

SAFETY PERFORMANCE EVALUATION OF SLACK EFFECTS
IN THREE-POINT SAFETY BELTS USING THE HYBRID III DUMMY
IN FRONTAL AND FRONTAL OBLIQUE SLED TESTS

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The data and information contained herein are preliminary.
Final results of the slack belt tests performed will be
published soon in another publication.

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ABSTRACT

A project was undertaken to study the relationship of slack effects in a typical American-made single retractor, continuous loop, three-point seat belt system using the Hybrid III dummy as the test device. Although the main focus of the study itself was to quantify the effects of slack on restraint system performance; a number of observations were made concerning the use of the Hybrid III to evaluate seat belts in general, and to evaluate the effects of slack in particular. The focus of this report is on the performance of the Hybrid III dummy in this application. More complete results of the belt slack portion of this study will appear in a later publication.

INTRODUCTION

The past development and present use of the Hybrid III is of interest to those involved in automotive safety both from the scientific and regulatory standpoints. It has been recognized by the NHTSA as a qualified test device for use in regulatory testing, while in the research community it is also frequently used for biomechanical and biofidelity research studies. At some level it is a tribute to the designers and developers of the Hybrid III that this device has achieved such wide applicability and acceptability. Indeed, the results of this study indicate that, in general, for evaluating seat belt performance in frontal impacts, it is a useful and predictable research test device.

A few comments will be made in this report concerning the use of the Hybrid III in the variety of seat belt evaluation and test conditions studied. These comments are not meant as criticisms of the Hybrid III device. Rather, these are observations which recognize that any one device may not have the capability to perform all biofidelity measurement tasks most effectively. This, of course, has already been recognized in the course of dummy development for side impact protection. In the three-point seat belt tests reported here, the Hybrid III performed in a repeatable and predictable manner for the 12 o'clock principle direction of force (PDOF) impacts.

During the oblique impact tests of this series, particularly when slack was present in the belt, the construction and contour of the Hybrid III shoulder caused the belt to snag at the arm/shoulder joint. This joint is not covered by flesh and this discontinuity forms a notch in which the belt catches in a non-human like manner, and for the Hybrid III, even this characteristic was somewhat repeatable. When an oblique test began with the torso belt off the Hybrid III shoulder, or slipped off in the course of the test (the snagging on the shoulder being

incomplete), the belt would invariably assume a position across the lower rib cage and abdomen. Although high speed motion pictures of the Hybrid III visually showed this configuration of dangerous belt loading, analysis of the study data discussed below failed to reveal consistent indicators from the standard Hybrid III measurements which would predict the probable chest/abdominal injuries.

This report describes the general test protocol for the belt slack tests; gives the results measured with the Hybrid III; makes some recommendations for possible future developmental work on the Hybrid III; and, alternatively, suggests study approaches with other possible ATD's or surrogates for belt performance tests.

GENERAL TEST PROTOCOL

Test Environment

Table 1 summarizes the test protocol and the results for the slack belt tests. Twenty-eight sled tests were run in a recent model Ford LTD/Crown Victoria front seat sled buck as representing the average full-sized American car interior layout (see Figures 1A and 1B). For economy of testing and repeatability, all occupants were tested in the left front seat position. The steering system was installed or removed to create a driver or passenger environment. The brow area of the driver side instrument panel with the instrument cluster removed was similar to the mirror image passenger side with both sides being constructed of plastic materials noticeably softer than older designs, which used sheet metal substructures.

The three-point belts used were the stock LTD belts obtained through the dealer. These belts were single retractor (chassis sensitive only), three-point continuous loop systems with a locking latch plate such that when the belt was on, webbing could move from the lap strap into the shoulder strap, but, as designed, not the other way. These belts are equipped with a tension relief (windowshade) device which prevents the shoulder belt webbing from retracting under certain circumstances after an occupant leans forward and back. For most tests a fresh belt was used, but in those instances where a belt was reused, no effect on performance was noted.

The split bench left front seats were from LTD's and each had two tracks. The seats were reinforced before the test series began and were checked frequently for deformation and repaired or replaced as necessary.

The barrier equivalent crash pulses used for 30 and 35 mph are shown in Figures 2A and 2B. The crash pulses were from actual LTD barrier tests while the sled pin chosen for the Transportation Research Center of Ohio (TRC) HYGE sled provided an acceptable analog.

TABLE 1

TEST DATA -- HYBRID III AND SLACK BELTS

TEST No	SPEED/ANG	SLACK SH/BLT LAP	HIC	HIC36	Chest G's	Sh BF	Chest Def	COMMENT
1	30*/0	-1.0 0	465	413	30.1	1504	1.35	PASS
2	30/0	0.0 0	525	404	37.7	1407	1.35	PASS
3	30/0	0.5 0	675	587	36.0	1302	1.21	PASS
4	30/0	1.0 0	644	486	38.4	1403	1.26	PASS
5	30/0	1.6 0	728	605	40.0	1397	1.21	PASS
6	30/0	2.3 0	821	730	44.0	1413	1.21	PASS
7	30/0	3.0 0	1026	880	41.9	1422	1.19	PASS
10	30/0	5.0 0	910	898	46.6	1616	1.66	PASS/OFF SHLDR
8	30/0	5.3 0	1023	986	43.9	1410	1.20	PASS
9	30/0	8.0 0	1359	1359	38.3	1292	1.01	PASS
11	30/0	18.0 0	735	726	37.6	818	0.88	PASS/OFF SHLDR
18	30/0	18.0 0	798	798	42.6	n/t*	0.88	PASS
19	30/38	-1.0 0	422	368	29.2	1607	1.49	PASS
24	30/38	0.0 0	352	228	33.6	n/t	1.54	PASS
26	30/38	0.0 3	618	415	38.2	n/t	1.70	PASS
23	30/38	1.3 0	379	301	29.9	n/t	1.45	PASS/OFF SHLDR
20	30/38	2.5 0	587	485	37.8	1522	1.38	PASS
21	30/38	3.0 0	398	283	30.4	2059	0.70	PASS/OFF SHLDR
25	30/38	3.0 3	542	414	42.8	n/t	1.75	PASS
27	30/38	3.0 3	413	325	37.1	n/t	3.25 q/d*	PASS/OFF SHLDR
28	30/38	3.0 0	256	167	34.7	n/t	2.87 q/d	PASS/LEAN FWD
22	30/38	2.3 0	507	351	37.9	n/t	1.36	PASS
16	35*/0	0.0 0	1192	1161	49.1	1738	1.44	PASS
17	35/0	3.0 0	1491	1370	52.3	1826	1.37	PASS
12	30/0	0.0 0	852	852	32.7	1449	1.30	DR
13	30/0	3.0 0	697	697	37.8	1295	1.41	DR
14	35/0	-1.0 0	1110	1110	45.4	1836	1.86	DR
15	30/0	3.0 0	1165	1165	39.0	1503	1.37	DR/REPEAT # 13

- * Notes: - Tests were 30 mph B.E.V., Actual Delta V = 32.5 mph.
- Tests were 35 mph B.E.V., Actual Delta V = 37.5 mph.
- In tests 10 an 11, the belt was off the shoulder.
- q/d denotes questionable chest deflection data in Tests 27 and 28.
- n/t denotes there was no transducer for this test.

Figure 1A

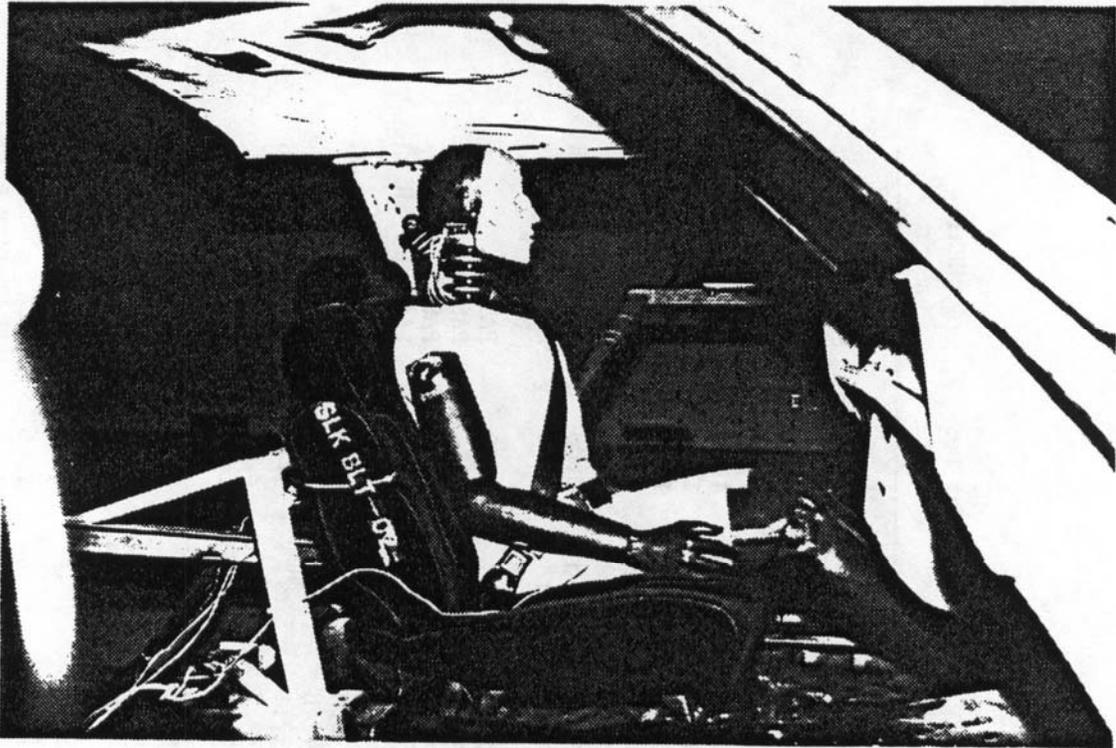
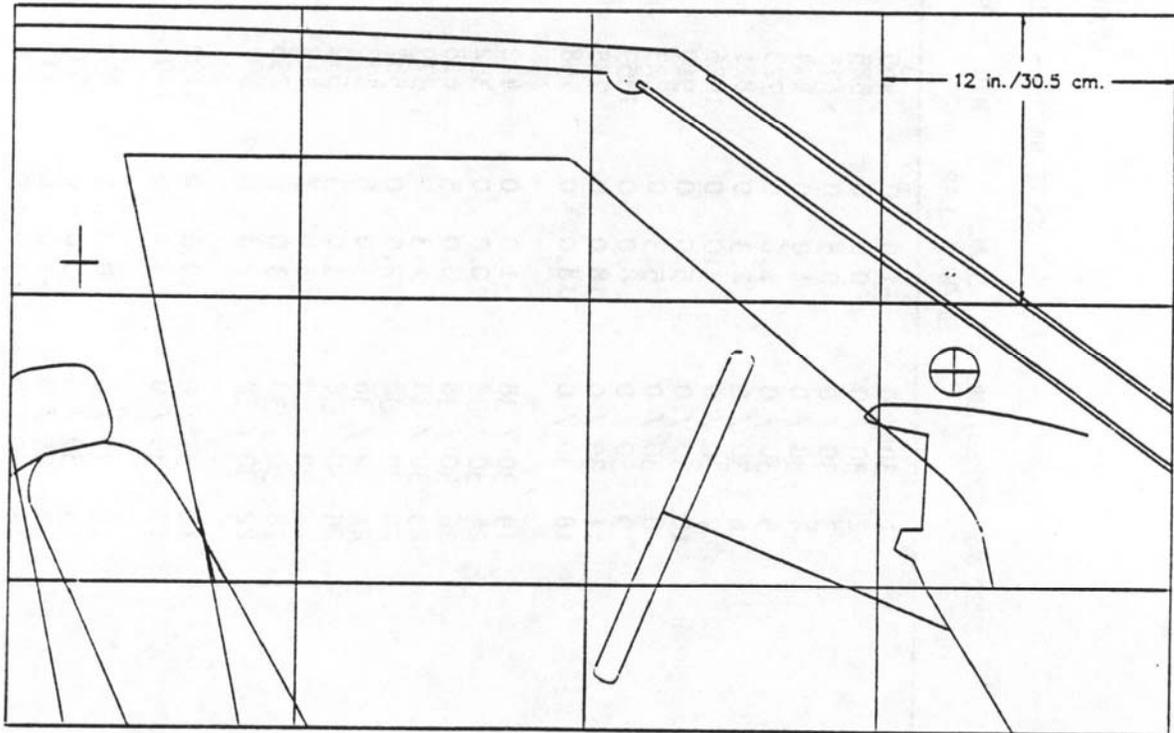


Figure 1B



Figures 1A and 1B - Sled Test Environment for the Slack Belt Study

Figure 2A

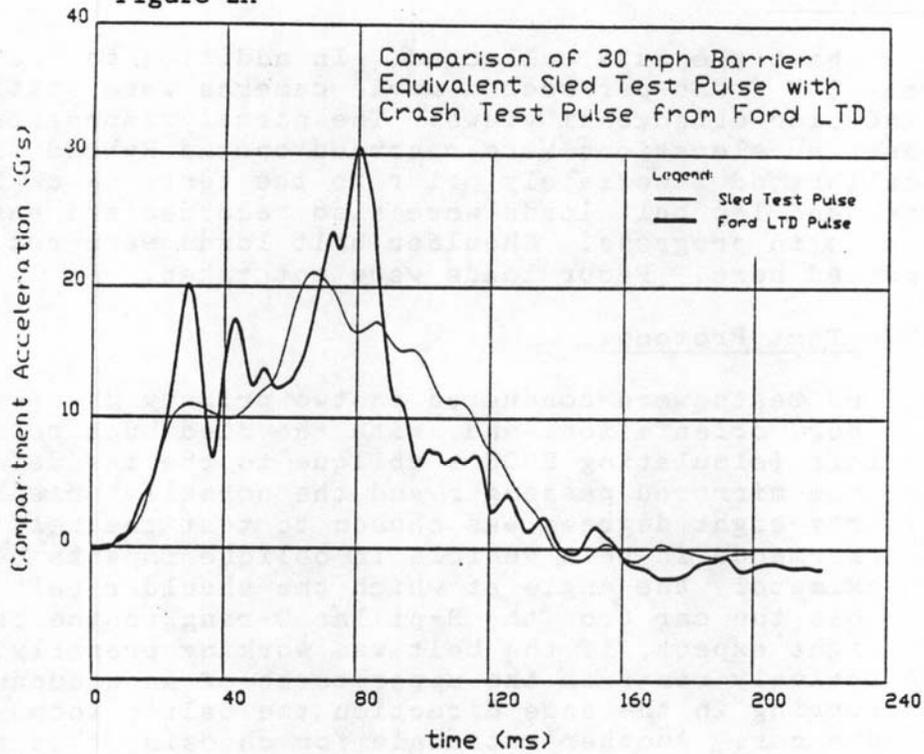
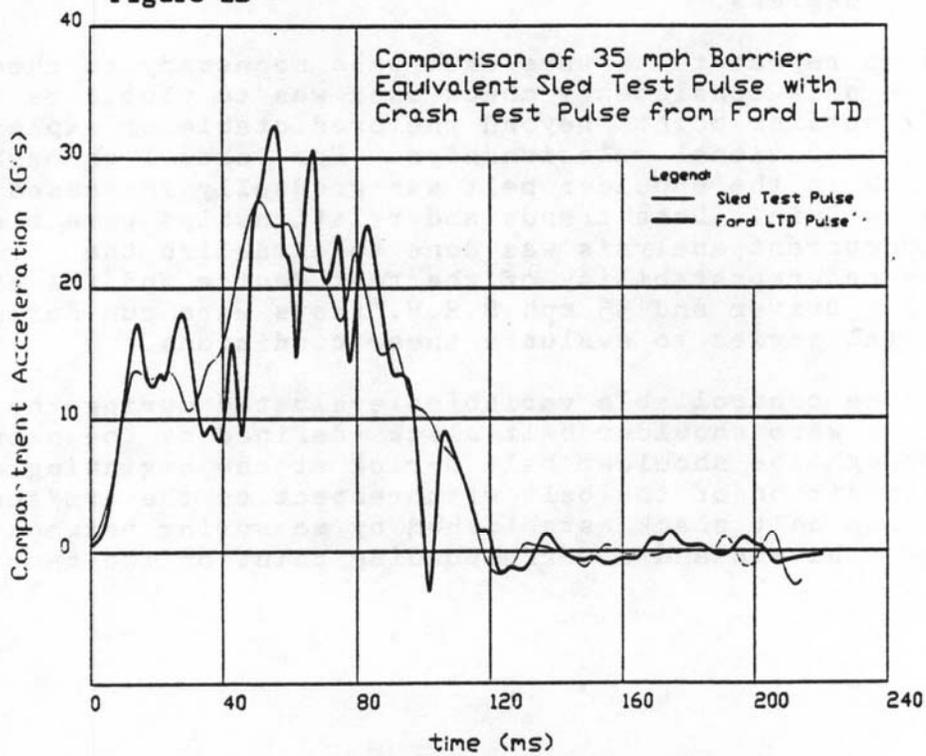


Figure 2B



Figures 2A and 2B - Comparison of 30 and 35 mph Sled Test Pulses with Ford LTD Crash Pulses

Data Recorded

Table 1 shows the data collected. In addition to the data shown, three 1000 frame-per-second movie cameras were stationed for front and side orthogonal views. The normal components of head and chest accelerations were recorded on the Hybrid III which was calibrated immediately prior to the test. Neck loads, neck moments, and lap belt loads were also recorded and analysis on that data is in progress. Shoulder belt loads were recorded and are reported here. Femur loads were not taken.

Specific Test Protocol

These sled tests were conducted in two primary phases: with a head-on, 0 deg. orientation, and, with the sled buck rotated 38 deg. to the left (simulating PDOF's oblique to the inside of the car for both the mirrored passenger and the normally oriented driver). Thirty-eight degrees was chosen to test the belt restraint performance in this vehicle in oblique impacts because this is approximately the angle at which the shoulder belt traverses across the car from the B-pillar D-ring to the latch plate. One might expect, if the belt was working properly, that it would effectively restrain the upper torso of an occupant in an impact occurring in the same direction the belt's loop was oriented in the car. Another rationale for choosing this angle for the sled was that, given practical resource limitations, this one fixed sled angle would give a good simulation of angles of impact orientation on the highway up to approximately twice this angle, or 76 degrees.

Although repeat tests were used when necessary to check results, the main consistency check used was to plot data trends to identify outlier points beyond the predictable or explainable envelope of conditional relationships. For Tests 1 through 11 and 18, slack in the shoulder belt was gradually increased from 1.0 in. to 18.0 in. Data trends and relationships were plotted and some concurrent analysis was done to establish the performance and repeatability of the test device and the crash environment. Driver and 35 mph B.E.V. tests were run during the 0 deg. frontal series to evaluate these conditions.

The three controllable variables evaluated during the oblique tests were shoulder belt slack (defined as the extra webbing through the shoulder belt D-ring at the beginning of the test), the position of the belt with respect to the arm/shoulder joint, and lap belt slack established by measuring between the center lower abdomen and a corresponding point on the taut belt.

FRONTAL 0 DEGREE SLED TESTS

Data Analysis and Results

For the 0 deg. tests the outcome variables most sensitive to the slack variable was head speed and displacement. Figure 3 shows the head excursion envelope for the passenger for Tests 1 through 11 and 18, while Figure 4 shows the head excursion envelope for the driver occupant in the 30 and 35 mph Tests 12 through 15.

