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**National Highway
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February 1992

Air Bag Deployment Characteristics

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16. Abstract

A study was conducted to examine the inflation characteristics of several production driver's side air bag systems relative to factors which may be important to the likelihood of injuries occurring as side effects of the inflation process. The study was limited to deployment of the air bag systems in a static, non-crash environment. Two phases of tests were conducted: (1) deployment of the air bags to determine inflation characteristics, and (2) deployment of the air bags with a 5th percentile female dummy positioned in front of the restraints to observe the interactions between dummy and air bags.

Four distinct air bag folding patterns were observed among the systems tested. Peak air bag velocities were similar for tethered and untethered systems. Distinct differences in the maximum displacement of the leading edge of the air bags were observed between tethered and untethered systems. The air bag folding pattern and the presence of tethers appeared to have significant effects, both singularly and in conjunction with one another, on the observed interactions with the small female dummy. The removal patterns of the powdered chalk from the dummy's face by the air bags' contact appeared to be primarily dependent upon these two factors.

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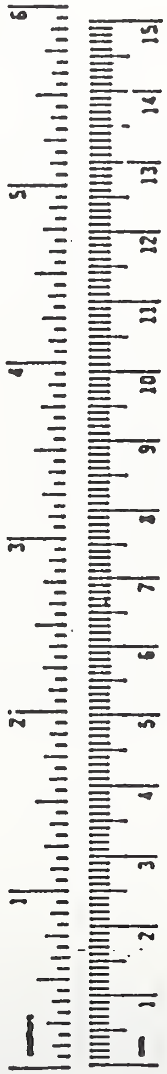
METRIC CONVERSION FACTORS

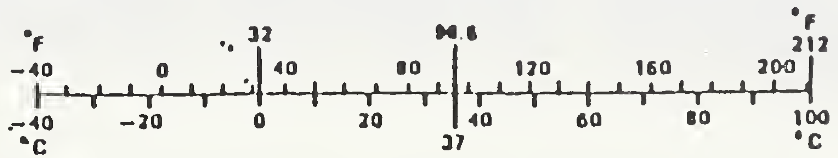
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	metric ton	t
		VOLUME		
tsp	teaspoons	5	milliliters	mL
Tbsp	tablespoons	15	milliliters	mL
in^3	cubic inches	16	milliliters	mL
fl oz	fluid ounces	30	milliliters	mL
c	cups	0.24	liters	L
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	5/9 (after subtracting 32)	degrees Celsius	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10 000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	metric ton (1000 kg)	1.1	short tons	
		VOLUME		
mL	milliliters	0.03	fluid ounces	fl oz
mL	milliliters	0.06	cubic inches	in^3
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5 (then add 32)	degrees Fahrenheit	°F



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Department of Transportation
National Highway Traffic Safety Administration

TECHNICAL SUMMARY

Report Title: Air Bag Deployment Characteristics	Date: February 1992
Report Author(s): Lisa K. Sullivan, Jerome M. Kossar	

A study was conducted to examine the inflation characteristics of several driver's side air bag restraints relative to factors which may be important to the possibility of injuries occurring as side effects of the inflation process. The deployment of the air bag restraints was limited to a static, non-crash environment. The study was conducted in two phases: (1) Phase I evaluated nine air bag systems, filming the deployments at 5,000 frames per second, to observe inflation characteristics, and (2) Phase II evaluated four of the previously tested air bag systems using a 5th percentile female dummy seated in front of the restraint system to observe interactions between the dummy and the air bags.

Four distinct air bag folding patters were observed among the nine systems tested in Phase I: (1) an accordion-type pattern, (2) a modified accordion-type pattern, (3) a pleated accordion-type pattern and (4) an overlap-type pattern. Air bags' peak velocity and maximum displacement were determined by digitizing the high speed films of the deployments. Similar peak velocities were observed for tethered and untethered systems. The velocities for all of the air bags ranged from 98 mph to 211 mph, with an average velocity of 144 mph. Distinct differences in maximum air bag displacements were observed between tethered and untethered systems. Tethered air bag displacements ranged from 12" to 15", with a mean value of 14". The displacements for the untethered air bags ranged from 17" to 20 ", with a mean value of 19". The time for full inflation of the air bag differed between tethered and untethered systems. For tethered systems, inflation times ranged from 21 msec to 29 msec, with a mean value of 25 msec. The inflation times for the untethered systems ranged from 21 msec to 47 msec, with a mean value of 34 msec.

For Phase II testing, the face of the 5th percentile female was painted with a tri-color scheme of powdered chalk to "record" the contact patterns produced by the deploying air bag systems. The dummy was positioned relative to the steering wheel/air bag system as a person of that size would be seated in the vehicle. The relative dummy-to-steering wheel position varied for each air bag system. The presence of tethers had an effect on maximum air bag displacement, which in turn had an effect on the type of chalk removal that the bags produced on facial contact. Untethered bags tended to engulf the dummy's face. The tethered bags contacted the lower jaw and chin areas, while not producing contact patterns above the upper jaw. The bag folding pattern appeared to be an important factor both singularly and in conjunction with the presence of tethers and positioning of the dummy.

1.0 INTRODUCTION

The primary goal of a restraint system is to reduce the probability and severity of occupant injuries during a crash. Federal Motor Vehicle Safety Standard 208 (FMVSS 208) requires motor vehicles manufactured for sale in the United States to be equipped with restraint systems for the vehicle occupants.

FMVSS 208 sets minimum requirements for occupant restraint systems. Most of the requirements are stated in performance terms; design requirements are avoided to allow vehicle manufacturers flexibility in the continuing development of improved systems.

The standard requires passenger cars to have passive restraint systems in front outboard seating positions. (Passive systems require no action by the vehicle occupants to be effective in a crash.) To date the passive systems that meet these minimum requirements are either passive belt restraint systems or combination belt and air bag systems.

Both passive belt systems and combination belt/bag systems are very effective in reducing serious injuries and fatalities. However, complete elimination of all injuries in crashes is not reasonably feasible. These residual injuries are either;

1. Injuries in crashes that are outside the occupant protection performance envelope of the combined vehicle/restraint system, or

2. secondary injuries that occur from the dynamic interaction of the combined vehicle/restraint occupant protection system.

Examples of crashes that are outside the performance envelope of the combined vehicle/restraint system include situations where the occupant compartment is extensively crushed, and crashes for which the particular restraint system is inherently not effective.

Examples of secondary injuries of the combined vehicle/restraint system include submarining injuries to the abdomen and spine of belted occupants; facial injuries to lap and shoulder belted drivers from steering wheel contact in more severe frontal crashes; thoracic injuries to belted occupants; head and neck injuries to belted occupants; and air bag inflation related arm, neck and facial injuries to air bag restrained occupants.

Although restraint systems provide tremendous net benefits in terms of crash injury reduction, residual injuries are a matter of continuing concern. Many research and development efforts are underway to develop occupant protection systems that have fewer and less severe residual injuries. These efforts must contend with limitations as to what is reasonably feasible in the passenger car environment, and reductions in one type of residual injury may only be achieved at the cost of comparable or greater increases in other residual injuries.

These factors tend to be in conflict. Progress often requires difficult trade-offs. Cars can be made stronger to prevent crushing the occupant compartment in more severe crashes, but the cost is bigger, heavier, more expensive cars that consume more fuel. Belt systems are in use in military aircraft that give better protection than automotive three point belt systems, but they have double shoulder belts, wide chest straps, crotch straps and wider belt material, all of which would reduce belt system acceptability and usage in passenger cars, not to mention substantially increased costs.

The possibility of injuries during air bag inflation can be reduced by reducing bag size and inflation speed, but this tends to reduce protection in severe crashes. Tethering air bags to limit rearward bag displacement can potentially reduce protection in more severe crashes.

With the increasing availability and usage of passive restraint systems, the number of reported residual injuries has increased. Although the systems have been performing as they were designed to, residual head, face, neck, thorax, and abdominal injuries in belted crash victims, and air bag inflation related face, neck and arm injuries are reported.

The objective of this study is to examine the inflation characteristics of several current production air bag systems relative to factors that may be important to the likelihood of injuries occurring as side effects of the inflation process. The majority of these injuries involve abrasions along the jawline, chin, cheekbones, eyes and forearms, and burns on the hands. A large portion of the reported injuries are to smaller occupants (such as the 5th percentile female), who would tend to be seated closer to the steering wheel than most other occupants.

This study is limited to the preliminary observation of the inflation patterns of several currently available air bag restraint systems in a static, non-crash environment. Neither the effects of crash dynamics, nor trade-off of inflation characteristics with the overall effectiveness of the systems are within the scope of this study. The reader is cautioned that the information in this report can not be used to rationalize specific design changes without consideration of the effects of crash dynamics, and of the effects of such design changes on overall system effectiveness. It should also be noted that all dummy testing was limited to a 5th percentile female seated in a position aligned with the center of the driver air bag. Effects observed in this program, therefore, do not address the full range of car driver sizes nor the effects of lateral misalignment of drivers at the time of air bag deployment.

2.0 OBJECTIVES

The objective of this study is to examine the inflation characteristics of several current production air bag systems relative to factors that may be important to the likelihood of secondary injuries occurring as side effects of the inflation process. The reader is cautioned that the information in this report can not be used to rationalize specific design changes without consideration of the effects of crash dynamics, and of the effects of such design changes on overall system effectiveness.

3.0 TEST FIXTURE/SET-UP

The test fixture used for both Phase I and Phase II testing consisted of a base frame bolted to the floor, with an angled beam attached simulating a vehicle's steering column. The steering wheel/air bag assembly was bolted to the beam - with the wheel rim vertical for Phase I testing and at predetermined angles, based upon the actual steering wheel angle for the test vehicle, for Phase II testing. A backboard grid (for film analysis) was attached to the base frame for Phase I tests. For Phase II tests involving the 5^{th} percentile Hybrid III female dummy, a generic seat surface was positioned on the base frame. The generic seat was adjustable fore and aft and vertically, plus the seat back was adjustable with respect to the seat pan. The test set-ups used for Phase I and II are shown in Figures 1 and 2, respectively.

4.0 PHASE I - DEPLOYMENT AND HIGH SPEED FILMING OF NINE AIR BAG SYSTEMS

A total of nine air bags were deployed and filmed at high speed (5000 fps) from three angles (overhead, side and full frontal) to evaluate the deployment characteristics of each bag. The air bag systems tested were identified alphabetically for reporting purposes (see Appendix E for identification). The high speed films were digitized to determine the displacement and velocity of the leading edge of each bag. A silhouette of the Hybrid III 5^{th} percentile female dummy was positioned 15" away from the steering wheel hub (attached to a side grid board). The position of 15" was selected as an average nose-to-steering wheel hub distance for the vehicle fleet.

4.1 Air Bag Characteristics

For each of the bags evaluated, the three high speed camera views were reviewed to determine such characteristics as presence of tethers, bag folding patterns, etc. The following features were observed:

Air Bag Tethers - Of the nine air bags deployed, five did not contain tethers. The four air bag systems containing tethers were systems A, F, G and H.

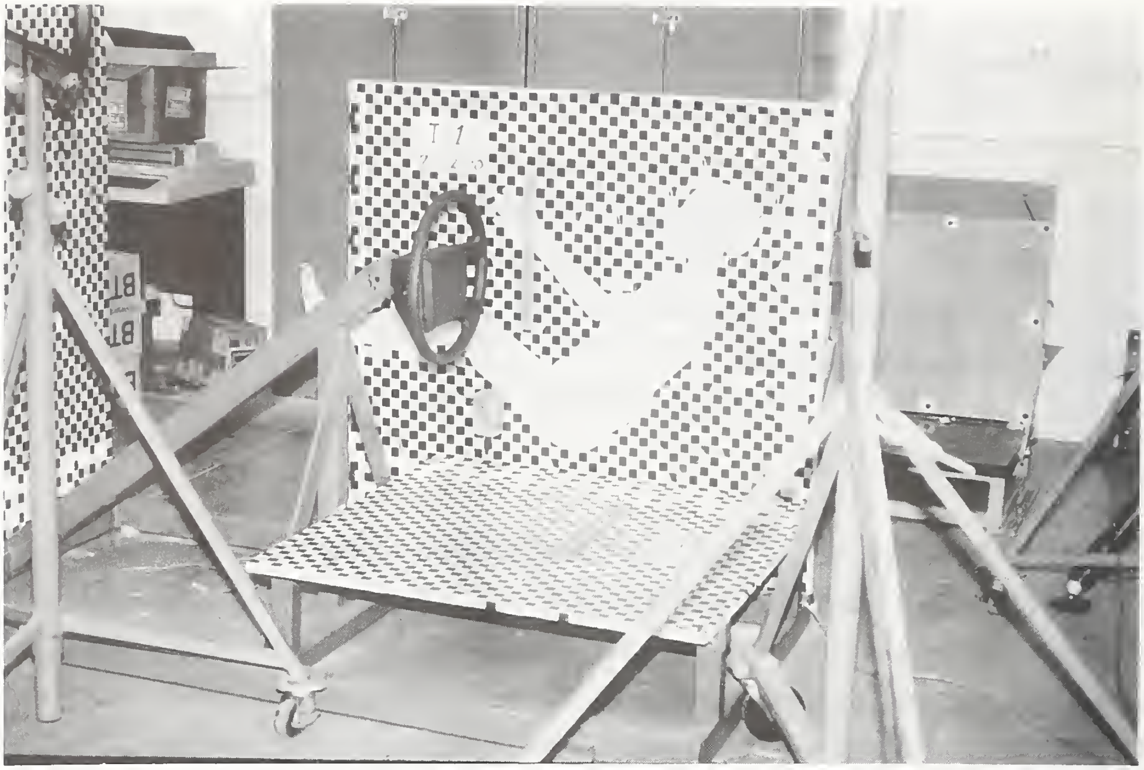


FIGURE 1 -- Test Set-up for Phase I Testing

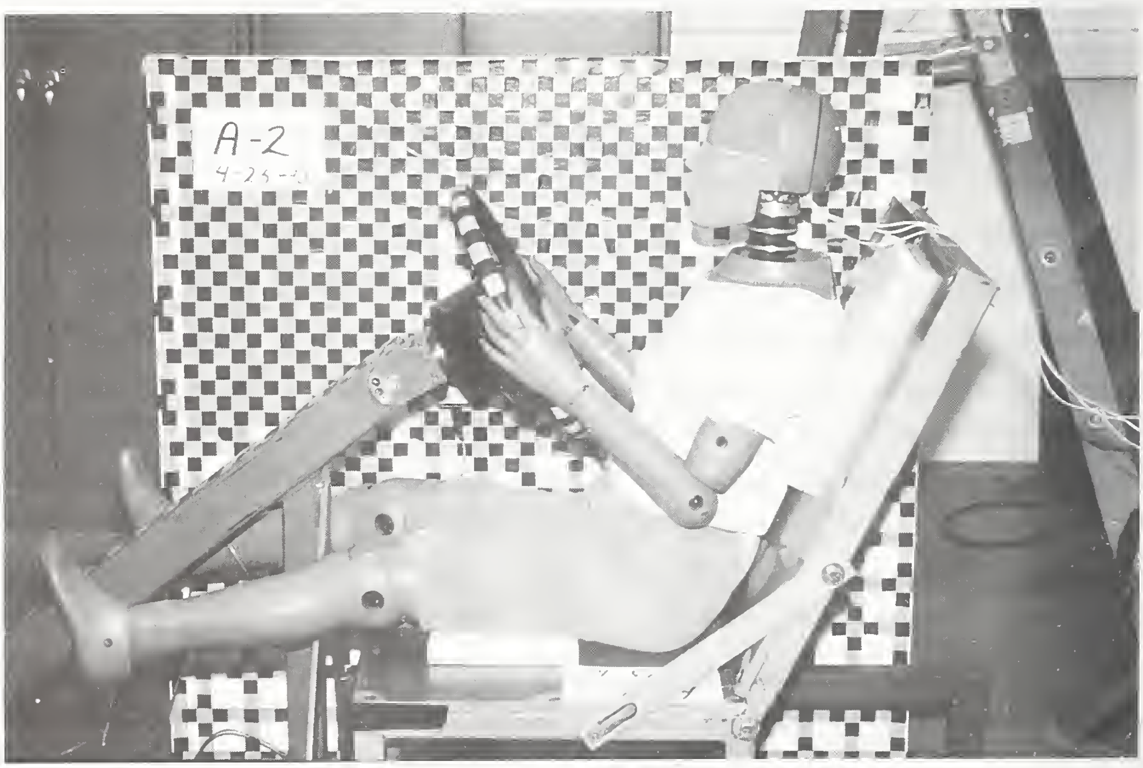


FIGURE 2 -- Test Set-up for Phase II Testing

Air Bag Folding Patterns - A total of 4 different types of folding patterns were observed in the air bag systems deployed. Systems A, B, C and H utilize an accordion folding pattern. The non-folded center section of these bags (which forms the base for the remainder of the bag to rest upon) range in width from 4.25" to 5". The top and bottom sections of the bag are folded in 2.25" to 2.5" widths until each section lies over the top of its respective half of the center section of the bag. The side sections are then folded inwardly so that they lay over the previously folded portions of the bag, thus creating "side lobes" which unfold first during deployment of the air bag. The accordion folding pattern is illustrated in Figure 3.

The second type of folding pattern can be described as a modified accordion fold in which the sides of the bag are rolled under from the left and right ends to lie on top of the central portion of the accordion folded bag. The modified accordion fold, which is shown in Figure 4, was found in air bag systems D and E. The rolled sides of the modified accordion fold result in the center portion of the bag forming an arc on initial deployment, followed by inflation of the side lobes which tend to maintain this leading surface of the expanding bag as an unwrinkled tensioned membrane.

The third folding pattern, a pleated accordion fold, was observed in the air bag system G. This folding pattern, which is depicted in Figure 5, employs shallow vertical pleats and over fold from the left and right sides of the accordion folded bag to provide fit into the bag storage compartment of the air bag module.

Air bag systems F and I both employ an overlapped fold, but system F employs internal bag tethers which prevent large rearward extension of the air bag during deployment, whereas system I is untethered. In the overlapped fold pattern the top section of the bag is folded in 5" widths over the center portion of the bag. The bottom section is then similarly folded over the combined center and top sections. The sides of the bag are then folded inwardly over the center of the bag, creating "side lobes" similar to those seen in the accordion type pattern. But unlike the other fold patterns which generally allow simultaneous expansion of the top and bottom bag segments, the overlap fold prevents free expansion of the upper bag segment until the overlaid lower segment volume is substantially inflated and off of the upper bag segment. Figure 6 is an illustration of the overlapped folding pattern.

Air Bag Vents - The majority of the air bags were vented at the 3 and 9 o'clock positions on the rear (steering wheel) side of the bags. The vents for system I were positioned at the 11 and 1 o'clock positions on the rear side of the bag. Air bag system G differed from all of the other systems in that the vent consisted of a 6" wide arc from the 10 o'clock to 2 o'clock positions along the rear side of the

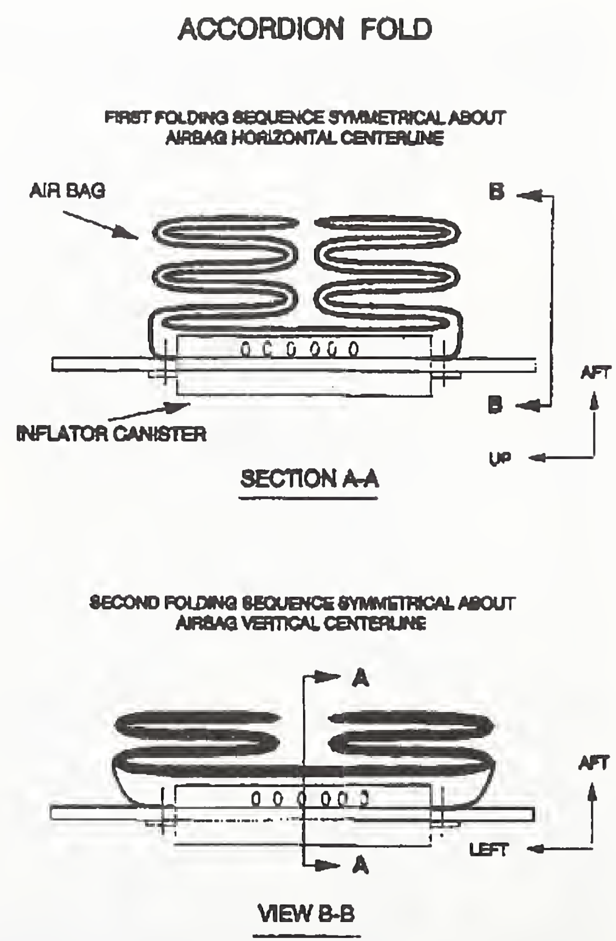


FIGURE 3 -- Diagram of Accordion Folding Pattern

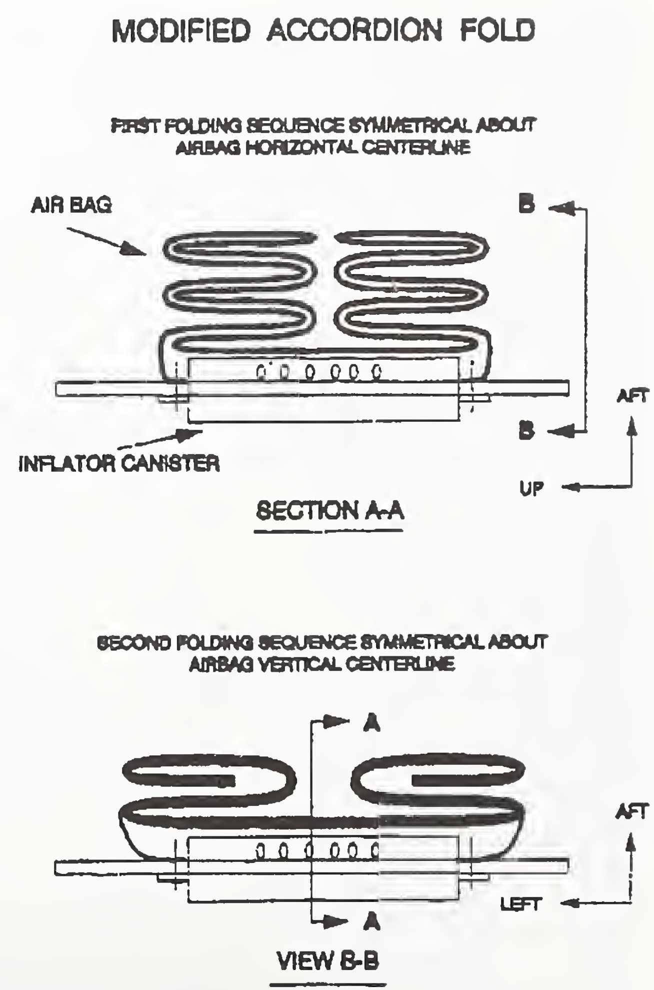


FIGURE 4 -- Diagram of Modified Accordion Folding Pattern

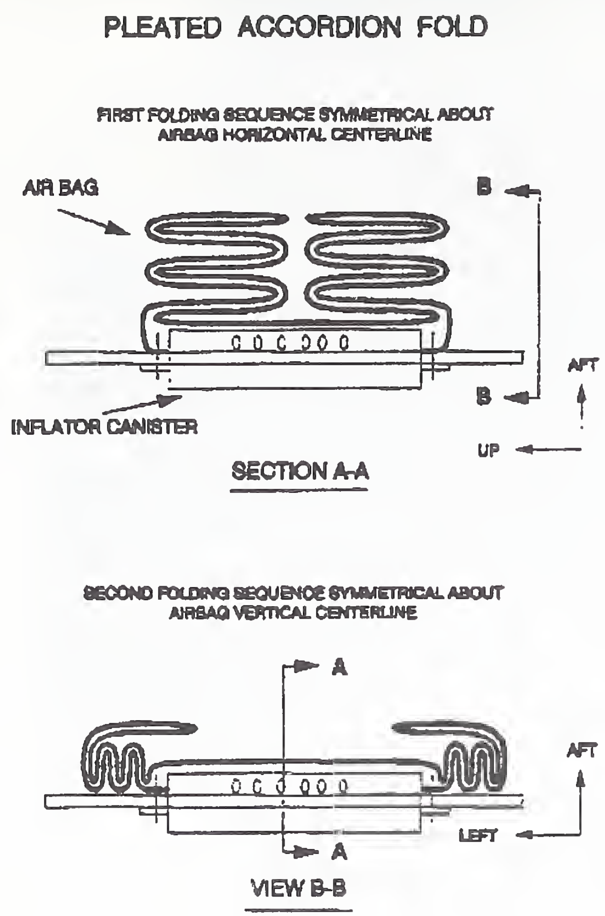


FIGURE 5 -- Diagram of Pleated Accordion Folding Pattern

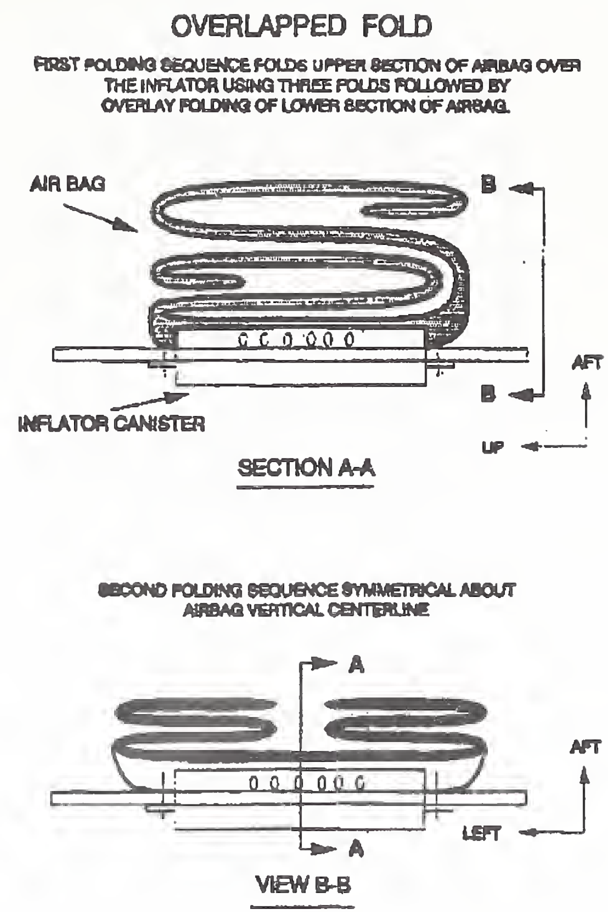


FIGURE 6 -- Diagram of Overlapped Folding Pattern

bag. This vent was covered with a thick woven porous Kevlar fabric, thereby providing an additional filter for the flow of escaping gases and particles. The vents on the remaining eight systems did not have any type of covering.

Air Bag Material - Seven of the air bags deployed used 840 denier nylon woven fabric material. Two of the bags, A and B, used a 420 denier nylon fabric. The lower the denier number is, the finer the woven yarn of the fabric is, giving the material a tighter weave and a smoother surface. Figure 7 shows the exterior texture of the two types of material observed among the air bags deployed. The nylon fabrics were all neoprene coated on the surface which faced the air bag interior in order to elimate fabric porosity.

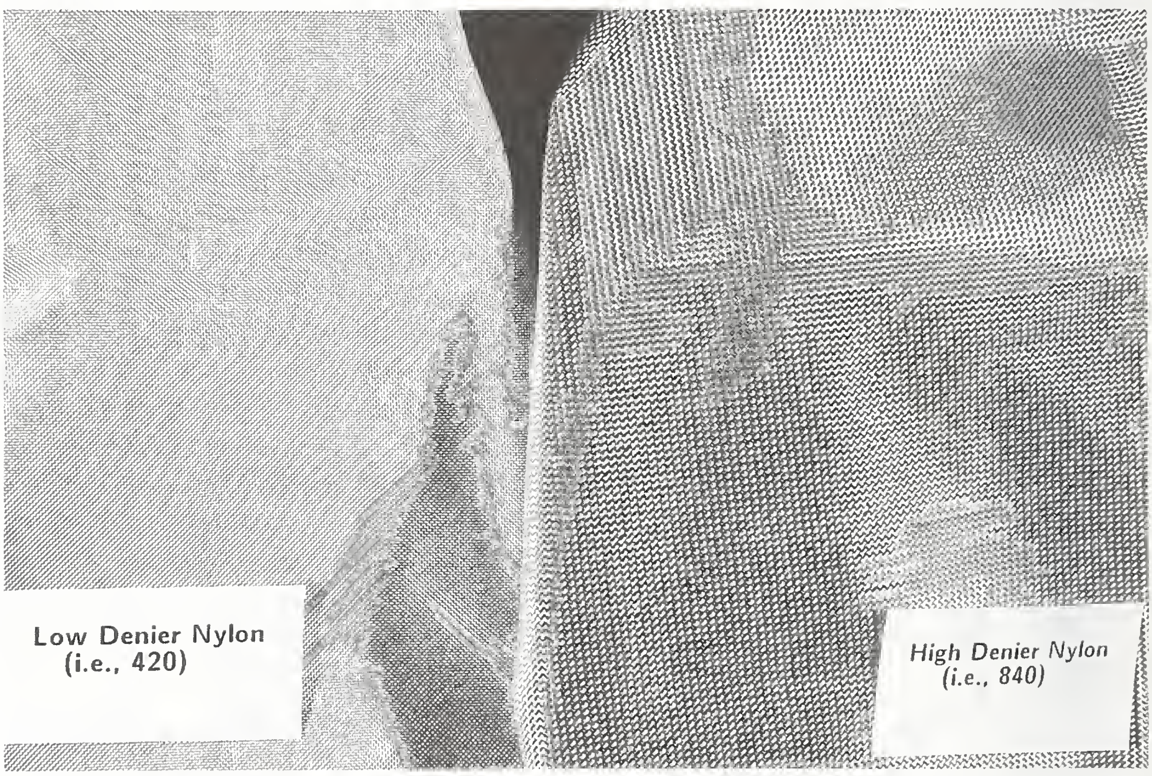


FIGURE 7 -- Examples of 420 and 840 Denier Nylon Strands

A photographic time-sequenced presentation of the bag deployments are contained in Appendix A, supplemented by a brief description of the deployments.

