FULL-SCALE VEHICULAR CRASH TESTING
of
EXPERIMENTAL SIGNS
on
BARRICADE STRUCTURES

by

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TRANSPORTATION RESEARCH REPORT TRP-03-017-88

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June 1989

ABSTRACT

Twelve full-scale 1800 lb. vehicle crash tests were conducted to evaluate the breakaway safety performance of Experimental Signs on PVC Barricade Structures. These barricade structures were Type III breakaway barricades constructed of polyvinyl chloride (PVC) pipe and have already been approved as being a standard breakaway barricade in the Manual on Uniform Traffic Control Devices and by the Federal Highway Administration. Therefore, what was to be tested was four foot by four foot sign panels that the New Jersey Department of Transportation used to modify the Type III breakaway barricades which were extended to allow higher sign installations. It was upon these changes that these full-scale crash tests were conducted to determine if the modification still allowed breakaway barricades to function as necessary.

The breakaway safety performance of the modified PVC breakaway barricades, in eleven of the twelve tests, were in compliance with the criteria in (a) "Recommended Procedures for Saftey Performance Evaluation of Highway Appurtenances," by the National Cooperative Highway Research Program Report 230, 1981, and (b) "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," by the American Association of State Highway and Transportationn Officials, 1985.

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation and thanks to the following people who made a contribution to the outcome of this research project.

New Jersey Department of Transportation

Thomas D. Davis, (Bureau of Transportation Systems Research)

University of Nebraska-Lincoln

Eugene Matson (C.E. Research Technician)
James Dunlap (Photographic Productions Manager)
Tom Grady (E.E. Technician)
Gerald Fritz (Electronics Shop Manager)
Michael Cacak (Automobile Support Services Manager)
Patrick Barrett (Automobile Support Services Assistant Manager)
William Kelly (Professor and C.E. Chairman)
Ron Hoffman (University Maintenance Electrician)
Naitai Wang (C.E. Graduate Student)
Brian Pfeifer (M.E. Student)
Jim Holloway (C.E. Student)
Todd Noble (C.E. Student)
Virgil Oligmueller (C.E. Student)
Mary Lou Tomka (C.E. Administrative Assistant)
Marilyn Mues (C.E. Secretary)
Mary Lou Wegner (C.E. Secretary)

Private

Larry Storjohann (Auto Buyer)

INTRODUCTION

A. Problem Statement

Portable 4-ft. x 4-ft. signs used for traffic lane operations in construction zones are often mounted on wood or metal frames. At times, this type of sign must be placed very close to the edge of the traveled way. When impacted by an errant small vehicle, the flying debris from the sign and frame members has resulted in injury to motorist and/or construction workers.

It is anticipated by the New Jersey Department of Transportation (NJDOT) that vehicle occupants and work zone safety could be improved by mounting the necessary 4-ft. x 4-ft. sign panels on Type III breakaway barricades constructed of polyvinyl chloride (PVC) pipe. Though these Type III breakaway barricades are currently approved in the Manual on Uniform Traffic Control Devices (MUTCD) (1) and by the Federal Highway Administration (2), the modification of a 4-ft. x 4-ft. poses concern to NJDOT as to whether or not the breakaway barricade still functions in a predictable manner as does the standard Type III PVC breakaway barricades.

B. Objective

The objective of the study was to evaluate the full-scale crash test performance of Type III PVC breakaway barricades modified with 4-ft.x 4-ft. sign panels and to determine if they continue to function in a manner consistent with the standard Type III PVC breakaway barricades.

C. Scope

The scope of the study was to conduct crash tests on the six breakaway barricade-sign designs stated above and to document their performance under both low and high speed impacts. Crash tests were to be conducted according to the guidelines in the (a) "Recommended Procedures for Saftey Performance Evaluation of Highway Appurtenances," by the National Cooperative Highway Research Program Report 230, 1981 (3), and (b) "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," by the American Association of State Highway and Transportationn Officials, 1985 (4).

TECHNICAL DISCUSSION

A. Test Conditions

A.1 Test Facility

The test site facility, where the full-scale vehicle crash testing is conducted, is located approximately 7 miles northwest of the University at the Lincoln Municipal Airport on the northwest end of the west apron. Appendix A explains the facility in greater detail and shows the guidance and towing methods used.

A.2 Test Articles

The test articles were Type III PVC breakaway barricades modified with 4-ft. x 4-ft. sign panels made out of aluminum or vinyl reflective sheeting (see Figure 1). Different heights of breakaway barricades were used for different tests and the attached sign panels were also mounted at varying heights at the discretion of the NJDOT. (Section A.5 'Test Parameters' gives a more in depth explanation of the barricade characteristics for each individual test.) The MUTCD (1) will permit a sign to be mounted on breakaway barricades as long as the bottom of the sign is at least 1-ft. above the traveled way; although higher mounting heights are desirable.

The breakaway barricades were constructed out of 3-in. PVC pipe with slip-fit joints that were not threaded or cemented. The signs for all twelve tests were 4-ft. x 4-ft.; however, in the first eight tests, the signs were 0.024-in. (24-Ga.) aluminum, while in the last four tests, the signs were reflective vinyl sheeting. One inch No. 14 pan head metal screws were used to attach the sign panels to the barricades; four for the aluminum signs and two for the vinyl signs. Barricade rails (or reflective panels) were also attached to the barricades below the sign panels. The number of barricade rails varied with the height of the breakaway barricade, but all of them were 9-in. x 48-in. 24-Ga. aluminum panels with rounded corners.

Two pieces of 12-Ga wire were used to tie the upper front portion of the barricade to the bottom back portion to help hold the barricade together. In addition to the wire, #6, 3/16-in. diameter solid braided nylon rope was tied in the upright frame and the front portion of the base frame of the barricade to help control the scatter of debris once the barricade is impacted.

NJDOT chose to use, 300 to 400 lbs. of sand, depending on the test being conducted, to stabilize the barricades from gusty winds or moving traffic; thus, sand was bagged in 35 lb. sacks and set on the bottom frame of the barricade.

NOTE:

All dinensions on full pipe length

Socket depth of fittings is 1 1/2"

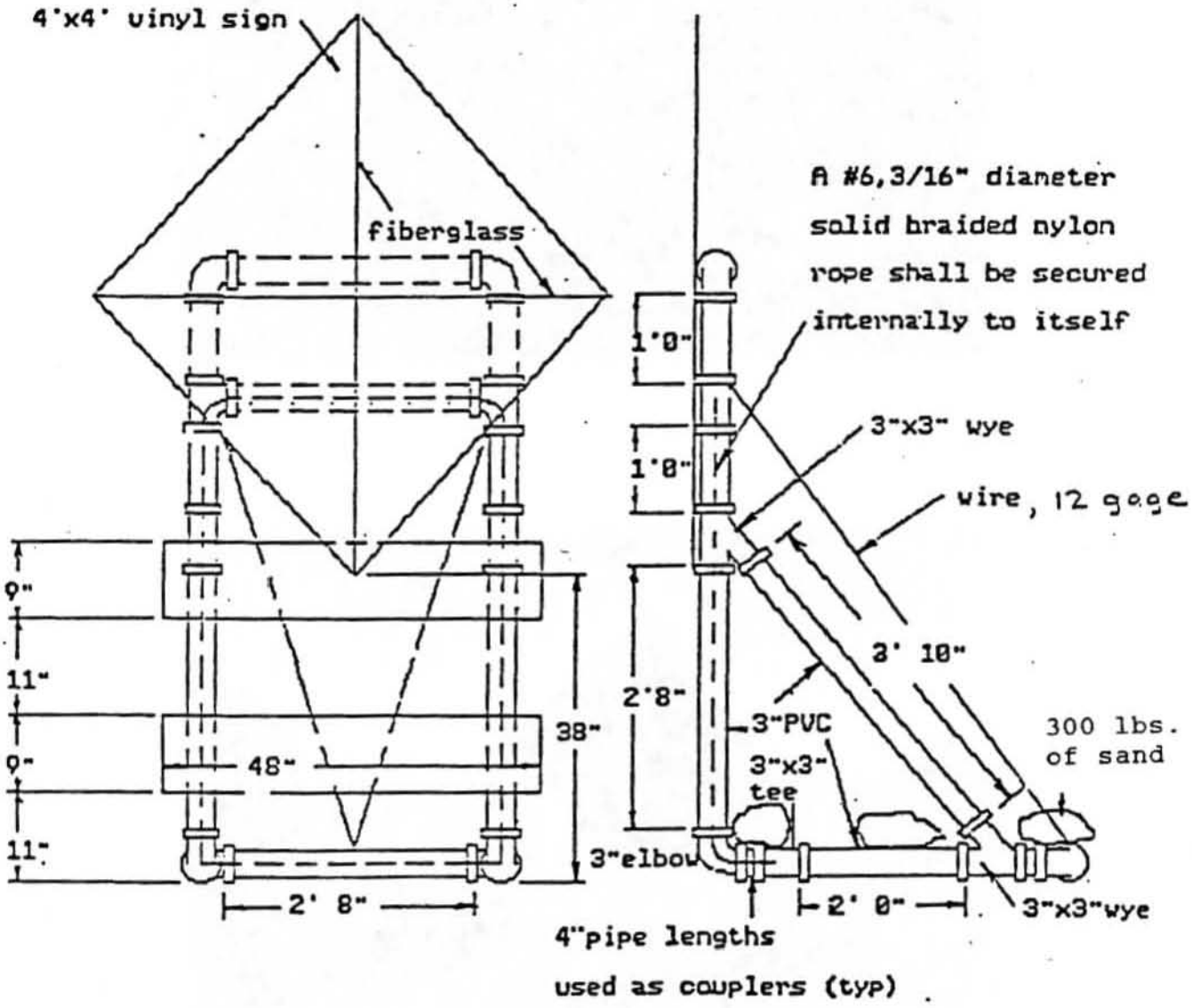
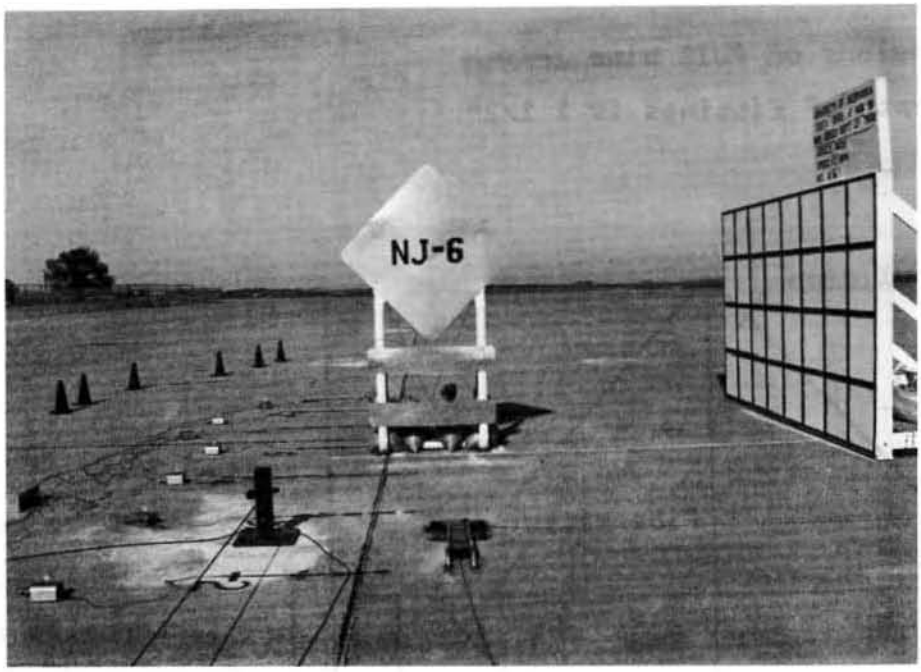


FIGURE 1. Schematic of Breakaway Barricade Test Articles



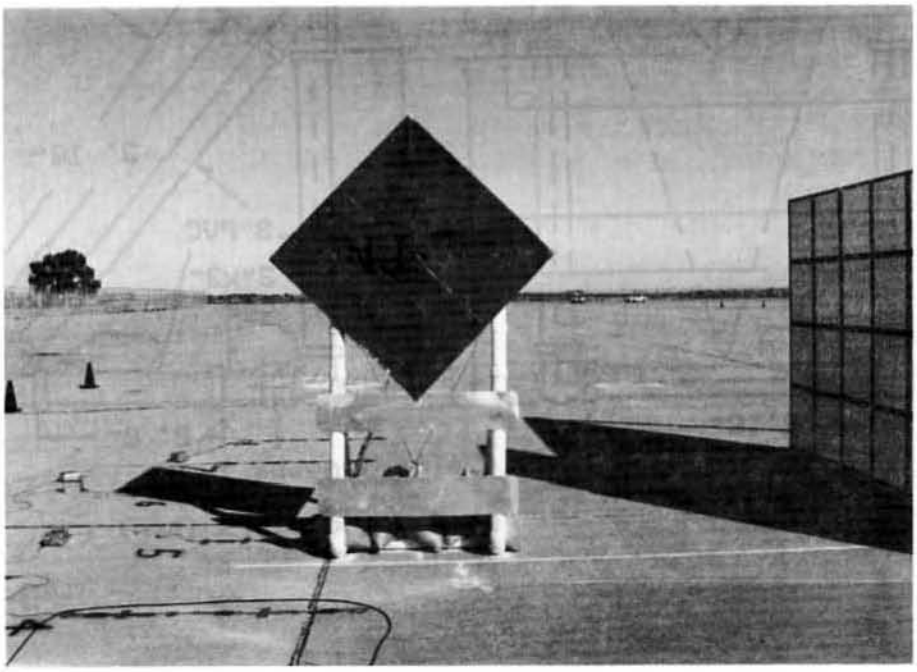


FIGURE 2. Photographs of Breakaway Barricade Test Articles

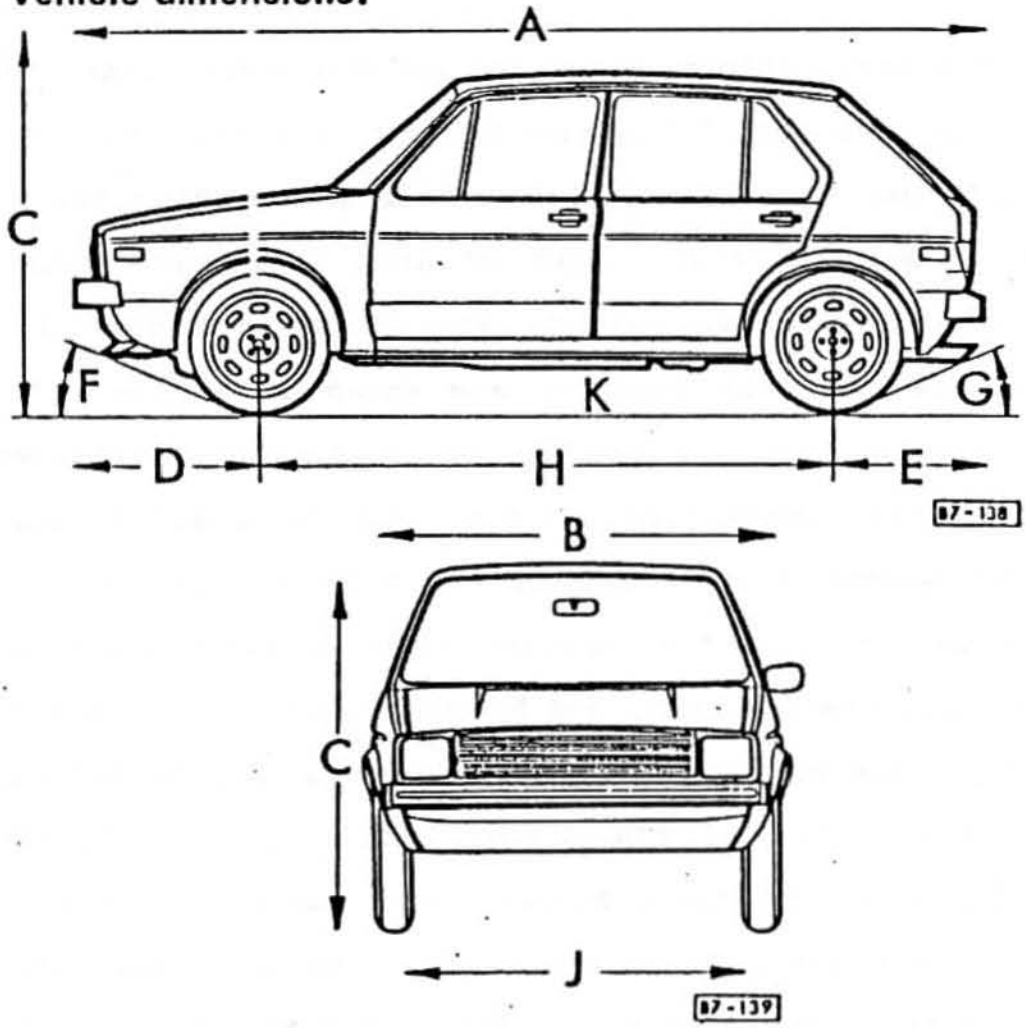
A.3 Test Vehicle

Two test vehicles were used for the twelve crash tests. Both vehicles were 1980 Volkswagon Rabbits; however, one of them had a final test inertial weight of 1835 lbs., while the other had a final test inertial weight of 1840 lbs. The vehicle's dimensions and relative weights are shown in Figure 3, and photographs of the test vehicles are shown in Figure 4. The vehicles were prepared for testing by removing such articles as the seats, radio, spare tire and rim, etc. in order to achieve the desired weight recommended by NCHRP Report 230 (3).

Instrumentation of the vehicles included two piezoresistive accelerometers, brake system, and FM multiplexer. Camera targets were also positioned on the vehicles to aid in the high-speed film analysis. Two 5B flashbulbs, fired by an electrical pressure taped on the front bumper, were mounted on the front hood of the test vehicles to record the time of impact with the barricade on the high-speed film. This instrumentation and high-speed film analysis is explained in further detail in Appendix B.

The front wheels of the vehicles were aligned to a toe-in value of zero-zero so that the vehicles would track properly along the guide cable.

Vehicle dimensions:



Geometry - (in.)

A. 155.3	D. 32.7	G. 22.5°	K. 4.8
B. 63.4	E. 27.2	H. 94.5	
C. 55.5	F. 24°	J. 53.9	

Mass - lb.	Test Inertial *
Front Axle	1026
Rear Axle	814
Total	1840

* Ready for testing. This is for 1840 lb. vehicle only.

FIGURE 3. Test Vehicle Weights and Dimensions

FIGURE 4. Photographs of Test Vehicles

A.4 Data Acquisition Systems

The data acquisition systems used in the full-scale crash testing includes piezoresistive accelerometers, high-speed photography, and an electronic speed trap. The two accelerometers placed in the test vehicles were used to measure the longitudinal accelerations of the vehicles. The accelerometers were mounted on metal blocks and bolted to the floorboard of the vehicles. One accelerometer was placed on the passenger's side and the other was placed on the driver's side; both were located where the front seats would be located. Photographs of the mounted accelerometers are included in Appendix B where the data acquisition systems are explained in greater detail.

The high-speed photography included two 16mm cameras that ran at approximately 500 frames per second. The cameras were strategically placed for analysis and documentation of the test results. Appendix B gives a more in-depth explanation of the camera positions as well as a schematic of the camera layouts.

A speed trap made of tape pressure switches was also used as one source to determine the speed of the vehicle before and after impact. Appendix B also explains the speed trap in greater detail.

A.5 Test Parameters

The full-scale crash tests were conducted on the barricade structures with experimental signs for the New Jersey Department of Transportation. The 1800 lb. Volkswagon Rabbit impacted the barricades at speeds of 20 mph and 60 mph with an impact angle of 90 degrees to produce the maximum vehicle velocity change.

There were six different types of tests conducted on the barricades altogether as shown in Table 1.

Test Number	Sign Material	Sign Height (in.)	Speed (mph)	Pounds of Sand
1	Aluminum	12	20	300
2	Aluminum	12	60	300
3	Aluminum	29	20	400
4	Aluminum	29	60	400
5	Aluminum	41	20	400
6	Aluminum	41	60	400
7*	Aluminum	41	20	400
8*	Aluminum	41	60	400
9	Vinyl	38	20	400
10	Vinyl	38	60	400
11	Vinyl	50	20	400
12	Vinyl	50	60	400

* One post hit at center of vehicle's bumper

TABLE 1. Descriptions of Tests

According to Table 3 in NCHRP 230 (3), when using an 1800 lb. vehicle on breakaway or yielding systems, the 20 mph test is designated as a type 62 test, while the 60 mph test is designated as a type 63 test. In the 20 mph tests, the test vehicle impacted the barricade at the center; midway between the upright PVC frame of the barricade where the sign panel was attached. This was said to be at the center of the vehicle bumper. In the 60 mph tests, the test vehicle again impacted the upright PVC frame; however, the barricade was placed in a manner so that one of the upright PVC supports (the right one) was contacted by the quarter point of the vehicle's front bumper. Both of these impact conditions were used to satisfy the recommended procedures in NCHRP 230 (3).

A.6 Performance Evaluation Criteria

The performance of the full-scale vehicle crash tests are evaluated upon two forms of criteria. The first form is from the guidelines given in the NCHRP Report 230 (3) which takes such things as structural adequacy, occupant risks, and vehicle trajectory into consideration. According to NCHRP 230, The objective of the 20 mph test was to evaluate the breakaway behavior of the test article, while the objective of the 60 mph test was to evaluate the stability and trajectory of the vehicle as well as the occupant risks and to also evaluate the test article penetration into the passenger compartment. The second form of criteria that the crash tests were evaluated on is from the guidelines given by AASHTO (4). This criteria requires that the maximum change in velocity of the vehicle does not exceed 15 fps but preferably does not exceed 10 fps.

Because test conditions are sometimes difficult to control, a composite tolerance limit, called the impact severity (IS), is presented in NCHRP 230. The IS values, both target and actual, for each tests are given in Table 19 of NCHRP 230. The formula used to calculate the impact severity is given as follows:

$$IS = \tfrac{1}{2}m(v\sin\theta)^2$$

where, m = vehicle test inertial mass (slugs)

v = impact velocity (fps)

θ = impact angle (degrees)

B. Test Results

The following section explains each individual test as well as their results. The accelerometer data was obtained in nine of the twelve tests while high-speed film analysis was used in evaluating the other three. Tests numbers 3, 6, and 10 were the tests that did not have any accelerometer data due to the coaxial cable breaking during the tests. Therefore, velocity of the vehicle was obtained from the high-speed film and then manually entered into the computer where further test evaluation was possible. Plots of the accelerometer and high-speed film data may be found in Appendix C.

Due to the oil pan under the test vehicle, the readings on the accelerometer traces are greater on the right (passenger) side of the vehicle. The oil pan was located on the right side of the vehicle and when the vehicle passed over the debris from the barricade, the oil pan would get caught up against the sandbags causing the vehicle to usually veer right.

It should also be noted that the tests were not conducted in the same order as shown in this report. The tests were conducted in an order that would cause the least amount of damage to the test vehicle so that the test vehicle could be used for the maximum number of tests before bodily repairs, if any, were necessary.

The brakes of the test vehicle were not applied in any of the 20 mph tests, and in all of the 60 mph tests. In the first 60 mph test, the brakes were applied at a time of 3 seconds after

impact. This time was too long; therefore, in the next three 60 mph tests, the brakes were applied 1/2 second after impact. Again the results of the vehicle braking distance were still unsatisfactory due to the distance that the vehicles were traveling after impact. Thus, brakes were applied immediately after impact in the last two 60 mph tests.

Values for the vehicle impact velocity, the vehicle change in velocity, and the occupant impact velocity were all normalized to give values that would be more indicative of the tests results had the tests been conducted at the exact target impact speed.

A matrix of the crash tests conditions is given in Table 2 while a final evaluation of the results for each tests, according to the NCHRP Report 230 criteria, may be found in Table 27 in the conclusion of this report.

Photographs of the damages to the test vehicles are shown in the following sections for each individual test. The damage to each vehicle was classified according to the Traffic Accident Data (TAD) scale (5), and the Vehicle Damage Index (VDI) scale (6).

APPURTENANCE: Type III PVC Breakaway Barricades with Experimental Signs

TEST CONDITIONS		TEST NUMBERS											
		1	2	3	4	5	6	7	8	9	10	11	12
NCHRP 230 Test Designation Number	62	x		x		x		x		x		x	
	63		x		x		x		x		x		x
Vehicle Type 1800 lb. ±50	1835	x		x		x		x		x	x	x	
	1840		x		x		x		x				x
Target Impact Speed (mph)	20	x		x		x		x		x		x	
	60		x		x		x		x		x		x
Target Impact Angle (deg)	90	x	x	x	x	x	x	x	x	x	x	x	x
Target Impact Severity (ft-k)	$24^{-3,+3}$	x		x		x		x		x		x	
	$216^{-21,+37}$		x		x		x		x		x		x
Impact Point	Center of bumper at center of barricade	x		x		x				x		x	x
	One post of barricade at ¼ pt. of bumper		x		x		x	x(1)	x(1)		x		
NCHRP 230 Evaluation Criteria	B,D,E,F, (G),H,J	x	x	x	x	x	x	x	x	x	x	x	x

(1) Hit at center of vehicle's bumper

TABLE 2. Crash Test Conditions

B.1 Tests No.'s 1 and 2

Tests no.'s 1 and 2 were conducted using an aluminum sign with a clearance height of 12-in. and 300 lbs of sand to ballast the barricades as shown in Figure 5. A summary of the results for test no. 1 is given in Table 3, while a summary of the results for test no. 2 is given in Table 5. Tables 4 and 6 give time-event summaries of the sequential photographs in Figures 6 and 10 for tests no.'s 1 and 2 respectively. Test no. 1 was conducted at a target impact speed of 20 mph and test no. 2 was conducted at a target impact speed of 60 mph.

In test no. 1, the PVC shattered upon impact and the aluminum sign stayed in front of the vehicle. The vehicle rode up on some of the barricade debris and continued to push the rest of the debris until the vehicle came to a stop. The vehicle received no damage. It traveled 44-ft. past the point of impact with the barricade and veered 9-ft. to the right of its initial path. Photographs the of barricade and test vehicle, before and after impact, are shown in Figures 7, 8, and 9.

In test no. 2, the test vehicle received a significant amount of damage. As in test no. 1, the PVC shattered upon impact; however, instead of the sign staying in front of the vehicle, as in test no. 1, it was projected into the windshield. The windshield shattered and was dished-in by a PVC elbow behind the aluminum sign panel. No debris from the test article penetrated the vehicle but, the integrity of the occupant compartment was not maintained due to the intrusion of the front

windshield as a result of the impact. The vehicle also received two dents in the hood where the vehicle and the two upright posts of the barricade contacted at impact. The vehicle traveled 279-ft. past the point of impact and veered 8-ft. to the left of its initial path before impact. Figures 11, 12, and 13 show photographs of the barricade and test vehicle before and after impact.

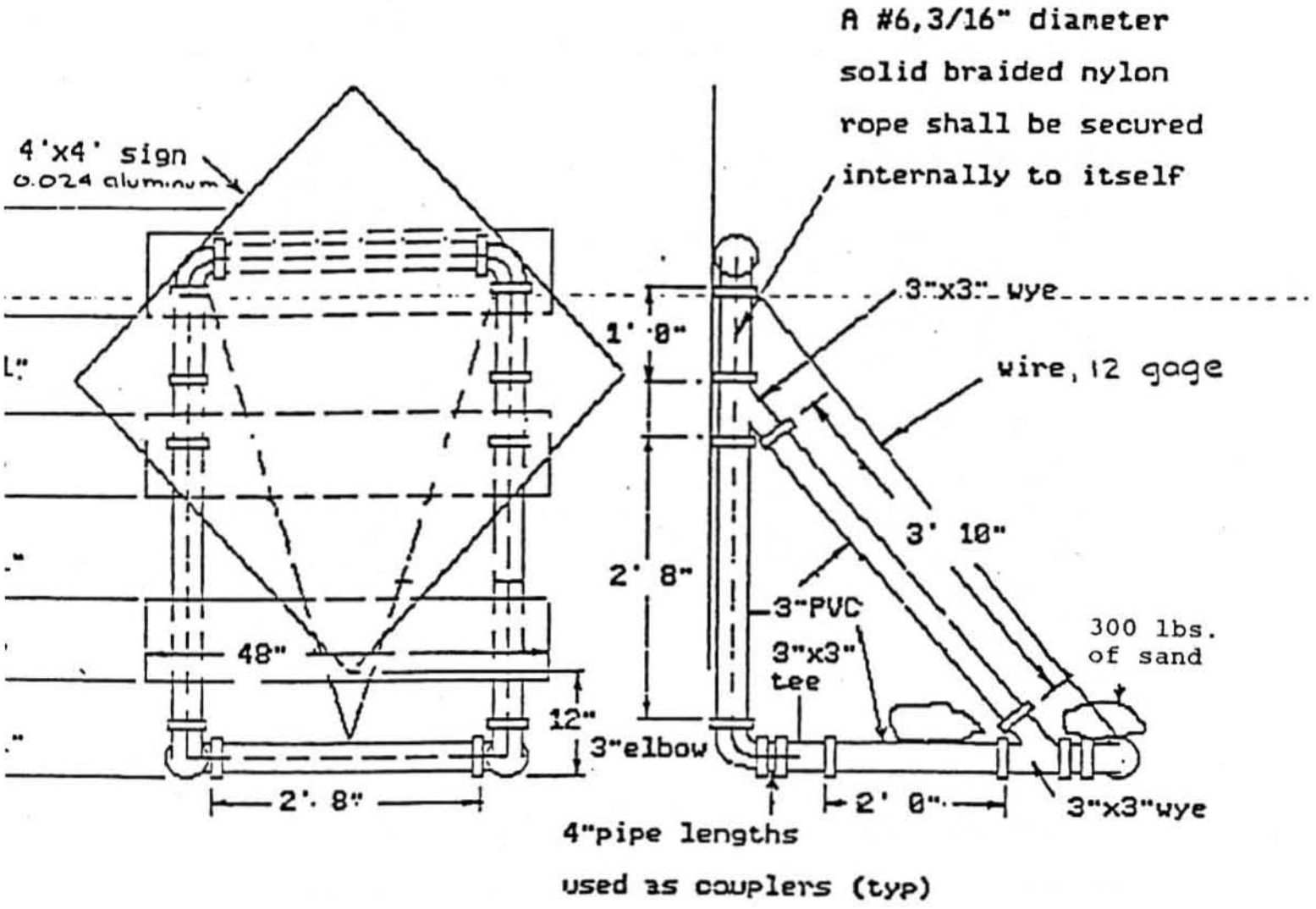


FIGURE 5. Breakaway Barricade For Test No. 1 and Test No. 2

TABLE 3.

SUMMARY OF TEST RESULTS FOR TEST NO. 1

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	12 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	300 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	19.8 mph
Duration of Event[a]	111 msec
Vehicle Change-in-Speed	10.3 fps
Occupant Impact Velocity	11.4 fps
Occupant Ridedown Acceleration	0.9 g's
Impact Severity	23.9 ft-kips

VEHICLE DAMAGE

TAD	FR-1
VDI	12FRMN1
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	No

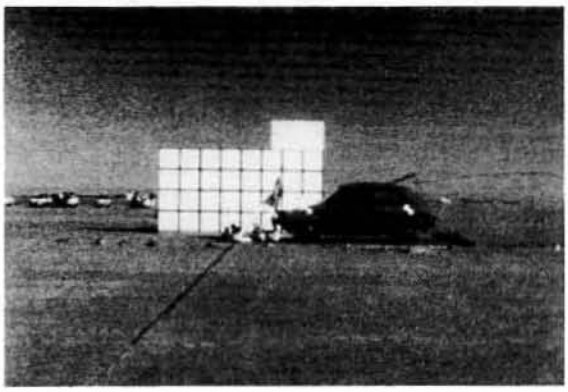
(a) Determined from accelerometer trace.

TABLE 4.