Chest Results - Before the head speed results are discussed in detail, it is instructive to inspect the trends in the measured chest variables. Figure 5 shows the peak values for chest accelerations (3 ms clip); shoulder belt loads; and, the Hybrid III chest deflections, all plotted versus shoulder belt slack. The results for Tests 10 and 11, where the shoulder strap started off the shoulder, are highlighted against the basic condition of the belt strap on the shoulder. The preset condition of -1.0 in. of slack was determined by pretightening the belt with a 40 to 50 lb. preload. With this modest preload, noticeable effects were seen on the chest responses. This preload did not increase chest deflection while it reduced the chest accelerations from 37.7 to 30.1 G's. The shoulder strap load increased from 1407 to 1504 pounds with this amount of preload.

For a slack of 5 in. with the strap off the shoulder (Test 10), chest deflections and accelerations were increased along with the shoulder belt loads as shown in Figure 5. In addition, the belt loaded into the chest below the right rib cage, into the right lower abdomen, and across the lower left rib cage structure. This concentrated loading on the Hybrid III chest structure, with reduced restraint contribution from the shoulder, caused the chest deflections to increase. For 18 in. slack and the belt off the shoulder (Test 11) the chest accelerations and belt loads were below those for the same amount of slack in which the belt was on the shoulder (Test 18). Chest deflections were the same for these two tests. Eighteen inches is the amount of slack one gets in a windowshade belt after leaning forward to look past the A-pillars - at an intersection for instance. Belt loads were not taken for Test 18, but chest responses for 18 in. of slack were somewhat below the peak values because of chest unloading from the head/neck impact into the instrument panel.

Head Results - Figures 6A through 6L are plots of (center of) head speeds relative to the interior of the compartment versus time for Tests 1 through 11 and 18. Figures 7A through 7L show this same relative head speed but plots it against forward head excursion for these same 30 mph frontal passenger tests. A head speed versus time and head speed versus forward excursion plot was constructed for each frontal test from detailed kinematic analyses of the high speed films. Cross checks indicated that the data was consistent and the Hybrid III's

Note: Head Starting Positions Have Been Adjusted for Camera Parallax

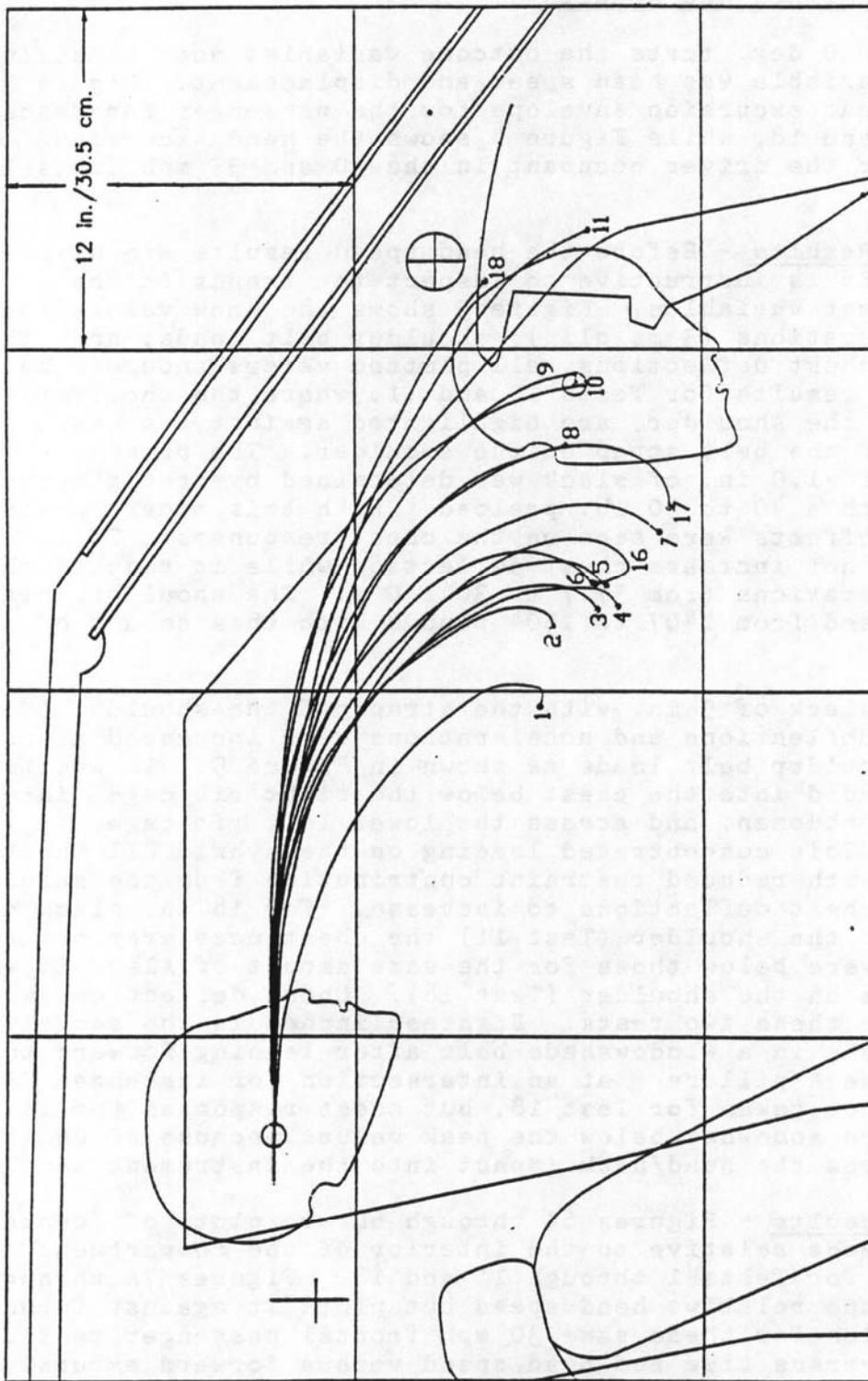


Figure 3 - Head Excursion Envelope for 30 mph Passenger Tests

Note: Head Starting Positions Have Been Adjusted for Camera Parallax

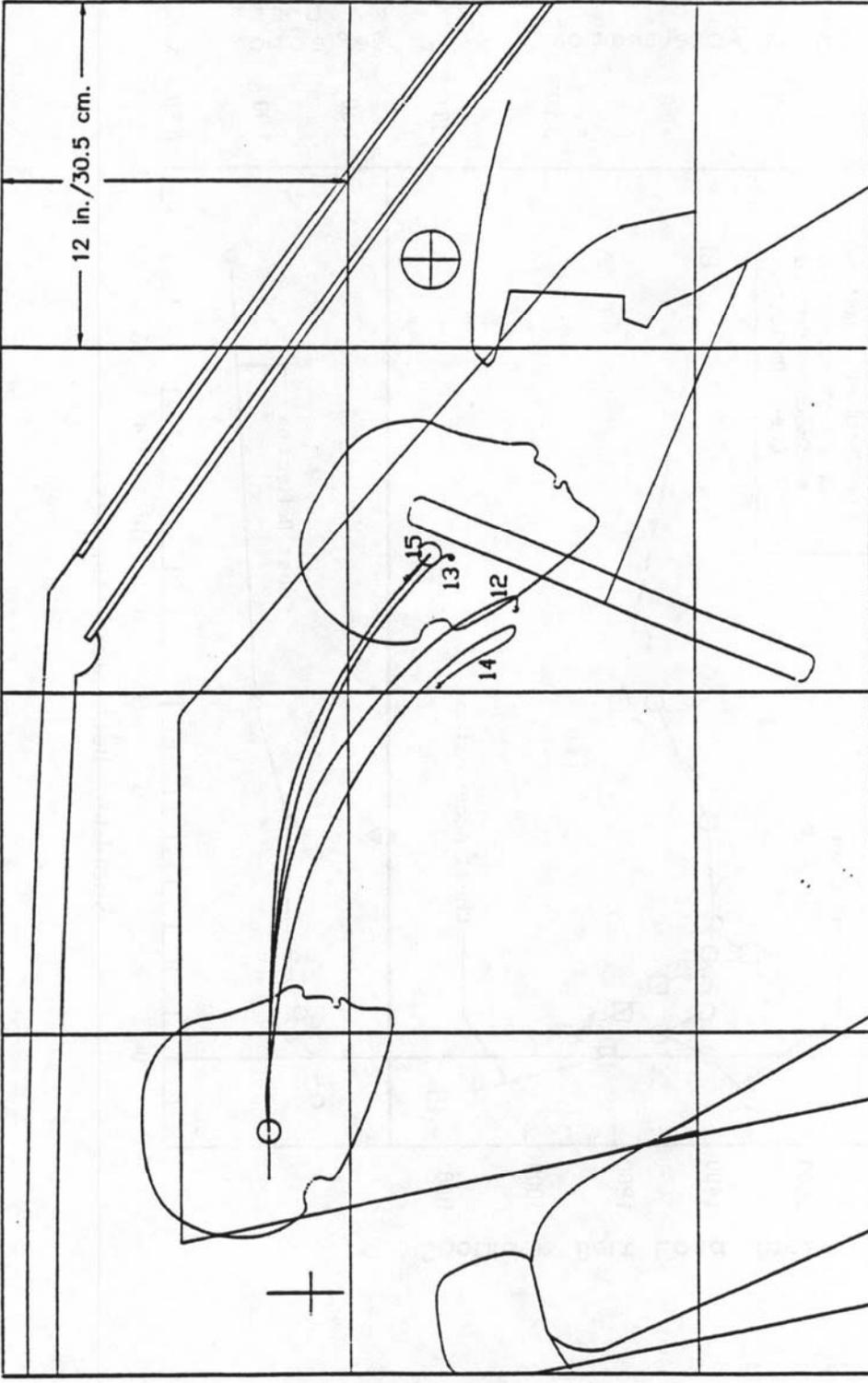


Figure 4 - Head Excursion Envelope for 30 and 35 mph Driver Tests

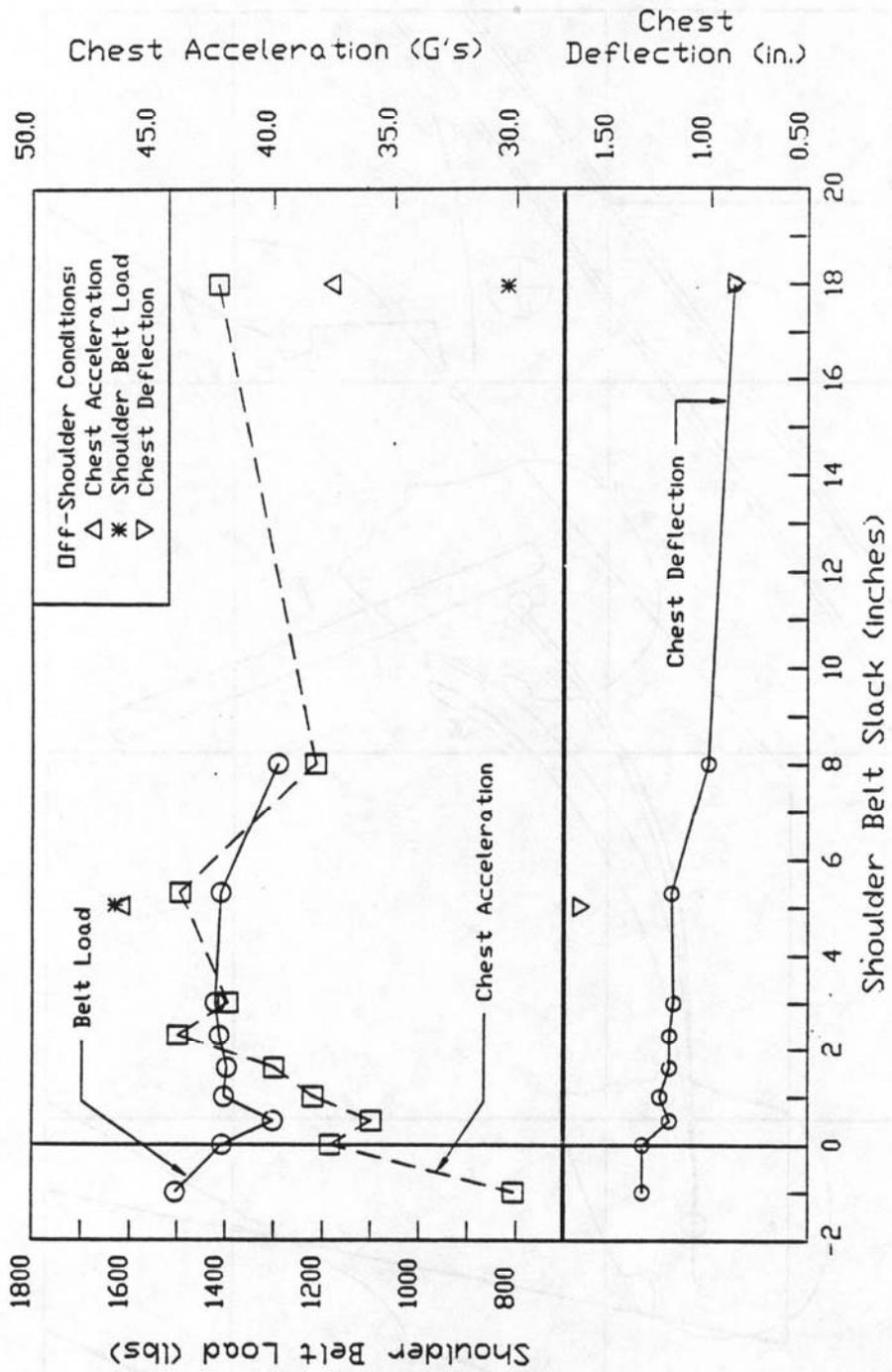


Figure 5 - Summary of Chest Response Data for 30 mph Passenger Tests

Figure 6A

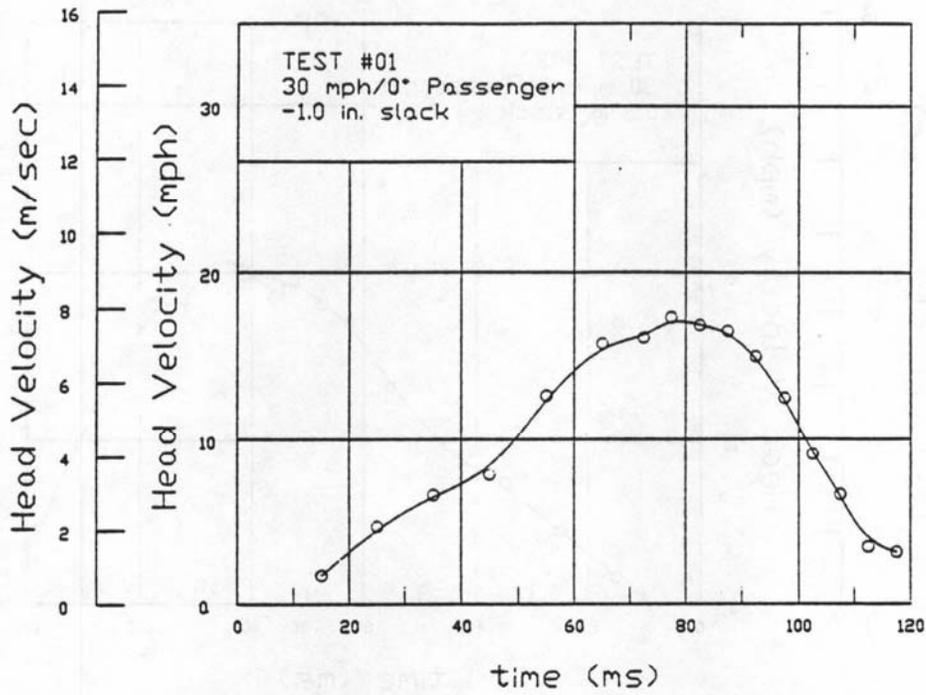
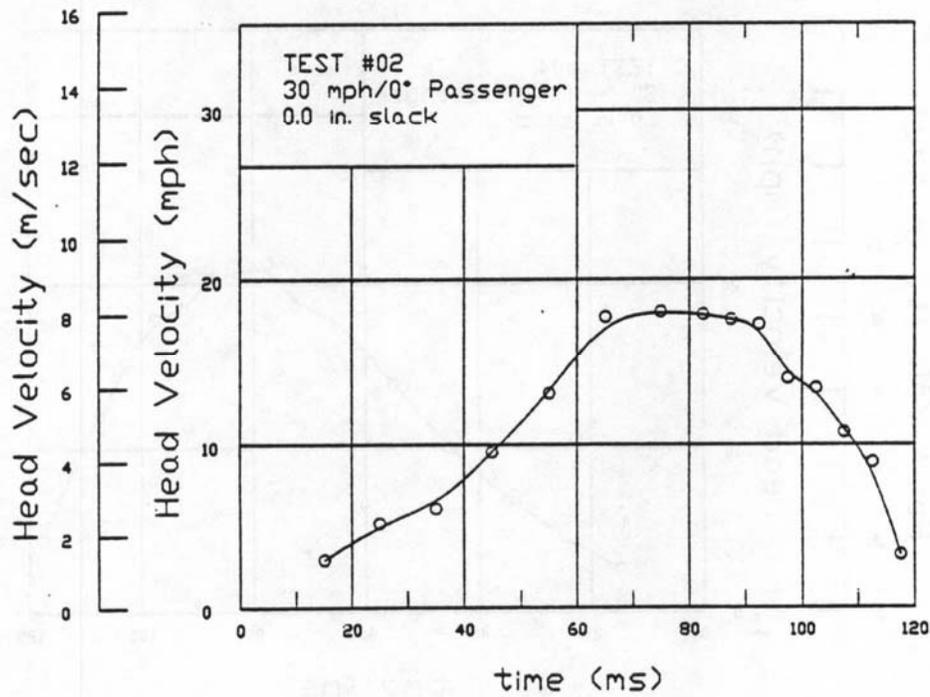