4.2 Phase I Air Bag Film Analysis Results

Phase I tests were conducted without a dummy positioned in front of the steering wheel assembly to allow the air bags to deploy without interference. Test results were derived from analysis of high speed films taken during deployments. A summary of peak bag displacement, peak velocity, bag velocity at the time of facial contact (if it would have occurred) and total inflation times for the bags tested are contained in Table 1. The individual air bag displacement time histories are contained in Appendix B. The velocity vs. displacement curves for the air bags are contained in Appendix C. Identifiction of vehicles from which driver air bags were tested is provided in Appendix E.

As stated previously, the leading edge of the bag was digitized from the high speed film to determine the bag displacement and velocity. Since the leading edge is not a fixed point on the bag, the velocity derived from the displacement is not an exact measurement. It is estimated that the true velocity is within ± 20% of the calculated value listed in Table 1. The calculated peak velocities for the nine systems ranged from 98 mph to 211 mph, with an average of 144 mph.

TABLE 1 -- Phase I Air Bag Test Results

Vehicle Code*	Bag Fold	Bag Type	Peak Velocity	Velocity at Face Contact	Time of Facial Contact	Peak Displacement	Inflation Time
A-1	Accordion	Tethered	120 mph	NA	NA	12"	25 msec
B-1	Accordion	Untethered	157 mph	95 mph	14 msec	20"	30 msec
C-1	Accordion	Untethered	116 mph	98 mph	16 msec	19"	28 msec
D-1	Mod. Accordion	Untethered	98 mph	46 mph	32 msec	17"	46 msec
E-1	Mod. Accordion	Untethered	112 mph	39 mph	22 msec	17"	47 msec
F-1	Overlap Fold	Tethered	167 mph	NA	NA	14"	29 msec
G-1	Pleated Accordion	Tethered	167 mph	NA	NA	14"	23 msec
H-1	Accordion	Tethered	150 mph	NA	NA	15"	21 msec
I-1	Overlap Fold	Untethered	211 mph	184 mph	9 msec	20"	21 msec
	Tethered	Mean =	151 mph	NA	NA	14"	25 msec
		S.D. =	22.2 mph			1.3"	3.4 msec
		C.V. =	14.7%			9.3%	13.6%
	Untethered	Mean =	139 mph	92 mph	19 msec	19"	34 msec
		S.D. =	46.0 mph	58.0 mph	8.8 msec	1.5"	11.5 msec
		C.V. =	33.1%	63.0%	46.3%	7.9%	33.8%

* Listings of Vehicles' Make/Model are contained in Appendix E.

The air bag velocities, at the time that facial contact would have occurred, were determined for the untethered systems. The values ranged from 39 mph to 184 mph, with an average of 92 mph. This was based on a 15" nose-to-hub distance for all systems. The four tethered air bags had peak displacements less than 15" (system H's value was slightly less than 15" and was rounded to 15" for reporting purposes).

The presence of tethers significantly affected the maximum amount of bag displacement which occurred during deployment. The peak displacements for the nine bags ranged from 12" to 20", with an average of 16.4". The average for the four tethered bags was 14", whereas, the average was 19" for the five untethered bags.

The average time for full inflation of the tethered air bags was 25 msec with a standard deviation of 3.4 msec. Average inflation time for the untethered bags was 34 msec, with a standard deviation of 11.5 msec.

4.3 Selection Process for Phase II Testing

Considerations of the air bag equipped fleet population and analysis of the high speed films of Phase I testing were used to select four air bag systems for continued testing in Phase II.

Air bag systems A, B and C are found in one automobile manufacturer's fleet. One tethered and one untethered bag were chosen from this group - systems A and B, respectively. Because systems A and B both exhibited an accordion folding pattern, systems using other folding patterns were chosen for testing with the dummy. System D was selected because it was untethered, but exhibited one of the slowest air bag speeds during deployment and used a modified accordion folding pattern. The third untethered air bag selected for Phase II testing was system I, which exhibited the highest bag leading edge velocity during deployment and used an overlapping fold pattern. The tethered system A allowed for further investigation of the influence of air bag tethering.

5.0 PHASE II - BAG DEPLOYMENT WITH SEATED 5th PERCENTILE FEMALE HYBRID III DUMMY

The second phase in the static test series was to repeat deployment tests on selected air bag systems, using a seated Hybrid III 5th percentile female dummy. The following concerns needed to be addressed prior to the onset of testing: 1) what type of medium could be applied to the dummy's face to record the pattern, and possibly extent, of contact with the air bag and 2) whether or not to account for a change in occupant position due the vehicle's velocity change at the time of bag deployment when positioning the Hybrid III 5th percentile dummy relative to the steering wheel.

5.1 Survey of Medium to Record Facial Contact

In an effort to record the pattern (and possible degree) of facial contact with the air bags, the following three mediums were surveyed:

- the standard powdered chalk solution currently used for crash testing to indicate occupant/object contact points,
- a soft wax applied to the face in layers which might indicate the depth and travel of the air bag contacts, and
- a paint-on solution containing pressure activated microencapsulated dyes which might indicate the forces produced by the bag during facial contact.

Problems were encountered with the wax and microencapsulation methods which were judged impracticable to deal with in meeting the needs of this project. We were unable to achieve application of the wax in uniform layers. Plus, after an experimental impact using wax on the dummy face, the wax cracked loose from the dummy skin. It was extremely difficult to distinguish the type of air bag contact that occurred.

The microencapsulation process had been developed for other applications and the manufacturer estimated a minimum of 6-8 weeks development time (@ $15,000) for our application. The cost and time required were not warranted for this project.

The standard chalk solution was selected for use in the air bag tests. This meant that it was not possible to measure the severity of bag contact. With chalk, it was only possible to determine where contact occurred to the face, and whether the bag material slid across the contact area as indicated by chalk smearing and/or removal.

5.2 Positioning of the 5th Percentile Female Dummy

Prior to conducting the air bag deployments using the small female dummy, the relative positioning between the dummy and the steering wheel was determined. This was accomplished by properly positioning the dummy in vehicles containing systems A, B, D and I and recording pertinent measurements. To accomplish this the seat was positioned fully forward and upward, the seat back angle was set as close to 25° as possible and the steering wheel was set at mid-position or one notch above mid if there was no setting at mid-position. Measurements taken included the steering wheel hub (center) angle, the distance and angle from the wheel hub to the dummy's chest, the distance and angle from the wheel hub to the dummy's nose and the dummy's pelvic angle. All recorded angles were referenced off of horizontal except for the steering wheel hub angle.

In addition to the above initial seating position measurements, it was decided to determine what amount of occupant displacement could have occurred from the onset of impact until the air bag sensor was triggered during a low speed crash. A 10 mph frontal FRB/Escort impact test in which air bag sensors had been placed was reviewed. The rear deck acceleration time history was used to derive the amount of occupant displacement. The curve was approximated by a 7 G square wave. At the time of the air bag sensor triggering (45.5 msec after initial contact with the rigid barrier), the displacement of the integrated square wave was approximately 3". This 3" of displacement would be the upper boundary of occupant movement if there were no forces acting on the occupant. The lower boundary of movement would theoretically be 0".

The initial Phase II tests consisted of positioning the dummy at the initial measurements taken in the actual vehicles. All four systems were tested at these conditions. Systems A and D were deployed a second time with the dummy seated 3" closer.

5.3 Summary of Phase II Test Results

Each of the four air bag systems were deployed with the 5th percentile female Hybrid III dummy seated in the initial position as measured in the actual vehicles. The dummy's face was painted in a tri-color chalk scheme to record bag contact and possible sliding motion of the bag (by transference of one color of chalk into a differently colored area). As with Phase I tests, three high speed cameras photographically recorded the deployments -a 90° side view, a 45° side view and an overhead view. The dummy's head was instrumented with a triaxial accelerometer array located at the C.G. Table 2 contains a summary of the dummy head resultant accelerations and calculated Head Injury Criteria (HIC) along with the test set-up measurements and the actual measurements taken in the vehicles. Also included in the summary are the results for systems A and D with the dummy positioned 3" closer to the steering wheel (chest-to-hub distance). The acceleration time histories for the tests are contained in Appendix D. Results of the tests will be reviewed individually.

5.3.1 Air Bag System A

The tethered system A was deployed with the small female dummy seated 7.0" from the center of the steering wheel hub at chest level. The resultant head acceleration was 10.35 G, producing a HIC value of 2. (The maximum allowable HIC in FMVSS 208 is 1000.) Review of test films revealed that the dummy's chin

Table 2 - Phase II Air Bag Test Summary

		System B Actual Meas'd	System B Init. Pos. Tested	System A Actual Meas'd	System A Init. Pos. Tested	System A 3" Closer Tested	System D Actual Meas'd	System D Init. Pos. Tested	System D 3" Closer Tested	System I Actual Meas'd	System I Init. Pos. Tested
Wheel Hub (Center) Angle (deg.)		28.00	28.00	30.00	30.00	30.00	22.50	22.50	22.50	28.00	29.00
Chest to Hub Center	Distance (in.)	7.25	7.50	7.00	7.00	4.25	7.75	8.00	5.00	8.19	8.25
	Angle (deg.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nose to Hub Center	Distance (in.)	8.88	9.50	10.25	11.25	10.25	12.00	12.00	10.25	13.25	13.25
	Angle (deg.)	52.00	51.00	51.00	51.00	57.00	48.50	48.00	54.00	46.50	42.00
Dummy Pelvic Angle (deg.)		14.90	15.00	20.00	20.00	20.00	21.00	20.00	19.50	20.00	20.50
Resultant Head Acceleration (G)		NA	**	NA	10.35	12.95	NA	18.13	NA	NA	23.50
Head Injury Criterion (HIC)		NA	***	NA	2.30	3.10	NA	8.74	NA	NA	2.91

Comments:

System B: Chalk removal on chin, lips, nose and cheeks. Transfer of chalk from jawline to chin.

System A: Initial Position - Chalk removal under and on chin. Transfer of chalk from jawline to chin. No indications of bag contact with nose, cheeks or brow.

3" Closer - Chalk removal under chin, along jawline and below lower lip area. Indications of bag contact on lips and tip of nose. No indications of any contact above the upper jaw.

System D: Initial Position - Chalk removal on chin, lips and end of nose. Transfer of chalk from jawline to chin, lips and nose. Bag imprint on cheeks and brow indicative of a slapping motion rather sliding motion by the bag.

3" Closer - Chalk removal on chin, lips, nose and brow areas. Some transfer of chalk from jawline to chin.

System I: Chalk removal on chin, nose, cheeks, brow and forehead areas. Slight transfer of chalk from jaw to chin area. Remainder of markings appear to indicate more of a slapping motion rather than a sliding motion by the bag.

** - Exceeded accelerometer full scale value of 50 G.
*** - Did not compute due to exceeding instrumentation's full scale value.

initially made slight contact with the center of the deploying/inflating bag, then the bag withdrew from the face. Facial contact was again made as the lower half of the bag firmed up during inflation, producing chalk removal along the jawline, the underside of the chin and the tip of the chin. There were no indications of bag contact on the nose, cheeks or brow. Figure 8 shows the post-test view of the dummy's face, with chalk removal present on the jawline and chin (the darker area in the red chalked portion). Figures 9 and 10 are close-up views of the chalk removal along the jawline and the end of the chin, respectively. The slight bit of red chalk seen just beneath the lips in Figure 10 is the result of the airborne chalk powder settling and not the result of direct transfer by bag contact.

Based on the above results a second air bag A was deployed with the dummy seated 3" closer. The chest-to-hub distance for this test was 4.25". It was impossible to place the dummy at the desired 4" distance due to the bottom of the wheel being in contact with the dummy's torso. The resultant head acceleration was 12.95 G and the HIC value was three for this second deployment. Repositioning of the dummy caused the expansion of the lower section of the bag to be blocked by the steering wheel's lower rim and dummy torso, forcing the bag to increase its upward expansion. This produced chalk removal along the jawline, the chin, the lips and end of the nose. There were no indications of bag contact above the upper jaw area of the dummy's face (i.e., cheeks, eyes, etc). Figure 11 shows the chalk removal pattern on the left underside of the jaw and chin and below the lip area. There was a slight transference of the red chalk from the jawline to upper chin and lower lip areas. A similar chalk removal pattern was observed on the right side of the face, as shown in Figure 12. A frontal view of the face (see Figure 13) shows the transference of the red chalk to the chin and lip areas and the chalk removal on the very tip of the nose.

Repositioning of the dummy closer to the air bag system did slightly increase the area of chalk removal on the face. Review of the high speed films and the patterns observed on the underside of the jaw and chin indicated a constant bag contact during inflation, providing for a sliding-type of contact. The pattern observed on the upper chin and lips during the second deployment indicated some period of bag contact having a sliding motion, but not a constant contact as for the jaw and lower chin.

5.3.2 Air Bag System B

The untethered system B was deployed with the dummy seated 7.5" from the center of the steering wheel hub at chest level. The resultant head acceleration and HIC values were not reported because the peak acceleration for head X exceeded the instrumentation full scale value of 50 G. Full scales were reset to 100 G for following tests, but it was not believed necessary to repeat the test to obtain the data since head accelerations are well below established injury thresholds. The air bag produced chalk removal on the chin,

FIGURE 8 -- System A's Initial Position Test Results

FIGURE 9 -- Close-up View of Chalk Removal on Jawline for System A

FIGURE 10 -- Close-up View of Chalk Removal on Chin for System A

FIGURE 11 -- Left Side Chalk Removal Pattern for System A Positioned 3" Closer

FIGURE 12 -- Right Side Chalk Removal Pattern for System A Positioned 3" Closer

FIGURE 13 -- Frontal Chalk Removal Pattern for System A Positioned 3" Closer

lips, nose and cheeks. There was transference of red chalk from the jaw onto the chin area. Figure 14 shows a close-up frontal view of the chalk removal pattern for system B. Close-up views of the right and left side chalk removal patterns are shown in Figures 15 and 16, respectively. It was observed from the high speed films that the air bag was still unfolding at the time it contacted the face. The lower expansion of the bag was blocked by the lower rim and the torso, causing the majority of inflation to occur while in contact with the face.

5.3.3 Air Bag System D

The untethered system D was deployed with the dummy seated 8.0" from the center of the steering wheel hub at chest level. The resultant head acceleration was 18.13 G, with a computed HIC value of 8. There was chalk removal on the chin, lips and end of nose. Transference of chalk from the lower jaw to the chin, lips and nose occurred. Bag material imprints were found on the cheeks and brow indicating a slapping contact rather than a sliding contact. A full frontal view of the chalk removal pattern for bag D is shown in Figure 17. Note the transfer of the red chalk from the jaw to the upper chin, lips and end of nose. A close-up view of the chalk removal and chalk transfer is shown in Figure 18. The blue located on the lower left side of the face is the result a second, light contact with the face after complete bag inflation. Figure 19 shows a close-up view of the bag material imprints on the cheeks and brow. Review of high speed films showed that the bag was virtually unfolded and partially inflated prior to facial contact, with the lower portion of the bag expanded into the area between the lower rim and torso. This lower bag expansion probably accounts for the bag material imprints on the cheeks and brow rather than the chalk removal patterns in those area, as was observed with bag B.

A second deployment was conducted with the dummy repositioned closer to the air bag system. The chest-to-hub center distance was 5". Dummy head C.G. acceleration data was not recorded for this deployment. There was chalk removal on the chin, lip, nose, cheek and brow areas, in addition to the transfer of chalk from the lower jaw onto the chin area. Figure 20 shows the chalk removal patterns on the left side of the face. The overall chalk removal pattern was very similar to that of the first deployment, with the exception that those areas which indicated bag material imprints now indicated actual chalk removal or sliding of the bag material. This increased chalk removal appeared to be primarily due to the lack of available space between the lower rim and torso for the expansion of the lower portion of the bag. The resulting inflation tended to look more like that of bag B's inflation rather than the first bag D's inflation pattern.

FIGURE 14 -- Frontal View of Facial Chalk Removal for System B

FIGURE 15 -- Right Side View of Facial Chalk Removal for System B

FIGURE 16 -- Left Side View of Facial Chalk Removal for System B

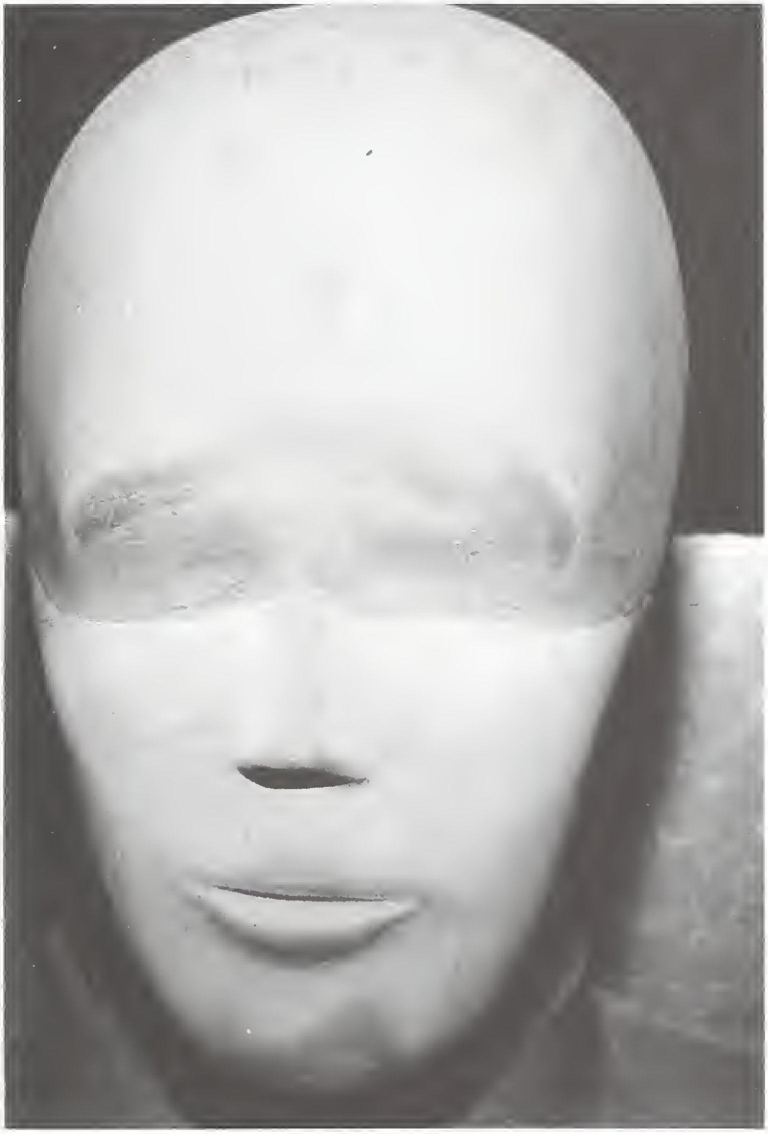


FIGURE 17 -- Frontal Chalk Removal Pattern for Initially Positioned System D

FIGURE 18 -- Close-up of Chalk Removal on Chin and Lips for Initially Positioned System D

FIGURE 19 -- Close-up of Bag Imprints for Initially Positioned System D

FIGURE 20 -- Chalk Removal Pattern for System D Positioned 3" Closer

5.3.4 Air Bag System I

The untethered system I was deployed with the dummy seated 8.25" from the steering wheel hub center at chest level. The peak resultant head acceleration was 23.5 G, with a computed HIC value of three. Chalk removal was present on the chin, lip, nose, cheek brow and forehead areas. There was a slight transference of chalk from the jawline to the chin area. A full frontal view of the chalk removal pattern is shown in Figure 21. The blue chalk dust around the nose and lower eye area is due to airborne chalk settling rather than direct transfer from the bag. The yellow arc of chalk over the brow area is a direct transfer from the bag which occurred during a second contact with the face after the bag was fully inflated. The chalk removal patterns for the right and left side of the face are shown in Figures 22 and 23, respectively.

FIGURE 21 -- Frontal View of Chalk Removal Pattern for System I

FIGURE 22 -- Right Side View of Chalk Removal Pattern for System I

FIGURE 23 -- Left Side View of Chalk Removal Pattern for System I

6.0 CONCLUSIONS

The conclusions herein result from the preliminary observation of the inflation characteristics of several currently available air bag restraint systems relative to factors that may be important to the likelihood of injuries occurring as side effects of the inflation process. All tests were performed in a static, non-crash environment. The only dummy size employed in this program was a 5th percentile female, and in all cases the dummy was aligned with the center of the driver air bag. Neither the effects of crash dynamics, nor trade-off of inflation characteristics with the overall effectiveness of the systems are within the scope of this study. Additionally, the effects of the range of driver sizes and the consequences of driver misalignment with the air bag at time of deployment were not evaluated. The reader is cautioned that the information in this report can not be used to rationalize specific design changes without consideration of the effects of crash dynamics, and of the effects of such design changes on overall system effectiveness.

- Four distinct air bag folding patterns were observed among the nine systems deployed:

    1. An accordion-type pattern in which the top and bottom sections of the bag are folded in approximately 2.5" folds toward the center, then placed on their respective half of the 5" unfolded center section. The side sections of the bag are then folded toward the center and juxtaposed over the center of the bag. This folding pattern is seen in air bag systems A, B, C and H.

    2. A modified accordion-type pattern in which the side sections of the bag are rolled under from the left and right ends to lie on top of the central portion of the accordion-folded bag. This type of folding pattern is seen in air bag systems D and E.

    3. A pleated accordion-type pattern in which the side sections of the air bag are vertically folded under and toward the center of the bag. The top and bottom sections of the bag are then folded in approximately 2.5" folds and placed over the 5" unfolded center section of the bag. This type of folding pattern is seen in air bag system G.

    4. An overlap-type pattern in which the top section of the bag is folded, in 5" widths, over the center portion of the bag. The bottom section is then similarly folded over the combined center and top sections. The sides of the

bag are then folded toward the center and juxtaposed over the center of the bag. This pattern is seen in air bag systems F and I.

- Similar peak air bag velocities were observed for tethered and untethered systems. The velocities of the deployed air bags ranged from 98 mph to 211 mph, with an average velocity of 144 mph. The average velocity for the untethered air bags was 139 mph with a standard deviation of 46 mph. For the tethered bags, the average velocity was 151 mph with a standard deviation of 22 mph.

- A distinct difference in the maximum displacement of the leading edge of the air bags was observed between tethered and untethered systems. The peak displacements for the tethered bags ranged from 12" to 15", with a mean value of 14" and a standard deviation of 1.3". For the untethered bags, the peak displacements ranged from 17" to 20", with a mean of 19" and a standard deviation of 1.5".

- The time for full inflation of the tethered air bags ranged from 21 msec to 29 msec, with an average of 25 msec and a standard deviation of 3.4 msec. Inflation time for the untethered bags ranged from 21 msec to 47 msec, with an average of 34 msec and a standard deviation of 11.5 msec.

- No lone bag characteristic appears to account for the type of chalk removal pattern observed when the bag contacts the dummy's face in these static tests. Certain physical properties combined with one another do appear to have an effect on chalk removal:

    - The presence of tethers has a significant effect on the bag's peak displacement, which in turn has an effect on the type of chalk removal that the bag produces on facial contact. The untethered bags tended to engulf the dummy's face and created chalk removal patterns either by a sliding motion or a slapping motion. The tethered bag contacted the face in the lower jaw and chin areas, while not producing contact patterns above the upper jaw.

    - The bag folding pattern appears to be an important factor both singularly and in conjunction with the presence or absence of tethers and positioning of the dummy. The three untethered bags (B, D and I) tested with the dummy at the initial position showed the effect of the folding pattern. The accordion and overlap folding types (B and I, respectively) produced comparable chalk removal and significantly more chalk removal than the modified accordion folding type (D). The combined effect of folding, tether/untethered and dummy positioning is evident from results with system A (tethered bag) and system D (untethered bag) tests. Regardless of dummy positioning, chalk removal patterns were significantly different between tethered and untethered bags. With the dummy positioned 3" closer to the steering wheel, the amount of chalk removal increased noticeably for the untethered bag but only slightly for the tethered bag.

- No perceptible differences in the type of chalk removal caused by the different nylon denier thicknesses comprising the bag material for the systems tested were observed.

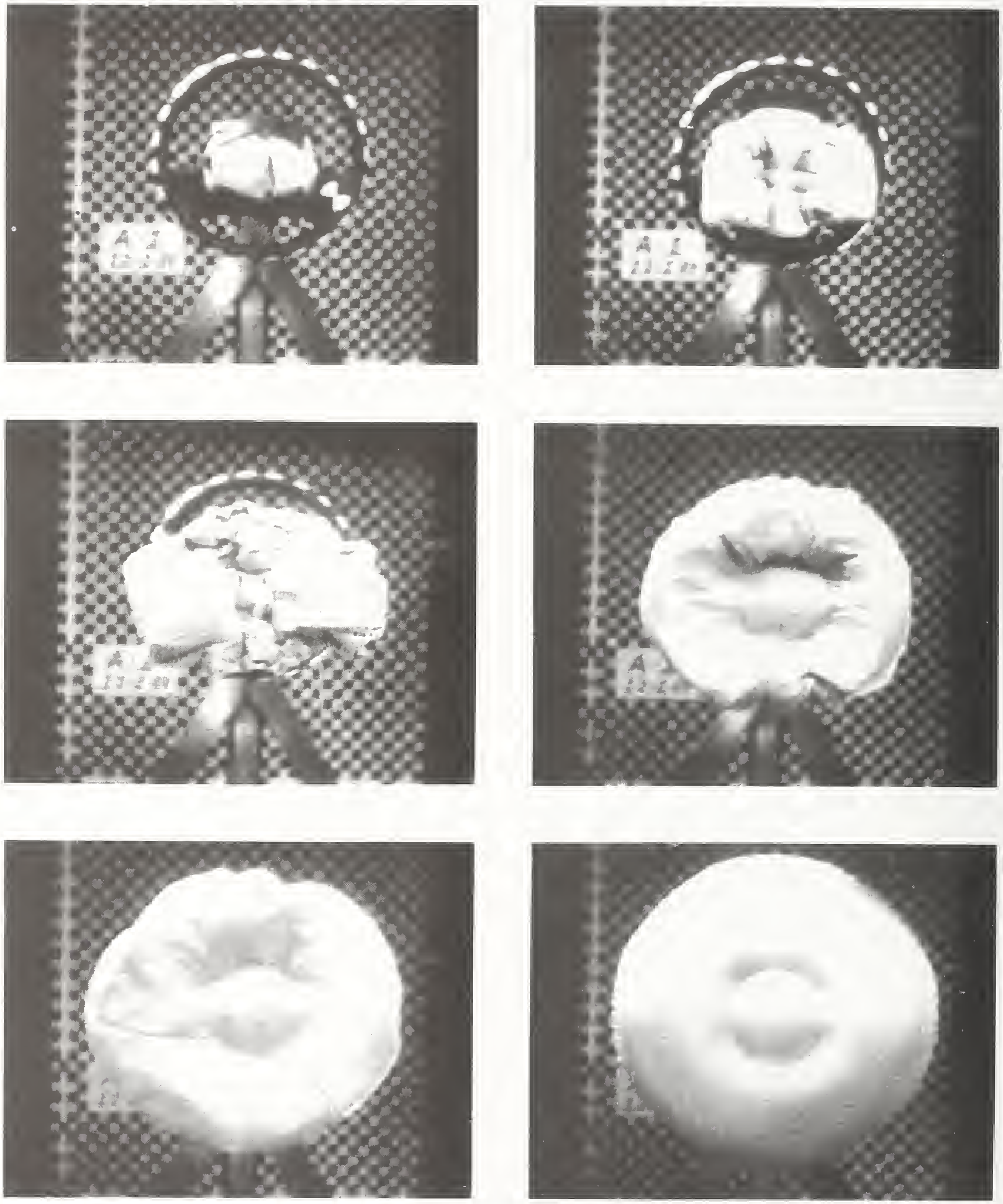
APPENDIX A

Air Bag Deployments

Time Sequence Photos and Descriptions

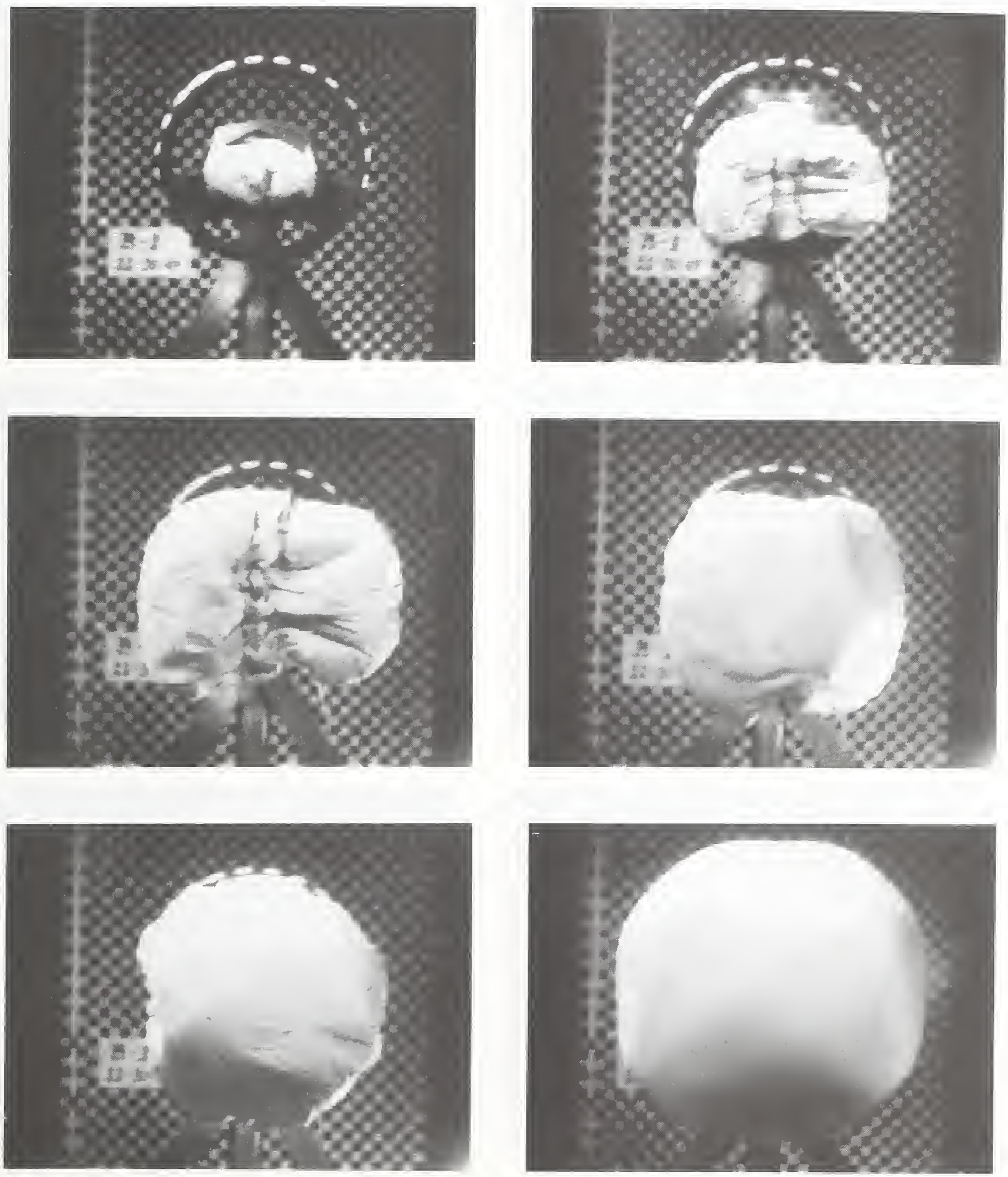
Test A-1 System A Air Bag Deployment

Side lobes unfurl first, followed by the unfurling of the top and bottom sections of the bag. The bag begins to radially expand, with the peripheral portion of the bag extending past the tethered center section of the bag. When the tether and available fabric limits are reached, the bag completes inflation and tensions against the wheel hub.