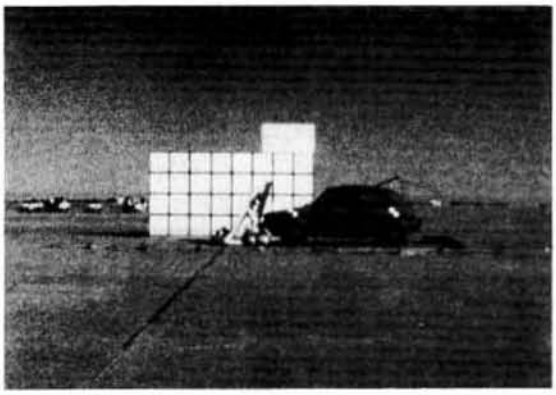
TIME-EVENT SUMMARY FOR TEST NO. 1

Time (sec)	Event
0.000	Impact
0.025	Lower vertical supports begin to fracture
0.040	Barricade begins to collapse
0.125	Sign contacts hood of vehicle and debris begins projectile motion
0.188	Sign begins to be pulled under vehicle
0.292	Sign continues to be pulled under vehicle
0.438	Vehicle begins to ride up on sign and sand bags
0.625	Vehicle pushes debris lodged underneath front end

Impact



0.025 s



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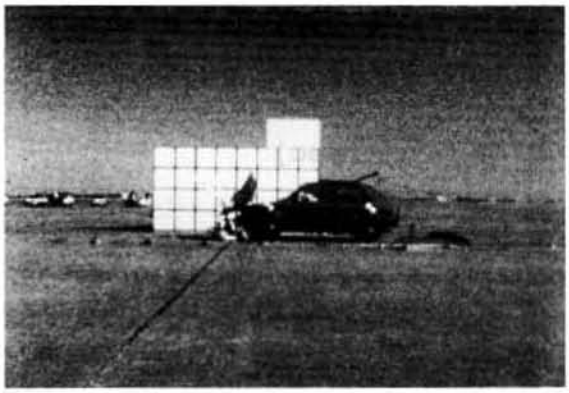
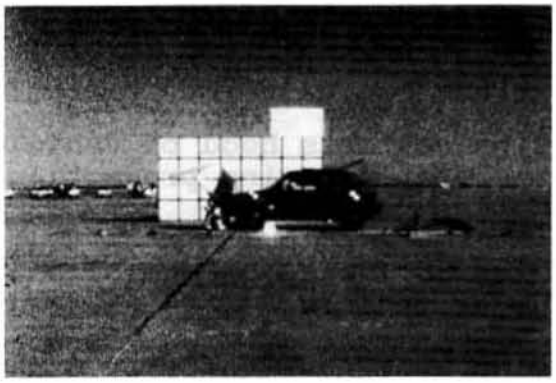
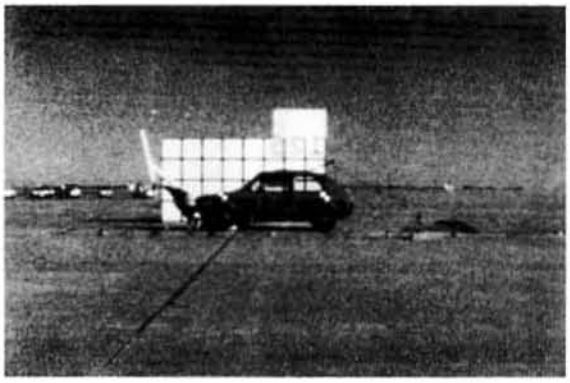


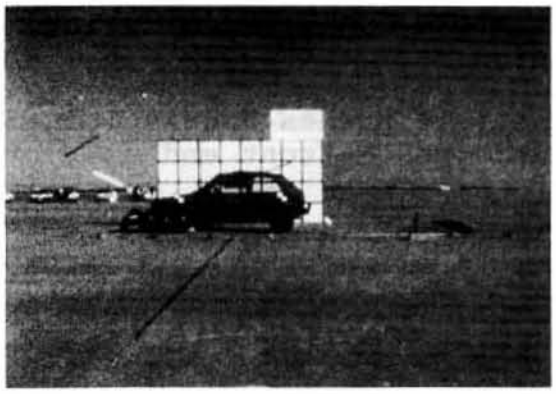
0.125 s



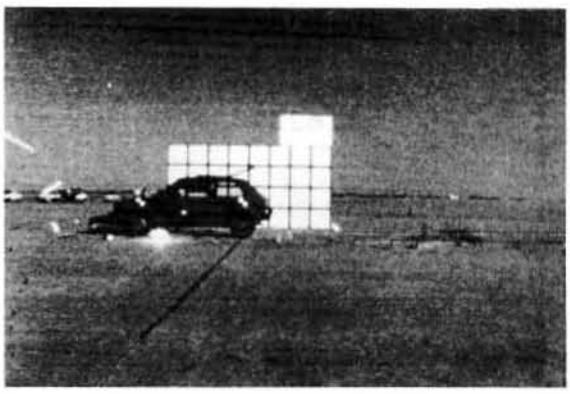
0.188 s



0.292 s

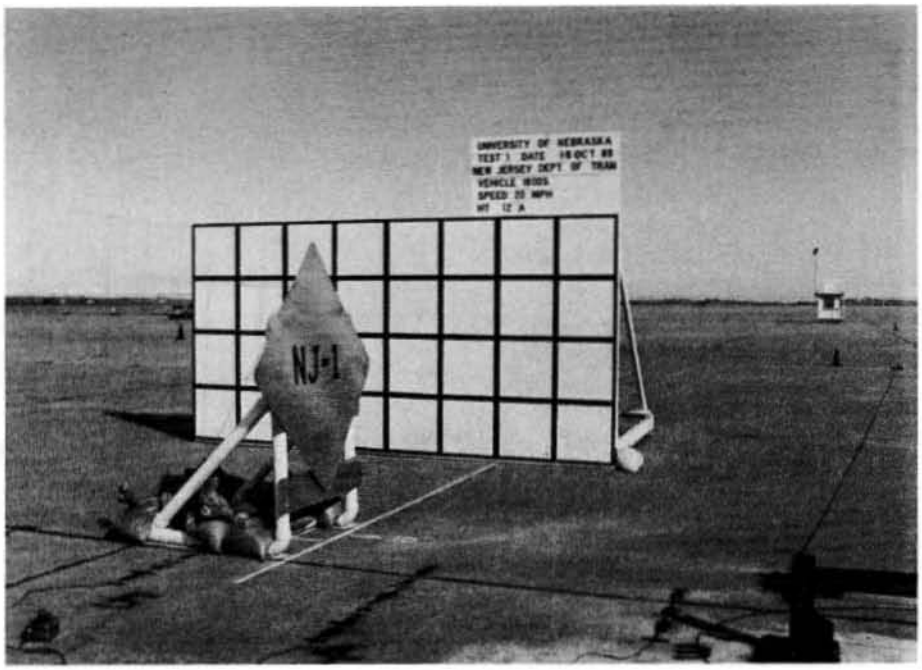


0.438 s



0.625 s

FIGURE 6. Sequential Photos of Test No. 1



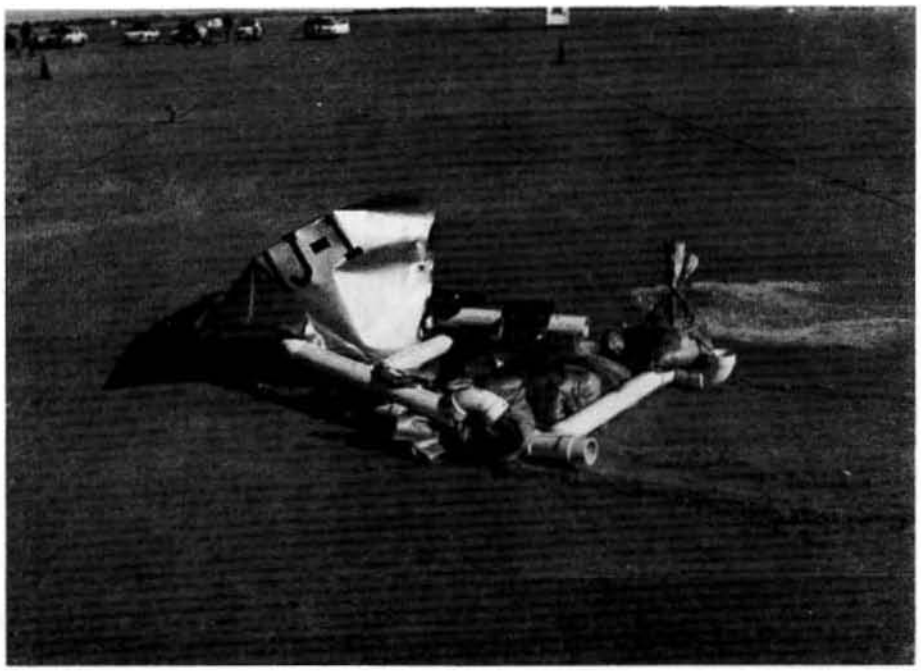
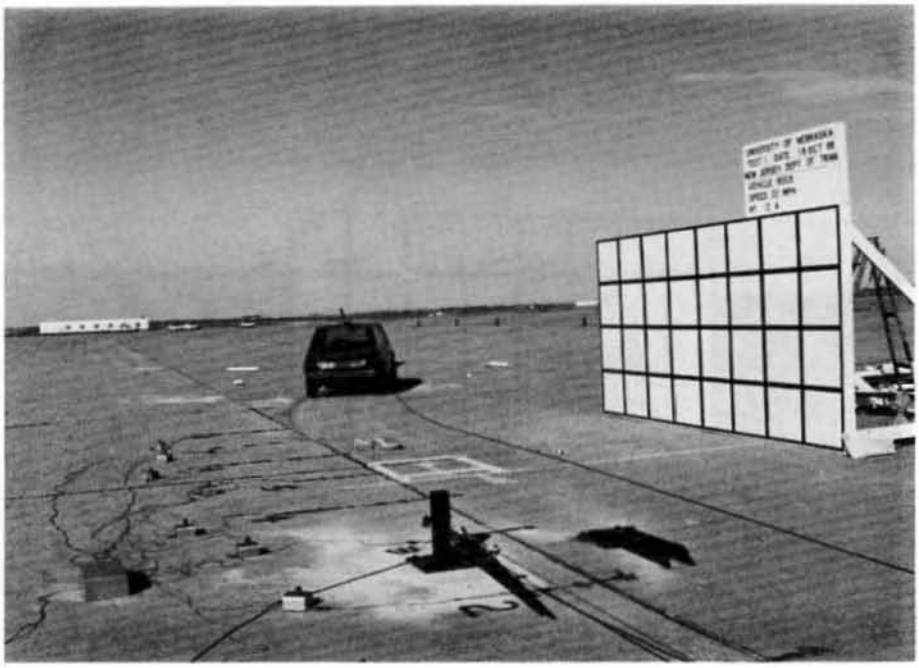


FIGURE 7. Photographs of Barricade Before and After Test No. 1



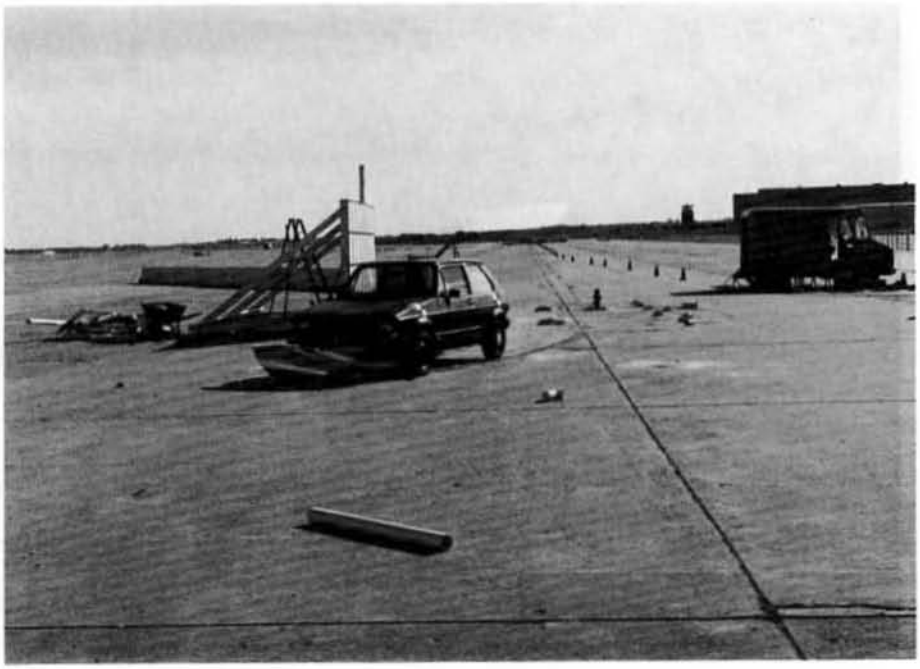


FIGURE 8. Photographs of Vehicle and Barricade After Test No. 1

FIGURE 9. Photographs of Vehicle Before and After Test No. 1

TABLE 5.

SUMMARY OF TEST RESULTS FOR TEST NO. 2

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1840
Impact Point	1 Post at 1/4 Point of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	12 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	300 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	62.4 mph
Duration of Event[a]	157 msec
Vehicle Change-in-Speed	8.7 fps
Occupant Impact Velocity	10.2 fps
Occupant Ridedown Acceleration	0.9 g's
Impact Severity	239.2 ft-kips

VEHICLE DAMAGE

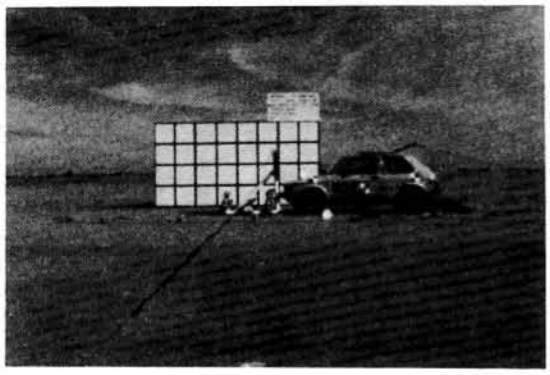
TAD	FD-1
VDI	12FDHN6
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	Yes (severe)

(a) Determined from accelerometer trace.

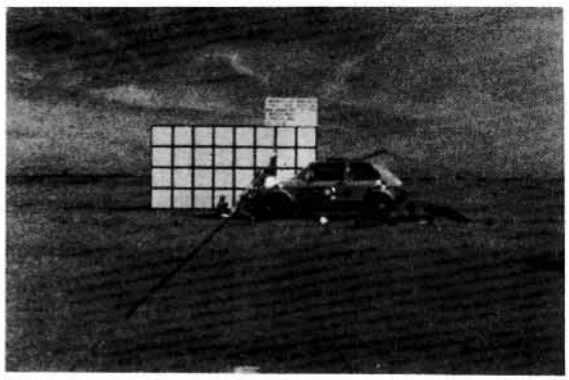
TABLE 6.

TIME-EVENT SUMMARY FOR TEST NO. 2

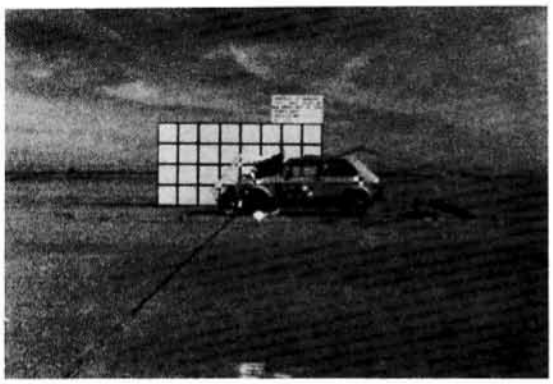
Time (sec)	Event
0.000	Impact
0.027	Barricade collapses
0.052	Sign contacts windshield
0.125	Sign has penetrated windshield and barricade debris is being projected
0.200	Rear left wheel is raised off pavement and sign begins to slide off vehicle
0.281	Sign is sliding off and vehicle debris is airborne above vehicle



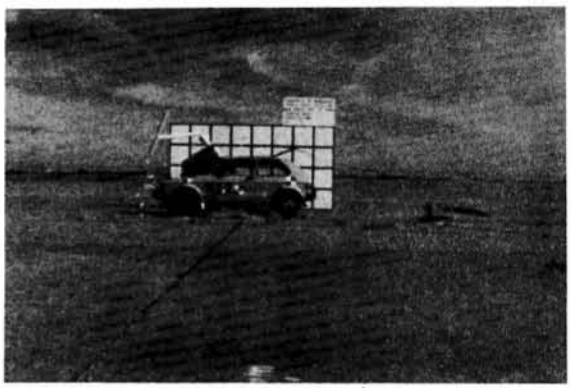
Impact



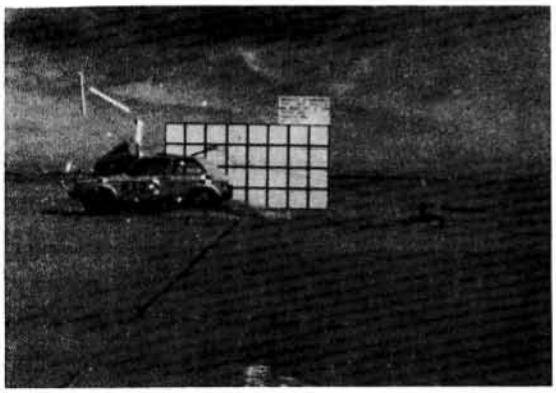
0.027 s



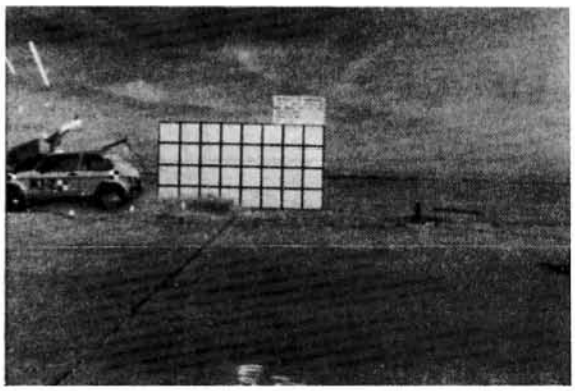
0.052 s



0.125 s

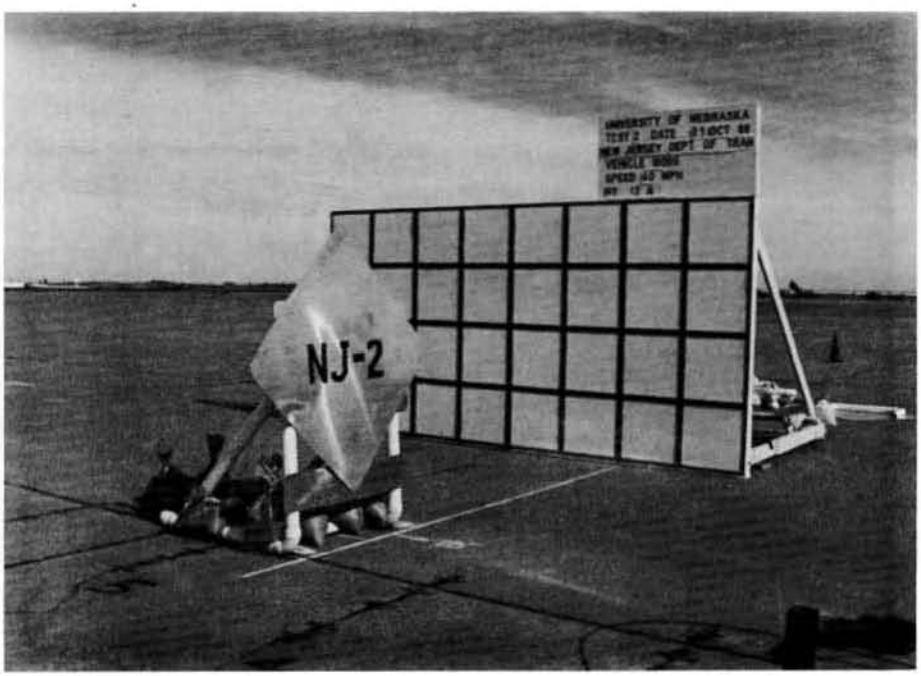


0.200 s



0.281 s

FIGURE 10. Sequential Photos of Test No. 2



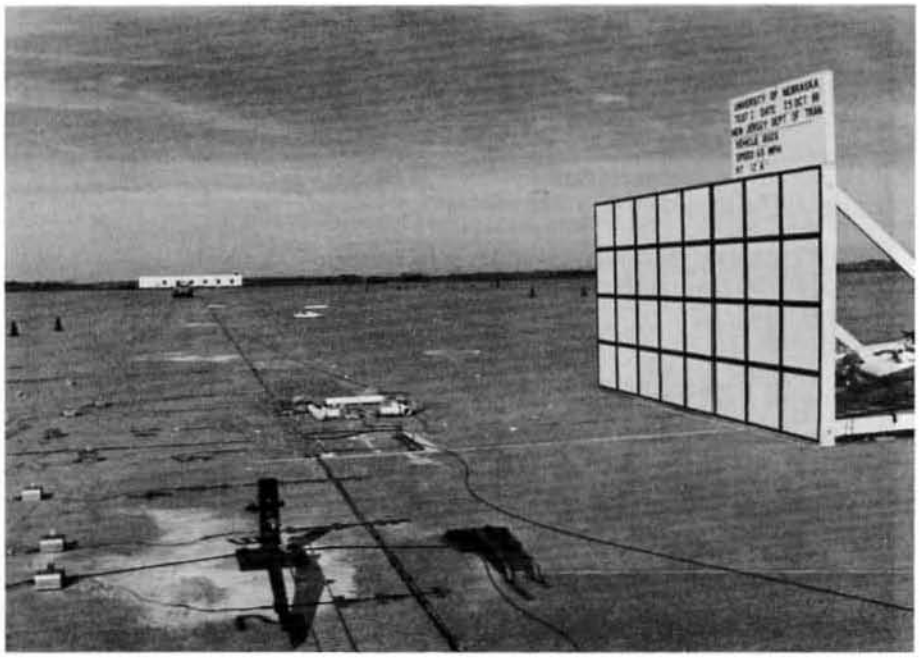


FIGURE 11. Photographs of Barricade Before and After Test No. 2

FIGURE 12. Photographs of Vehicle Before and After Test No. 2

FIGURE 13. Photographs of Vehicle Damage in Test No. 2

B.2 Tests No.'s 3 and 4

In tests no.'s 3 and 4 the clearance height of the sign panels were 29-in. The sign panels were aluminum and 400 lbs. of sand were used to ballast each barricade. The barricade was extended up one foot to accomodate the higher sign. Figure 14 shows a schematic of the barricade used in conducting these tests and Tables 7 and 9 give summaries of tests no.'s 3 and 4 respectively. Table 8 gives a time-event summary of the sequential photographs in Figure 15 for test no. 3 and Table 9 gives a time-event summary of the sequential photographs in Figure 19 for test no. 4.

Test no. 3 was conducted at a target impact speed of 20 mph. At impact, the barricade collapsed and began to pile-up underneath the front end of the vehicle while the sign panel fell off to the passenger's side of the vehicle on the front right quarter panel. The vehicle proceeded to drag the barricade debris under its front end until it finally came to a stop 28-ft. beyond the point of impact. The test vehicle received no damage in this test. The duration of the event was not available since the accelerometer data cable broke during the test and the barricade debris stayed in contact with the vehicle until the vehicle stopped. The duration of the event is not evident without the accelerometer data since one does not know how much the barricade debris affected the braking of the vehicle. Figures 16, 17, and 18 show photographs of the test vehicle and barricade before and after impact.

Test no. 4 was conducted at a target impact speed of 60 mph. Upon impact, the barricade collapsed and pieces of PVC pipe were projected out in front of the vehicle. The sign panel detached from the barricade, impacted the vehicle's windshield, and then proceeded to slide over the roof of the vehicle. The sign panel ended up 35-ft. beyond the point of impact, while the vehicle ended up 217-ft. beyond the point of impact and veered 44-ft. to the left of it's initial path. The only damage done to the vehicle was a small crack in the windshield (a ' bird's eye ' approximately the size of a half dollar) and two dents on the hood where the vehicle impacted the two upright posts of the barricade. Photographs of the barricade and vehicle, before and after impact, are shown in Figures 20, 21, and 22.

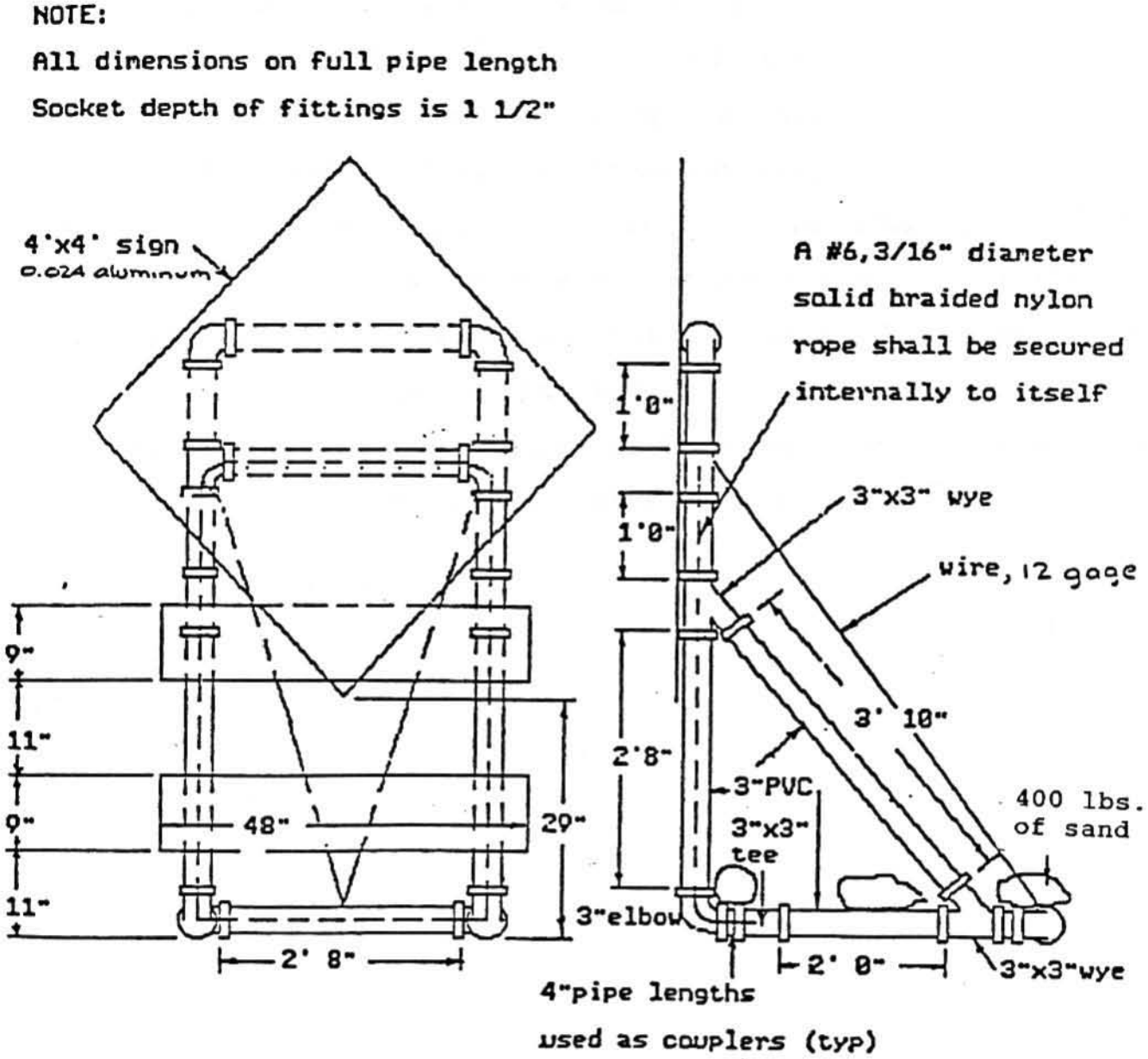


FIGURE 14. Breakaway Barricade For Test No. 3 and Test No. 4

TABLE 7.

SUMMARY OF TEST RESULTS FOR TEST NO. 3

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	29 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	19.6 mph
Duration of Event	N.A.[a]
Vehicle Change-in-Speed	N.A.[a]
Occupant Impact Velocity	12.5 fps[b]
Occupant Ridedown Acceleration	3.9 g's[b]
Impact Severity	23.4 ft-kips

VEHICLE DAMAGE

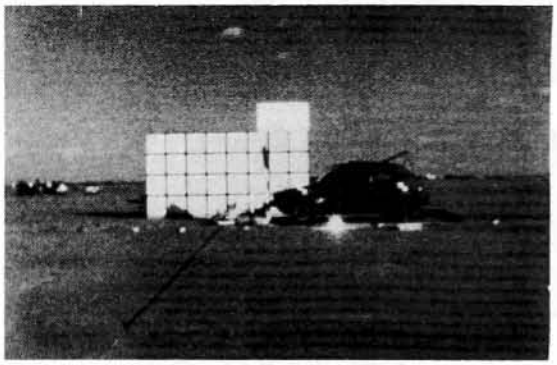
TAD	FL-1
VDI	12FLMN1
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	No

(a) Accelerometer data cable broke. This information was not available from high-speed film.
(b) Determined from high-speed film analysis. (24-in. Flail Space Model was used)

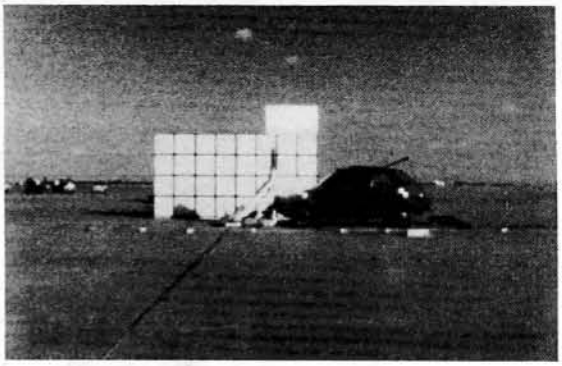
TABLE 8.

TIME-EVENT SUMMARY FOR TEST NO. 3

Time (sec)	Event
0.000	Impact
0.021	Lower vertical supports begin to fracture
0.075	Barricade collapses
0.375	Sign contacts hood of vehicle and debris begins projectile motion
0.469	Sign is resting on hood of vehicle
1.106	Sign slides off right front side of vehicle
1.292	Sign loses contact with right front side of vehicle
2.083	Vehicle has come to a complete stop

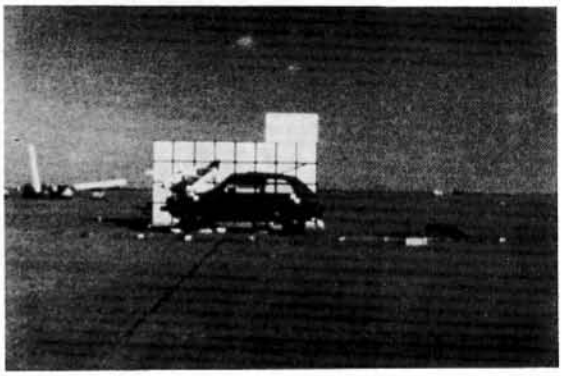


Impact



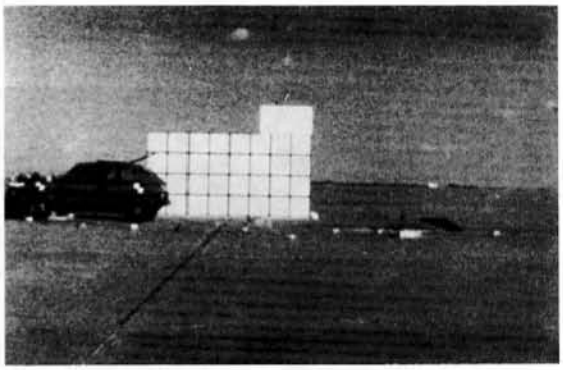
0.021 s

0.075 s

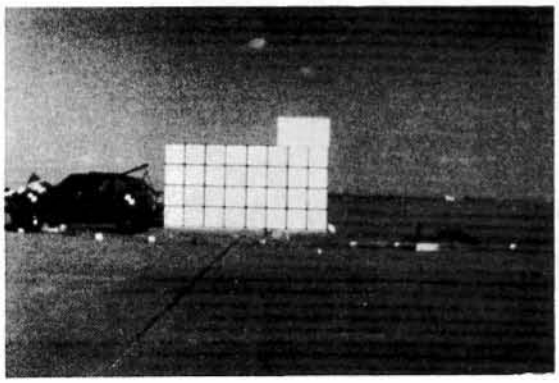


0.375 s

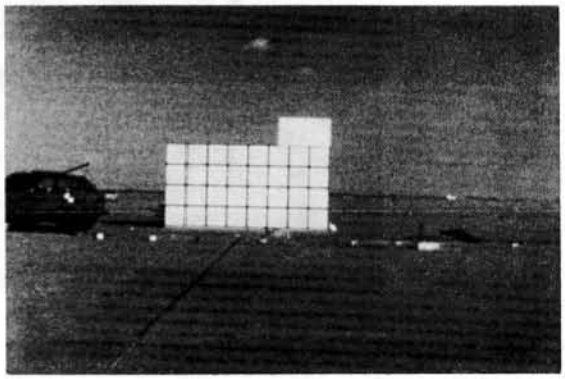
0.469 s



1.106 s



1.292 s



2.083 s

FIGURE 15. Sequential Photos of Test No. 3

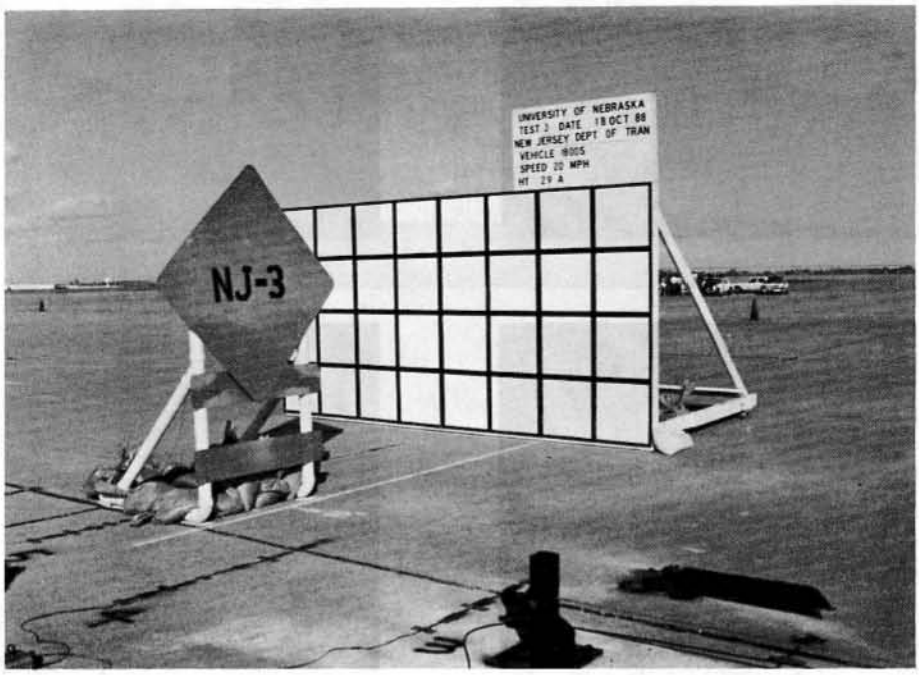


FIGURE 16. Photographs of Barricade Before and After Test No. 3

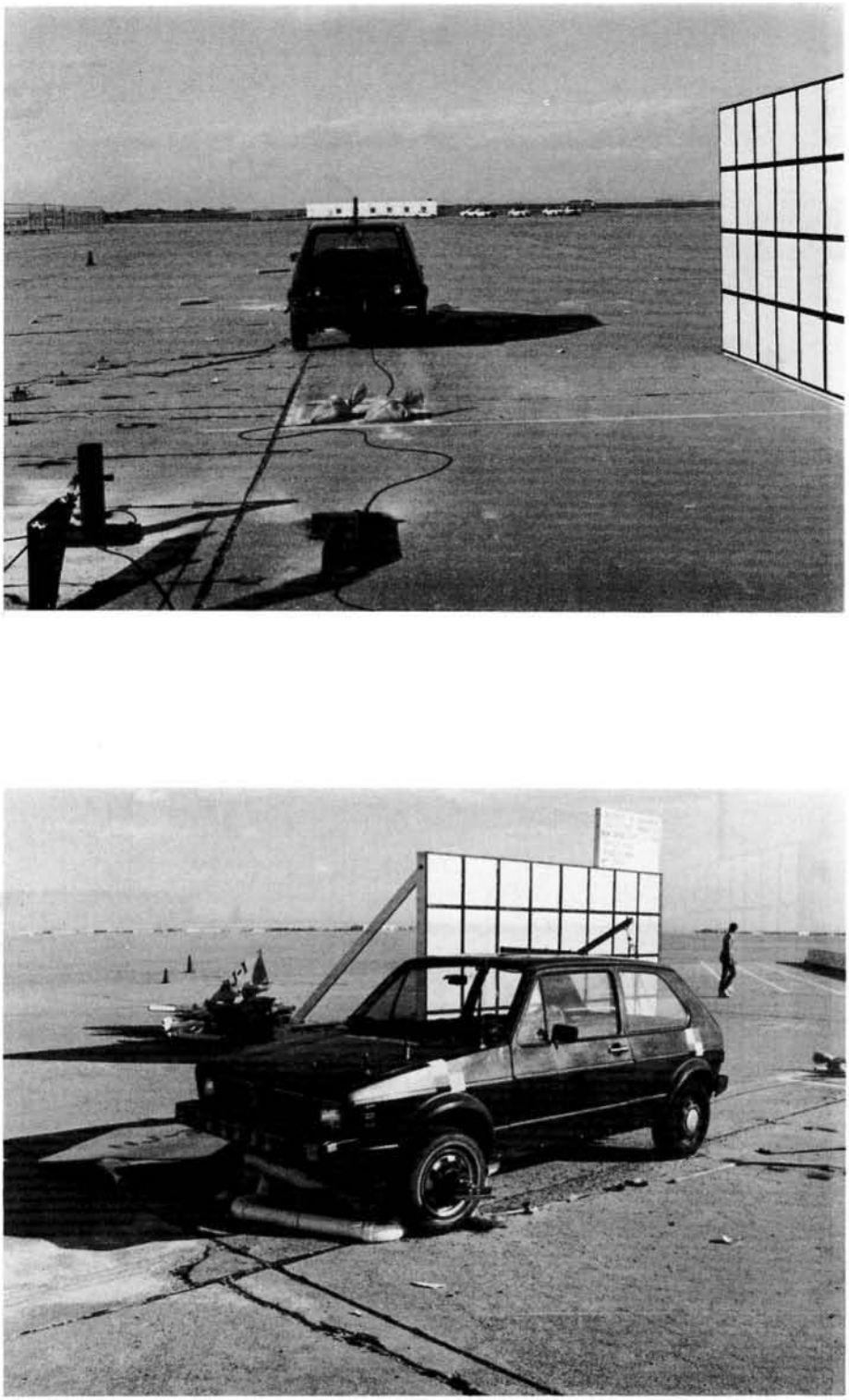


FIGURE 17. Photographs of Vehicle and Barricade After Test No. 3

FIGURE 18. Photographs of Vehicle Before and After Test No. 3

TABLE 9.

