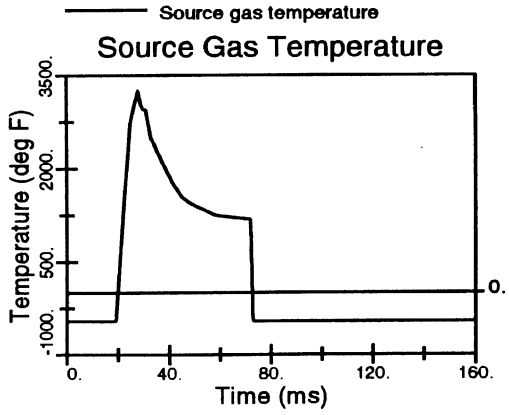


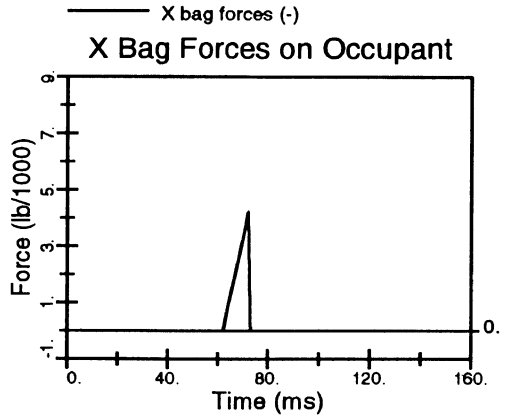
Figure 20.

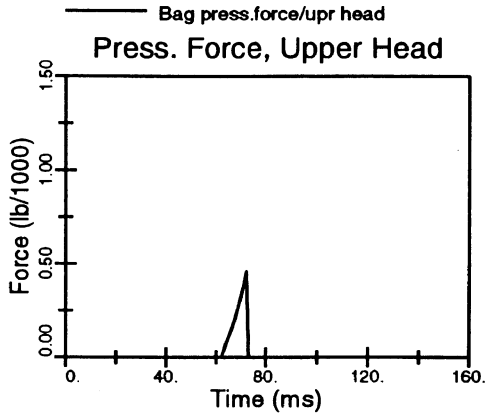
MVMA 2-D CVS Quasi-Finite Element Airbag Model

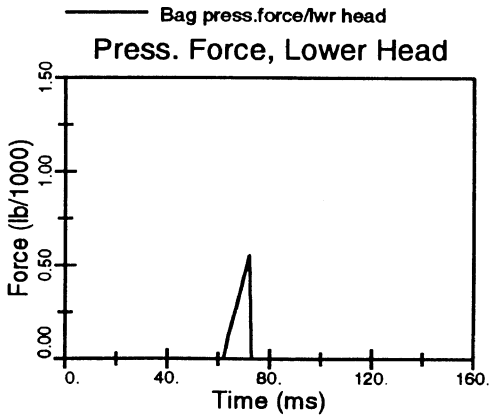
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







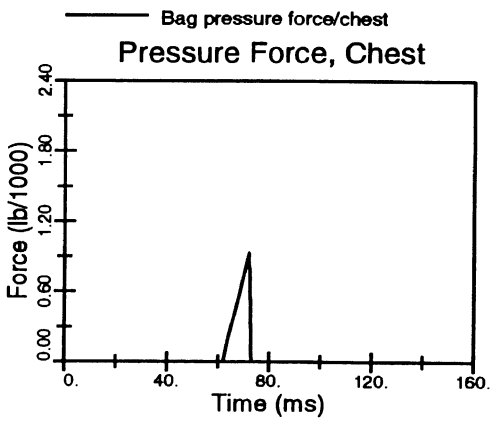


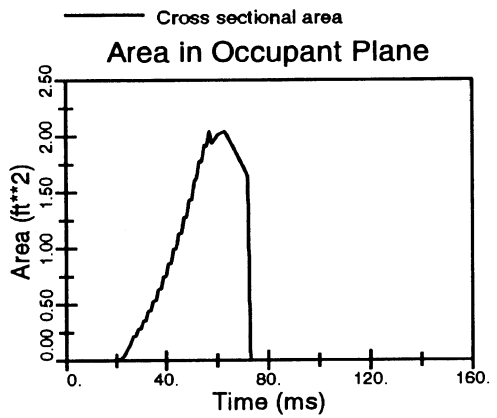
Figure 20.

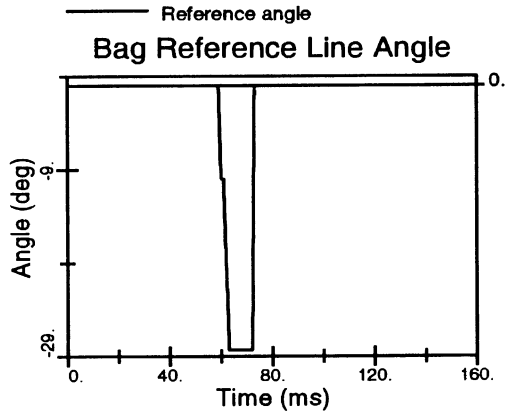
MVMA 2-D CVS Quasi-Finite Element Airbag Model

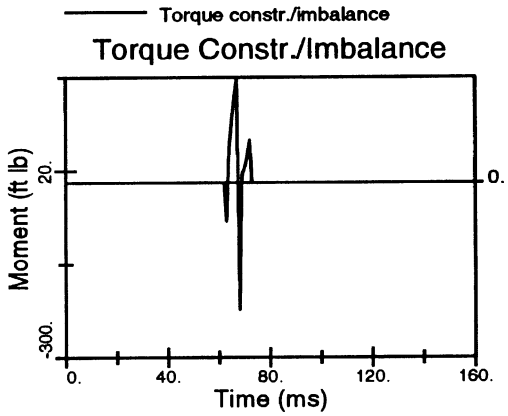
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 5-degree vehicle pitch , Tests IS11144/45

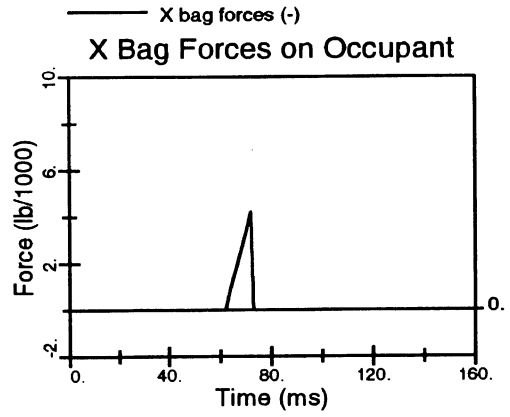
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









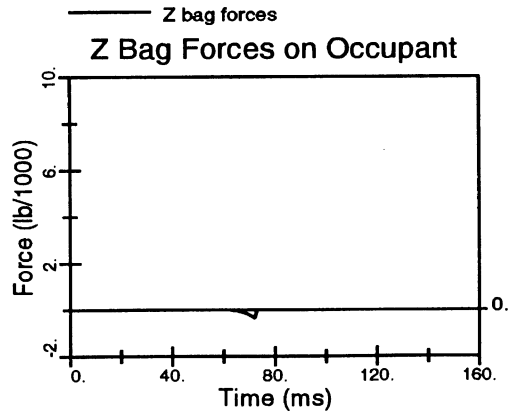


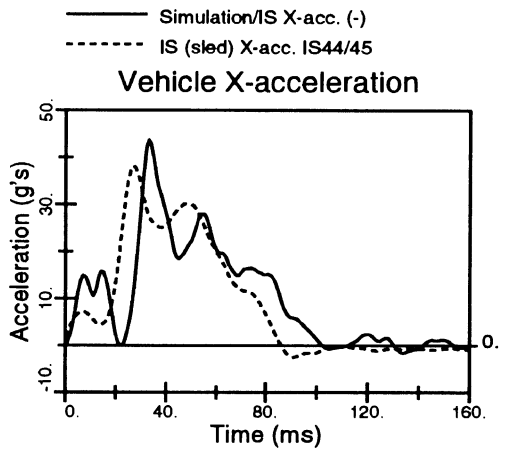
Figure 20.

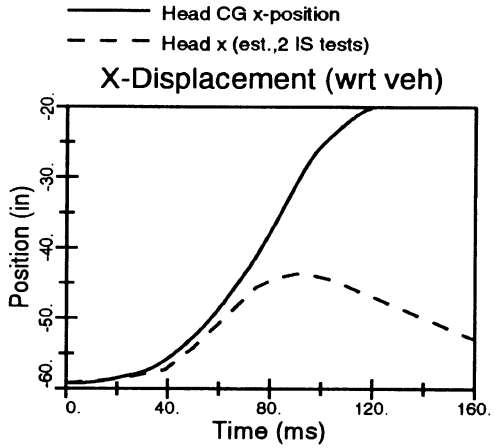
MVMA 2-D CVS Quasi-Finite Element Airbag Model

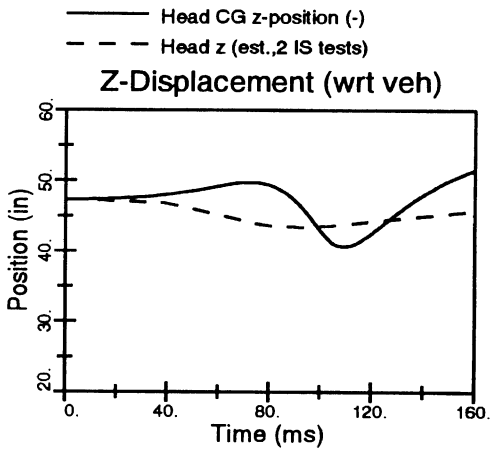
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

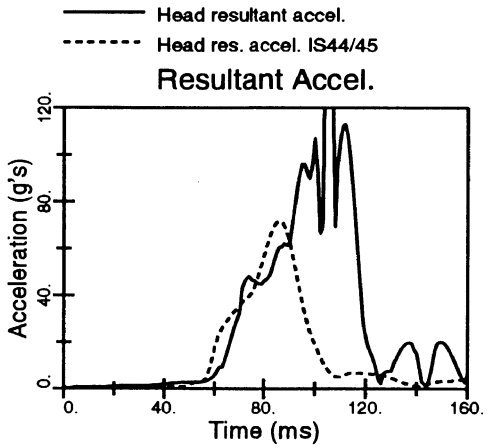
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

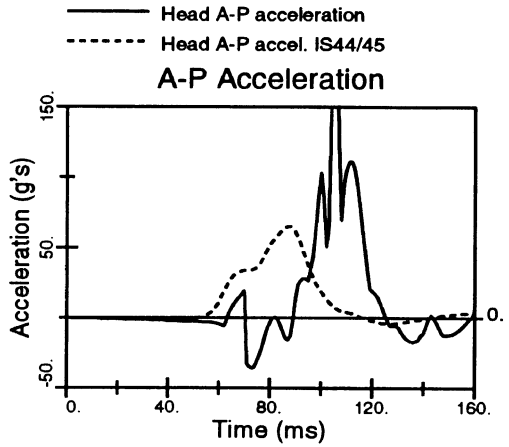
HEAD KINEMATIC RESPONSE











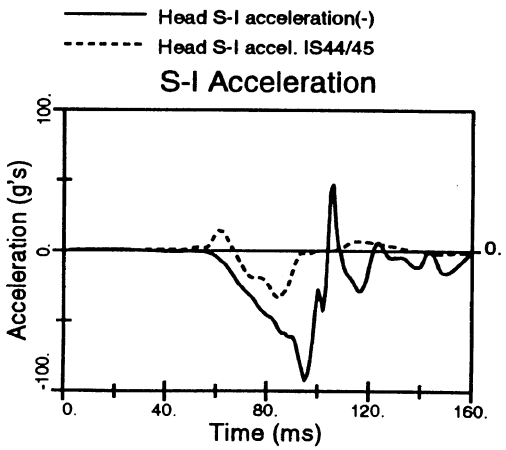


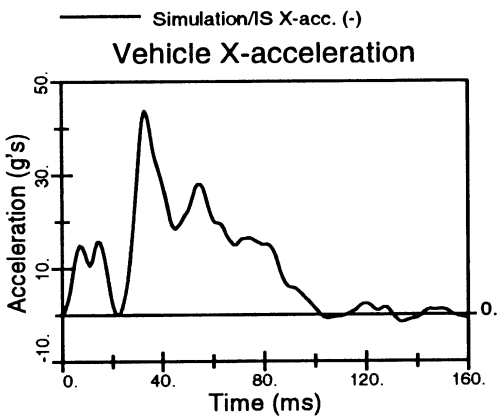
Figure 21.

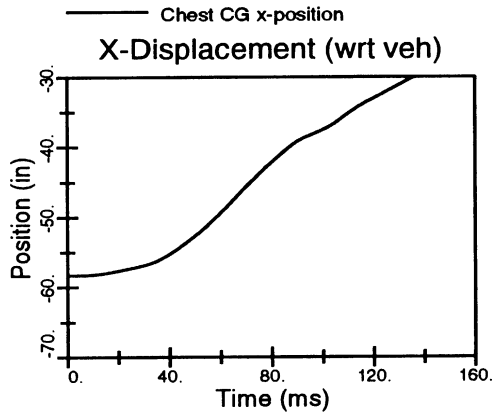
MVMA 2-D CVS Quasi-Finite Element Airbag Model

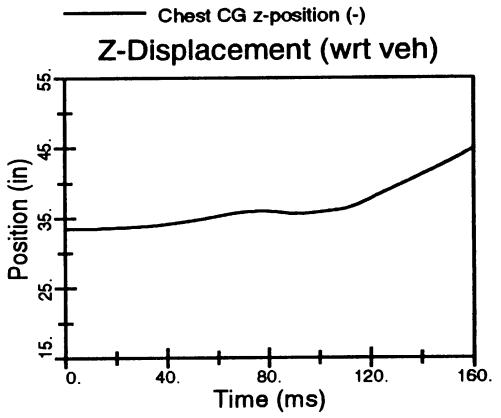
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

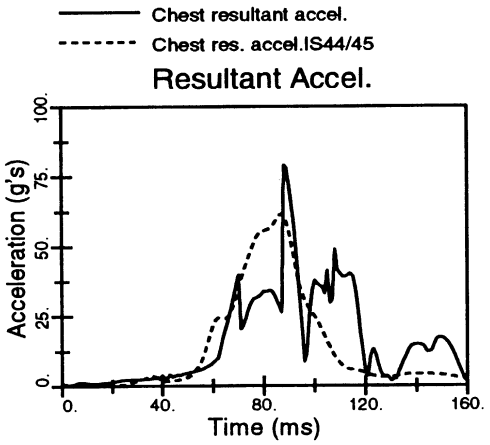
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

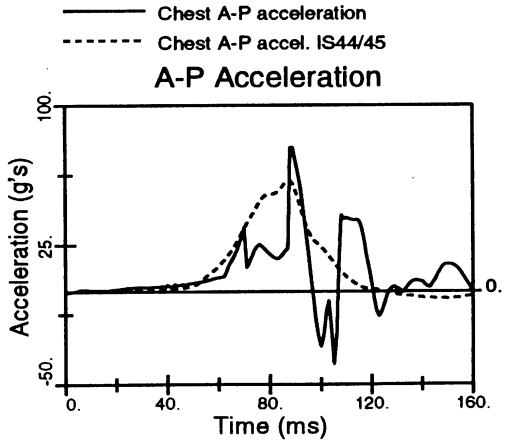
CHEST KINEMATIC RESPONSE











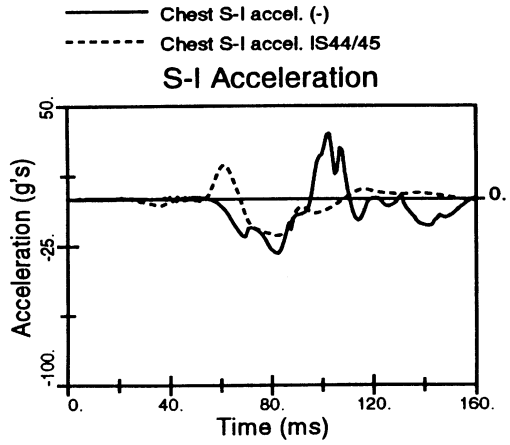


Figure 21.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

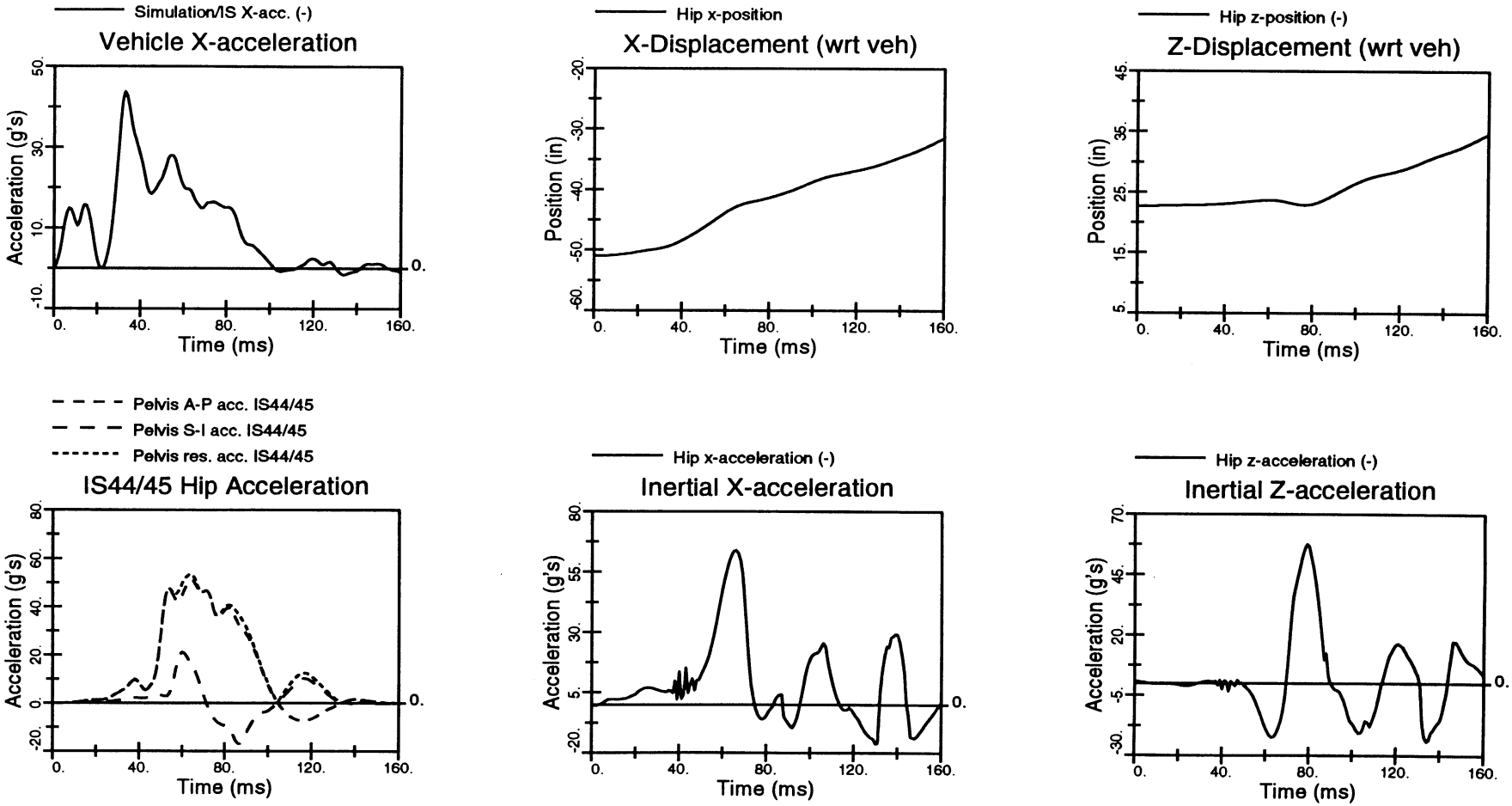


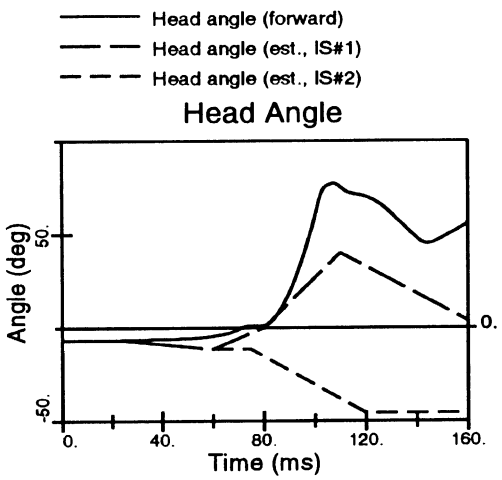
Figure 21.

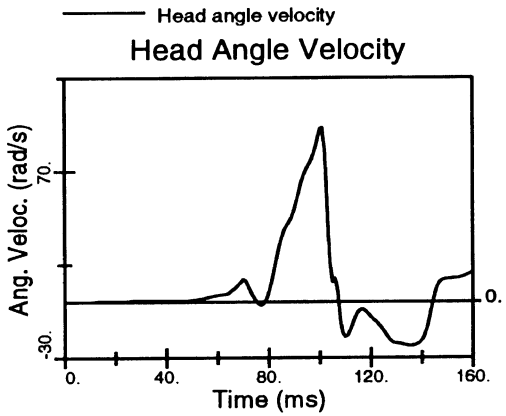
MVMA 2-D CVS Quasi-Finite Element Airbag Model

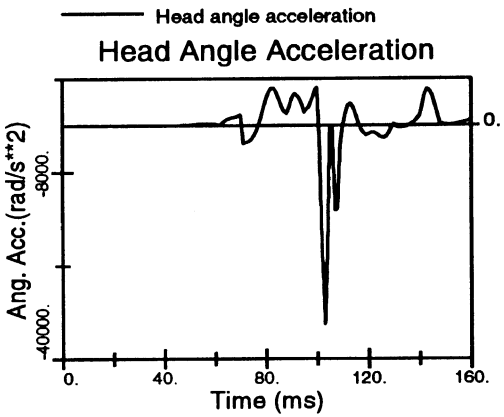
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

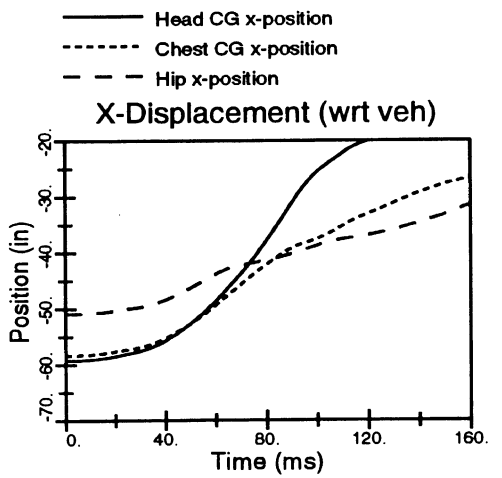
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

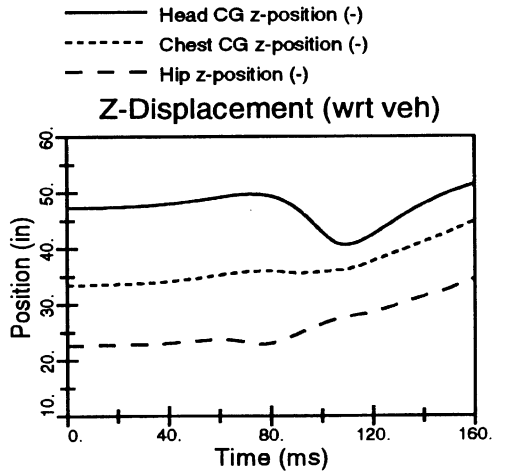
HEAD ANGULAR RESPONSE / OTHER RESPONSES











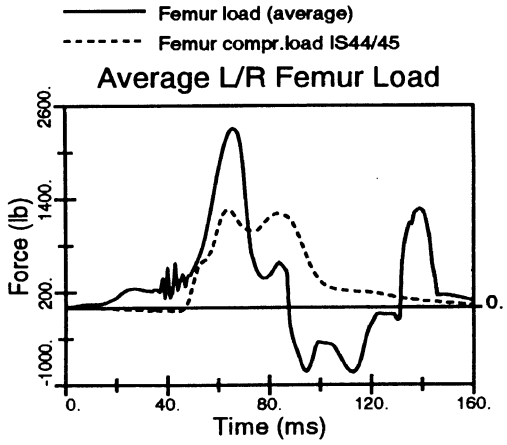


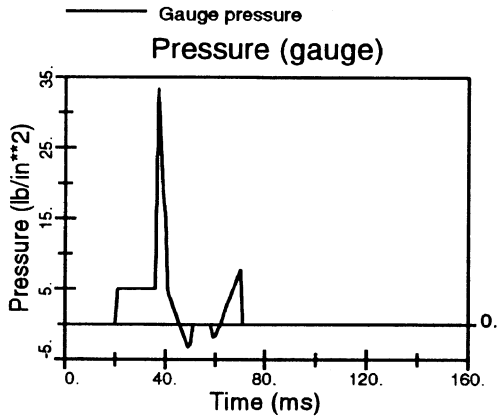
Figure 21.

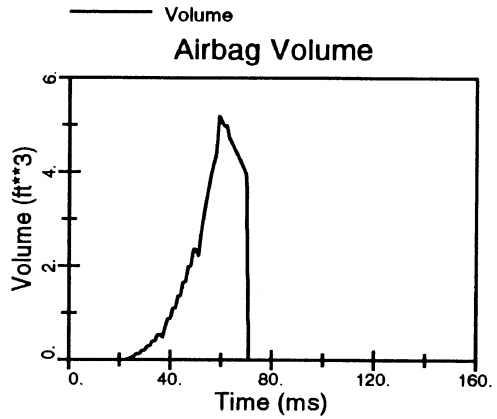
MVMA 2-D CVS Quasi-Finite Element Airbag Model

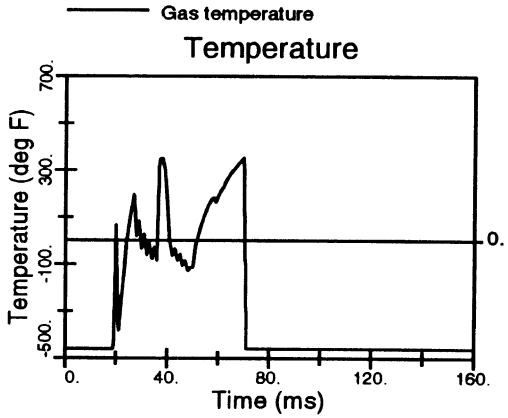
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

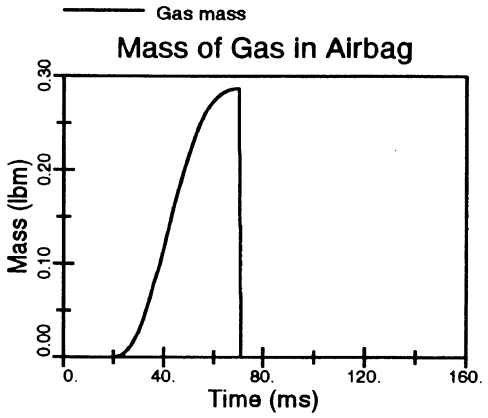
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

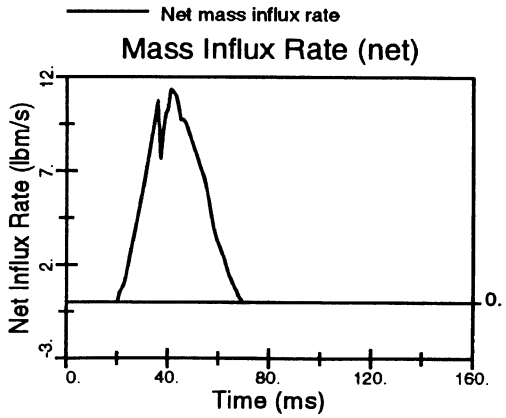
THERMODYNAMIC VARIABLES











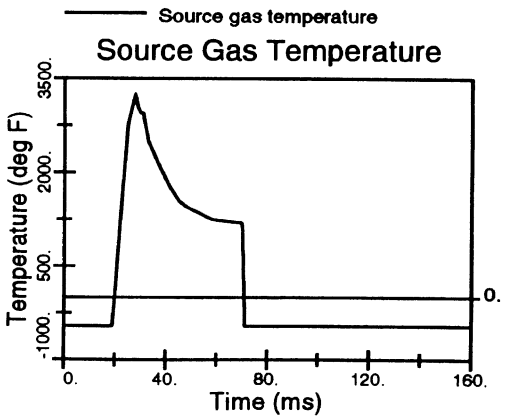


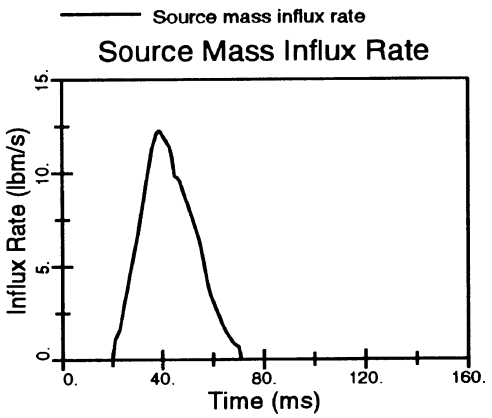
Figure 21.