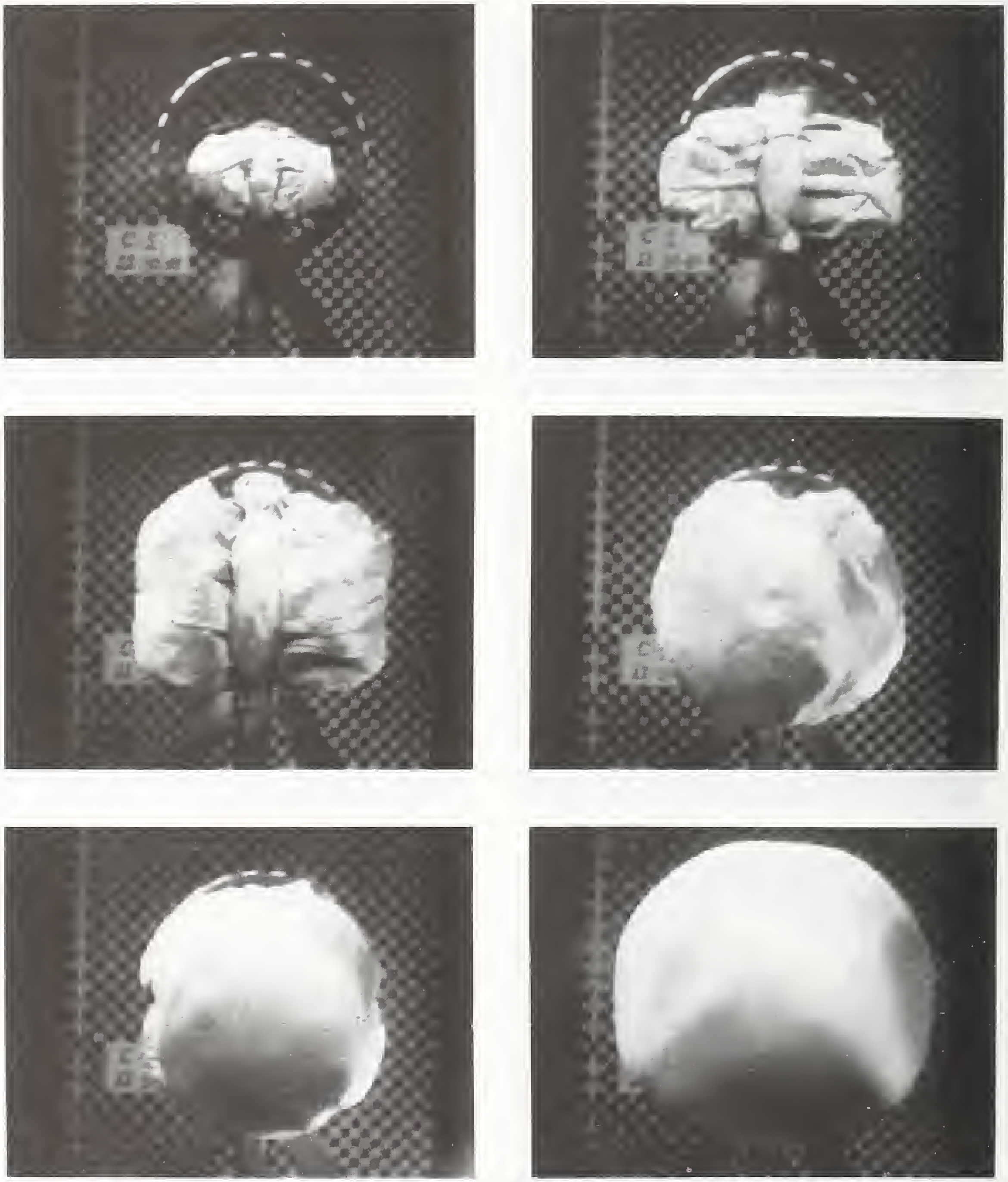
Test B-1 System B Air Bag Deployment

Side lobes unfurl first, followed by the unfurling of the top and bottom sections of the bag. The bag extends outward to form an elongated cylinder, reaching its maximum displacement. The bag then begins to radially expand and drawback its leading edge, finally ending in tension against the wheel hub.



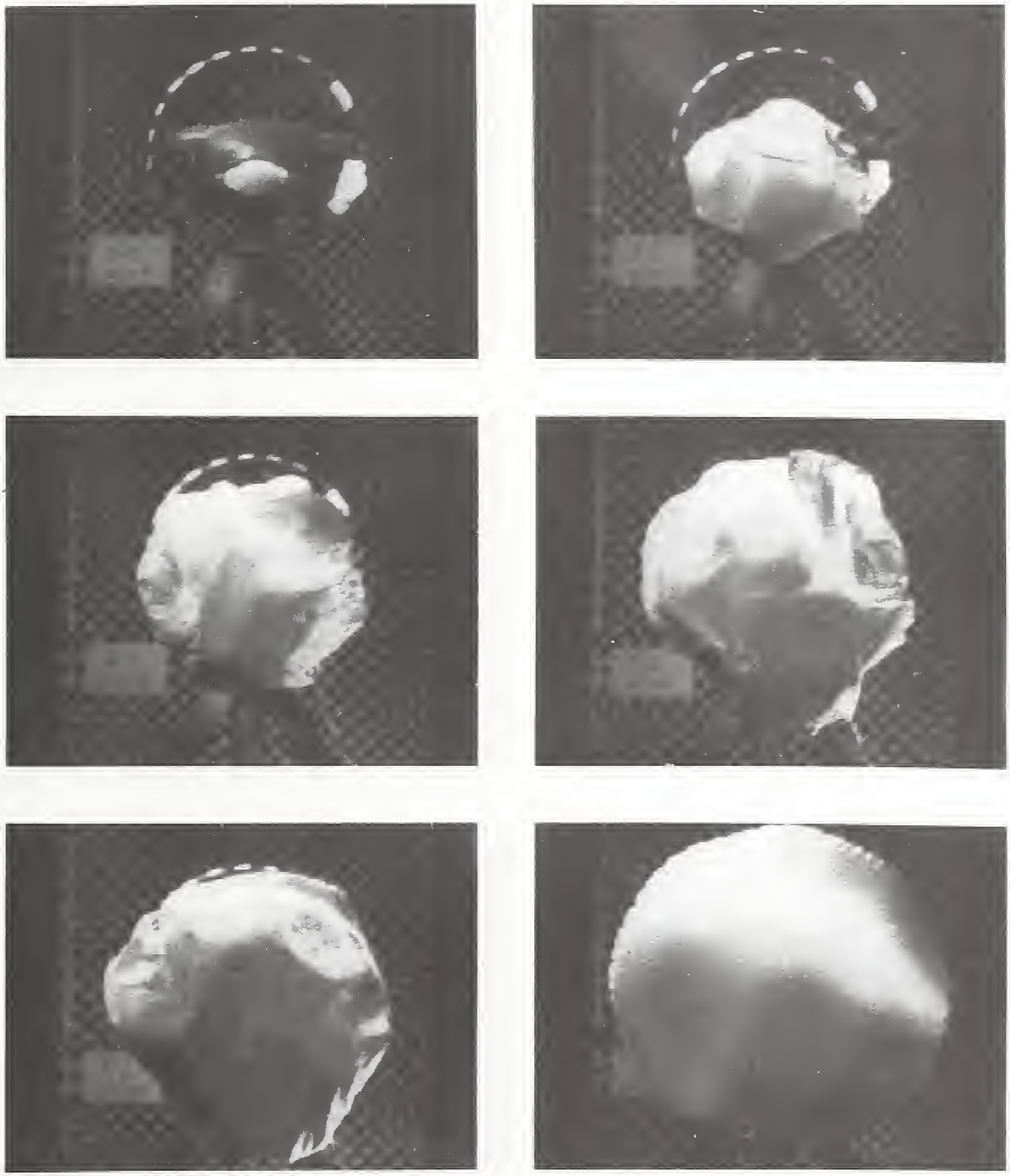
Test C-1 System C Air Bag Deployment

Side lobes unfurl first, followed by the unfurling of the top and bottom sections of the bag. The bag extends outward to form an elongated cylinder, reaching its maximum displacement. The bag then begins to radially expand and drawback its leading edge, finally ending in tension against the wheel hub.



Test D-1   System D Air Bag Deployment

The center of the bag begins an outward expansion first, followed by expansion of the sides of the bag. The bag extends to its maximum displacement, forming a "mushroom" shape and then begins its radial expansion and completes the process by ending in tension against the wheel hub.

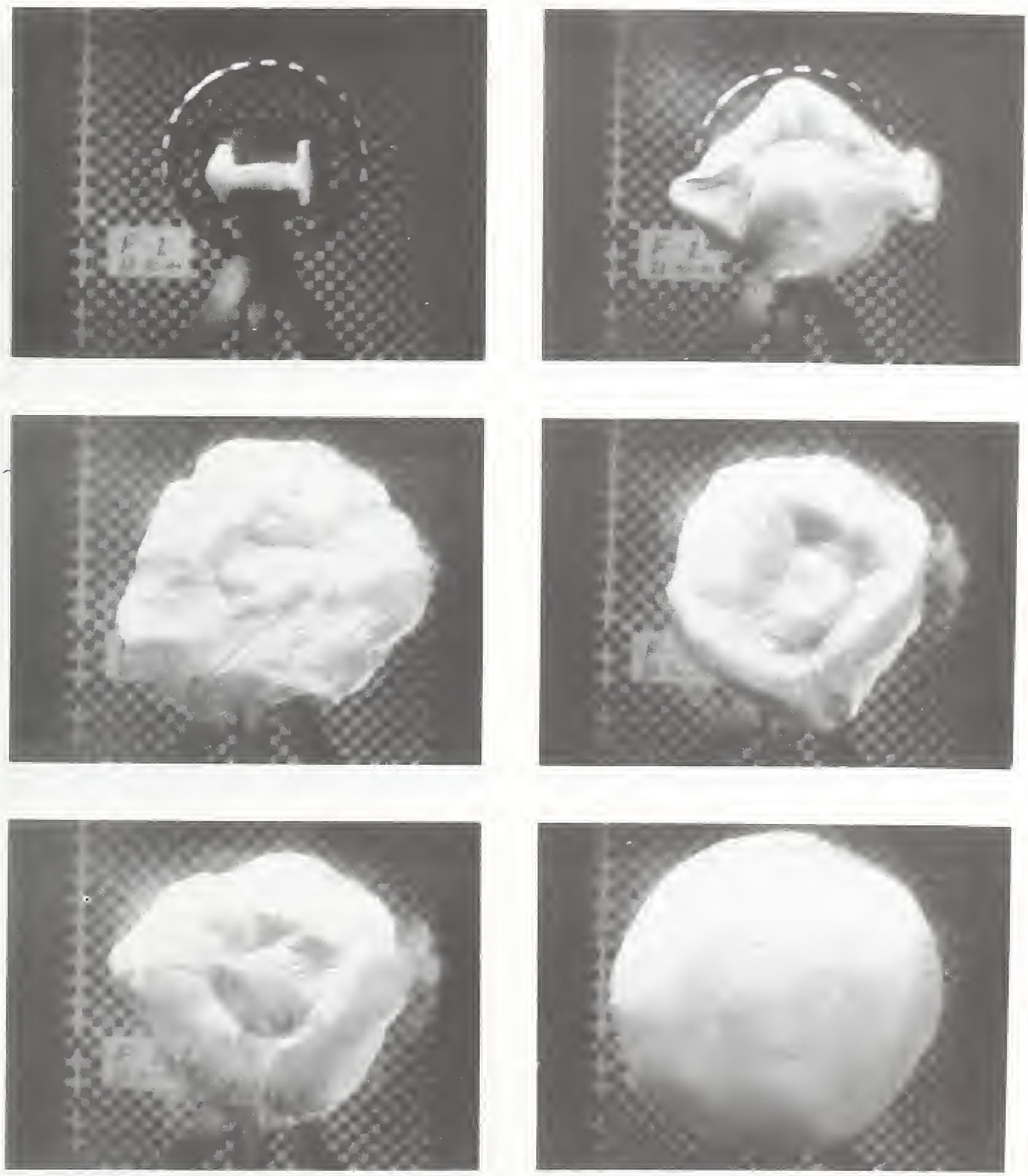


Test E-1 System E Air Bag Deployment

The center of the bag begins an outward expansion, followed by expansion of the sides of the bag. The bag reaches its maximum displacement, begins its radial expansion and completes the process by ending in tension against the wheel hub.

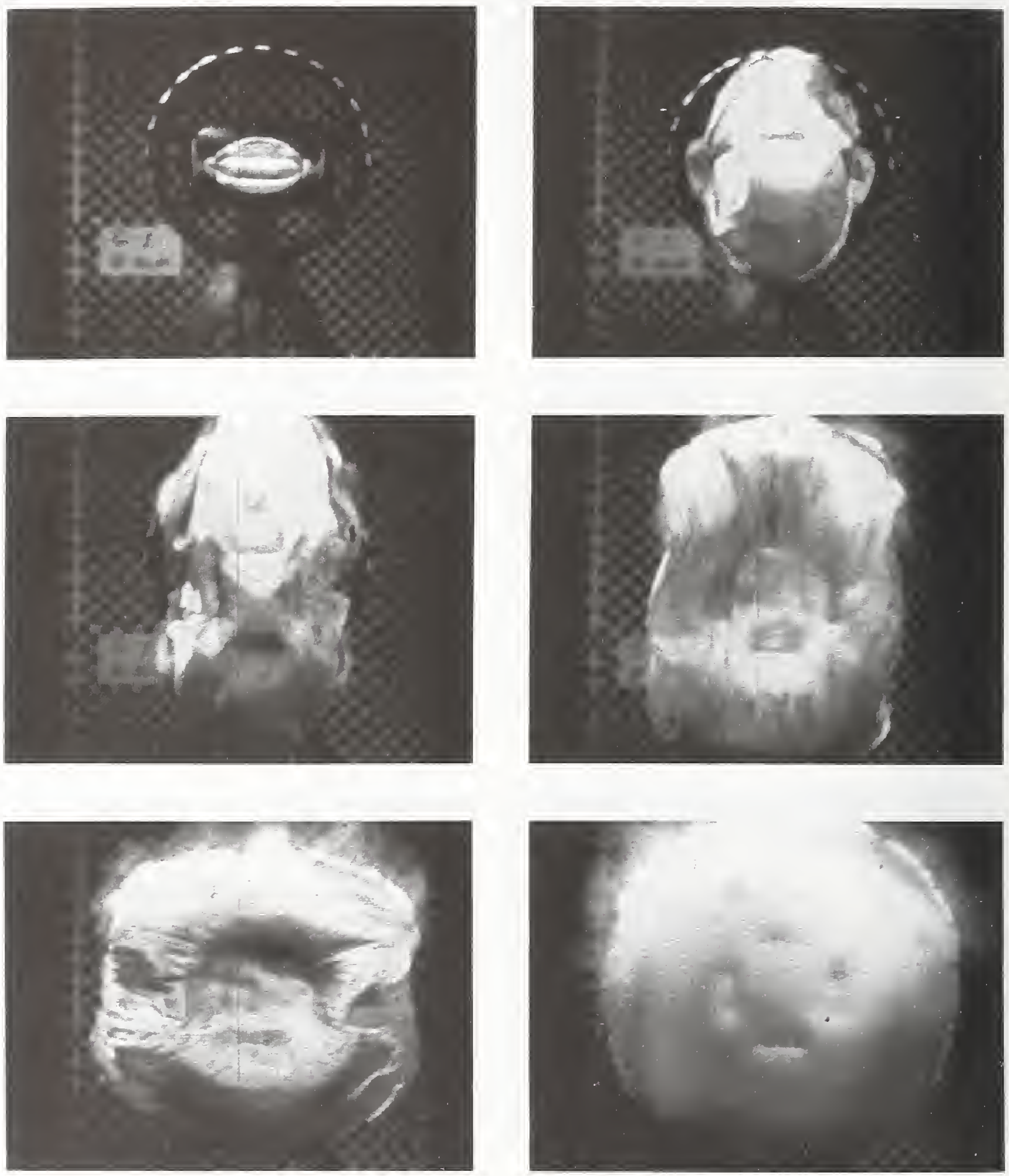
Test F-1 System F Air Bag Deployment

Side lobes unfurl first, followed by the unfurling of the bottom and then the top sections of the bag. The bag begins to radially expand, with the peripheral portion of the bag extending past the tethered center section of the bag. When the tether and available fabric limits are reached, the bag completes inflation and goes into tension against the wheel hub.



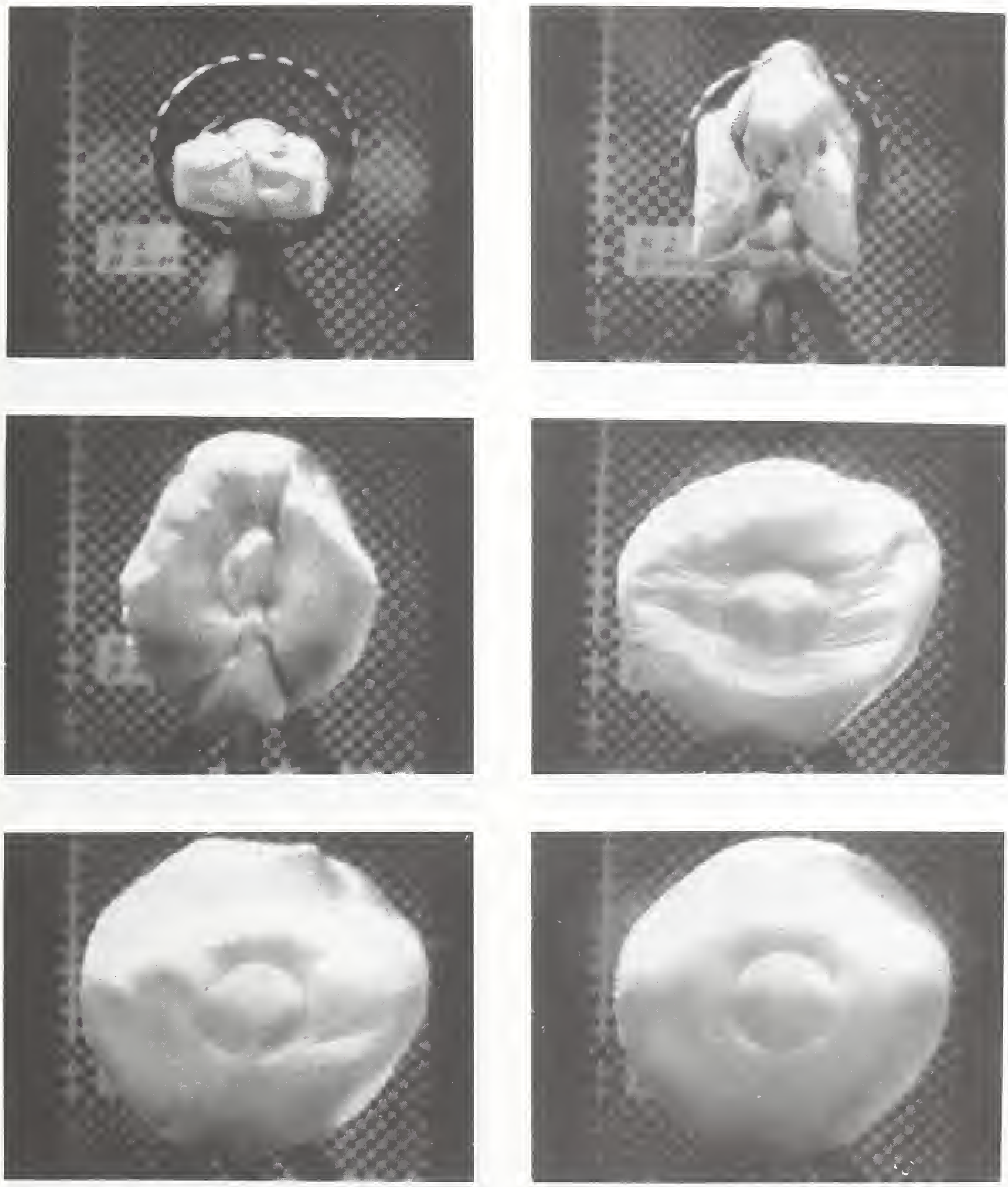
Test G-1 System G Air Bag Deployment

The center of the bag begins an outward expansion first, followed by expansion of the sides of the bag. The bag begins to radially expand, with the peripheral portion of the bag extending past the tethered center section of the bag. When the tether and available fabric limits are reached, the bag completes inflation and goes into tension against the wheel hub.



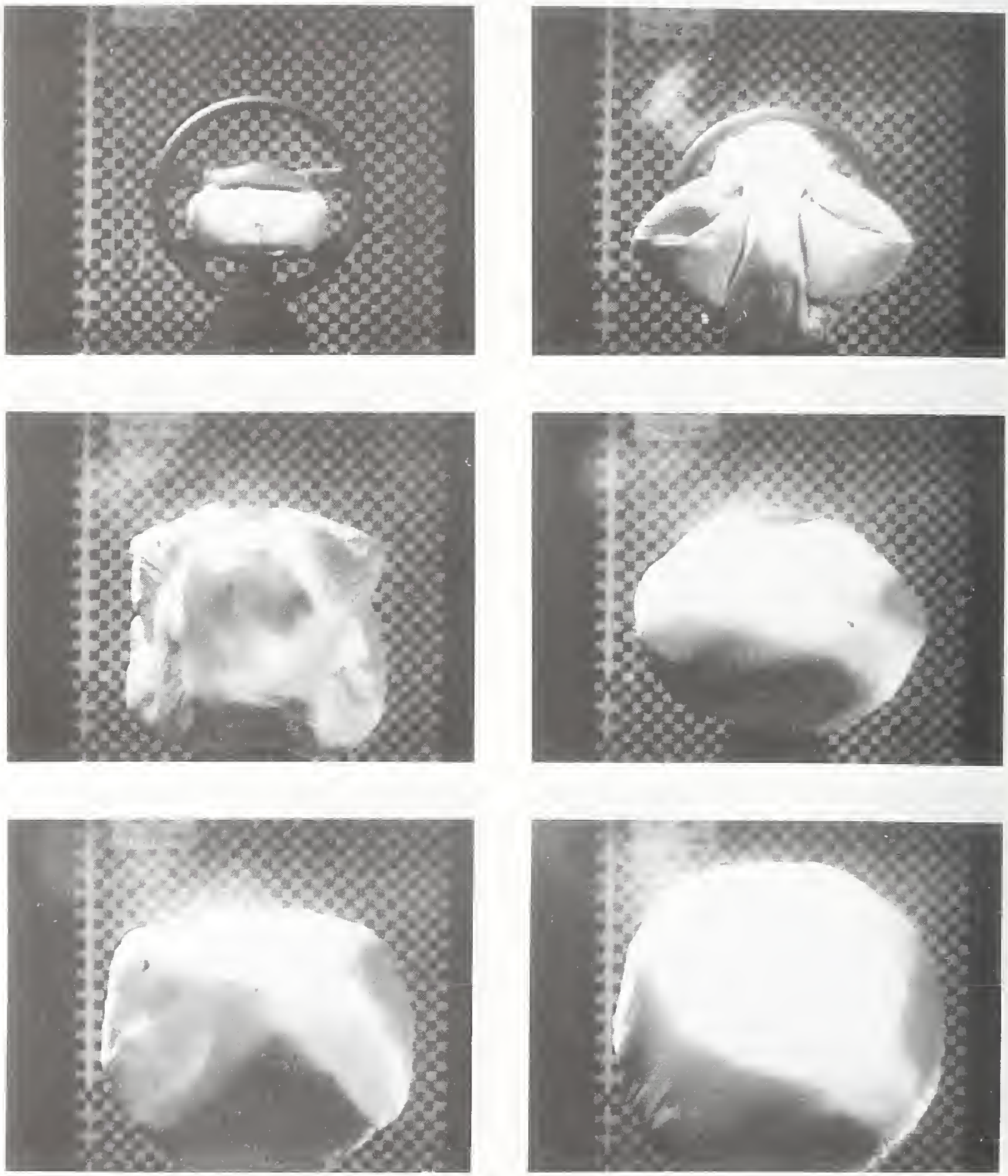
Test H-1 System H Air Bag Deployment

Side lobes unfurl first, followed by unfurling of the top and bottom sections. The bag begins to radially expand, with the peripheral portion of the bag extending past the tethered center section of the bag. When the tether and available fabric limits are reached, the bag completes inflation and goes into tension against the wheel hub.