SUMMARY OF TEST RESULTS FOR TEST NO. 4

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1840
Impact Point	1 Post at 1/4 Point of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	29 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	58.3 mph
Duration of Event[a]	149 msec
Vehicle Change-in-Speed	16.9 fps
Occupant Impact Velocity	17.4 fps
Occupant Ridedown Acceleration	1.6 g's
Impact Severity	209.8 ft-kips

VEHICLE DAMAGE

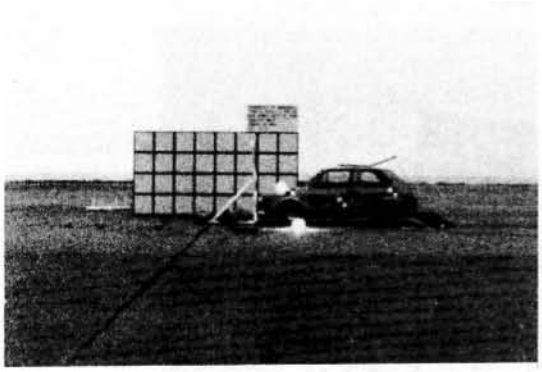
TAD	FD-1
VDI	12FDHN6
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	Yes

(a) Determined from accelerometer trace.

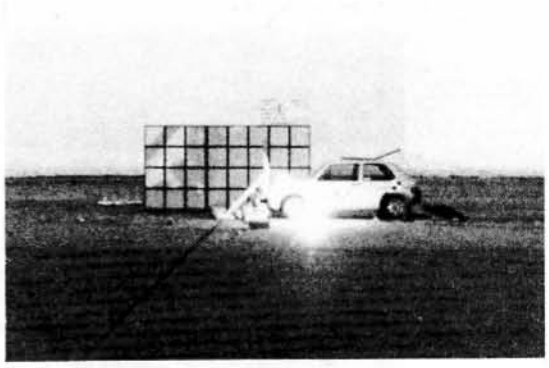
TABLE 10.

TIME-EVENT SUMMARY FOR TEST NO. 4

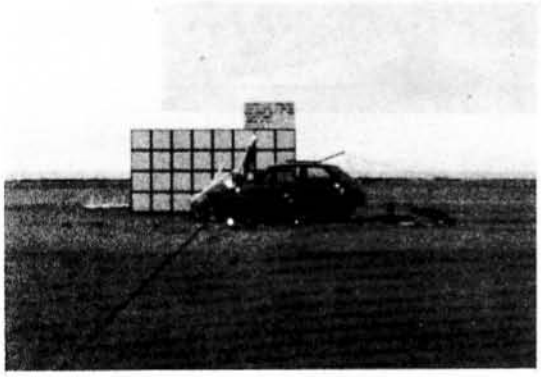
Time (sec)	Event
0.000	Impact
0.008	Lower vertical supports begin to fracture
0.048	Barricade collapses and sign approaches vehicle
0.073	Sign contacts windshield of vehicle
0.106	Sign slides over top of vehicle
0.194	Sign slides off back end of vehicle



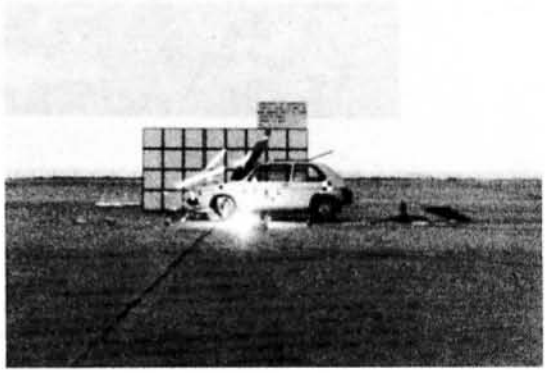
Impact



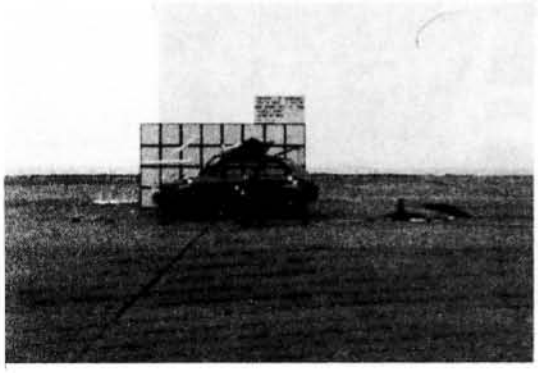
0.008 s



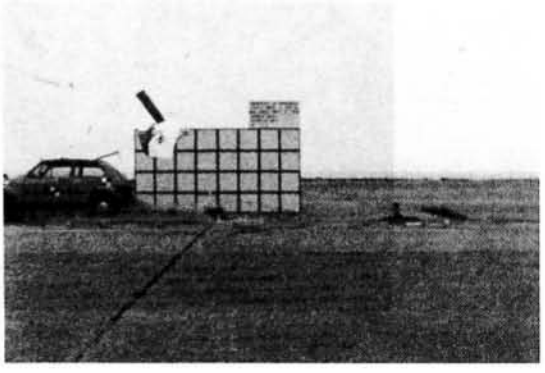
0.048 s



0.073 s

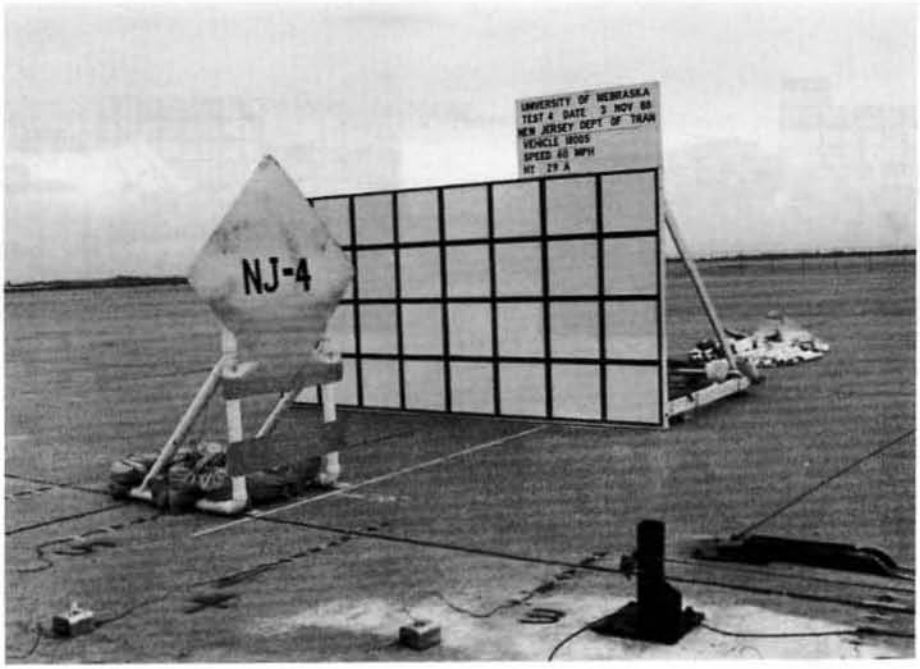


0.106 s



0.194 s

FIGURE 19. Sequential Photos of Test No. 4



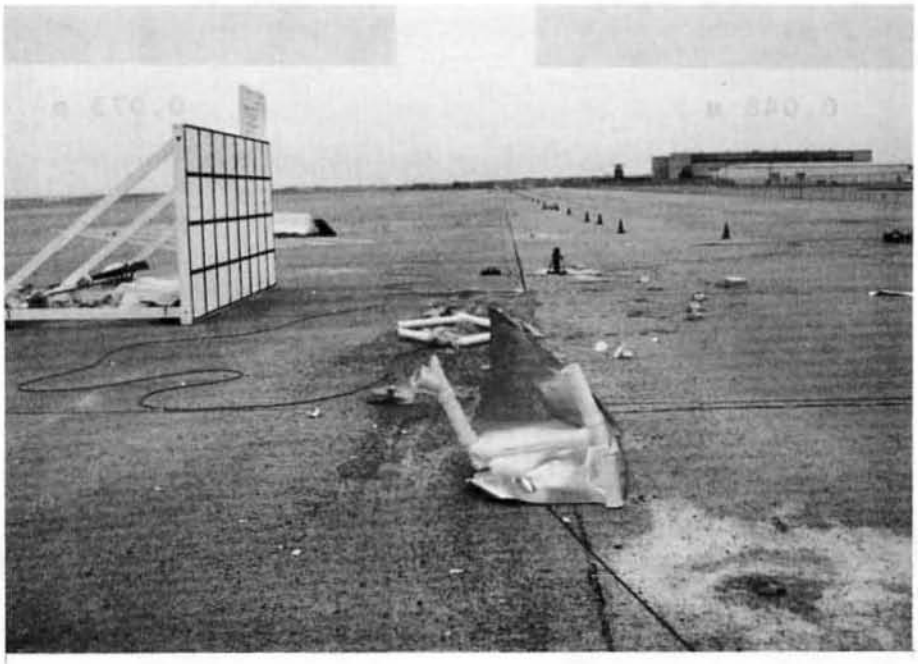
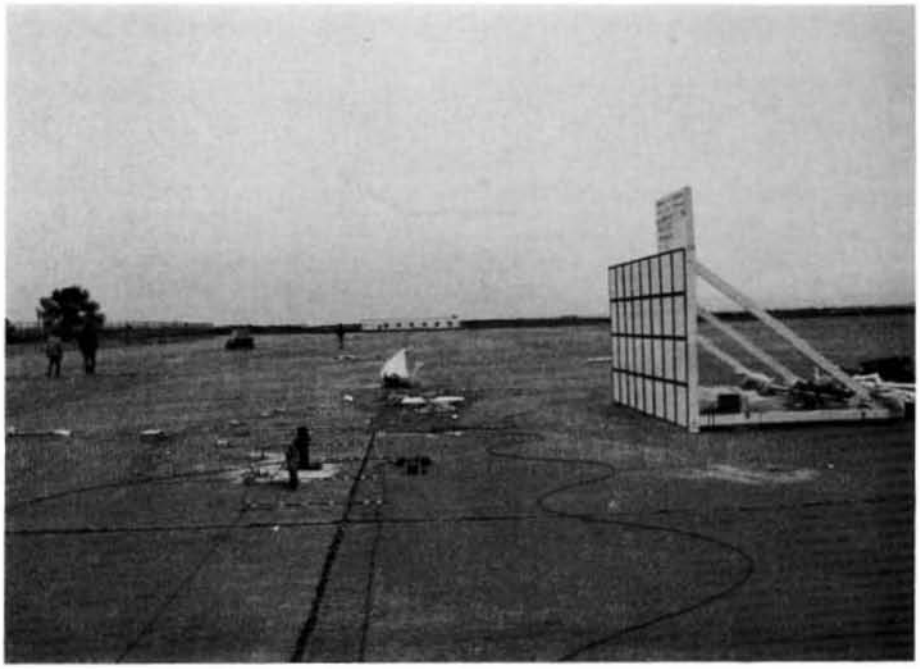


FIGURE 20. Photographs of Barricade Before and After Test No. 4



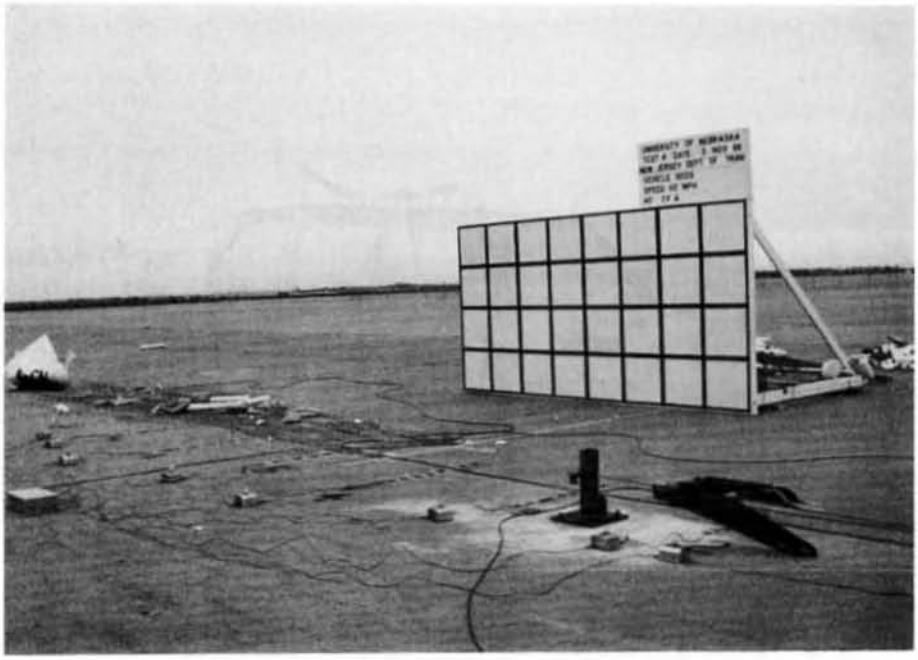


FIGURE 21. Photographs of Vehicle and Barricade After Test No. 4

FIGURE 22. Photographs of Vehicle Before and After Test No. 4

B.3 Tests No.'s 5 and 6

Tests no.'s 5 and 6 were conducted using an aluminum sign panel with a clearance height of 41-in. and 400 lbs. of sand to ballast the barricade. The barricade was extended up two feet to accomodate the higher sign. Figure 23 shows a schematic of the barricade used in both of the tests and summaries of these tests are given in Tables 11 and 13 for tests no.'s 5 and 6 respectively. Table 12 gives a time-event summary of the sequential photographs in Figure 24 for test no. 5 and Table 14 gives a time-event summary of the sequential photographs in Figure 28 for test no. 6.

In test no. 5, which was conducted at a target impact speed of 20 mph, the barricade again collapsed and the barricade debris piled-up underneath the front end of the vehicle as in tests no. 1 and test no. 3. The barricade continued to push the debris until the vehicle came to a stop 33-ft beyond the point of impact. The pile-up of barricade debris caused a higher 'g' force than one might expect, as shown in Table 11. The sign panel detached from the barricade and was projected over the vehicle coming to a resting point which was 11-ft beyond the point of impact. The vehicle received no damage. Photographs of the test vehicle and barricade, before and after impact, are shown if Figures 25, 26, and 27.

Test no. 6 was conducted at a target impact speed of 60 mph. At impact, the barricade shattered and pieces of PVC pipe were projected from the barricade. Again the sign panel detached from

the barricade and was projected over the the vehicle landing 10-ft. beyond its initial position before impact. The vehicle traveled 285-ft. beyond the point of impact and received a small amount of damage to the two front corners of its hood as a result of the impact. The accelerometer data cable broke in this test so the high-speed film was used for analyzing purposes. It should be noted here that not enough data could be obtained from the high-speed film to get the time at which the occupant 24-in. flail space would have occurred; therefore, the occupant impact velocity and the occupant ridedown acceleration are not available for this test. However, looking at the vehicle's change-in-velocity plot in Appendix C, one can see that the curve starts to level out near the end of the plot; thus, one may assume that at the time the occupant reaches the 24-in. flail space, the change-in-velocity would be around the 15 fps range. Also, looking at the deceleration curve, one may assume that the maximum deceleration experienced by the occupant would not be much more than 2.5 g's. Figures 29, 30, and 31 show photographs of the barricade and test vehicle before and after impact.

NOTE:

All dimensions on full pipe length.

Socket depth of fittings is 1 1/2".

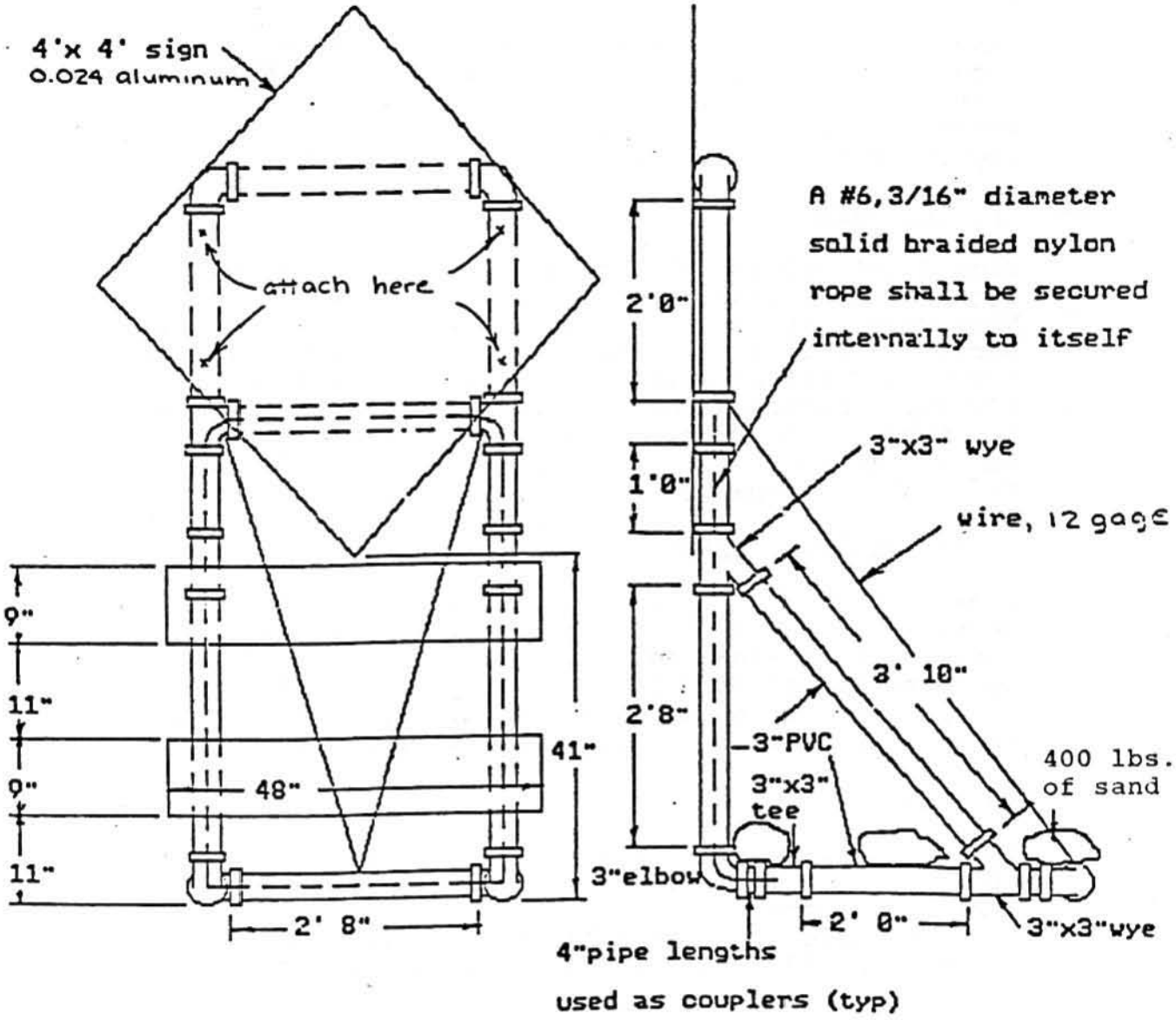


FIGURE 23. Breakaway Barricade For Test No. 5 and Test No. 6

TABLE 11.

SUMMARY OF TEST RESULTS FOR TEST NO. 5

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	41 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	20.2 mph
Duration of Event[a]	254 msec
Vehicle Change-in-Speed	10.5 fps
Occupant Impact Velocity	13.4 fps
Occupant Ridedown Acceleration	5.83 g's
Impact Severity	25.0 ft-kips

VEHICLE DAMAGE

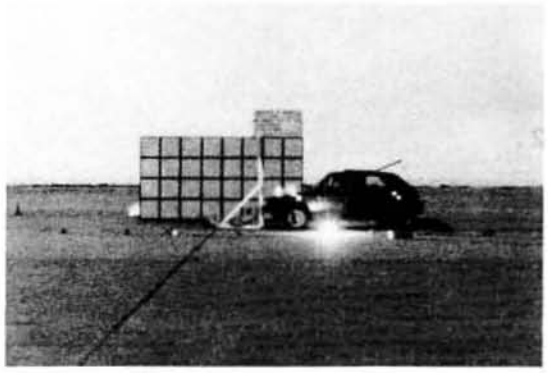
TAD	FD-0
VDI	None
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	No

(a) Determined from accelerometer trace.

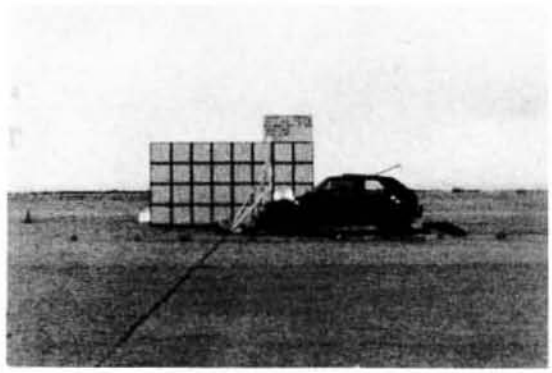
TABLE 12.

TIME-EVENT SUMMARY FOR TEST NO. 5

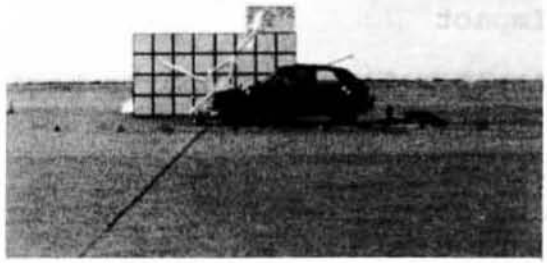
Time (sec)	Event
0.000	Impact
0.017	Lower vertical supports begin to fracture
0.125	Sign separates from barricade and debris begins projectile motion
0.271	Front end of vehicle begins uplift due to sandbags piling up under vehicle
0.333	Airborne sign begins falling toward vehicle
0.452	Sign is on top of vehicle



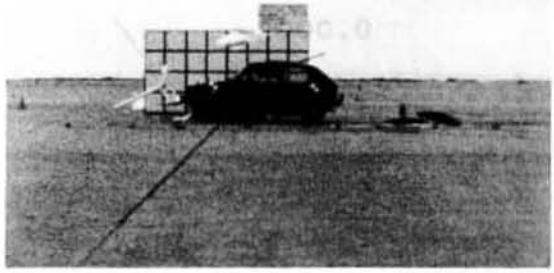
Impact



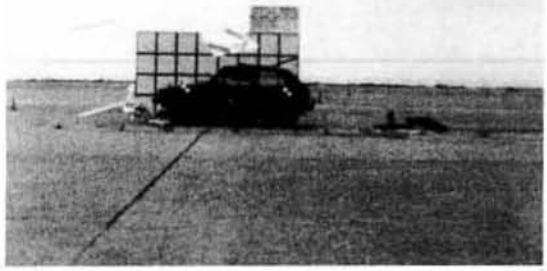
0.017 s



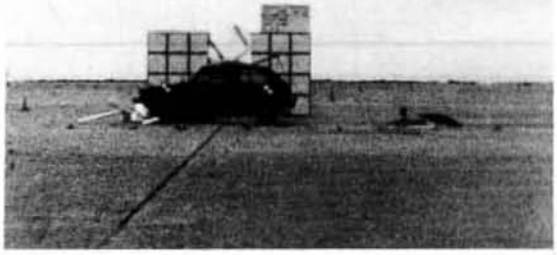
0.125 s



0.271 s

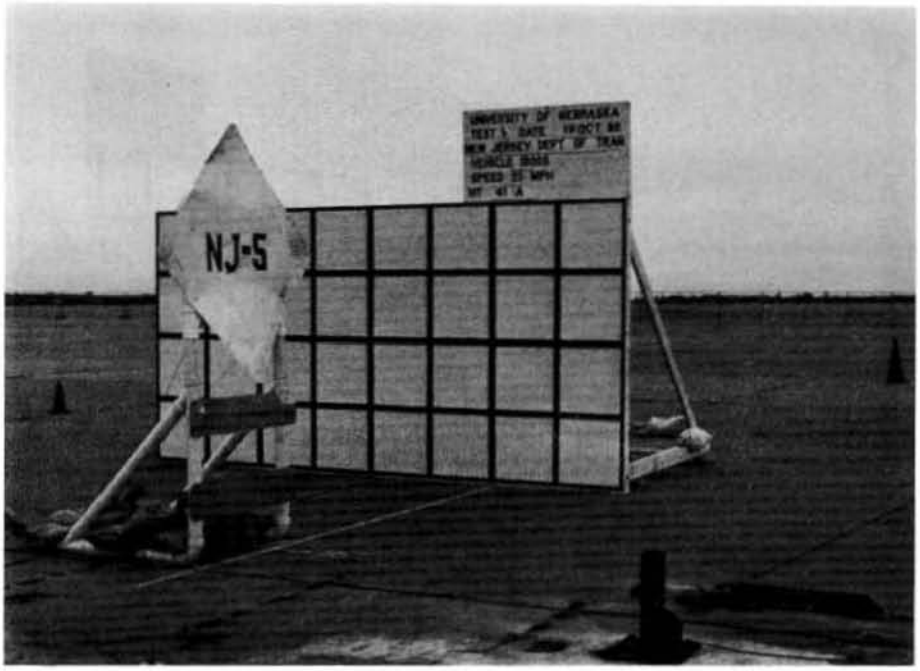


0.333 s



0.452 s

FIGURE 24. Sequential Photos of Test No. 5



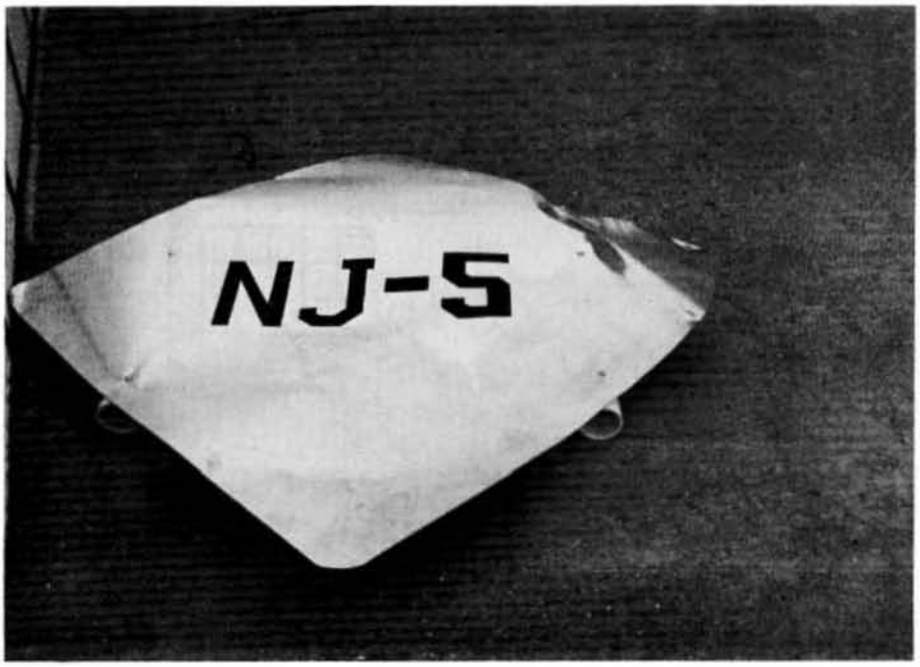


FIGURE 25. Photographs of Barricade Before and After Test No. 5

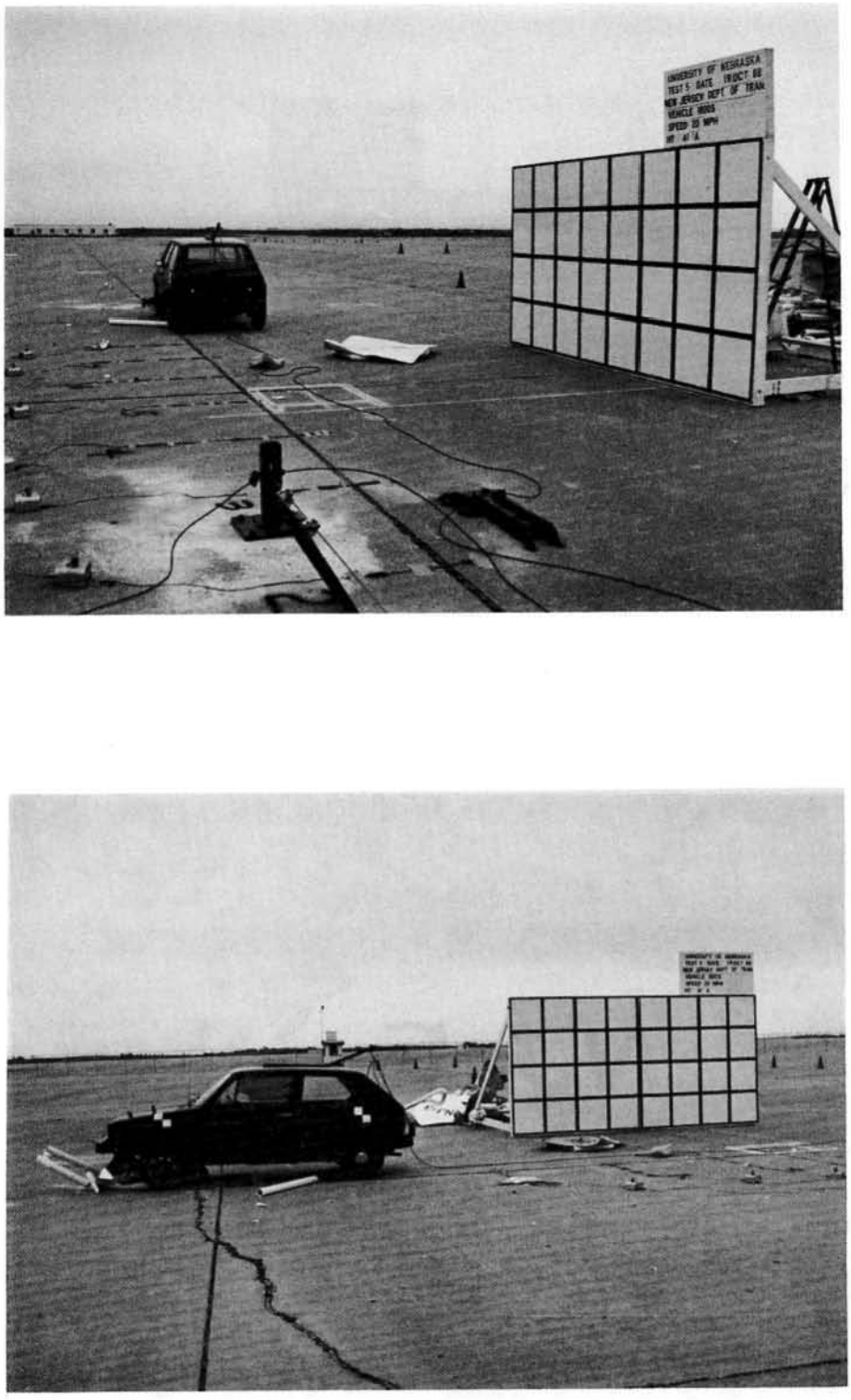


FIGURE 26. Photographs of Vehicle and Barricade After Test No. 5

FIGURE 27. Photographs of Vehicle Before and After Test No. 5

TABLE 13.

SUMMARY OF TEST RESULTS FOR TEST NO. 6

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1840
Impact Point	1 Post at 1/4 Point of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	41 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	62.2 mph
Duration of Event	N.A.[a]
Vehicle Change-in-Speed	14.3 fps[b]
Occupant Impact Velocity	N.A.[a]
Occupant Ridedown Acceleration	N.A.[a]
Impact Severity	237.4 ft-kips

VEHICLE DAMAGE

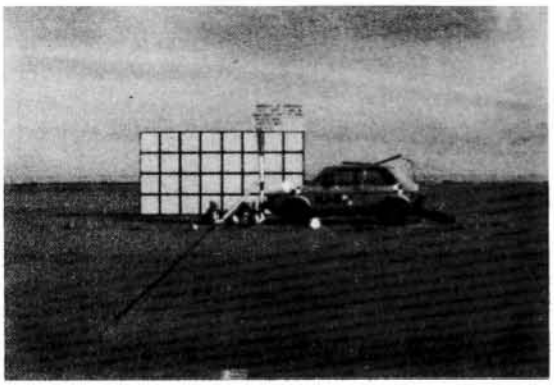
TAD	FD-1
VDI	12FDHN6
Passenger Compartment Intrusion By Test Article	No
Was Windsheild Broken ?	No

(a) Accelerometer data cable broke. See Test No. 6 summary.
(b) Arbitrarily taken at 170 msec to compare to other 60 mph tests. (170 msec is average change in speed for tests No.'s 4,8,& 12)

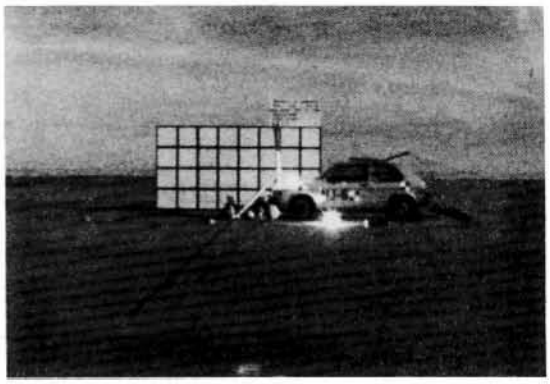
TABLE 14.