Figure 6B



Figures 6A and 6B - Head Speed vs. Time for Tests 1 and 2

Figure 6C

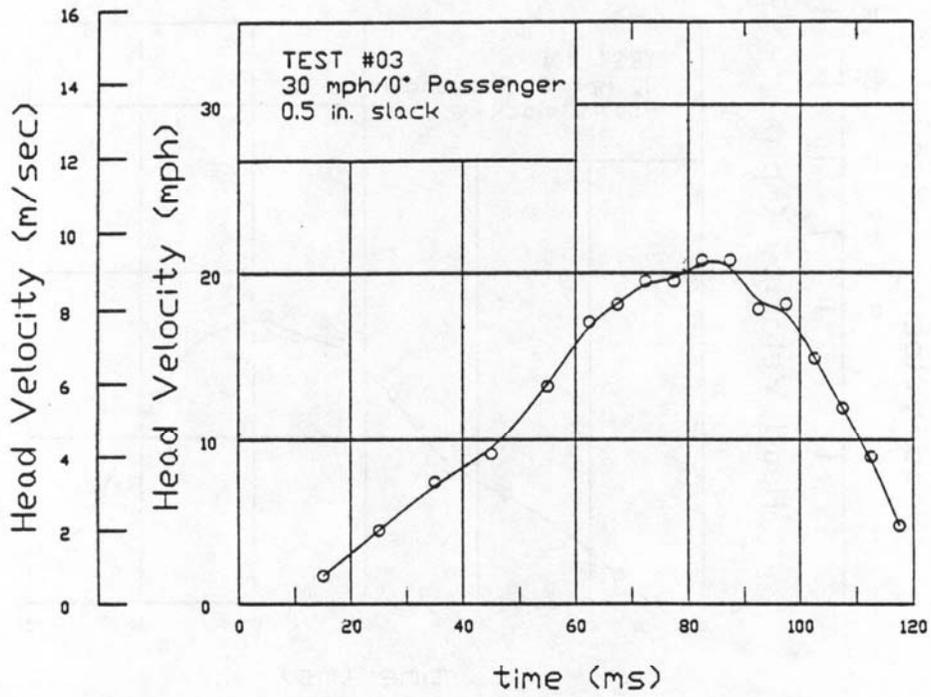
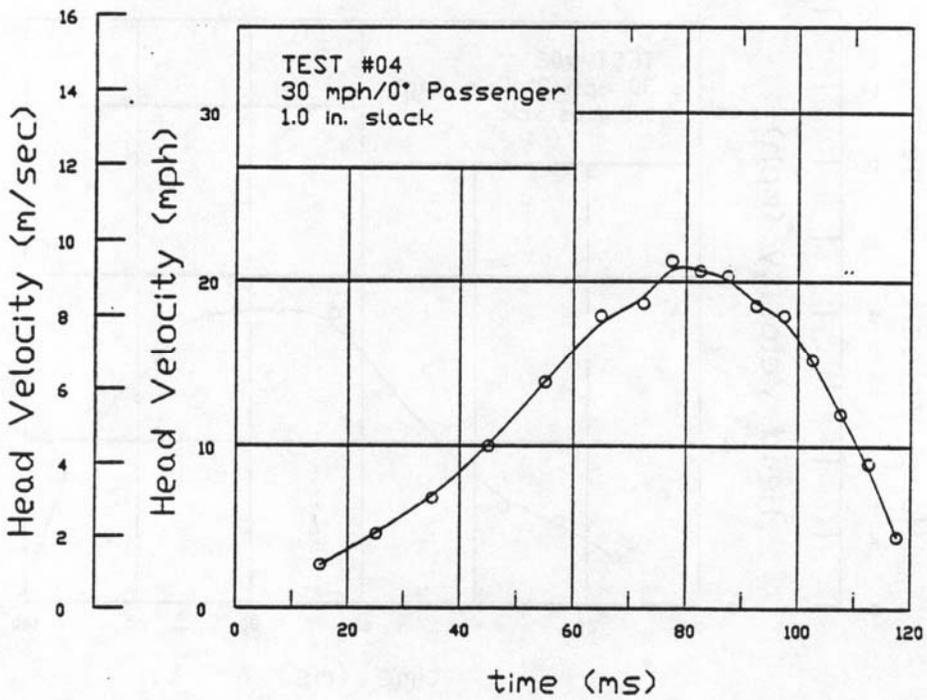


Figure 6D



Figures 6C and 6D - Head Speed vs. Time for Tests 3 and 4

Figure 6E

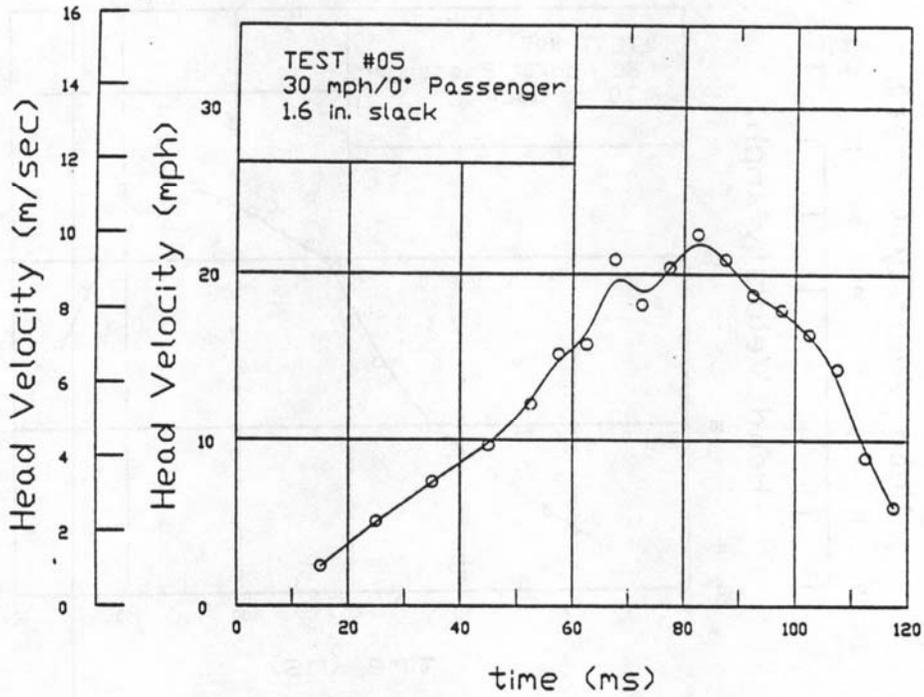
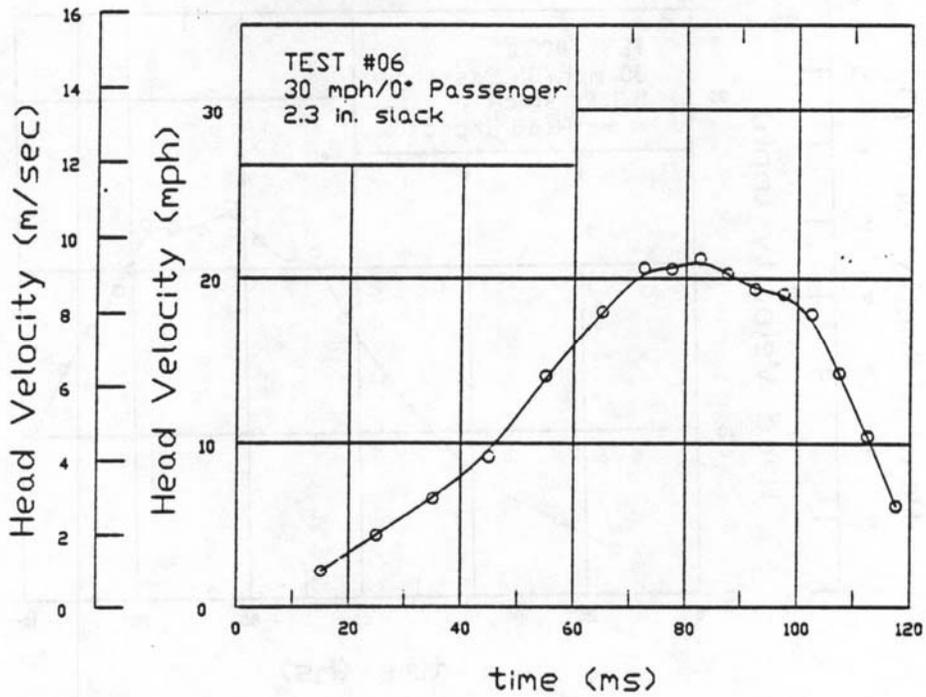


Figure 6F



Figures 6E and 6F - Head Speed vs. Time for Tests 5 and 6

Figure 6G

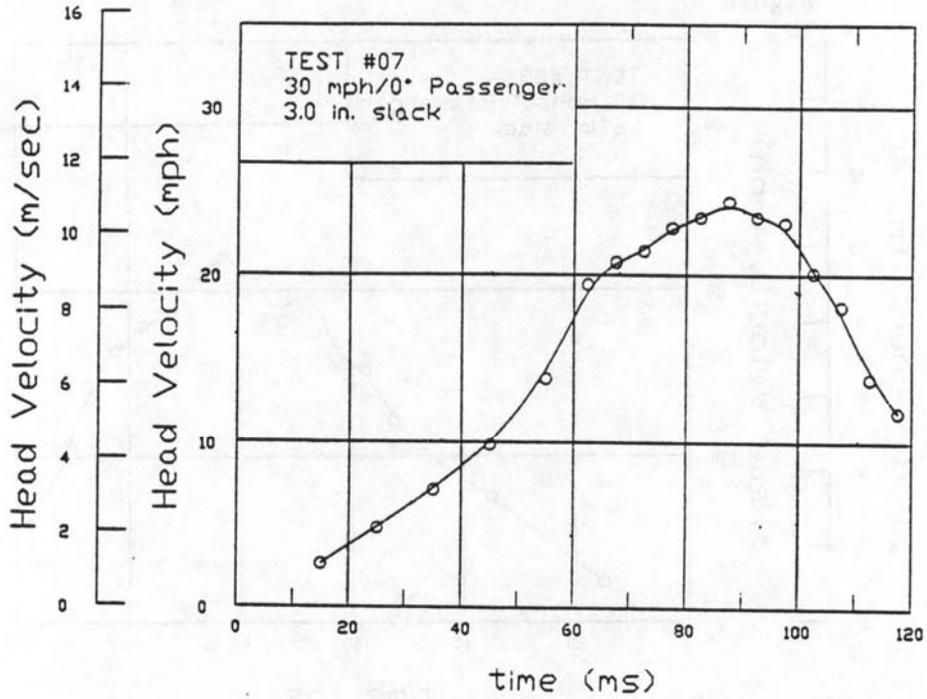
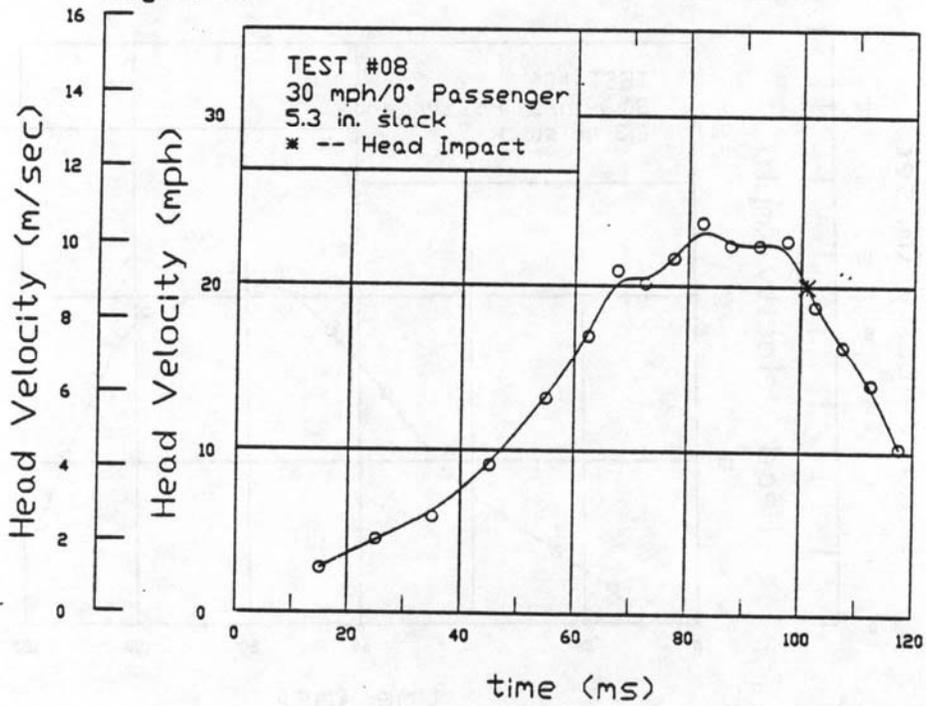


Figure 6H



Figures 6G and 6H - Head Speed vs. Time for Tests 7 and 8

Figure 6I

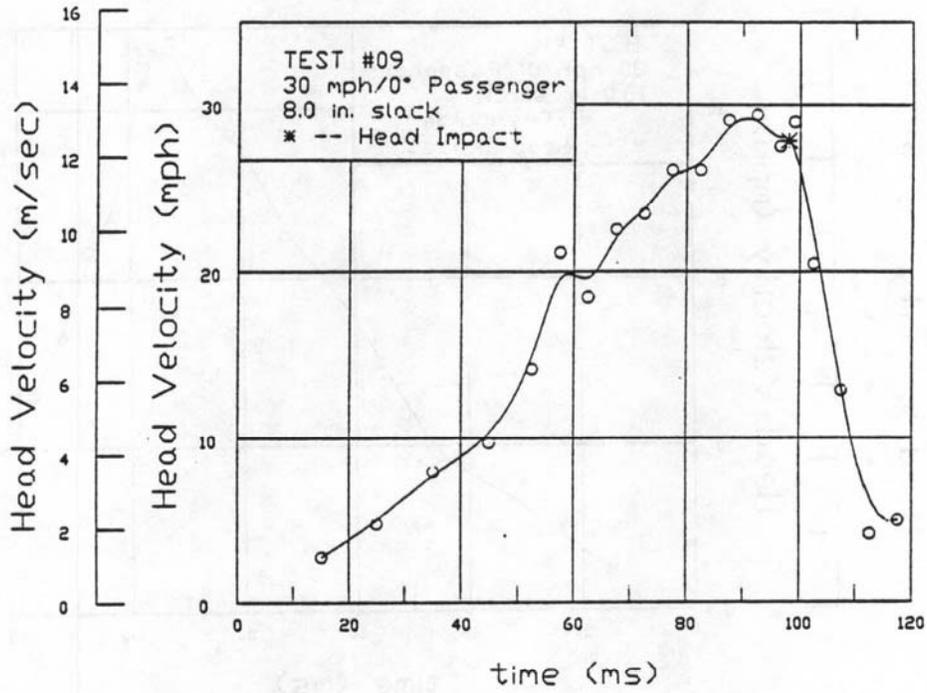
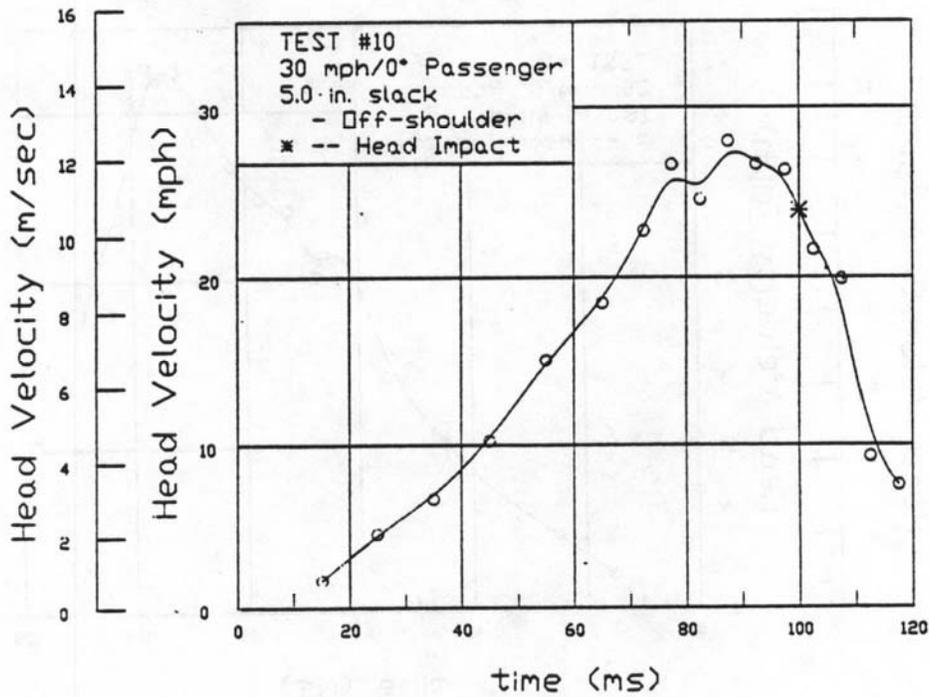


Figure 6J



Figures 6I and 6J - Head Speed vs. Time for Tests 9 and 10

Figure 6K

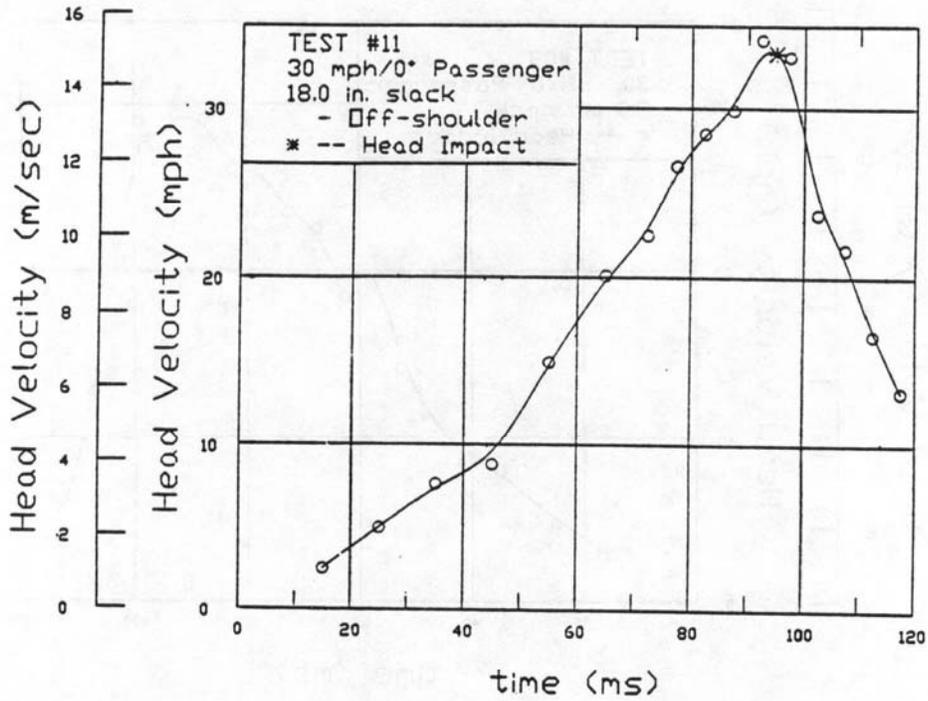
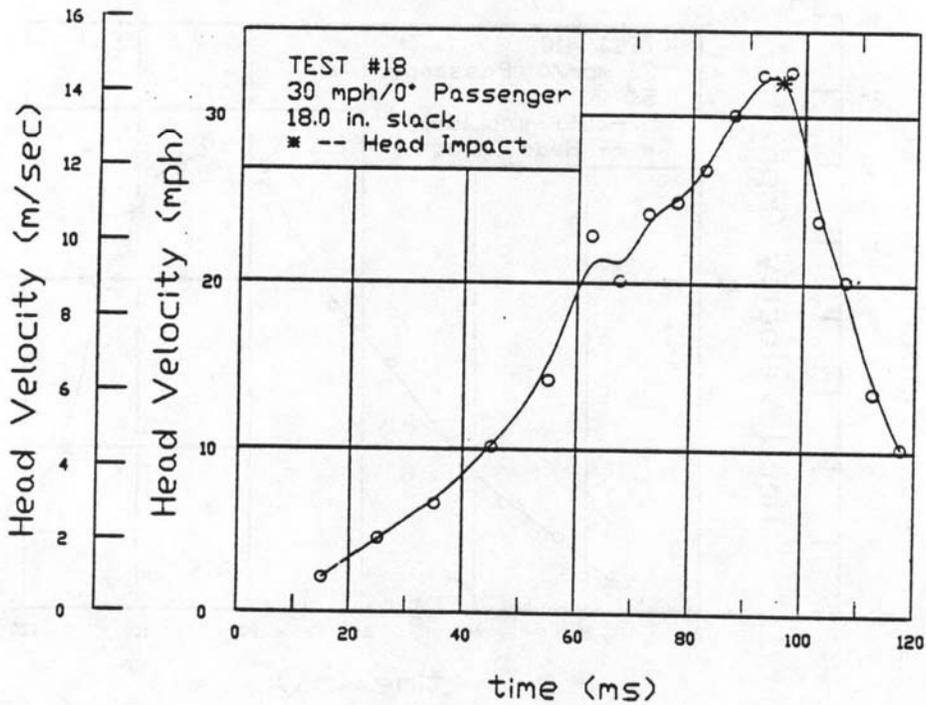