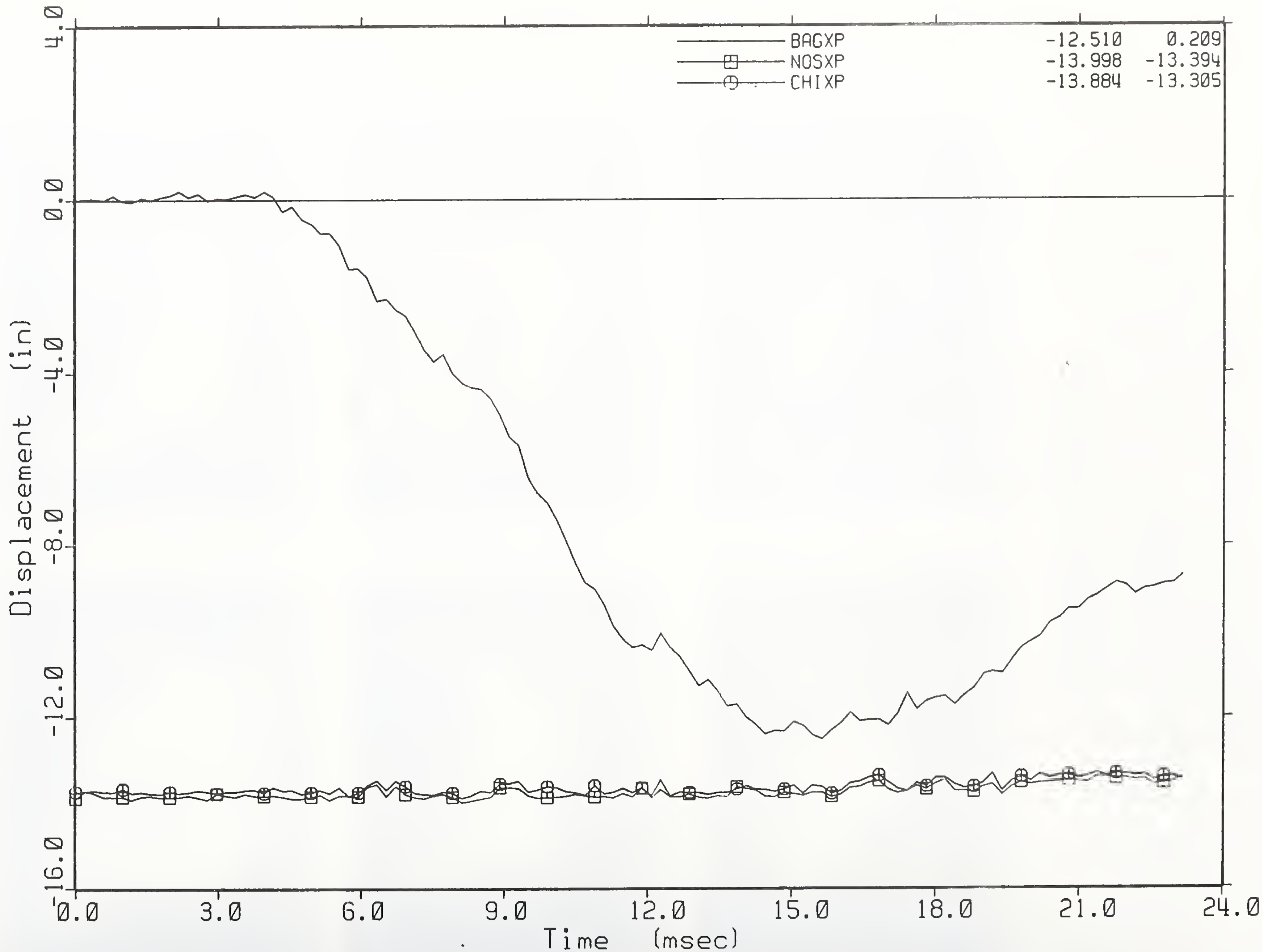
Test I-1 System I Air Bag Deployment

Side lobes unfurl first, followed by unfurling and inflation of the lower section of the bag. Expansion and beginning inflation of the bag occur with slack cloth folds of the bag's upper section not inflating but being drawn outward by the expanding lower section. After significant inflation of the lower air bag sector occurs, the upper section accelerates its expansion and the bag reaches its maximum displacement. Radial inflation of the bag occurs and the bag then goes into tension against the wheel hub.