TIME-EVENT SUMMARY FOR TEST NO. 6

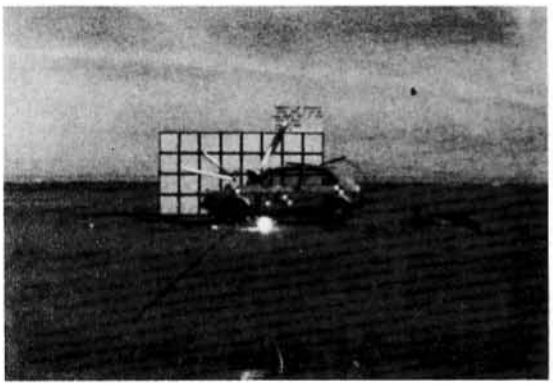
Time (sec)	Event
0.000	Impact
0.008	Lower vertical supports begin to fracture
0.069	Barricade debris begins projectile motion
0.121	Sign flies over top of vehicle
0.198	Rear left tire of vehicle is raised off concrete
0.346	Sign begins descent



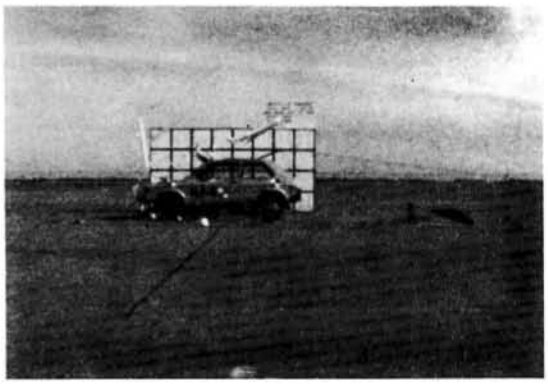
Impact



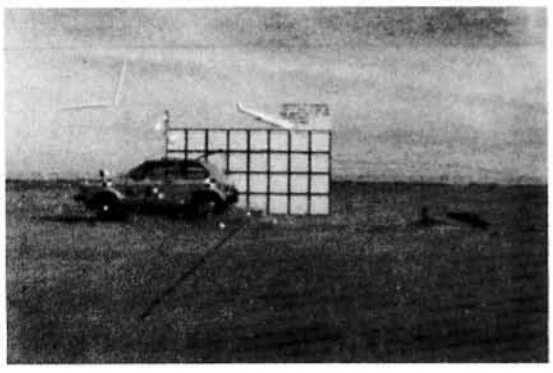
0.008 s



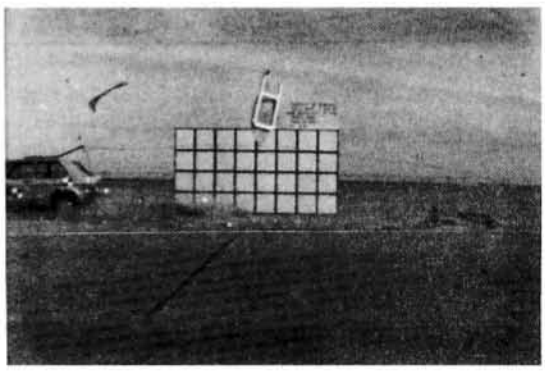
0.069 s



0.121 s

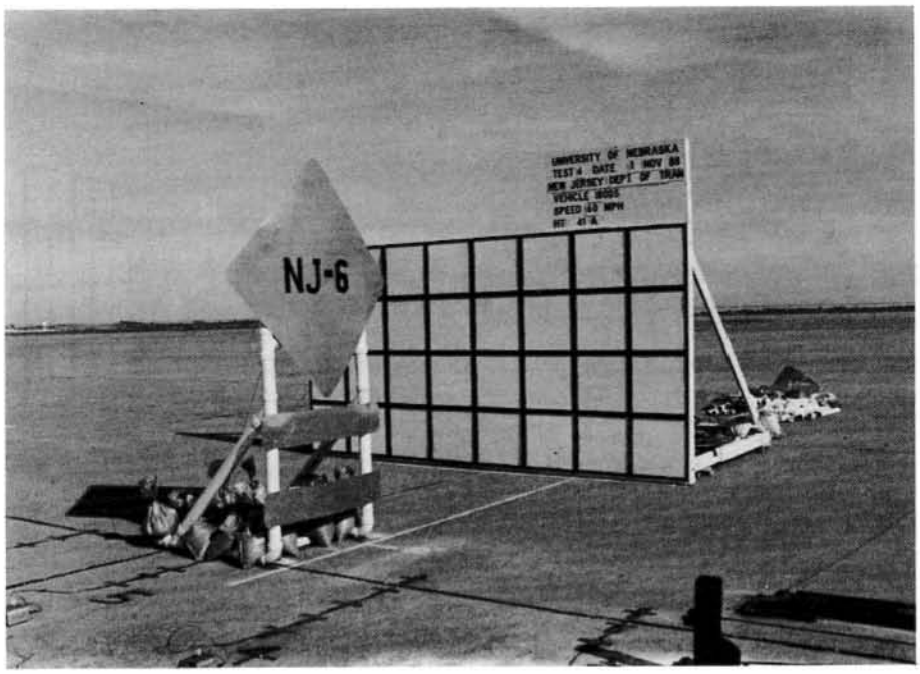


0.198 s



0.346 s

FIGURE 28. Sequential Photos of Test No. 6



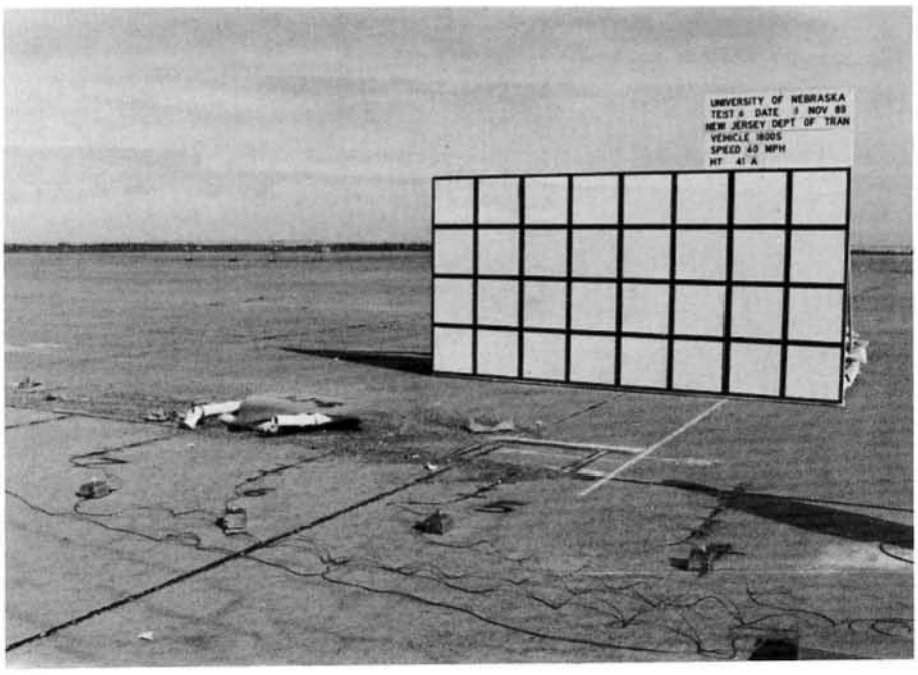


FIGURE 29. Photographs of Barricade Before and After Test No. 6

FIGURE 30. Photographs of Vehicle and Barricade After Test No. 6

FIGURE 31. Photographs of Vehicle Before and After Test No. 6

B.4 Tests No.'s 7 and 8

The clearance height of the aluminum sign panel in tests no.'s 7 and 8 was also 41-in. as in tests no.'s 5 and 6 as shown in Figure 32. In these tests, 400 lbs. of sand were also used to ballast the barricades, but what made tests no.'s 7 and 8 different from tests no.'s 5 and 6, was the point of impact between the vehicle and the barricade. In tests no.'s 7 and 8 only one upright post on the barricade was impacted at the center of the vehicle's bumper. This was at the discretion of NJDOT to evaluate the results of these tests if only one post of the barricade was impacted instead of two. A summary of the results for test no. 7 is given in Table 15, while a summary of the results for test no. 8 is given in Table 17. Tables 16 and 18 give time-event summaries of the sequential photographs in Figures 33 and 37 for tests no.'s 7 and 8 respectively.

Test no. 7 was conducted at a target impact speed of 20 mph. The upright post of the barricade on the driver's side was the only post impacted during this test. At impact, the barricade collapsed and the sign panel detached from the barricade. The sign then proceeded over the vehicle where it hit the coaxial cable support bar used to support the accelerometer data cable. After the sign hit the support bar, it was deflected left and landed 21-ft. beyond the point of impact. The vehicle traveled 45-ft. past the point of impact and veered 8-ft. to the right of its initial path. No damage was done to the vehicle. Figures 34, 35, and 36 show photographs of the barricade and the test

vehicle before and after the test.

In test no. 8, which was conducted at a target impact speed of 60 mph, again only the left upright post of the barricade was impacted. The barricade collapsed at impact and some pieces of PVC were projected. The sign panel did not detach , but just fell to the side after the post on the driver's side was impacted. The vehicle came to rest 405-ft. beyond the point of impact and did receive some minor damage. The damage was a broken windshield and a dent on the front center of the hood. Before and after photographs of the test vehicle and barricade are shown in Figures 38, 39, and 40 .

NOTE:

All dimensions on full pipe length.

Socket depth of fittings is 1 1/2".

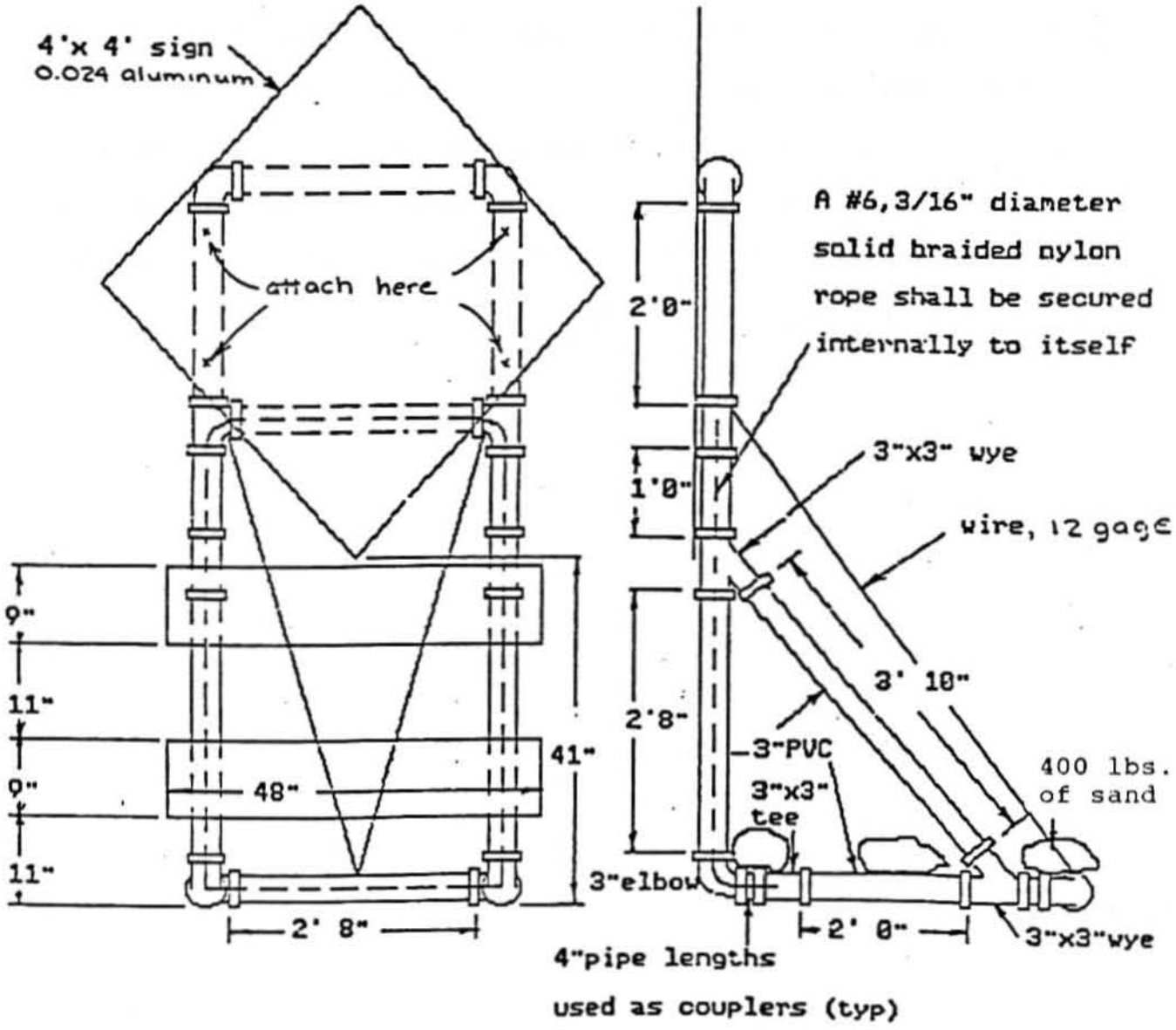


FIGURE 32. Breakaway Barricade For Test No. 7 and Test No. 8

TABLE 15.

SUMMARY OF TEST RESULTS FOR TEST NO. 7

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	1 Post at Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	41 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	1 (on driver's side)

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	20.7 mph
Duration of Event[a]	164 msec
Vehicle Change-in-Speed	7.6 fps
Occupant Impact Velocity	10.1 fps
Occupant Ridedown Acceleration	0.9 g's
Impact Severity	26.3 ft-kips

VEHICLE DAMAGE

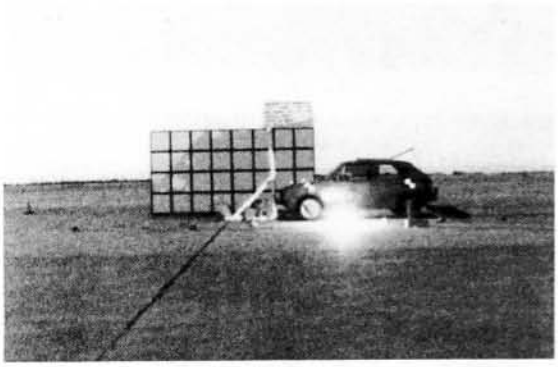
TAD	FD-0
VDI	None
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	No

(a) Determined from accelerometer trace.

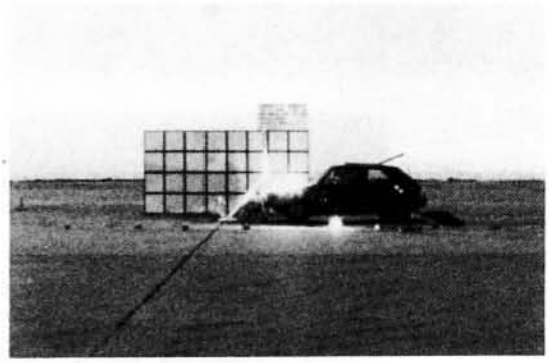
TABLE 16.

TIME-EVENT SUMMARY FOR TEST NO. 7

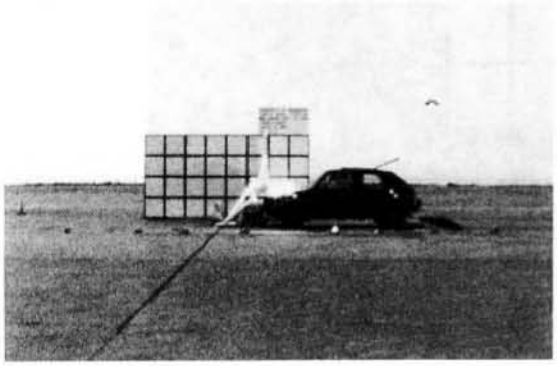
Time (sec)	Event
0.000	Impact
0.015	Lower vertical supports begin to fracture
0.027	Slanted supports are disengaged from barricade
0.069	Barricade collapses
0.267	Sign begins to fly over vehicle
0.490	Sign hits coaxial cable support bar and is deflected to the side
0.812	Sign slides off to the right hand side of the vehicle
1.344	Sign is on the concrete



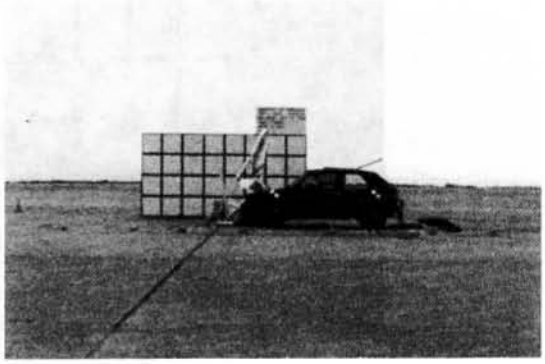
Impact



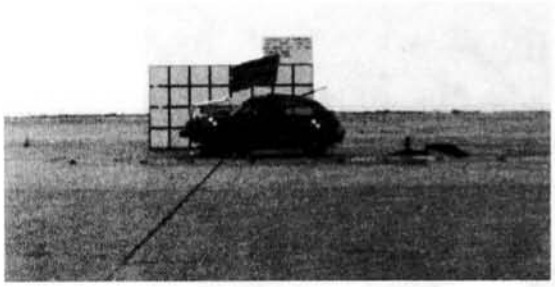
0.015 s



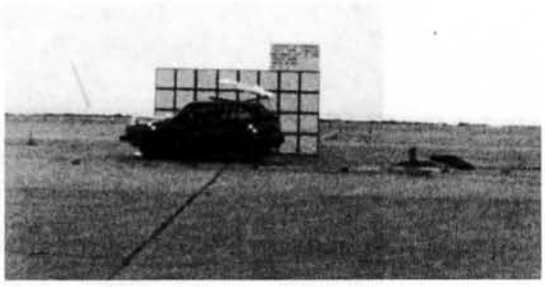
0.027 s



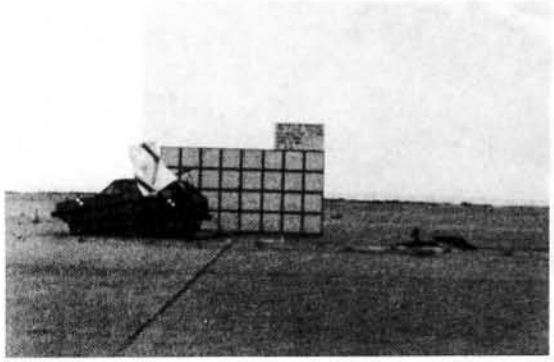
0.069 s



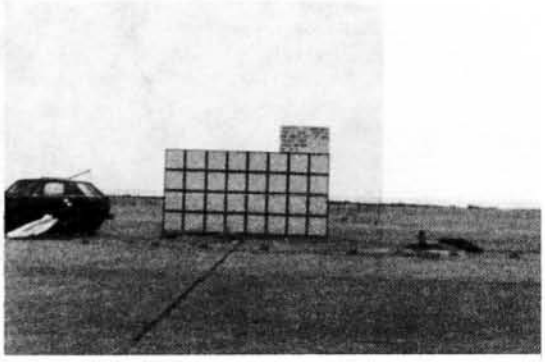
0.267 s



0.490 s



0.812 s



1.344 s

FIGURE 33. Sequential Photos of Test No. 7

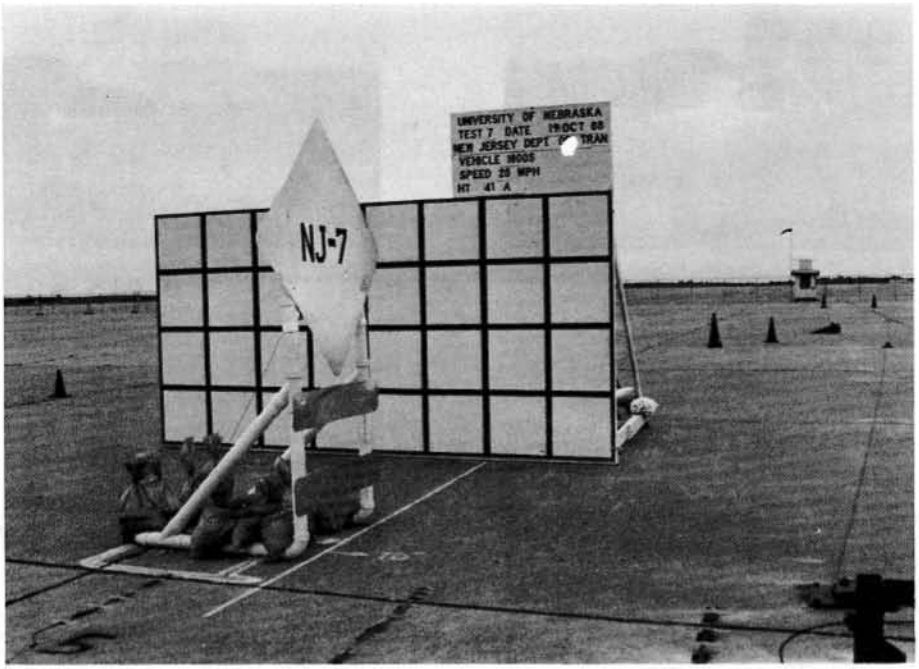


FIGURE 34. Photographs of Barricade Before and After Test No. 7

FIGURE 35. Photographs of Vehicle and Barricade After Test No. 7

FIGURE 36. Photographs of Vehicle Before and After Test No. 7

TABLE 17.

SUMMARY OF TEST RESULTS FOR TEST NO. 8

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1840
Impact Point	1 Post at Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	41 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	24 Ga. Alum.
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	1 (on driver's side)

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	62.9 mph
Duration of Event[a]	190 msec
Vehicle Change-in-Speed	13.8 fps
Occupant Impact Velocity	14.1 fps
Occupant Ridedown Acceleration	1.4 g's
Impact Severity	243.1 ft-kips

VEHICLE DAMAGE

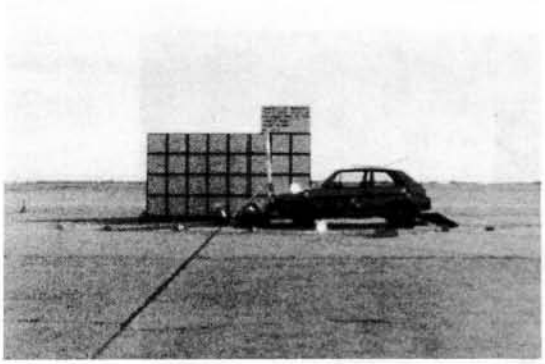
TAD	FC-1
VDI	12FCHN6
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	Yes[b]

(a) Determined from accelerometer trace.
(b) Middle of windshield on passenger's side.

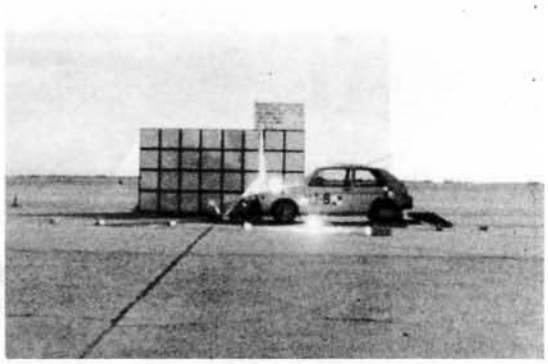
TABLE 18.

TIME-EVENT SUMMARY FOR TEST NO. 8

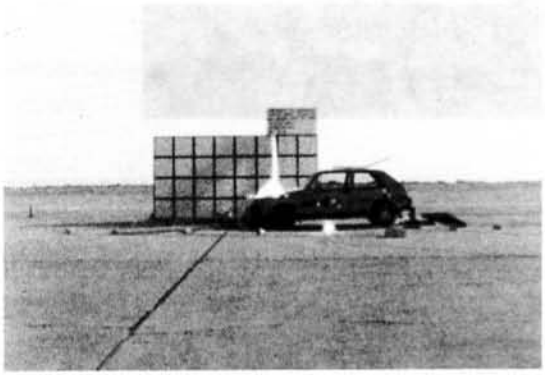
Time (sec)	Event
0.000	Impact
0.010	Lower vertical supports begin to fracture
0.023	Slanted barricade supports are fractured
0.071	Sign is directly above hood of vehicle
0.121	Sign is above roof of vehicle and debris is being projected
0.229	Vehicle is separated from the majority of barricade debris



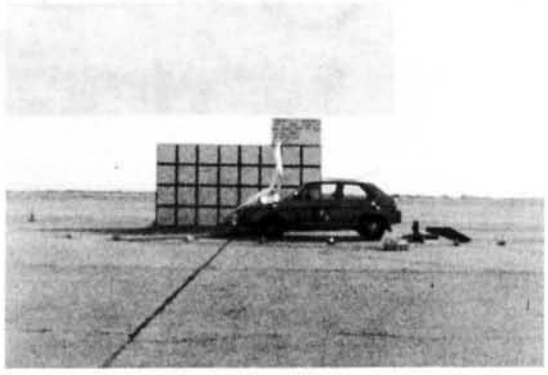
Impact



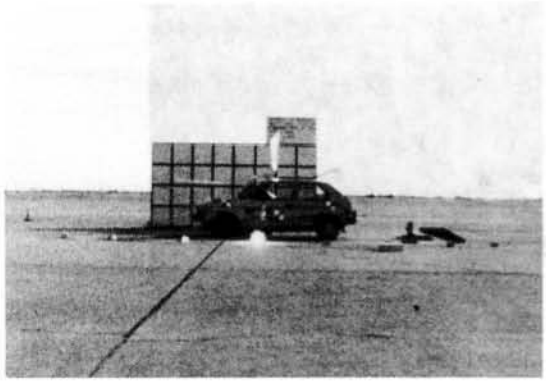
0.010 s



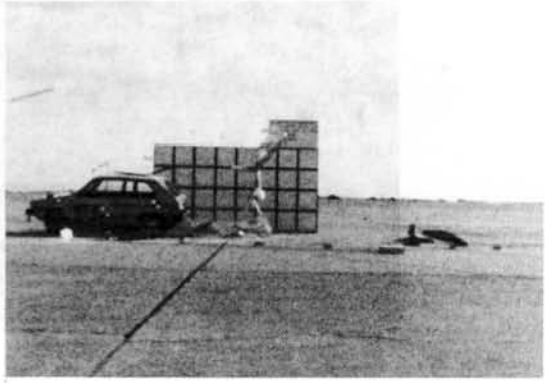
0.023 s



0.071 s



0.121 s



0.229 s

FIGURE 37. Sequential Photos of Test No. 8

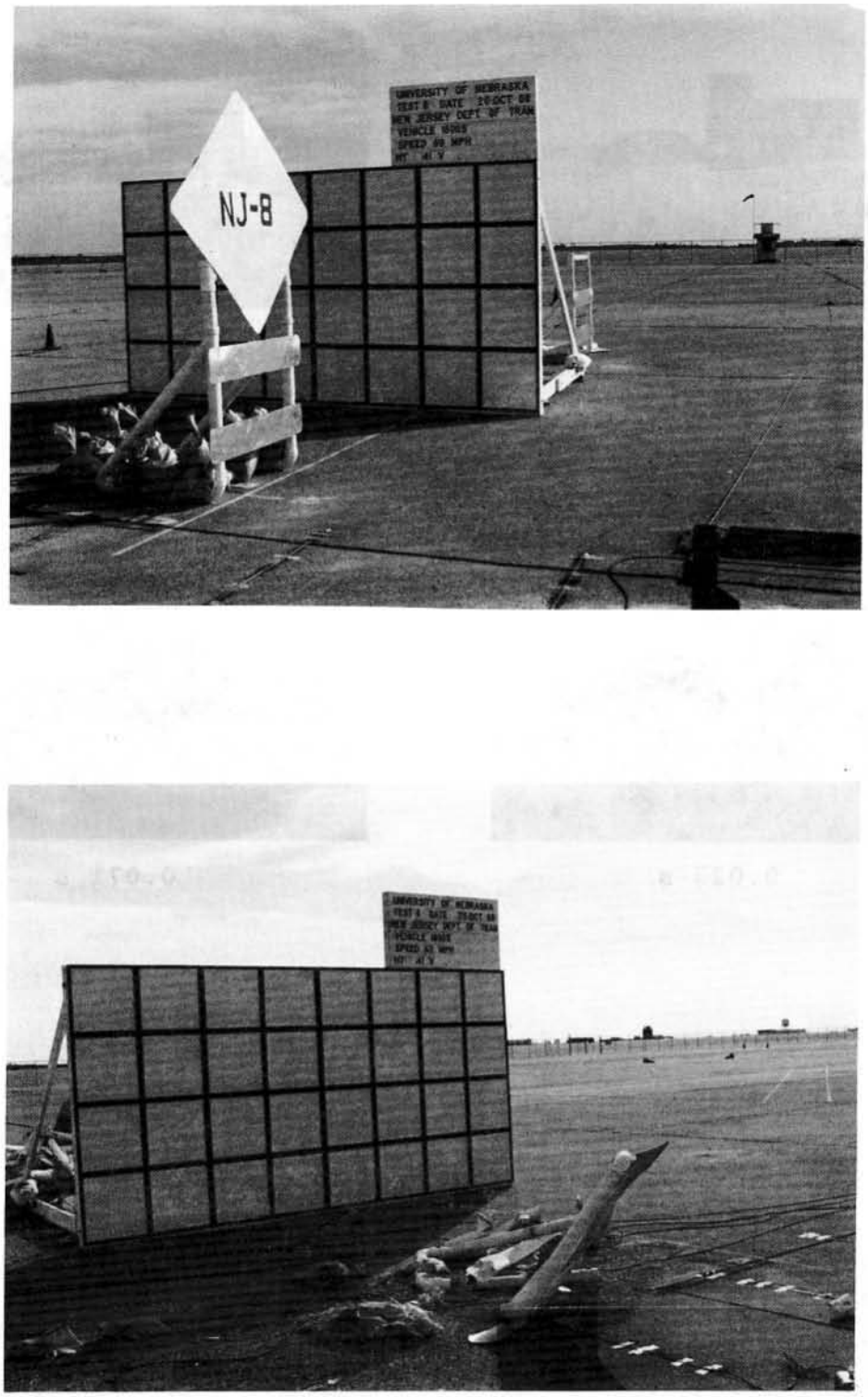


FIGURE 38. Photographs of Barricade Before and After Test No. 8

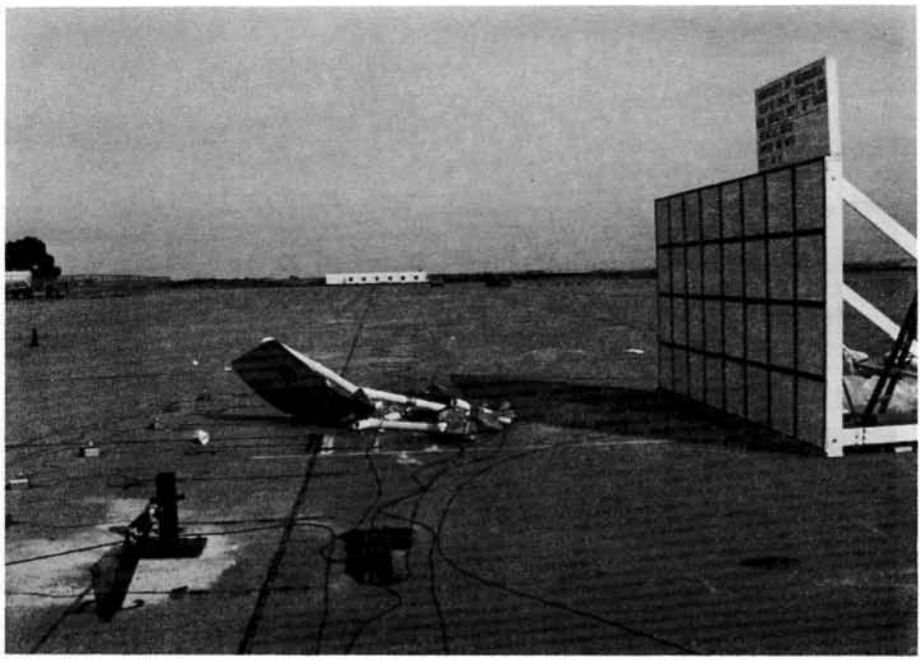


FIGURE 39. Photographs of Vehicle and Barricade After Test No. 8

FIGURE 40. Photographs of Vehicle Before and After Test No. 8

B.5 Tests No.'s 9 and 10

In tests no.'s 9 and 10 the clearance height of the sign panels were 38-in. The sign panels were made of a vinyl reflective sheeting and 400 lbs. of sand were used in ballasting the barricades. Figure 41 shows a schematic of the barricade used in conducting these tests and Tables 19 and 21 give summaries of tests no.'s 9 and 10 respectively. Table 20 gives a time-event summary of the sequential photographs in Figure 42 for test no. 9 and Table 22 gives a time-event summary of the sequential photographs in Figure 46 for test no. 10. Test no. 9 was conducted at a target impact speed of 20 mph while test no. 10 was conducted at a target impact speed of 60 mph.

In test no. 9 the barricade collapsed upon impact without projecting many pieces of PVC pipe. The debris from the barricade stayed in front of the vehicle and piled-up underneath the vehicle's front end. The vehicle rode up on some the barricade debris and continued to push the rest out infront of it until its final stopping distance of 33-ft. past the point of impact. The sign panel detached from the barricade and impacted the front windshield of the vehicle. The sign then proceeded to go over the vehicle but came to a rest on the roof of the vehicle. This final resting place for the sign might have been caused by the sign getting caught on the coaxial cable support bar that is mounted on the roof of the vehicle. The only damage done to the vehicle was a small 'chip' in the windshield due to the impact of the sign panel. Photographs of the barricade and

test vehicle, before and after the test, are shown in Figures 43, 44, and 45.

In test no. 10 the barricade was shattered upon impact and pieces of PVC pipe were projected from the barricade. The sign detached and was projected over the vehicle and landed 13-ft. infront of the initial position of the barricade. Figures 47 and 48 show photographs of the barricade before and after the test. In this test, the accelerometer data cable broke; therefore, all the analyses of this test were from the high-speed film. Accessing the damage to the test vehicle was impossible due to the test vehicle going through the fence which borders the test facility. The damage to the vehicle after going through the fence was far more extensive than what would be expected from the impact with the barricade; thus, the damage resulting from the impact could not be determined.