Figure 6L



Figures 6K and 6L - Head Speed vs. Time for Tests 11 and 18

Figure 7A

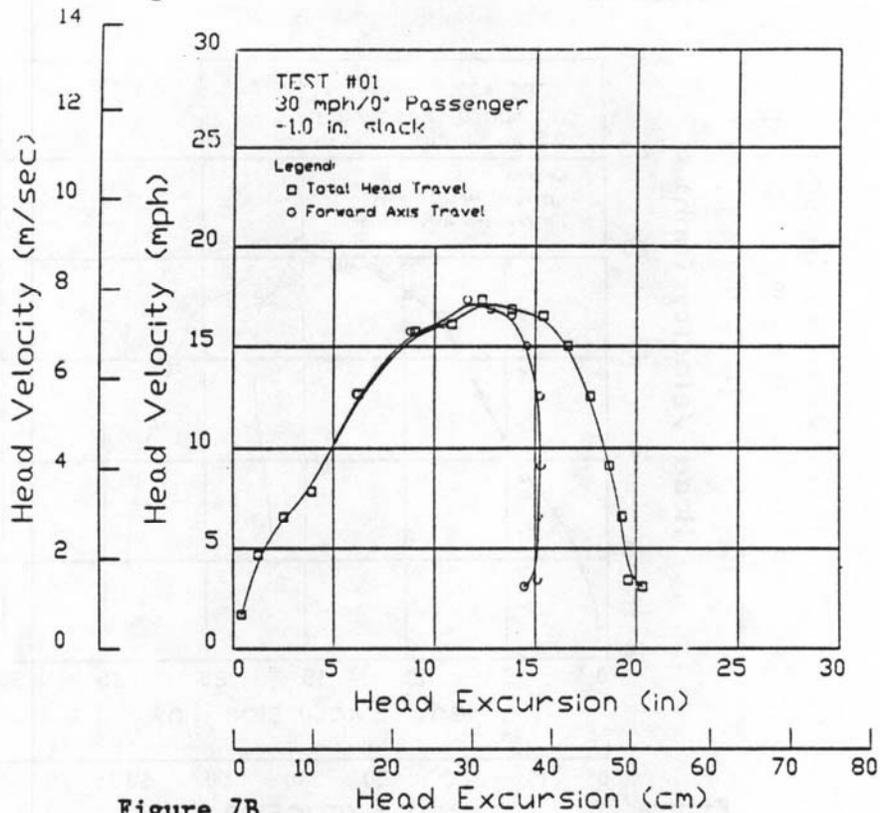
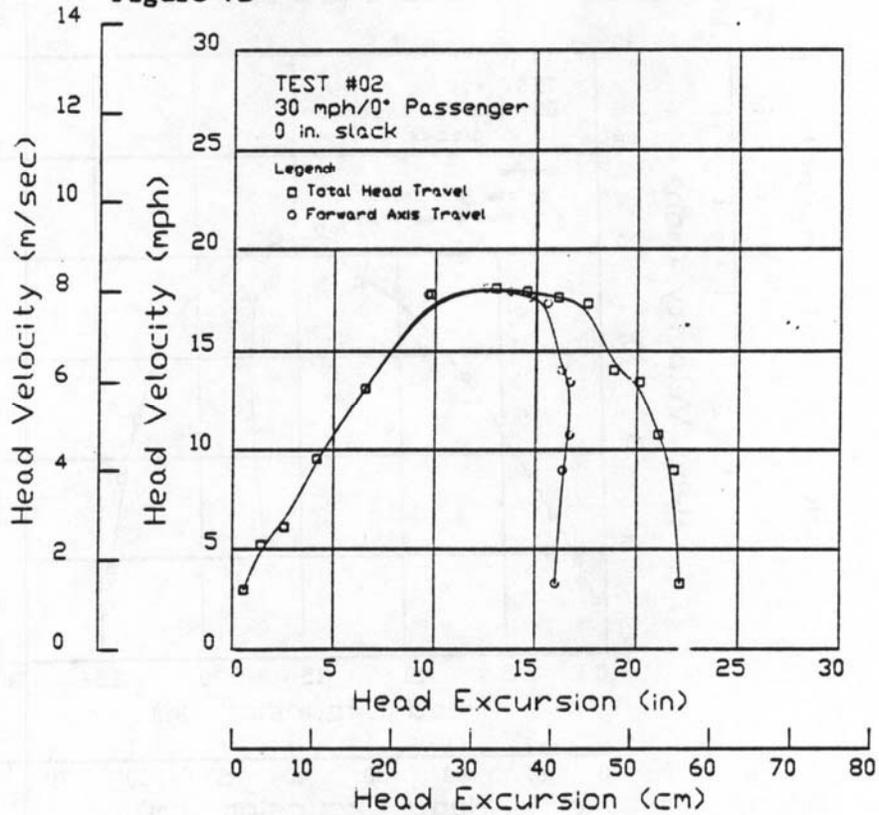


Figure 7B



Figures 7A and 7B - Head Speed vs. Head Displacement for Tests 1 and 2

Figure 7C

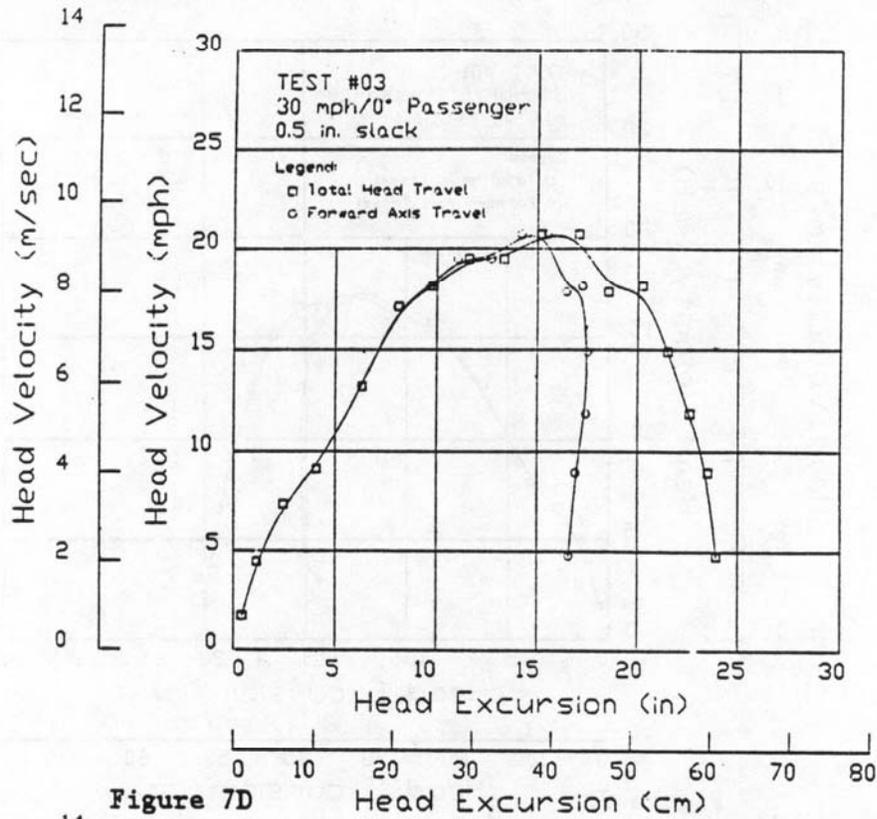
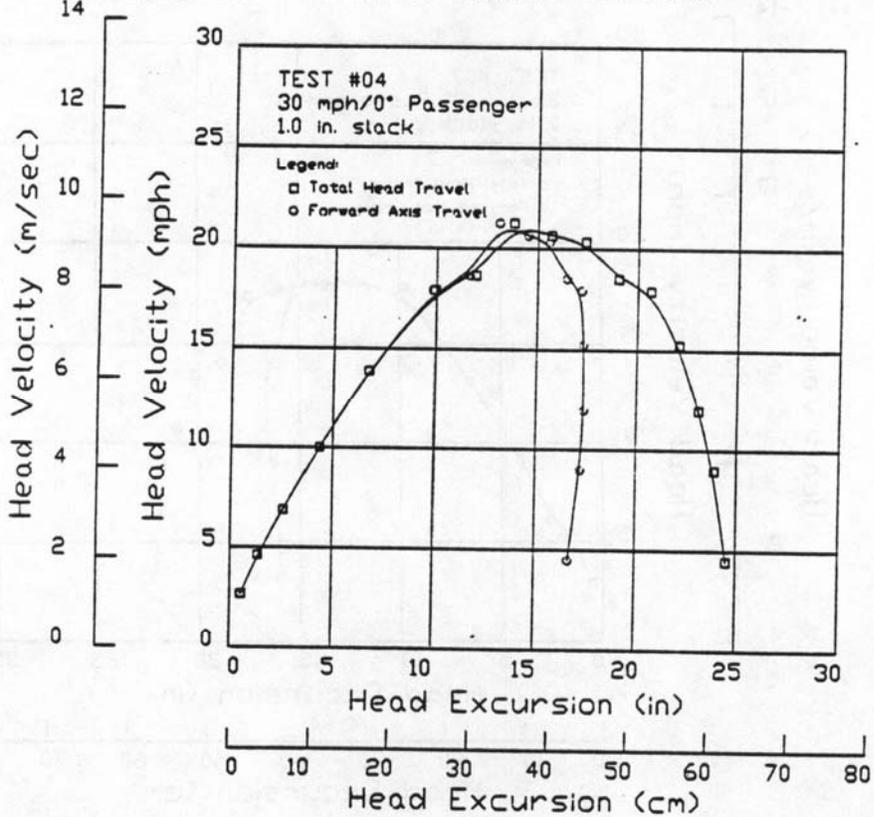
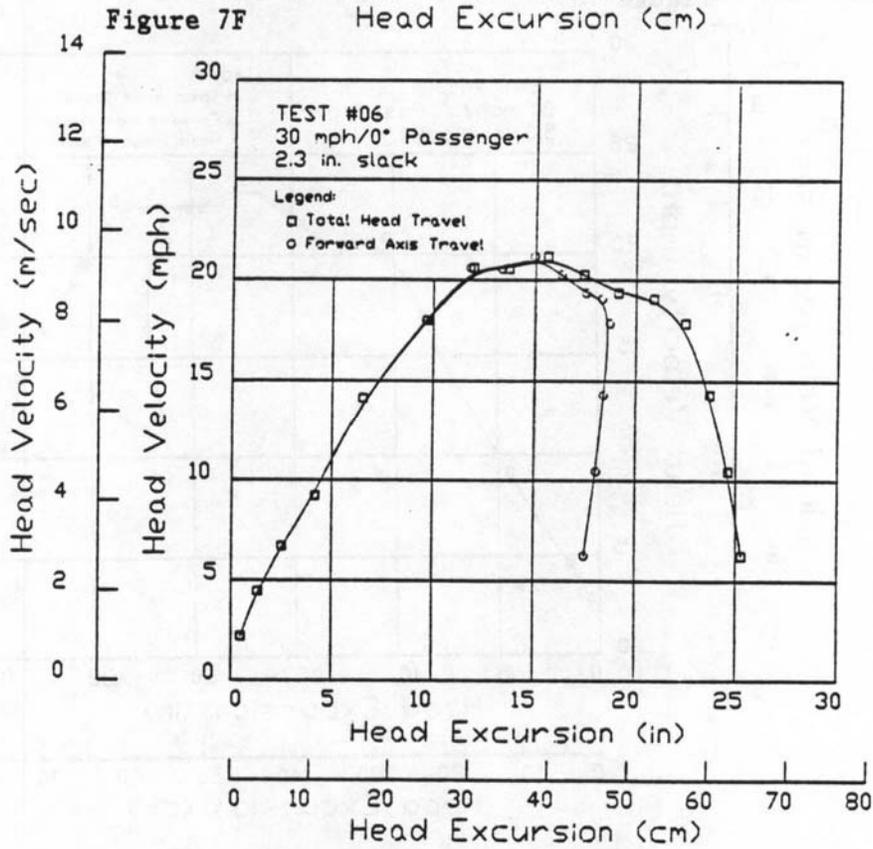
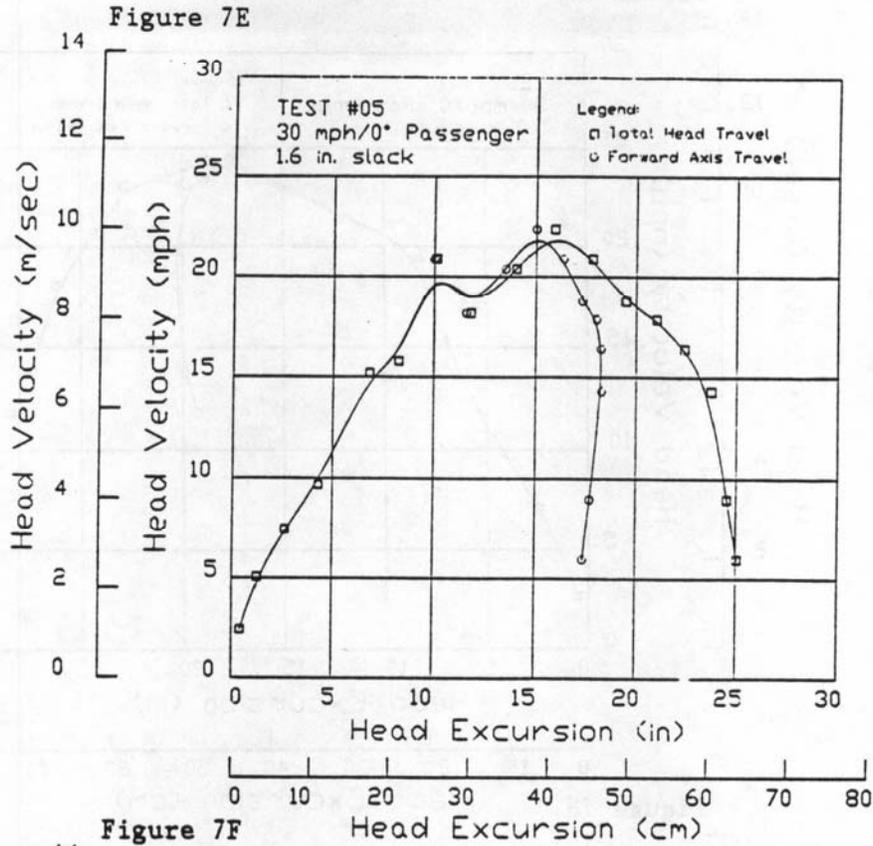


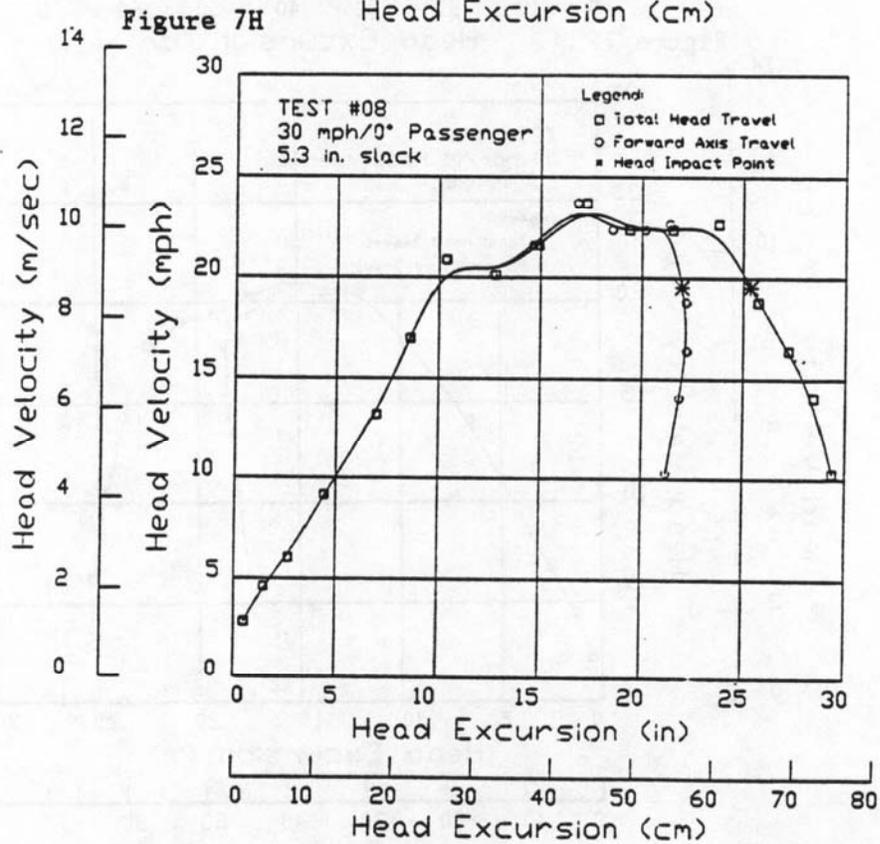
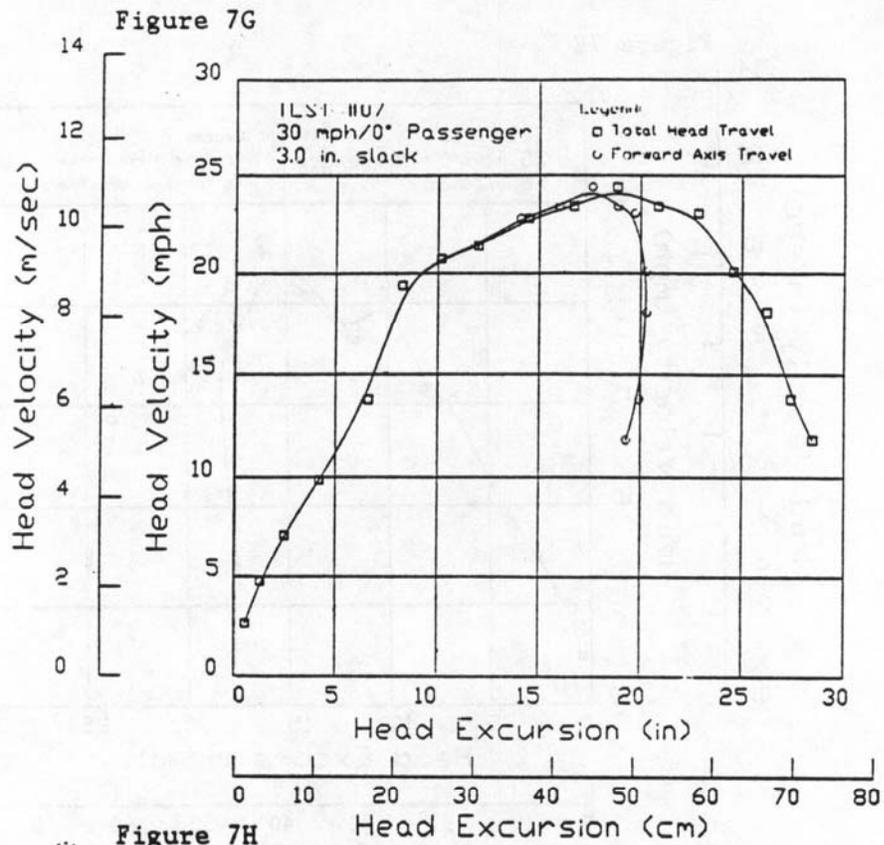
Figure 7D