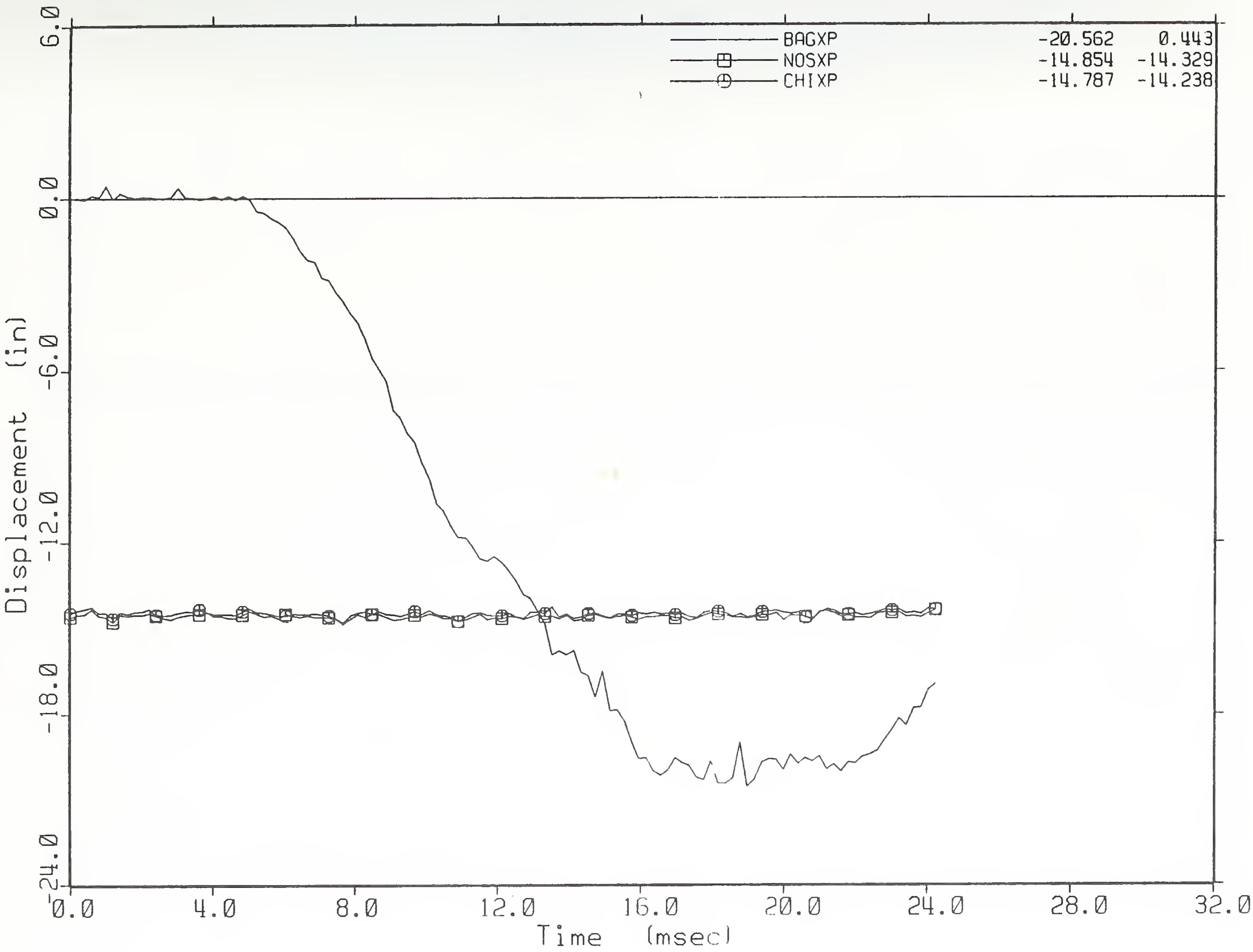


APPENDX B

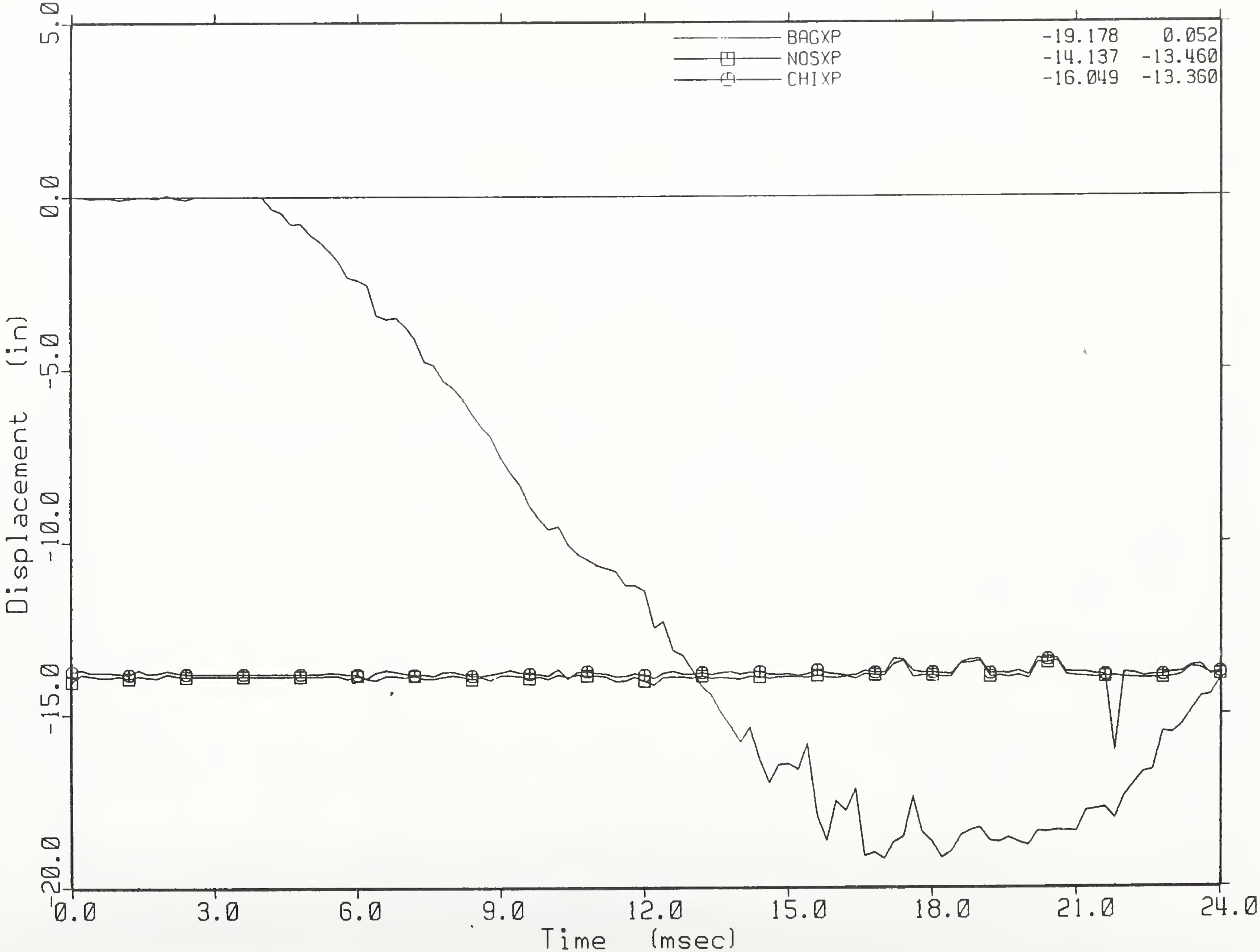
Air Bag Displacement Time Histories



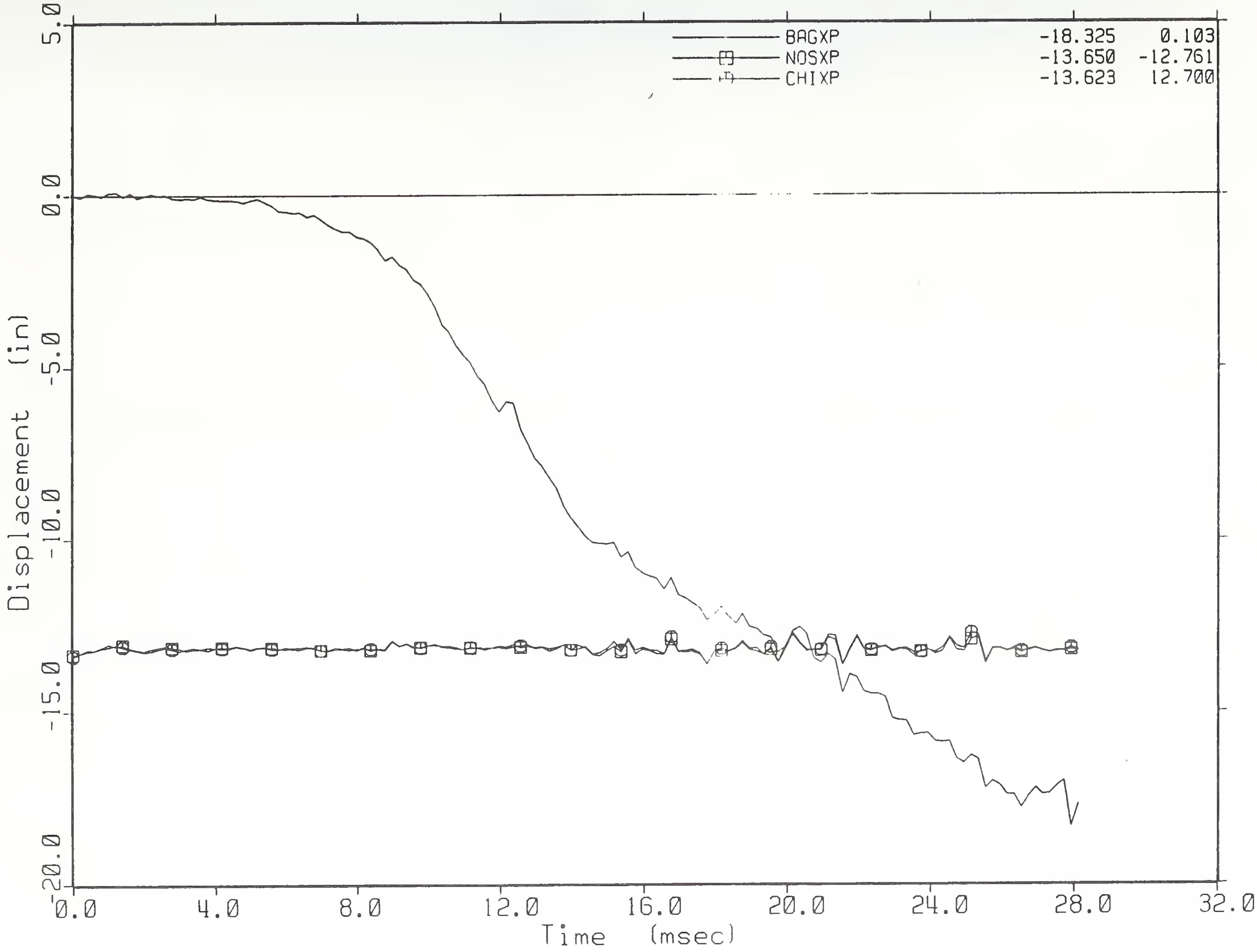
SYSTEM A TEST 1



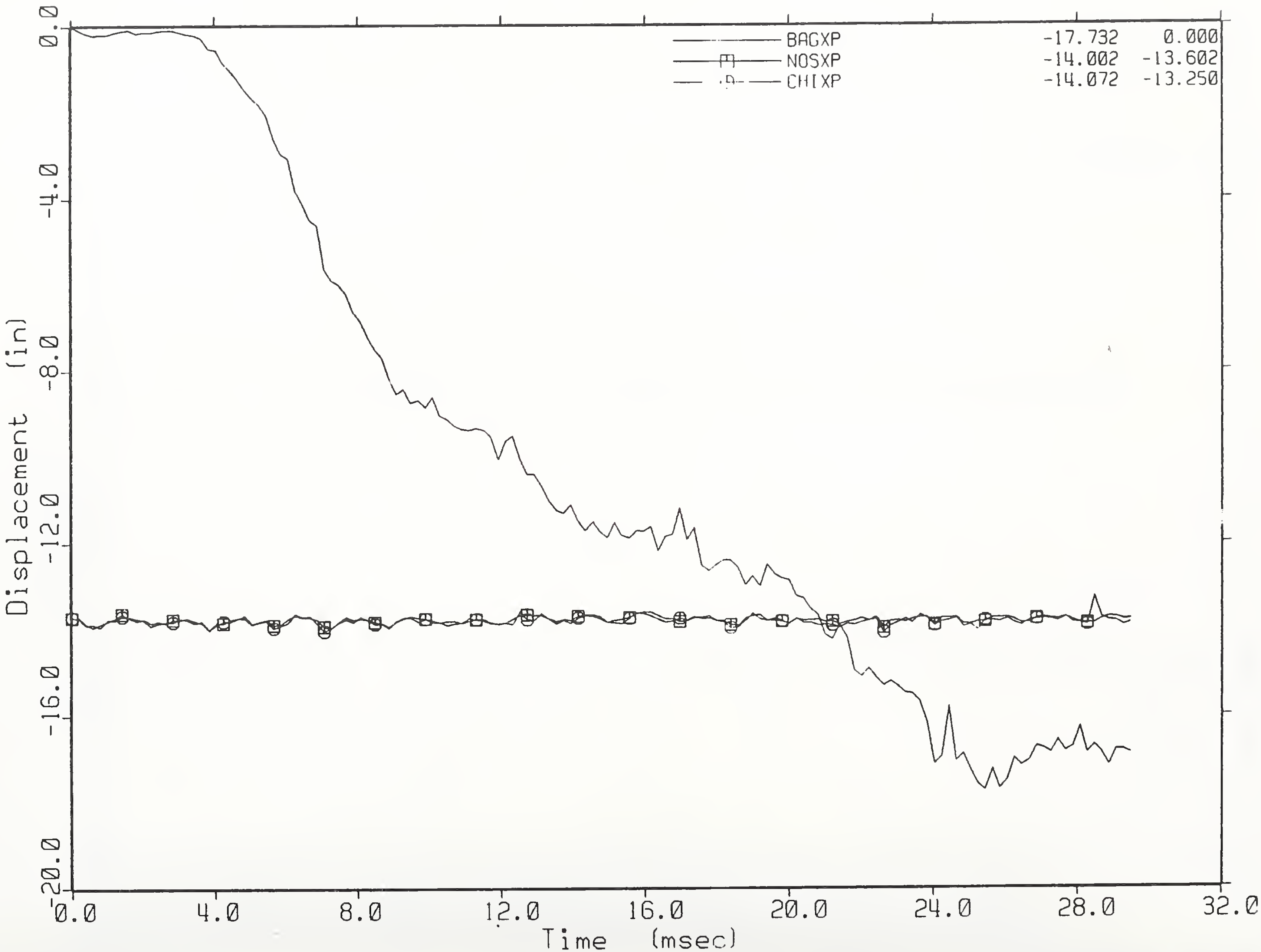
SYSTEM B TEST 1



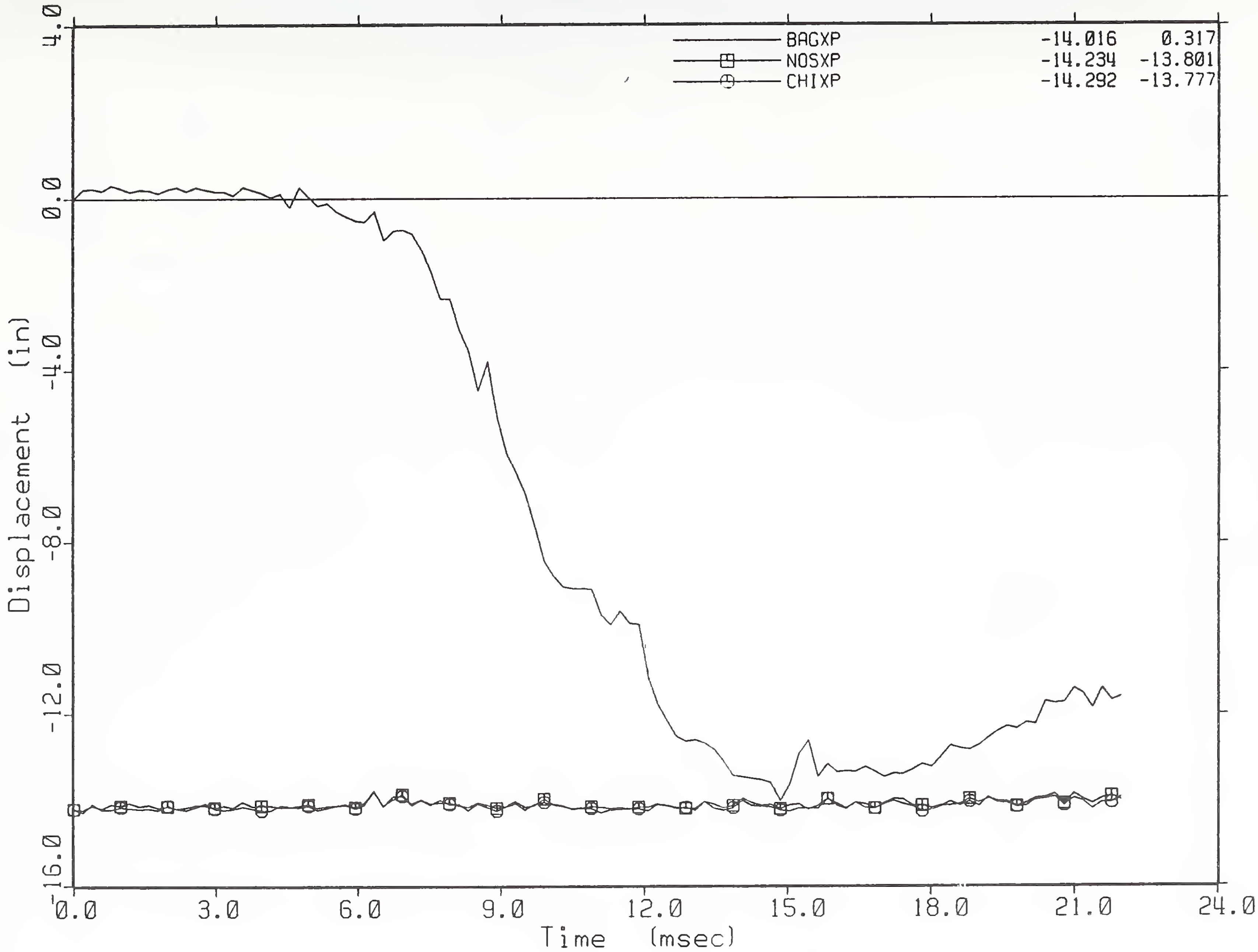
SYSTEM C TEST 1



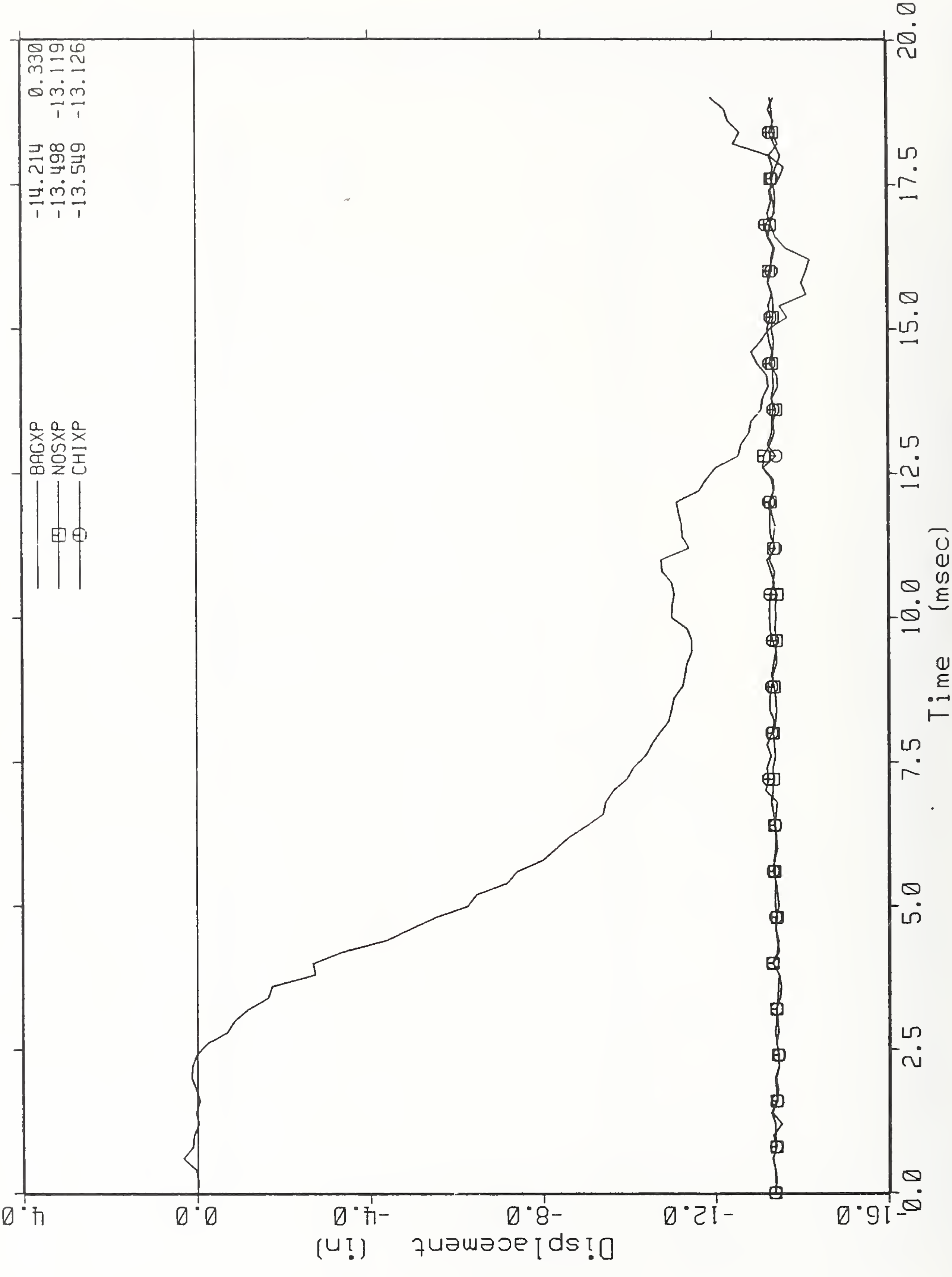
SYSTEM D TEST 1



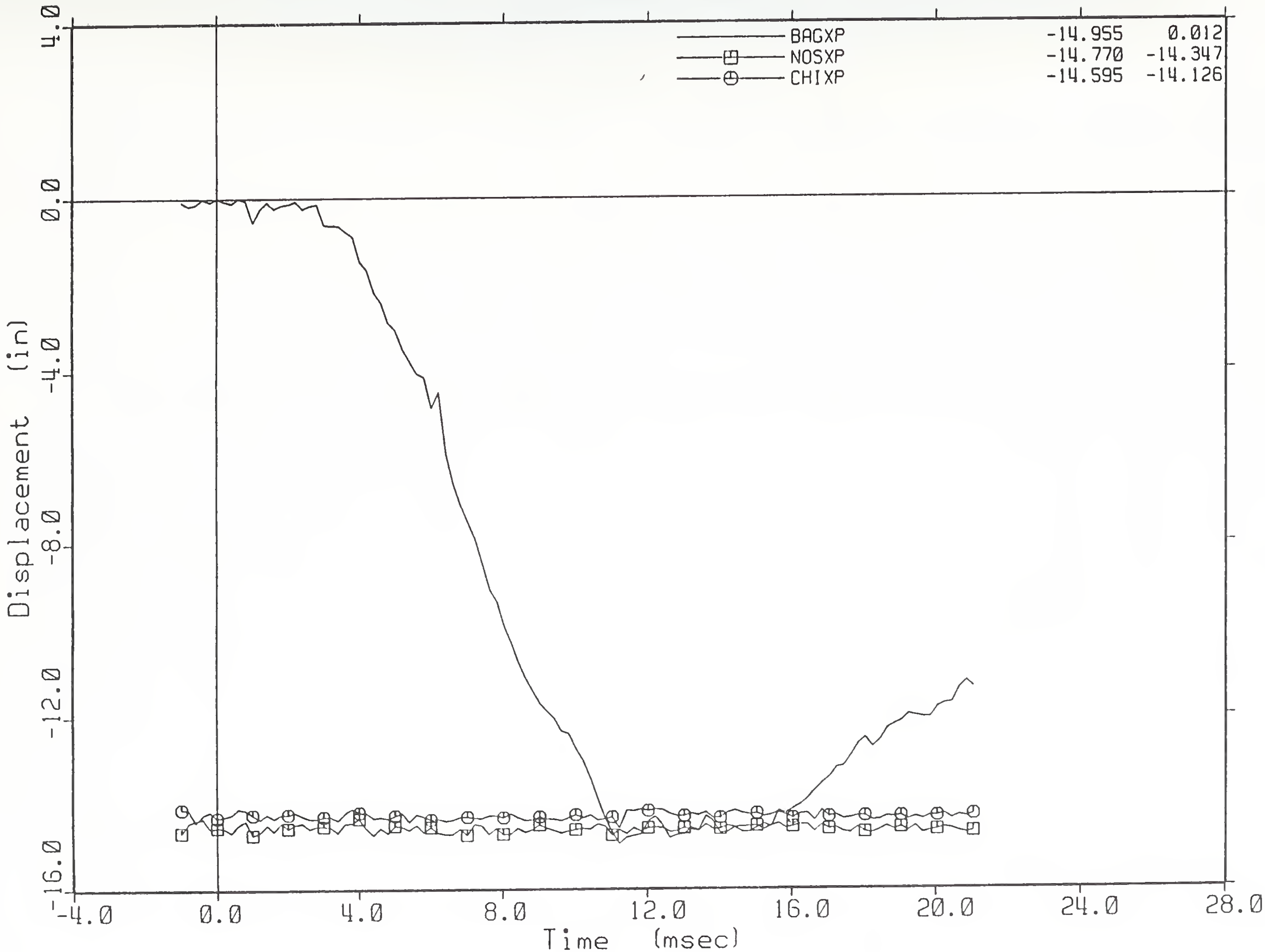
SYSTEM E TEST 1



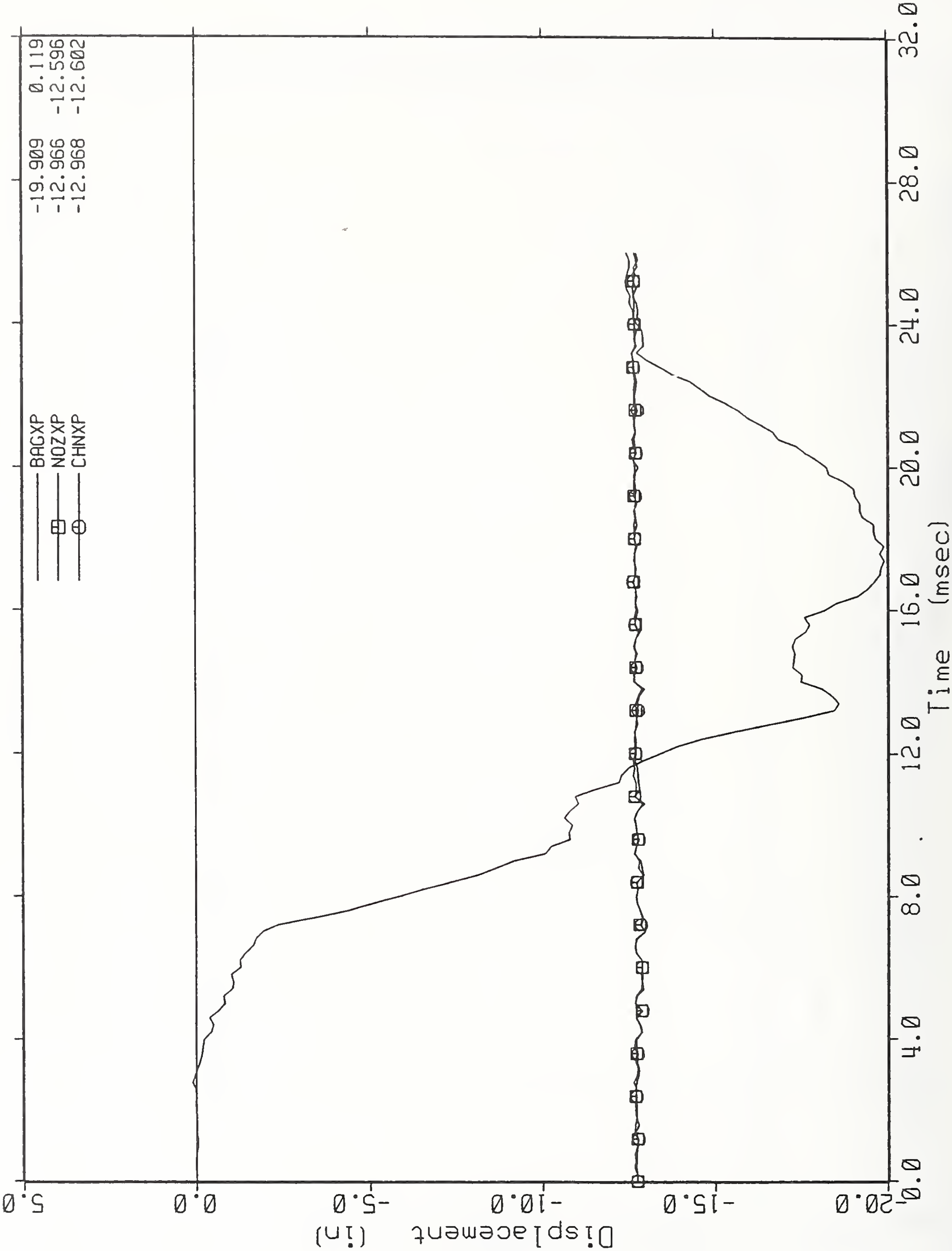
SYSTEM F TEST 1



SYSTEM G TEST 1



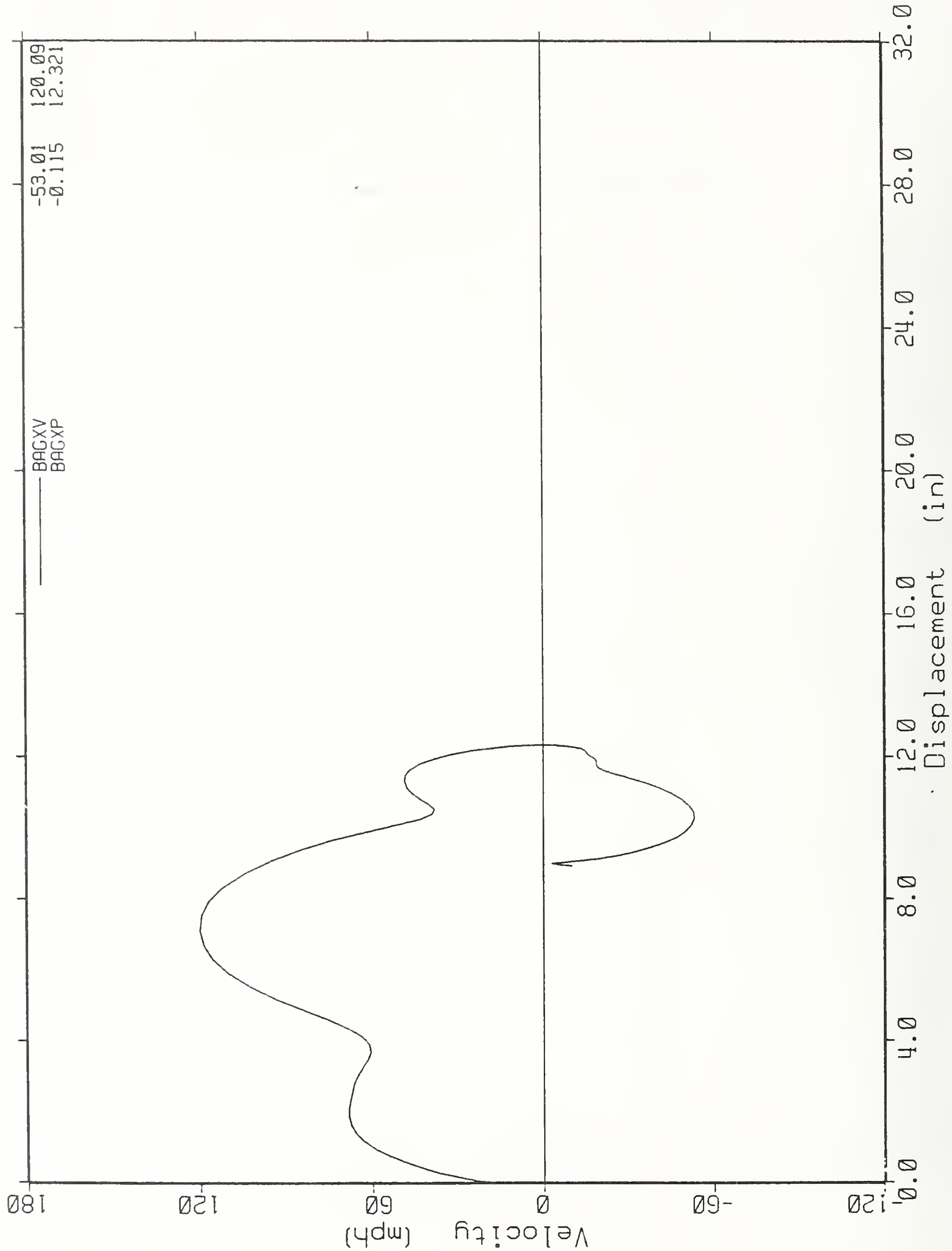
SYSTEM H TEST 1



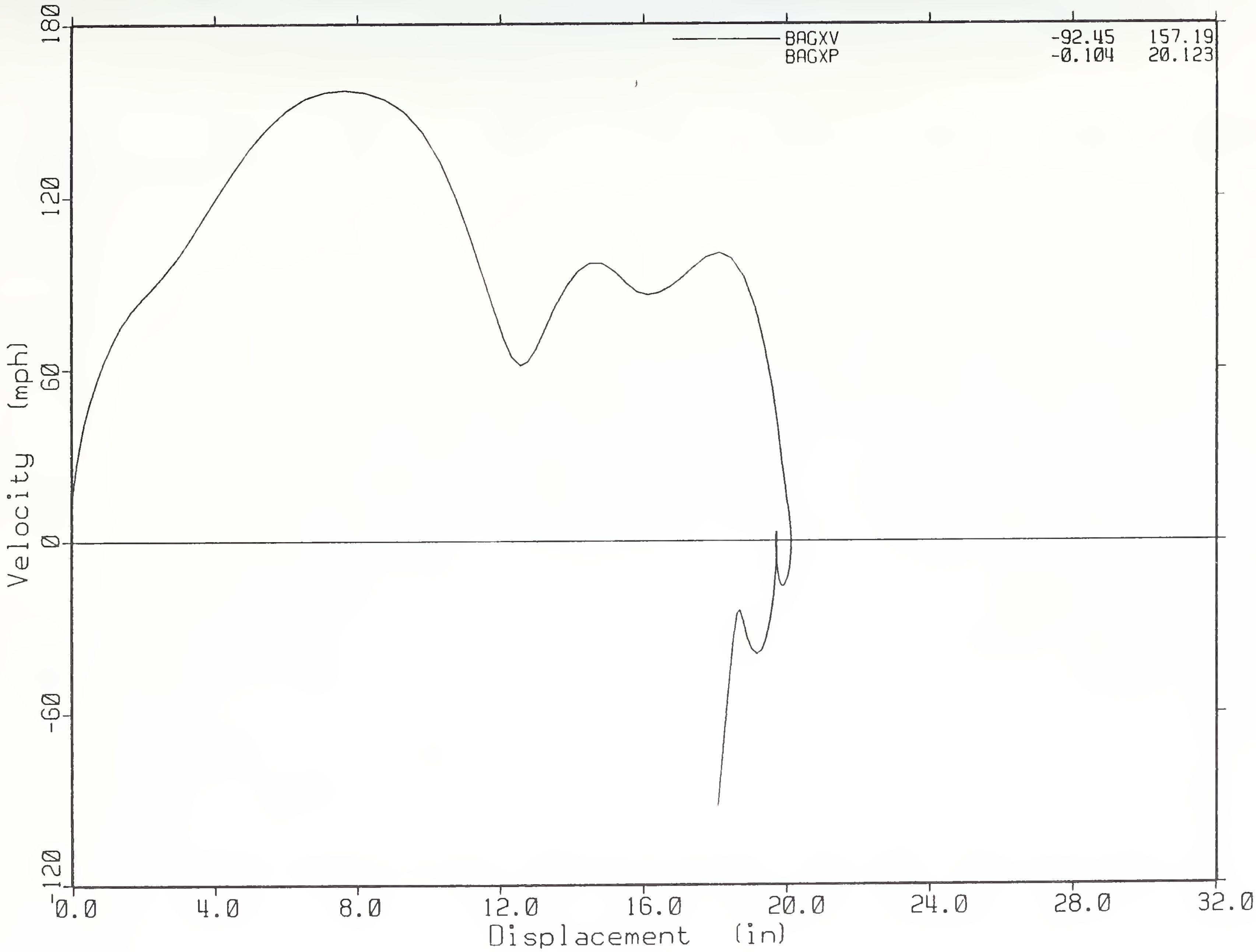
SYSTEM I TEST 1

APPENDIX C

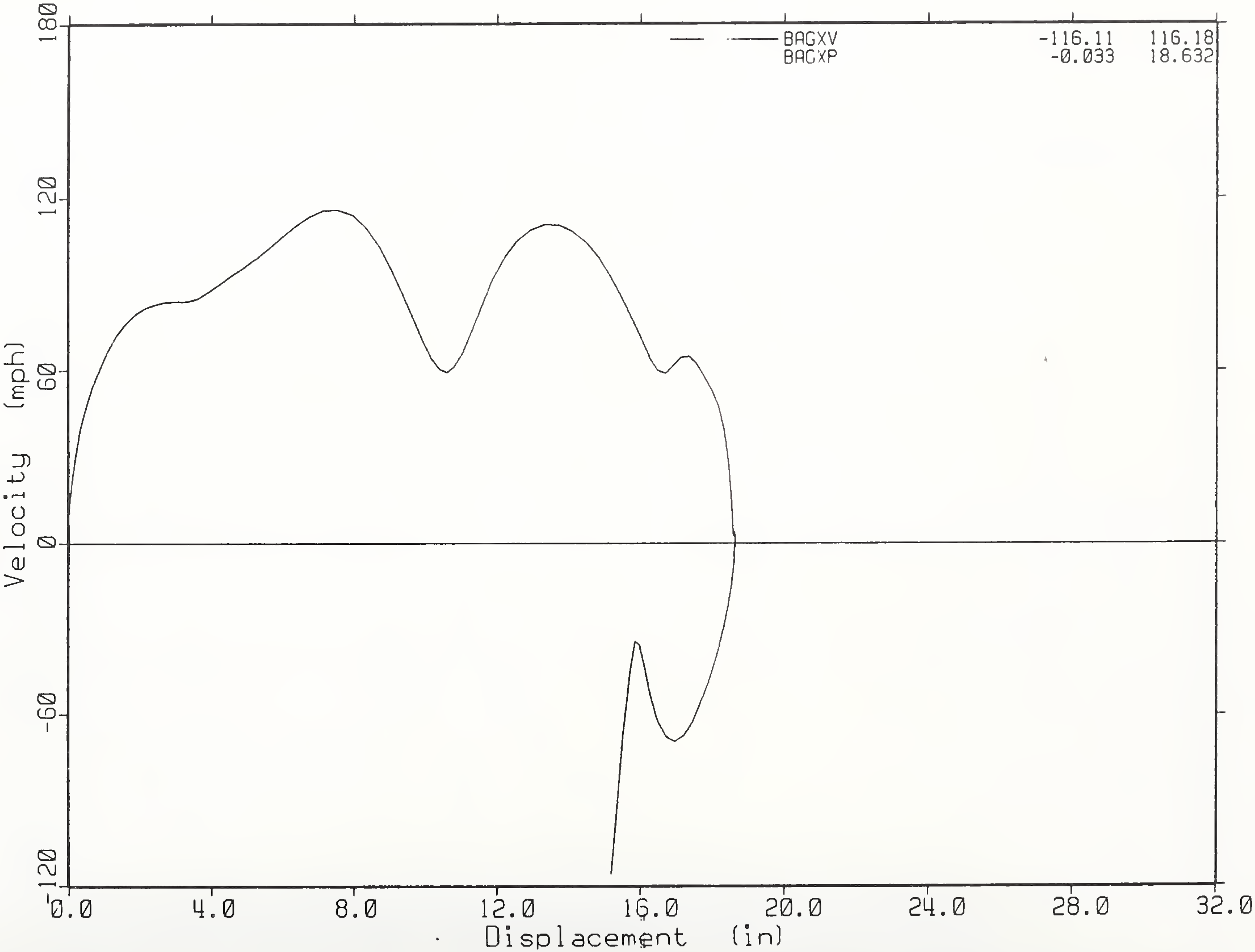
Air Bag Velocity vs. Displacement Curves