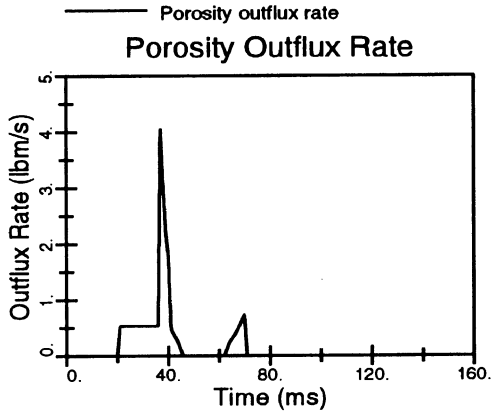
MVMA 2-D CVS Quasi-Finite Element Airbag Model

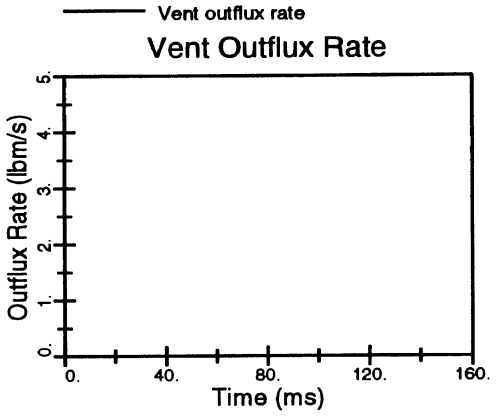
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

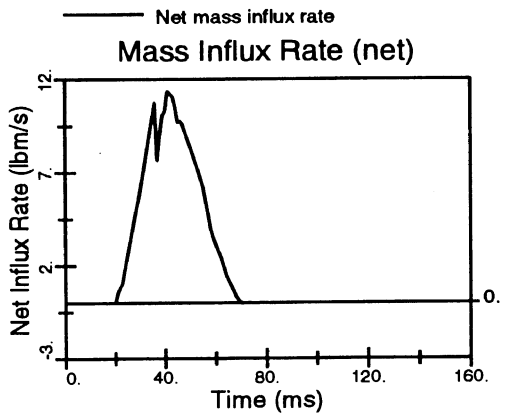
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

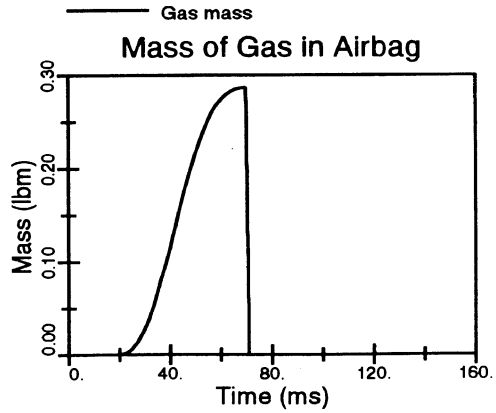
AIRBAG MASS INFLUX/OUTFLUX











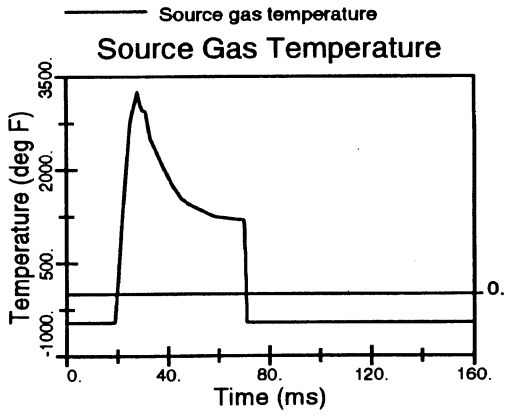


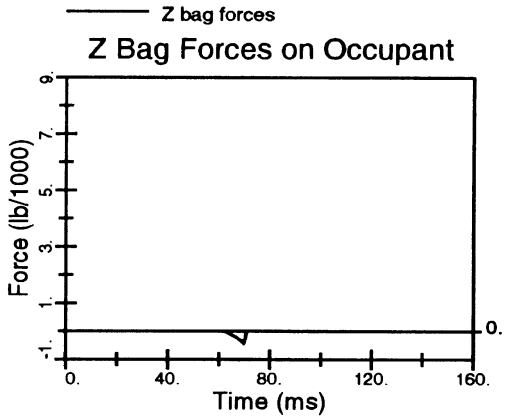
Figure 21.

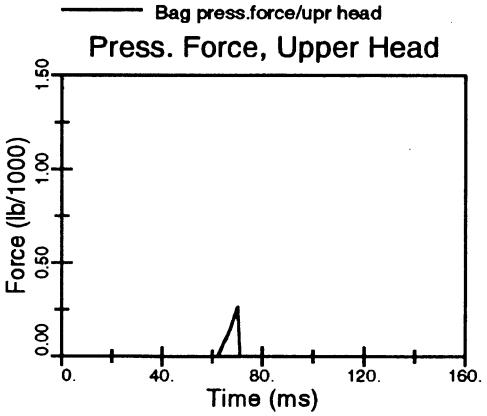
MVMA 2-D CVS Quasi-Finite Element Airbag Model

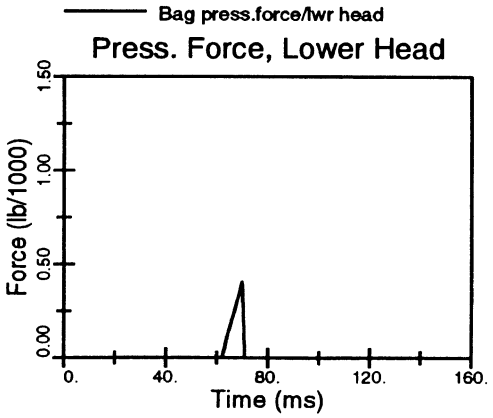
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







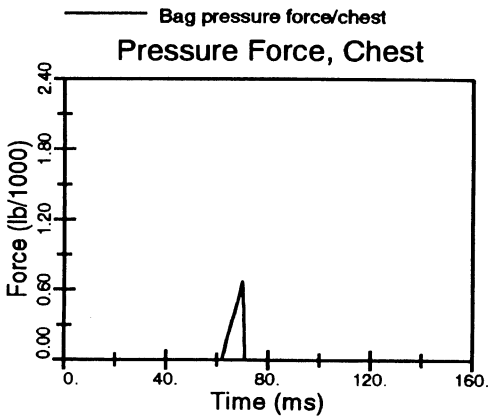


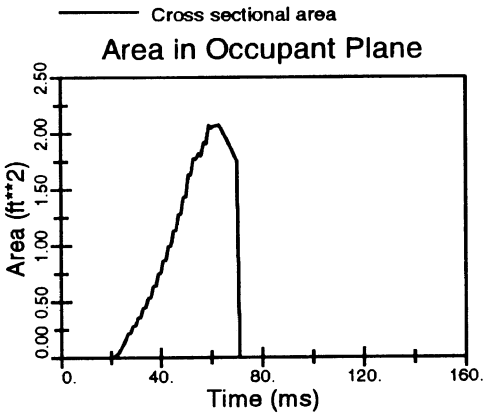
Figure 21.

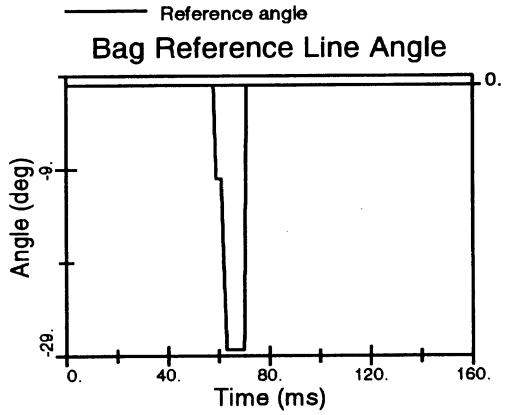
MVMA 2-D CVS Quasi-Finite Element Airbag Model

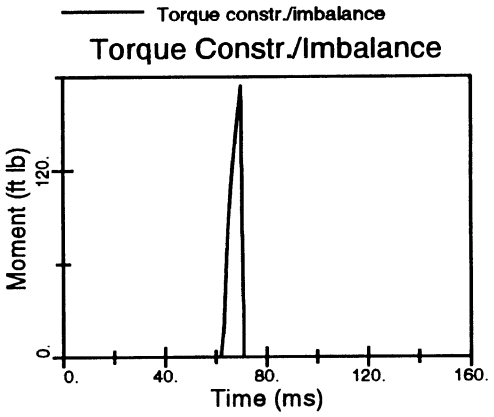
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

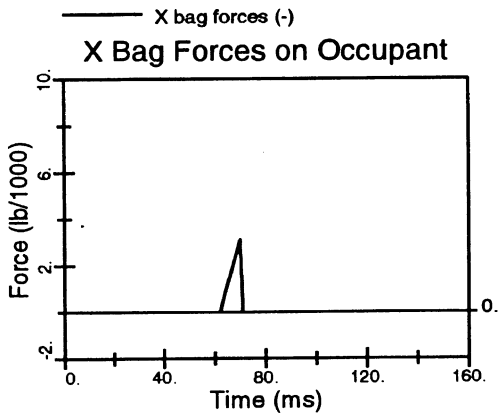
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









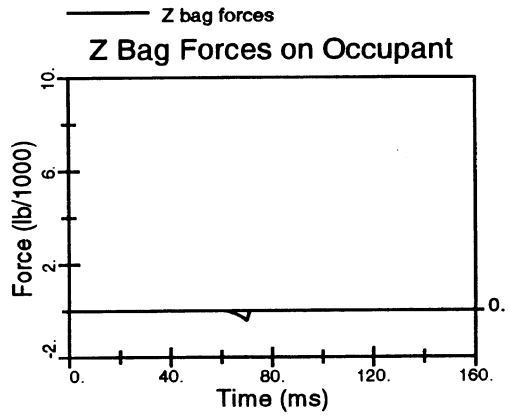


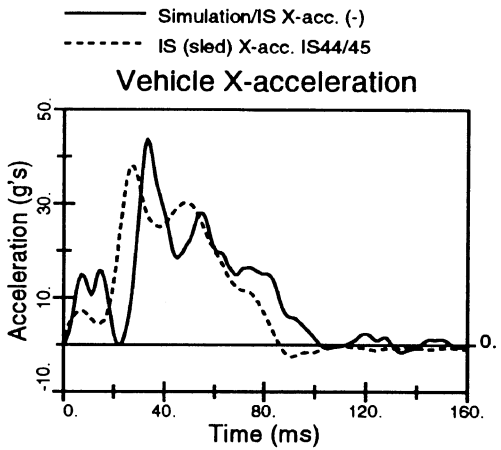
Figure 21.

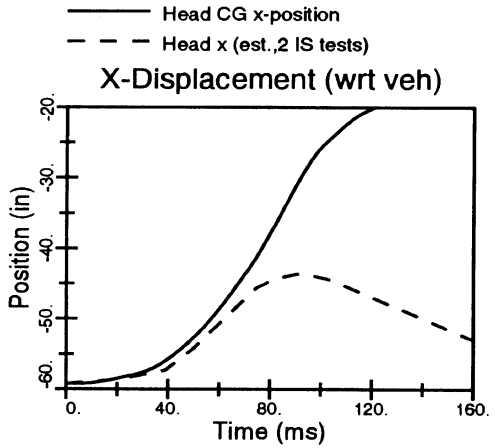
MVMA 2-D CVS Quasi-Finite Element Airbag Model

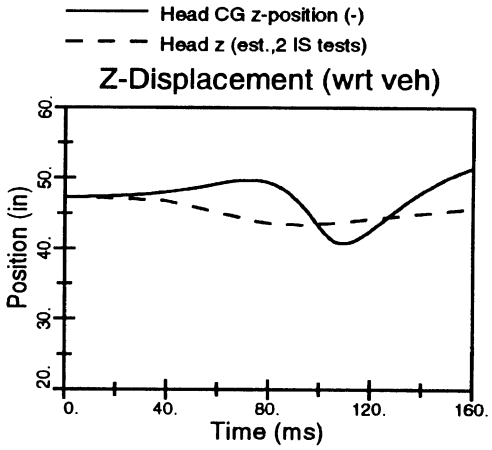
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

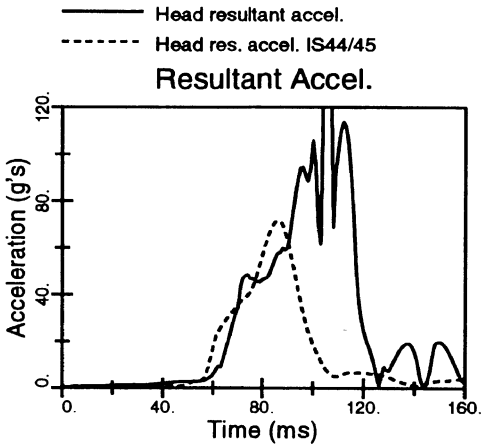
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

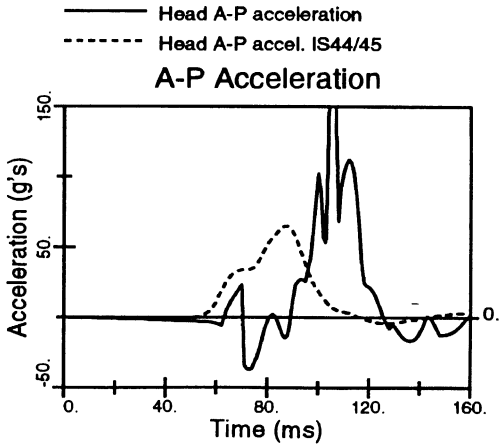
HEAD KINEMATIC RESPONSE











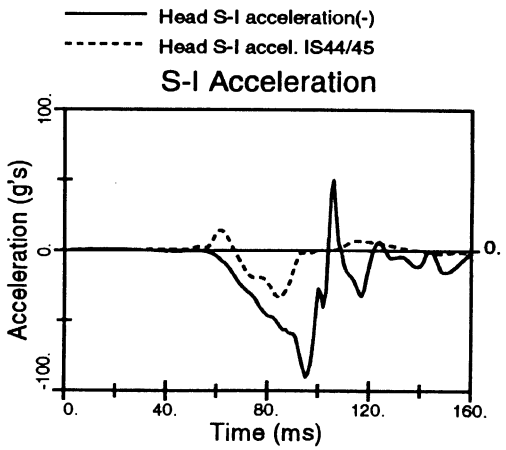


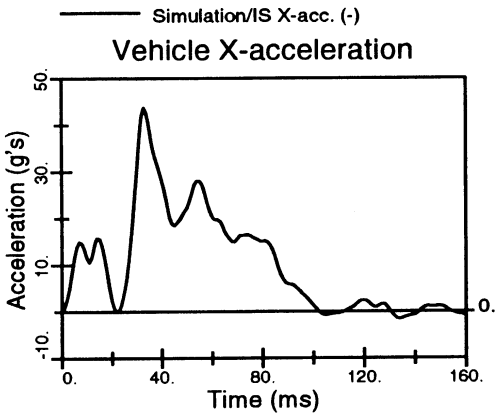
Figure 22.

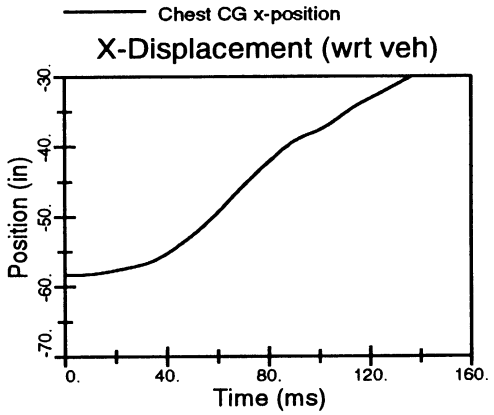
MVMA 2-D CVS Quasi-Finite Element Airbag Model

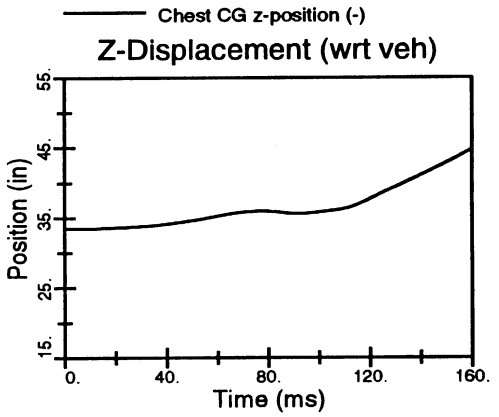
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

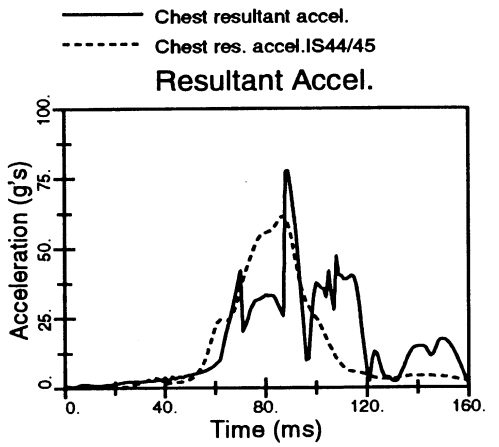
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

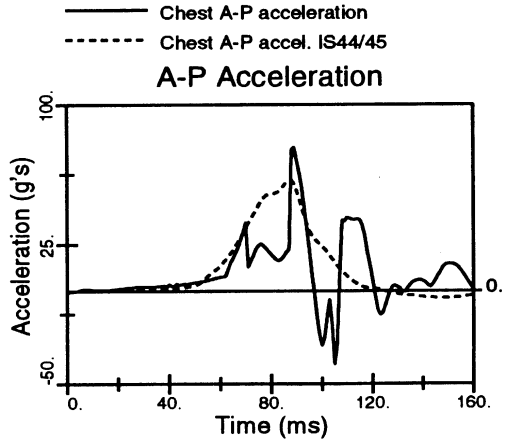
CHEST KINEMATIC RESPONSE











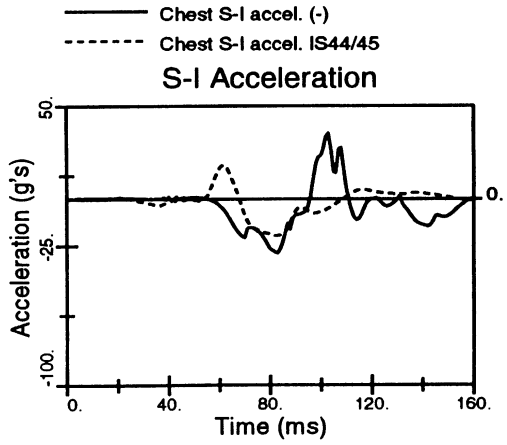


Figure 22.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

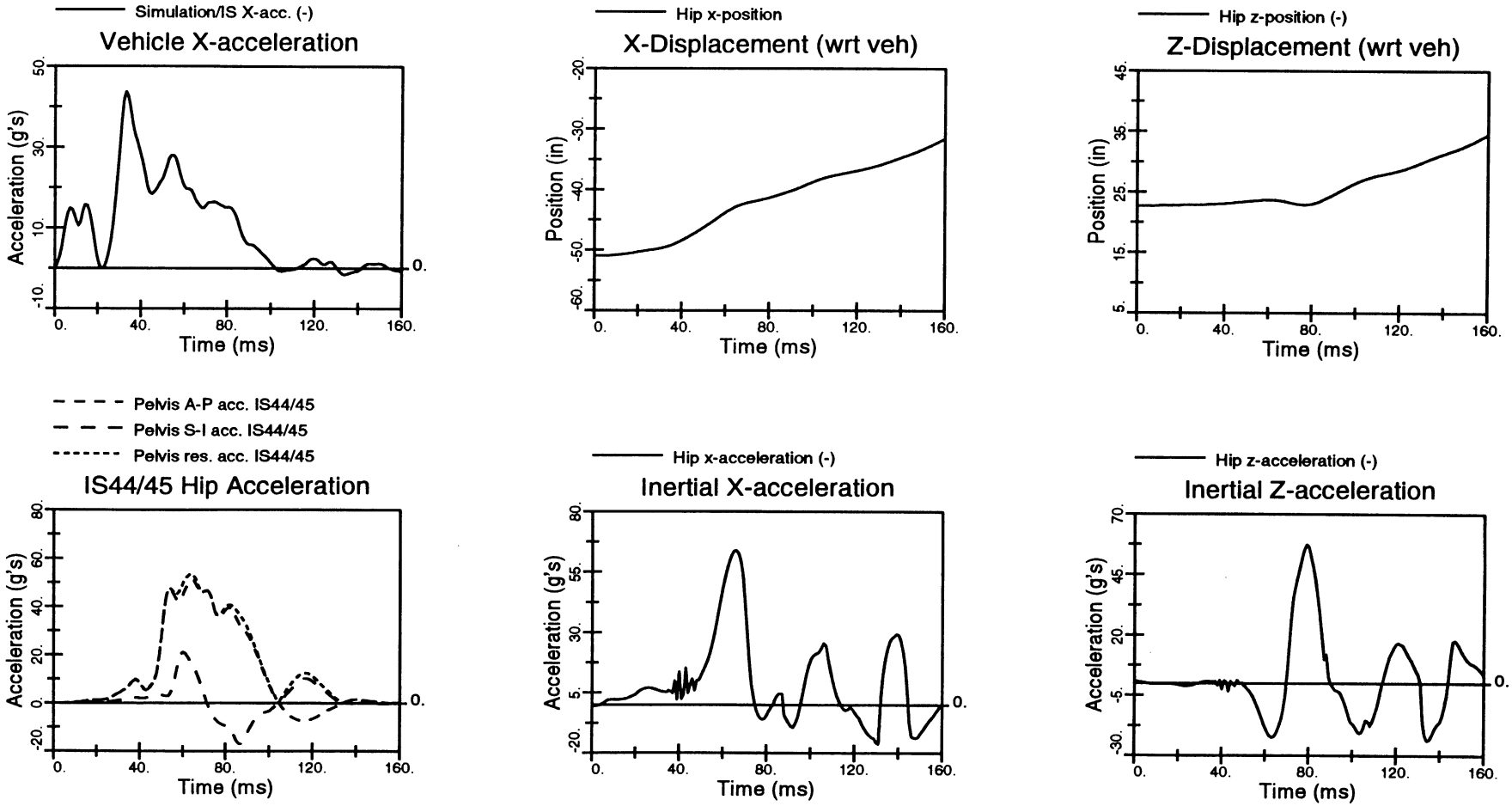


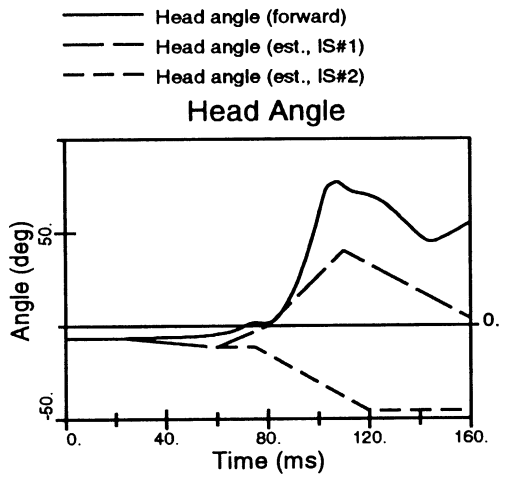
Figure 22.

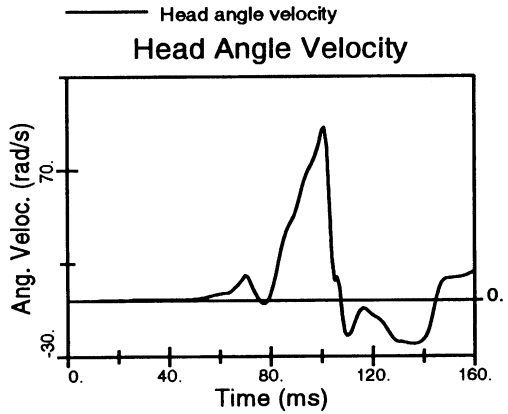
MVMA 2-D CVS Quasi-Finite Element Airbag Model

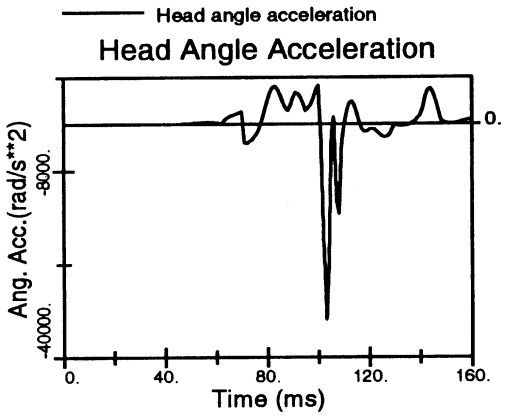
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

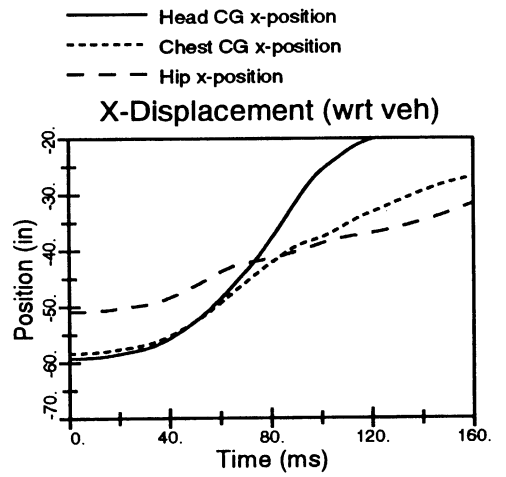
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

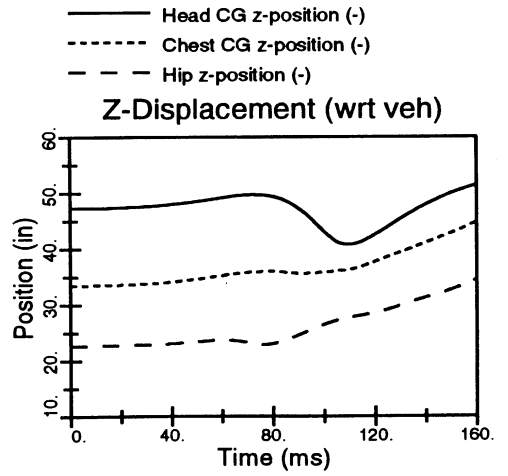
HEAD ANGULAR RESPONSE / OTHER RESPONSES











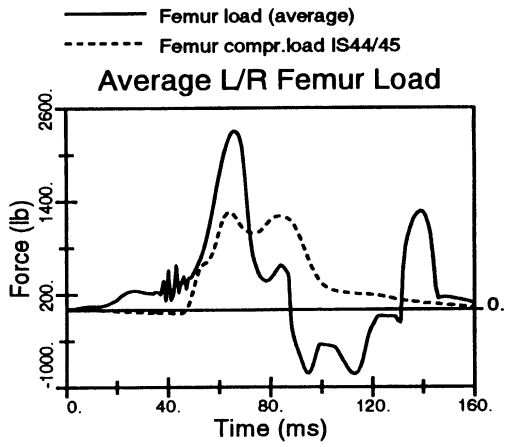


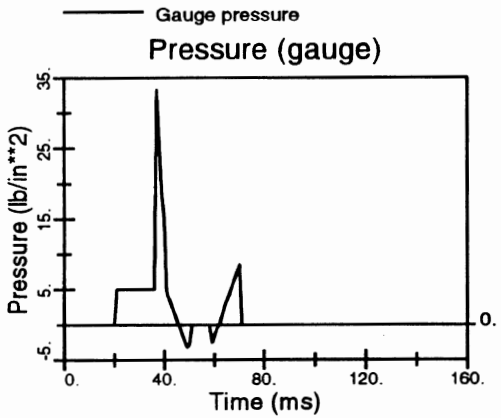
Figure 22.