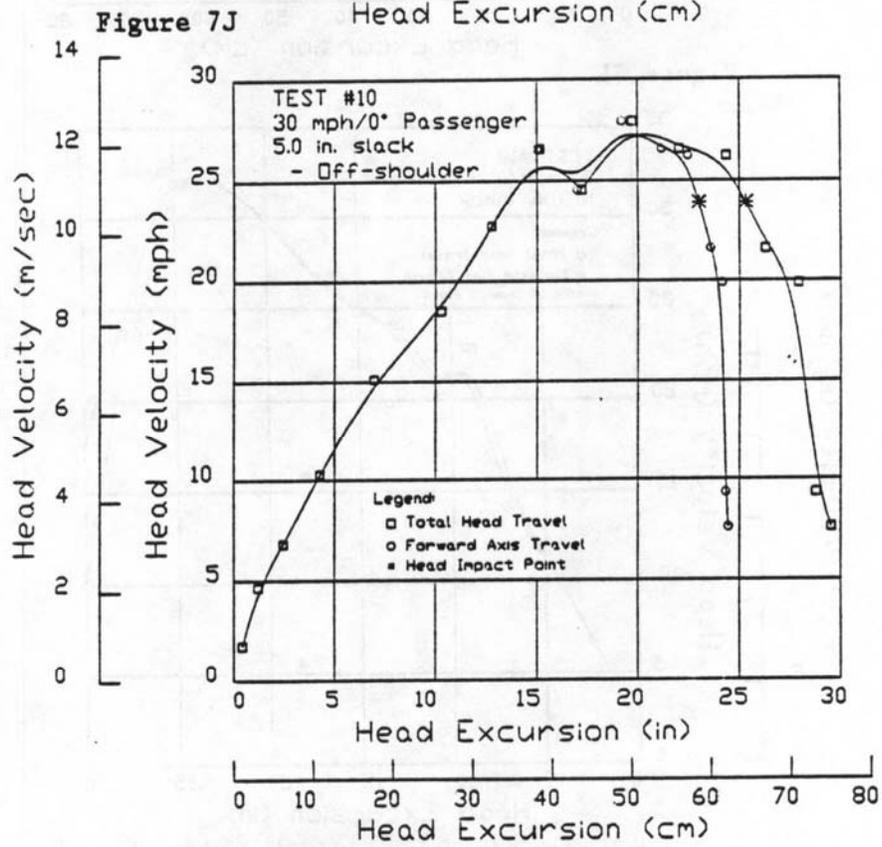
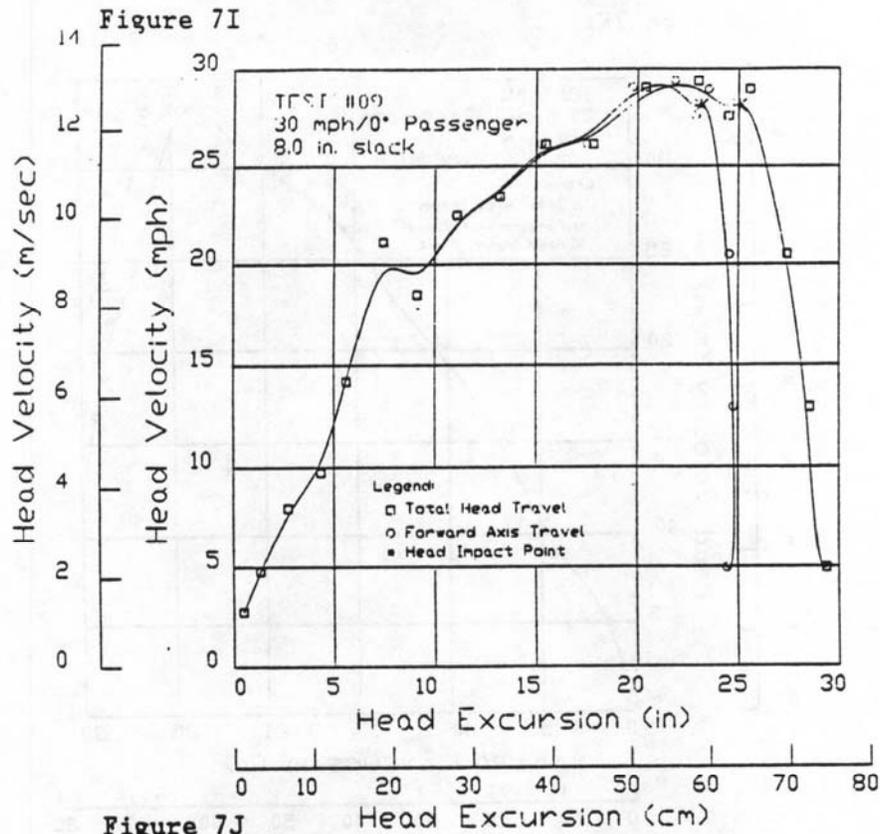
Figures 7C and 7D - Head Speed vs. Head Displacement for Tests 3 and 4



Figures 7E and 7F - Head Speed vs. Head Displacement for Tests 5 and 6



Figures 7G and 7H - Head Speed vs. Head Displacement for Tests 7 and 8



Figures 7I and 7J - Head Speed vs. Head Displacement for Tests 9 and 10

Figure 7K

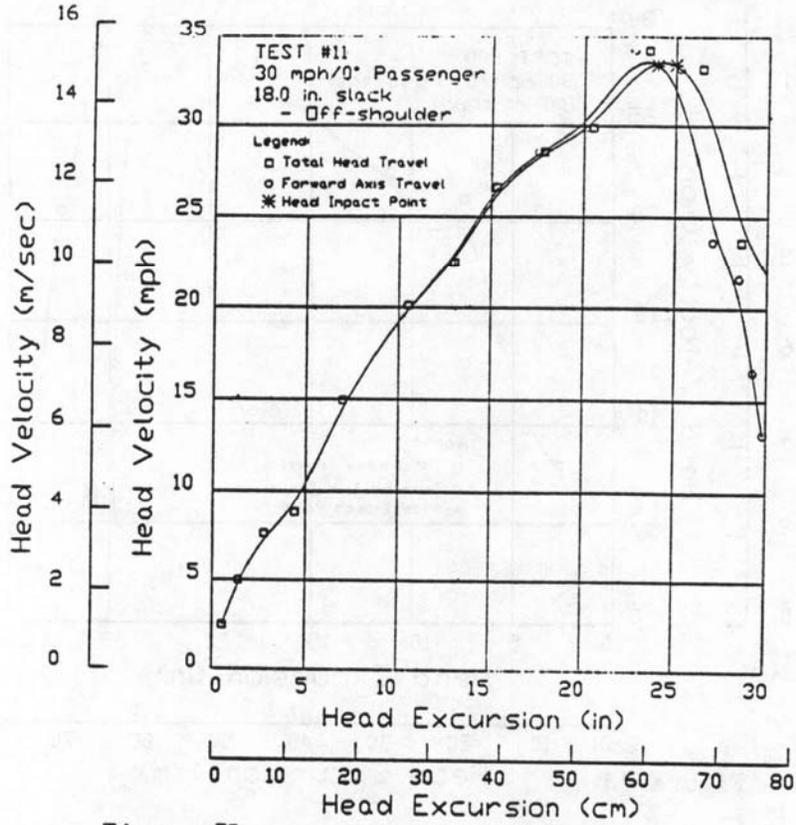
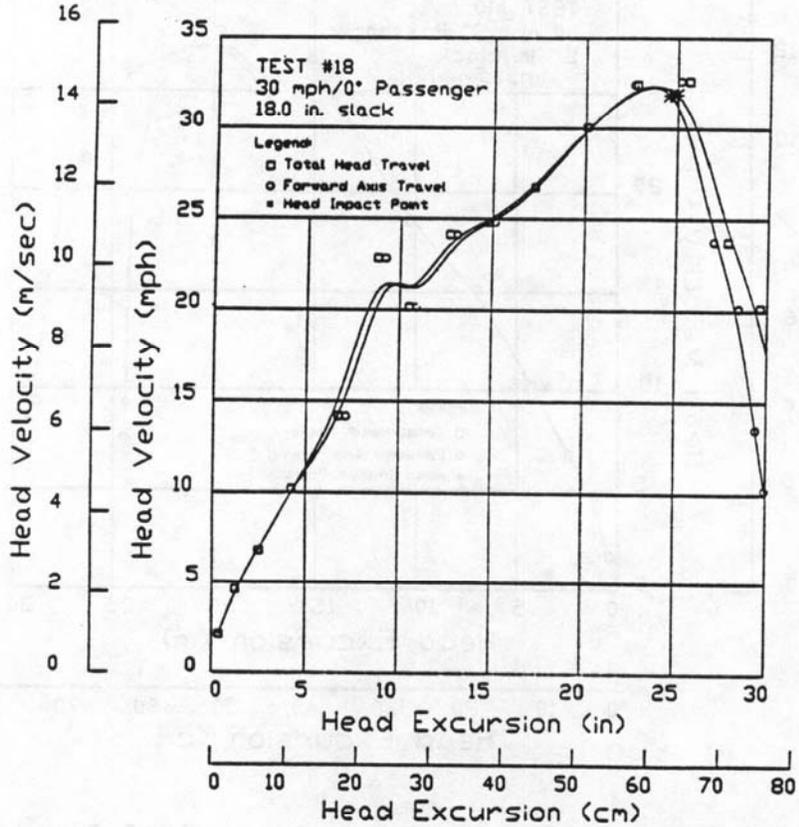


Figure 7L



Figures 7K and 7L - Head Speed vs. Head Displacement for Tests 11 and 18

performance was repeatable. As these plots show, the head speed increases uniformly and predictably as the amount of slack in the shoulder belt is increased. Predictable exceptions occurred in Tests 10 and 11 where the belt strap started off the shoulder and those results will be discussed in more detail later. Because of present space limitations, head speed plots will not be presented for the driver or for the 35 mph tests. This data will appear in another publication in the near future.

Preliminary analysis showed that peak head velocities and excursions within the compartment were sensitive and repeatable outcome variables when plotted against the controlled shoulder belt slack variable. In this series of tests, and indeed in any similar belt restraint tests conducted in a realistic compartment interior, variables such as the head accelerations and Head Injury Criteria (HIC) will be strongly influenced by which surface the head impacts and how it impacts that surface. These considerations were explored to some extent by Tarriere (Ref. 1), and his diagram showing the component forces acting on a three-point belted driver's head impacting a vehicle's steering wheel, is reproduced here as Figure 8. Tarriere's argument, however, that the HIC can be safely increased to 1500 for belted driver, gives insufficient attention to the fact that for this occupant, many impacts of the steering system with the head occur into the delicate facial area. The relatively weak facial bones are easily fractured causing serious cosmetic injuries, and these structures can also be driven rearward into the brain area.

The rationale for the present analysis approach then is that a higher relative head speed inside the compartment should be a good predictor of the potential for serious head and facial injuries. Substantiation for such an approach is given in terms of the kinetic energy dissipated in stopping the head from various relative interior velocities. For instance, the kinetic energy of the head (assuming a weight of 12 pounds) at a relative head speed of 17.4 mph (which is the head speed for the best performing belt test of this series) is 121 ft-lb, whereas the kinetic energy for the head with 8 in. of slack in the belt and a head speed of 29.4 mph is 346 ft-lb, a factor of 2.86 increase. As a comparison, the kinetic energy associated with the maximum relative head speed of 34.2 mph achieved in these tests, is 469 ft-lb for a belt slack of 18 in.

Figure 9 summarizes the maximum relative head-to-interior velocity versus shoulder belt slack for the 30 mph frontal passenger tests in which the strap was on the shoulder. Figure 10 summarizes the maximum head excursion inside the compartment versus shoulder belt slack for these same conditions. For ten of the 18 frontal 0 deg. sled tests in this program, the test conditions were closely enough controlled that the results can be directly compared in Figures 9 and 10. There is a perceptible break or knee in all these curves at around eight inches slack, probably attributable to the kinematics and dynamics of the Hybrid III neck. This break in the curve would be defined with

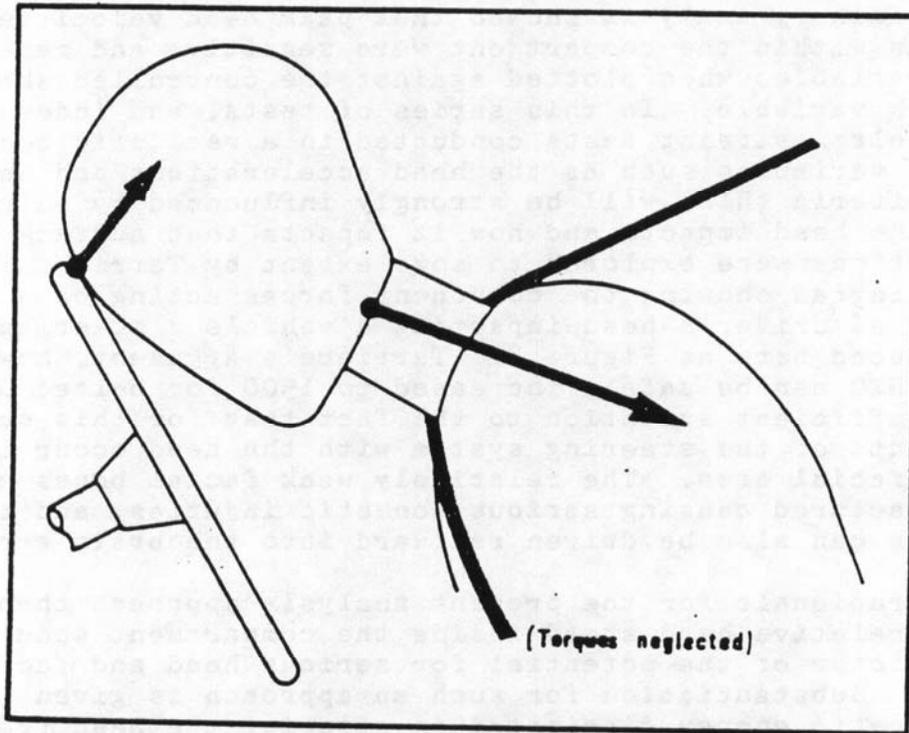


Figure 8 - Tarriere's Illustration of Head Stopping Force Components (from Reference 1)