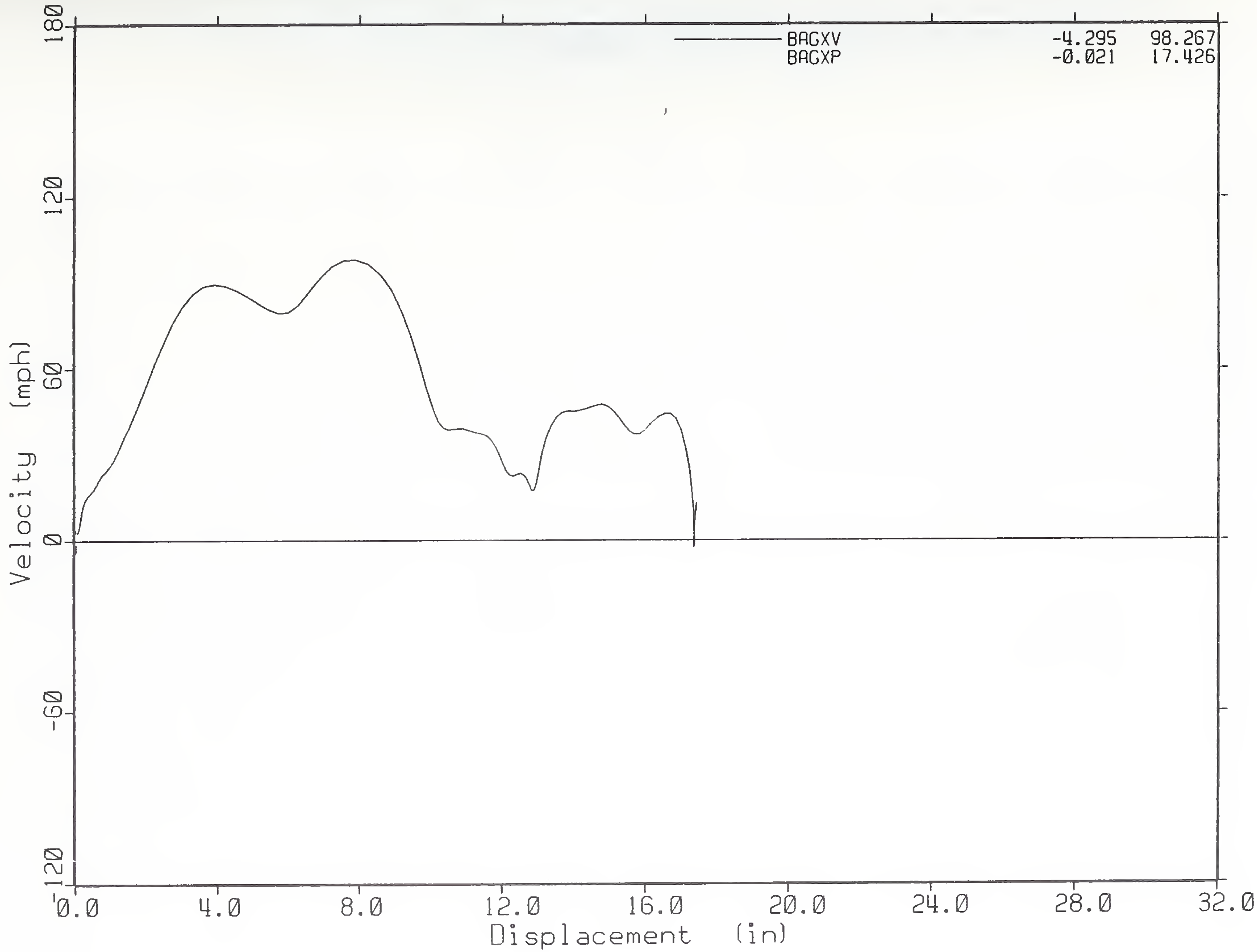
SYSTEM A TEST 1



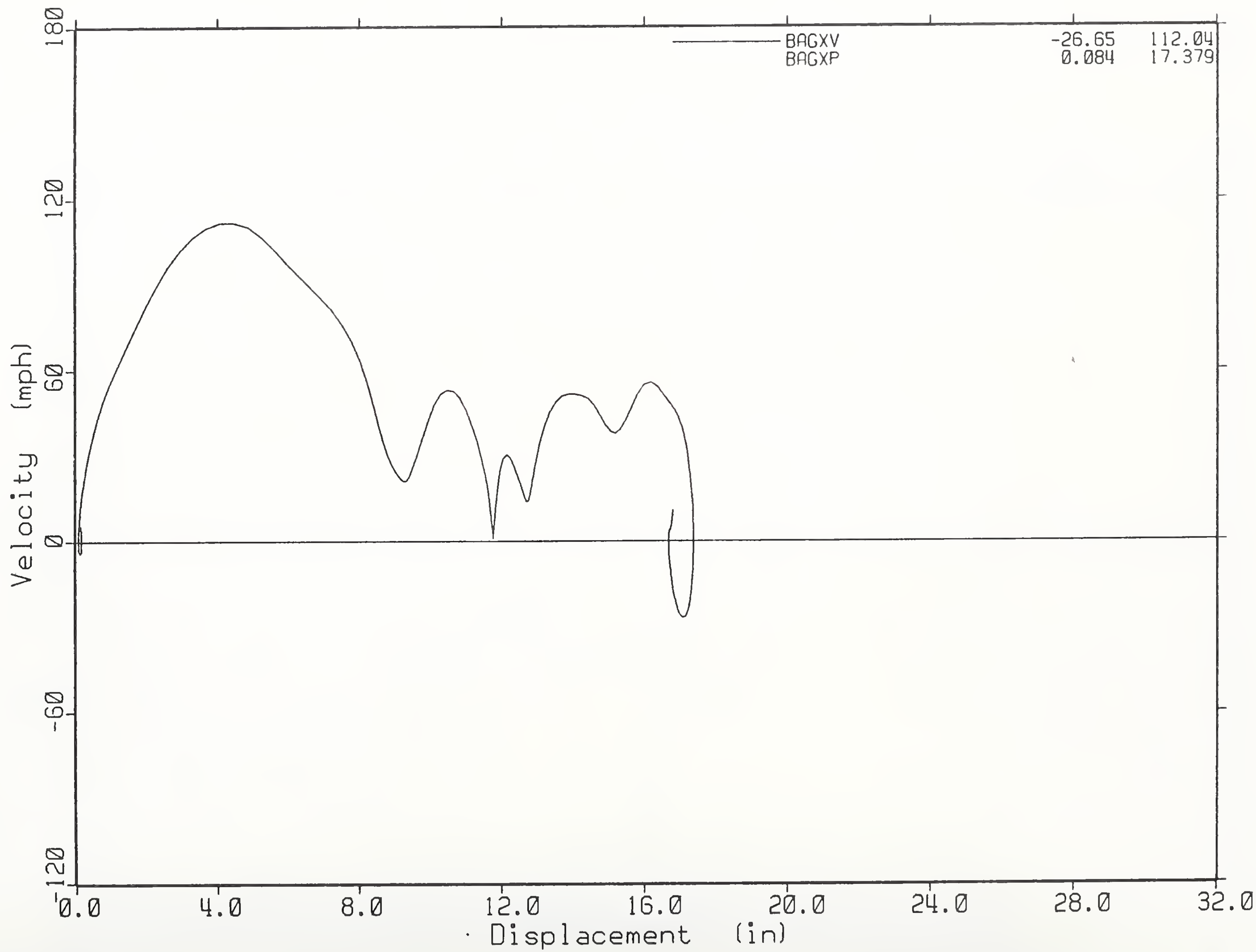
SYSTEM B TEST 1



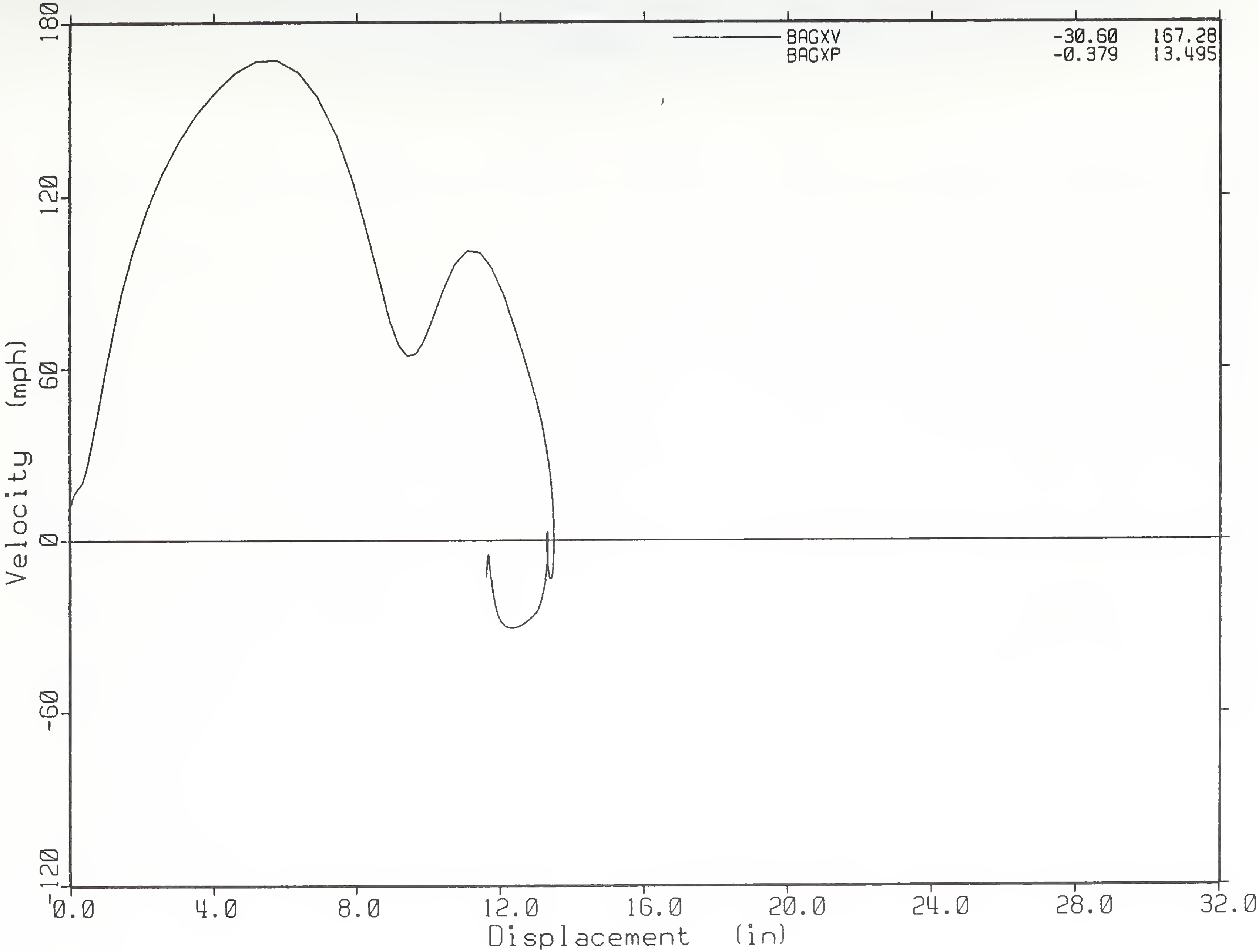
SYSTEM C TEST 1



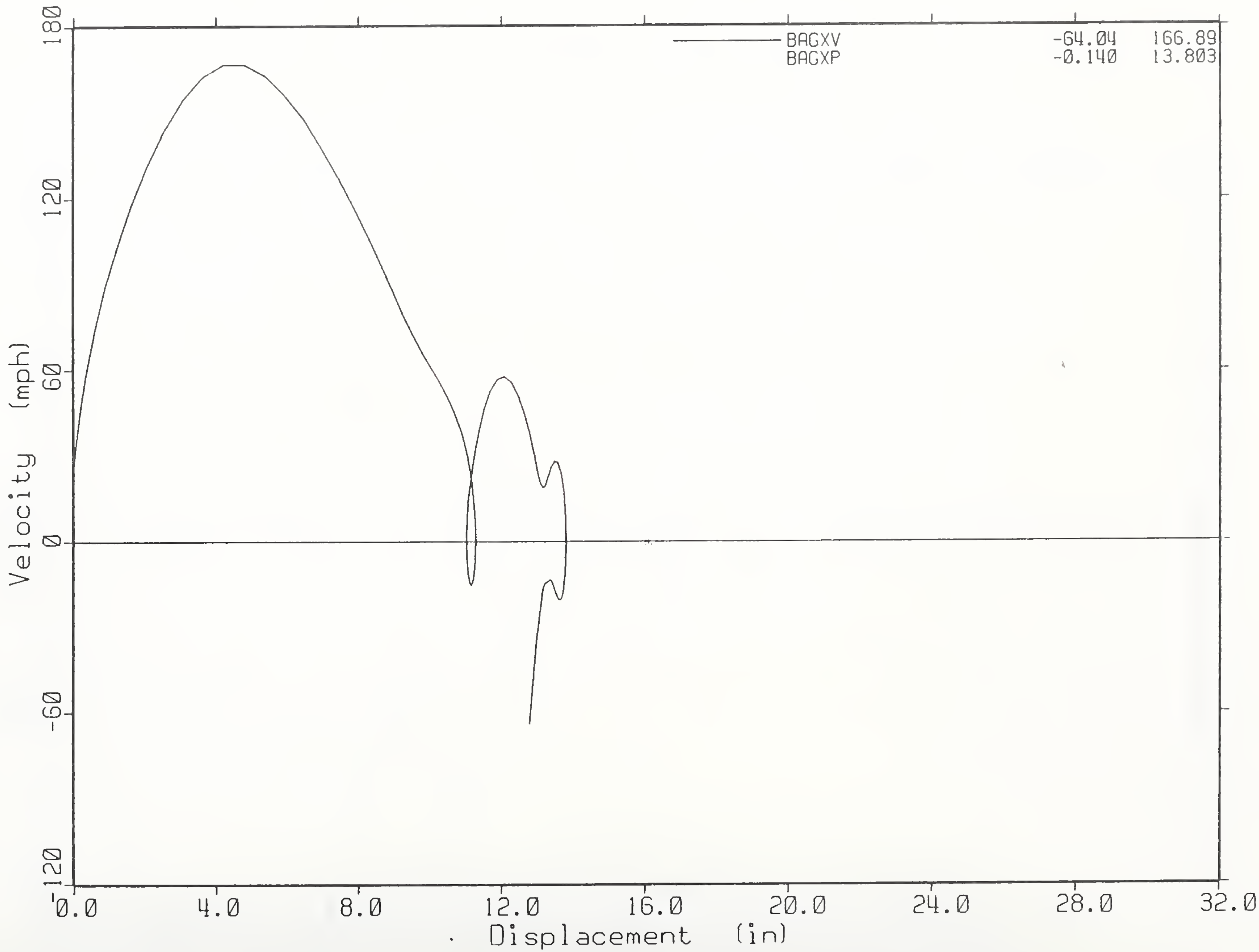
SYSTEM D TEST 1



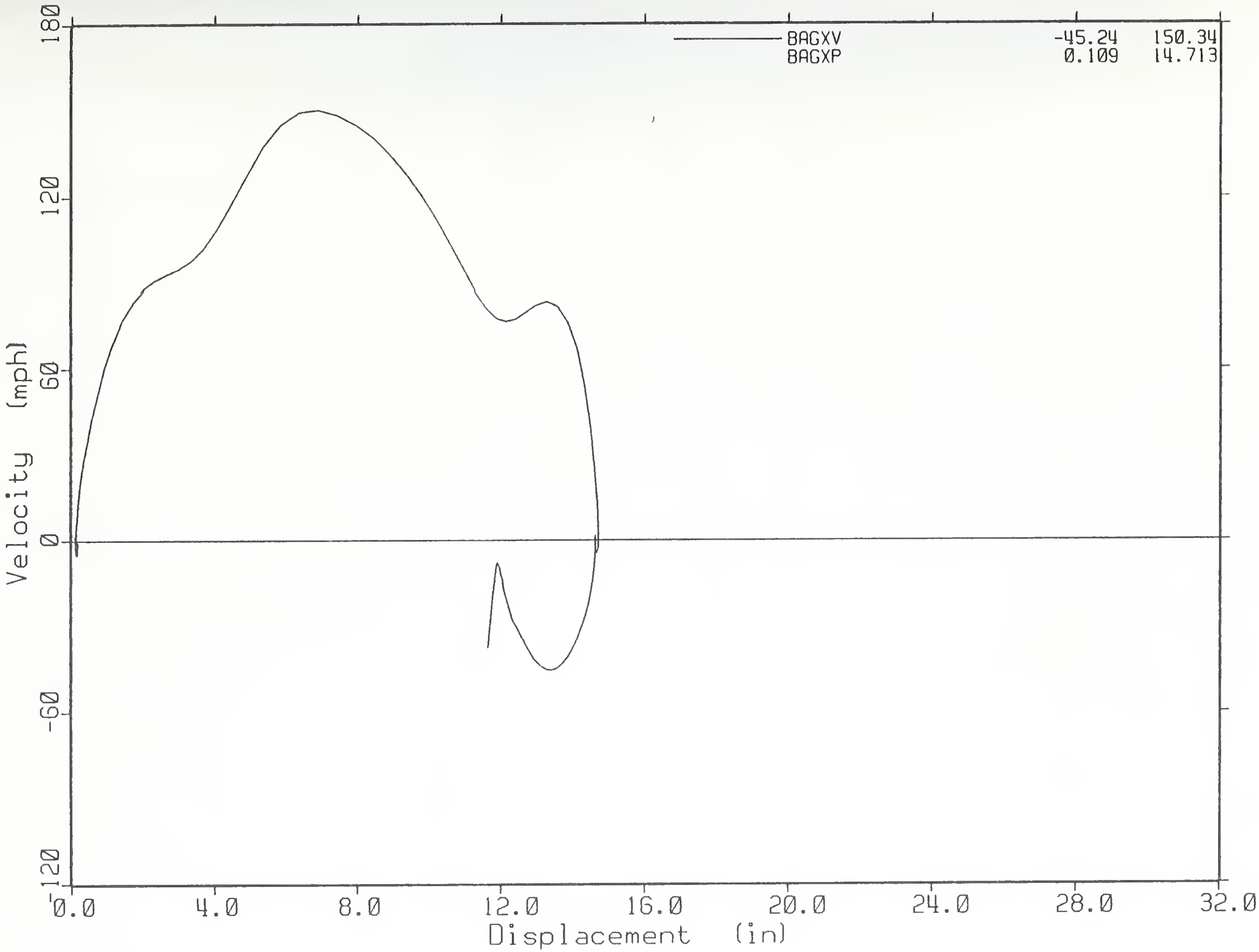
SYSTEM E TEST 1



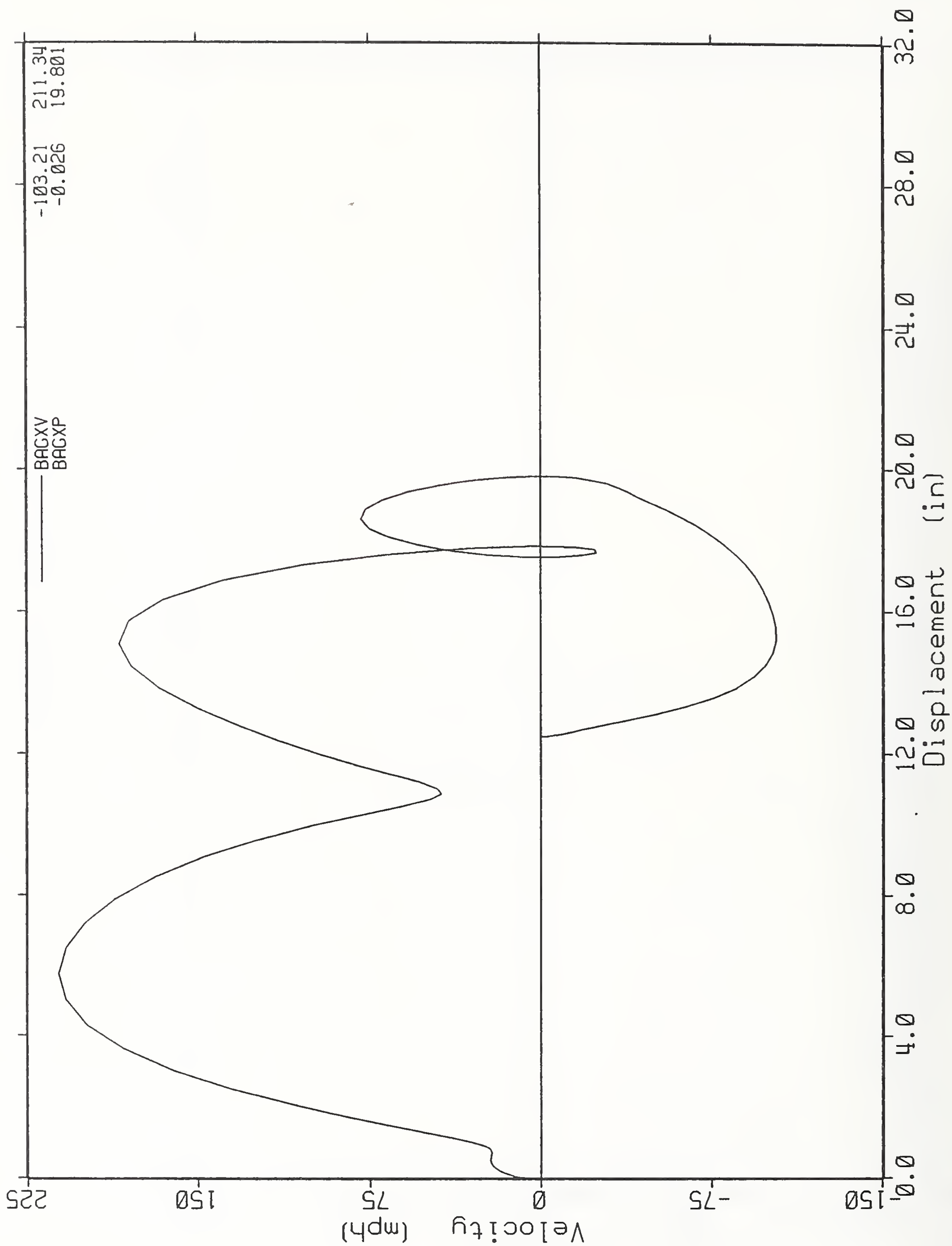
SYSTEM F TEST 1



SYSIEM G TEST 1



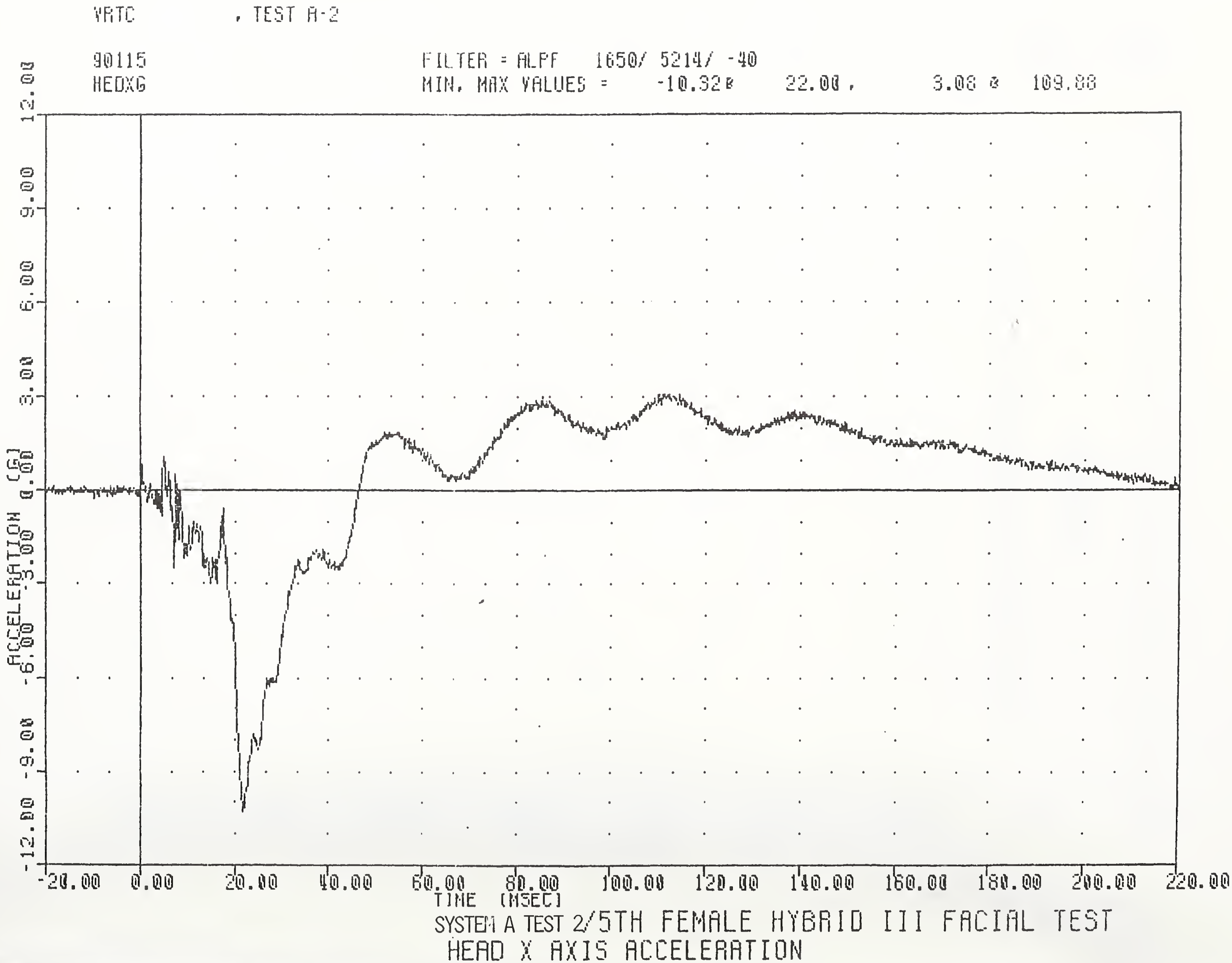
SYSIEM H TEST 1



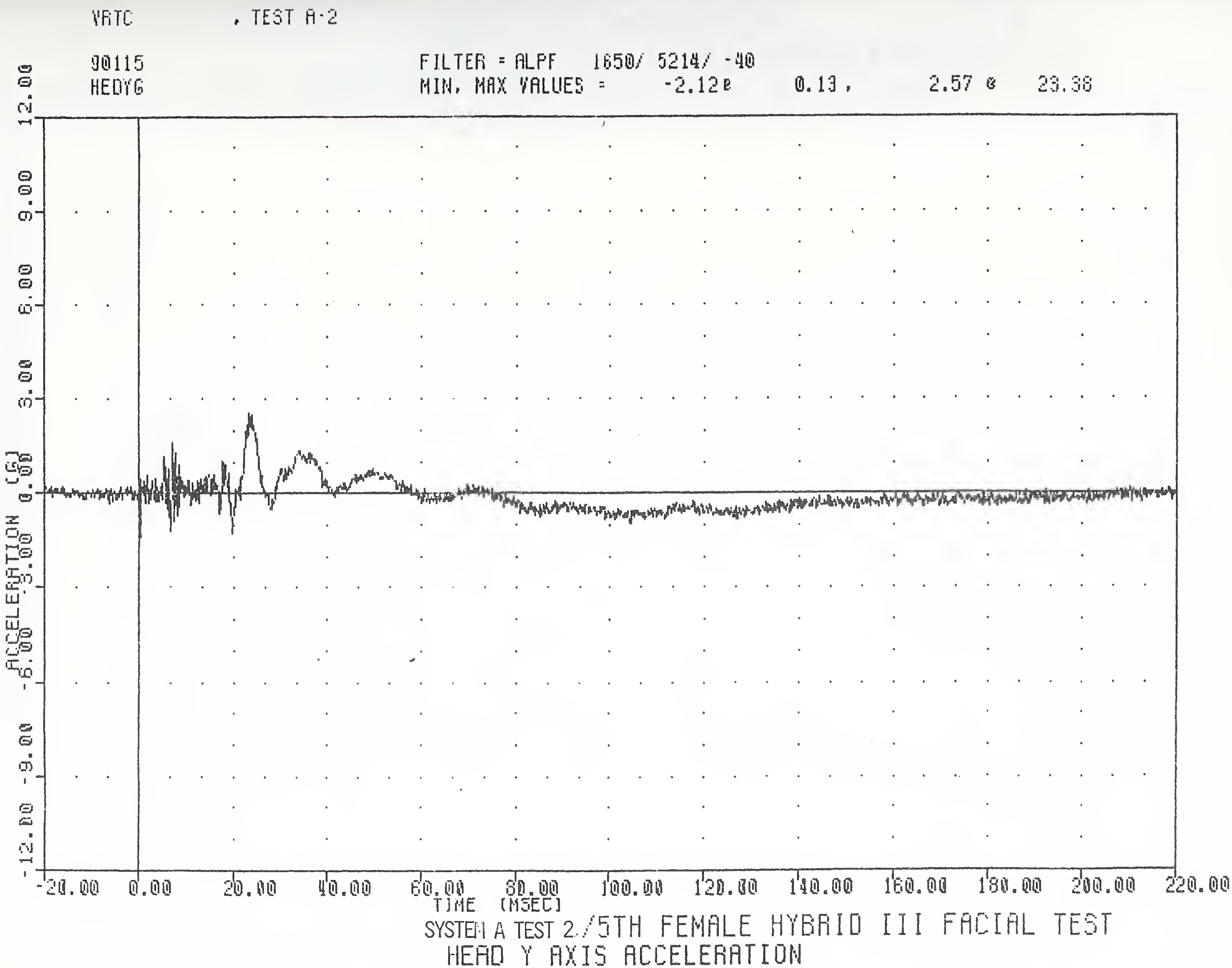
SYSTEM I TEST 1

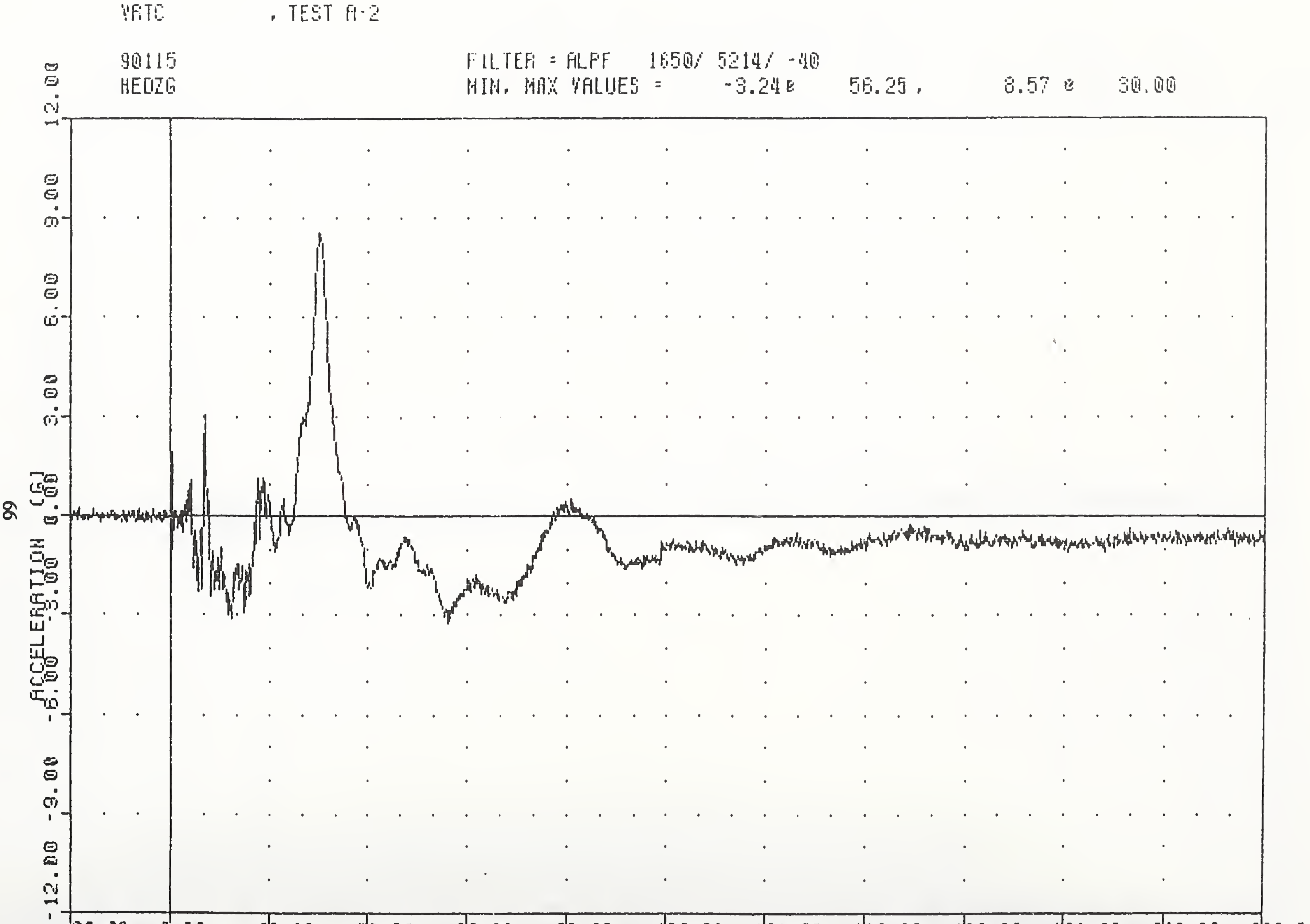
APPENDIX D

5th Percentile Female Dummy Head Acceleration Time Histories



VRTC , TEST A-2
90115
HEDXG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -10.32 @ 22.00 , 3.08 @ 109.88
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
ACCELERATION (G)
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM A TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD X AXIS ACCELERATION

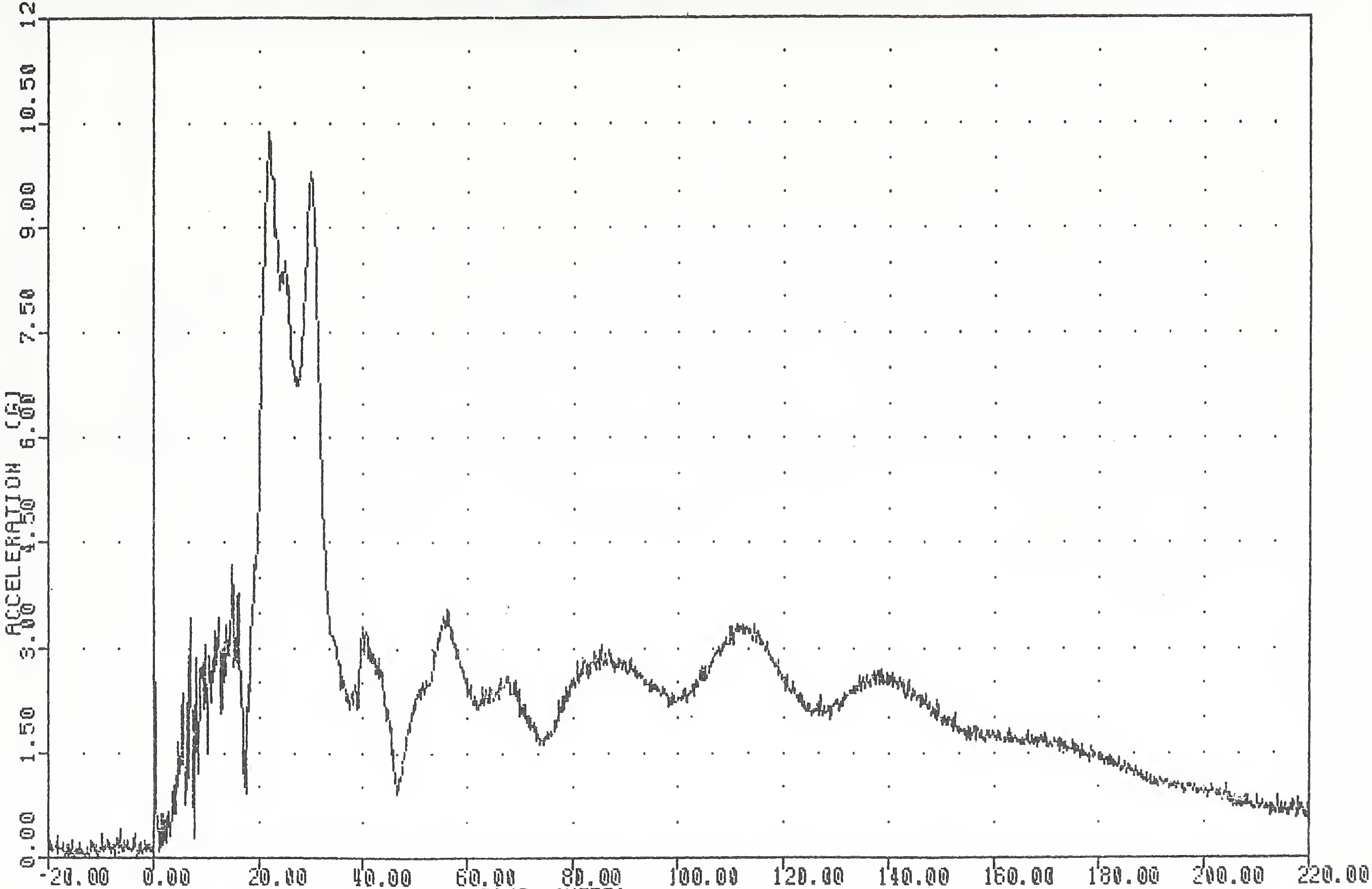

VRTC , TEST A-2
90115
HEDYG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -2.12 @ 0.13 , 2.57 @ 23.38
ACCELERATION (G)
12.00
9.00
6.00
3.00
0.00
-3.00
-6.00
-9.00
-12.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM A TEST 2 /5TH FEMALE HYBRID III FACIAL TEST
HEAD Y AXIS ACCELERATION



SYSTEM A TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD Z AXIS ACCELERATION

YRTC , TEST A-2

90115 FILTER = ALPF 1650/ 5214/ -40
HEDRG MIN, MAX VALUES = 0.03 @ -16.38 , 10.35 @ 22.00

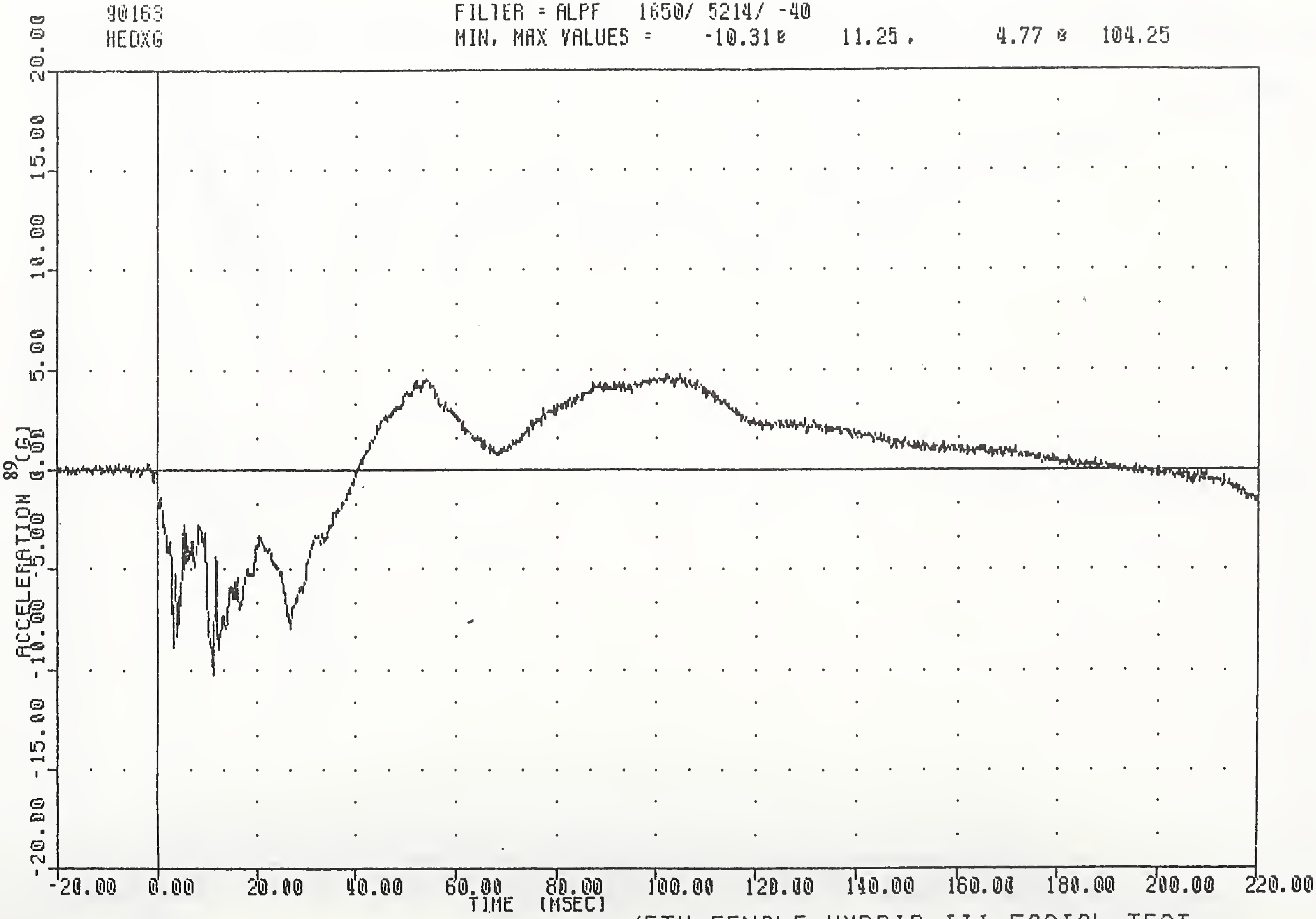


SYSTEM A TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD RESULTANT ACCELERATION

VRTC TEST A-3

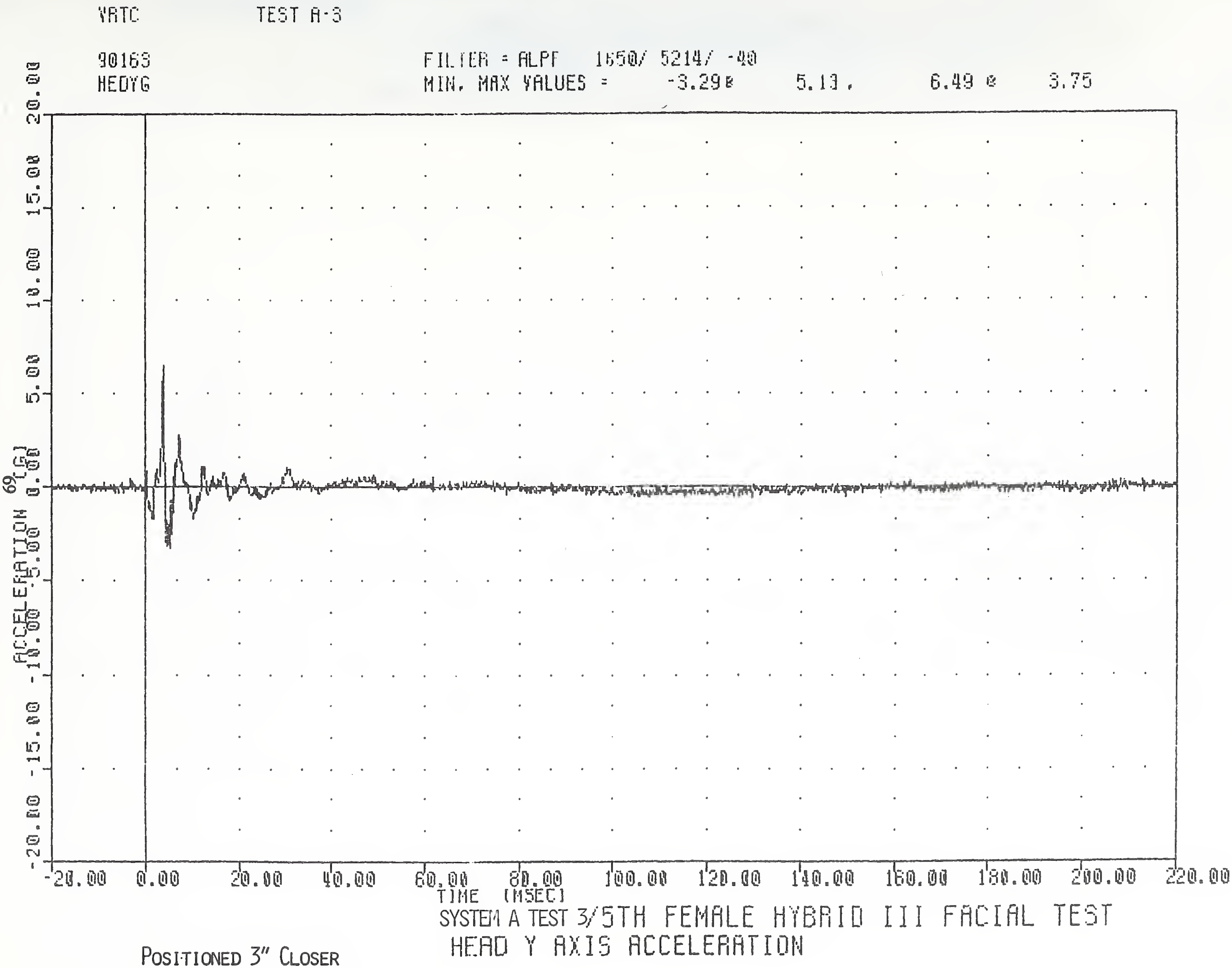
90163
HEDXG

FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -10.31 @ 11.25 , 4.77 @ 104.25