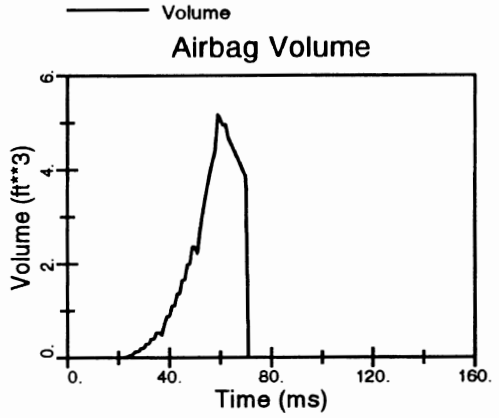
MVMA 2-D CVS Quasi-Finite Element Airbag Model

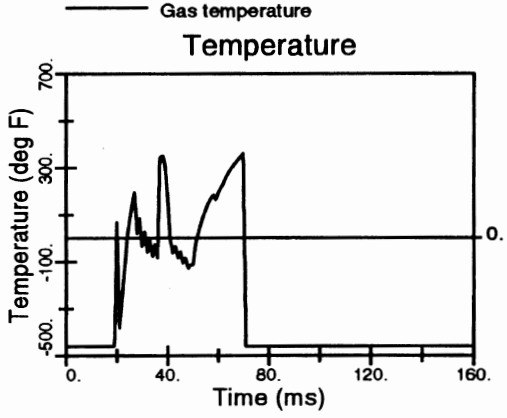
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

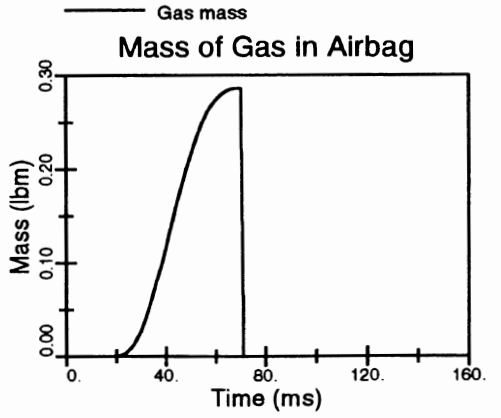
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

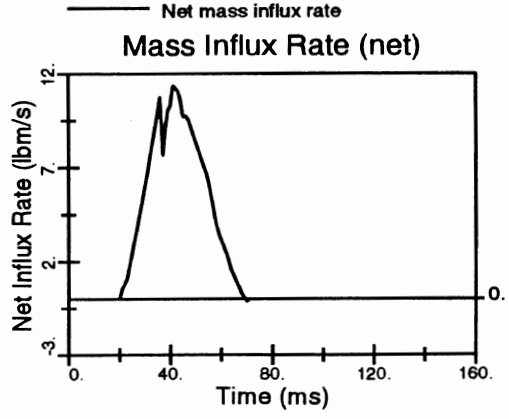
THERMODYNAMIC VARIABLES











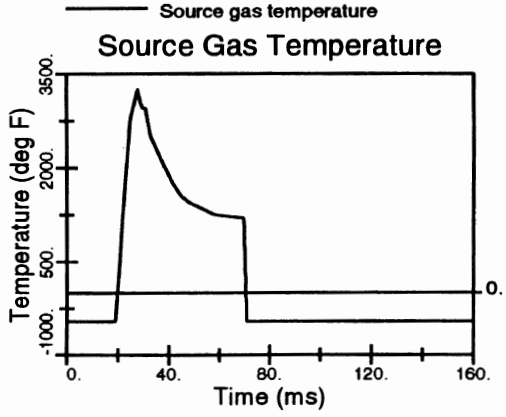


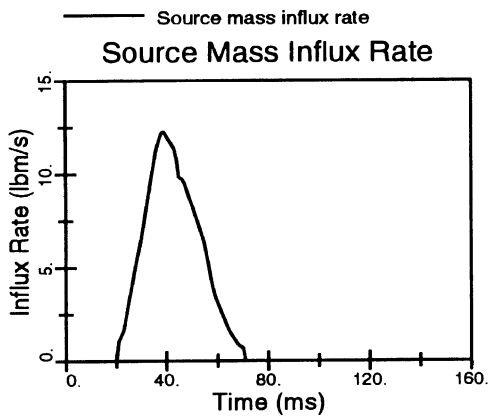
Figure 22.

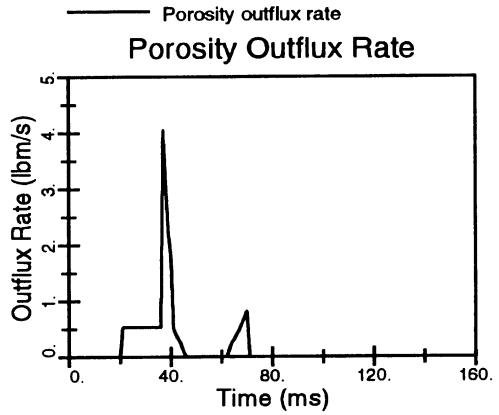
MVMA 2-D CVS Quasi-Finite Element Airbag Model

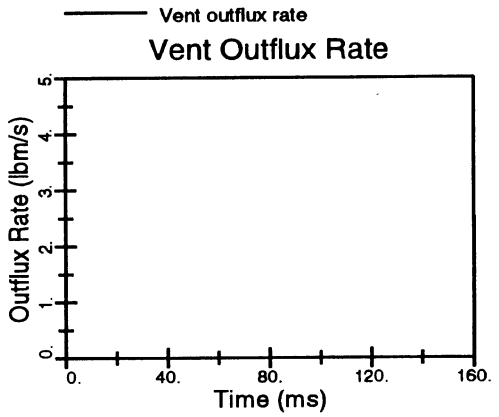
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

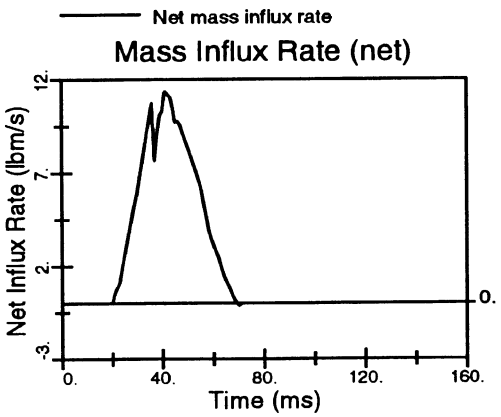
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

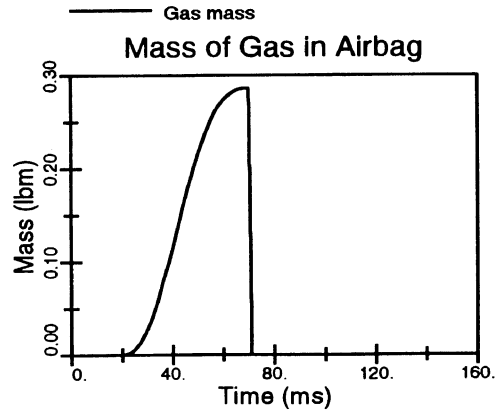
AIRBAG MASS INFLUX/OUTFLUX











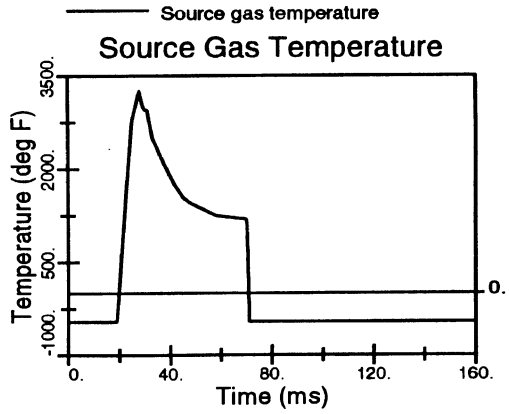


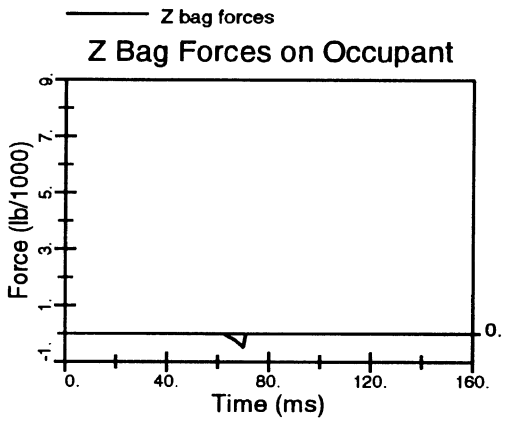
Figure 22.

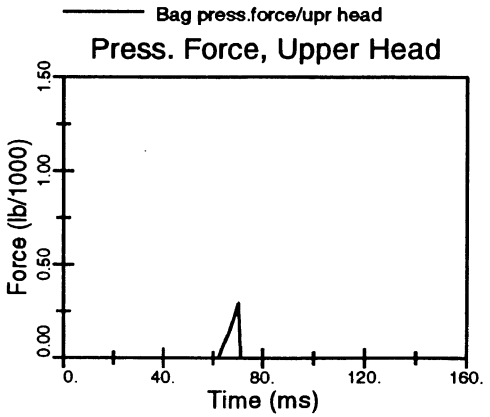
MVMA 2-D CVS Quasi-Finite Element Airbag Model

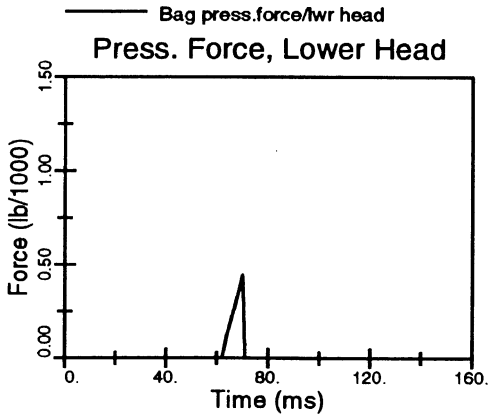
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







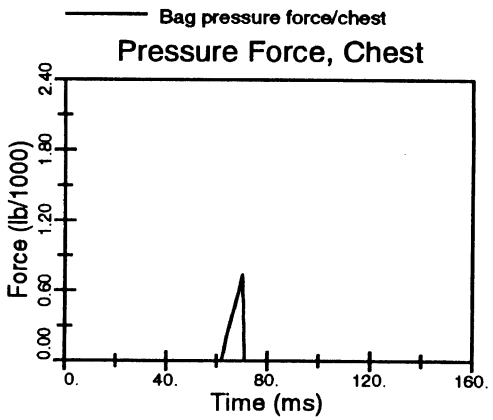


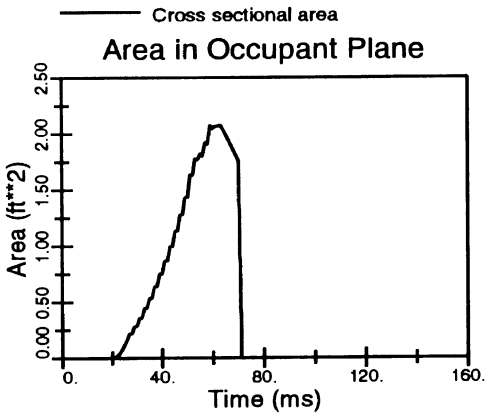
Figure 22.

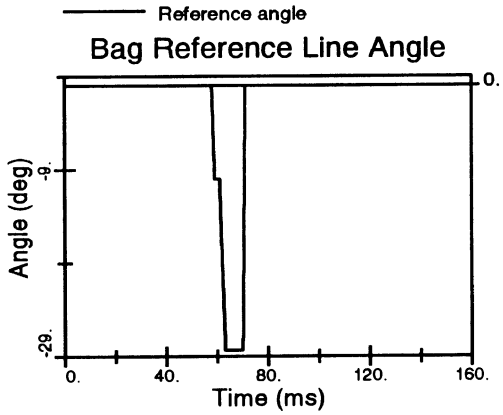
MVMA 2-D CVS Quasi-Finite Element Airbag Model

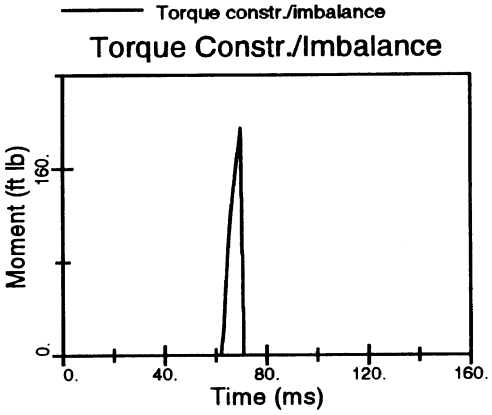
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with VC X-acceleration and fixed, 9-degree vehicle pitch , Tests IS11144/45

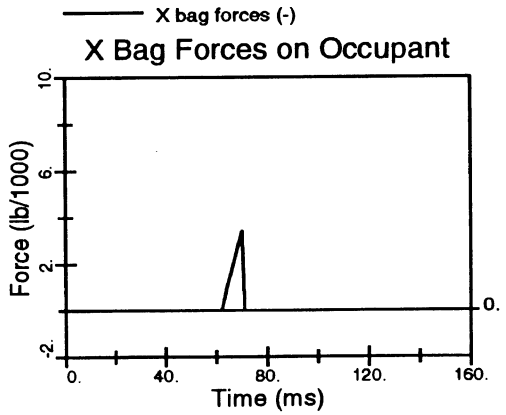
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









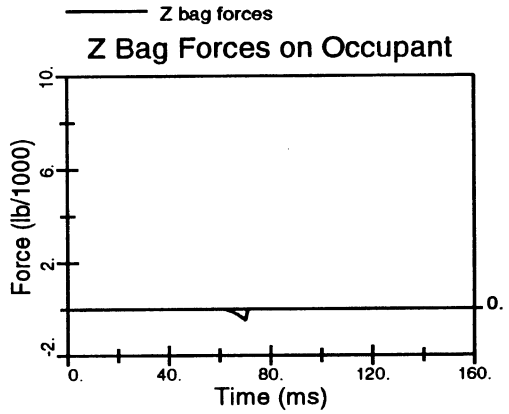


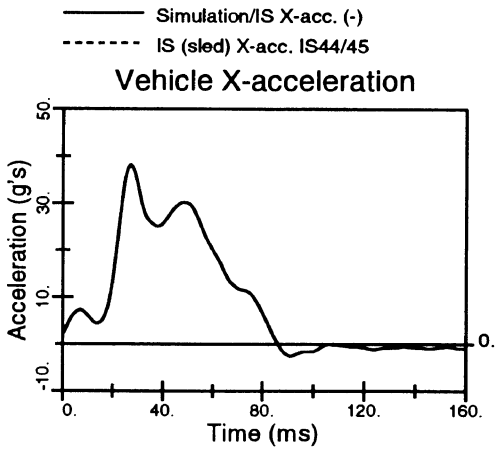
Figure 22.

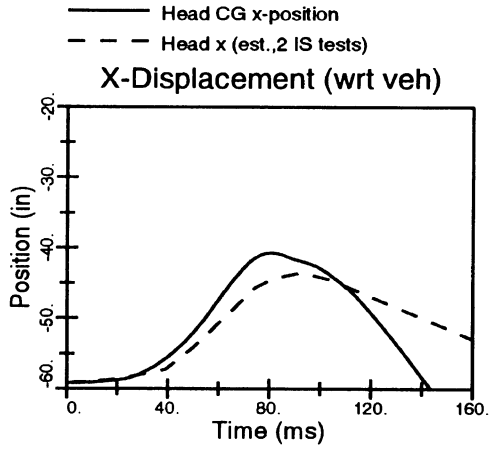
MVMA 2-D CVS Quasi-Finite Element Airbag Model

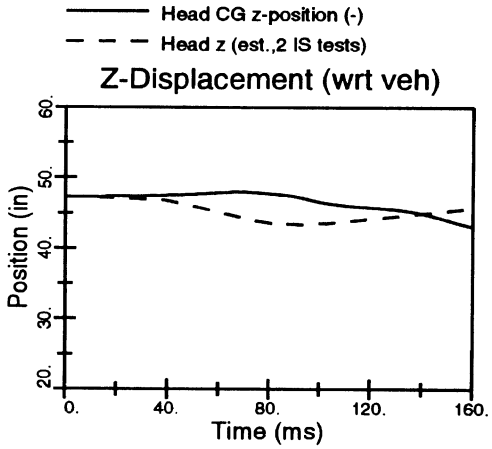
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

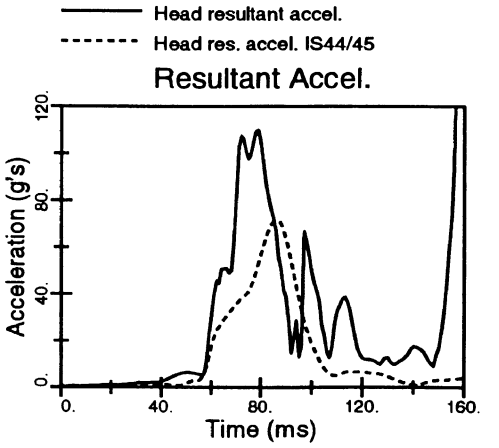
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

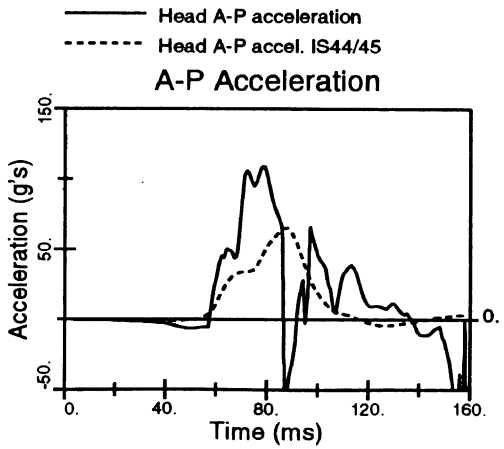
HEAD KINEMATIC RESPONSE











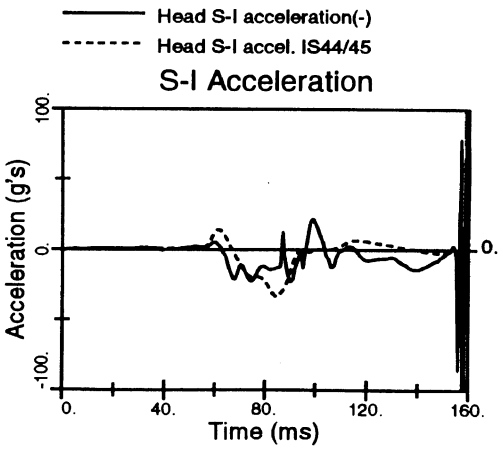


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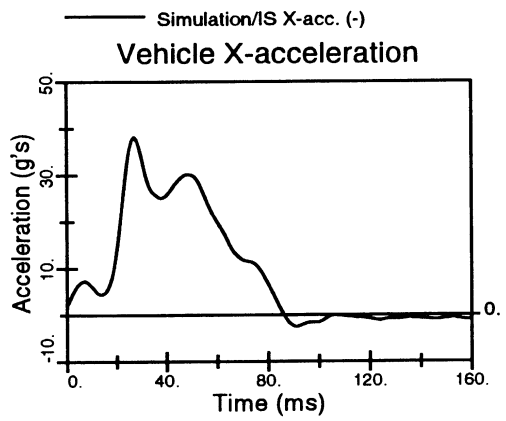
Figure 23.

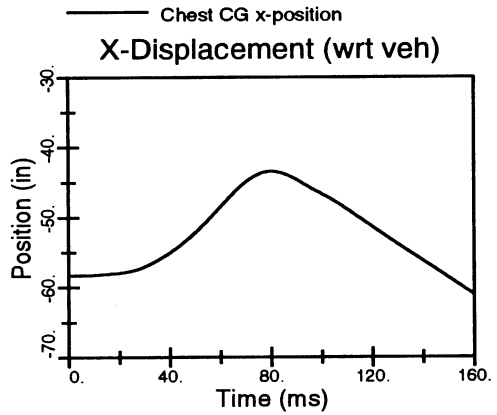
MVMA 2-D CVS Quasi-Finite Element Airbag Model

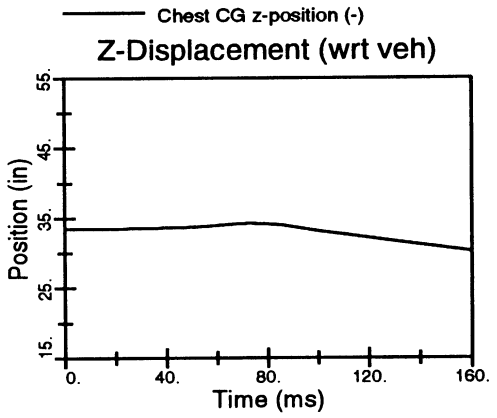
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

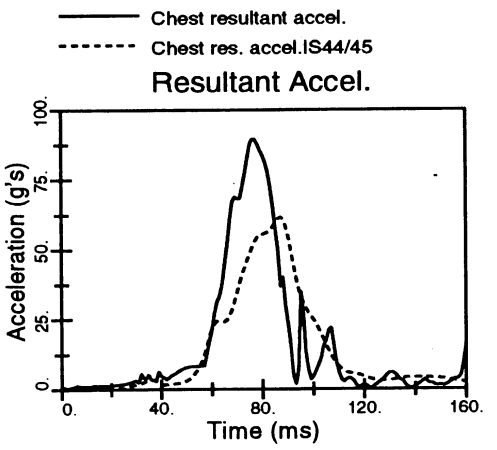
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