NOTE:

All dinensions on full pipe length

Socket depth of fittings is 1 1/2"

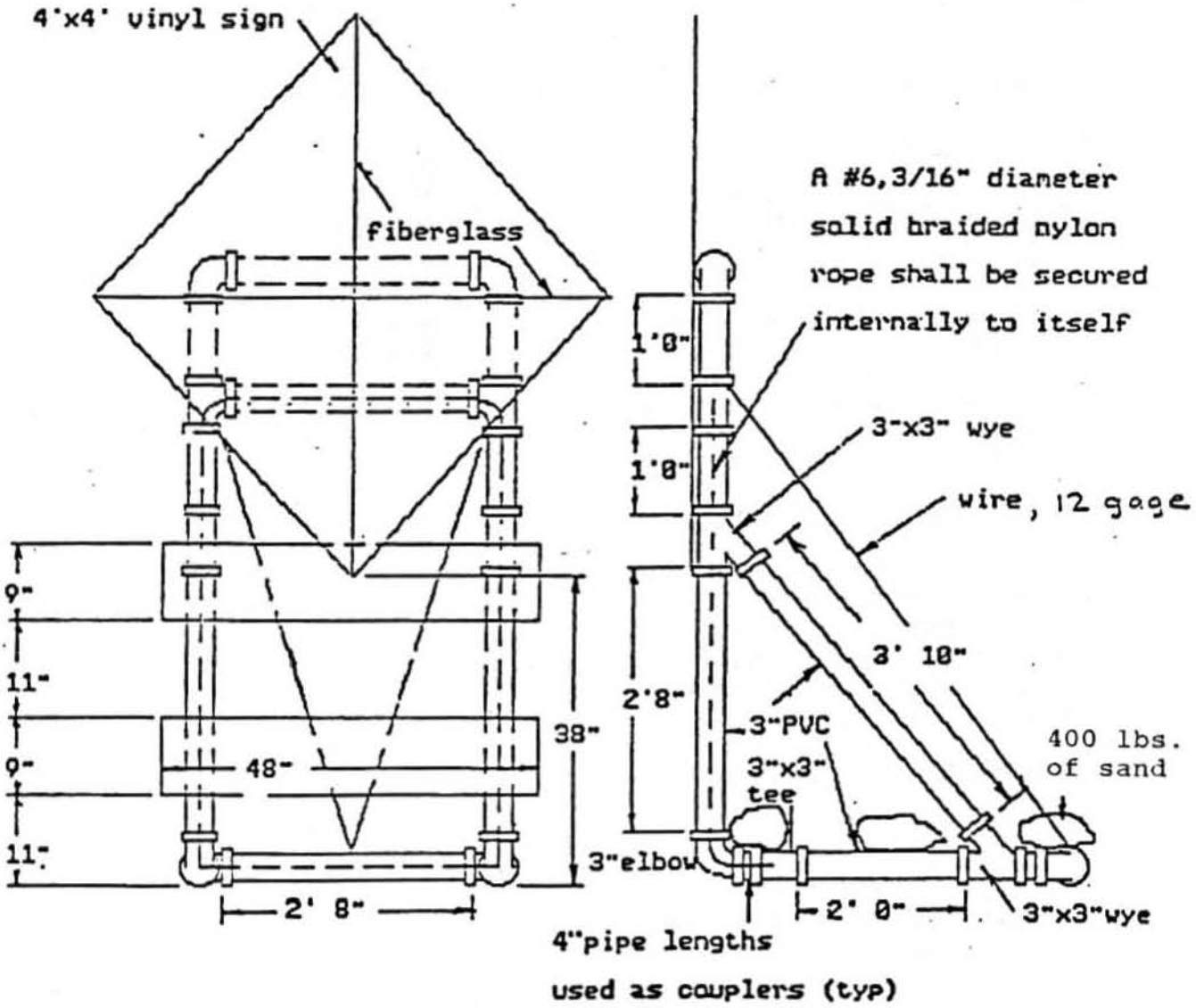


FIGURE 41. Breakaway Barricade For Test No. 9 and Test No. 10

TABLE 19.

SUMMARY OF TEST RESULTS FOR TEST NO. 9

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	38 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	Vinyl Reflective Sheeting
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	19.6 mph
Duration of Event[a]	465 msec[b]
Vehicle Change-in-Speed	10.8 fps
Occupant Impact Velocity	9.6 fps
Occupant Ridedown Acceleration	0.8 g's
Impact Severity	23.6 ft-kips

VEHICLE DAMAGE

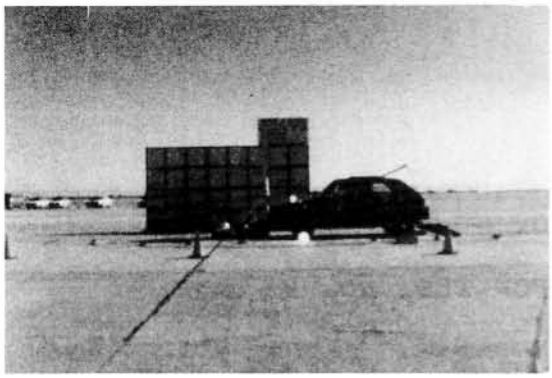
TAD	FD-0
VDI	None
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	Yes[c]

(a) Determined from accelerometer trace.
(b) Long duration due to sandbags.
(c) Round chip about the size of a half dollar on driver's side.

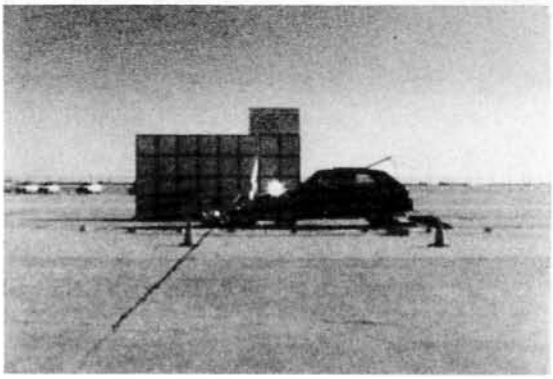
TABLE 20.

TIME-EVENT SUMMARY FOR TEST NO. 9

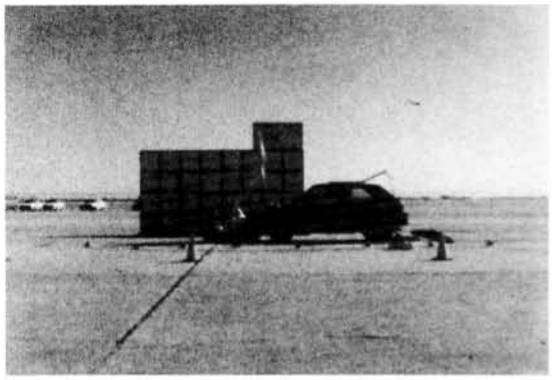
Time (sec)	Event
0.000	Impact
0.023	Lower vertical supports begin to fracture
0.046	Slanted supports are disengaged from barricade
0.131	Sign is projected over vehicle
0.379	Sign is over roof of vehicle
0.485	Sign is lying flat on roof of vehicle
0.625	Vehicle continues to proceed with sign on roof
1.229	Vehicle comes to a complete stop with sign on roof



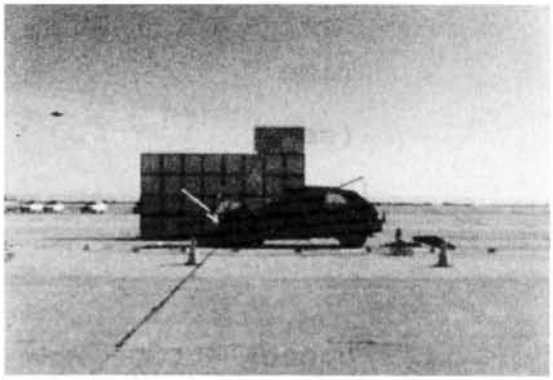
Impact



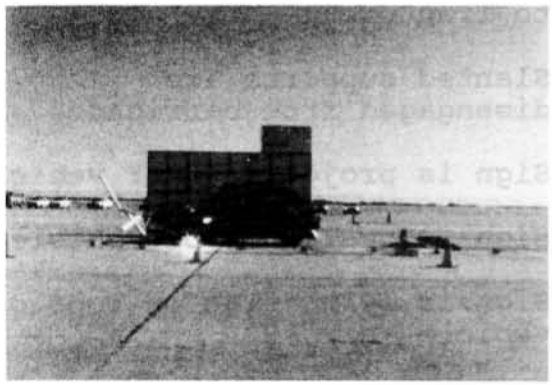
0.023 s



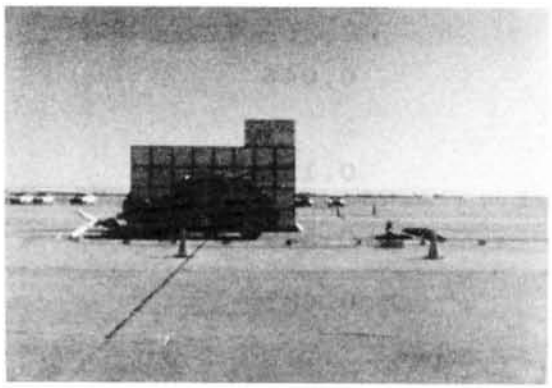
0.046 s



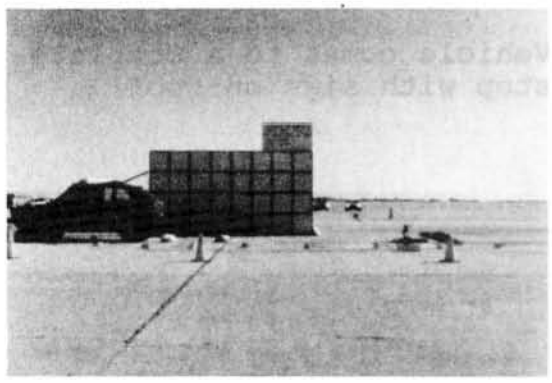
0.131 s



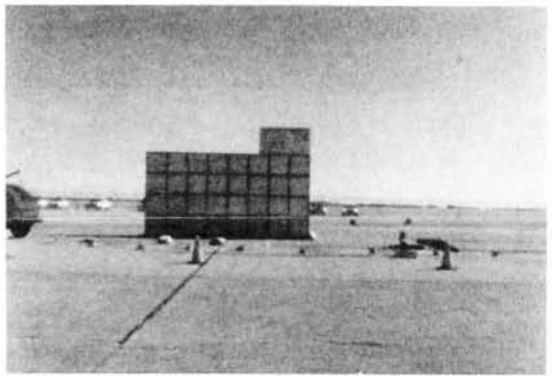
0.379 s



0.485 s



1.229 s



0.625 s

FIGURE 42. Sequential Photos of Test No. 9

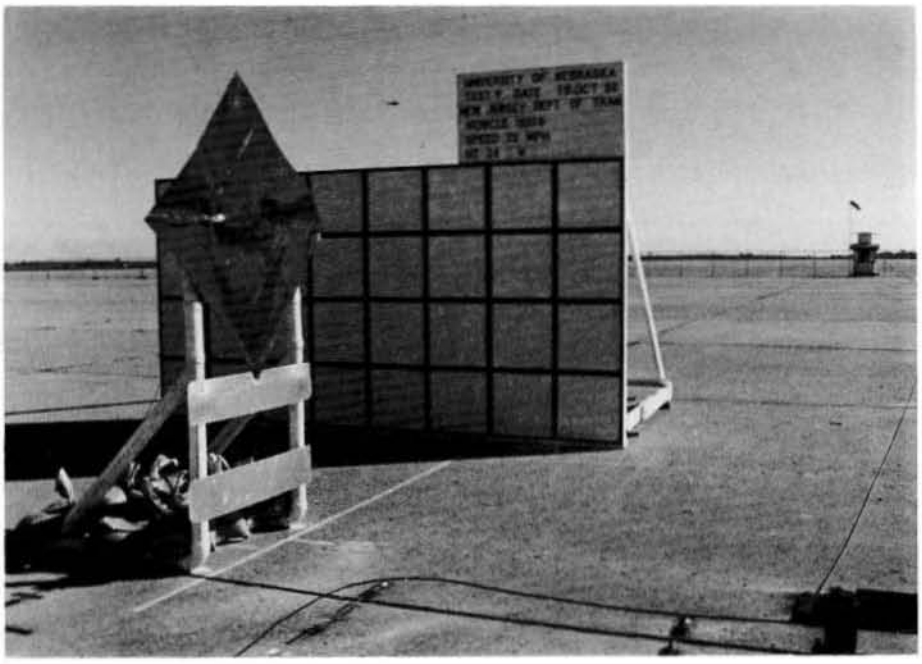
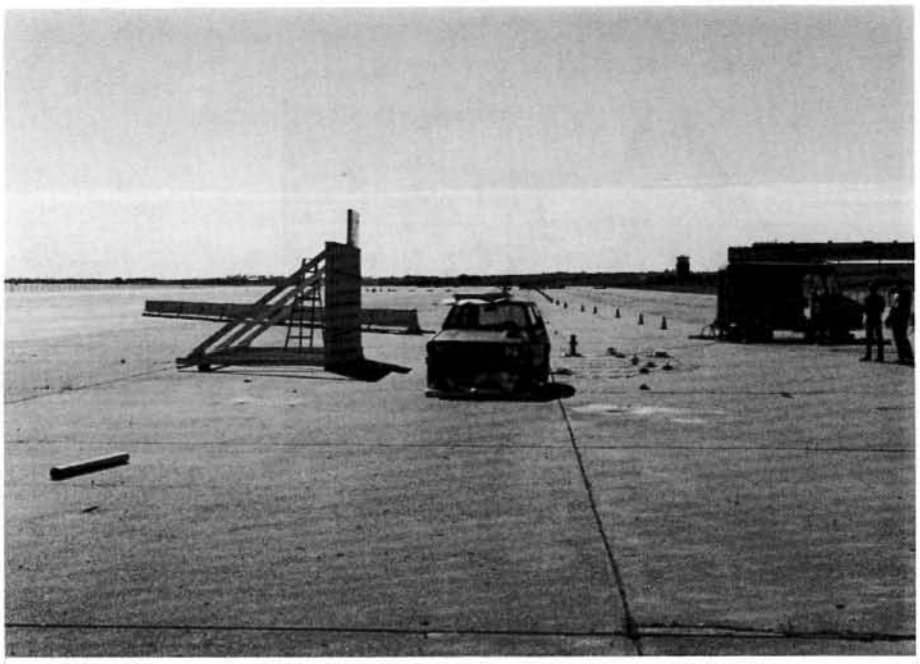


FIGURE 43. Photographs of Barricade Before and After Test No. 9



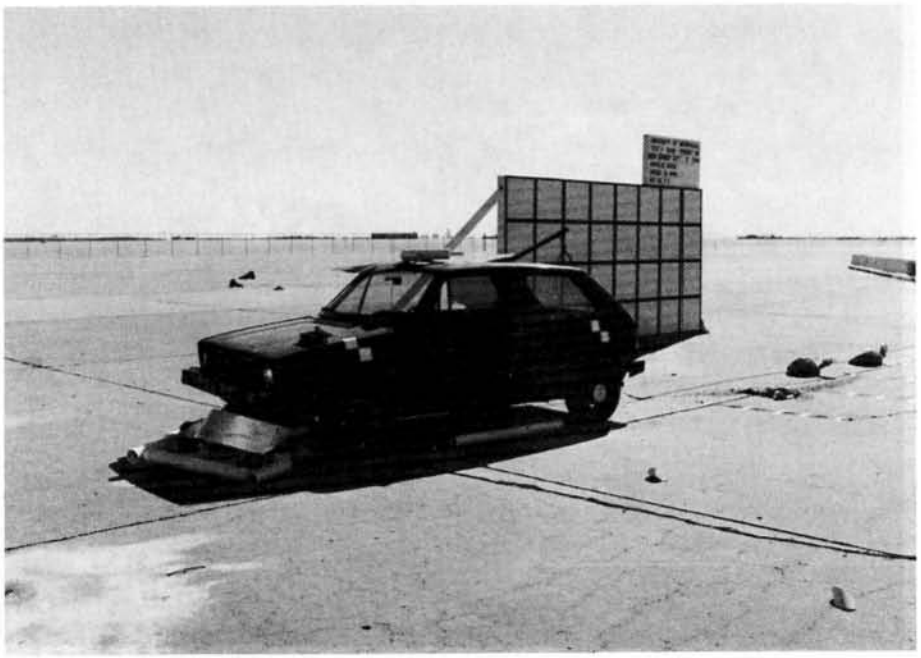


FIGURE 44. Photographs of Vehicle and Barricade After Test No. 9

FIGURE 45. Photographs of Vehicle Before and After Test No. 9

TABLE 21.

SUMMARY OF TEST RESULTS FOR TEST NO. 10

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	1 Post at 1/4 Point of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	38 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	Vinyl Reflective Sheeting
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	60.3 mph
Duration of Event[a]	N.A.[a]
Vehicle Change-in-Speed	N.A.[a]
Occupant Impact Velocity	14.9 fps[b]
Occupant Ridedown Acceleration	-2.2 g's[b]
Impact Severity	222.9 ft-kips

VEHICLE DAMAGE

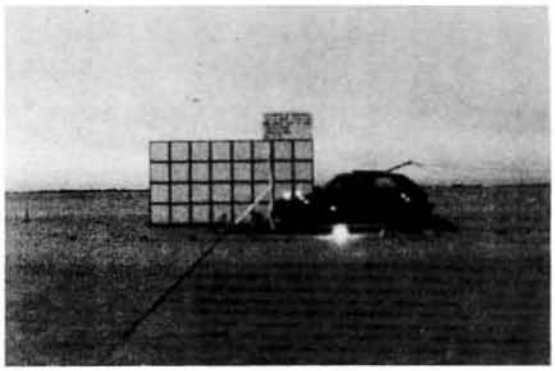
TAD	N.A.[c]
VDI	N.A.[c]
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	No

(a) Acceleromater data cable broke. This information was not available from high-speed film.
(b) Determined from the high-speed film analysis. (24-in. Flail Space Model was used)
(c) Not available due to vehicle going through fence

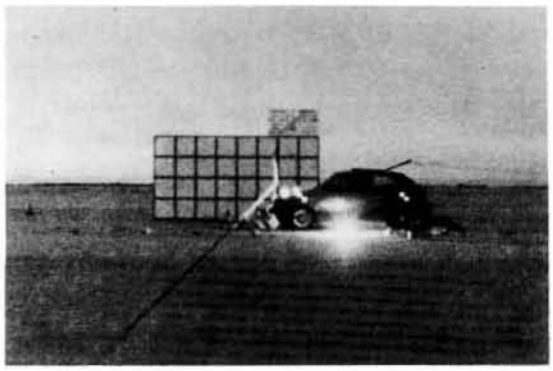
TABLE 22.

TIME-EVENT SUMMARY FOR TEST NO. 10

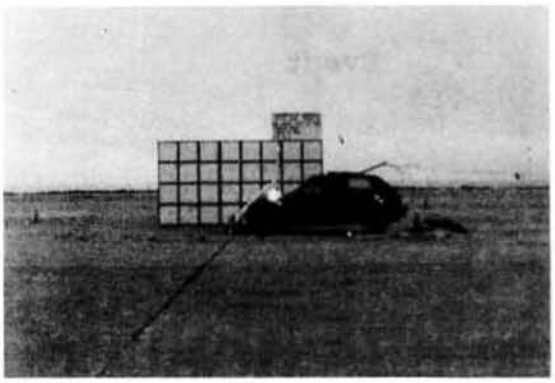
Time (sec)	Event
0.000	Impact
0.006	Lower vertical supports begin to fracture
0.031	Slanted supports are disengaged from barricade
0.044	Barricade collapses
0.062	Sign is over roof of vehicle
0.131	Sign is over rear of vehicle and barricade debris is projected
0.190	Left wheels of vehicle are off concrete
0.310	Vehicle proceeds with barricade still being projected



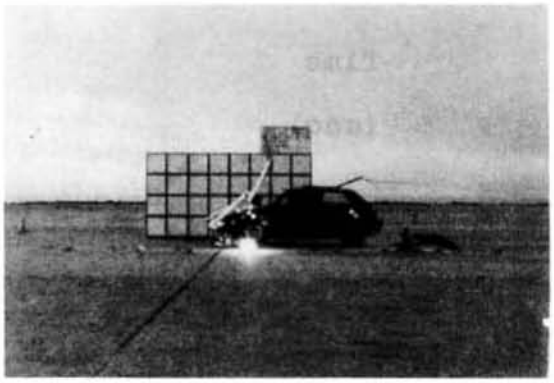
Impact



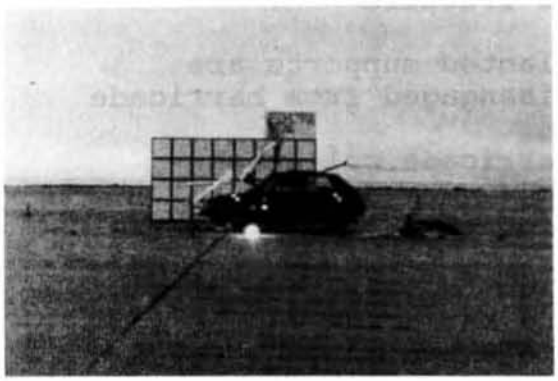
0.006 s



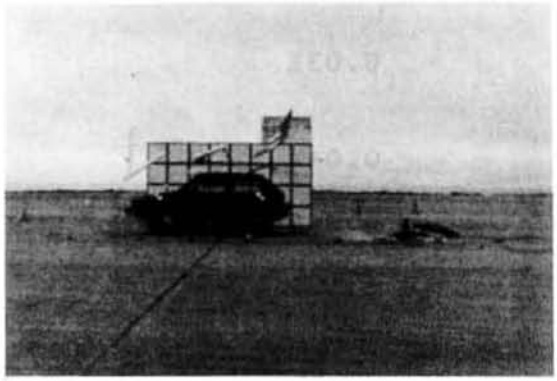
0.031 s



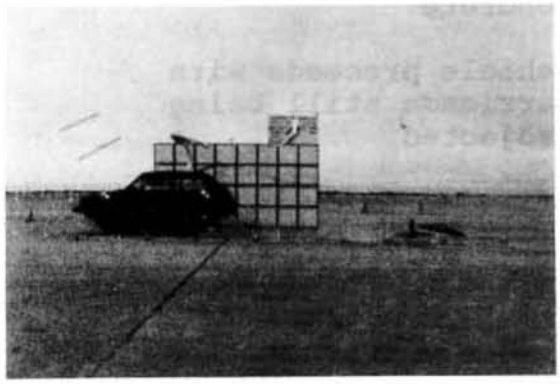
0.044 s



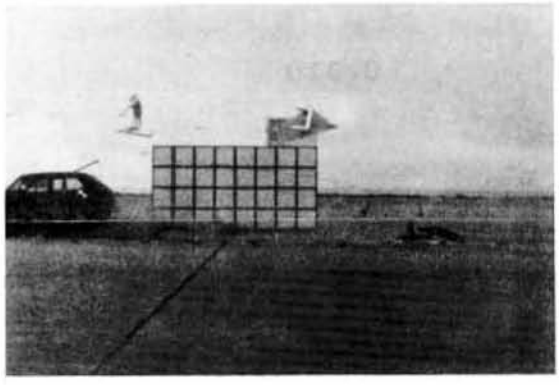
0.062 s



0.131 s

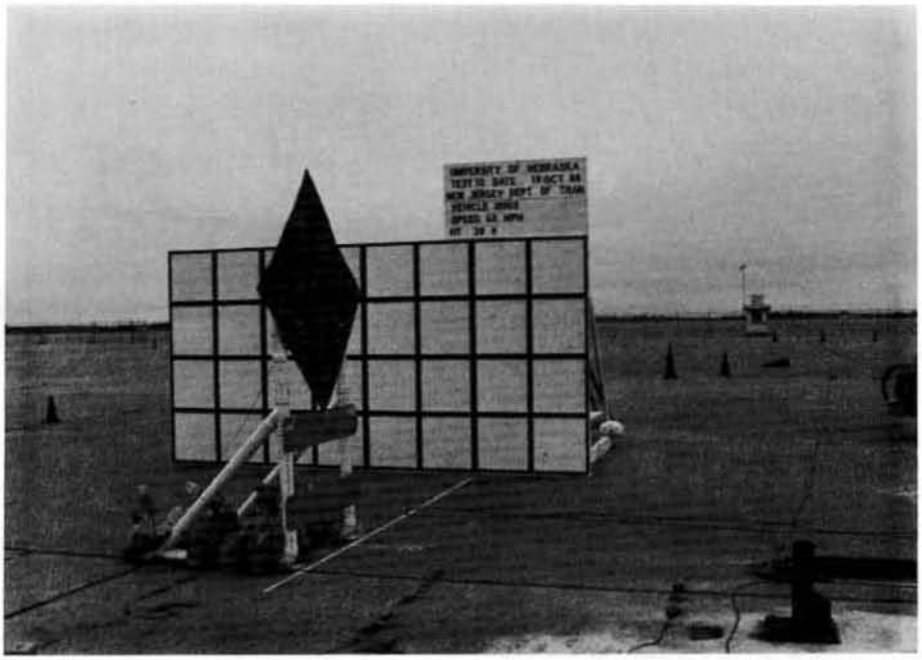


0.190 s



0.310 s

FIGURE 46. Sequential Photos of Test No. 10



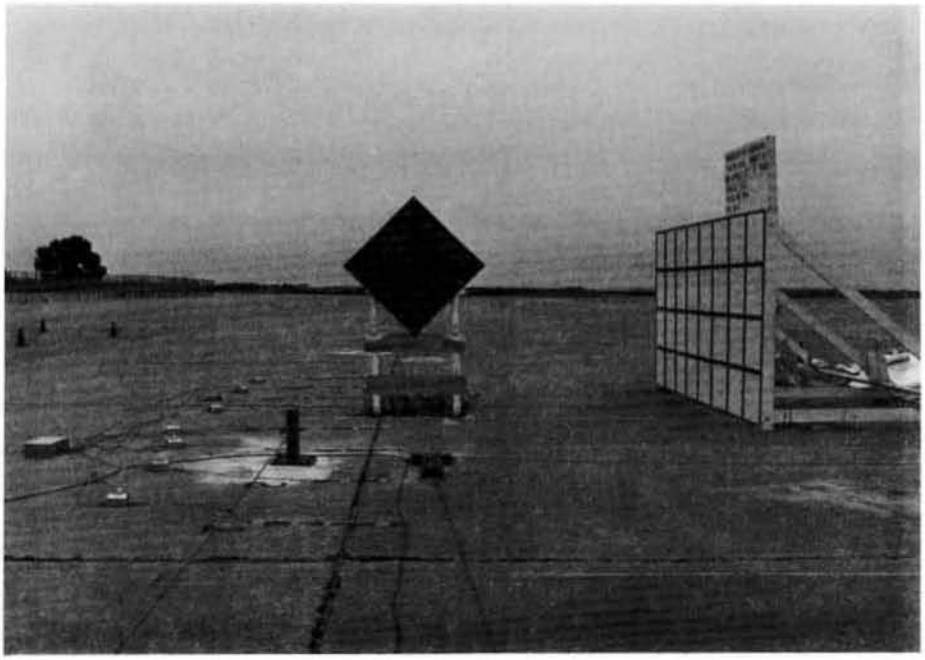


FIGURE 47. Photographs of Barricade Before Test No. 10

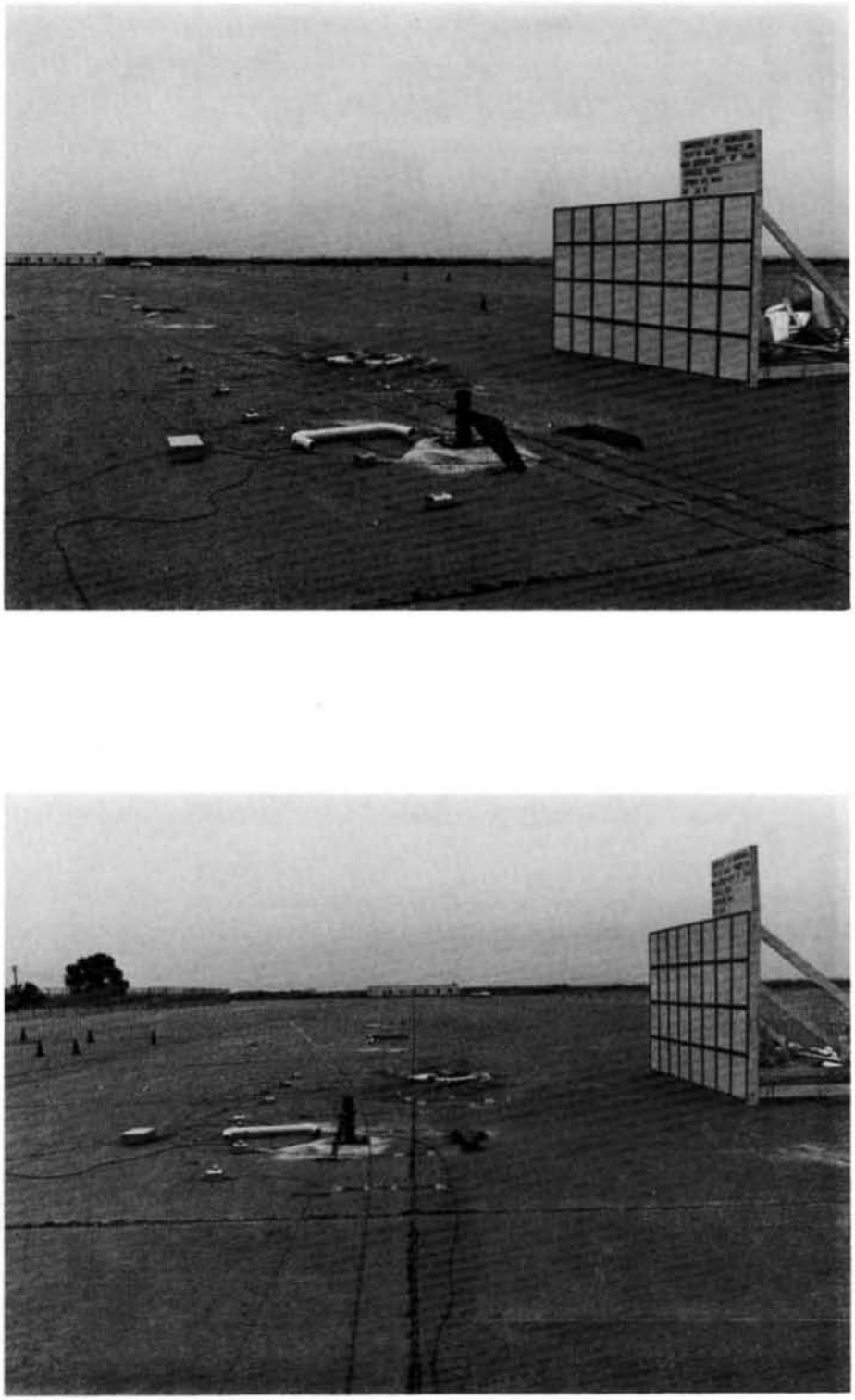


FIGURE 48. Photographs of Barricade After Test No. 10

B.6 Tests No.'s 11 and 12

Tests no.'s 11 and 12 were conducted using a reflective vinyl sign panel with a clearance height of 50-in. The barricades were also ballasted with 400 lbs. of sand for stabilizing purposes. A summary of the the test results for test no. 11 is given in Table 23, while a summary of the test results for test no. 12 is given in Table 25. Tables 24 and 26 give time-event summaries of the sequential photographs in Figures 50 and 54 for tests no.'s 11 and 12 respectively.

Test no. 11 was conducted at a target impact speed of 20 mph. At impact, the barricade collapsed with some of the debris from the barricade getting piled-up under the front end of the vehicle. The vehicle then proceeded to drag the debris until it came to a stop 66-ft. beyond the point of impact. The sign panel was projected over the vehicle and landed 5-ft. behind the initial position of the barricade. The vehicle did not receive any damage during the test. Figures 51, 52, and 53 show photographs of the test vehicle before and after impact.

In test no. 12, which was conducted at a target impact speed of 60 mph, the barricade shattered upon impact and pieces of PVC pipe were projected from the barricade. Again the sign panel detached from the barricade and was projected over the vehicle landing right on the spot where the barricade was positioned before impact. The vehicle traveled 236-ft. beyond the point of impact and received only minor damage which consisted of two small dents on the front of the vehicle's hood. Figures 55, 56,

and 57 show photographs of the test vehicle and barricade before and after the test. It should be noted that this test was conducted with the vehicle impacting the center of the barricade with the center of the vehicle's bumper. Actually, the vehicle should have impacted the barricade at the center with the point of contact on the vehicle's bumper being the quarter point as required in NCHRP 230 (3). However, seeing that the outcome of this test was satisfactory, and realizing that AASHTO considers the impact at the quarter point of the bumper too stringent for 60 mph tests (4), the test was considered valid.

NOTE:

All dinensions on full pipe length.

Socket depth of fittings is 1 1/2".