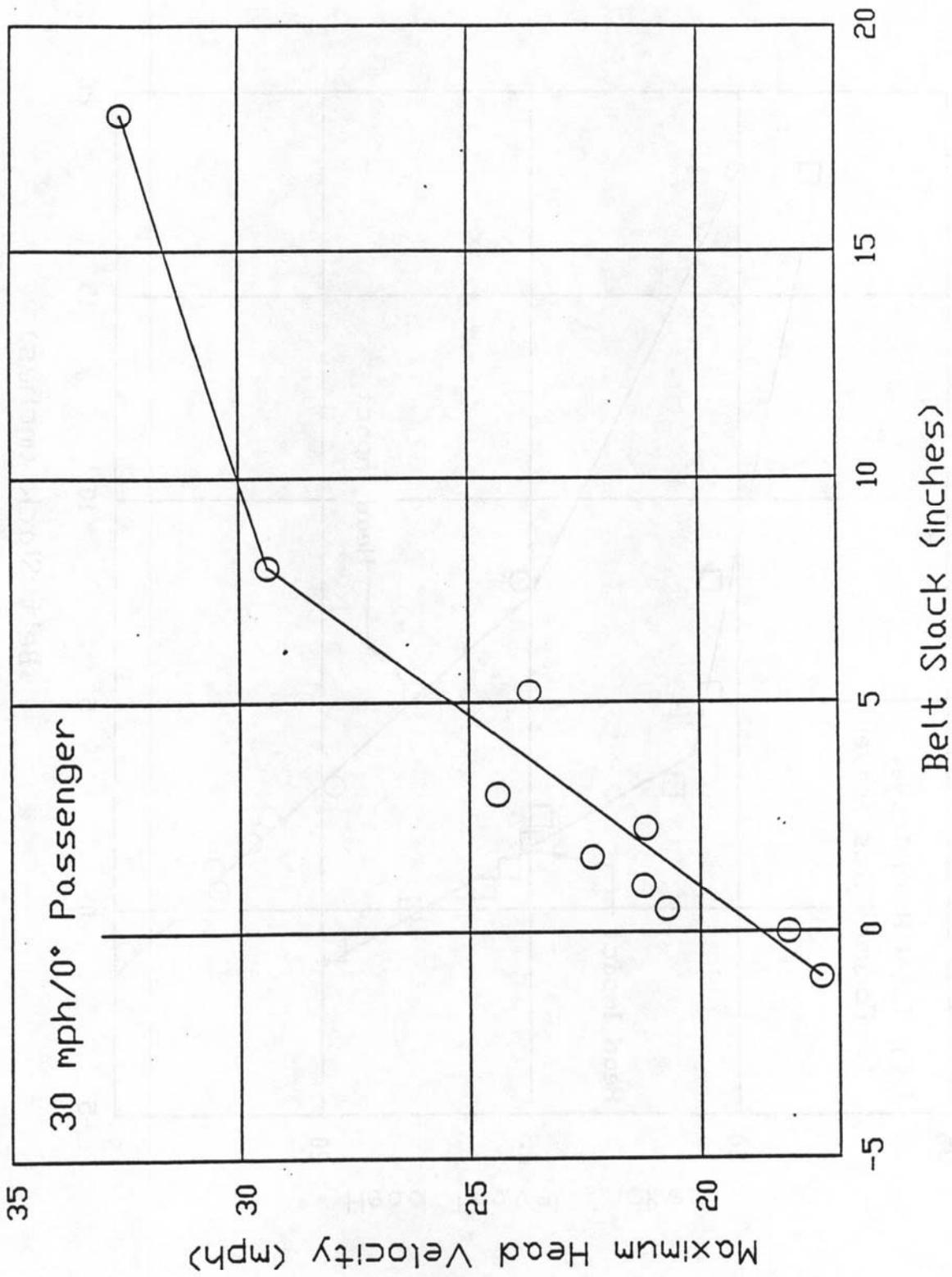


Figure 9 - Maximum Head Velocities vs. Shoulder Belt Slack

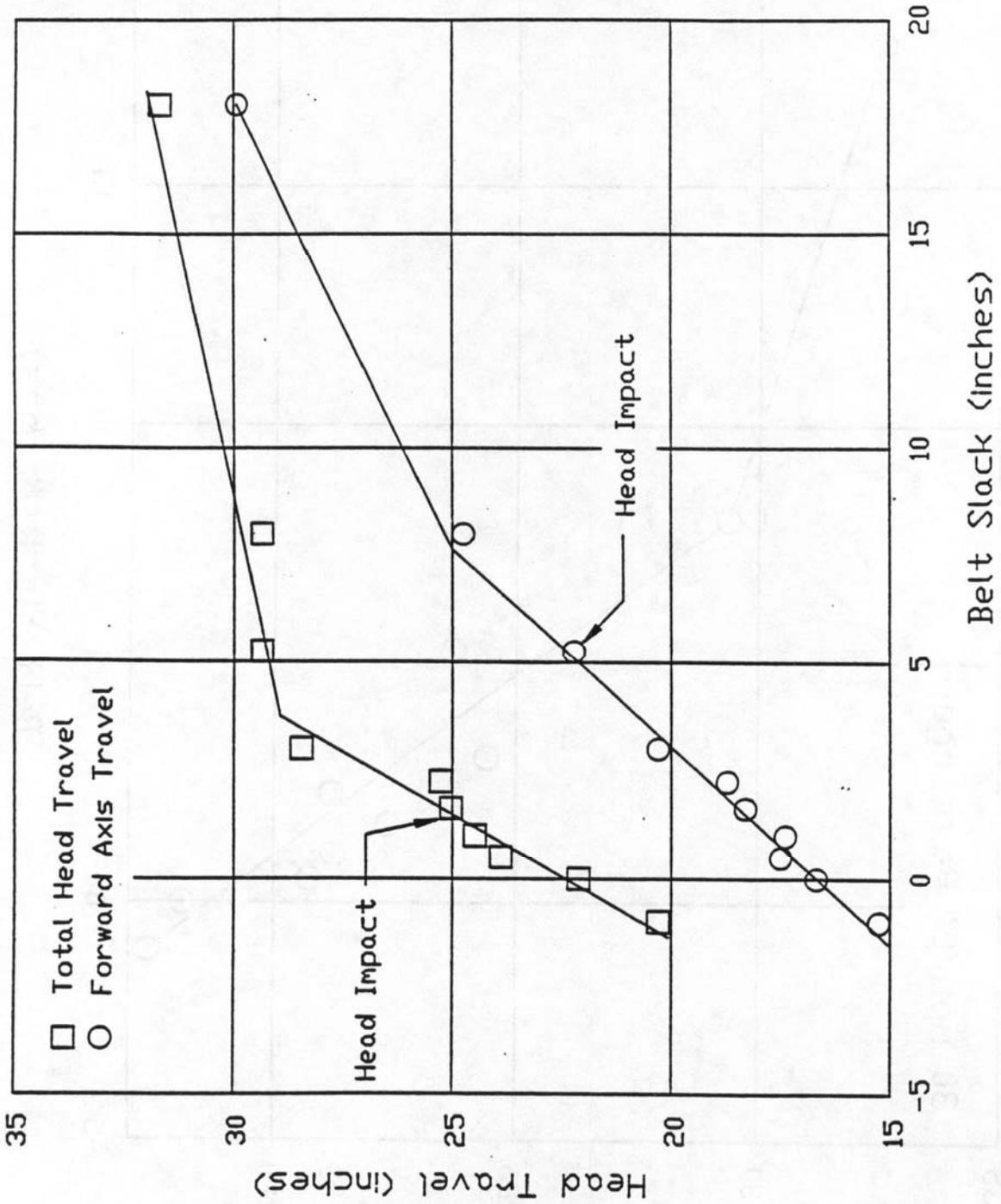


Figure 10 - Maximum Head Excursions vs. Shoulder Belt Slack

more precision with additional repeat tests and data points in the range of slacks between 5 and 10 inches and such recommendations for future research programs will be discussed in more detail later. However, enough tests and observations were made in this program to predict that this same break in the head speed and excursion curves will indeed be there upon further testing and analysis.

To consider the effect of the shoulder strap being off the shoulder before impact, Figures 11 and 12A were prepared which include Tests 11 and 18. A simple normalization process was used by plotting the actual head speed and displacements for these off shoulder tests, and then considering what additional apparent slacks might be introduced to have the off-shoulder data points fall on the on-shoulder curves. The results of this analysis indicates that with the belt off the shoulder, a slack of 5 inches looks kinematically like a slack of 7 inches. With 18 inches of slack, the belt off the shoulder looks kinematically like a slack of 24 inches. The 5 to 7 inch slack analogy for the on and off-shoulder conditions is reasonable to describe this effect quantitatively. However, at the 18 inch slack setting the head impacts the instrument panel so heavily that this kind of comparison is presented as descriptive only. It is interesting to compare the responses for the off-shoulder conditions in Figures 11 and 12A with those in Figure 5. For the 5 inch off-shoulder condition, the chest acceleration, shoulder belt load, and chest deflection was the highest for any of the 30 mph frontal 0 deg. passenger tests, whereas the head responses were not the highest in this series.

Figure 12B compares the peak head speed versus shoulder belt slack for the previously discussed 30 mph frontal 0 deg. passenger tests with these same variables for the 30 mph frontal 0 deg. driver tests and the 35 mph frontal 0 deg. driver/passenger tests. This last comparison can be made because the peak head speed occurs before impact. Even so, when comparing the 30 mph driver with the 30 mph passenger, the driver peak head velocities are slightly and consistently higher. This effect has not as yet been totally explained but it is probably due in part to the positioning of the hands and arms holding the steering wheel.

Slacks in the range of 0 to 5 inches are found most frequently in American cars because the automobile and belt manufacturers designed the U.S. type windowshade tension relief device to introduce slack amounts in this range. These devices will however, introduce any amount of available slack under certain circumstances. The results of these tests, as presented in Figure 12B, show that the effects of introducing 5 inches of slack into a shoulder belt is approximately equivalent to raising the barrier equivalent impact severity from 30 to 35 mph, a severe result when kinetic energies are considered. At a given slack, going from a 30 to 35 mph B.E.V. raised the maximum head speed about 6.5 mph.

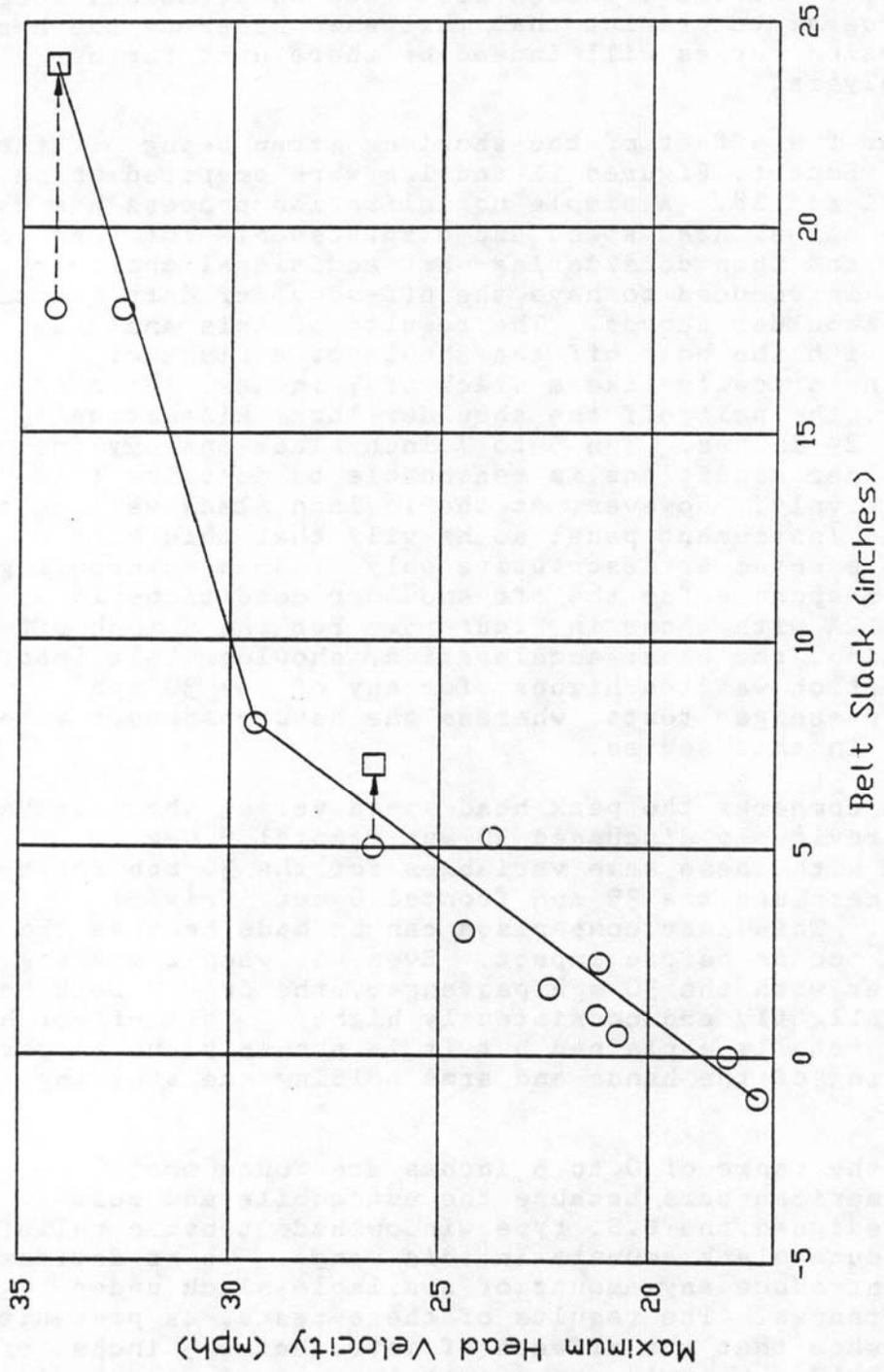


Figure 11 - Maximum Head Velocities vs. Shoulder Belt Slack with Off-Shoulder Conditions Included

Note: The Belt Off-Shoulder Increases the Effective Slack By:

- Test 10: from 5 in. to 7 in. = 2 in.
- Test 11: from 18 in. to 24 in. = 6 in.

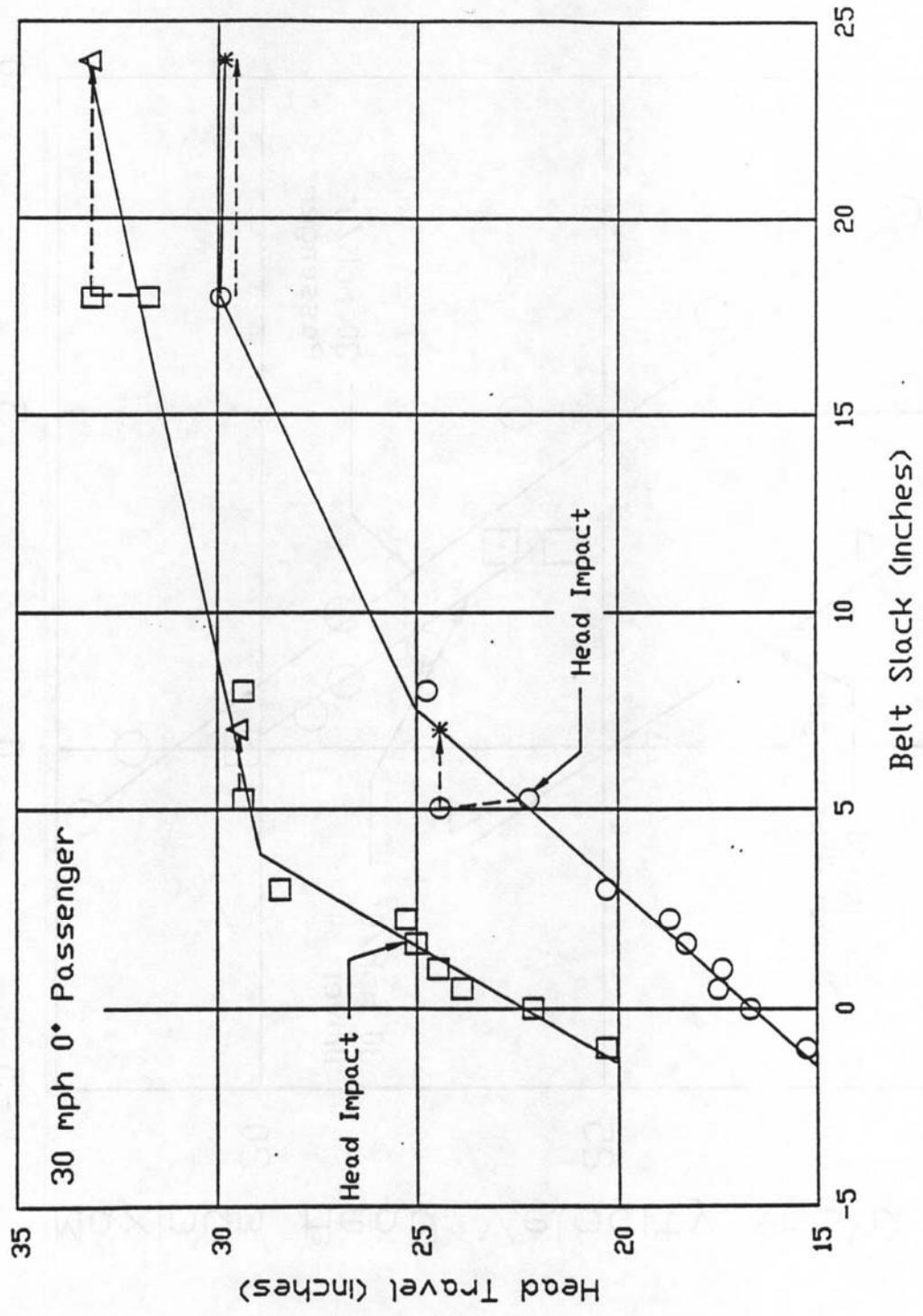


Figure 12A - Maximum Head Excursions vs. Shoulder Belt Slack with Off-Shoulder Conditions Included

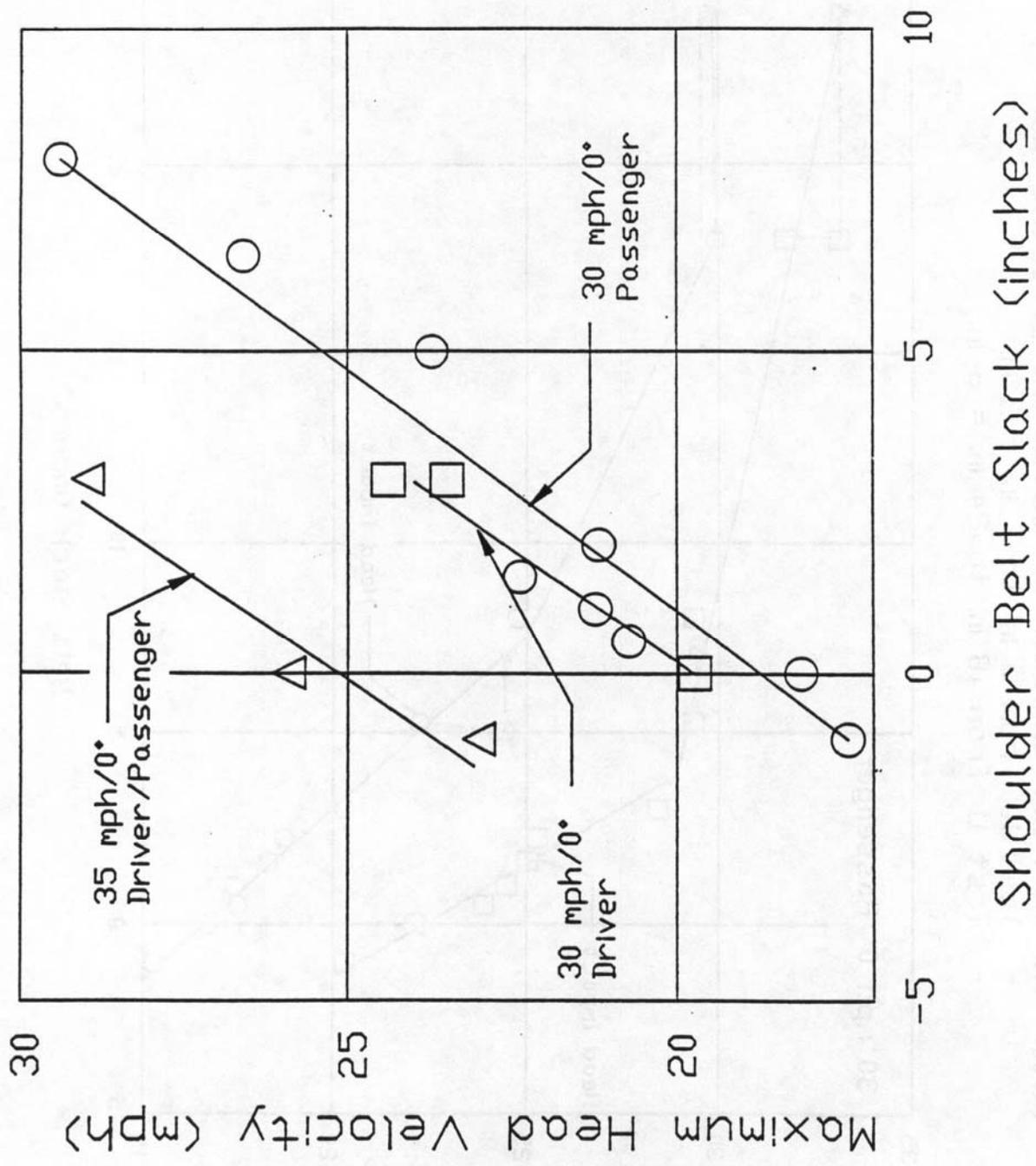


Figure 12B - Maximum Head Velocity vs. Shoulder Belt Slack for Frontal Drivers and Passengers at 30 and 35 mph

Figure 13 relates both HIC and HIC36 to the shoulder belt slack for Tests 1 through 9 and 18. The HIC's rise predictably from slacks of -1.0 to 8 in., but then fall significantly from 8 to 18 in. Of course, more data points would be desirable in this range to fully explain this drop at the higher slack levels. In the absence of such additional data points, the following observations can be made here. First, the top and brow of the instrument panel in the late model Ford LTD is constructed of a plastic substructure which is a good energy absorber if impacted in an advantageous direction. With the 18 in. of slack in these tests the Hybrid III's head hit more of the flat upper yielding surface of this instrument panel, and in two tests yielded HIC's between 700 and 800.

Figure 14 compares the HIC values from this study with previous three-point belt sled tests performed by Esser and Romeo (Refs. 2 and 3) at TRC in Ford sedan sled bucks with the same Ford belts. For the Esser passenger tests at 30 mph, the HIC values match the present data closely up to 2 inches. He then has no data to report until a fourth test at 24 inches slack. In his tests, the instrument panel was constructed using a sheet metal substructure which probably explains the difference in the HIC values for the 18 and 24 in. slack tests. Romeo conducted a 30 mph three-point belted driver sled test in the same body buck used for this study and his test produced a HIC of 865, essentially the same as obtained in this test. In this same test series, Romeo tested a lap belted only driver and obtained an HIC of 2584, considerable more than the peaks for either the present tests, or Esser's tests.

This study has considered the influences of the various surfaces impacted by the head during the presently reported tests, but these influences have not been rigorously quantified. In general, it is difficult to control head impact experiments for three-point belted occupants whose heads impact the vehicle interior. The presently reported tests show that this may be possible using the Hybrid III dummy and with considerably more resources than were expended in study. Using the maximum relative head velocities as a predictor of injury potential is an intermediate, but useful tool in studying the effects of shoulder belt slack on occupant injury potential.

OBLIQUE SLED TEST RESULTS

Figure 15 shows two high speed movie views of the kinematics of the Hybrid III in the 30 mph, 38 deg. oblique sled test in which the belt was pretightened to -1.0 inches. This pretightening seated the belt into the dummy's clothing and skin and as the impact progressed, it became obvious that this preseating contributed to the belt staying on the shoulder and chest structure (clearly across the sternum) throughout the test.