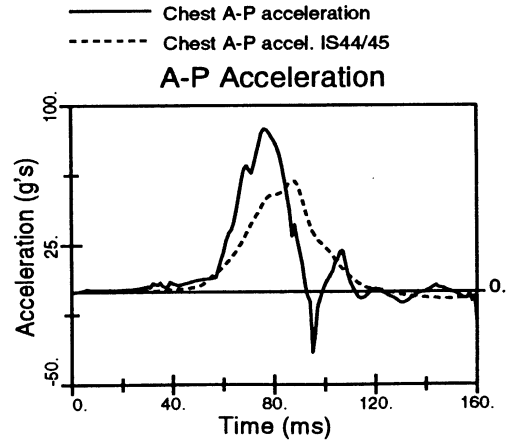
CHEST KINEMATIC RESPONSE











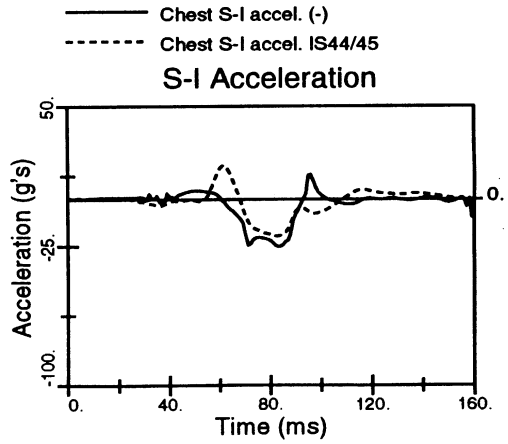


Figure 23.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

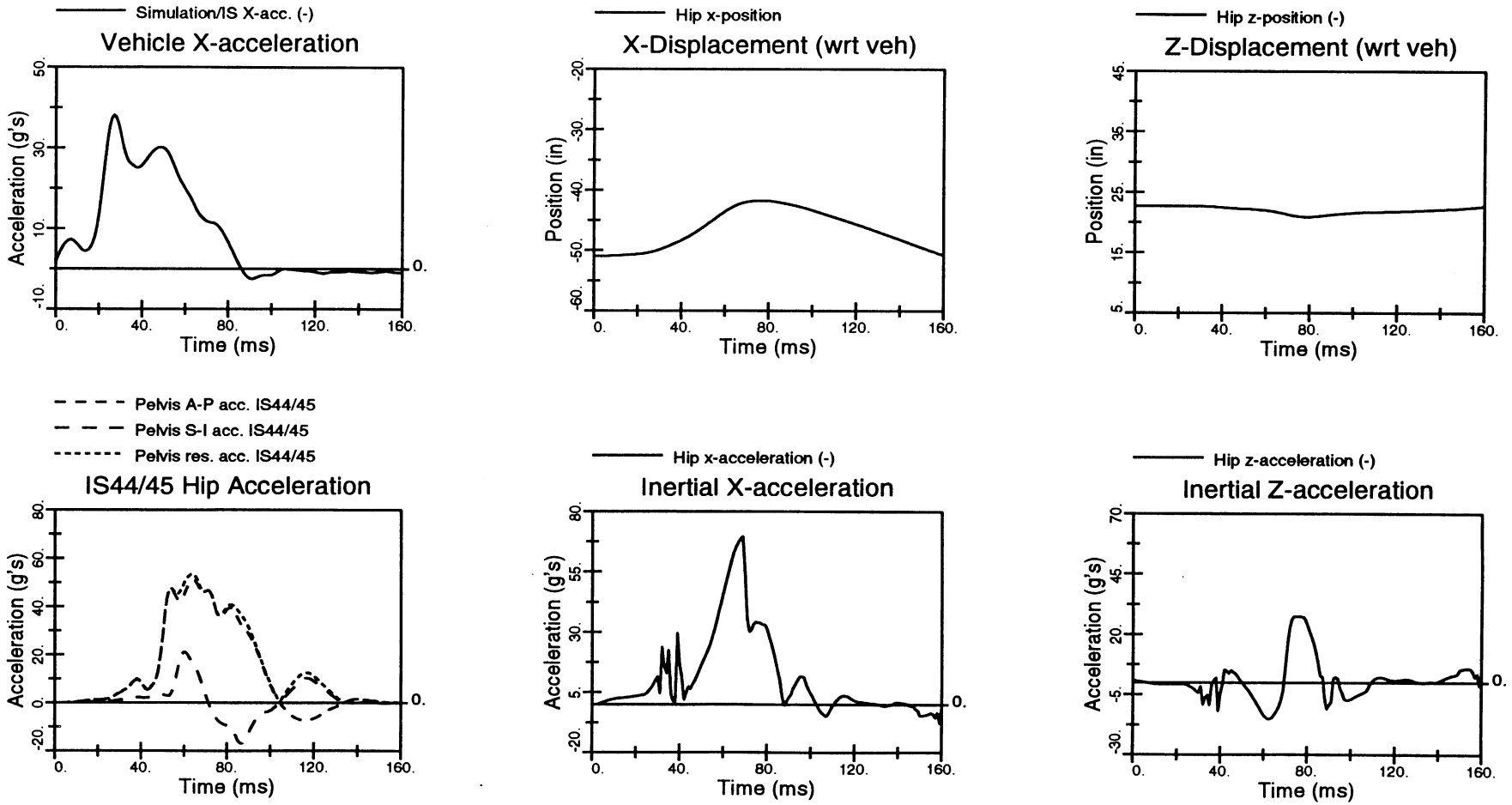


Figure 23.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

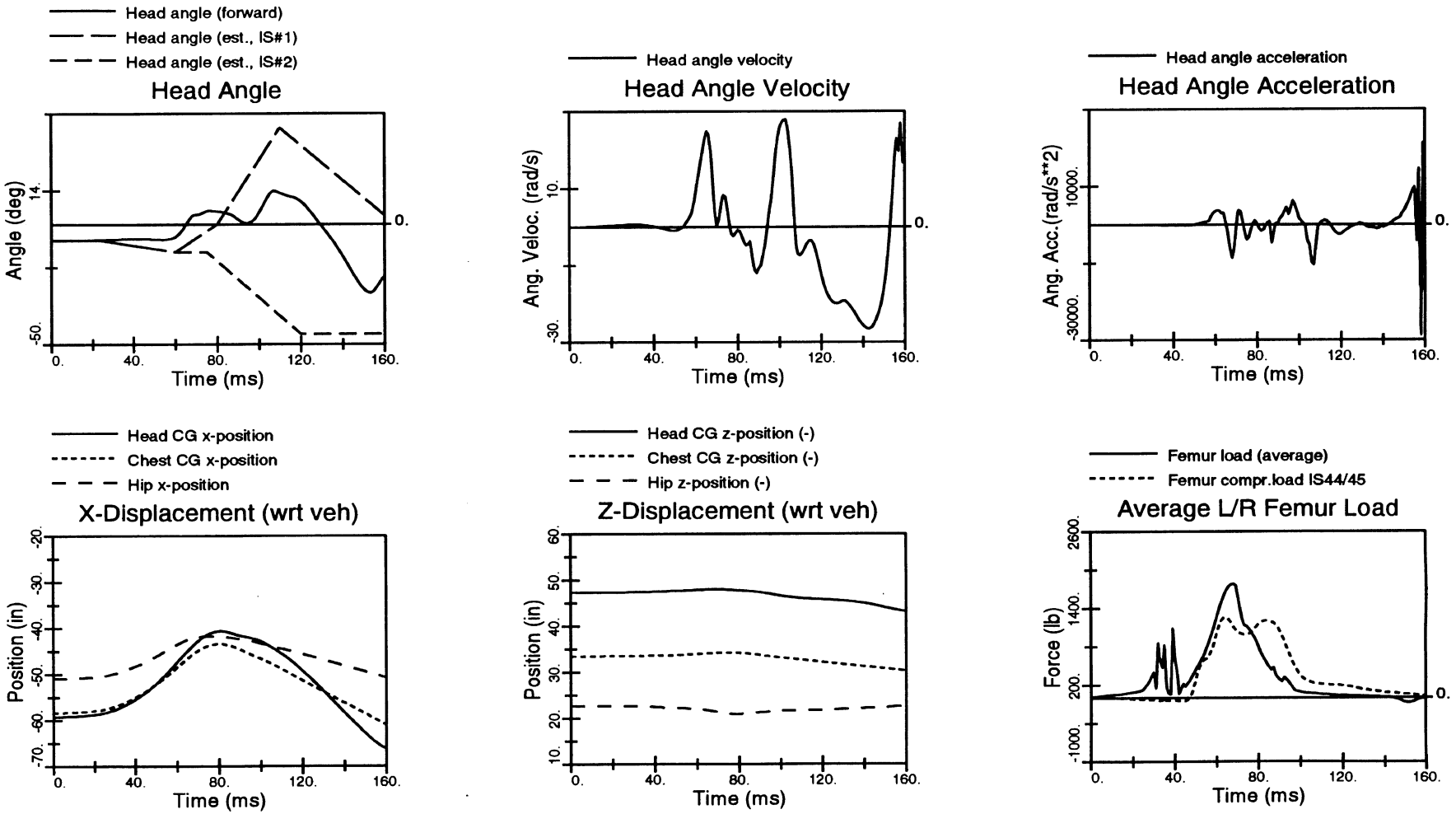


Figure 23.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

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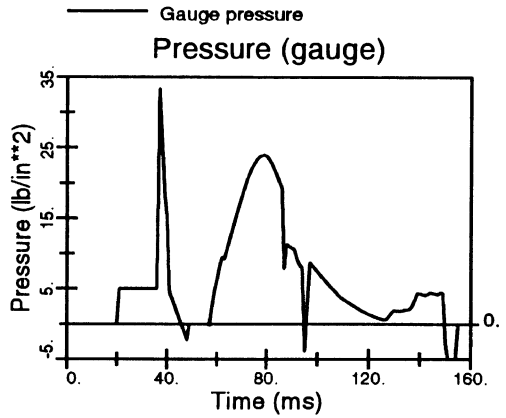
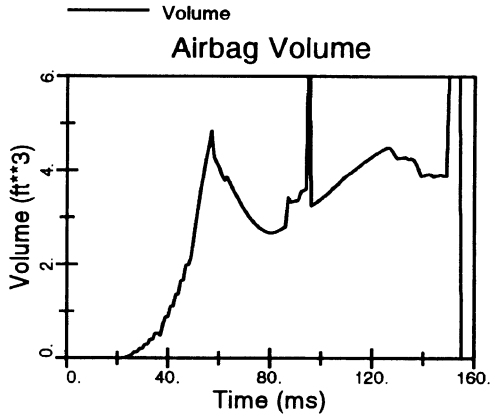
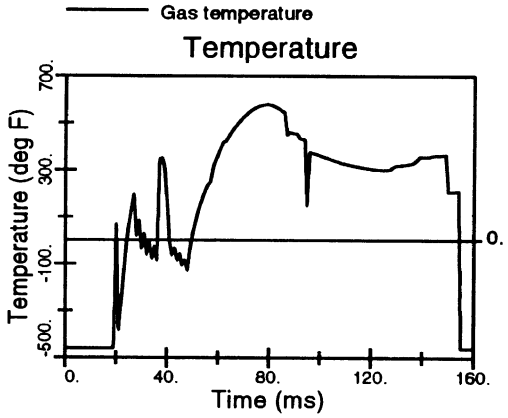
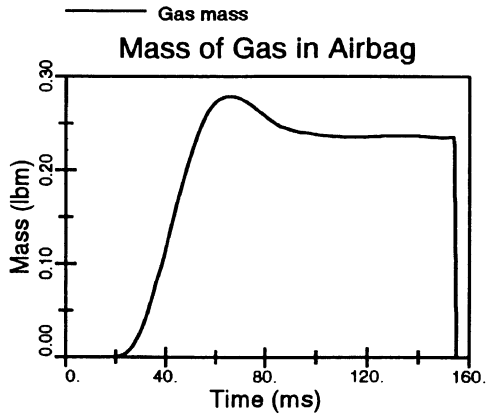
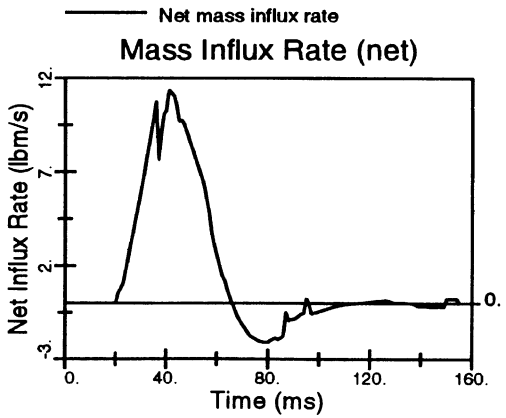
THERMODYNAMIC VARIABLES











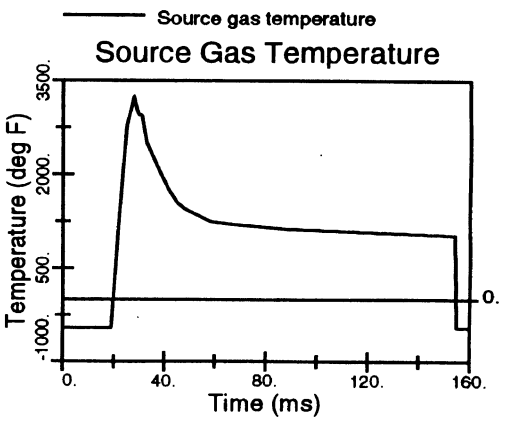


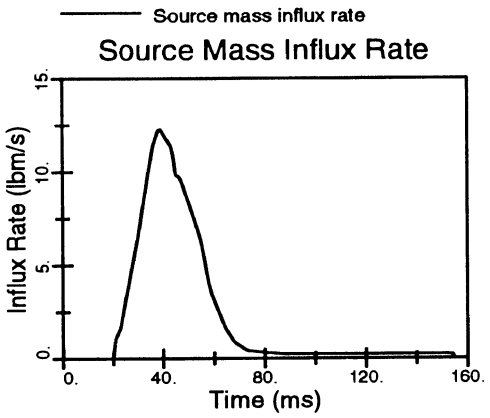
Figure 23.

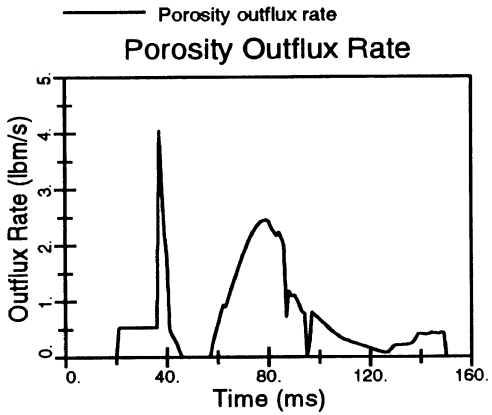
MVMA 2-D CVS Quasi-Finite Element Airbag Model

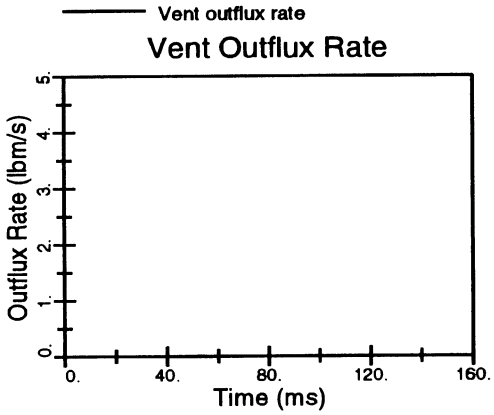
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

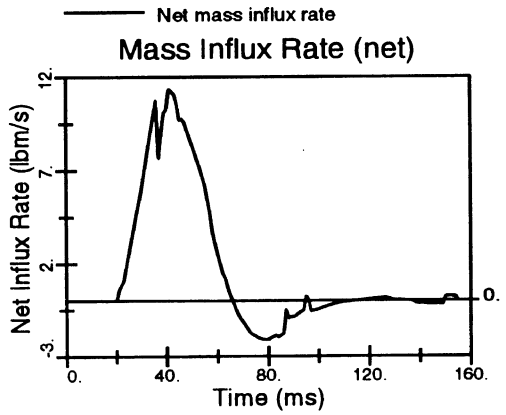
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

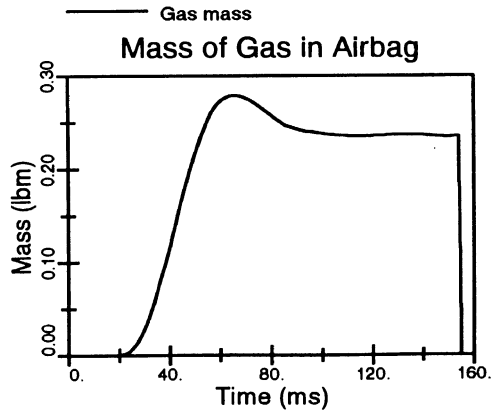
AIRBAG MASS INFLUX/OUTFLUX











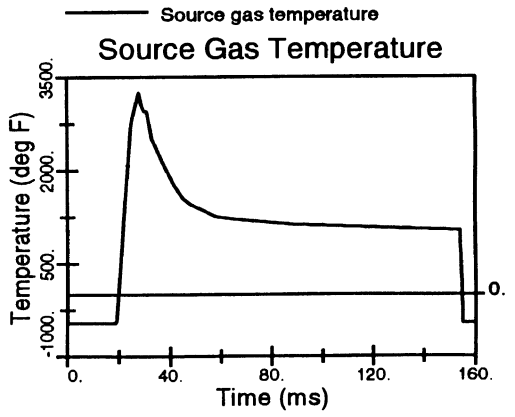


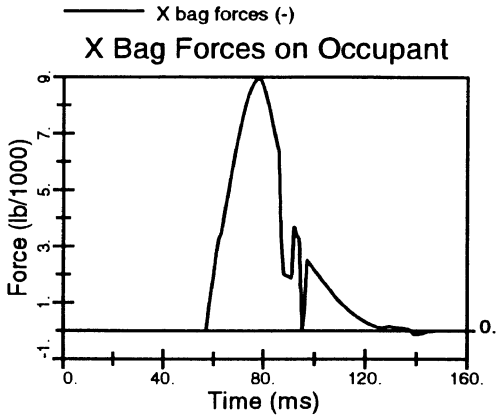
Figure 23.

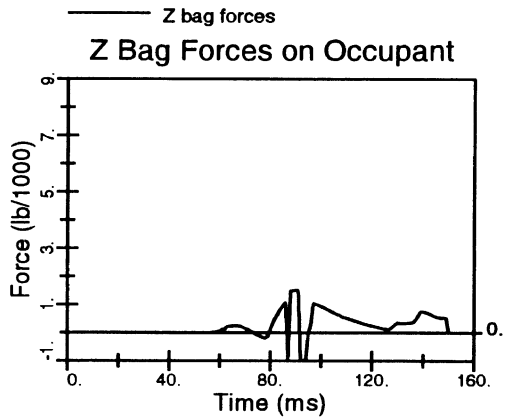
MVMA 2-D CVS Quasi-Finite Element Airbag Model

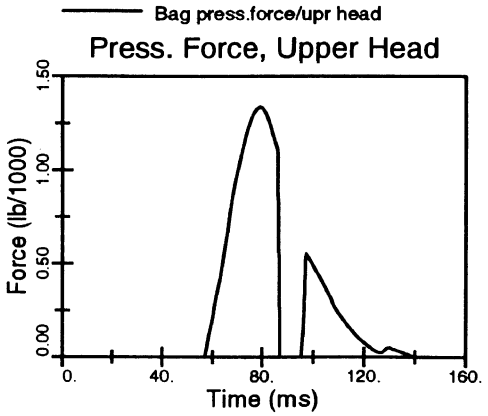
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

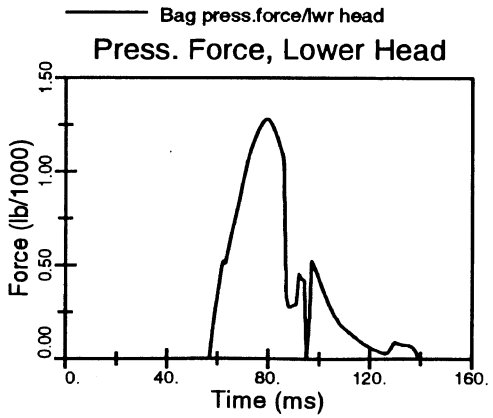
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









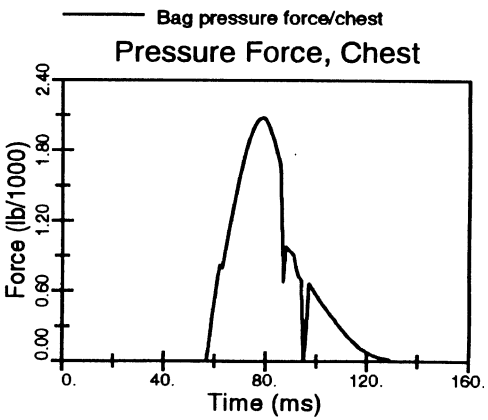


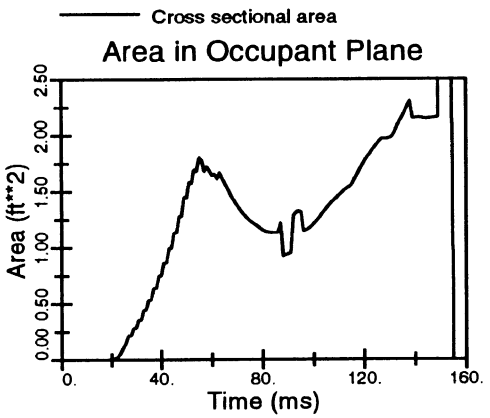
Figure 23.

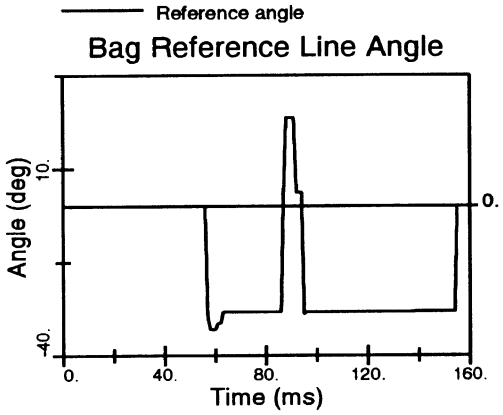
MVMA 2-D CVS Quasi-Finite Element Airbag Model

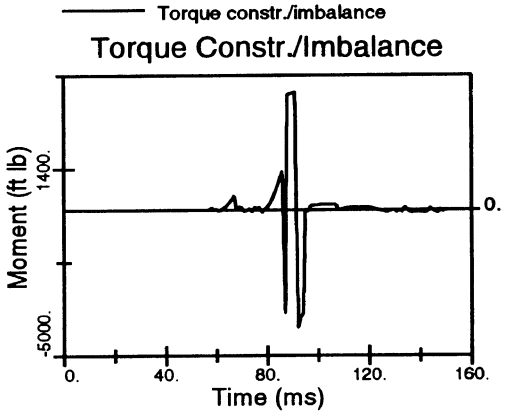
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with occupant surfaces 2" forward , Tests IS11144/45

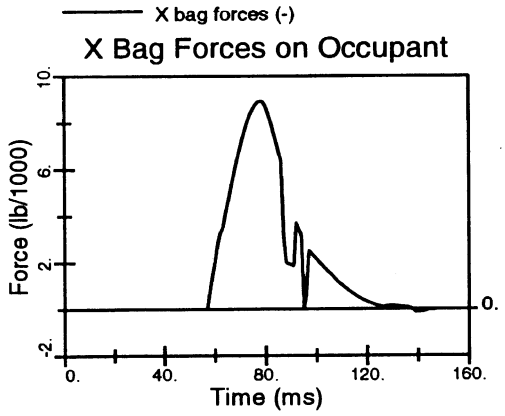
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









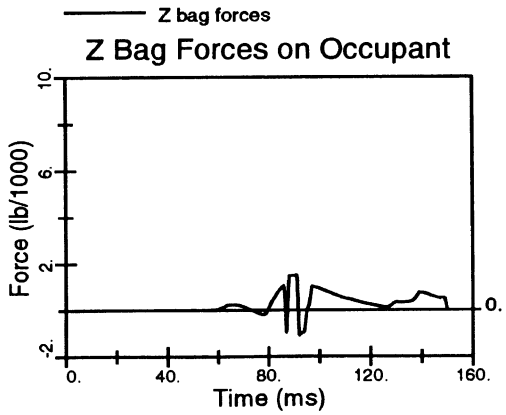


Figure 23.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

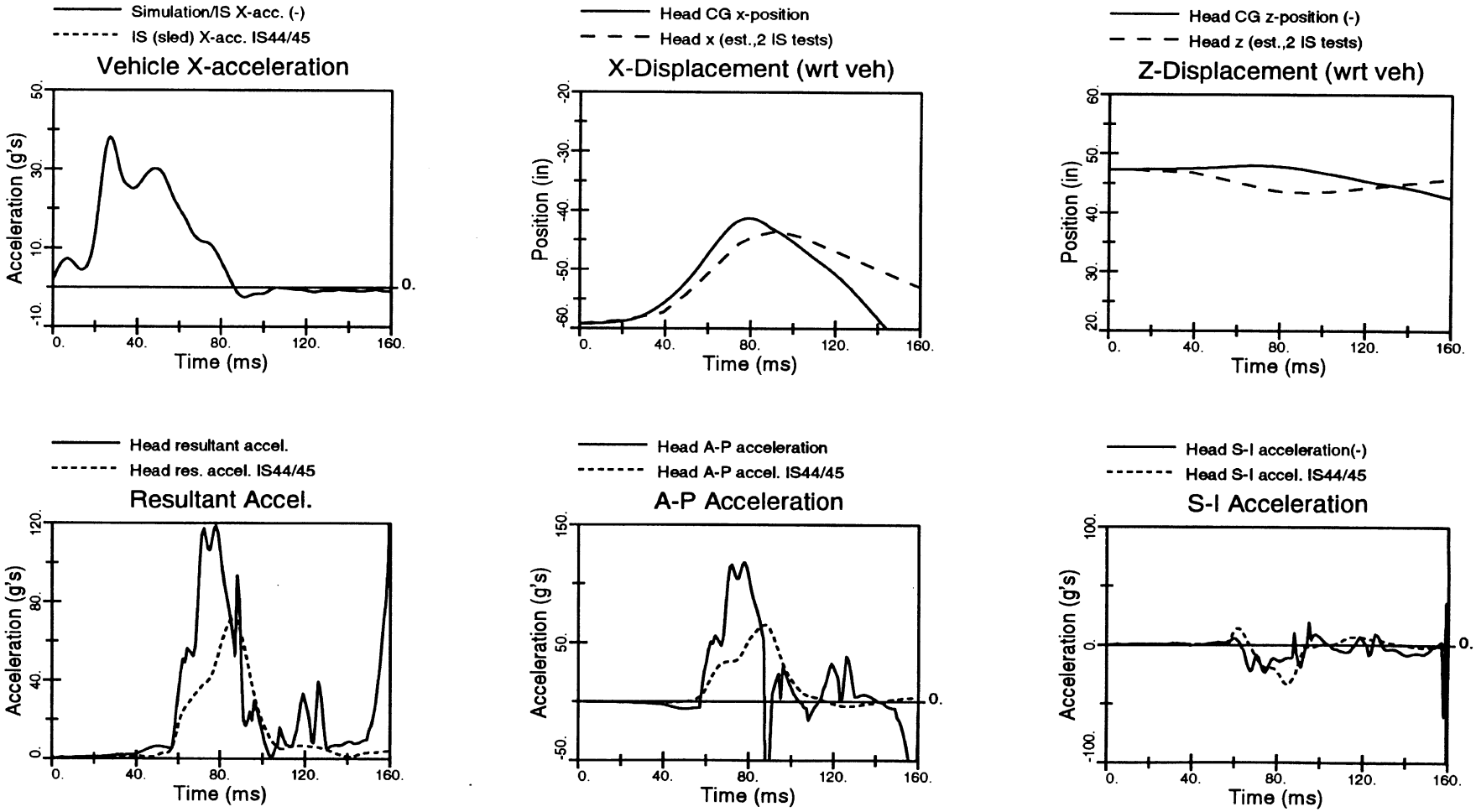


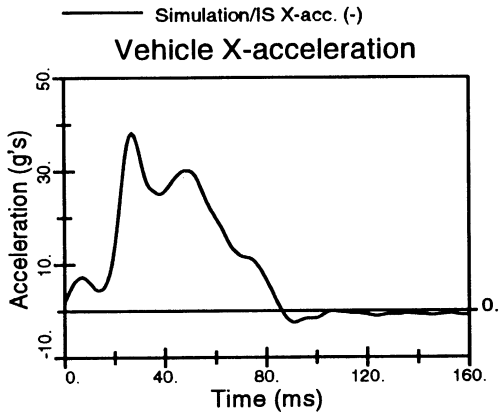
Figure 24.

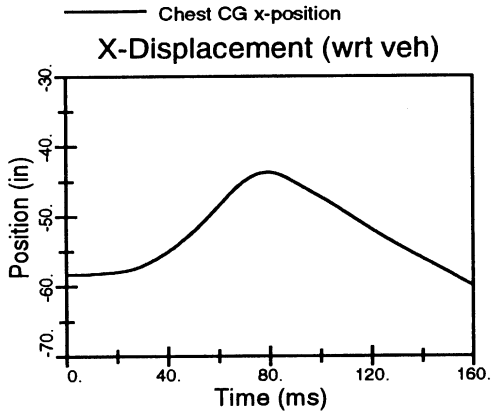
MVMA 2-D CVS Quasi-Finite Element Airbag Model

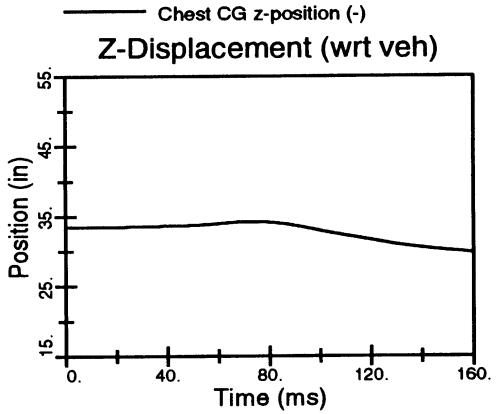
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

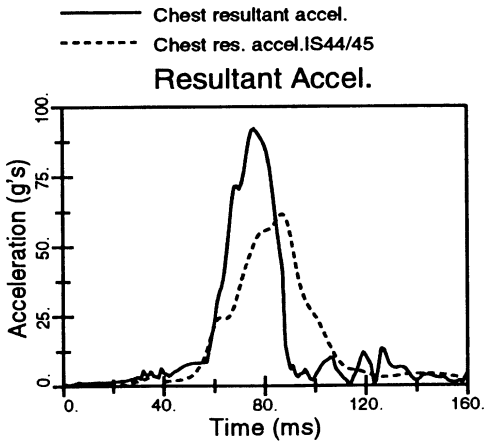
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

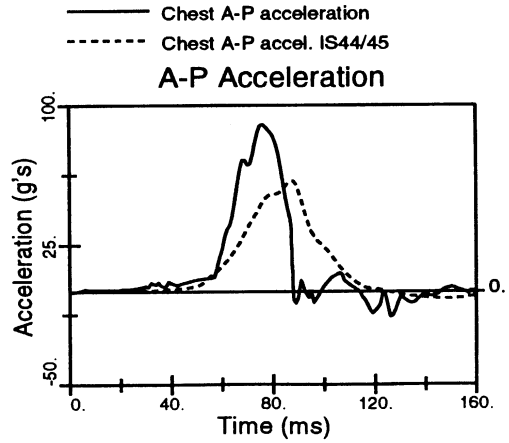
CHEST KINEMATIC RESPONSE











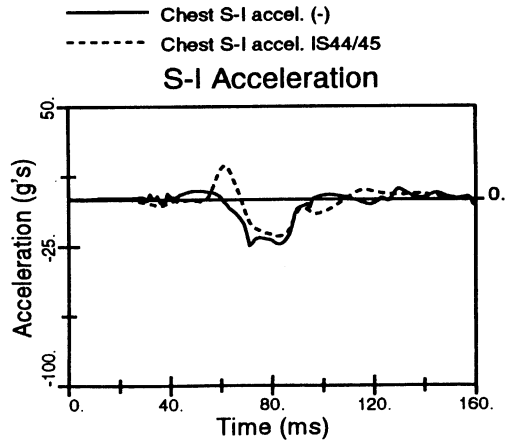


Figure 24.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

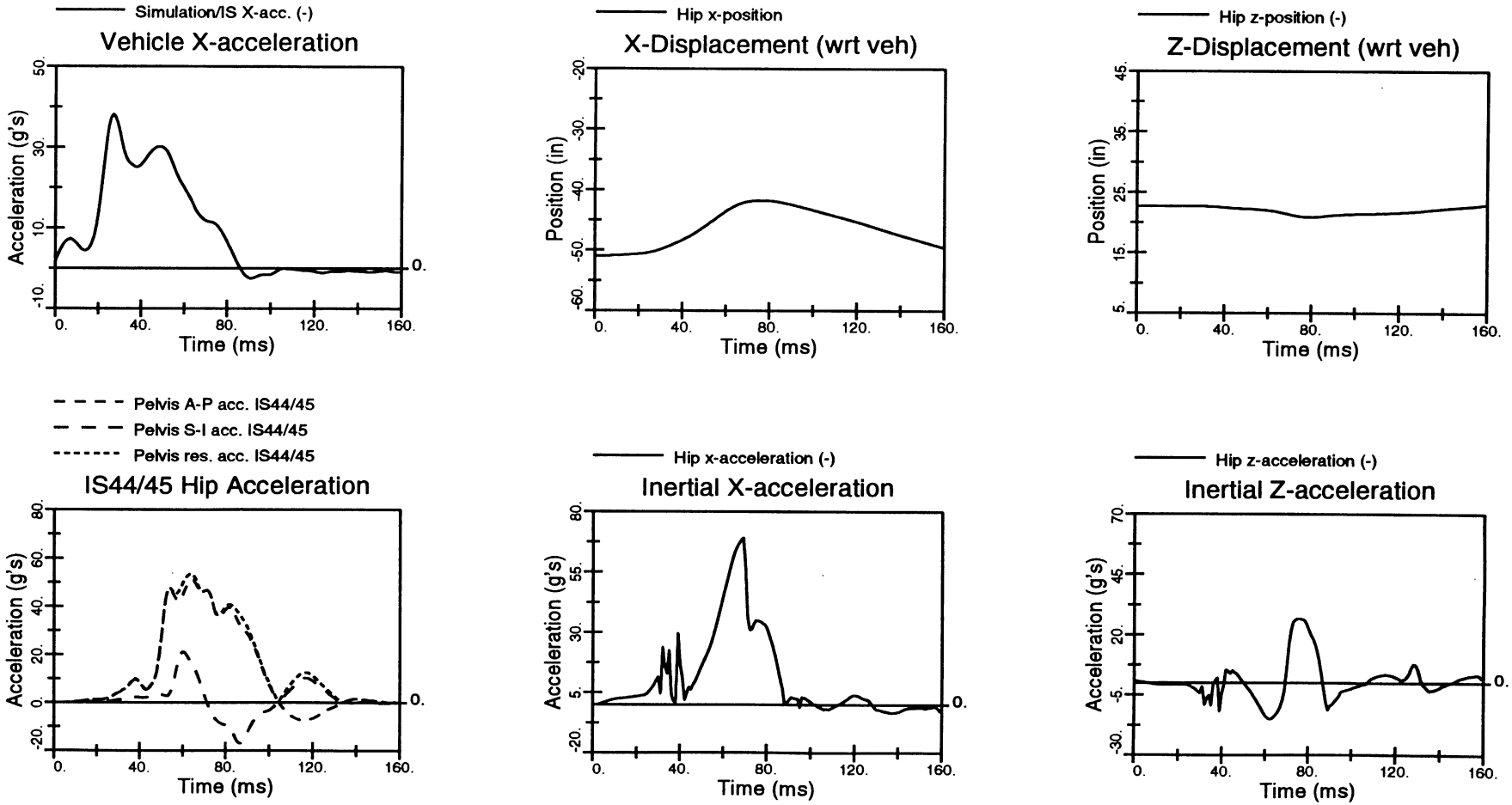


Figure 24.