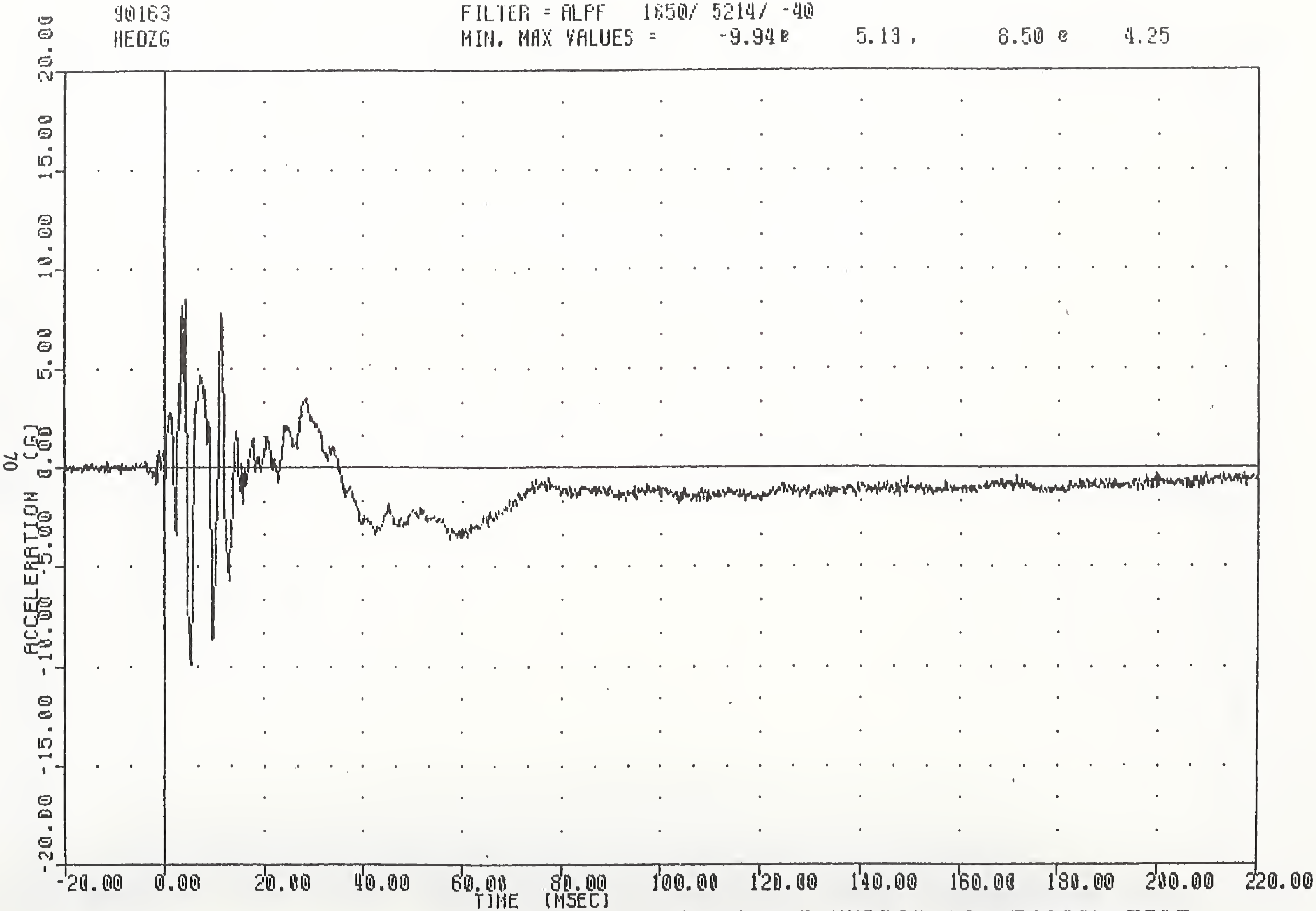
SYSTEM A TEST 3/5TH FEMALE HYBRID III FACIAL TEST
HEAD X AXIS ACCELERATION

POSITIONED 3" CLOSER


VRTC
TEST A-3
90163
HEDYG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -3.29 @ 5.13 , 6.49 @ 3.75
ACCELERATION (G)
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM A TEST 3/5TH FEMALE HYBRID III FACIAL TEST
HEAD Y AXIS ACCELERATION
POSITIONED 3" CLOSER

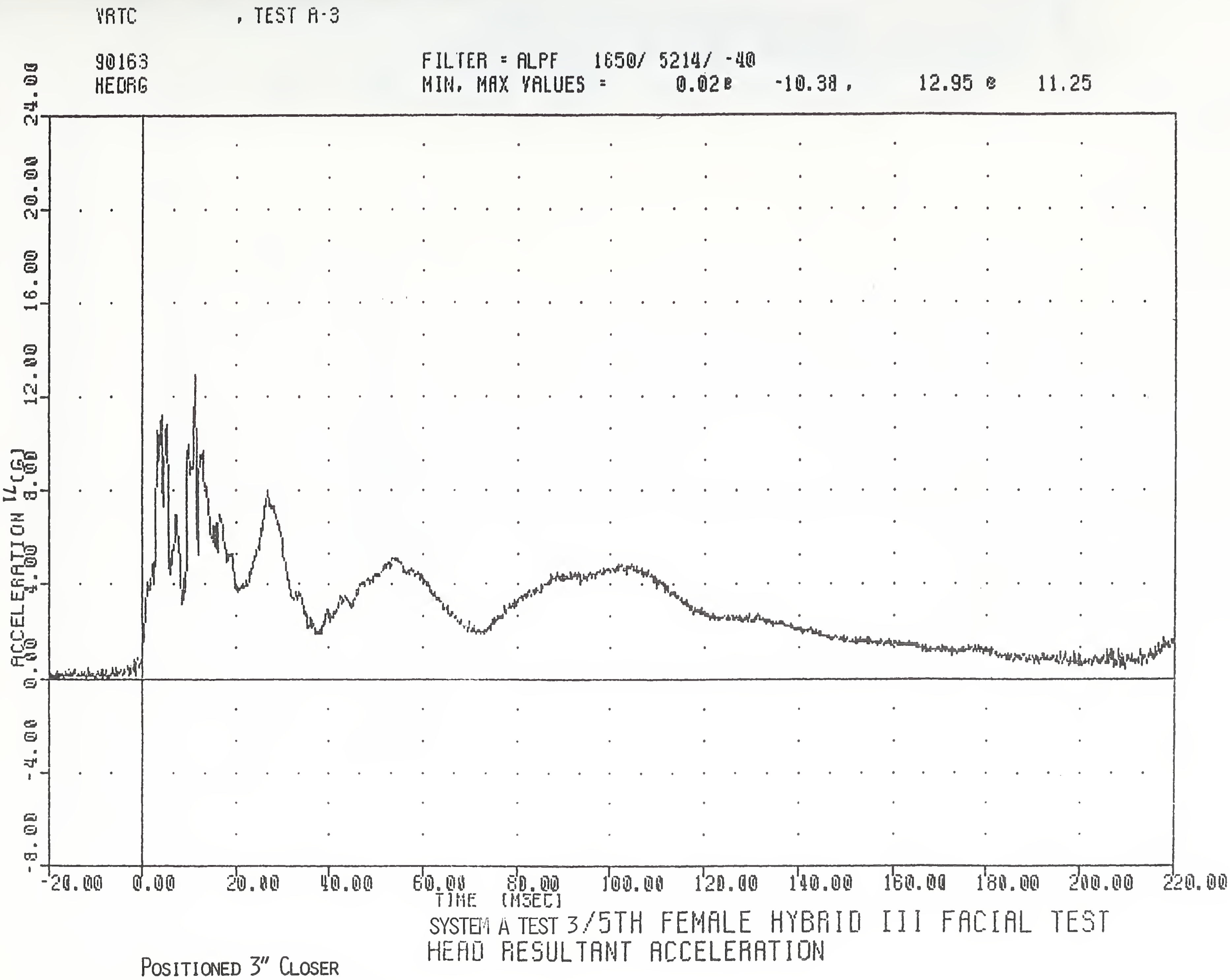
VRTC , TEST A-3

90163 FILTER = ALPF 1650/ 5214/ -40
HEDZG MIN, MAX VALUES = -9.94 @ 5.13 , 8.50 @ 4.25

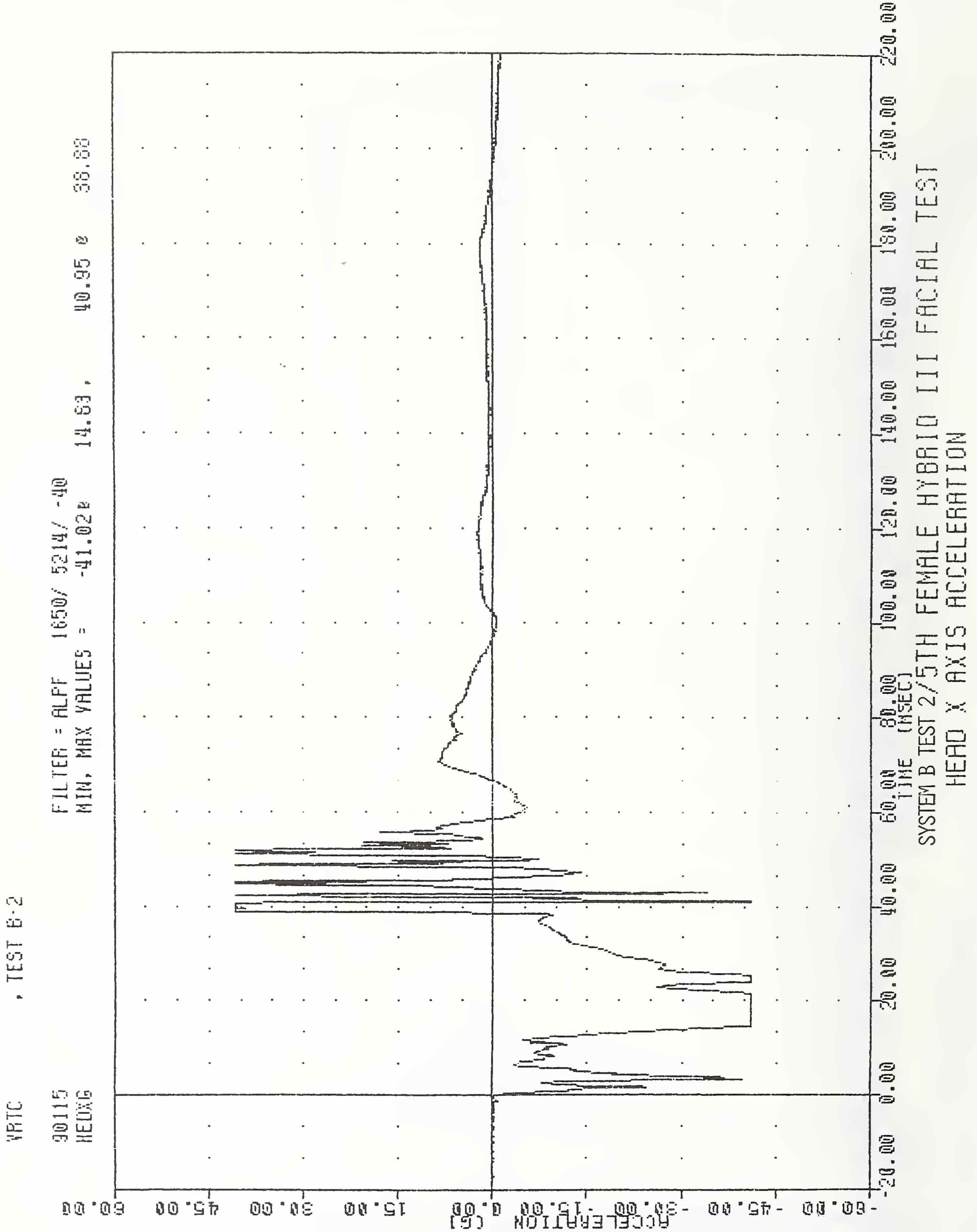


SYSTEM A TEST 3/5TH FEMALE HYBRID III FACIAL TEST
HEAD Z AXIS ACCELERATION

POSITIONED 3" CLOSER

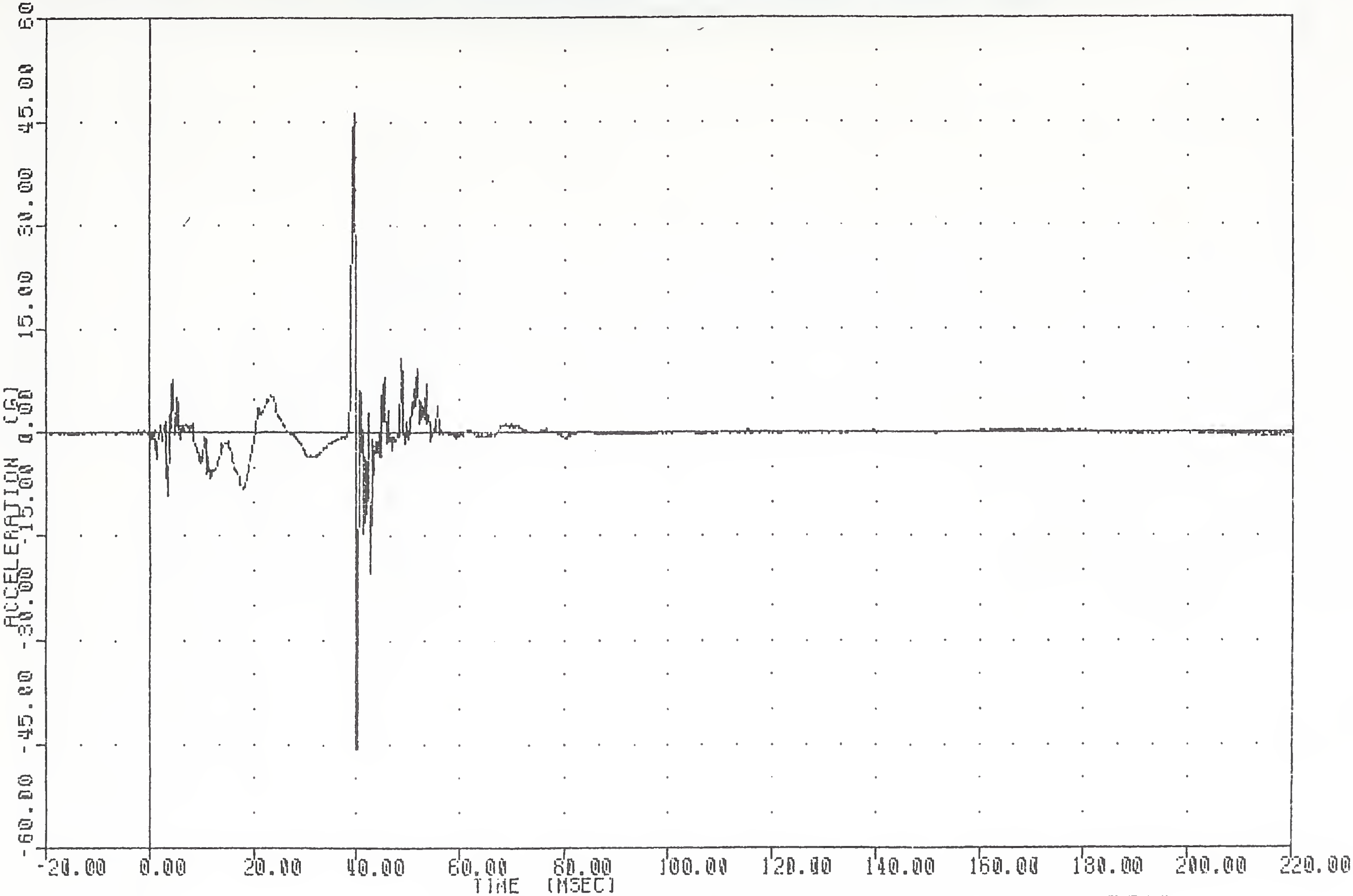


VRTC , TEST A-3
90163
HEDRG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = 0.02 @ -10.38 , 12.95 @ 11.25
24.00
20.00
16.00
12.00
8.00
4.00
0.00
-4.00
-8.00
ACCELERATION (G)
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM A TEST 3/5TH FEMALE HYBRID III FACIAL TEST
HEAD RESULTANT ACCELERATION
POSITIONED 3" CLOSER


VRTC , TEST B-2
90115
HEDXG
FILTER = ALFF 1650/ 5214/ -40
MIN, MAX VALUES = -41.02 @ 14.63 , 40.95 @ 38.88
SYSTEM B TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD X AXIS ACCELERATION
TIME (MSEC)
ACCELERATION (G)
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
60.00
45.00
30.00
15.00
0.00
-15.00
-30.00
-45.00
-60.00

VRTC , TEST B-2

90115 FILTER = ALPF 1650/ 5214/ -40
HEDYG MIN, MAX VALUES = -45.77 @ 40.00 , 46.21 @ 39.38

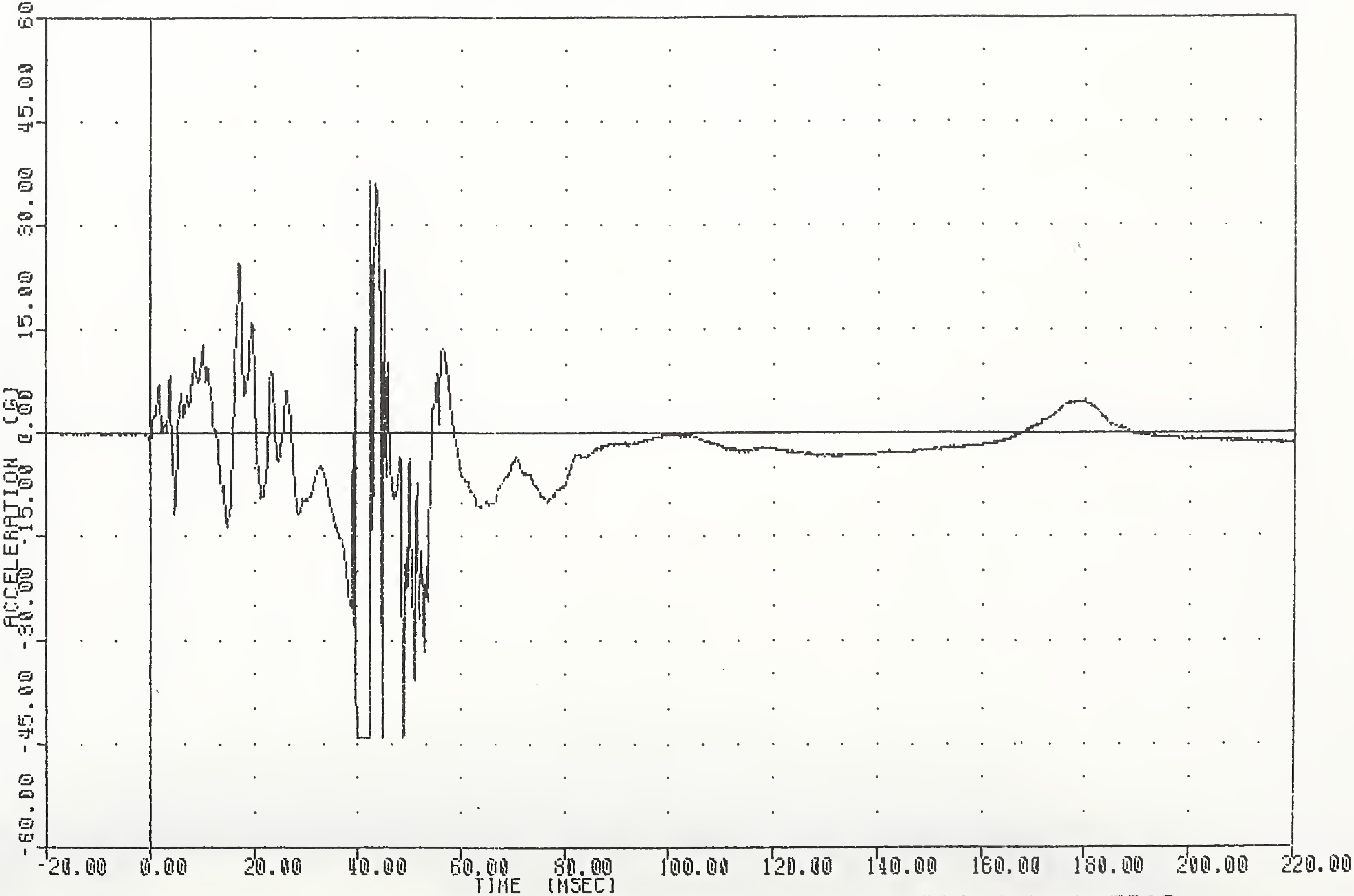


SYSTEM B TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD Y AXIS ACCELERATION

VRTC TEST B-2

90115
HEDZG

FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -44.24 @ 39.75 , 36.50 @ 42.50

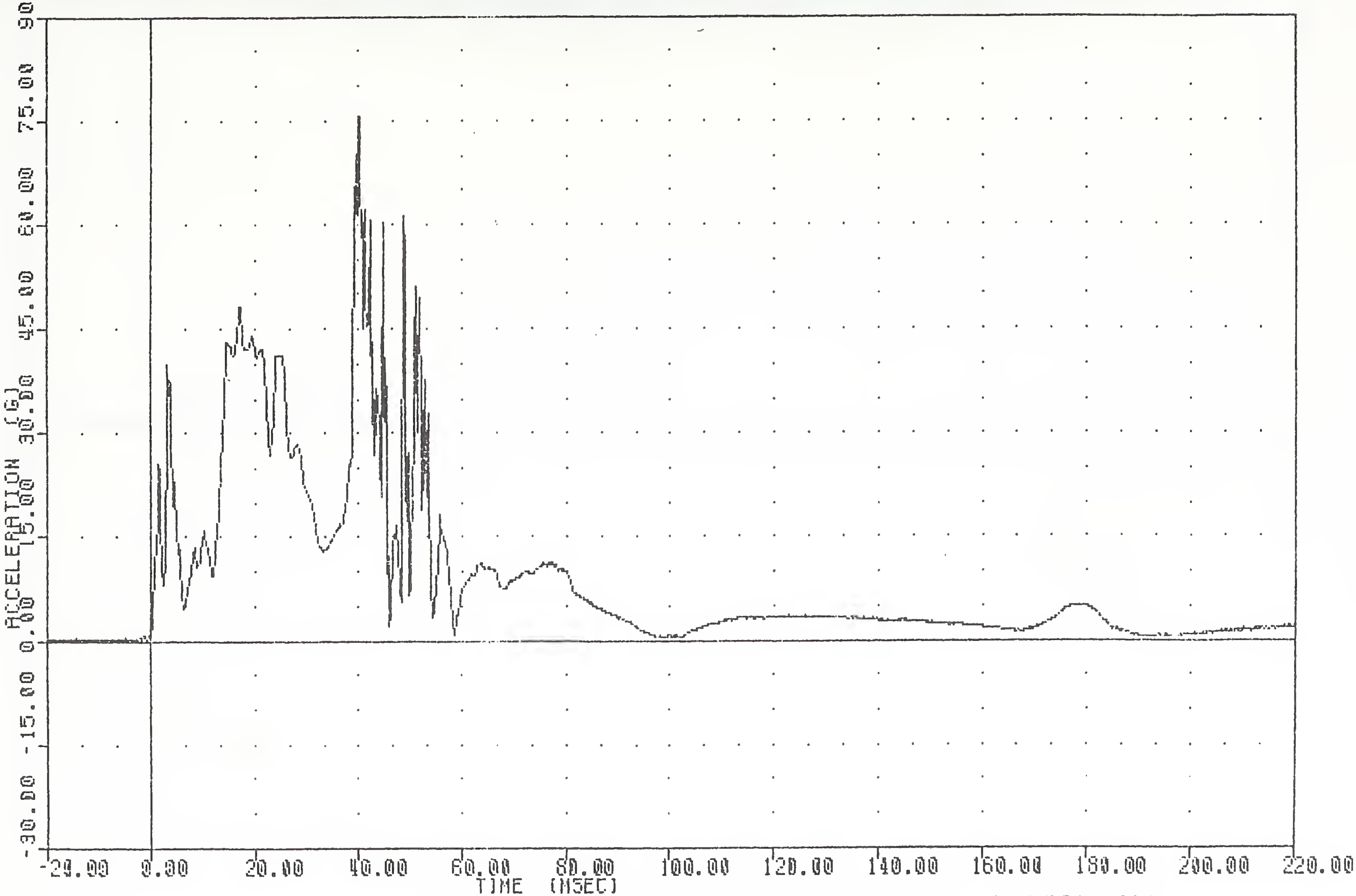


SYSTEM B TEST 2 /5TH FEMALE HYBRID III FACIAL TEST
HEAD Z AXIS ACCELERATION

VRTC , TEST B-2

90115
HEDRG

FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = 0.02 @ -7.88 , 75.69 @ 40.00

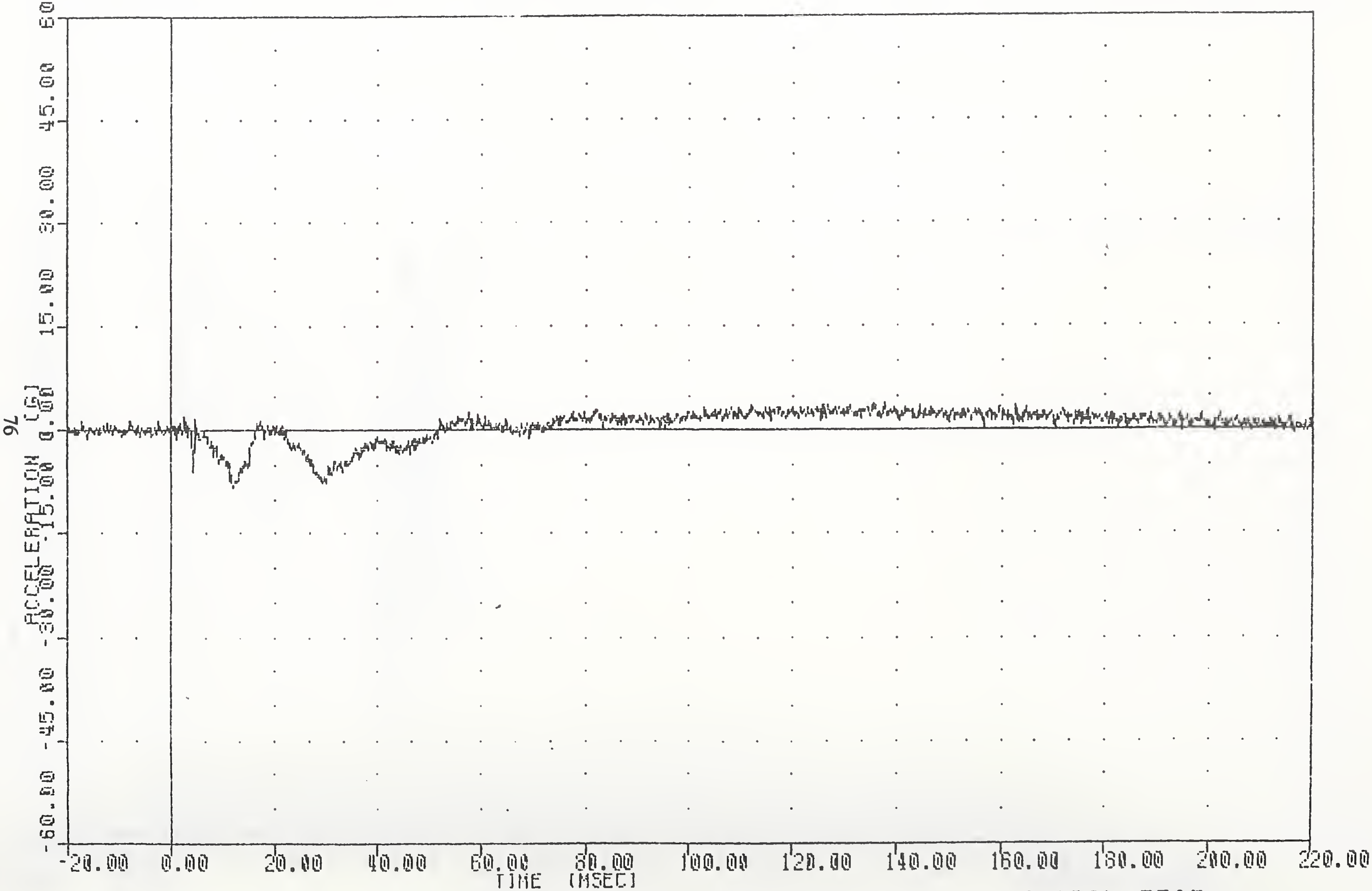


SYSTEM B TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD RESULTANT ACCELERATION