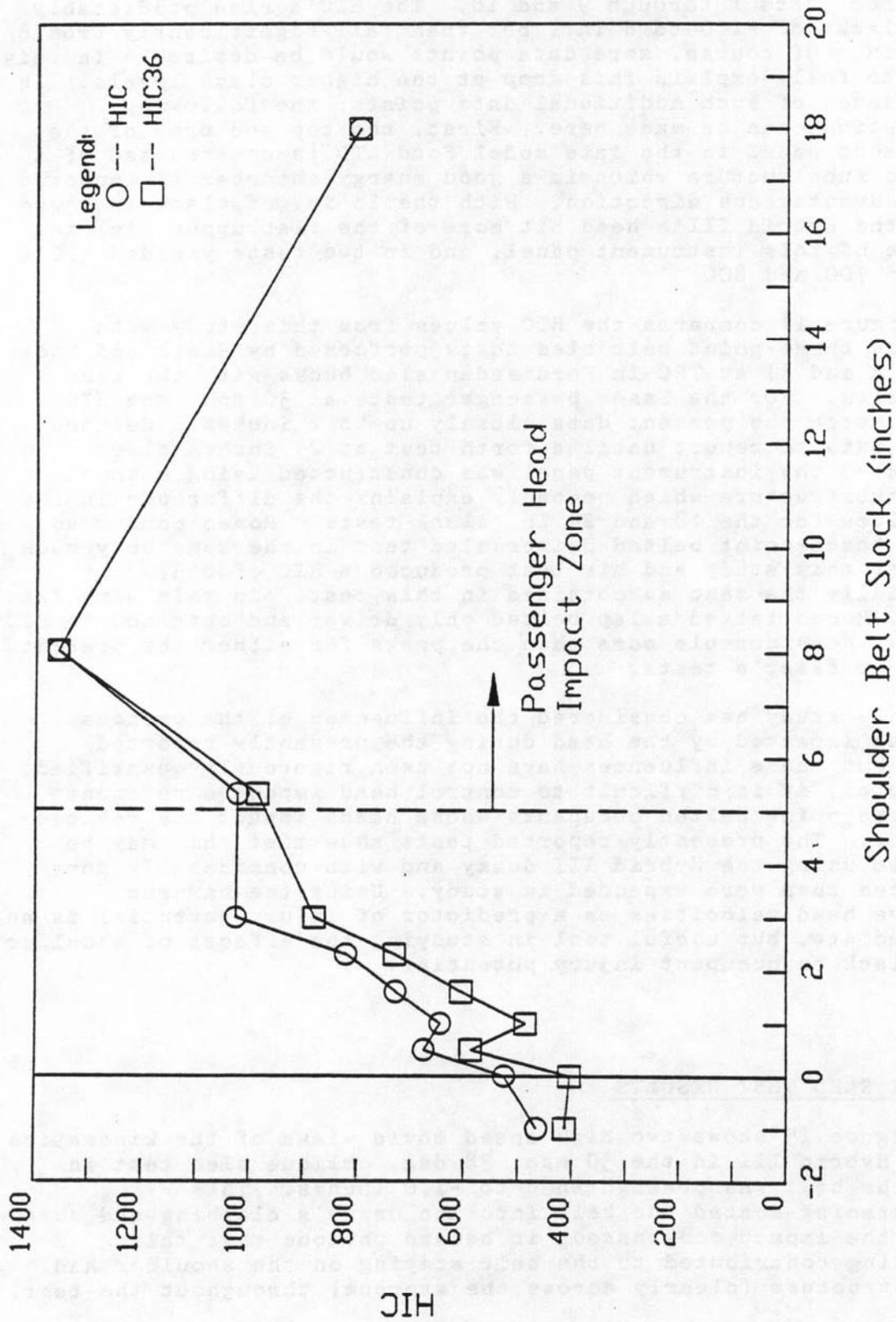


Figure 13 - HIC and HIC36 vs. Shoulder Belt Slack for 30 mph Passenger

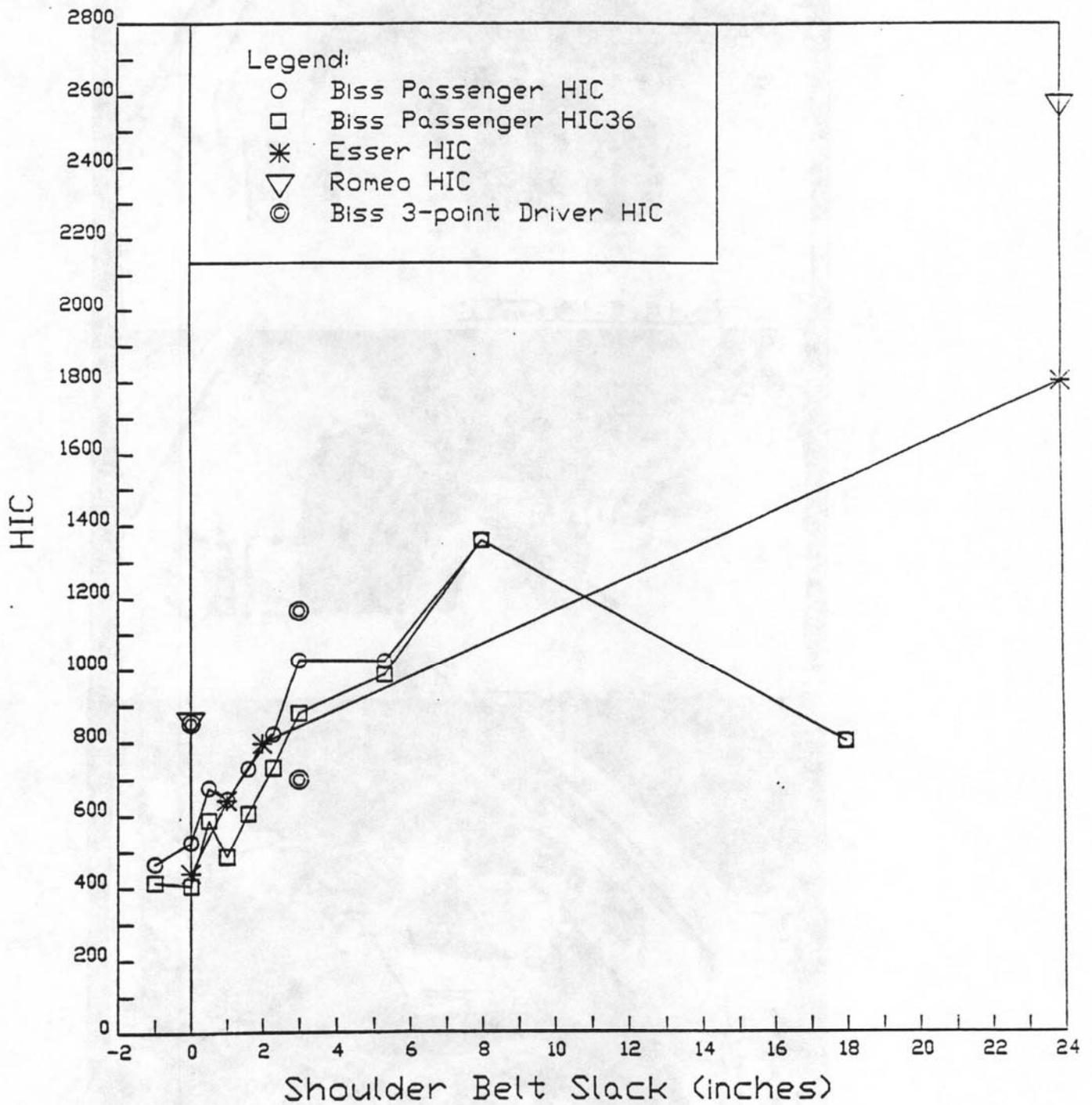


Figure 14 - Comparisons of HIC vs. Shoulder Belt Slack from Various Research Programs

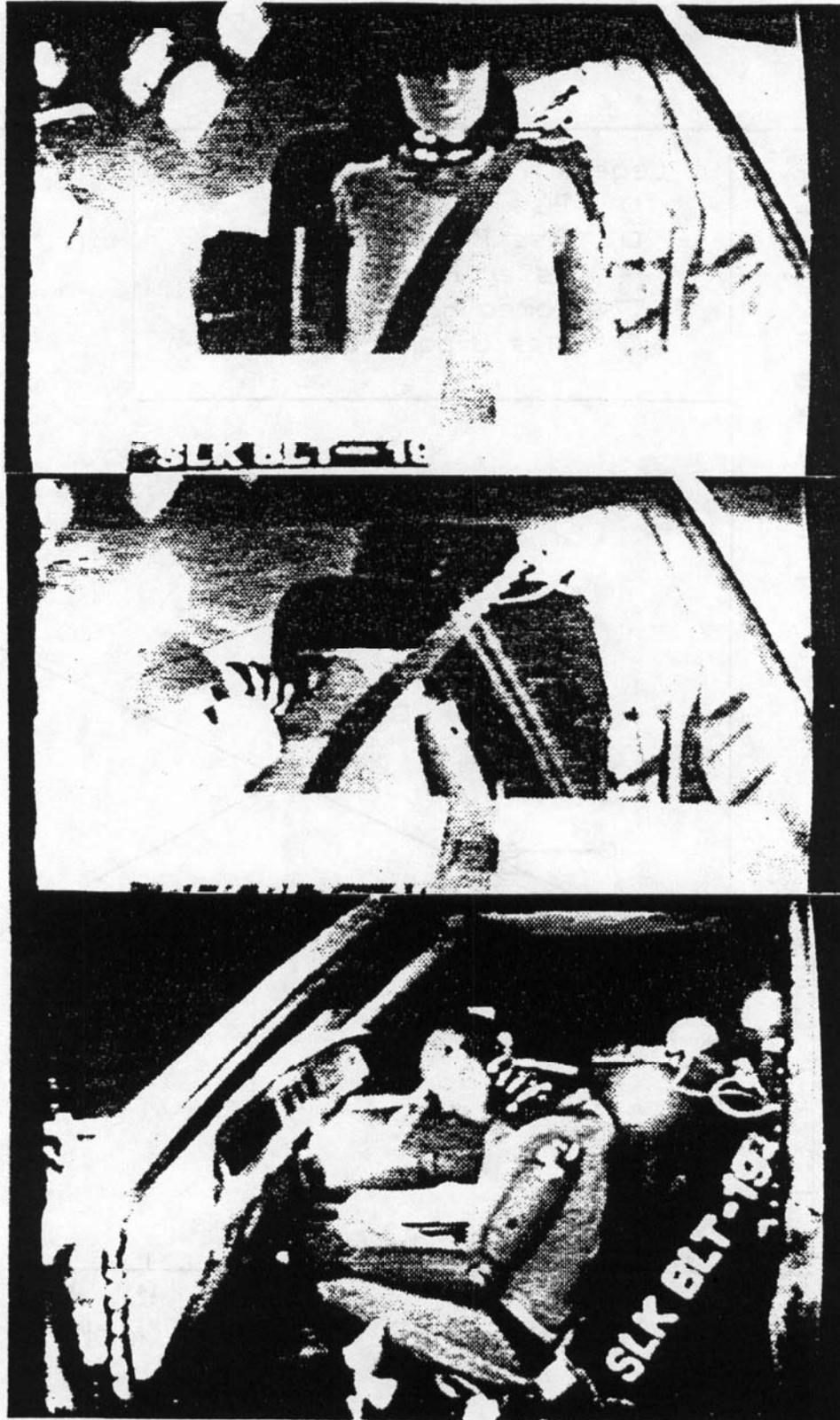


Figure 15 - Occupant Kinematics for Test 19
30 mph, 38 deg. Oblique, -1.0 in. Slack

The second two frames of this Figure show the Hybrid III at its maximum forward excursion to the front and right.

Figure 16 shows two high speed movie views of the kinematics of the Hybrid III for these same test conditions but with the belt slack set at 0. In this condition, when the belt starts out on the shoulder, it seats itself into the occupant's clothing and flesh early in the impact sequence and the strap stays on the shoulder/chest structure, well up on the sternum throughout the impact.

The effect of slack on Hybrid III responses in frontal sled tests has been discussed above and is a good starting point to discuss the effects of slack in the oblique sled tests reported here. Figure 17 shows the effect of 3.0 in. of slack in the oblique test when the shoulder strap is off the shoulder before the impact. Added to the forward motions are the lateral motions cause by the sled orientation. Three inches of slack is enough to permit the belt to hang low on the chest/sternum area, off the right rib cage and barely on the left rib cage structure. This amount of slack also allows the belt to hang over the corner of the shoulder, but in the Hybrid III, that is still within the range of the notch in the shoulder joint flesh at that point. As the impact progresses the belt catches in the shoulder notch, but that is not enough to keep the belt from assuming a dangerous biomechanical position across the chest during loading.

Figures 18A and 18B shows the high speed movie results for oblique sled Test 23 in which the belt was able to be initially positioned off the shoulder with as little as 1.63 inches of slack. The initial position of this belt is firmly in the top of the Hybrid III shoulder flesh notch, but despite this, during impact the belt loaded heavily into the lower chest/abdomen area. The strap snagged into the notch early in the event and the dummy twisted out of the belt as the impact progressed. Again, this test emphasizes the importance of the initial position of the shoulder strap on an occupant just before an impact. As little as 1.63 inches of slack allows the belt to drop 6 to 8 inches vertically on the chest/sternum, and this initial orientation seems to be a dominant factor in the configuration of the belt loading during impact.

There is no analog in the human for a notch in the flesh at the shoulder. It is doubtful that the human shoulder would act like the Hybrid III shoulder in these tests, catching the belt during oblique tests. As such, it is probable that the belt would end up even lower on the human or cadaver than on the Hybrid III as demonstrated here. Accordingly, oblique occupant retention tests on three-point belts which have a tendency to introduce slack during use should be tested not only with the Hybrid III, but with surrogates in which the shoulder simulates the human both in the pre-test and test conditions.

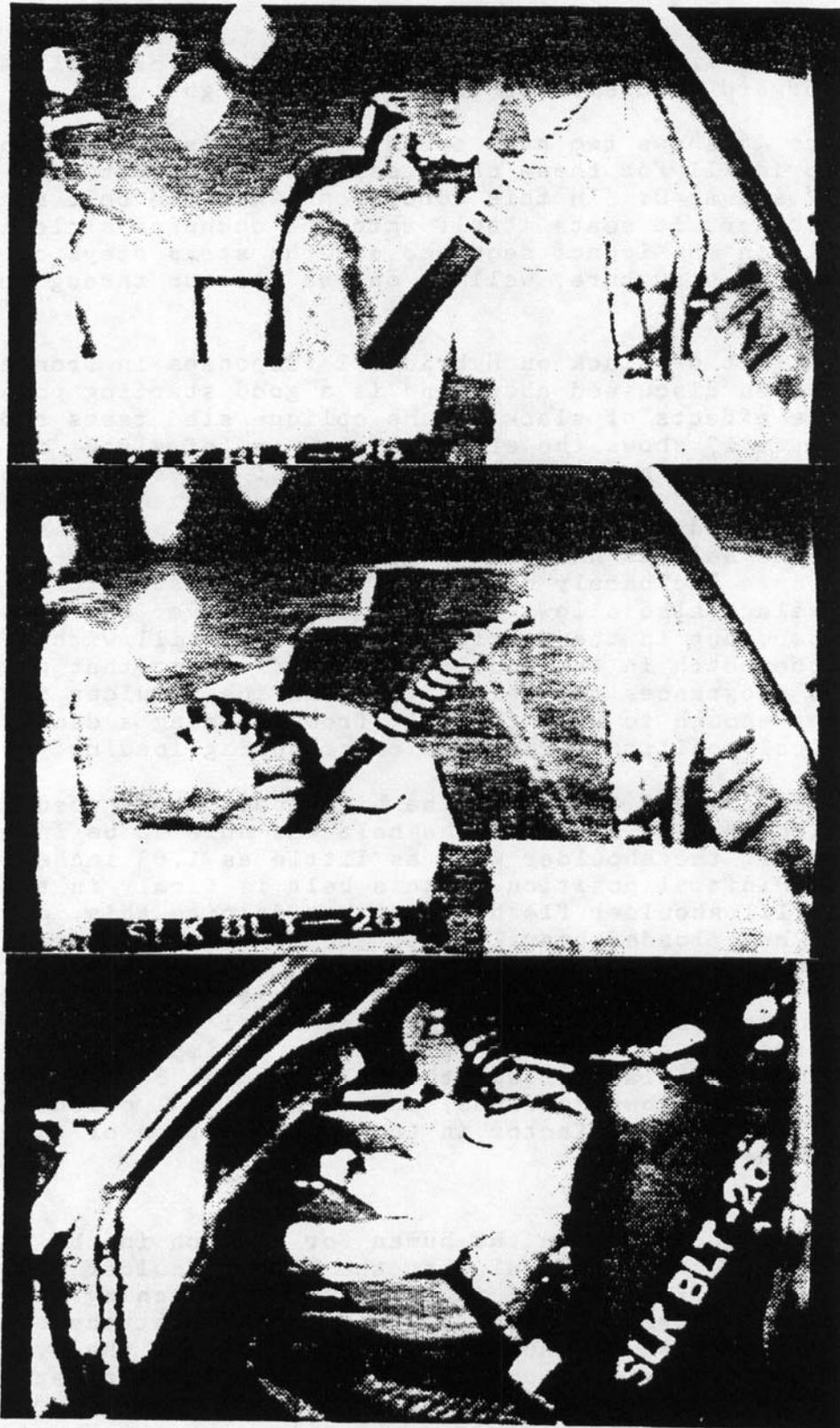


Figure 16 - Occupant Kinematics for Test 26
30 mph, 38 deg. Oblique, 0.0 in. Slack