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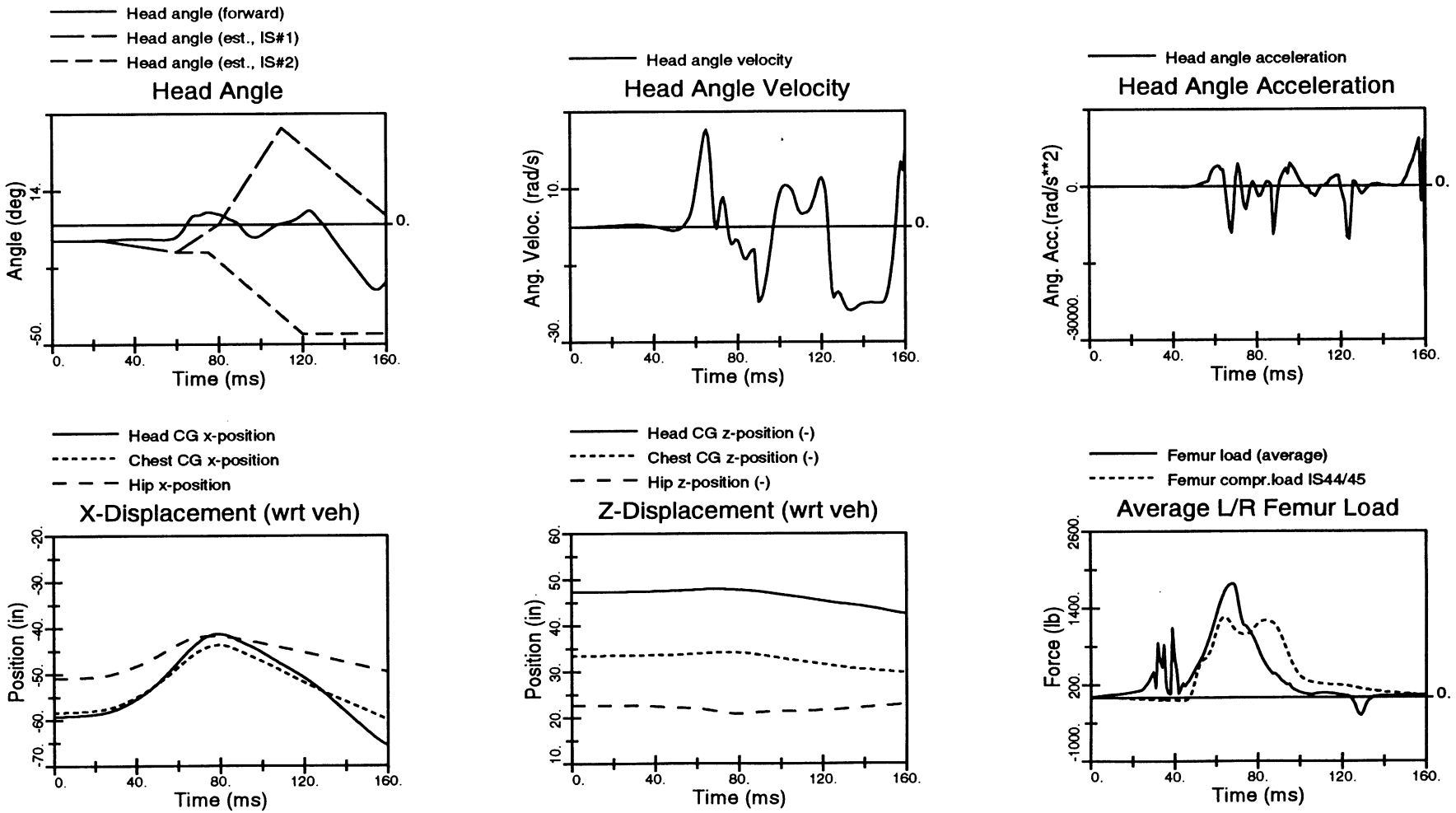


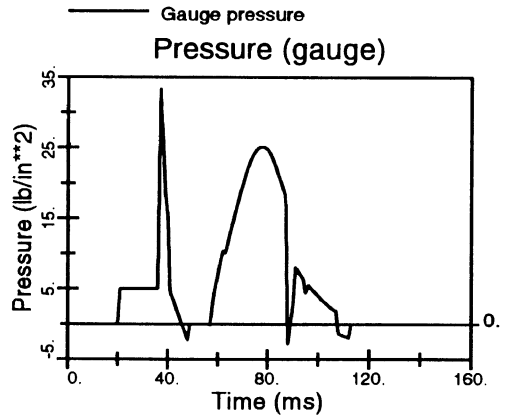
Figure 24.

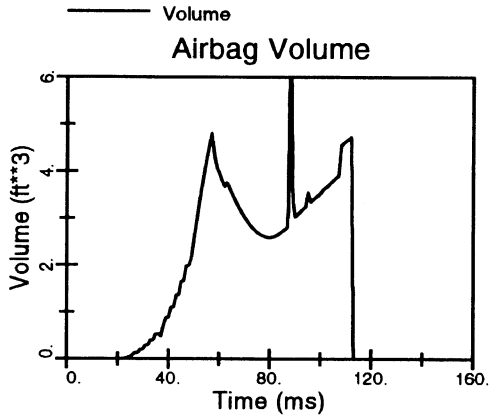
MVMA 2-D CVS Quasi-Finite Element Airbag Model

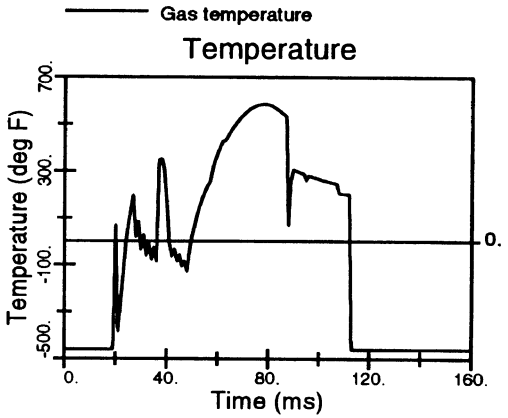
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

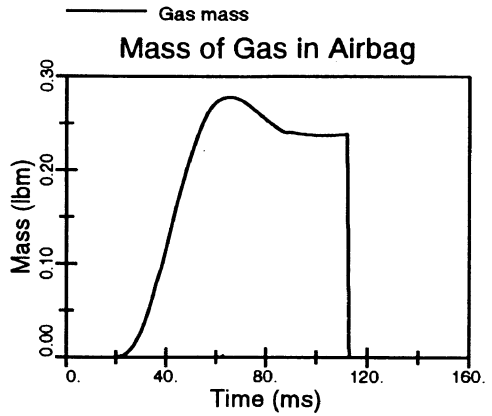
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

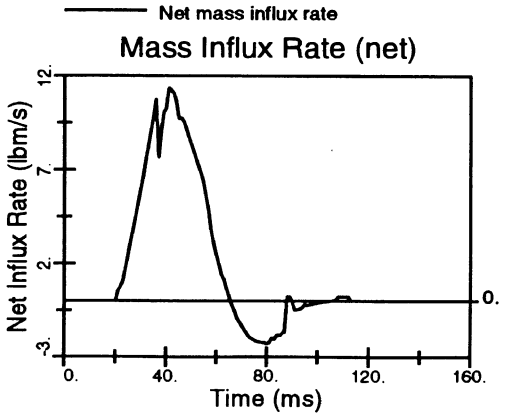
THERMODYNAMIC VARIABLES











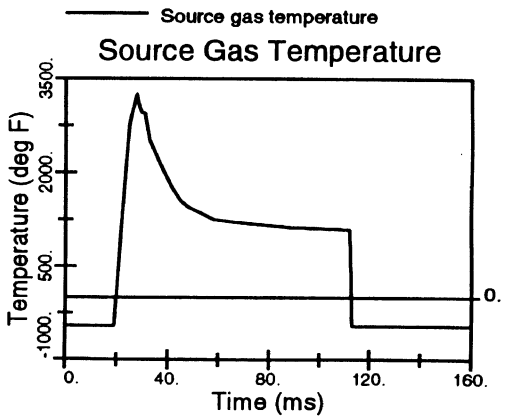


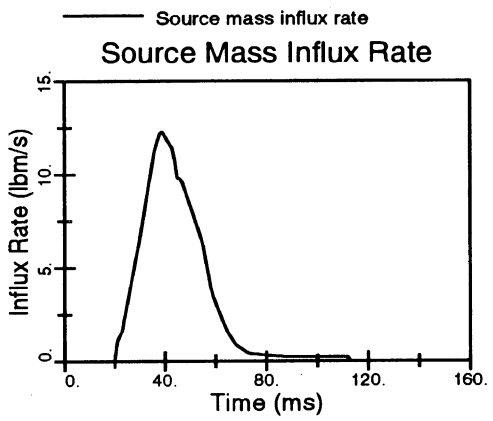
Figure 24.

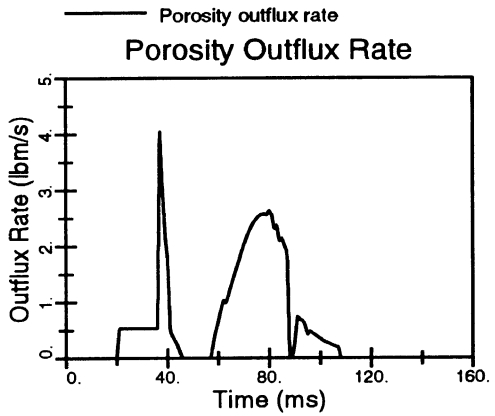
MVMA 2-D CVS Quasi-Finite Element Airbag Model

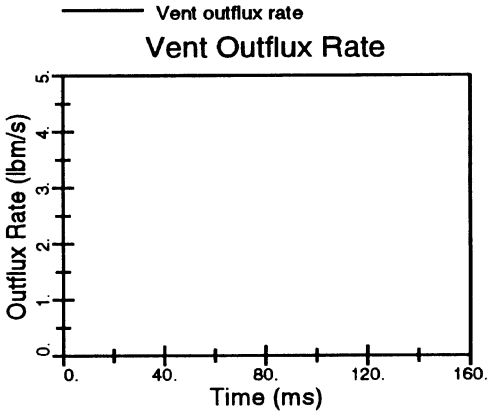
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

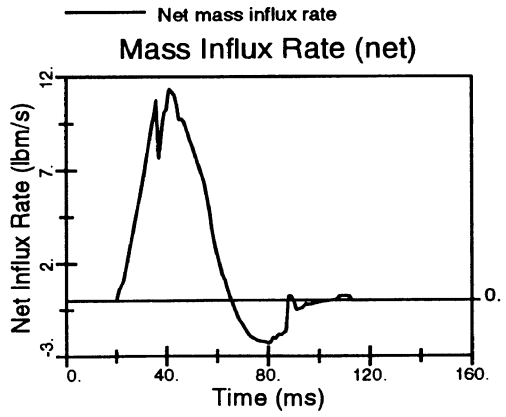
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

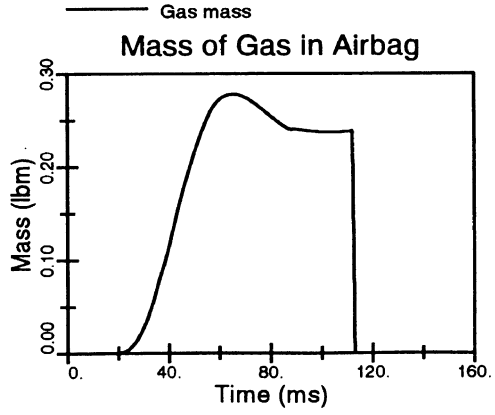
AIRBAG MASS INFLUX/OUTFLUX











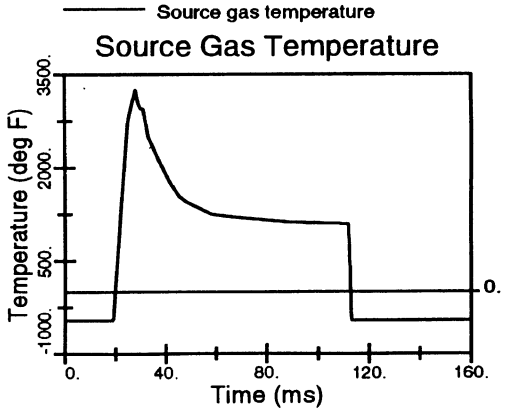


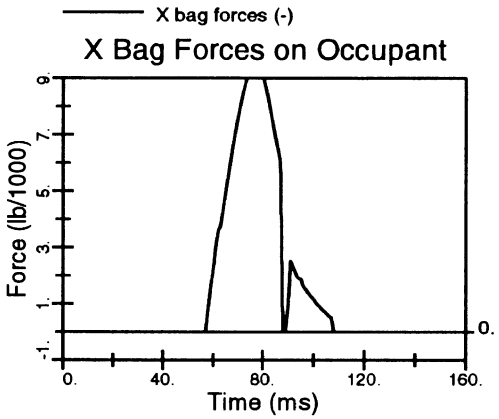
Figure 24.

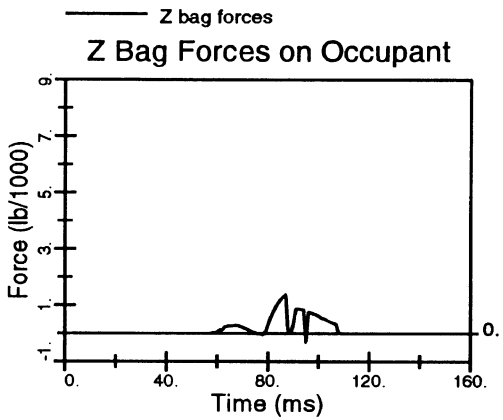
MVMA 2-D CVS Quasi-Finite Element Airbag Model

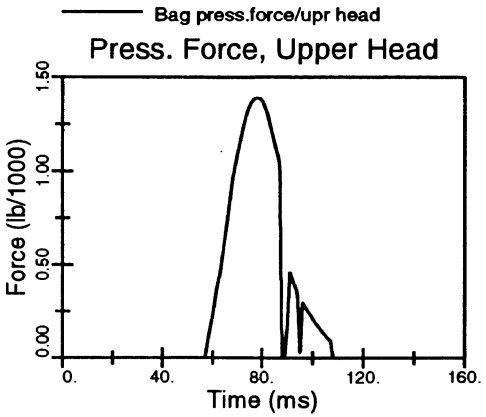
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with occupant surfaces 2" forward , Tests IS11144/45

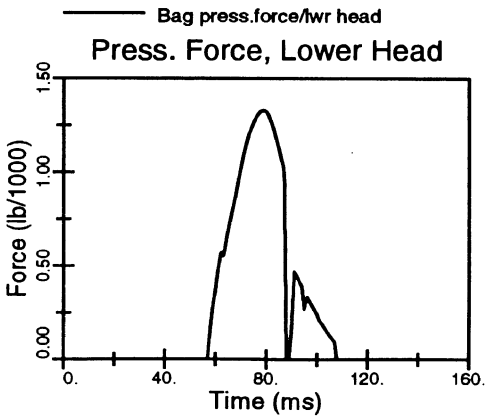
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

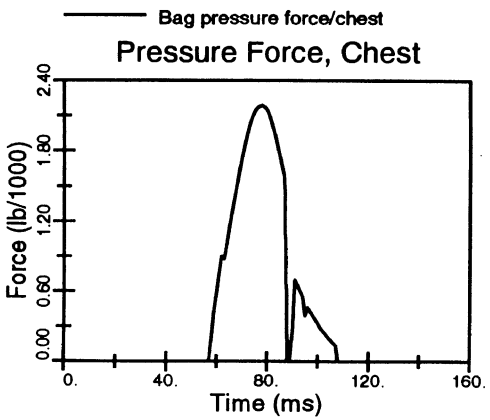
AIRBAG FORCES (SUMMARY)











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MVMA 2-D CVS Quasi-Finite Element Airbag Model

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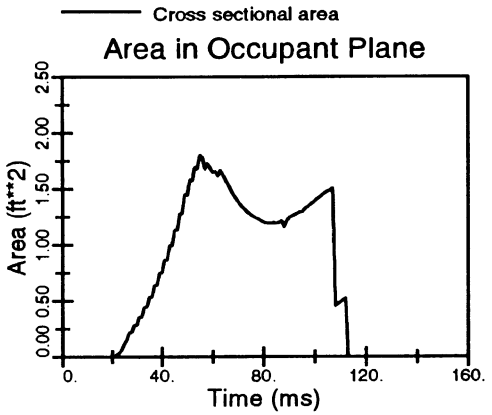
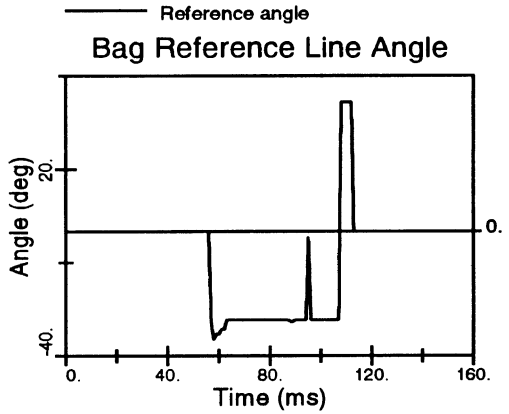
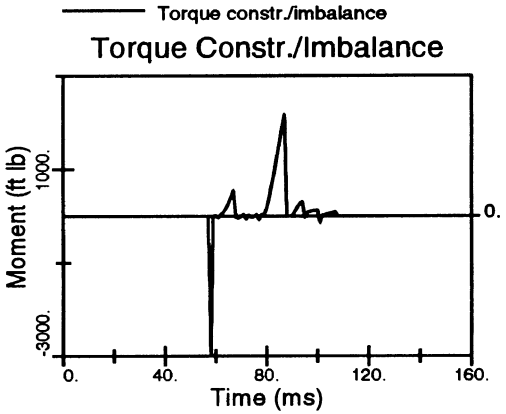
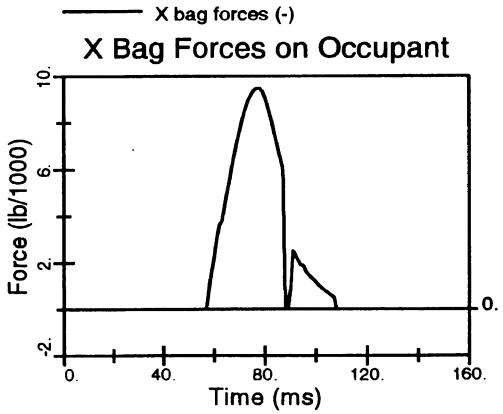
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









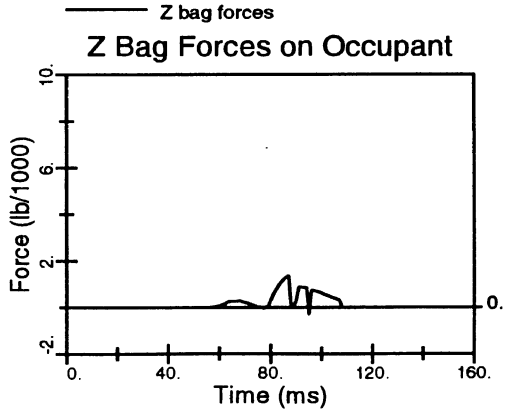


Figure 24.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD KINEMATIC RESPONSE

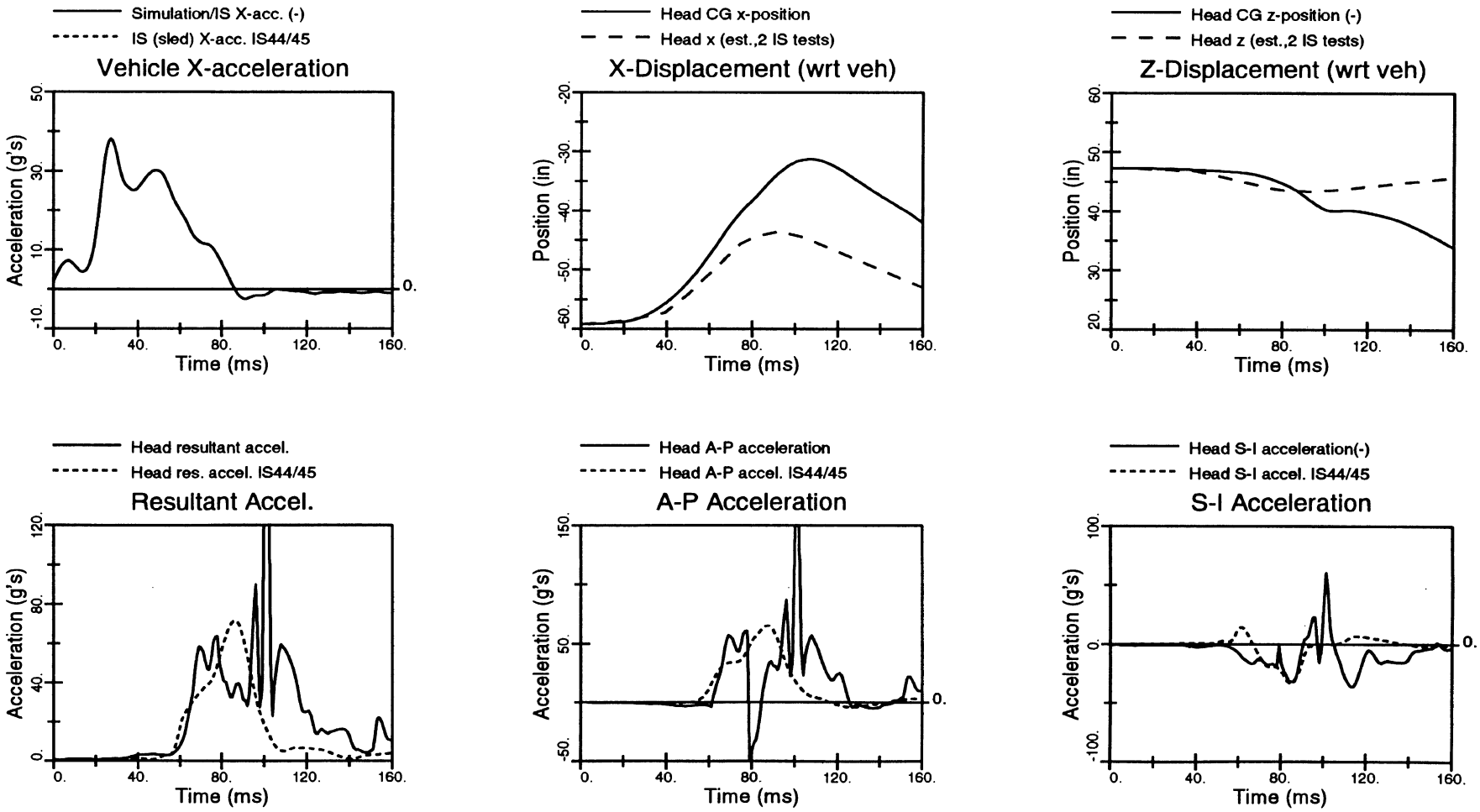


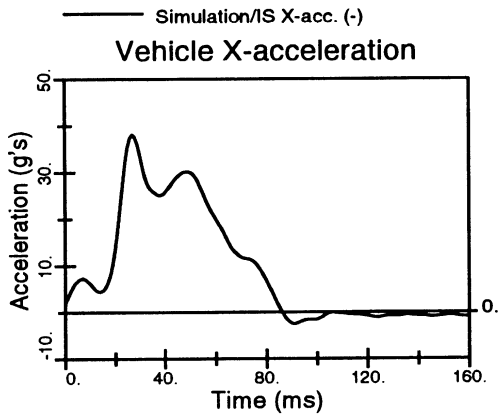
Figure 25.

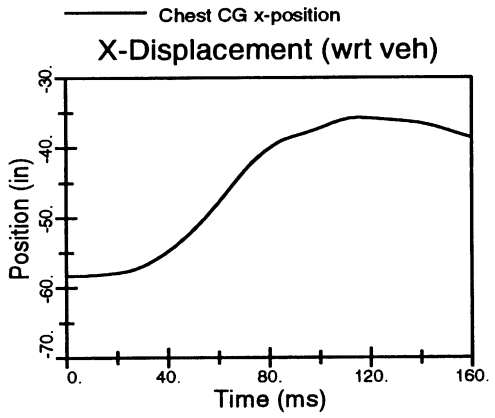
MVMA 2-D CVS Quasi-Finite Element Airbag Model

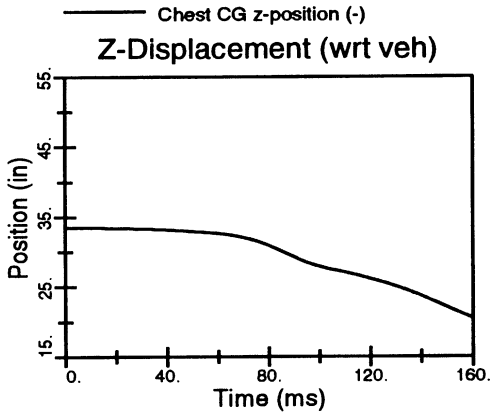
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static), Tests IS11144/45

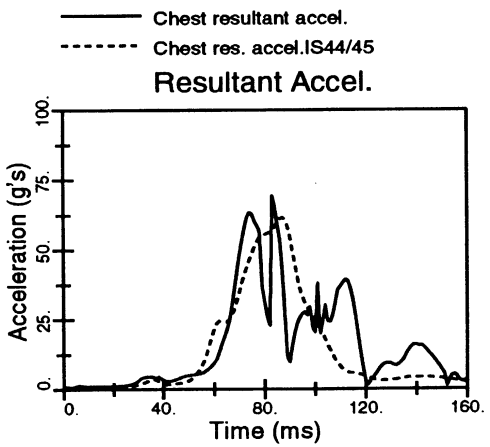
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

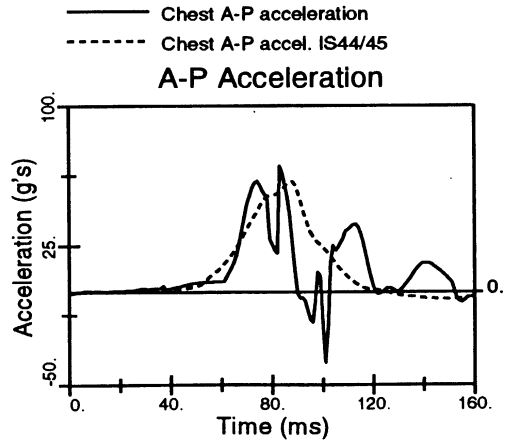
CHEST KINEMATIC RESPONSE











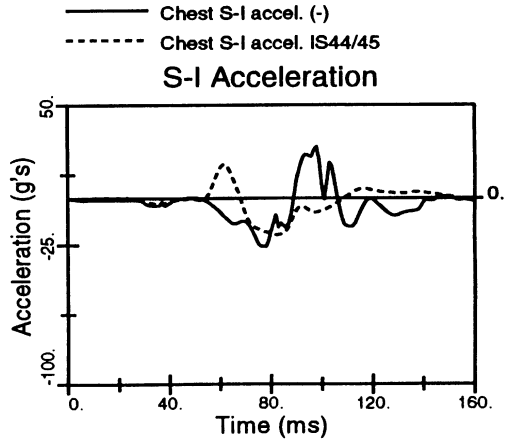


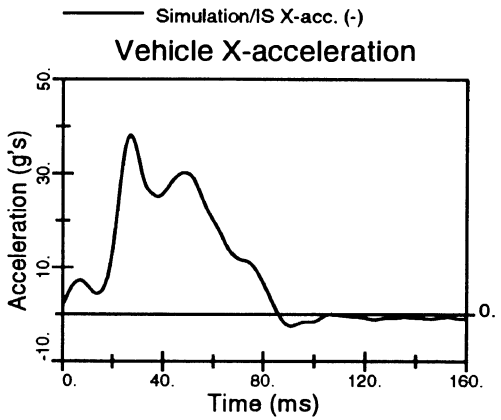
Figure 25.