VRTC , TEST D-5

90107
HEDXG

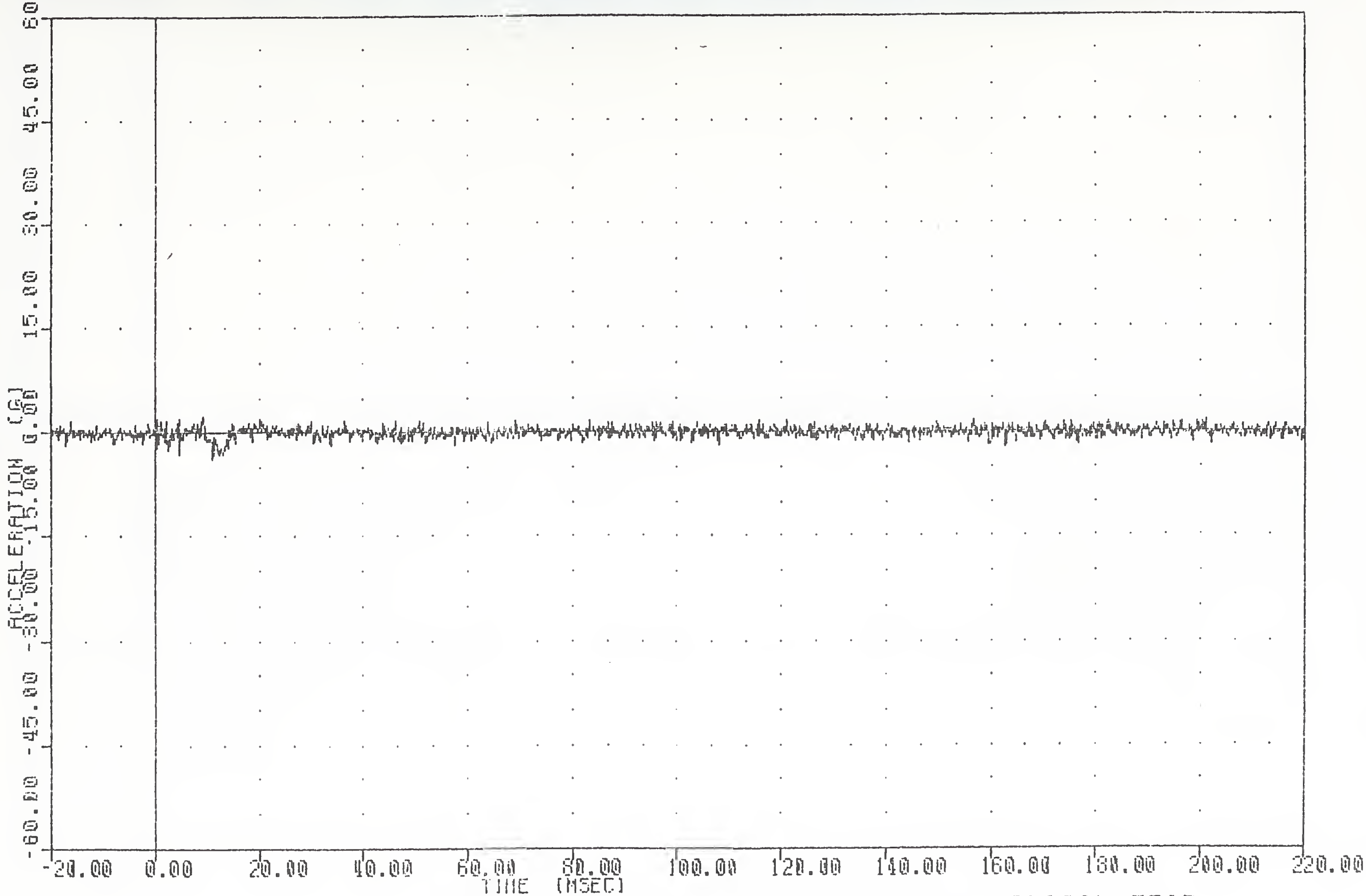
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -8.29 @ 11.88 , 4.05 @ 135.63



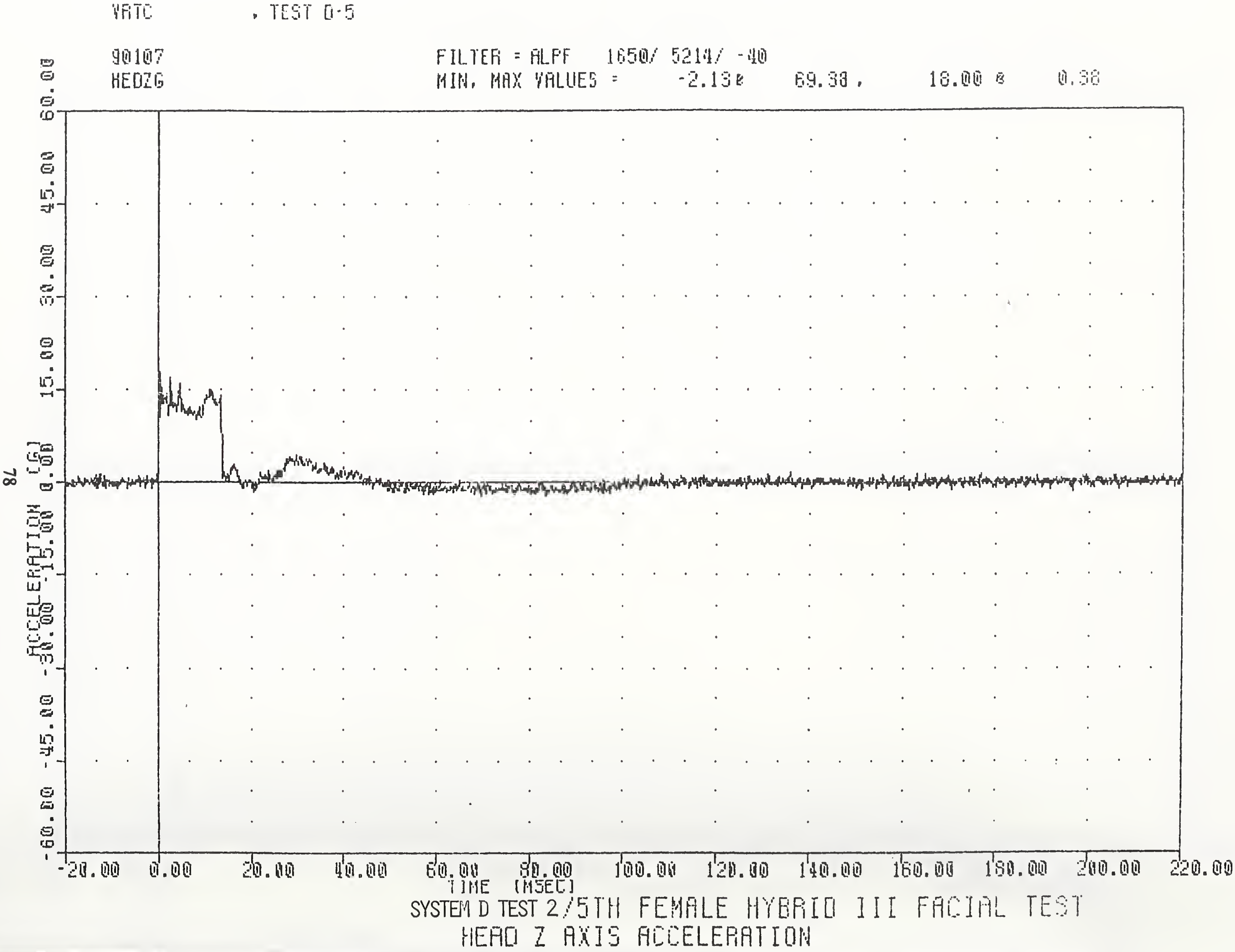
SYSTEM D TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD X AXIS ACCELERATION

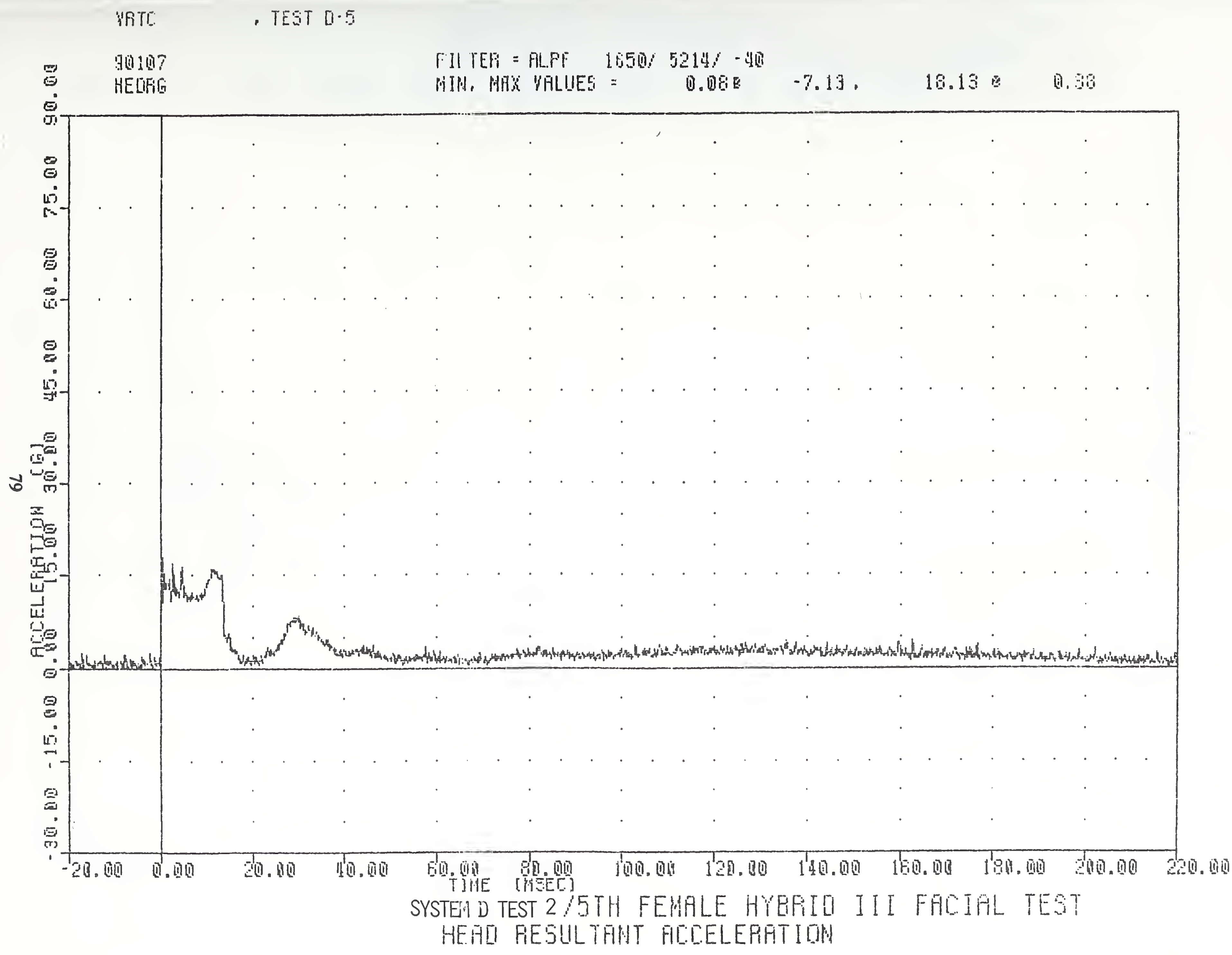
VRTC , TEST D-5

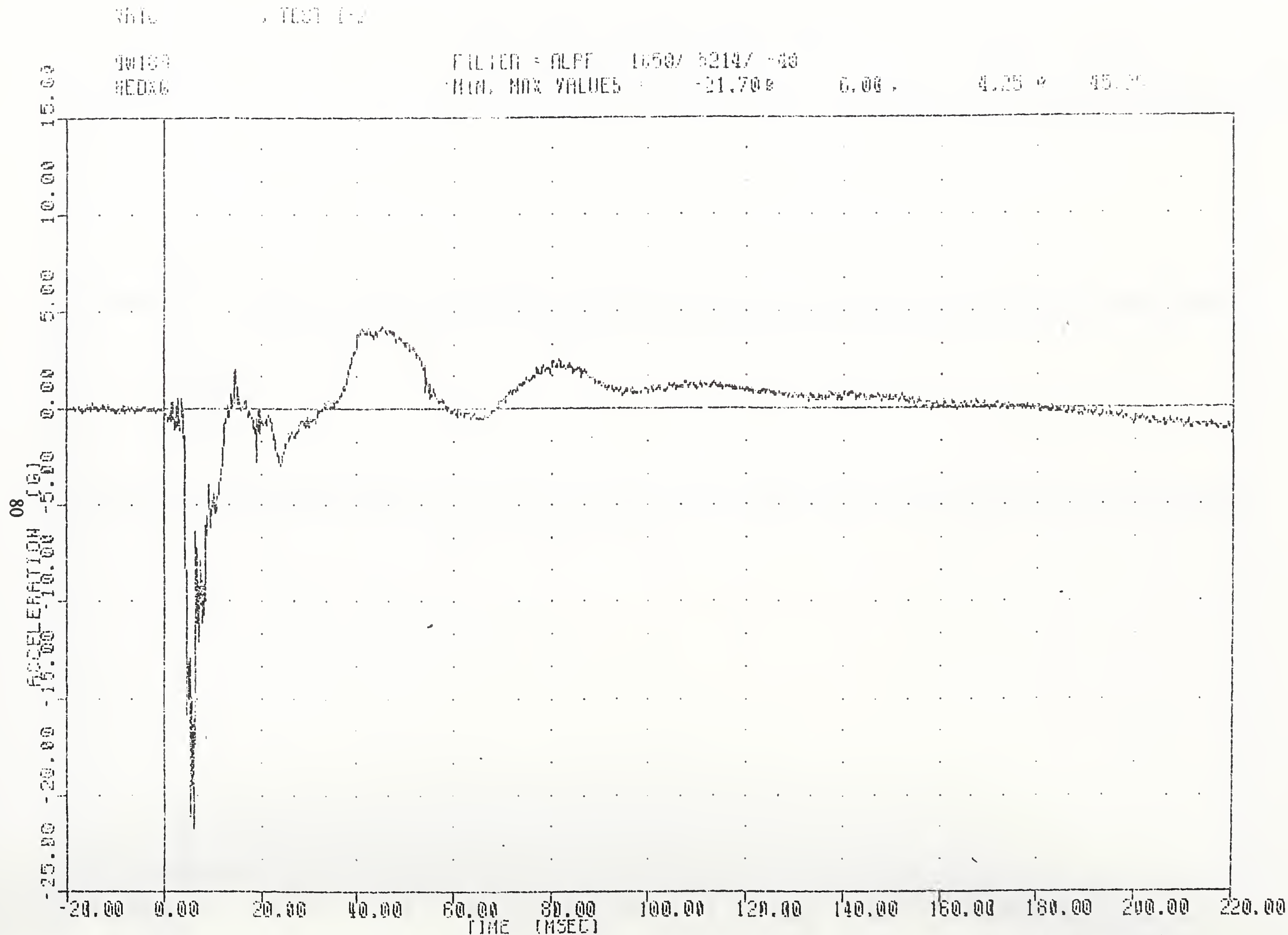
90107 FILTER = ALPF 1650/ 5214/ -40
HEDYG MIN, MAX VALUES = -3.86 @ 11.00 , 3.00 @ 0.00



SYSTEM D TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD Y AXIS ACCELERATION


VRTC , TEST D-5
90107
HEDZG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -2.13 @ 69.38 , 18.00 @ 0.38
60.00
45.00
30.00
15.00
0.00
-15.00
-30.00
-45.00
-60.00
ACCELERATION (G)
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM D TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD Z AXIS ACCELERATION

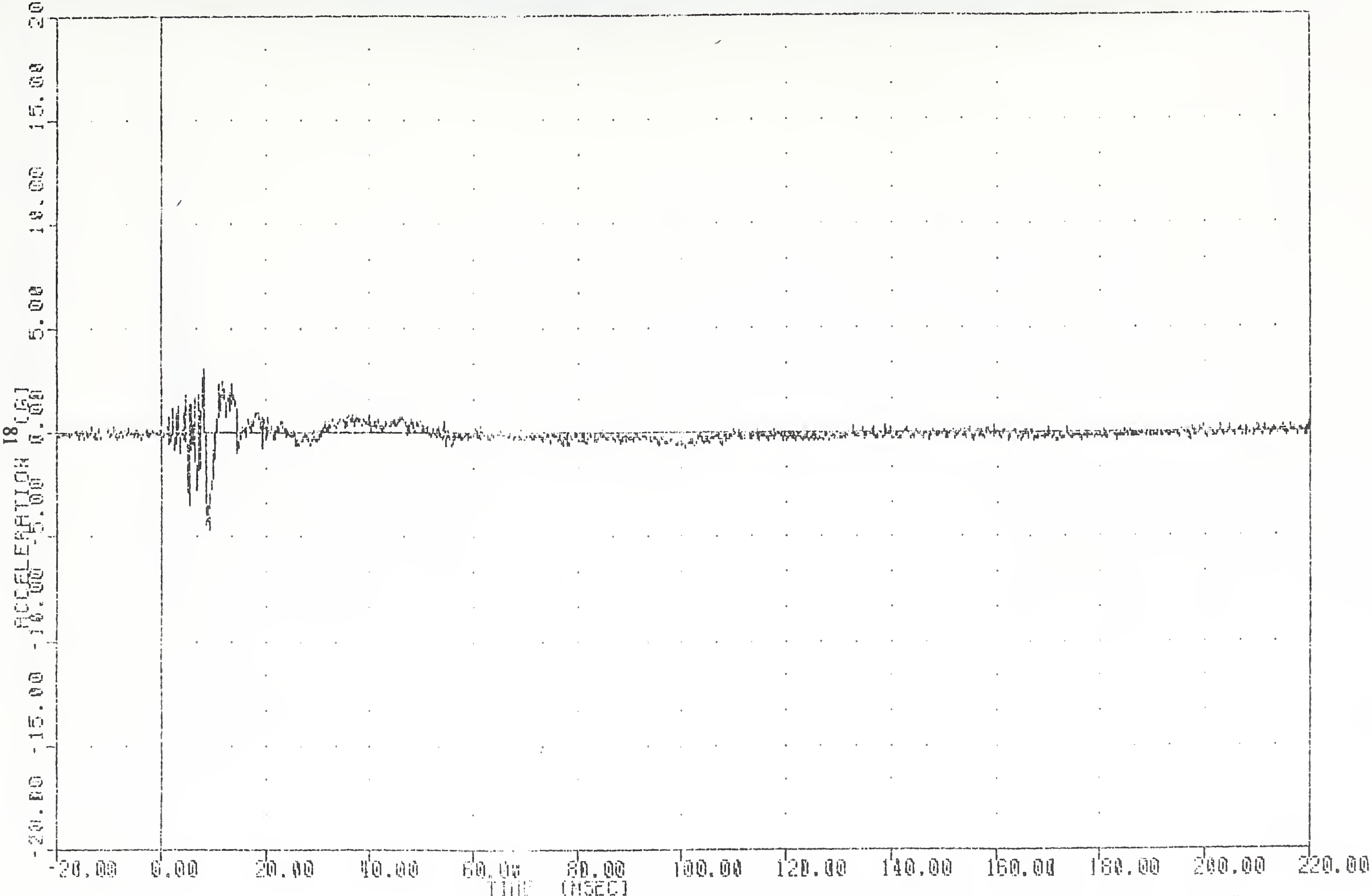

VRTC , TEST D-5
90107
HEDRG
FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = 0.08 @ -7.13 , 18.13 @ 0.38
ACCELERATION (G)
90.00
75.00
60.00
45.00
30.00
15.00
0.00
-15.00
-30.00
-20.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
TIME (MSEC)
SYSTEM D TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD RESULTANT ACCELERATION



SYSTEM I TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD X AXIS ACCELERATION

VRTC , TEST I-2

90183 FILTER = ALPF (450/ 5214/ -40
HEDY6 MIN, MAX VALUES = -4.67 @ 9.08, 3.14 @ 8.13

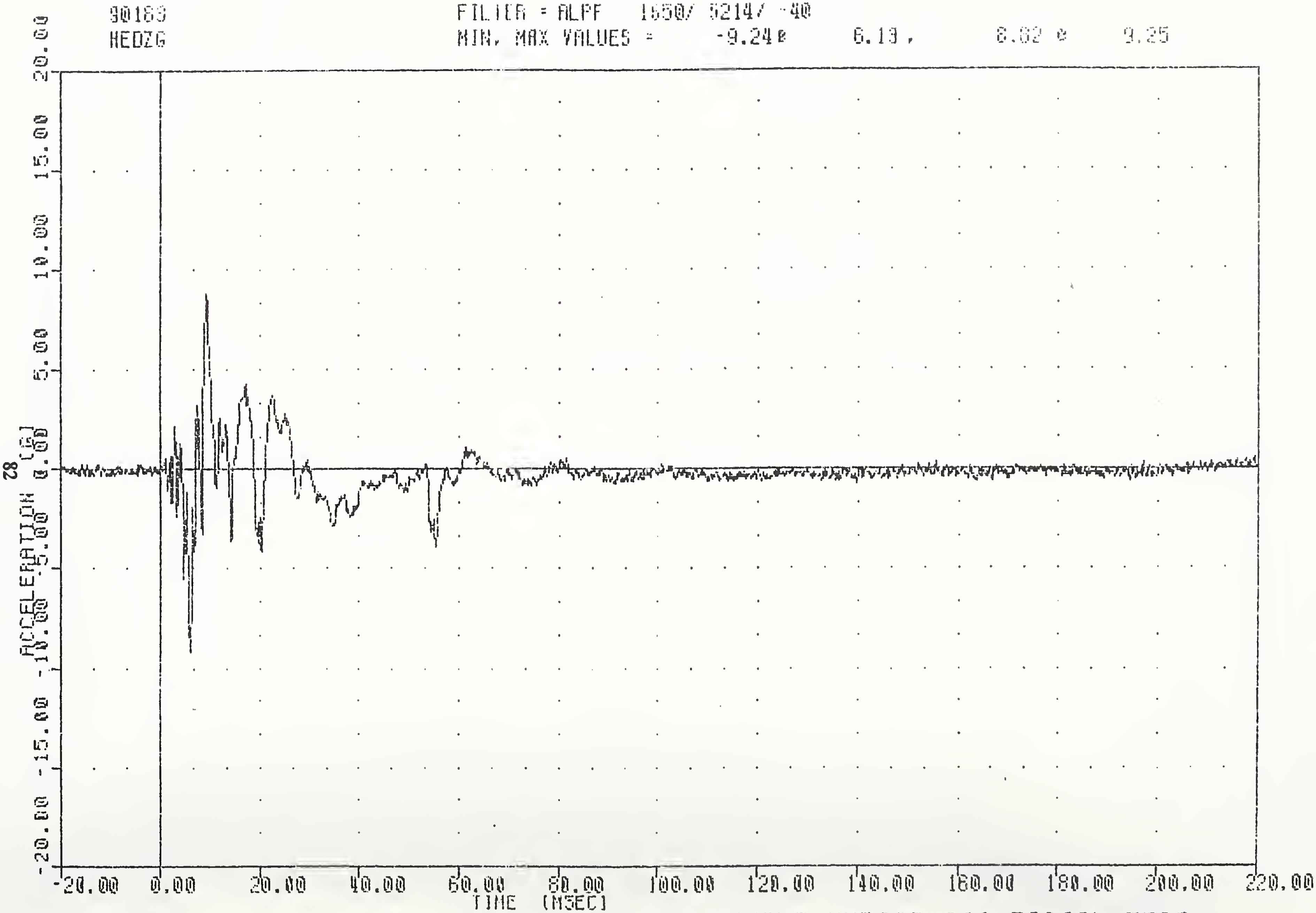


SYSTEM I TEST 2 / 5TH FEMALE HYBRID III FACIAL TEST
HEAD Y AXIS ACCELERATION

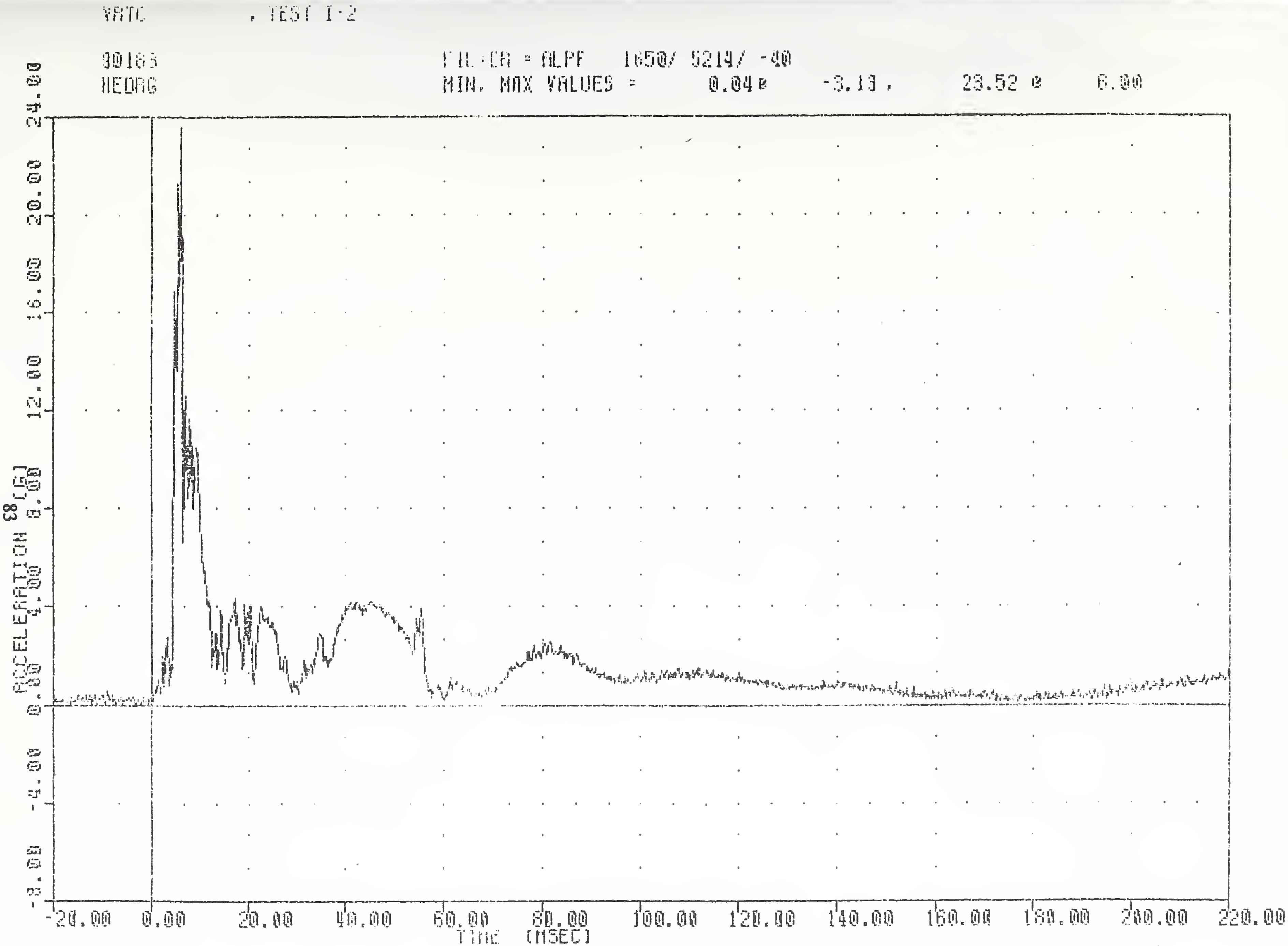
VRTC , TEST I-2

90183
HEDZG

FILTER = ALPF 1650/ 5214/ -40
MIN, MAX VALUES = -9.24 @ 6.13 , 8.02 @ 9.25



SYSTEM I TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD Z AXIS ACCELERATION



SYSTEM I TEST 2/5TH FEMALE HYBRID III FACIAL TEST
HEAD RESULTANT ACCELERATION

APPENDIX E

Air Bag System Identification

Vehicle Codes for Driver Airbags

Vehicle, System, and Test Prefix Letter Designation	1990 Model Year Production Car
A	Chrysler 5th Avenue
B	Chrysler LeBaron
C	Chrysler Daytona
D	GM Oldsmobile Toronado
E	GM Chevrolet Camero
F	Ford Tempo
G	Mercedes Benz 300
H	Mazda Miata
I	Acura Legend