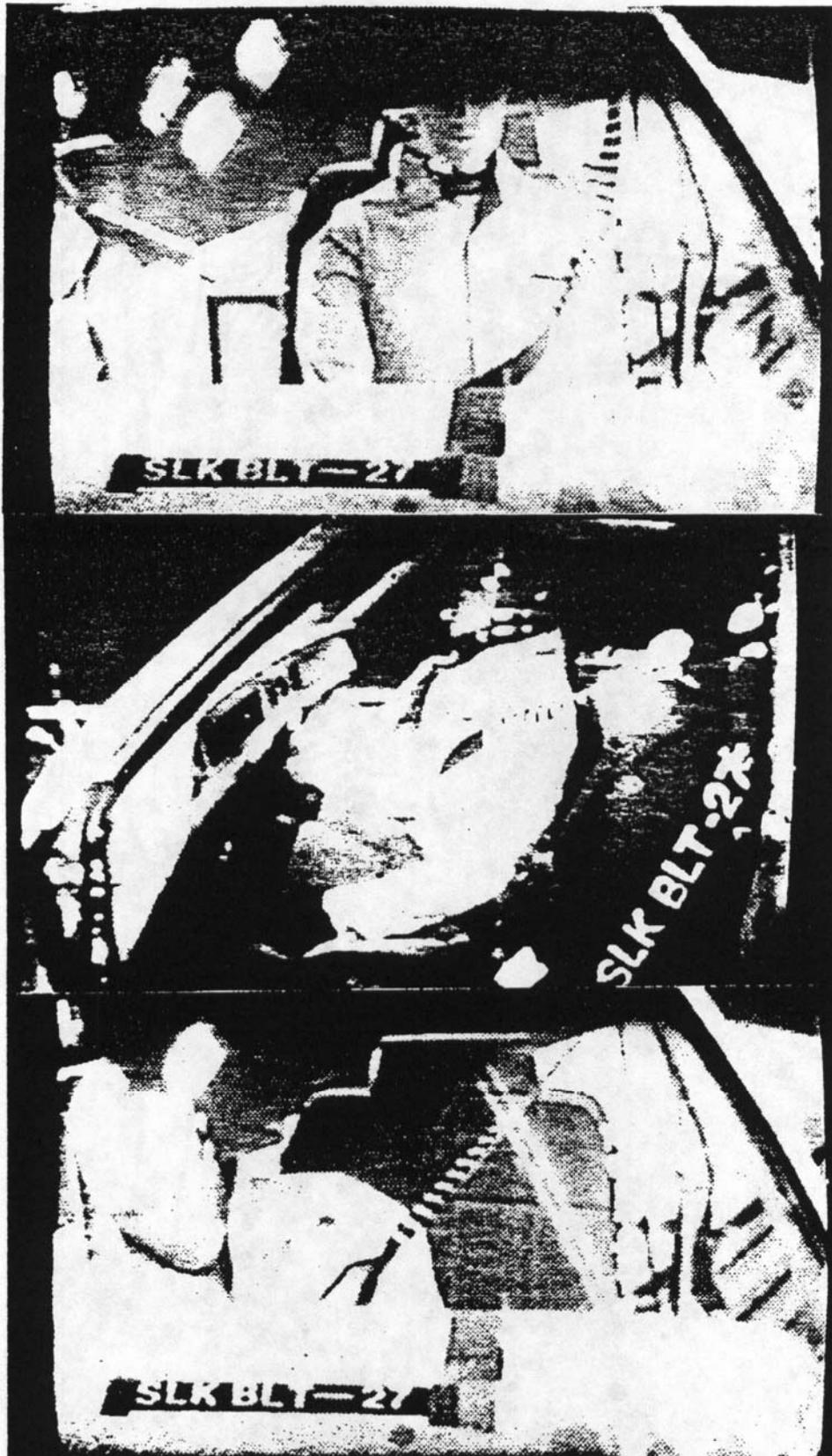


Figure 17 - Occupant Kinematics for Test 27
30 mph, 38 deg. Oblique, 3.0 in. Slack
Off-shoulder Condition

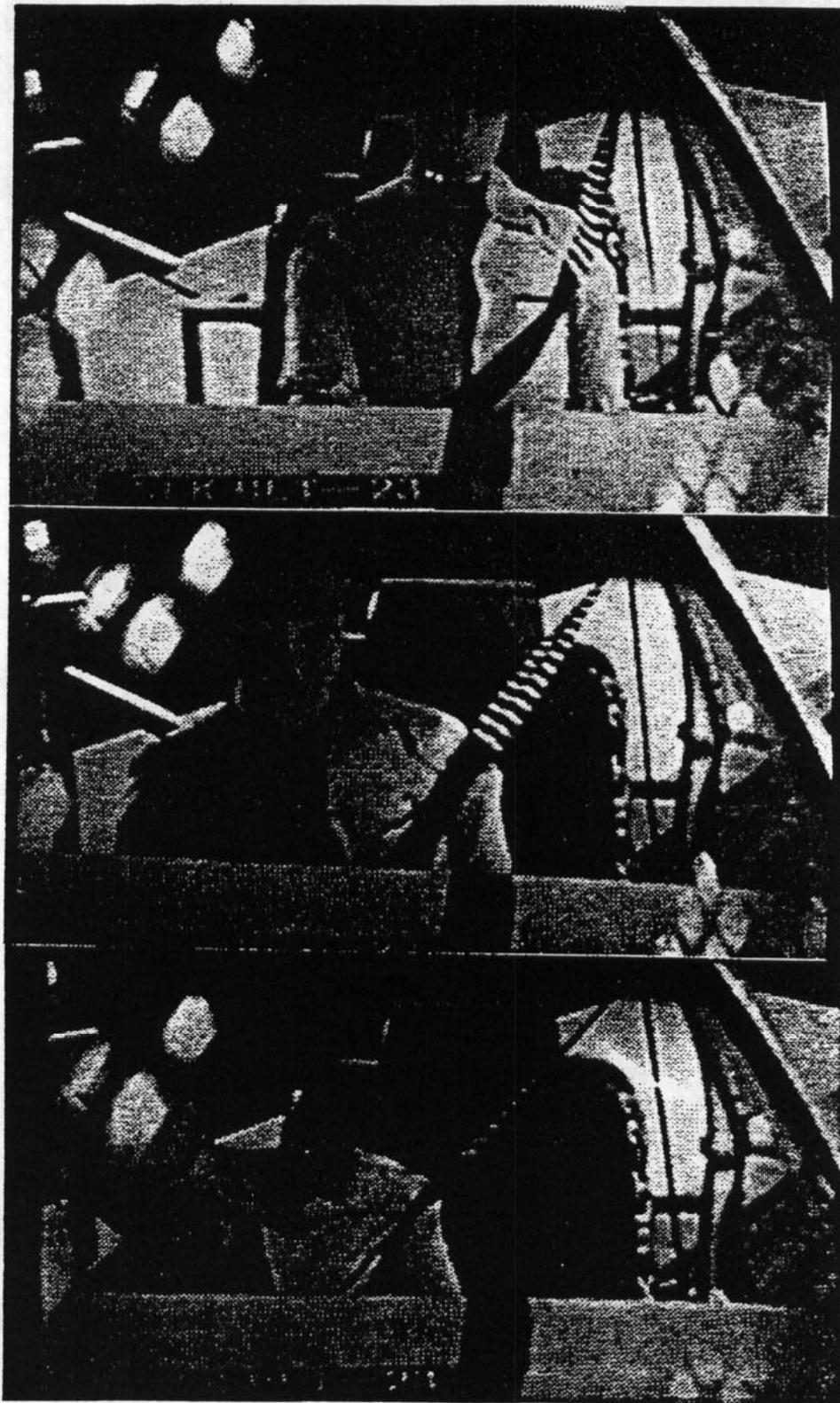


Figure 18A - Occupant Kinematics for Test 23
30 mph, 38 deg. Oblique, 3.0 in. Slack
Off-shoulder Condition

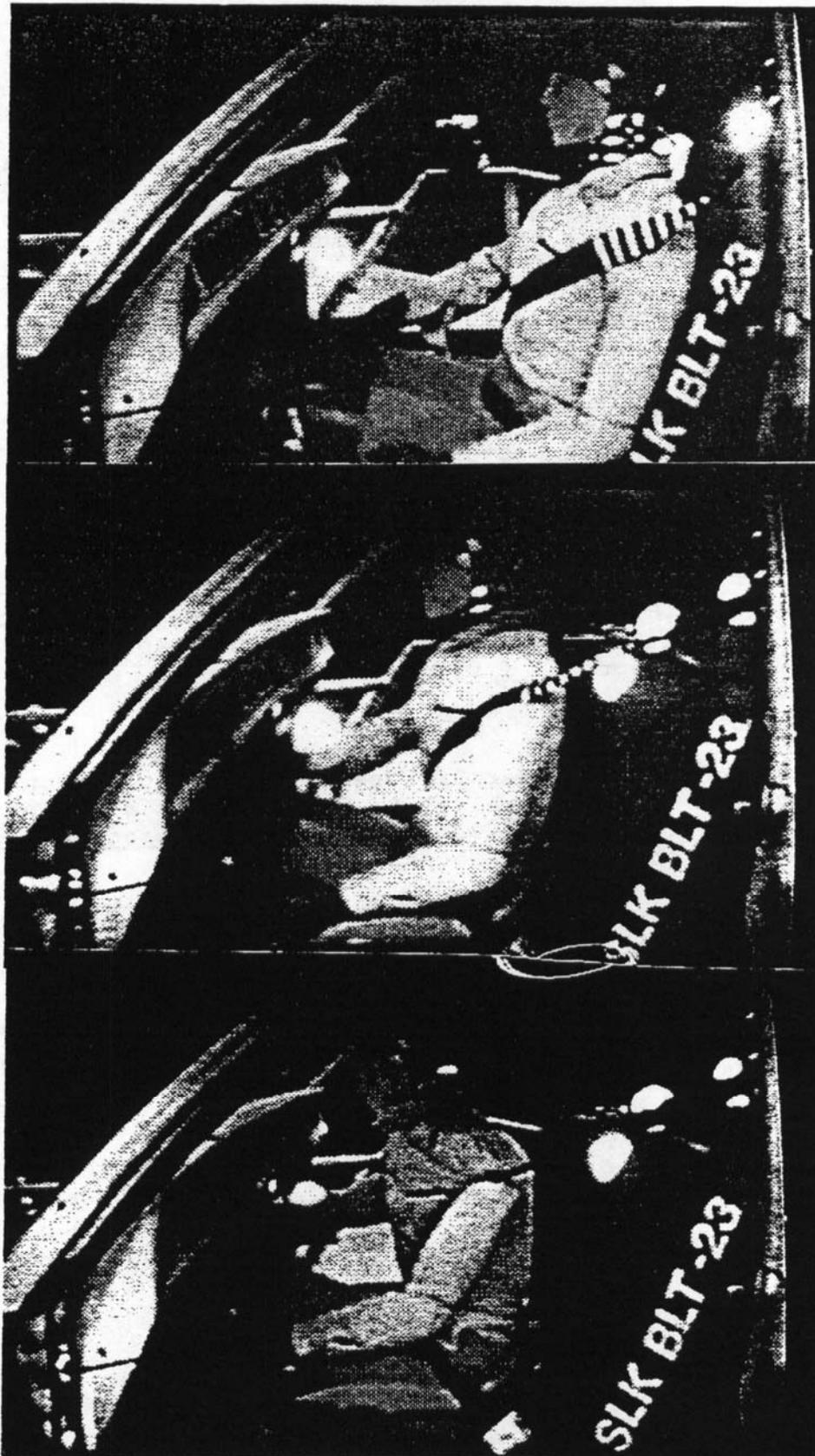


Figure 18B - Occupant Kinematics for Test 23
30 mph, 38 deg. Oblique, 3.0 in. Slack
Off-shoulder Condition

Figure 19 shows the high speed movie kinematics for oblique Test 20 with 2.5 in. slack in the strap which started the test on the shoulder. With the strap initially on the shoulder, the strap seats itself into the dummy's clothing and flesh, and although the strap loads slightly lower than for the -1.0 and 0 in. tests, at the point of maximum occupant excursion, the belt is still clearly on the rib cage/sternal structure. Photographic results for Test 25, a 3.0 in. slack, on-shoulder test, are not presented here but they are similar to the kinematics for Test 20. This again emphasizes that the initial position of the belt before the impact has a dominant effect on the biomechanical loading of the strap on the rib cage during impact.

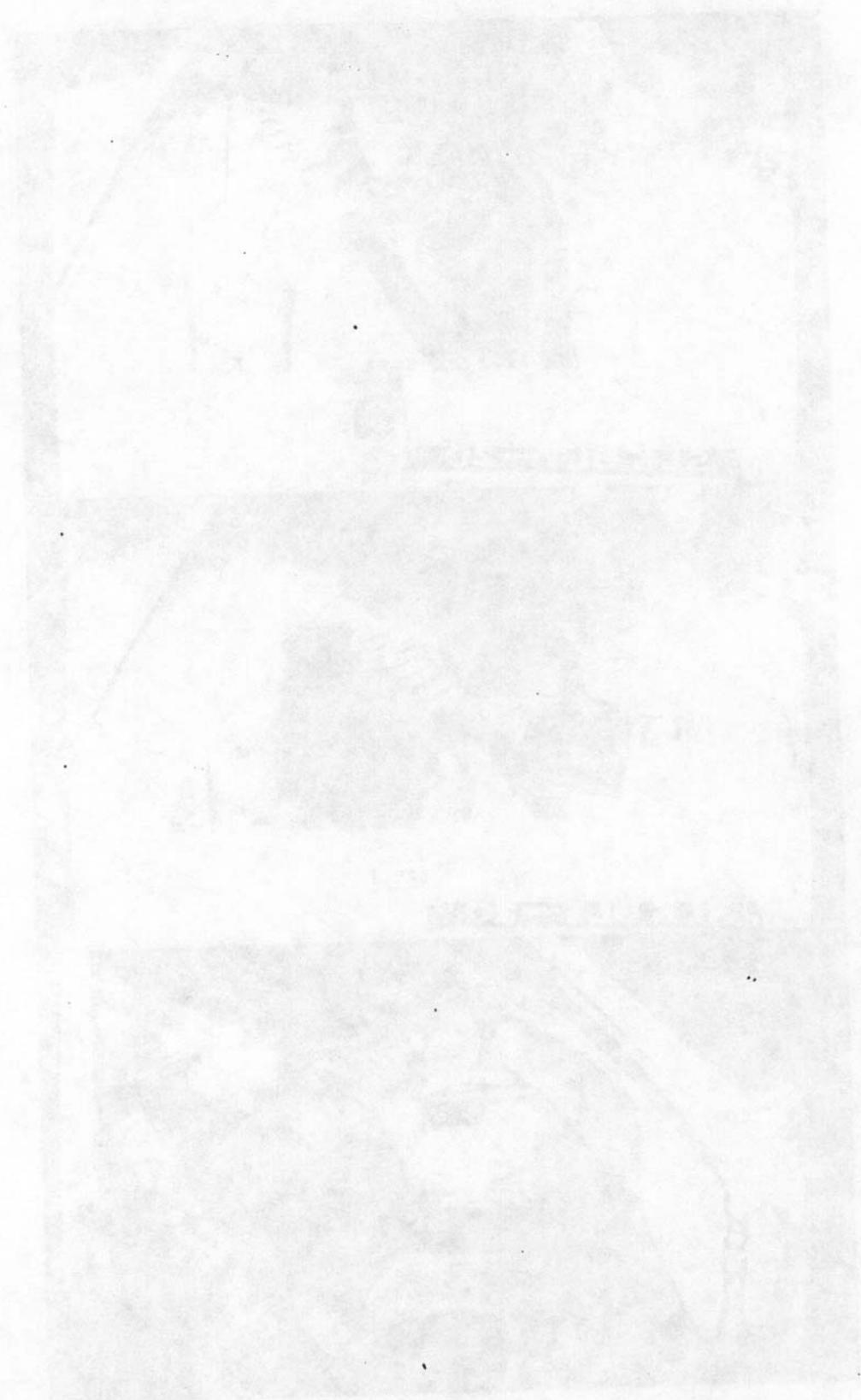
These results strongly suggest that public information campaigns are needed to better educate belt users about the biomechanical implications both of wearing shoulder belts slack and of not having them positioned on the clavicle area before any potential collision. Those of us in the biomechanical and restraints community should apply our considerable talents to communicating with the public on this very important issue. This is an area where biomechanics research can have an immediate payoff as opposed to many basic biomechanics research projects which take years to reach fruition.

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2. "Restraint Model Validation Tests (Phase 1)", R. C. Esser, Report No. SRL-51, Vehicle Research and Test Center - USDOT NHTSA, February 1983.
3. "Airbag Demonstration Program (Volume I)", R. C. Esser and D. Romeo, Report No. RD 583-2, Vehicle Research and Test Center - USDOT NHTSA, January 1984.



Figure 19 - Occupant Kinematics for Test 20
30 mph, 38 deg. Oblique, 2.5 in. Slack



11

DISCUSSION

PAPER: Safety Performance Evaluation of Slack Effects in Three Point Belts on the Hybrid III Dummy During Frontal and Frontal Oblique Sled Test

SPEAKER: D. J. Biss

Q: Barbara Kelleher, Hartley Associates

I have a question on your data on Tests 11 and 12. I think what you said 12 is a repeat of 11 which was 18 inches slack at the zero degrees. You had a belt load on Test 11 of close to 900 pounds, which is kind of understandable because the dummy's into the instrument panel at the same time he's loading a belt. On the repeat test you had about 1900 pounds on the belt load.

A: David Biss

I think the repeats were 11 and 18. One was on the shoulder and one was off the shoulder to begin with.

Q: On the shoulder you got the high belt load?

A: On the shoulder he gets the 1900 with 18 inches. When it's off the shoulder he gets the 800. It's explainable.

Q: John States, University of Rochester

On those head velocities of 32 and 33 mph; Were those 30 mph or 35 mph impacts?

A: Those were all normalized to a 30 mph barrier. There were about 31 or 32 sled velocities.

Q: In other words, the head was going a little faster than the sled was?

A: Yes. For the eight inches of slack it's going the same speed as the head. For eighteen inches of slack the belt was beginning to revert to a lap belt condition. Which of course can multiply the head velocity even further.

Q: Lloyd Thompson, McGill University

Three questions: Why was the head rest raised in only one of your tests as shown on you high speed film? Was there a seat pan in the seat? Have you been able to compare any of this data with field accident data?

A: What was the first part of the question?

Q: Why was the head rest raised on only one of your high speed movie tests?

A: I believe it was the camera coverage. The dummy was not interacting with the head rest until very late in the event, on rebound. We were looking at everything up through rebound. What was the second part of your question?

Q: Was there a seat pan in the seat?

A: No. These were stock seats that came for this particular sedan.

Q: Have you been able to compare any of your excellent data with field accident data?

A: From a case study standpoint, I think I'm seeing it in the field. But no end up studies otherwise.

Q: Forit Bendjellal, APR

I would like to know if you investigated chest deflection as a function of the slack of the belt in your study?

A: Yes sir, we did.

Q: Was it presented in your figures or not? I don't remember.

A: Yes sir it was. There was nothing remarkable. All the chest deflections were between 1-1/2 and 2 inches. They did not vary much more than the shoulder belt forces that I mentioned. We did trash the chest deflection pot on one of the tests. I'm still investigating. It tended to be one in which the belt was off the shoulder coming up through the abdomen. I'm trying to determine whether that was a function of excessive chest deflection or if the pot just decided to give out at that point. Up until that time, we had run a number of tests where the shoulder harness had come off. The chest deflections were not out of line. Then on that one chest deflection it came out to be 3-1/2 inches so we're still checking to see if it was real or not.

Q: How do you explain the fact that the acceleration of the chest was over all approximately constant?

A: I would like to have some more inputs on this. The particular belt that was in this car other than the window shade feature appeared to be tuned quite well. The spool out and the stretch in the webbing seemed to be nearly ideal if the belt was initially positioned on the body properly. That, coupled with the Hybrid III chest dynamics, served to level out all the chest accelerations, the shoulder belt loads and the chest deflection. I'm still looking at data and I would appreciate any ideas on whether that relates to cadavers.

Q: Joslyn Peddison, Biokinetics

I know you haven't yet analyzed all the data on the steering wheel impact crash test, but I was interested in how you decided or selected the position of the steering wheel and whether you

attempted in any way to address the movement or the fact that the steering wheel does move during real accidents?

A: Correct. The steering wheel was positioned exactly where it would be in the sedan in these overlays. We do have sled tests with the steering wheel in that position. You address an interesting point. If the steering column is permitted to stroke, the head itself will stroke the steering column about 3/4 of an inch. That's enough to drop the HIC about 200 points from 900 to 700. However, that impact is right in the facial area so its questionable whether you should be dealing with HIC alone.

A second test was run and the steering column was locked out from stroking forward. As I think you're suggesting, in a crash all the motion would be the other way, toward the head. I think a good baseline condition is to hold the wheel where it is for the sled. It does appear that the steering wheel design is quite critical for facial injury because if you want to use 30 mph as a baseline for adult performance the heads are typically getting into the steering wheel and the only question is where, in the head. Many times it's the face that's getting into the steering wheel.

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