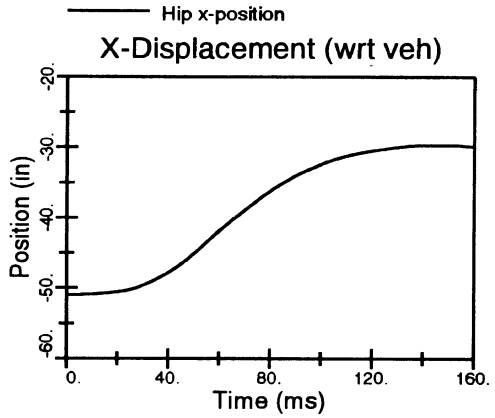
MVMA 2-D CVS Quasi-Finite Element Airbag Model

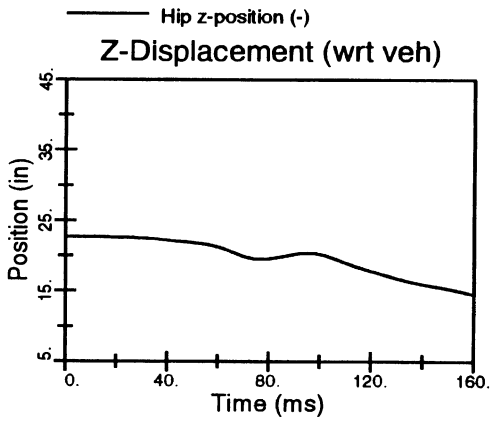
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

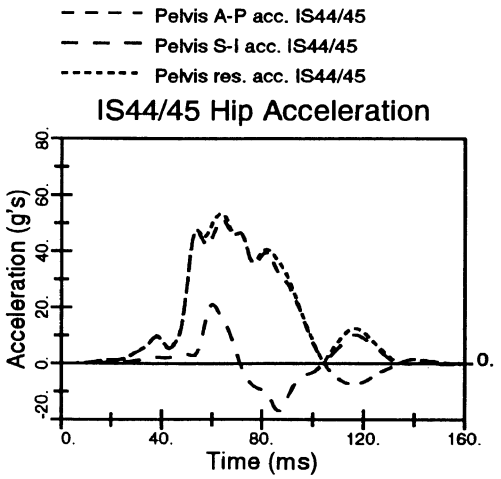
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

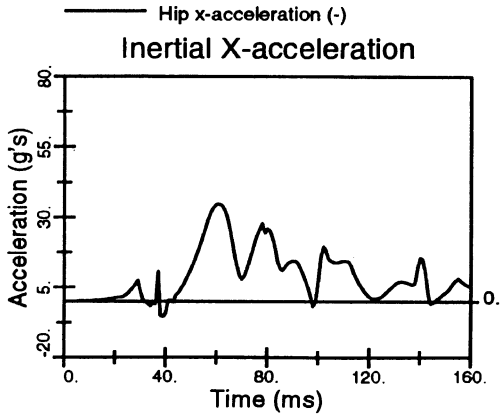
HIP KINEMATIC RESPONSE











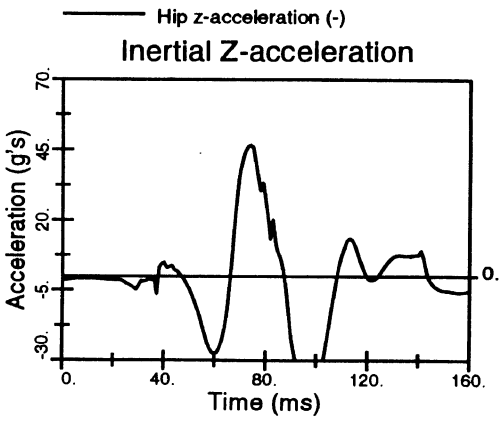


Figure 25.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

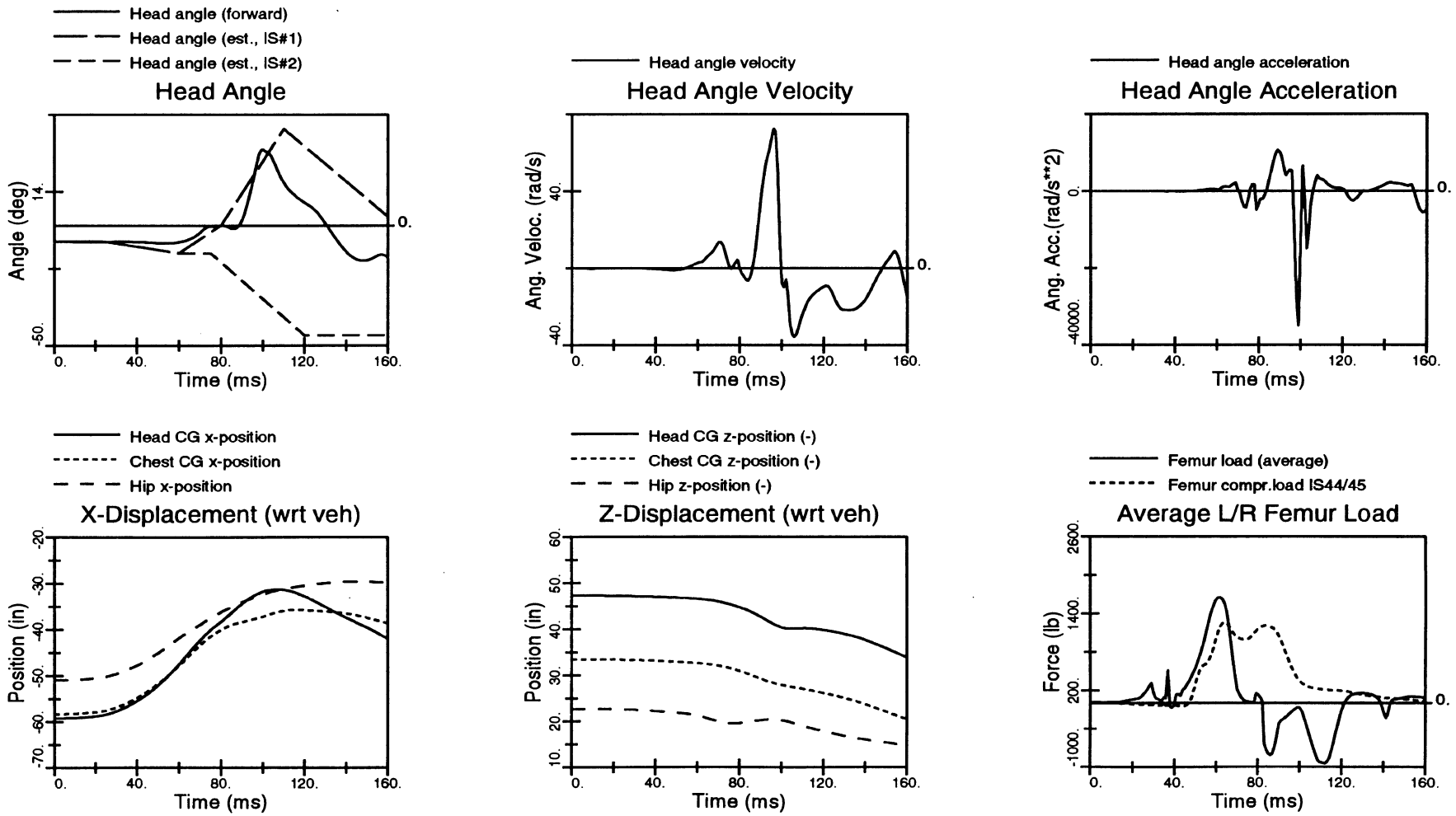


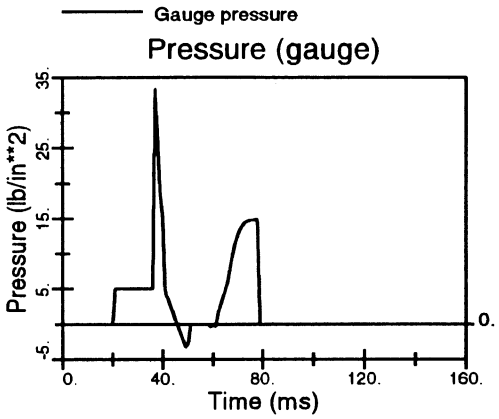
Figure 25.

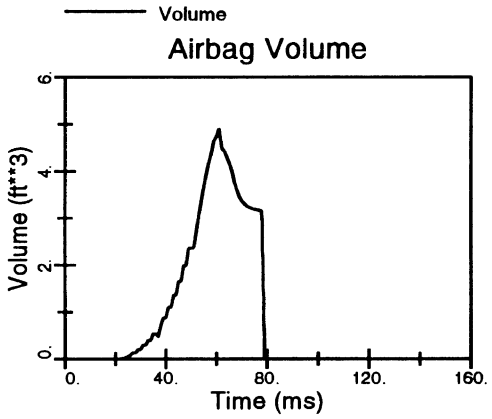
MVMA 2-D CVS Quasi-Finite Element Airbag Model

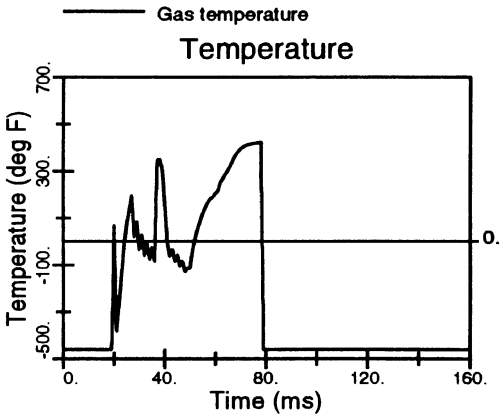
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

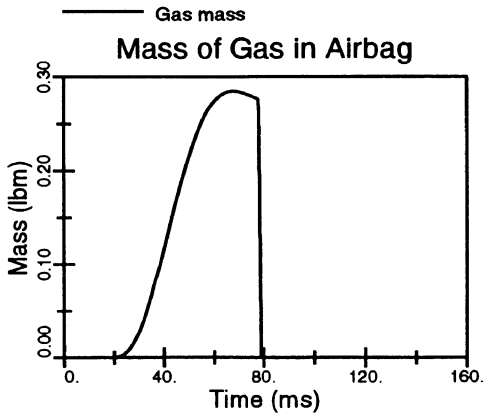
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

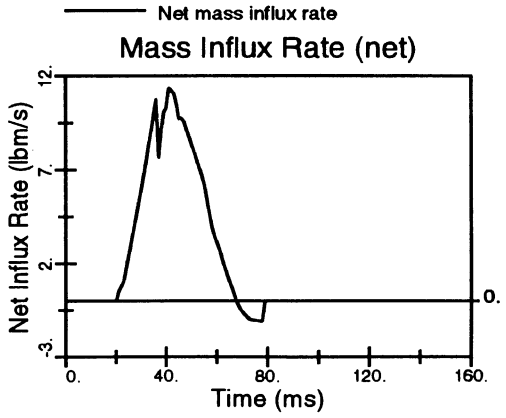
THERMODYNAMIC VARIABLES











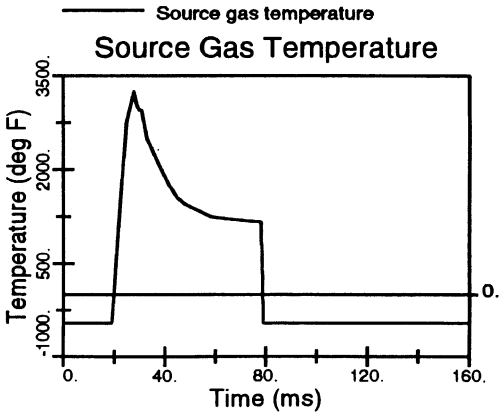


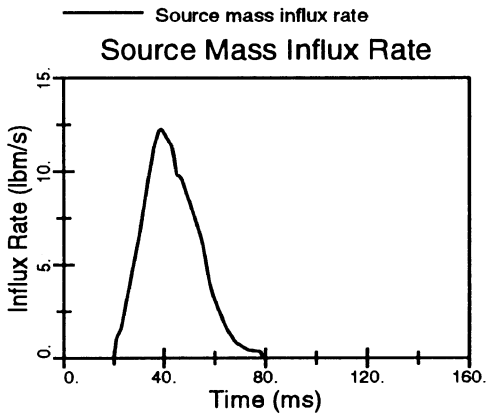
Figure 25.

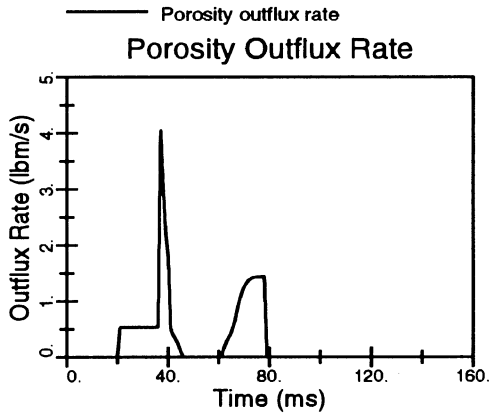
MVMA 2-D CVS Quasi-Finite Element Airbag Model

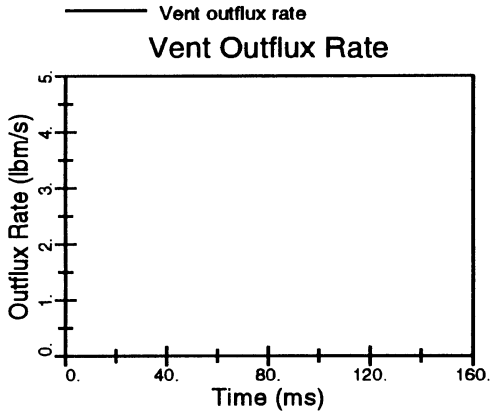
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static), Tests IS11144/45

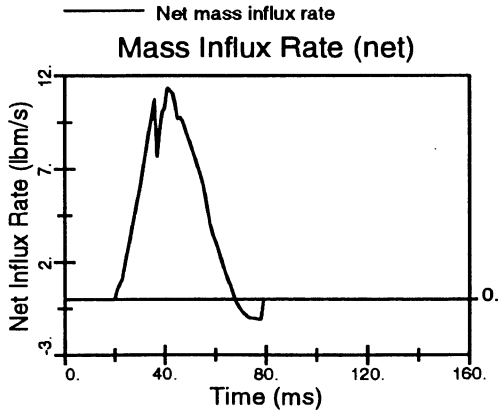
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

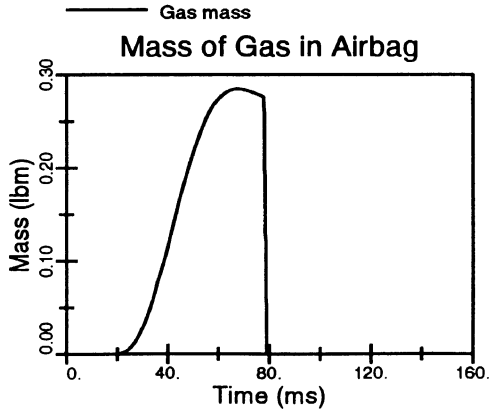
AIRBAG MASS INFLUX/OUTFLUX











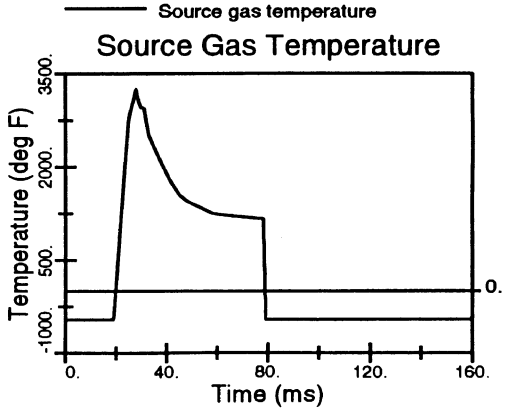


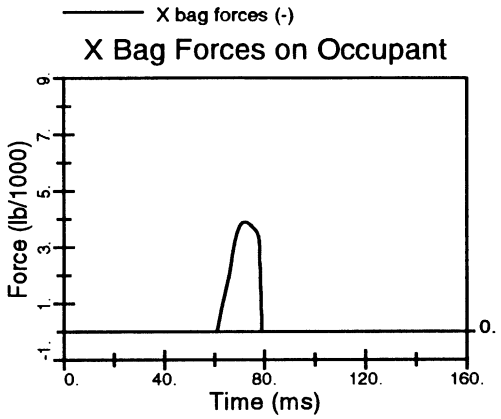
Figure 25.

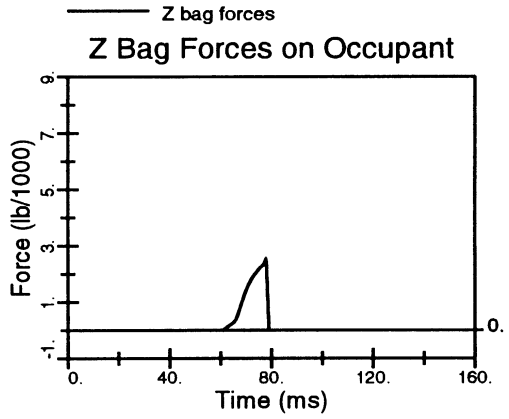
MVMA 2-D CVS Quasi-Finite Element Airbag Model

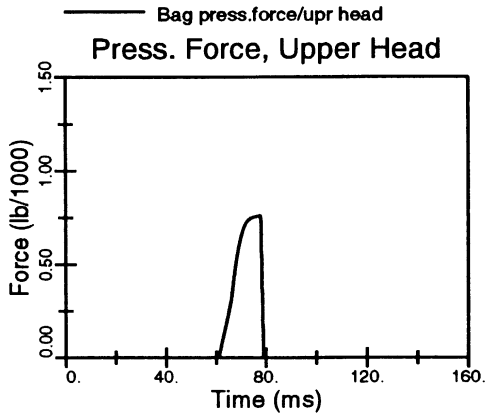
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

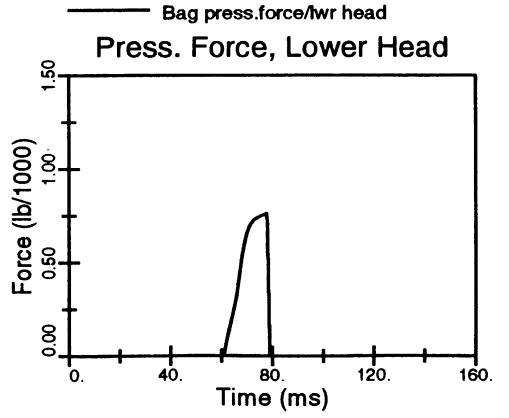
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)









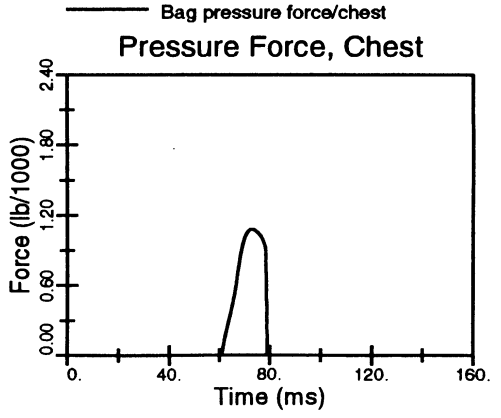


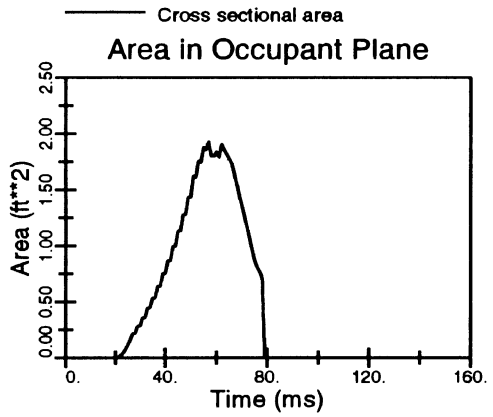
Figure 25.

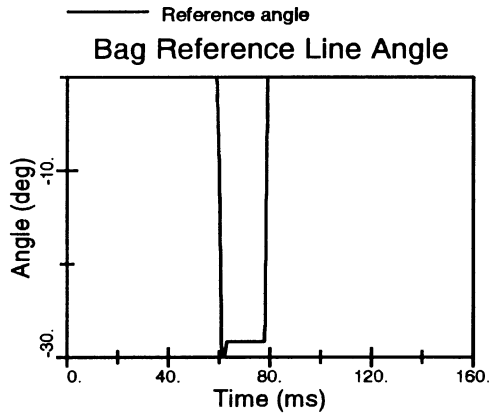
MVMA 2-D CVS Quasi-Finite Element Airbag Model

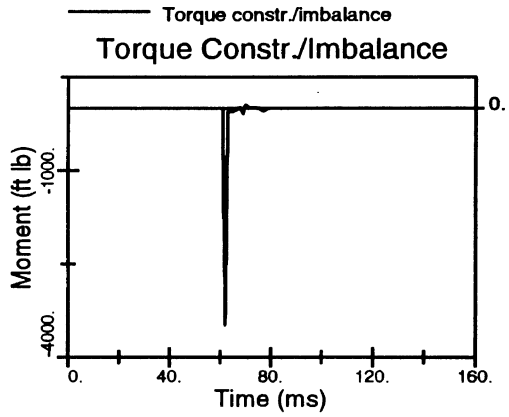
UMTRI Preliminary S-Body IS Test Simulation / IS #1 with 3"-lower seat (static) , Tests IS11144/45

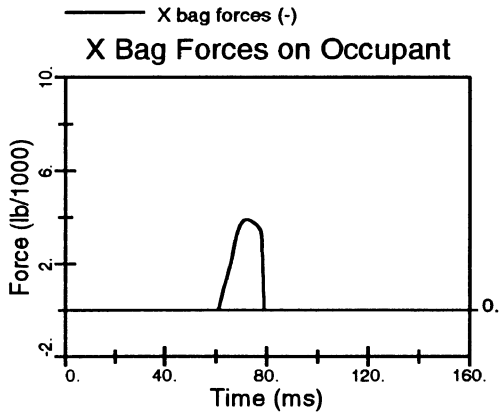
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









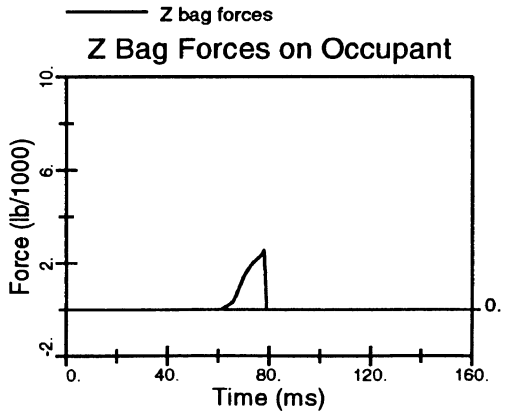


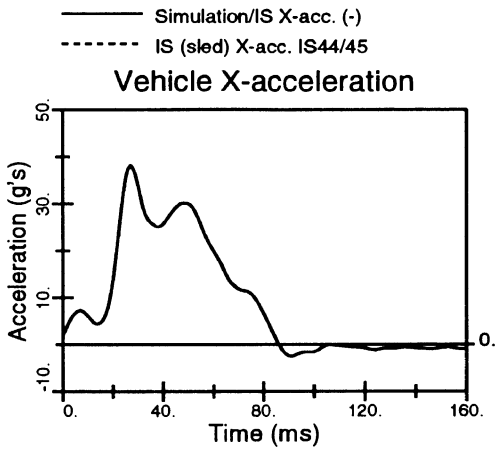
Figure 25.

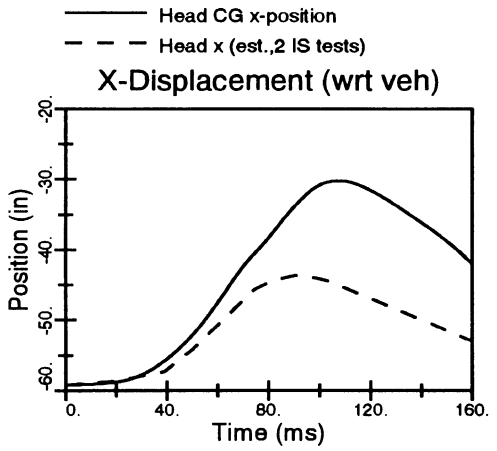
MVMA 2-D CVS Quasi-Finite Element Airbag Model

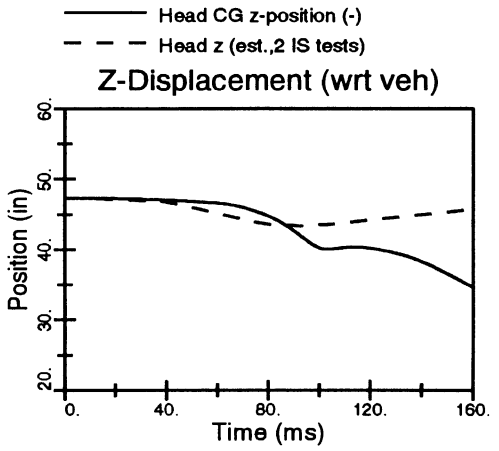
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static) , Tests IS11144/45

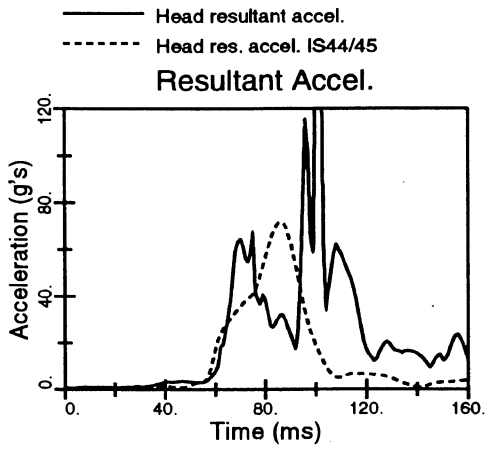
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

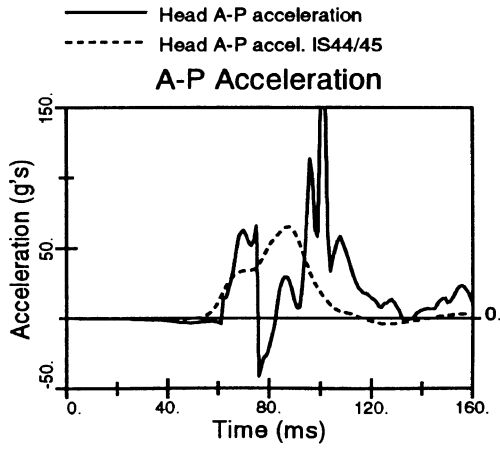
HEAD KINEMATIC RESPONSE











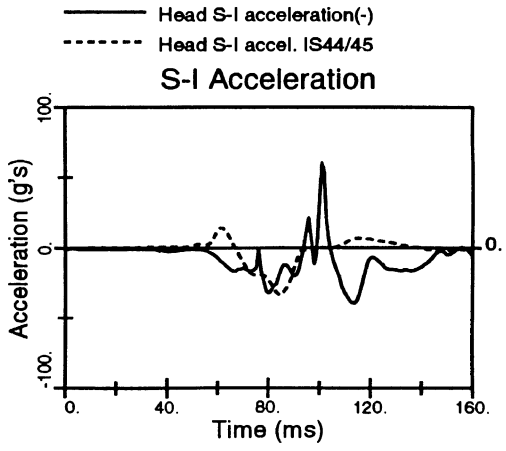


Figure 26.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static), Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