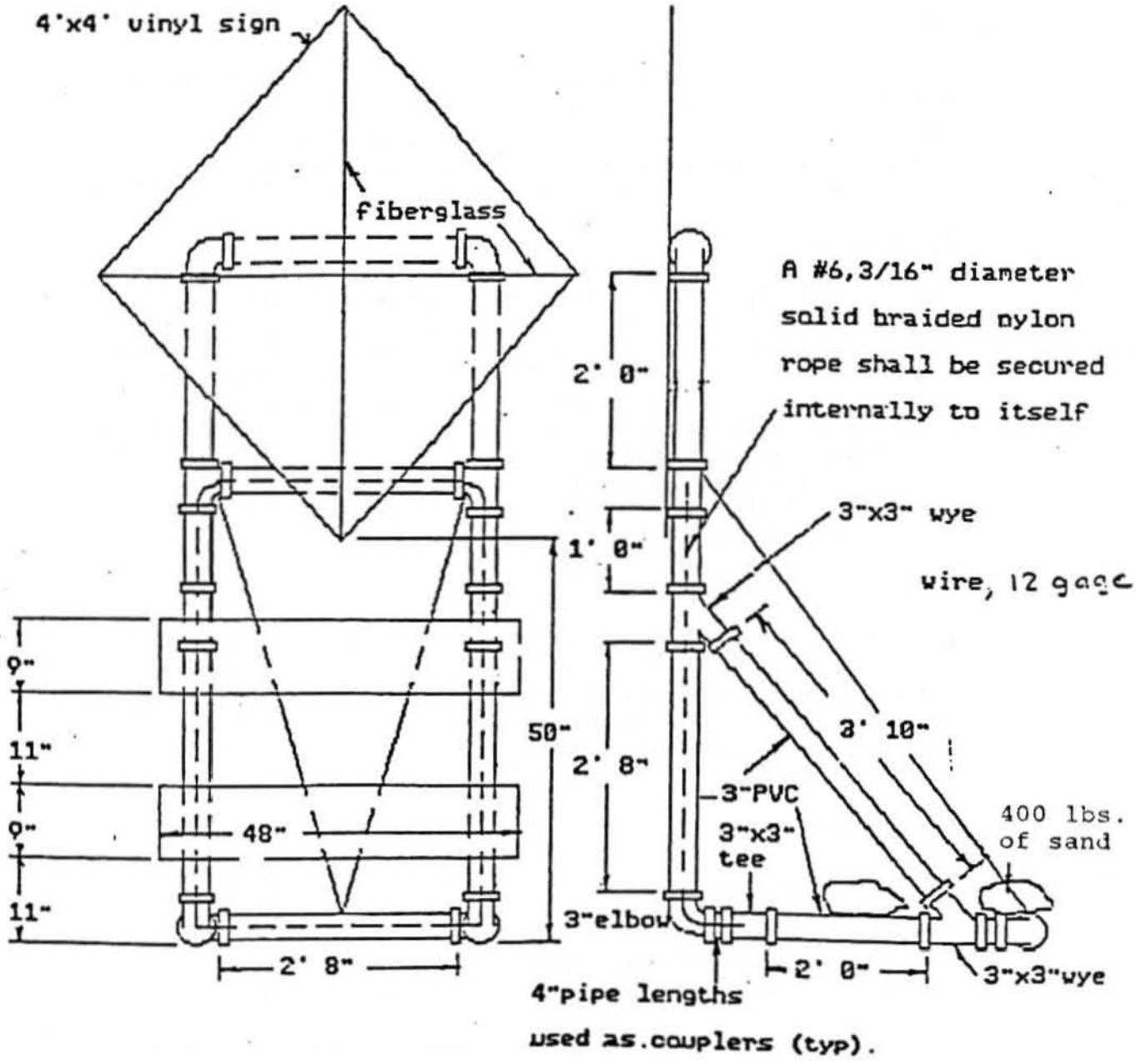


FIGURE 49. Breakaway Barricade For Test No. 11 and Test No. 12

TABLE 23

SUMMARY OF TEST RESULTS FOR TEST NO. 11

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1835
Impact Point	Center of Bumper

TEST ARTICLE DATA

Sign Panel Height (clearance)	50 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	Vinyl Reflective Sheeting
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	19.9 mph
Duration of Event[a]	335 msec
Vehicle Change-in-Speed	7.7 fps
Occupant Impact Velocity	8.6 fps
Occupant Ridedown Acceleration	0.7 g's
Impact Severity	25.7 ft-kips

VEHICLE DAMAGE

TAD	FD-0
VDI	None
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	No

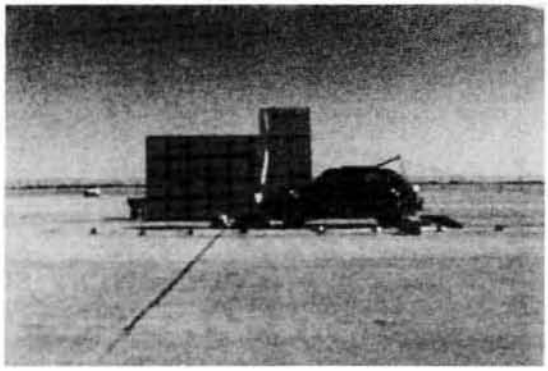
(a) Determined from accelerometer trace.

TABLE 24.

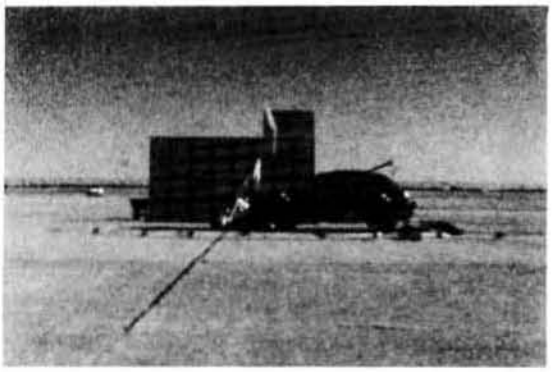
TIME-EVENT SUMMARY FOR TEST NO. 11

Time (sec)	Event
0.000	Impact
0.031	Lower vertical supports begin to fracture
0.062	Barricade collapses
0.125	Sign detaches and starts projectile motion
0.262	Sign is above roof of vehicle
0.521	Sign contacts roof of vehicle
0.804	Sign slides off roof of vehicle
1.375	Sign is on concrete behind vehicle

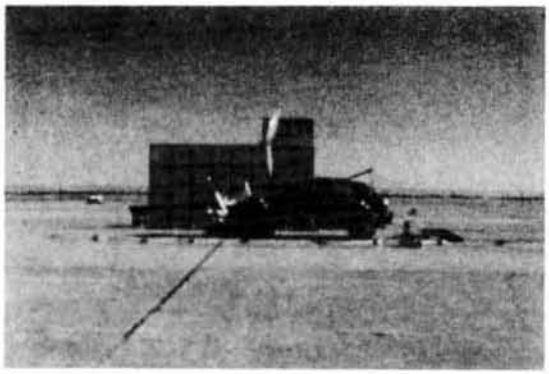
Impact



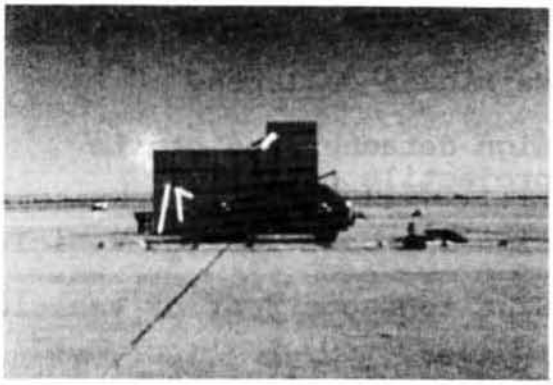
0.031 s



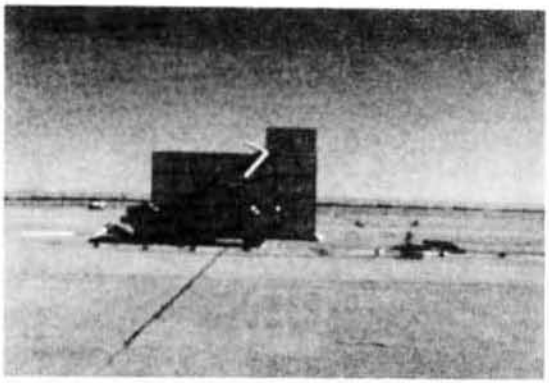
0.062 s



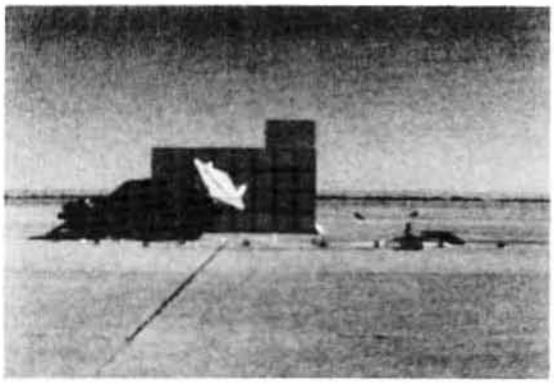
0.125 s



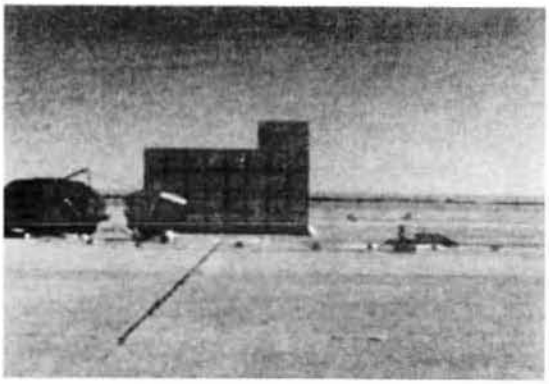
0.262 s



0.521 s



0.804 s



1.375 s

FIGURE 50. Sequential Photos of Test No. 11

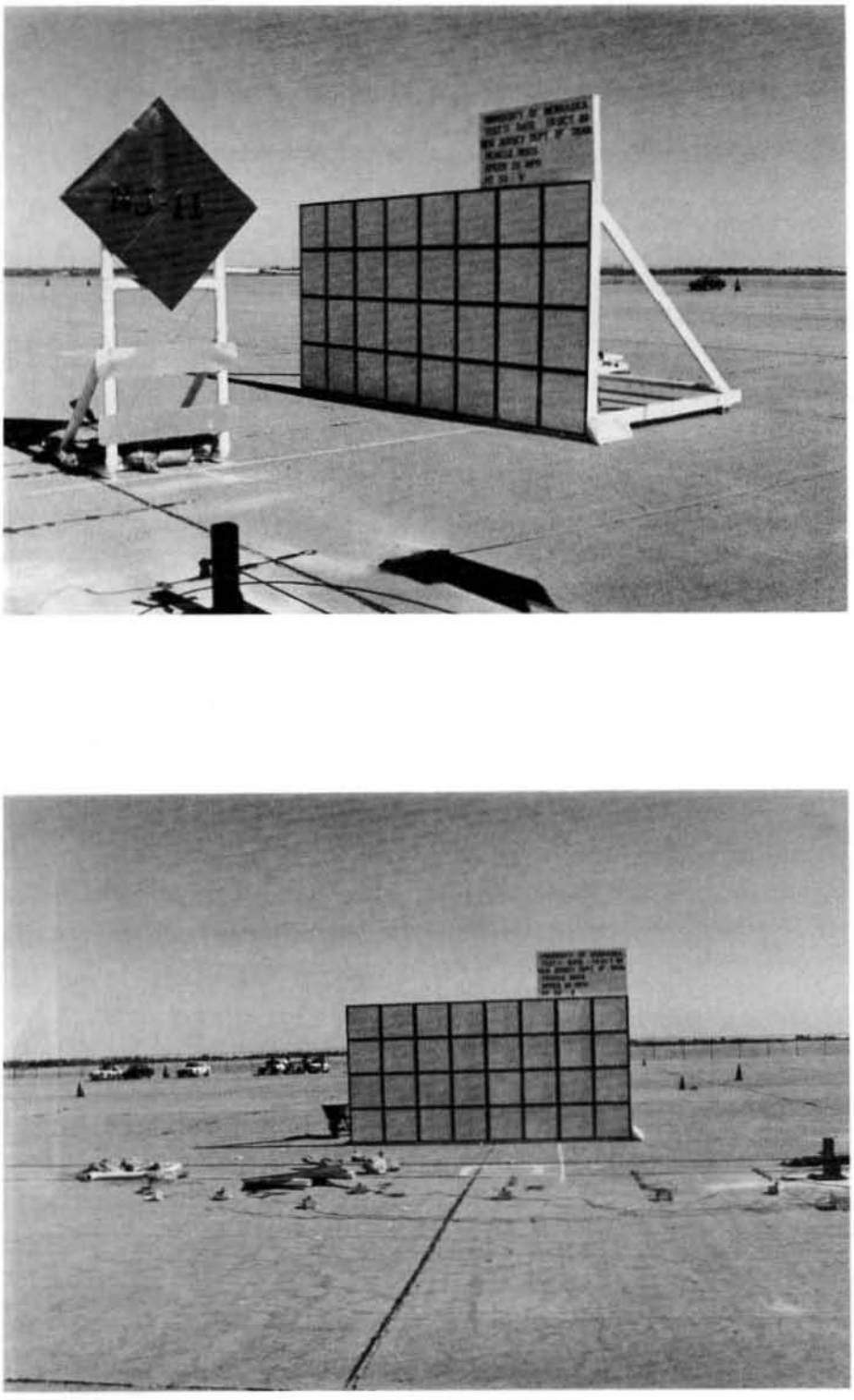


FIGURE 51. Photographs of Barricade Before and After Test No. 11

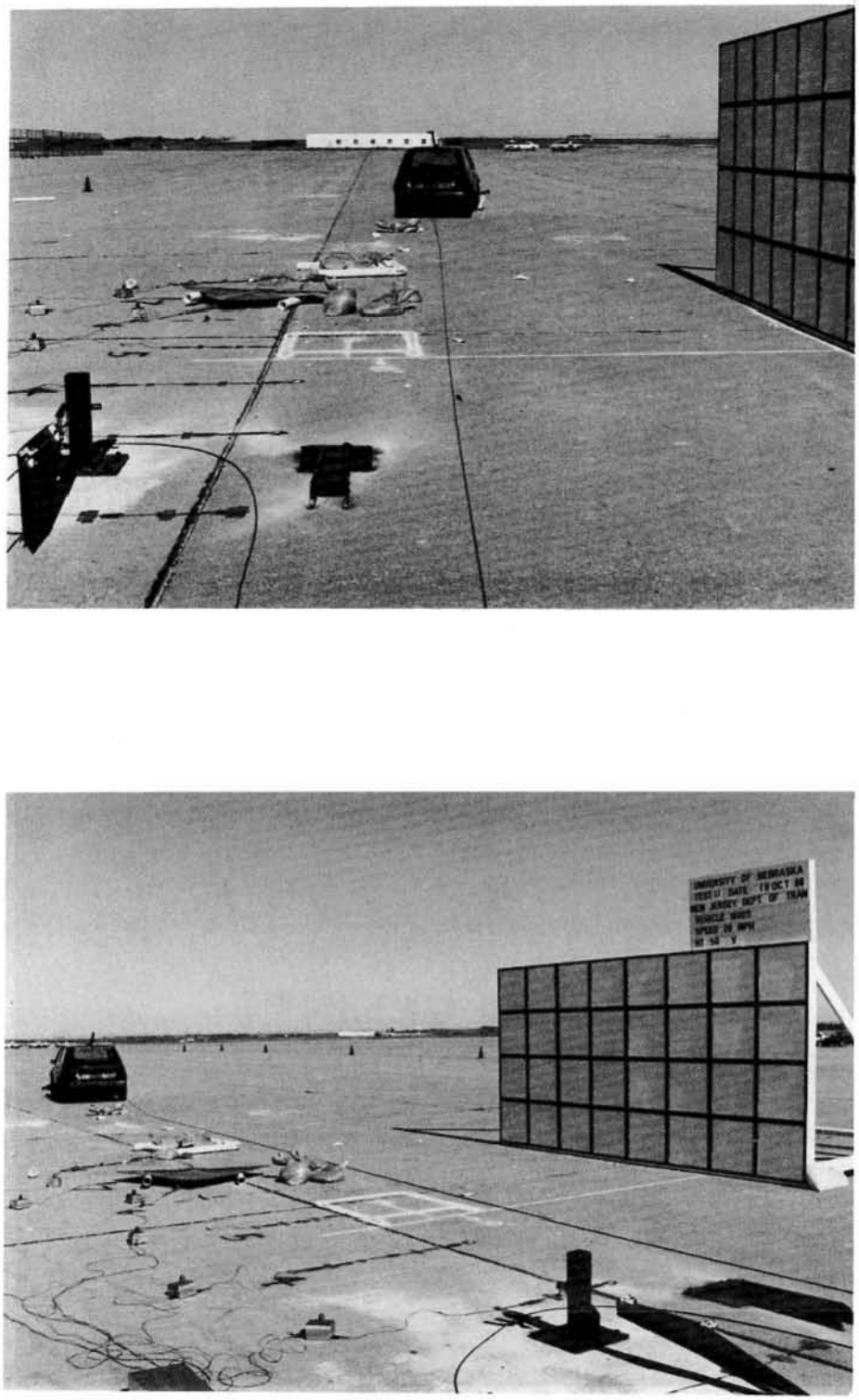


FIGURE 52. Photographs of Vehicle and Barricade After Test No. 11

FIGURE 53. Photographs of Vehicle Before and After Test No. 11

TABLE 25.

SUMMARY OF TEST RESULTS FOR TEST NO. 12

VEHICLE DATA

Make	Volkswagon
Model	Rabbit
Year	1980
Weight	1840
Impact Point	Center of Bumper[a]

TEST ARTICLE DATA

Sign Panel Height (clearance)	50 in.
Sign Panel Dimensions	48 x 48-in.
Sign Panel Material	Vinyl Reflective Sheeting
Barricade Rail Dimensions	9 x 48-in.
Barricade Rail Material	24 Ga. Alum.
PVC Pipe Specifications	SCH 40 ASTM D1785
PVC Pipe Inside Diameter	3 in.
Ballast (sand)	400 lbs.
No. of Posts Impacted	2

VEHICLE AND OCCUPANT KINEMATICS

Impact Velocity	58.3 mph
Duration of Event[b]	171 msec
Vehicle Change-in-Speed	12.2 fps
Occupant Impact Velocity	12.6 fps
Occupant Ridedown Acceleration	0.8 g's
Impact Severity	209.0 ft-kips

VEHICLE DAMAGE

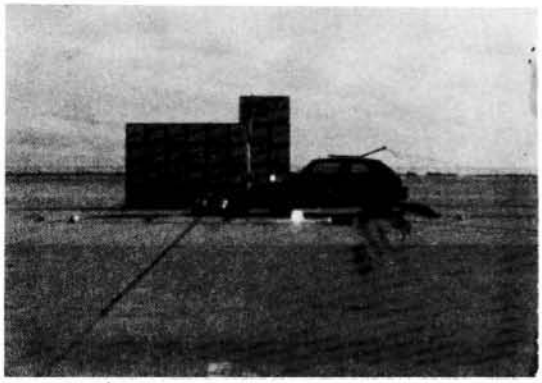
TAD	FD-1
VDI	12FDMN1
Passenger Compartment Intrusion By Test Article	No
Was Windshield Broken ?	No

(a) This test was supposed to be impacted at the 1/4 point of the bumper.
(b) Determined from accelerometer trace.

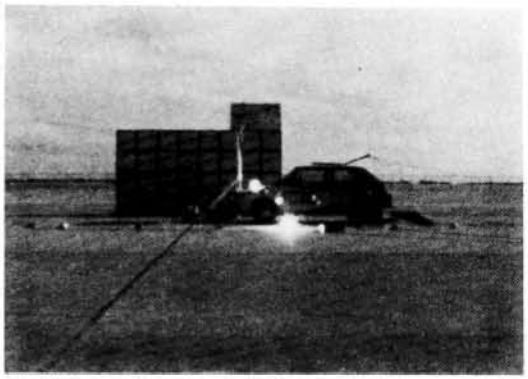
TABLE 26.

TIME-EVENT SUMMARY FOR TEST NO. 12

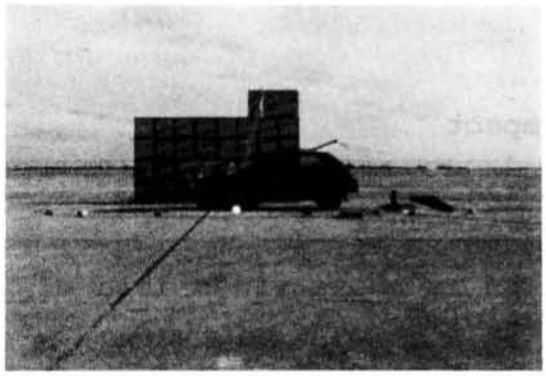
Time (sec)	Event
0.000	Impact
0.003	Lower vertical supports begin to fracture
0.018	Sign is above windshield of vehicle
0.031	Sign is above roof of vehicle and debris is being projected
0.050	Barricade debris is on roof of vehicle
0.096	Vehicle loses contact with all debris and sign is descending



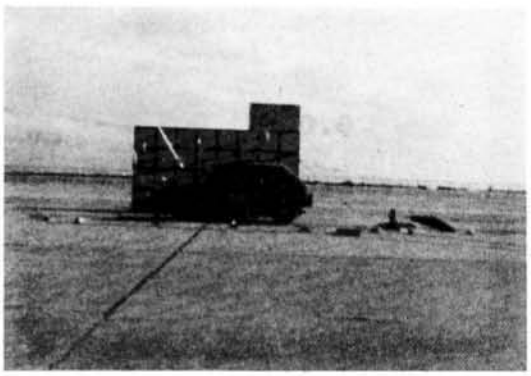
Impact



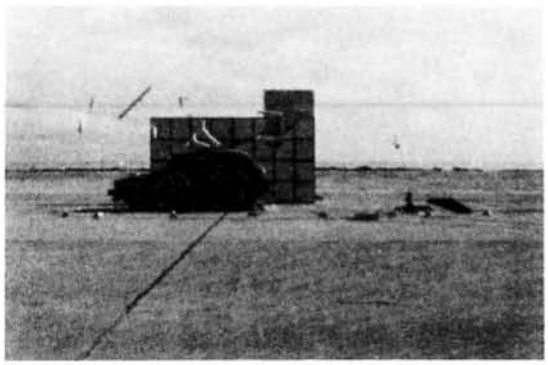
0.003 s



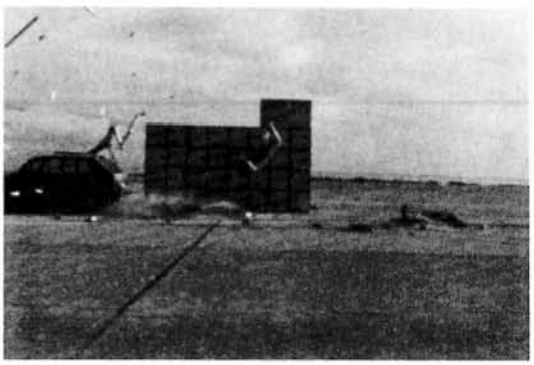
0.018 s



0.031 s



0.050 s



0.096 s

FIGURE 54. Sequential Photos of Test No. 12

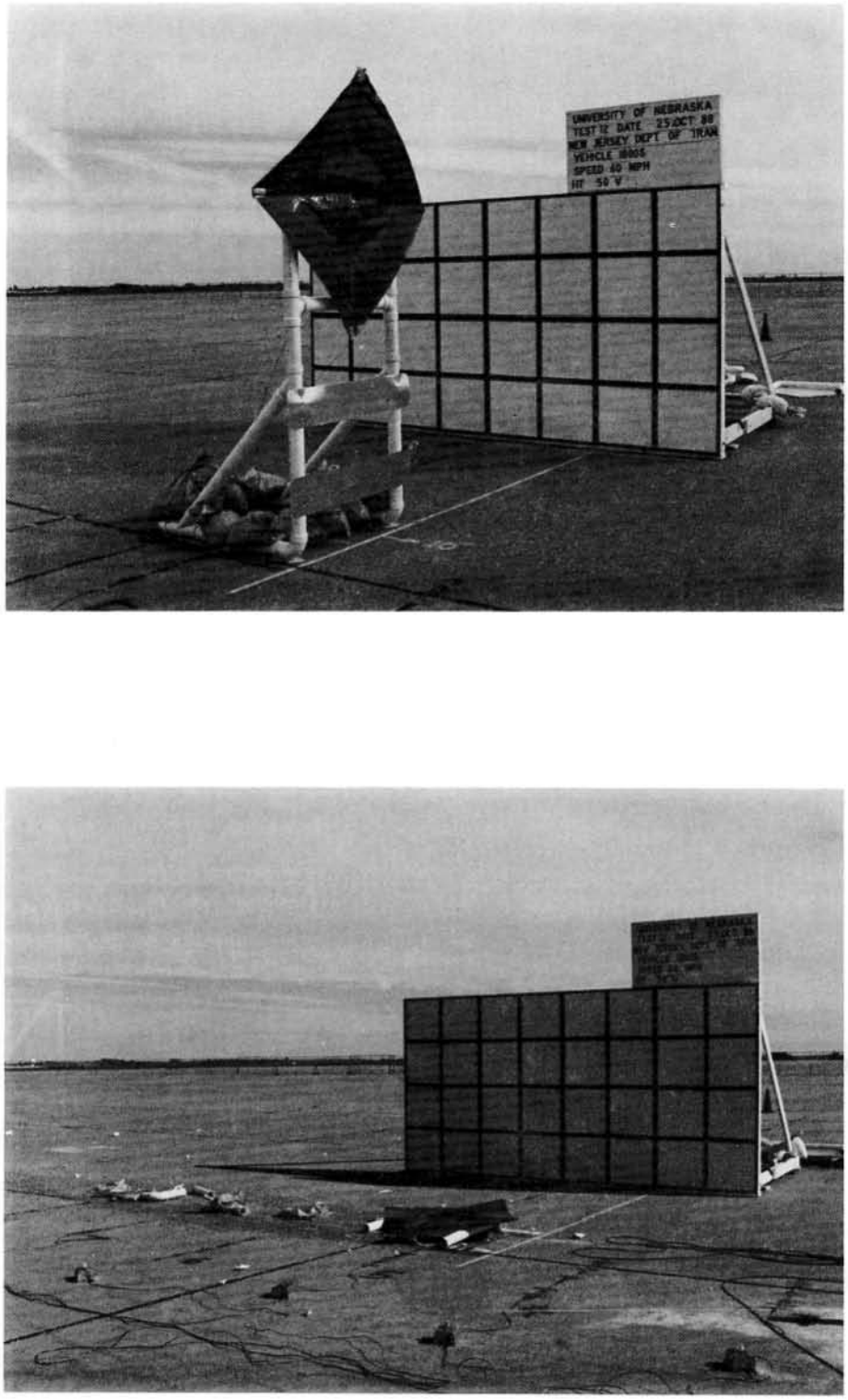


FIGURE 55. Photographs of Barricade Before and After Test No. 12

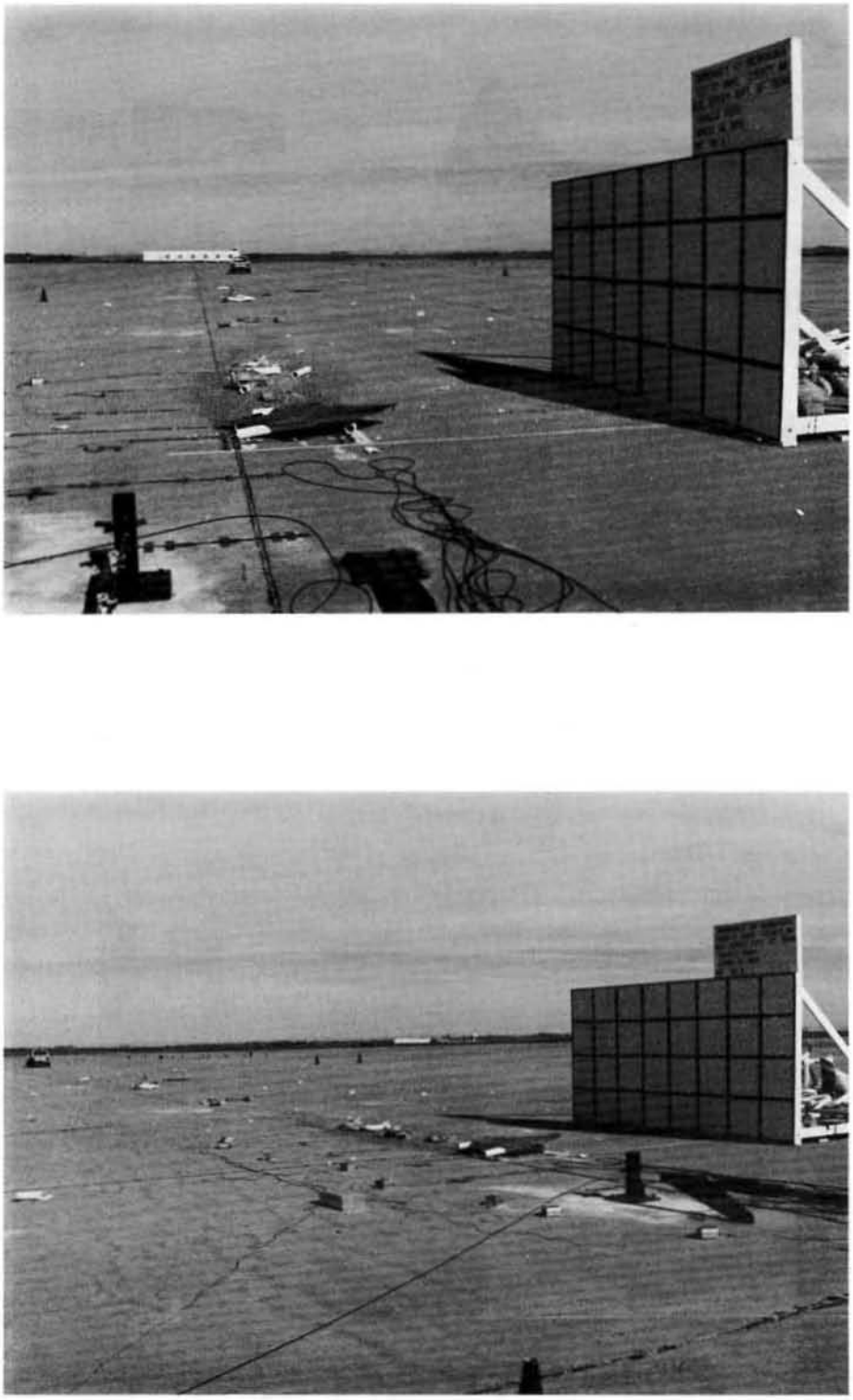


FIGURE 56. Photographs of Vehicle and Barricade After Test No. 12

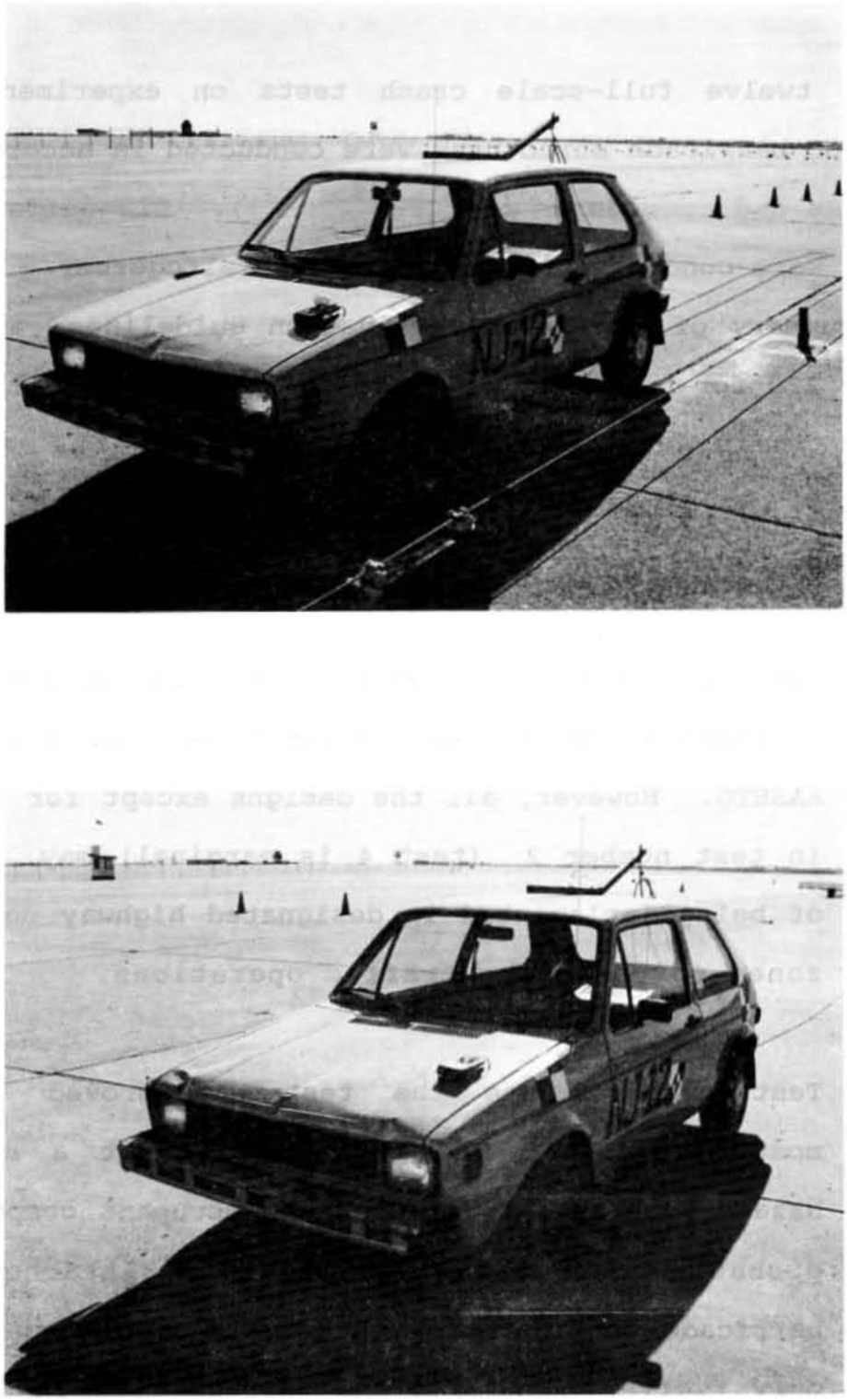


FIGURE 57. Photographs of Vehicle Before and After Test No. 12

CONCLUSIONS

The twelve full-scale crash tests on experimental signs mounted on barricade structures were conducted in accordance with guidelines and procedures in NCHRP 230 (3). Six different types of tests were conducted on the barricades altogether.

A summary of the safety evaluation guidelines, as provided by NCHRP 230 for breakaway or yielding supports, and the results of each individual test as it applies to the evaluation guidelines, is given in Table 27. Results of the full-scale crash tests revealed the following:

1. Ten of the twelve tests proved to be satisfactory in meeting the required specifications of NCHRP 230 and AASHTO. However, all the designs except for the design in test number 2, (test 4 is marginal) may be worthy of being implemented in designated highway construction zones for changing traffic operations.

2. Test number 2 was the test that proved to be the most hazardous. The test showed that a significant hazard such as intrusion of the occupant compartment is probable when the sign panel is attached to the barricade configuration that has a clearance height of only twelve inches and the barricade is impacted at a speed of 60 mph. Test number 4 is the only other test that must be carefully evaluated when determining if

these barricade designs are acceptable. Though the design looked to be satisfactory when impacted, evaluation of the test showed considerably higher occupant impact velocities and occupant ridedown accelerations that exceed the recommended values given in NCHRP 230 (see Table 27). However, one must also consider the affect that sandbags have on the vehicle's deceleration and stability when used to ballast barricades (7). Another item that must be considered in test number 4 is the potential of the windshield shattering as in test number 2. Though the windshield in test 4 did not intrude the occupant compartment, it should be noted, that of the twelve tests conducted, test number 4 was second to test number 2 in hazard potential for occupant compartment intrusion.

3. Though these type of barricades structures have been previously tested and said to be reusable (2, 7), the barricade structures used in these tests did not hold up as well. In numerous tests, the barricade structures shattered into pieces upon impact to where many barricades were unsalvageable. Since these tests were conducted in the latter part of the year, namely the end of October and the beginning of November, the PVC material, of which the barricades were constructed, was more brittle. This may be of concern to NJDOT as to under what conditions the barricades perform the best.

4. Both the aluminum and vinyl signs were extremely adequate in their performance; however the vinyl signs were much more durable and showed the least amount of necessary repairs for reusing the sign panels.

Though the design in test number 4 performed marginally, it is the belief of the testing agency at the University of Nebraska that this design has the ability to perform satisfactorily provided that it is ballasted properly.