CHEST KINEMATIC RESPONSE

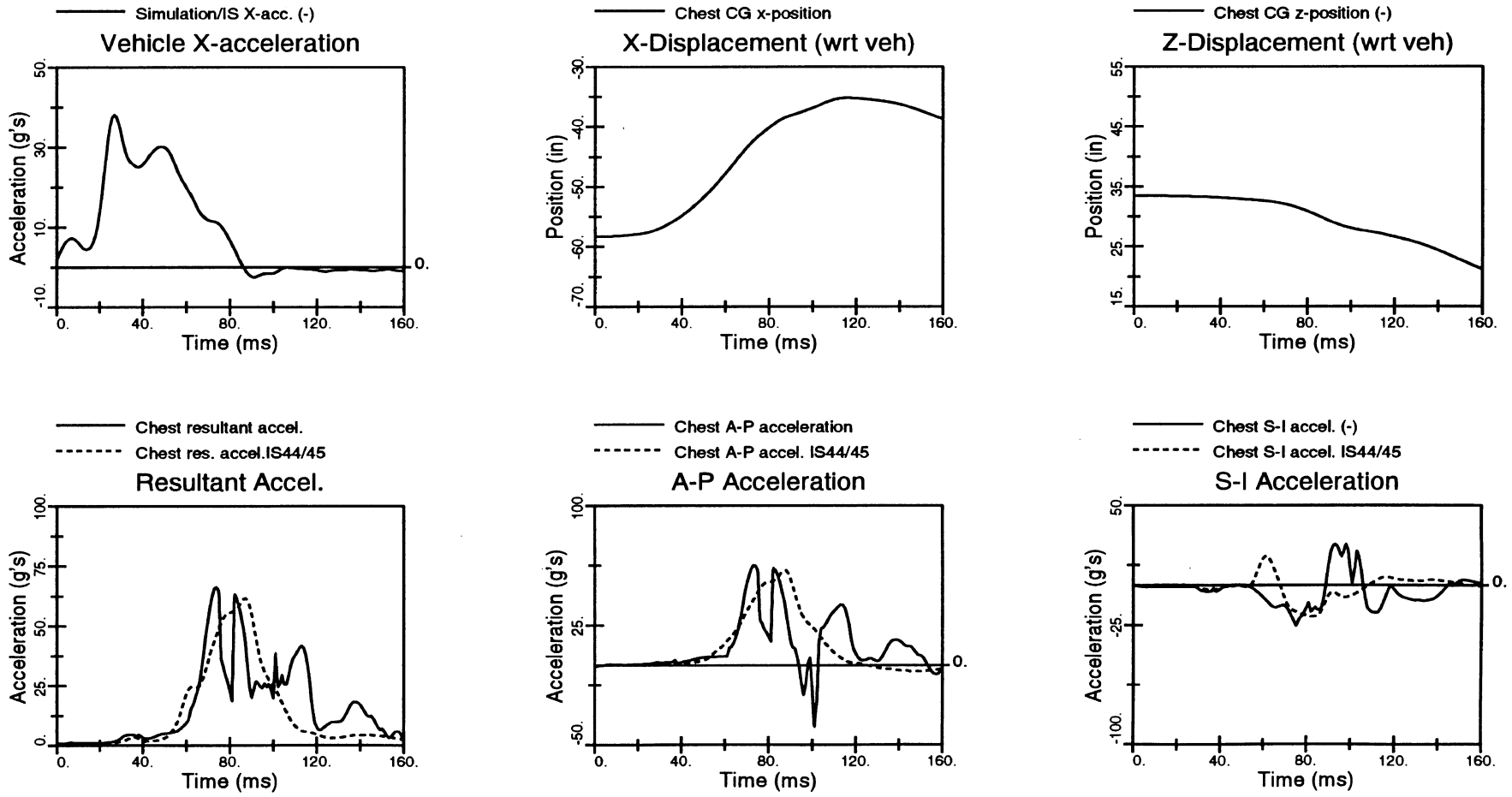


Figure 26.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static) , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HIP KINEMATIC RESPONSE

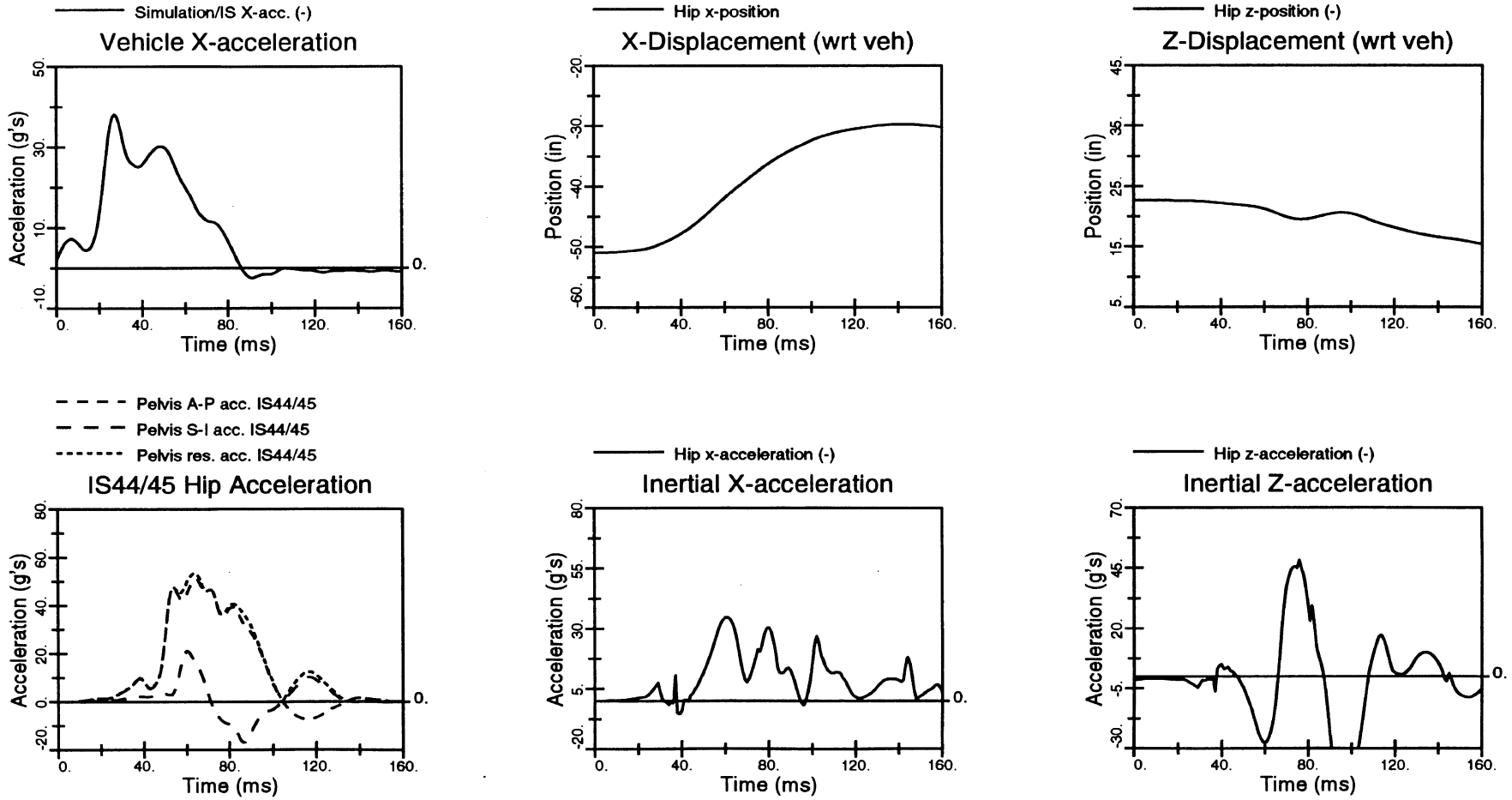


Figure 26.

MVMA 2-D CVS Quasi-Finite Element Airbag Model

UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static) , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

HEAD ANGULAR RESPONSE / OTHER RESPONSES

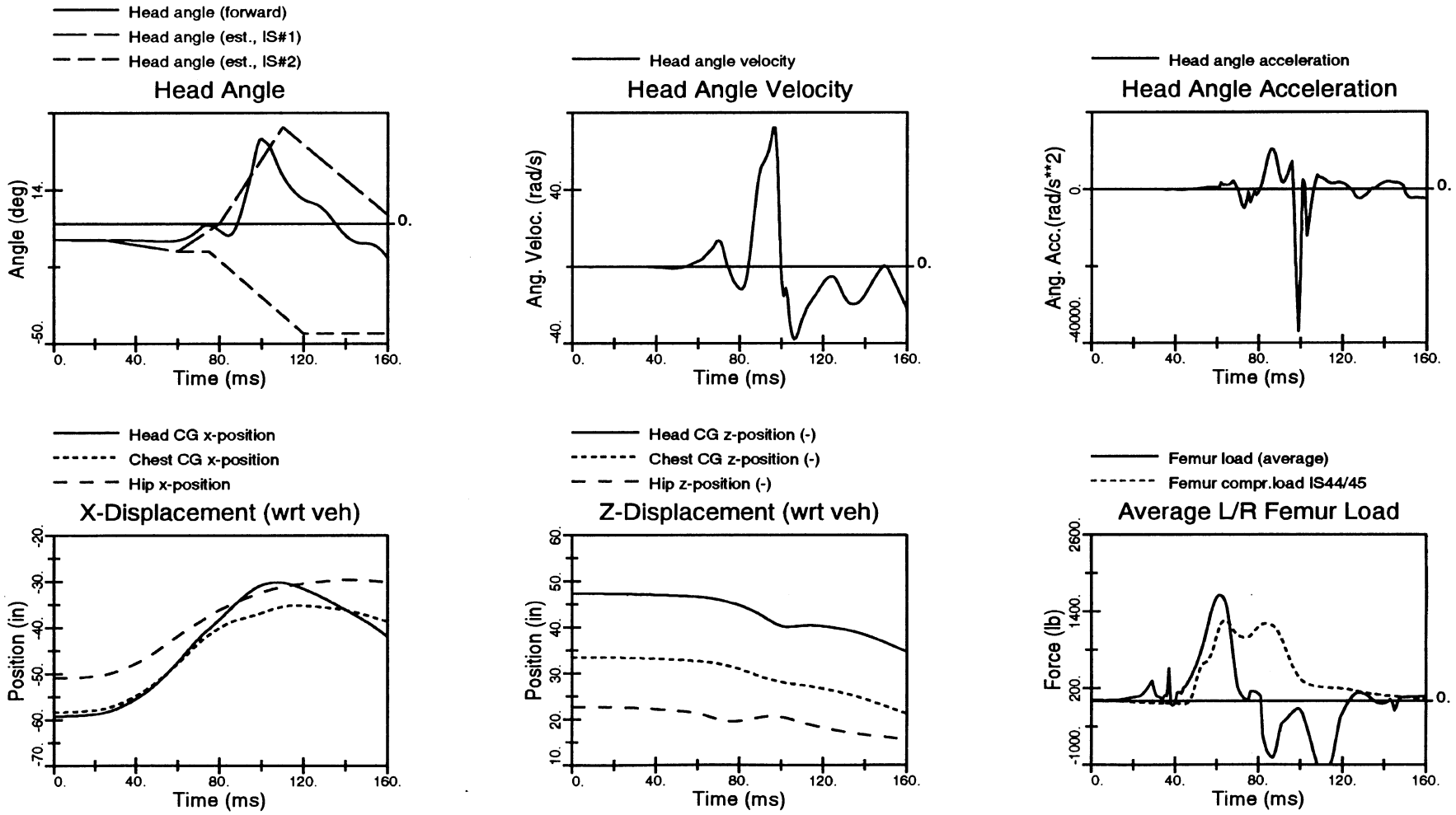


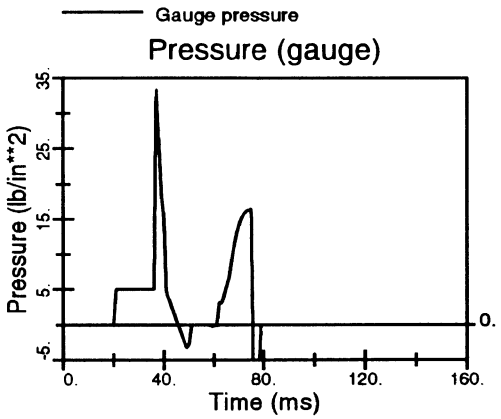
Figure 26.

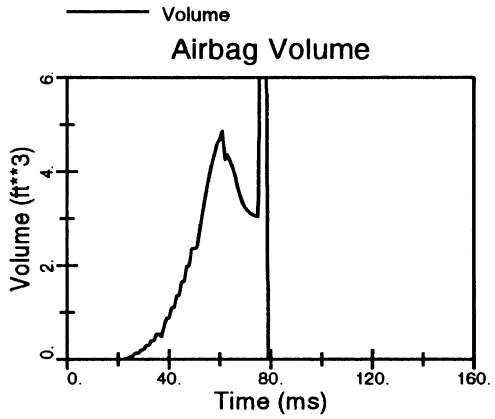
MVMA 2-D CVS Quasi-Finite Element Airbag Model

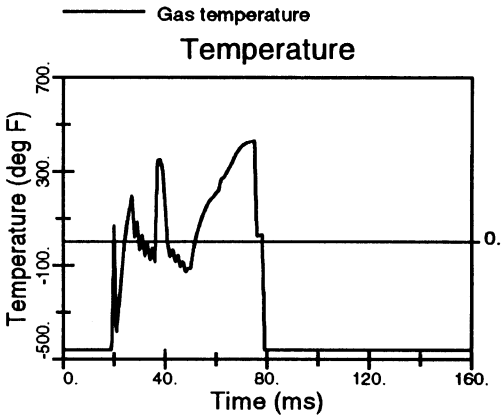
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static) , Tests IS11144/45

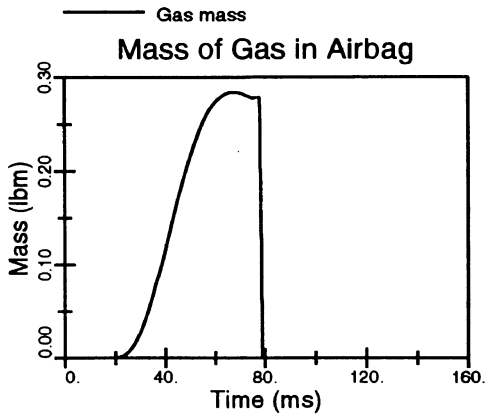
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

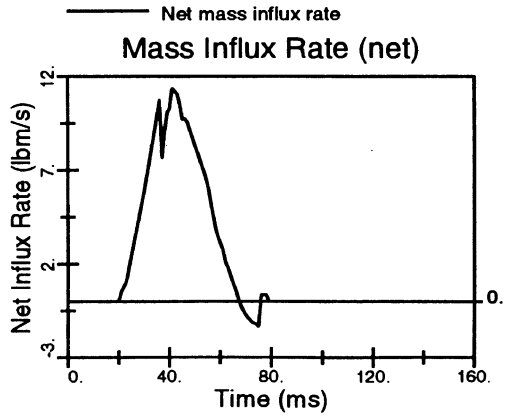
THERMODYNAMIC VARIABLES











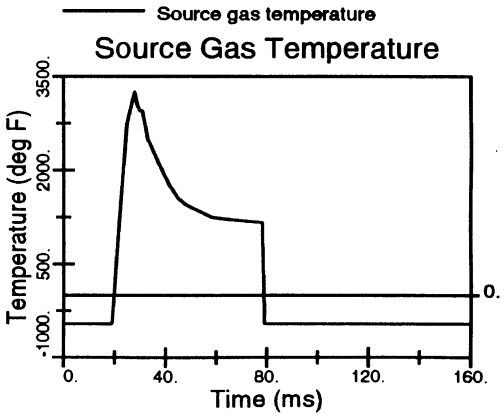


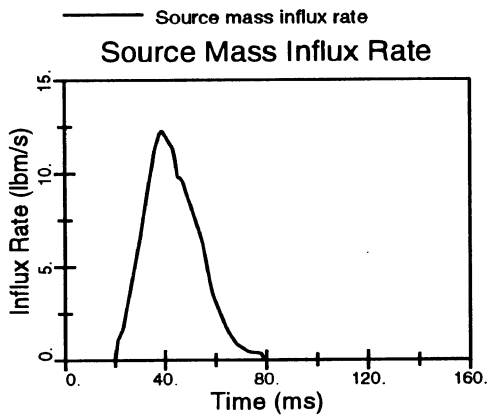
Figure 26.

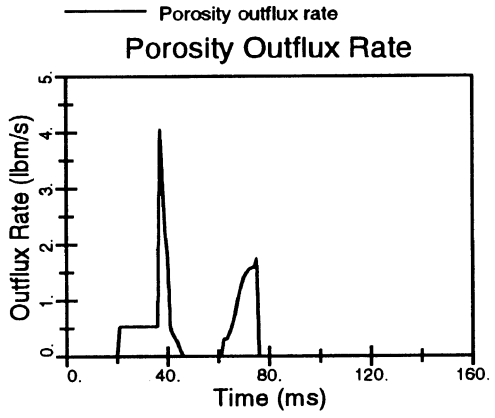
MVMA 2-D CVS Quasi-Finite Element Airbag Model

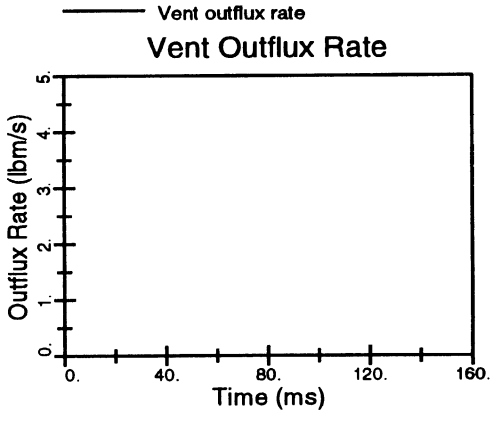
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static), Tests IS11144/45

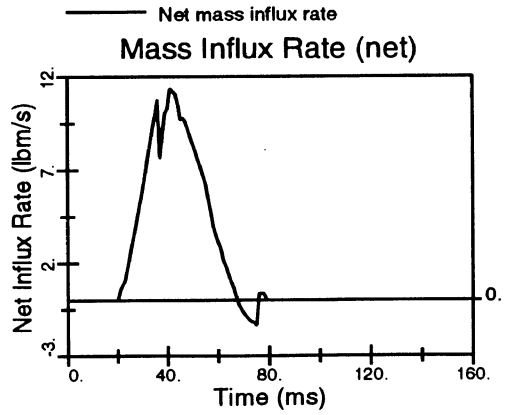
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

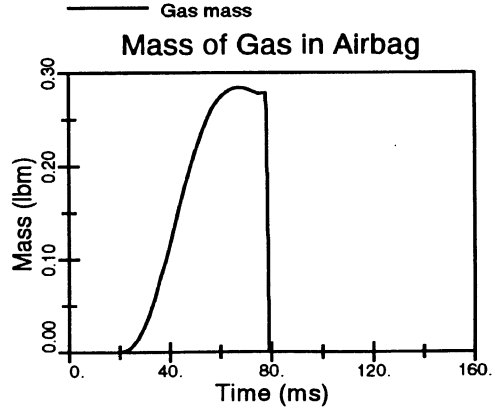
AIRBAG MASS INFLUX/OUTFLUX











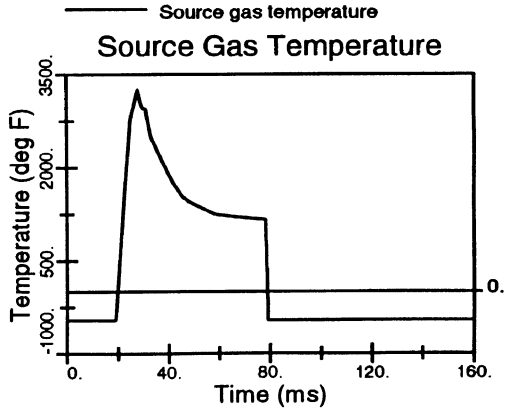


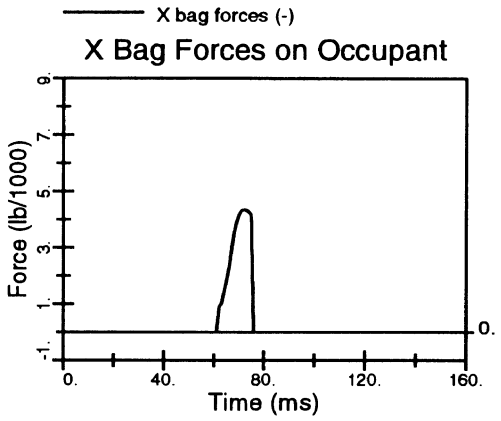
Figure 26.

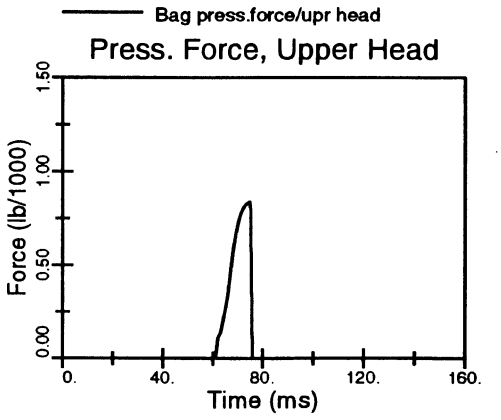
MVMA 2-D CVS Quasi-Finite Element Airbag Model

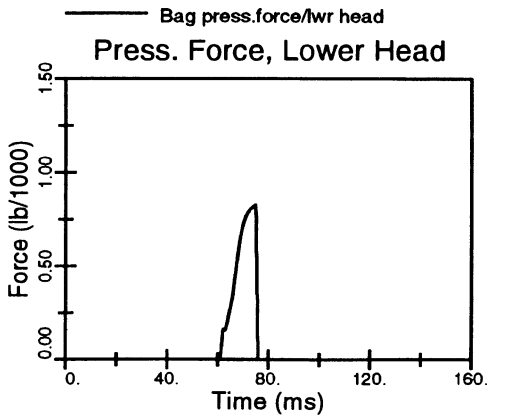
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static) , Tests IS11144/45

IP-Mount Passenger Airbag / mixed Bendix data and estimated data

AIRBAG FORCES (SUMMARY)







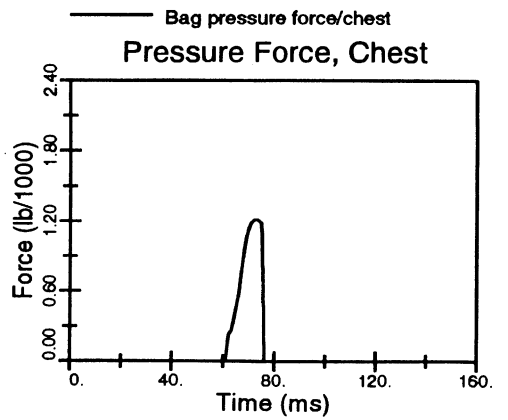


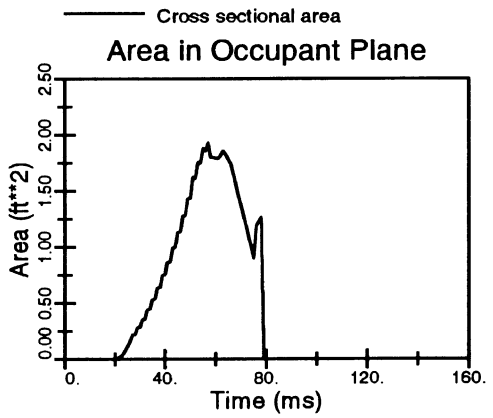
Figure 26.

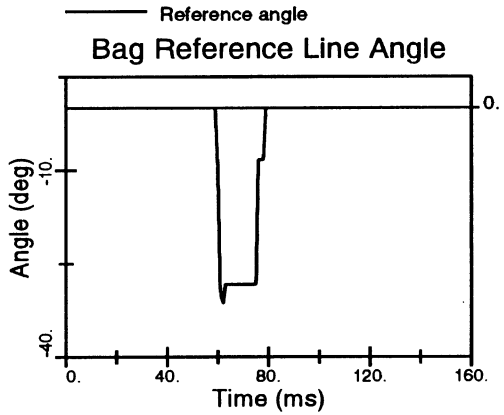
MVMA 2-D CVS Quasi-Finite Element Airbag Model

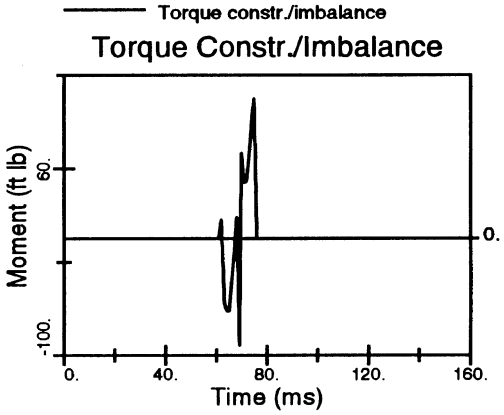
UMTRI Preliminary S-Body IS Test Simulation / IS #2 with 3"-lower seat (static), Tests IS11144/45

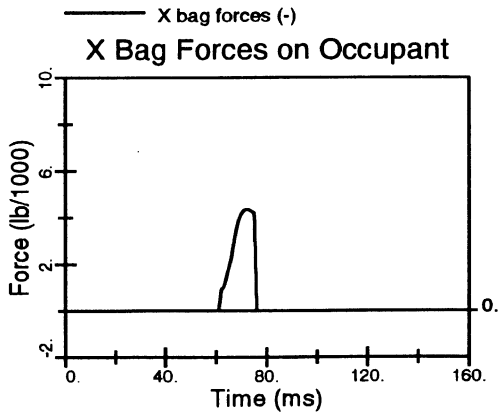
IP-Mount Passenger Airbag / mixed Bendix data and estimated data

MISCELLANEOUS AIRBAG RESPONSE VARIABLES









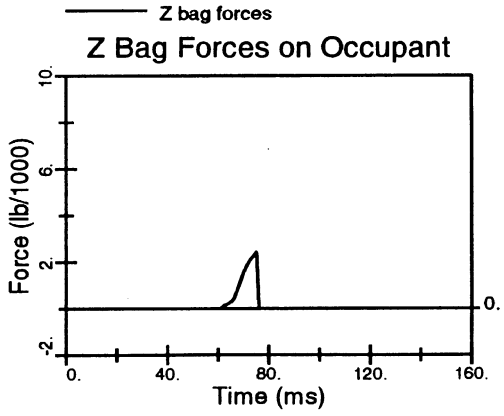


Figure 26.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HEAD KINEMATIC RESPONSE

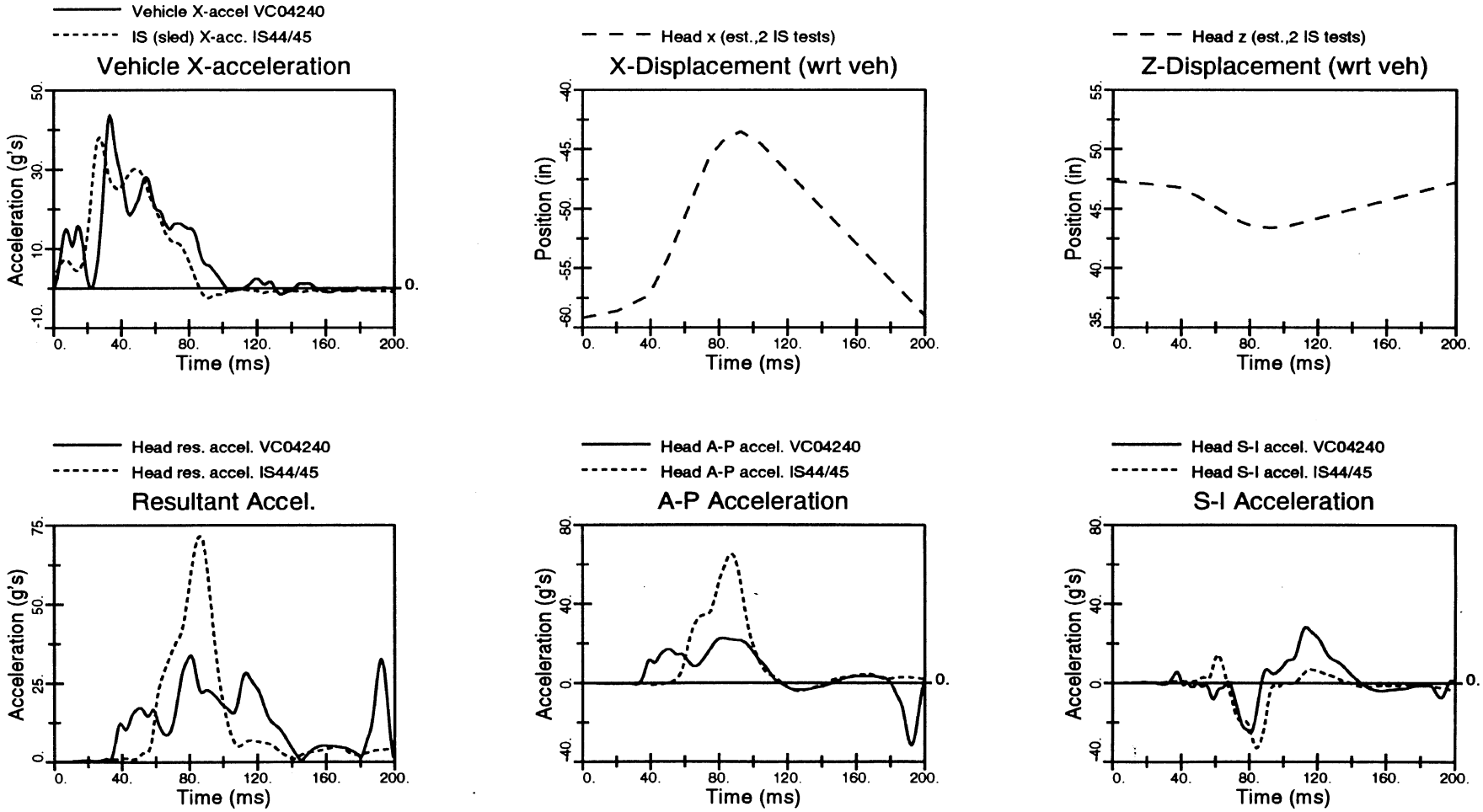


Figure 27.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
CHEST KINEMATIC RESPONSE

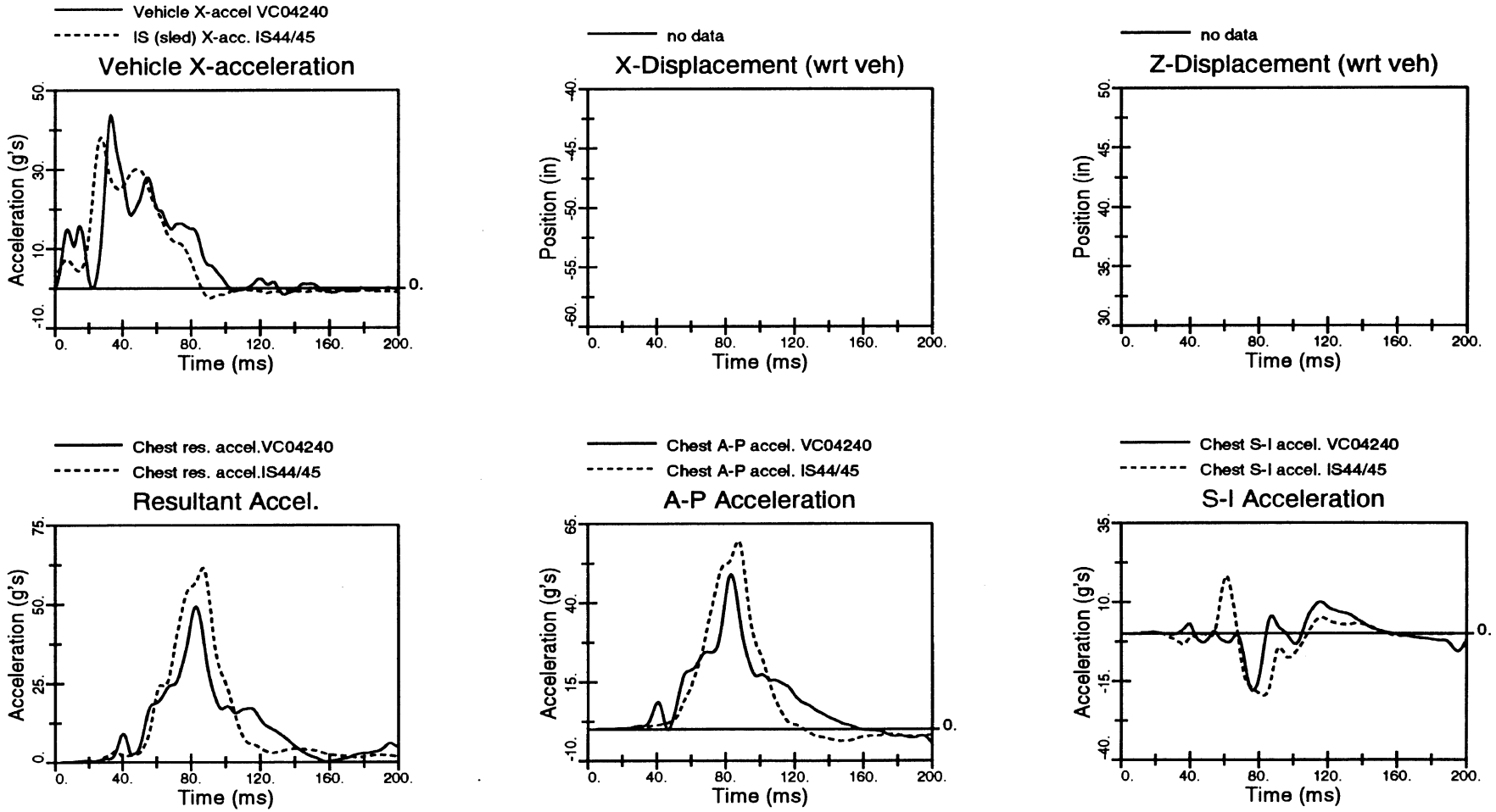


Figure 27.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HIP KINEMATIC RESPONSE / FEMUR LOAD

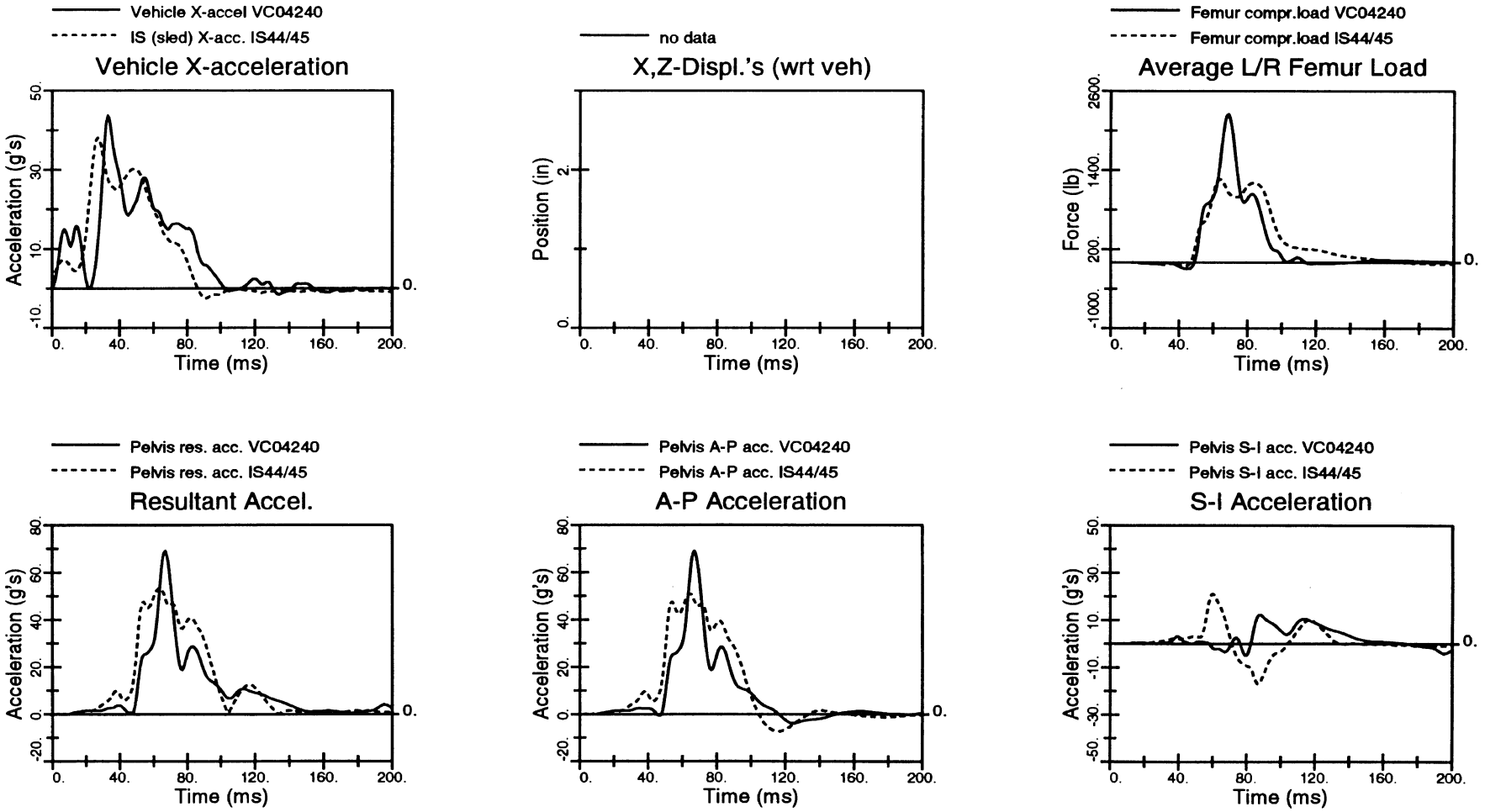
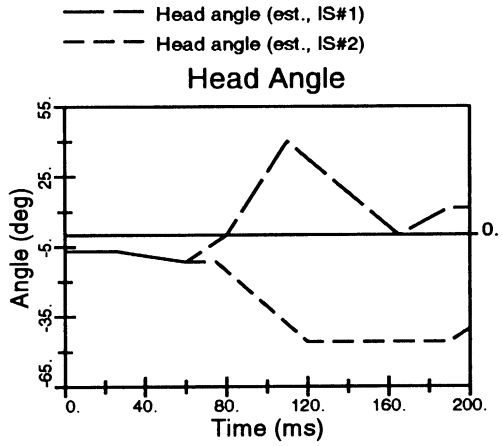
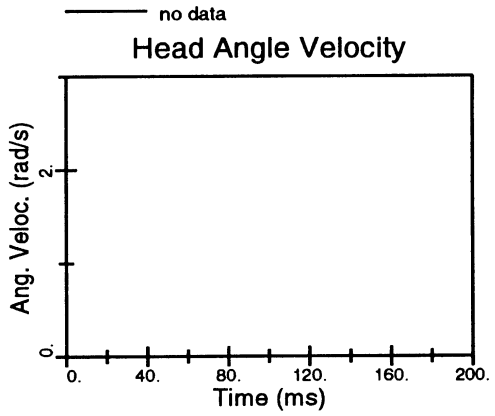
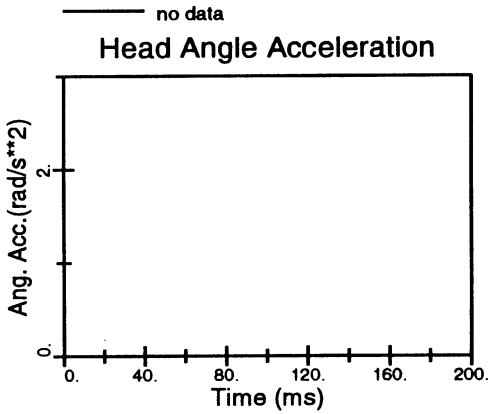


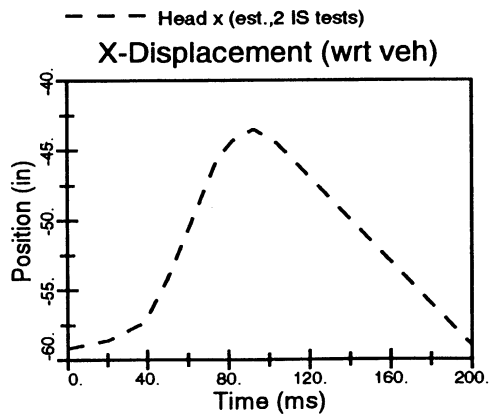
Figure 27.

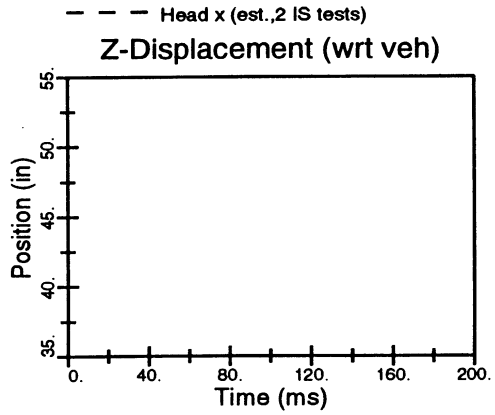
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
HEAD ANGULAR RESPONSE / OTHER RESPONSES











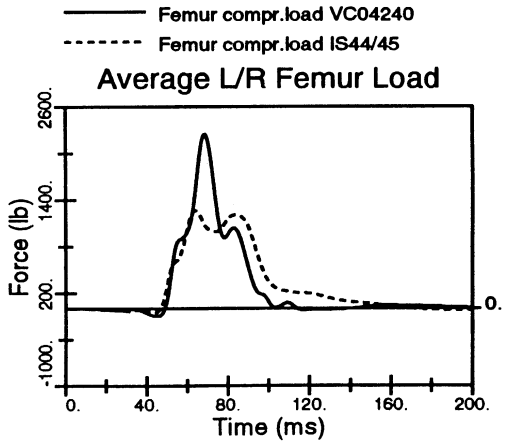
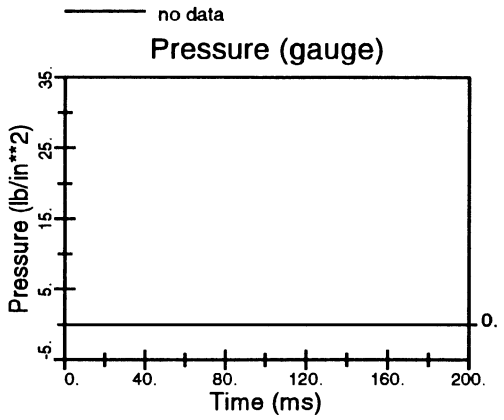
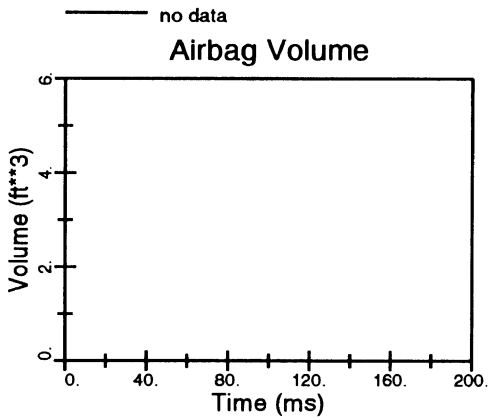
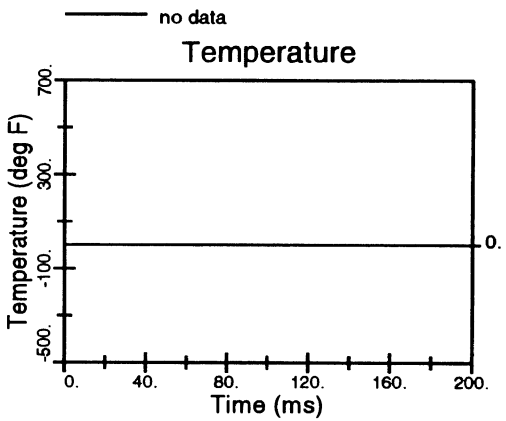


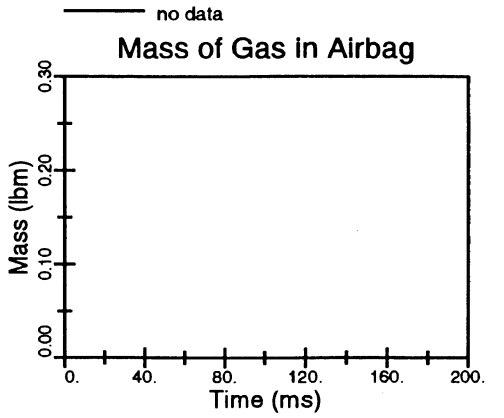
Figure 27.

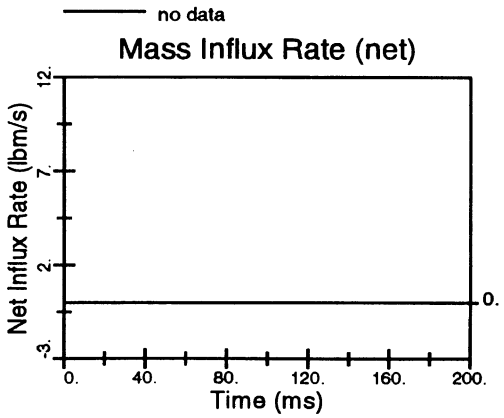
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
THERMODYNAMIC VARIABLES











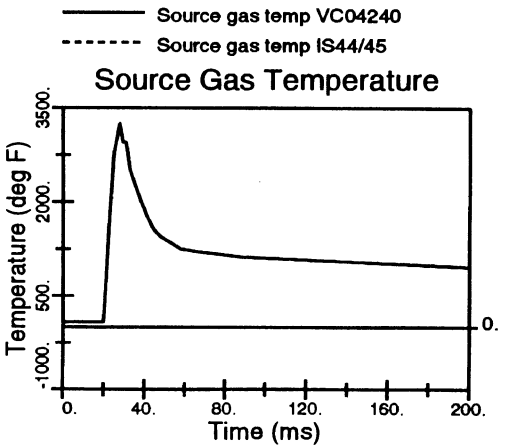
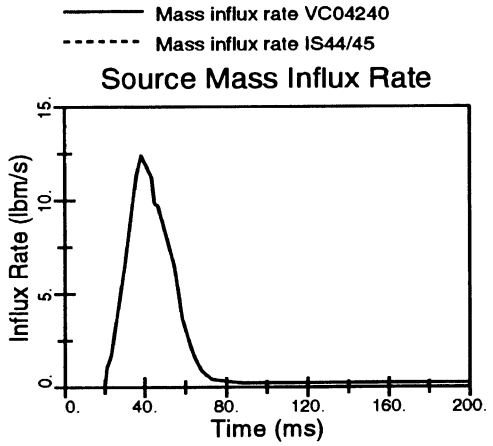
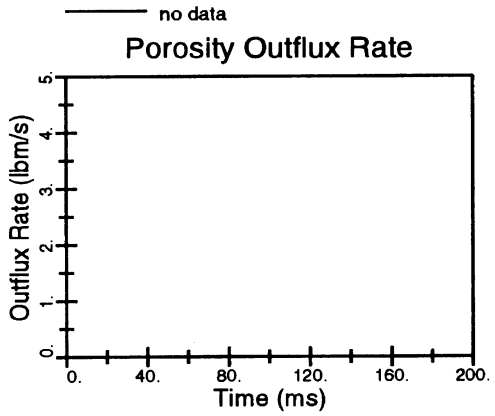
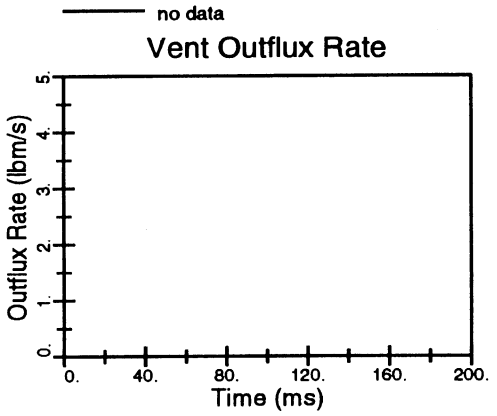


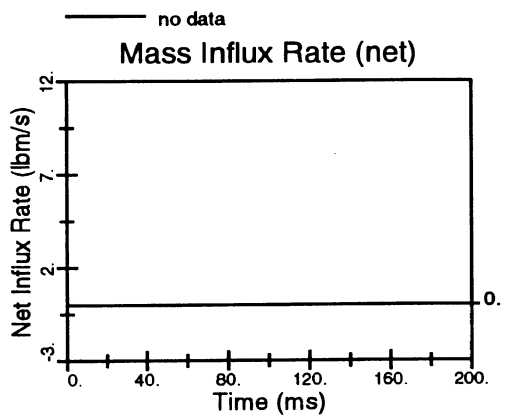
Figure 27.

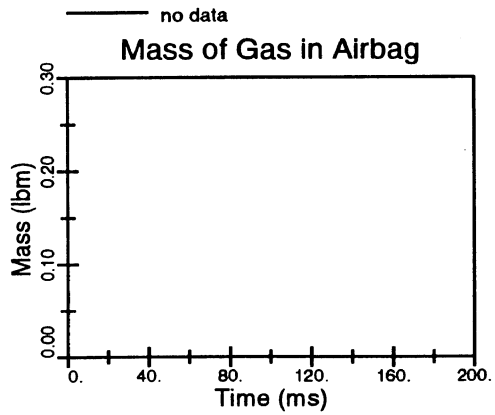
CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
AIRBAG MASS INFLUX/OUTFLUX











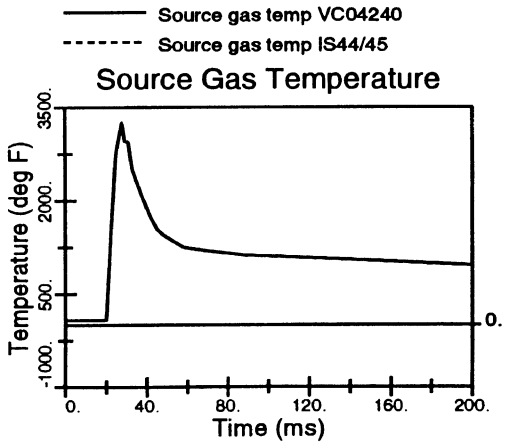
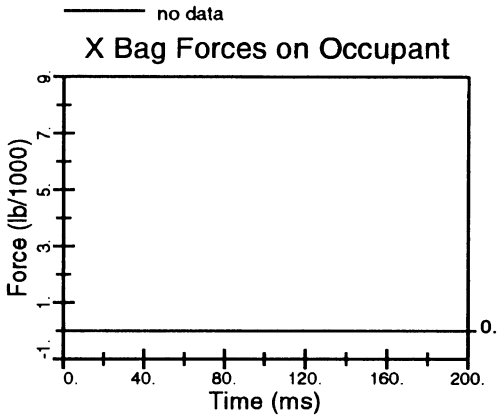
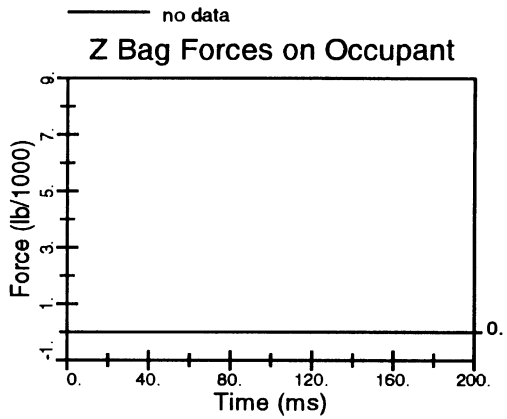
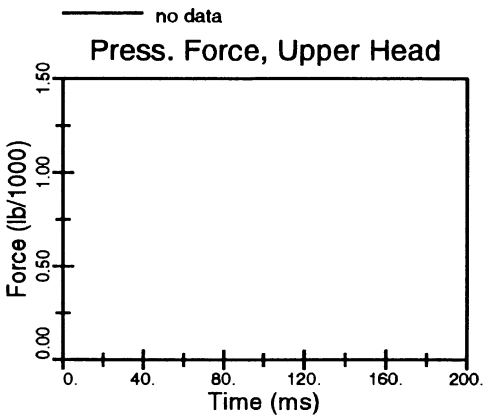


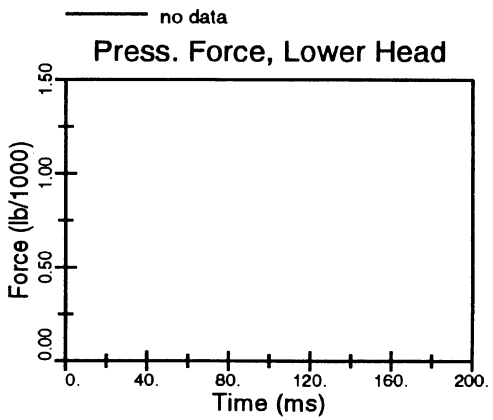
Figure 27.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
AIRBAG FORCES (SUMMARY)









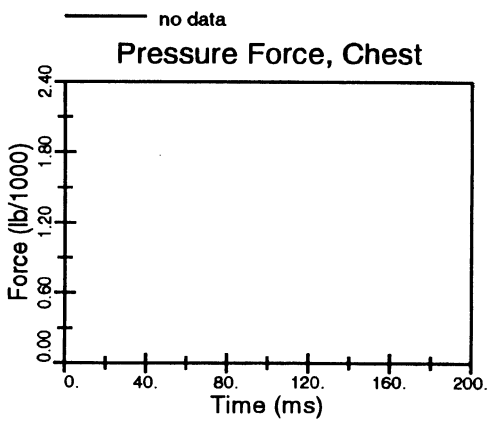
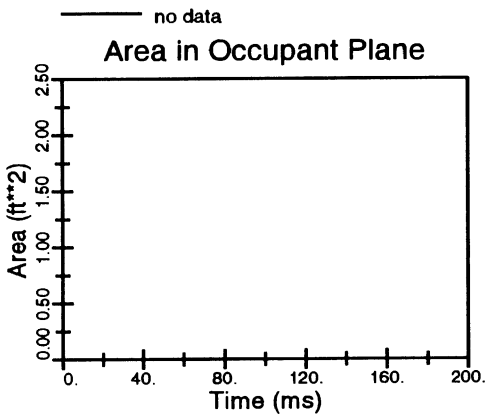
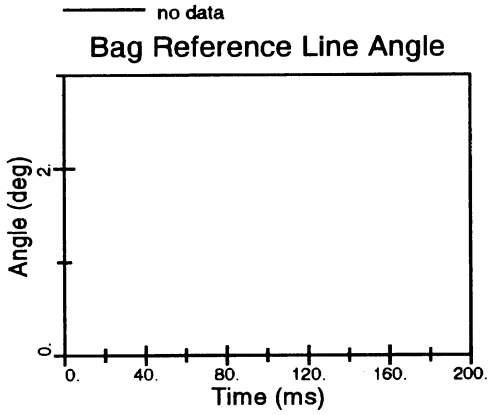
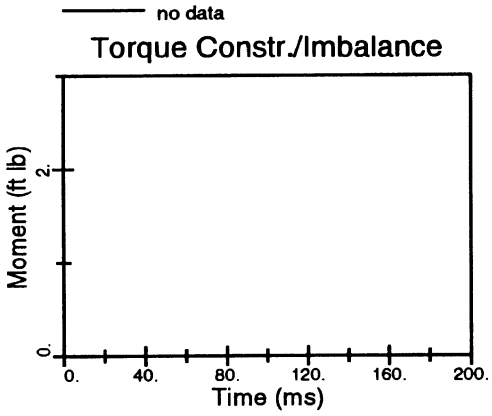


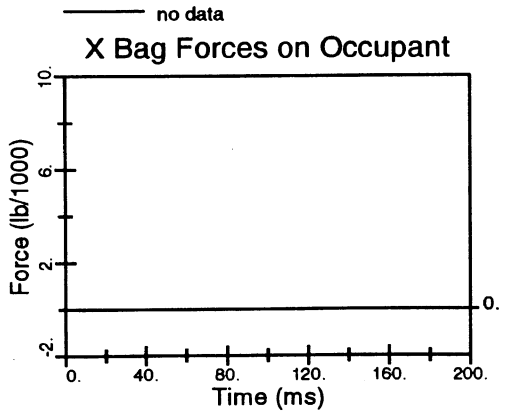
Figure 27.

CHRYSLER S-BODY TESTS (35 mph Delta-V)
WITH IP-MOUNT PASSENGER AIRBAG
Vehicle Crash Test VC04240 / Impact Simulator Tests IS11144/45
MISCELLANEOUS AIRBAG RESPONSE VARIABLES









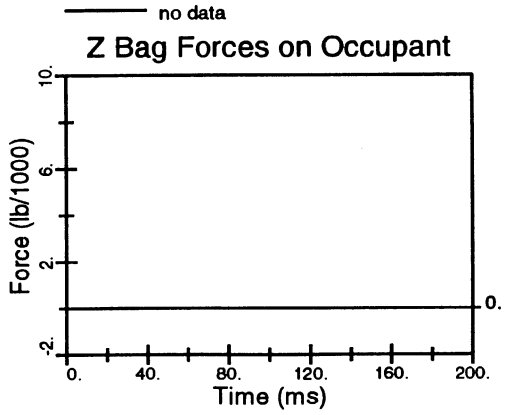


Figure 27.