It is, therefore, the recommendation of the University of Nebraska research testing agency, that the Federal Highway Administration accept the following designs of 4-ft. x 4-ft. signs on type III breakaway barricades when impacted by an 1800 lb. vehicle at 20 mph and 60 mph:

1. Aluminum sign on barricade with 29-in. clearance
2. Aluminum sign on barricade with 41-in. clearance
3. Vinyl sign on barricade with 38-in. clearance
4. Vinyl sign on barricade with 50-in. clearance

Evaluation Criteria	Test Number											
	1	2	3	4	5	6	7	8	9	10	11	12
Part B: The test article shall readily activate in a predictable manner by breaking away or yielding.	S	S	S	S	S	S	S	S	S	S	S	S
Part D: Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	S	M	S	M	S	S	S	M	S	S	S	S
Part E: The vehicle shall remain upright during and after collision although moderate roll, pitching, and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	S	U	S	S	S	S	S	S	S	S	S	S
Part F: Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from vehicle accelerations and 24 in. forward and 12 in. lateral displacement, shall be less than: Occupant Impact Velocity - fps Longitudnal / Lateral 15 (Not Applicable) and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than: Occupant Ridedown Accelerations - g's Longitudnal / Lateral 15 (Not Applicable)	S	S	S	M	S	NA	S	S	S	S	S	S
Part H: After collision, vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	S	S	S	S	S	S	S	S	S	M	S	S
Part J: Vehicle trajectory behind the test article is acceptable.	S	S	S	S	S	S	S	S	S	S	S	S

NOTE: S = Satisfactory M = Marginal U = Unsatisfactory NA = Not Available

Table 27. NCHRP 230 Criteria For Evaluating Breakaway or Yielding Supports

REFERENCES

1. "Manual on Uniform Traffic Control Devices," U.S. Department of Transportation, Federal Highway Administration, 1983.

2. "Breakaway Barricades," U.S. Department of Transportation, Federal Highway Administration, Demonstration Project No.41, Interim Report No. FHWA-DP-41-1, October 1978.

3. NCHRP 230 Report, "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," National Cooperative Highway Research Program Report, Transportation Research Board, March 1981.

4. "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," American Association of State Highway and Transportation Officials, 1985.

5. "Vehicle Damage Scale for Traffic Accident Investigators," Traffic Accident Data Project Technical Bulletin No. 1, National Safety Council, Chicago, Ill., 1971.

6. "Collision Deformation Classification, Recommended Practice J224 Mar 80," SAE Handbook Vol. 4, Society of Automotive Engineers, Warrendale, Penn., 1985.

7. "Miller, A.S., "Breakaway Barricades," Public Roads Magazine, Federal Highway Administration, Vol. 40/No. 1, pp. 6-8, June 1976.

8. Hinch, J., Yang, T-L, and Owings, R., "Guidance Systems for Vehicle Testing," ENSCO, Inc., Springfield, VA, 1986.

APPENDICES

Appendix A. Test Facility

1. Test Site

The location of the test site, with respect to the Lincoln Municipal Airport is shown in Figure A1. An 8 ft. high chain-linked fence surrounds the facility to ensure security for the test article and any test equipment that is setup and left on the facility grounds.

2. Vehicle Tow System

A reverse cable tow system, with a 1:2 mechanical advantage, was used to propel the test vehicle. Using this tow system allows the tow vehicle to travel half the distance at half the speed than that of the test vehicle. A sketch of the cable tow system is shown in Figure A2. The test vehicle was released from the tow cable approximately 6 ft. before impact with the breakaway barricades. Photographs of the tow vehicle and the attached fifth-wheel are shown in Figure A3. The fifth-wheel, built by Nucleus Corporation, was used for accurately towing the test vehicle at the required target speed with the aid of a digital speedometer in the tow vehicle.

3. Vehicle Guidance System

A vehicle guidance system, developed by Hinch (6), was used to steer the test vehicle. A sketch of the guidance system is shown in Figure A2, while photographs of the guidance system before and after impact are shown in Figure A4. The guide flag was attached to the front left wheel of the test vehicle and was sheared off (at the distances stated above) before impact with the barricade. The 3/8 in. diameter cable was tensioned to 3,000 lbs., and was supported laterally and vertically every 100 ft. by hinged stanchions which stood upright while holding up the guide cable. When the vehicle passed, the guide flag struck each stanchion and knocked it to the ground. The vehicle guidance system was approximately 1,000 ft. in length.

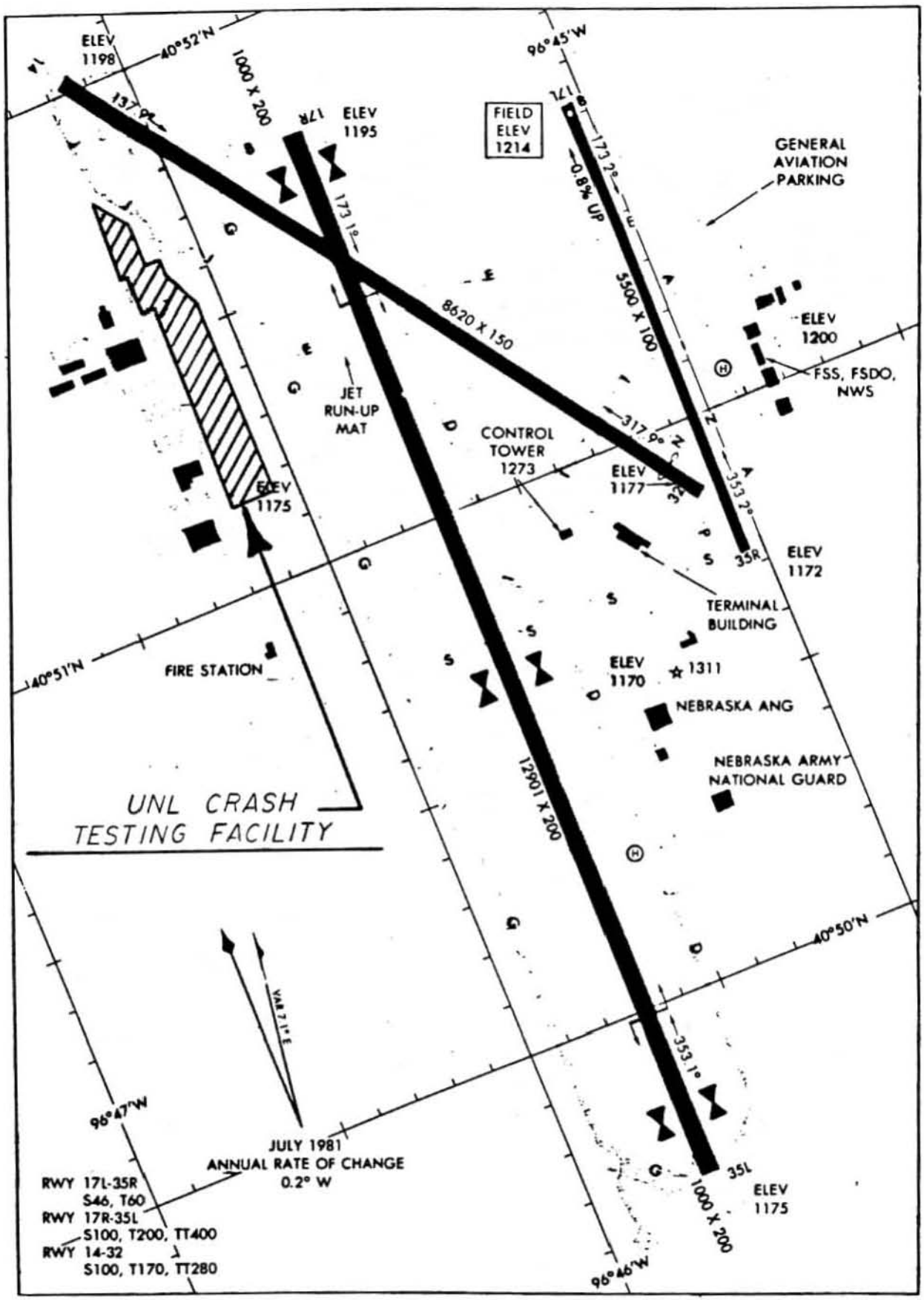


FIGURE A1. Full-Scale Vehicle Crash Testing Facility

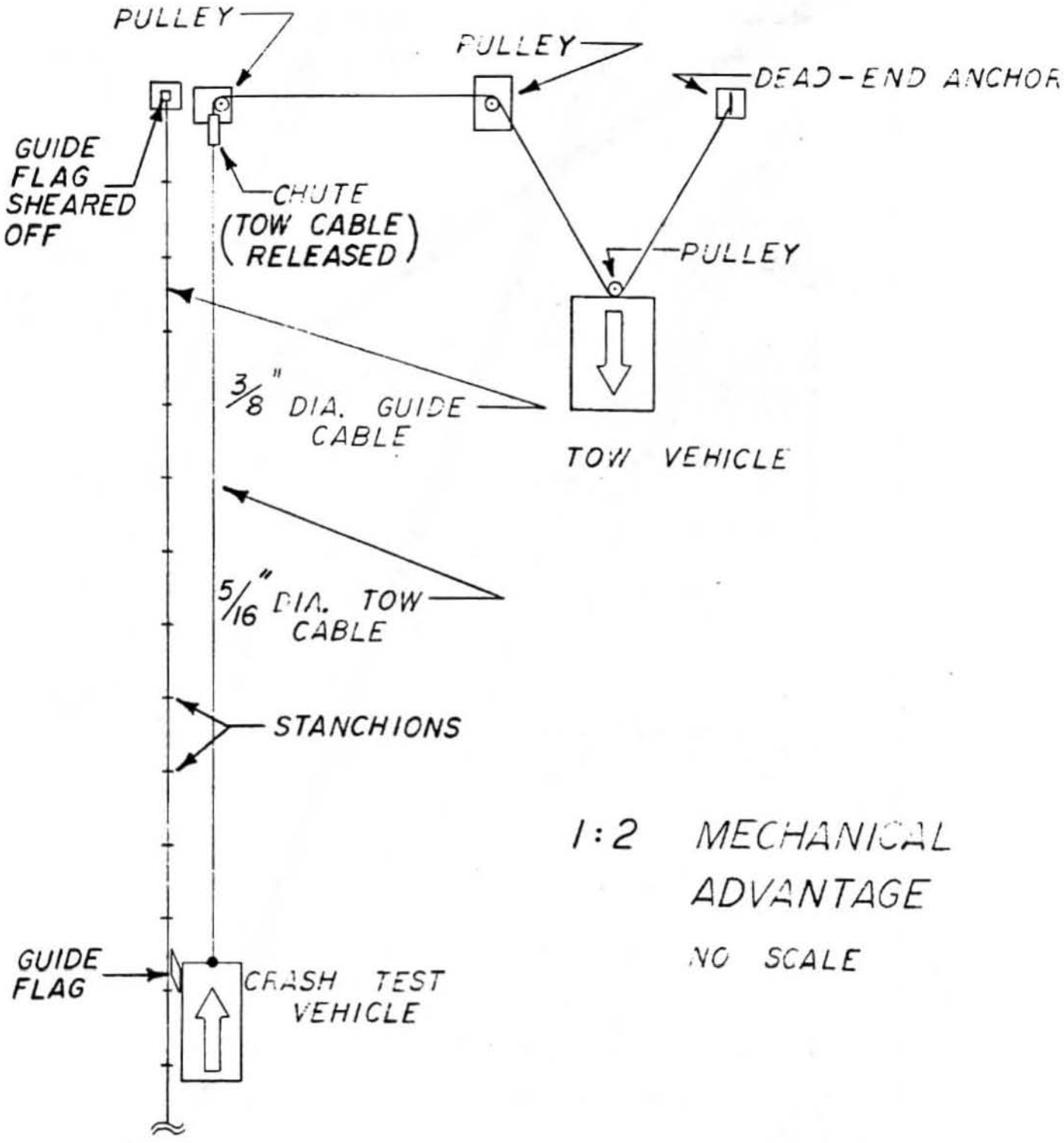


FIGURE A2. Sketch of Tow and Guidance Systems

FIGURE A3. Photographs of Tow Vehicle with Fifth-Wheel

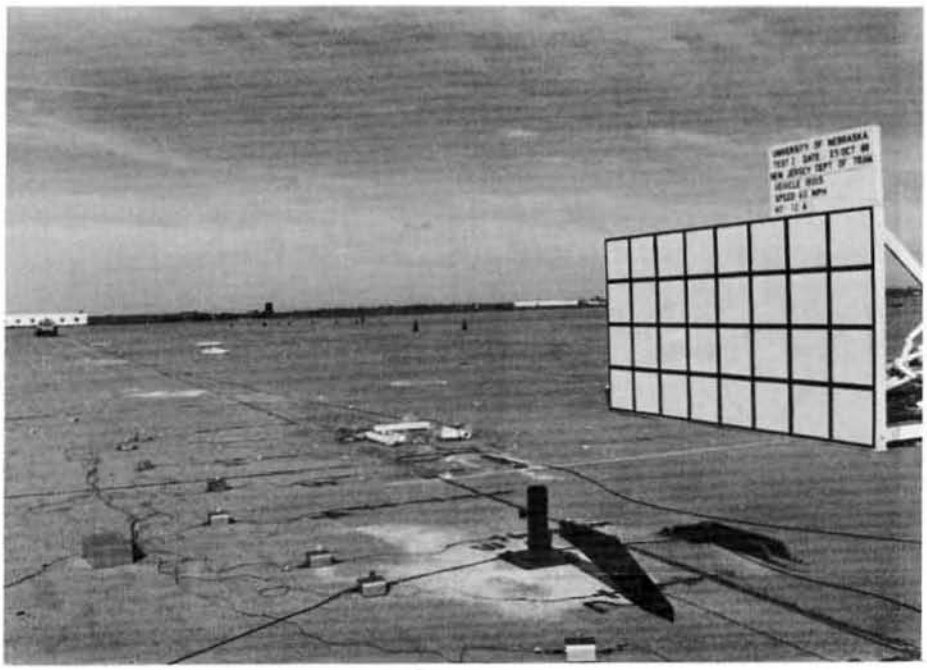


FIGURE A4. Photographs of Vehicle Guidance System

Appendix B. Data Acquisition Systems

1. Accelerometers

Two Endevco piezoresistive accelerometers (Model 7264) with a range of 200 g's were used to measure the accelerations in the longitudinal direction of the test vehicle. The accelerometers were rigidly attached to metal blocks mounted in the transverse plane of the vehicle which also contained the center of mass of the vehicle. One accelerometer block was mounted to the floorboard on driver's side and the other was mounted to the floorboard on the passenger's side. A photograph of the accelerometers mounted in the test vehicle are shown at the top of Figure B1. The signals from the accelerometers were received and conditioned by an onboard vehicle Metraplex unit shown at the bottom of Figure B1. The multiplexed signal was then sent through a single coaxial cable to the Honeywell (101) Analog Tape Recorder in the central control van. Photographs of the system located in the centrally controlled step-van are shown in Figures B2 and B3, and a flowchart of the accelerometer data aquisition system is shown in Figure B4. The latest state-of-the-art computer software, 'Computerscope' and 'DSP' was used to analyze and plot the accelerometer data on a Cyclone 386/AT, which uses a very high speed data aquisition board.

2. High-Speed Photography

Two high-speed 16mm cameras were used to film the crash tests and were placed perpendicular to the path of the test

vehicle. The cameras ran at approximately 500 frames per second. The first camera was a Red Lake Locam with a wide angle 12.5 millimeter lens. It was placed 60-ft. from the barricade (72-ft. from the backboard). The second camera was a Photec IV with a 55 millimeter lens and was located 96-ft. from the barricade (108-ft. from the backboard). A schematic of the camera layouts is shown in Figure B5.

An 8-ft. high by 16-ft. long backboard, with a 2-ft. line grid layout, was used as a reference for the analysis of the high-speed film. The backboard was placed facing the cameras 12-ft. from the centerline of the test vehicle's path of travel. The camera divergence correction factors were also taken into consideration in the analysis of the high-speed film.

3. Speed Trap Switches

Eight tape pressure switches spaced at 5 ft. intervals were used to determine the speed of the vehicle before and after impact. Each tape switch fired a blue 5B flashbulb located near each switch on the concrete slab as the left front tire of the test vehicle passed over it. The average speed of the test vehicle between the tape switches was determined by knowing the distance between the tape switches, the calibrated camera speed, and the number of frames, from the high-speed film, between flashes. In addition, the average speed was determined from electronic timing mark data recorded on the oscilloscope software used with the 386/AT computer as the test vehicle passed over each tape switch.

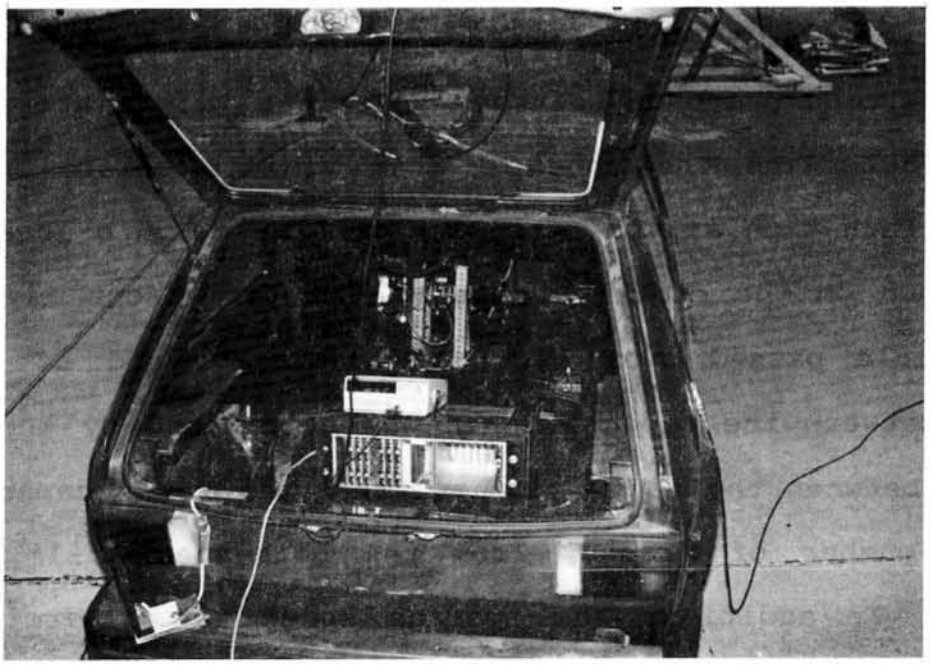


FIGURE B1. Photographs of Onboard Data Acquisition System

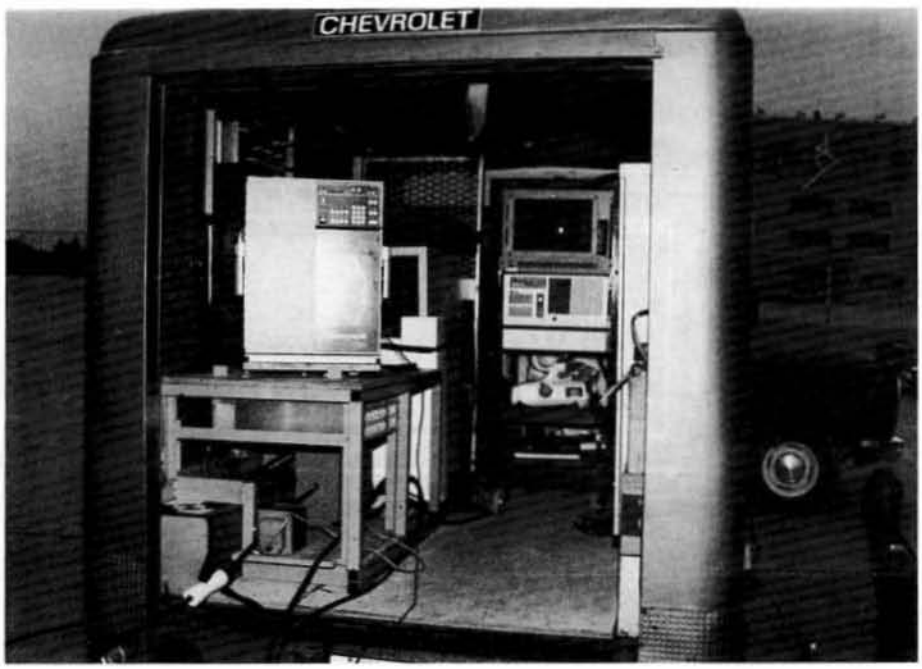
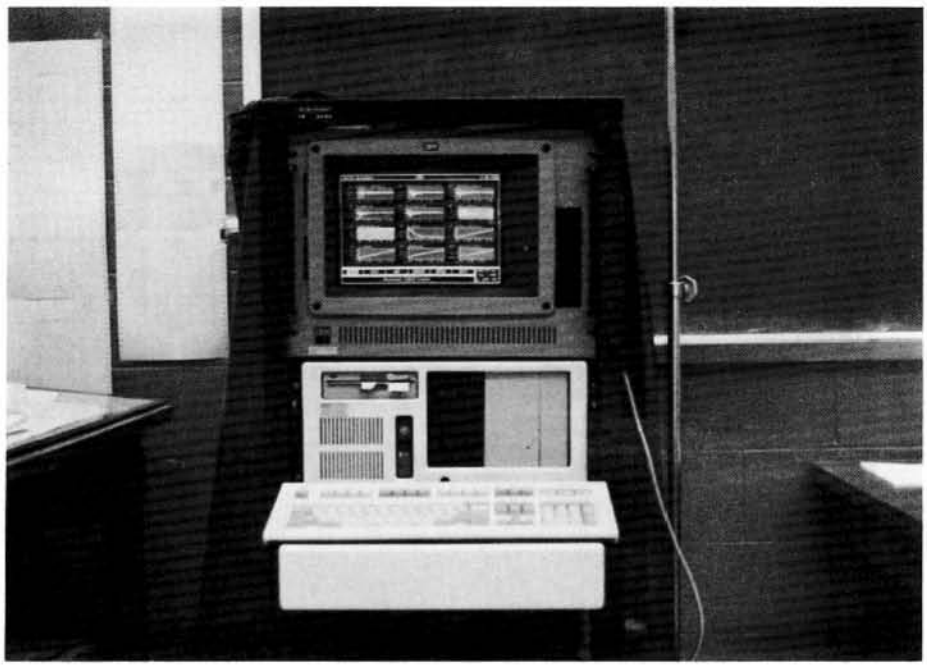


FIGURE B2. Photographs of Central Control Van



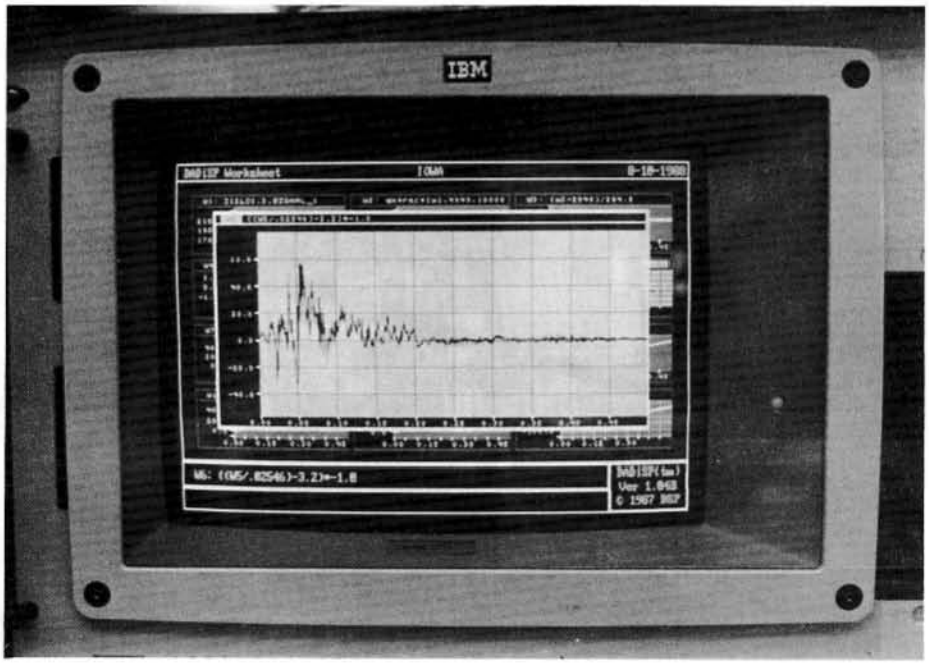


FIGURE B3. Photographs of 386/AT Computer and Computer Software

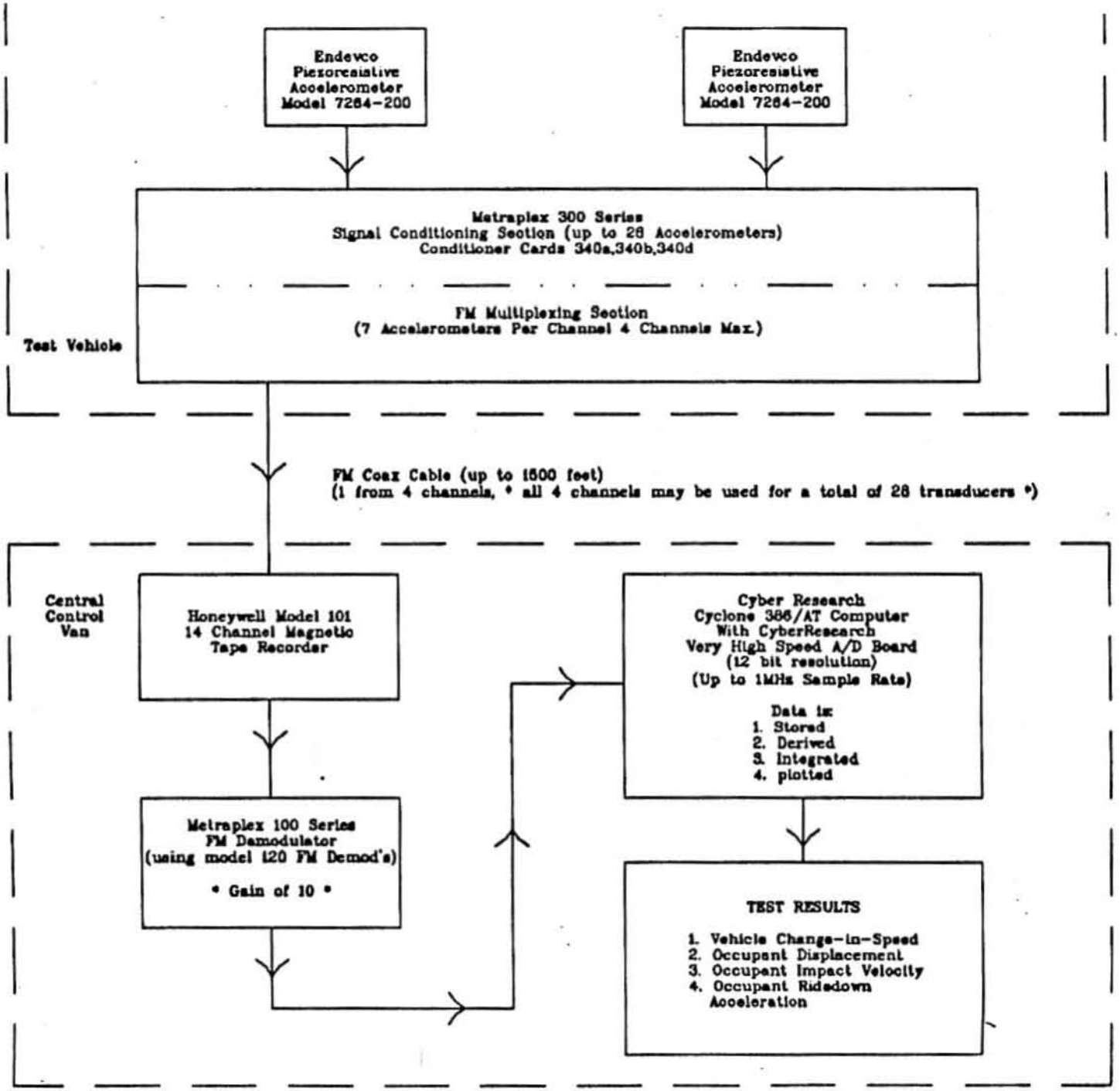


FIGURE B4. Flowchart of Accelerometer Data Acuisition System

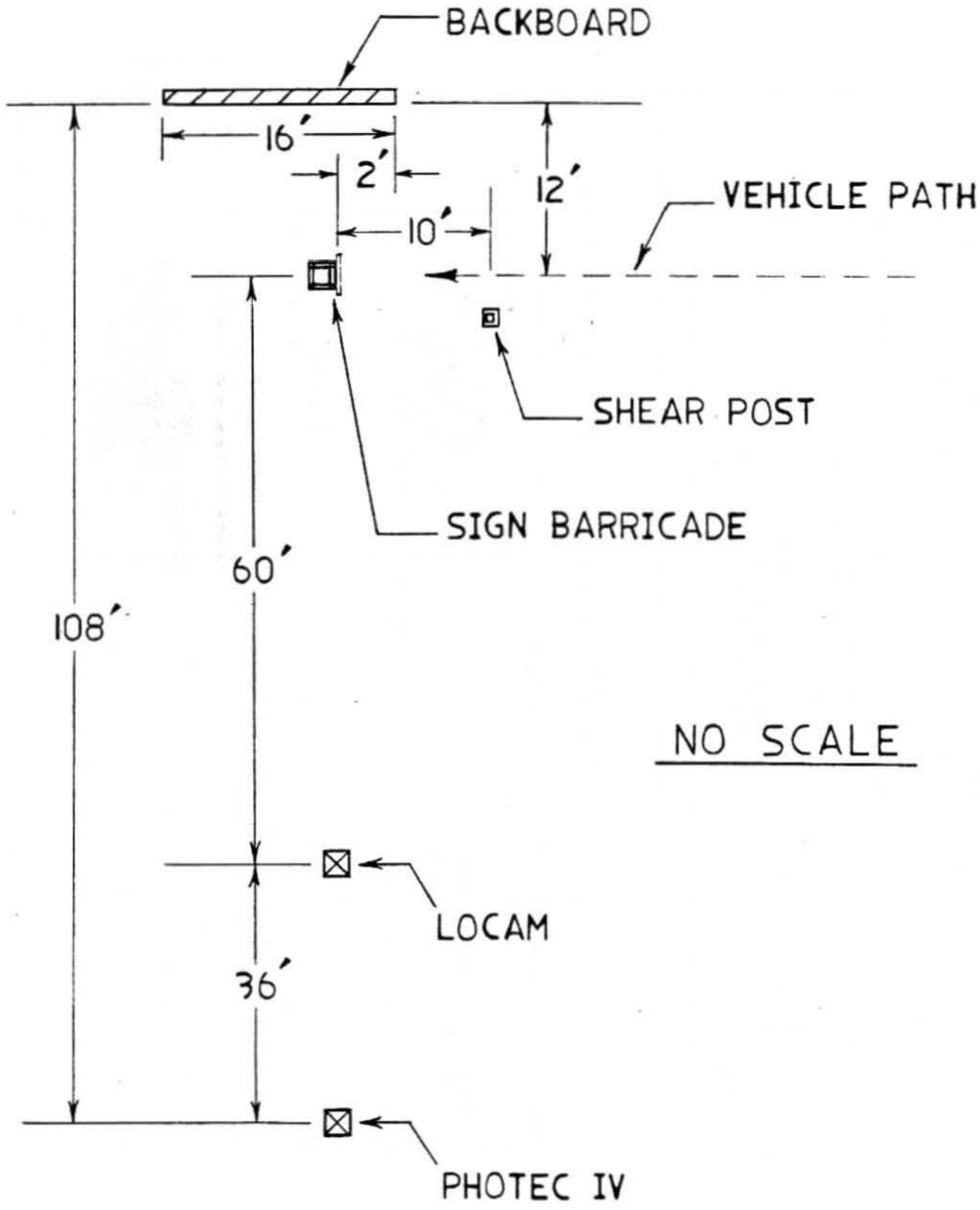
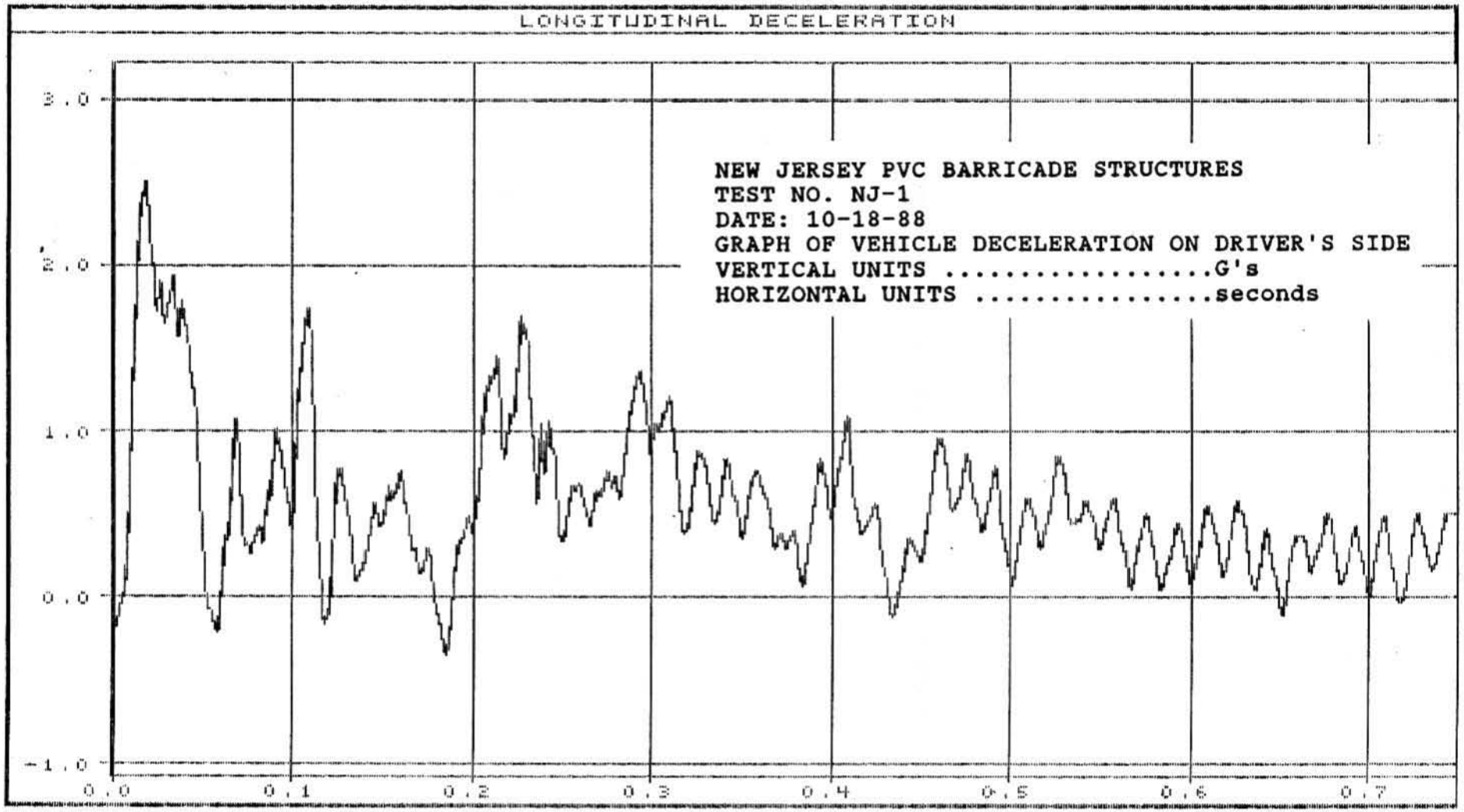
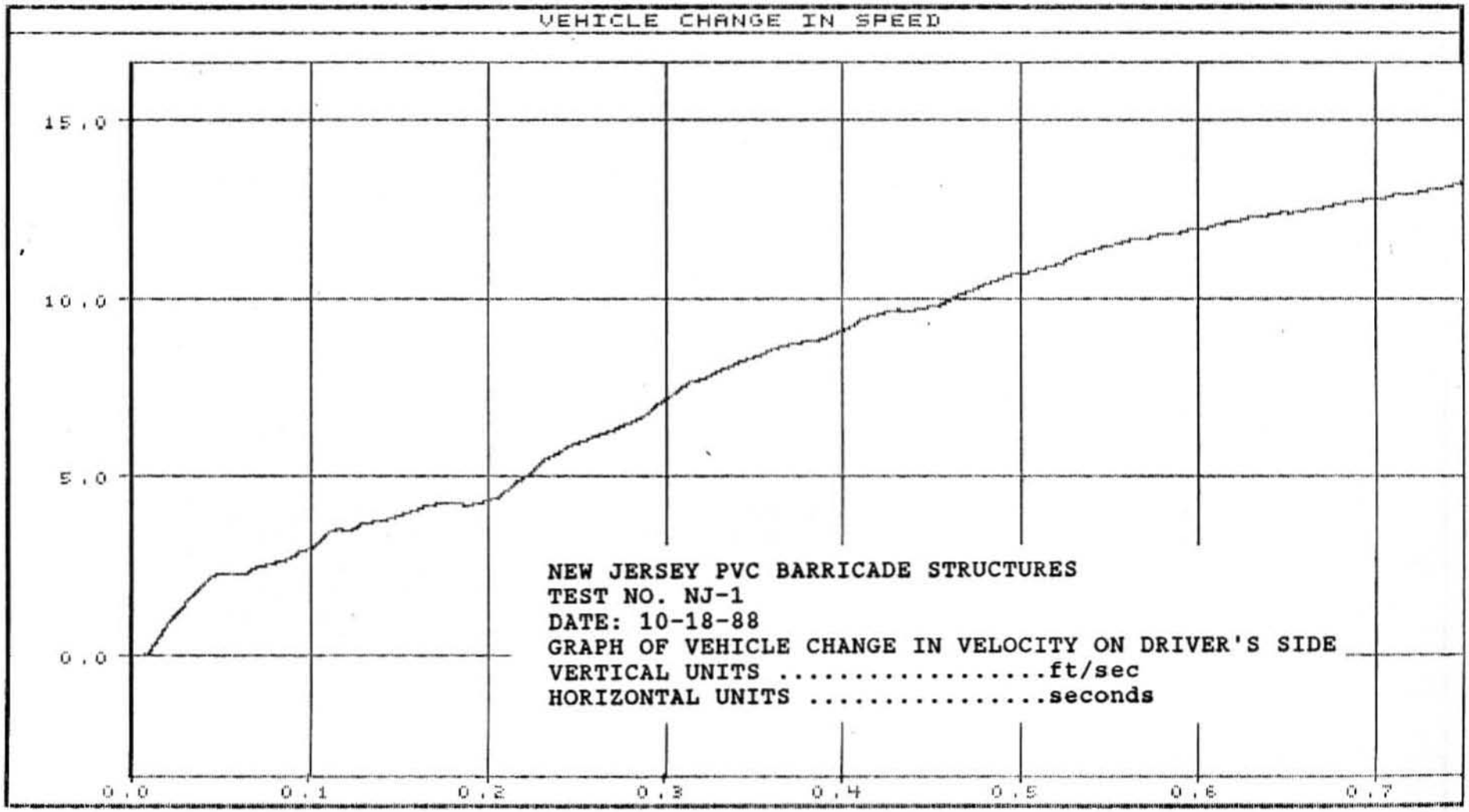


FIGURE B5. Schematic of High-Speed Camera Locations

Appendix C. Graphs of Accelerometer Data


LONGITUDINAL DECELERATION
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-1
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds


VEHICLE CHANGE IN SPEED
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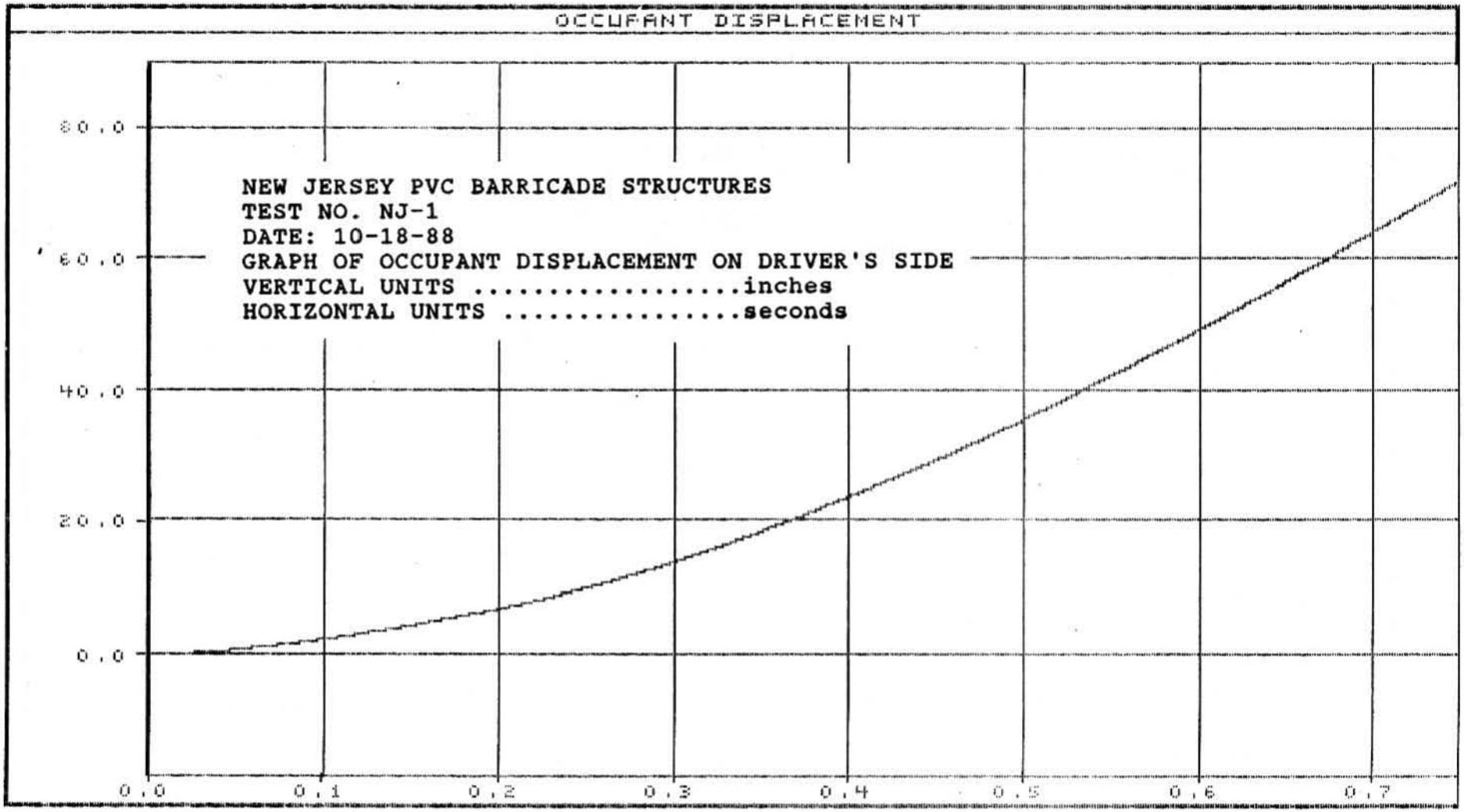
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-1
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds


OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-1
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
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20.0
0.0
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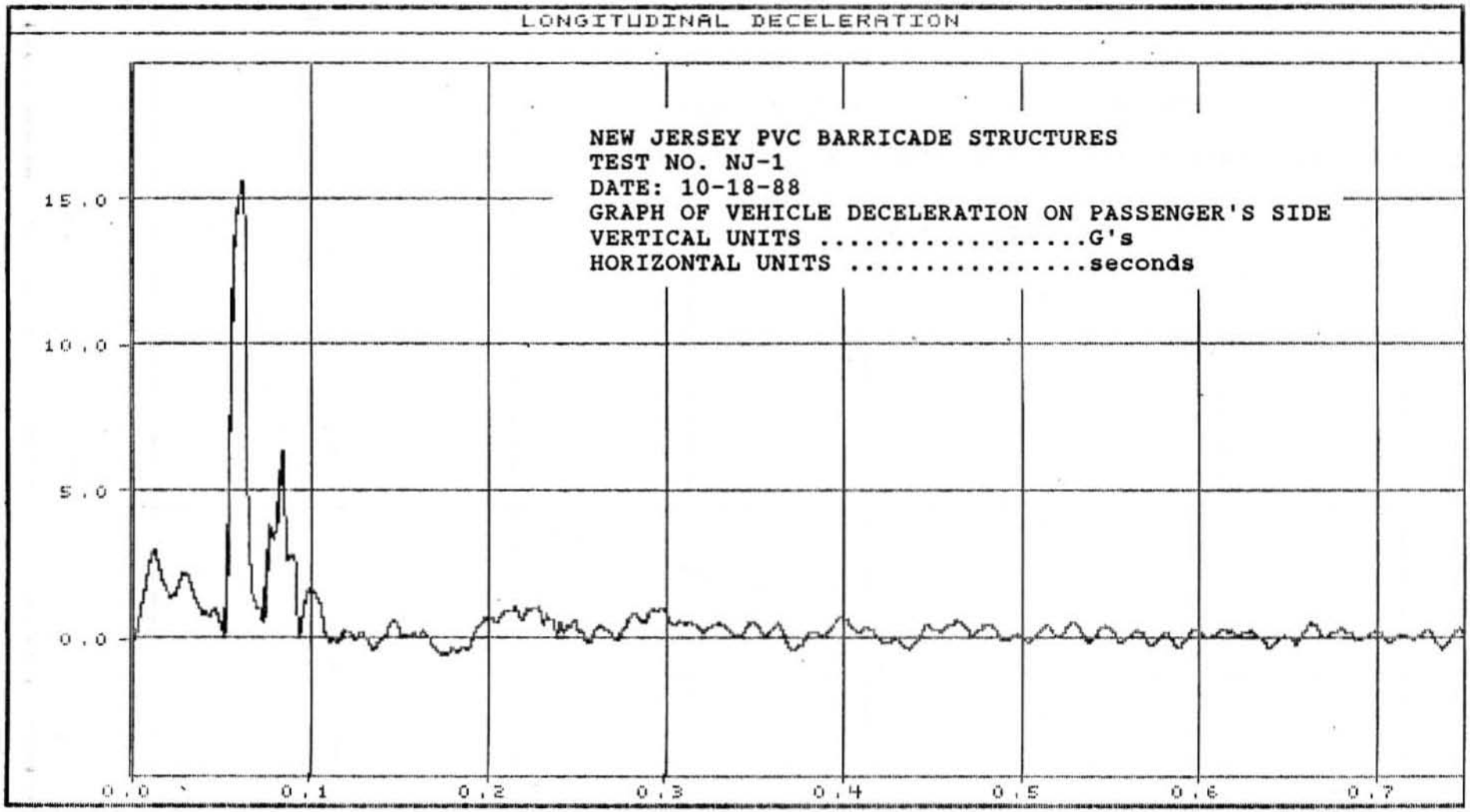
0.2
0.3
0.4
0.5
0.6
0.7


LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-1
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
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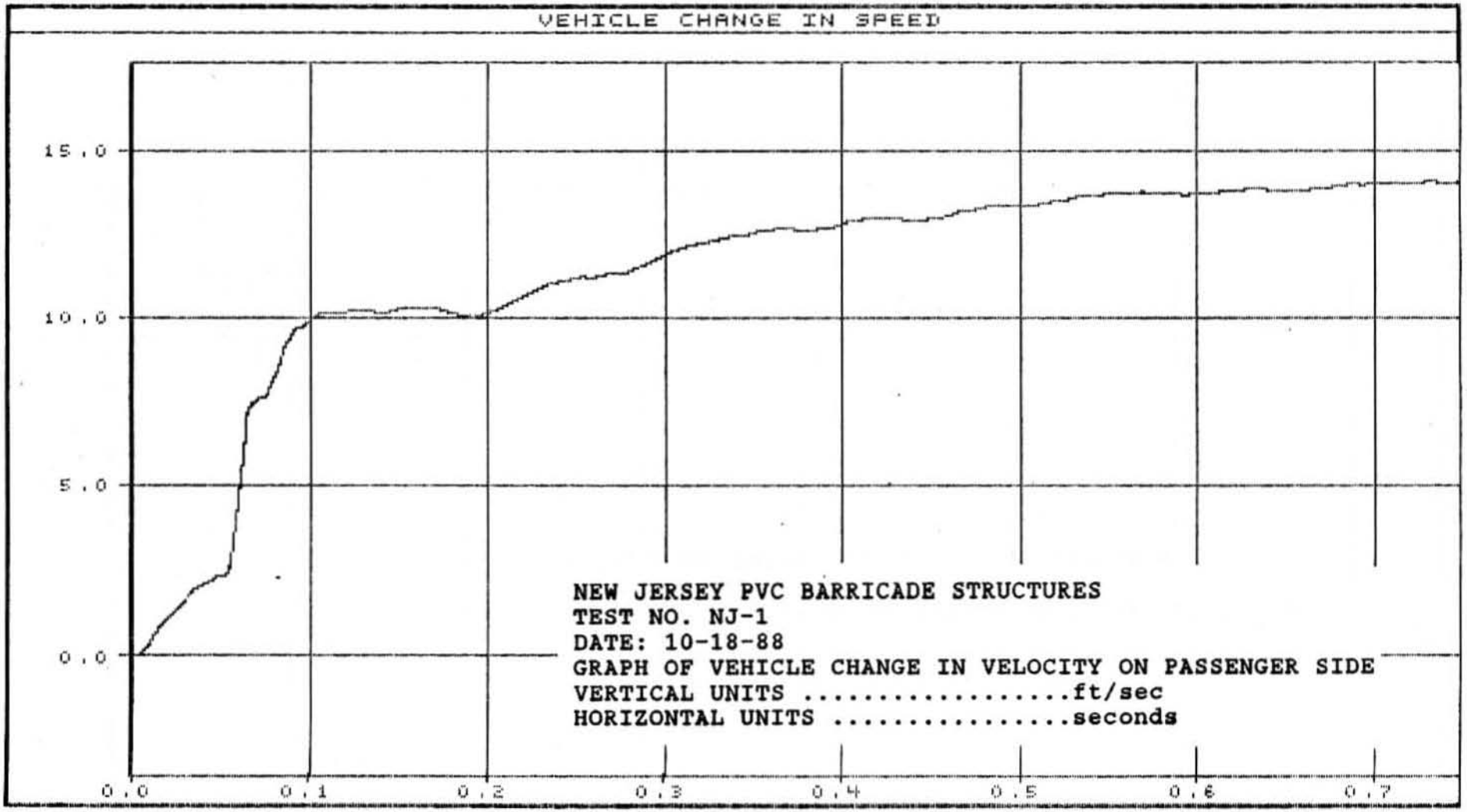
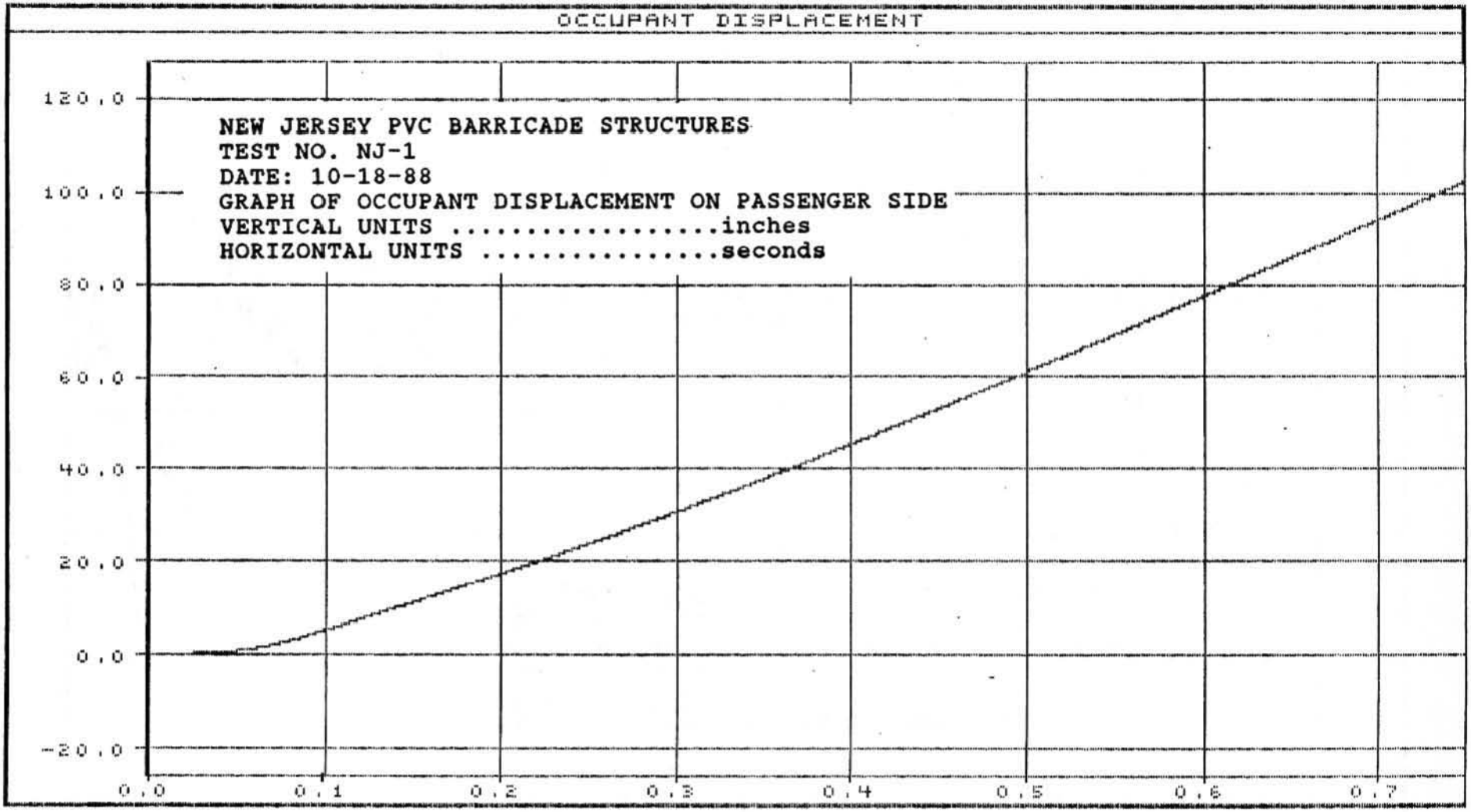
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-1
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds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NEW JERSEY PVC BARRICADE STRUCTURES
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GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
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80.0
60.0
40.0
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0.0
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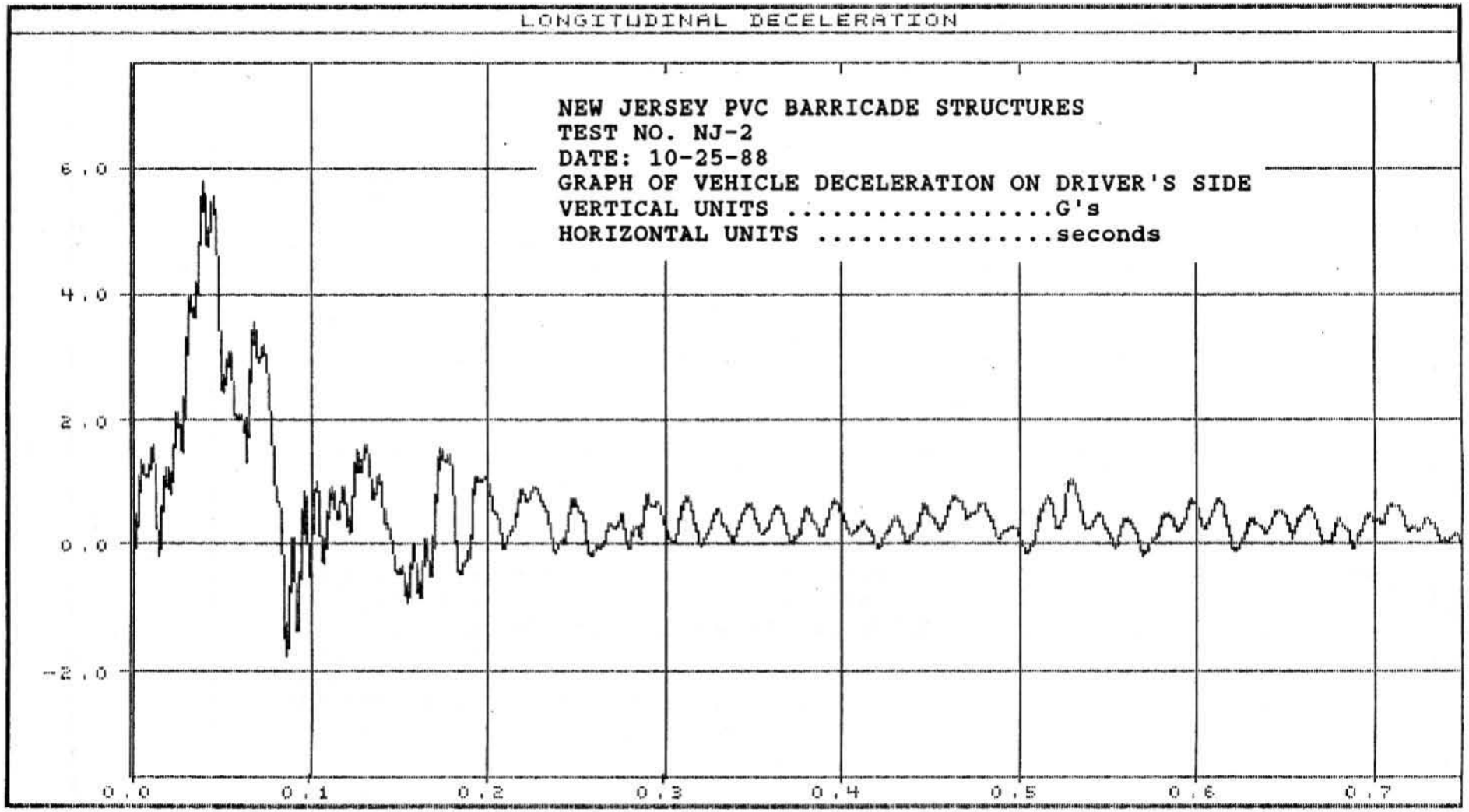
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7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TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
6.0
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-2.0
0.0
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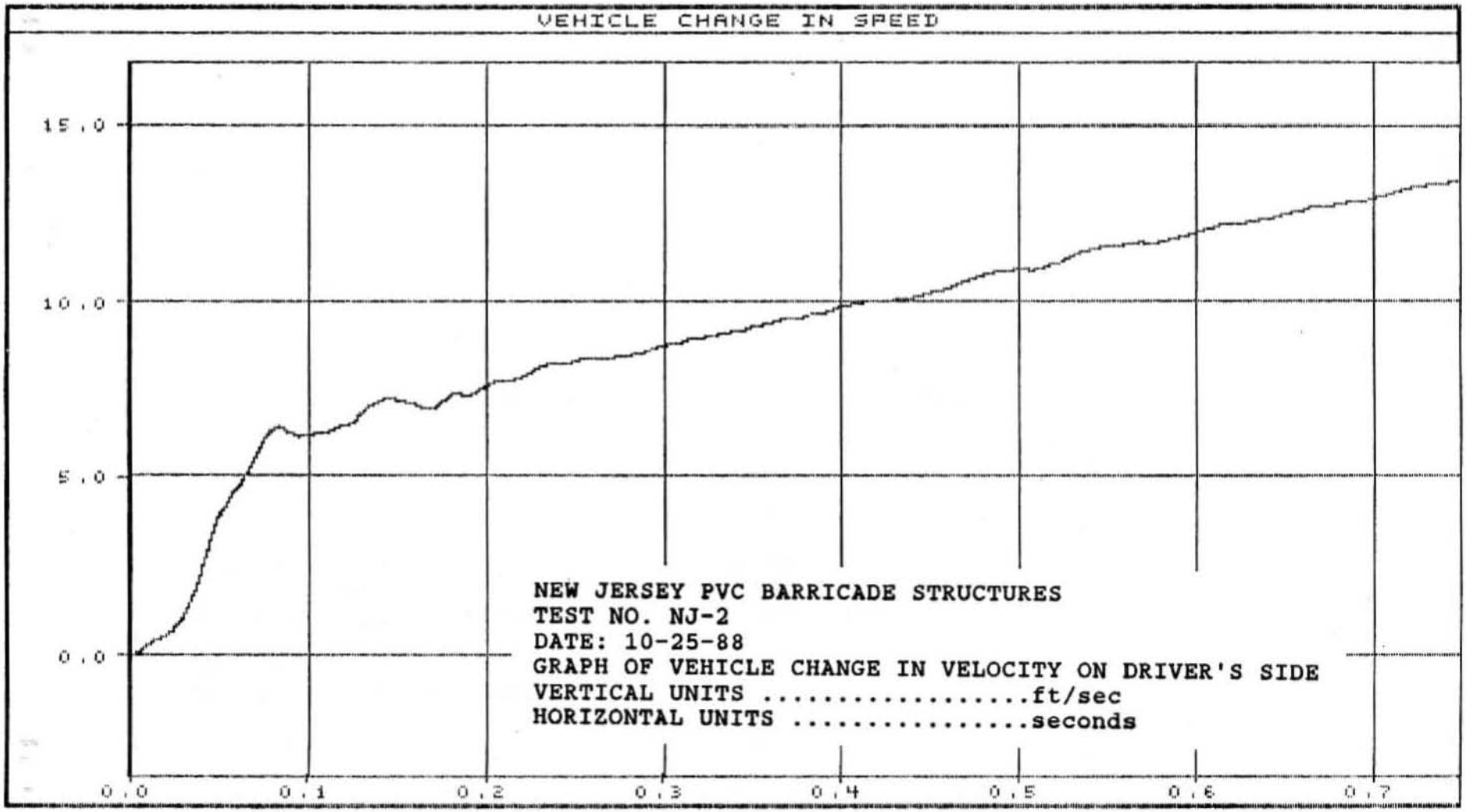
0.6
0.7


VEHICLE CHANGE IN SPEED
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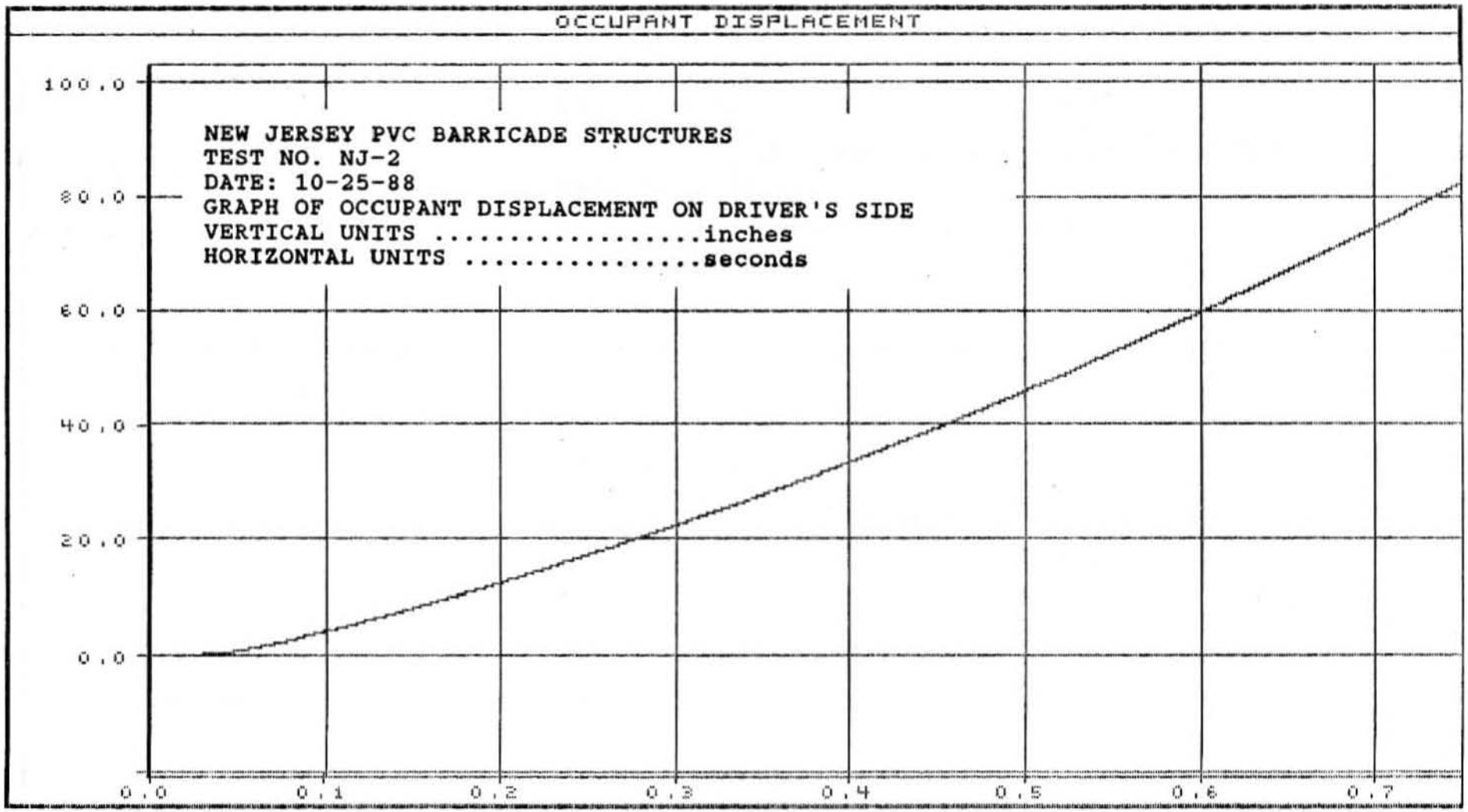
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds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TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
100.0
80.0
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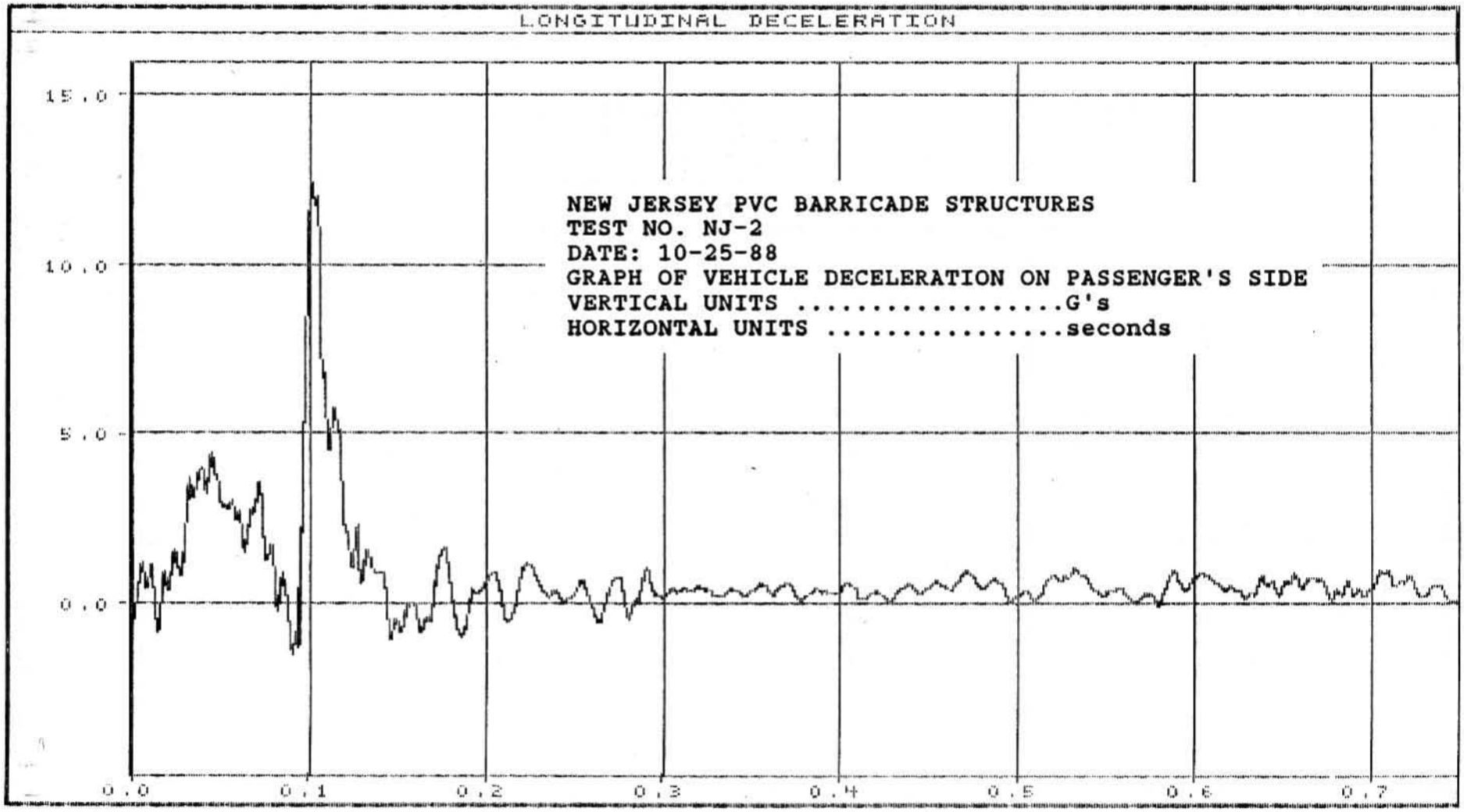
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7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0.4
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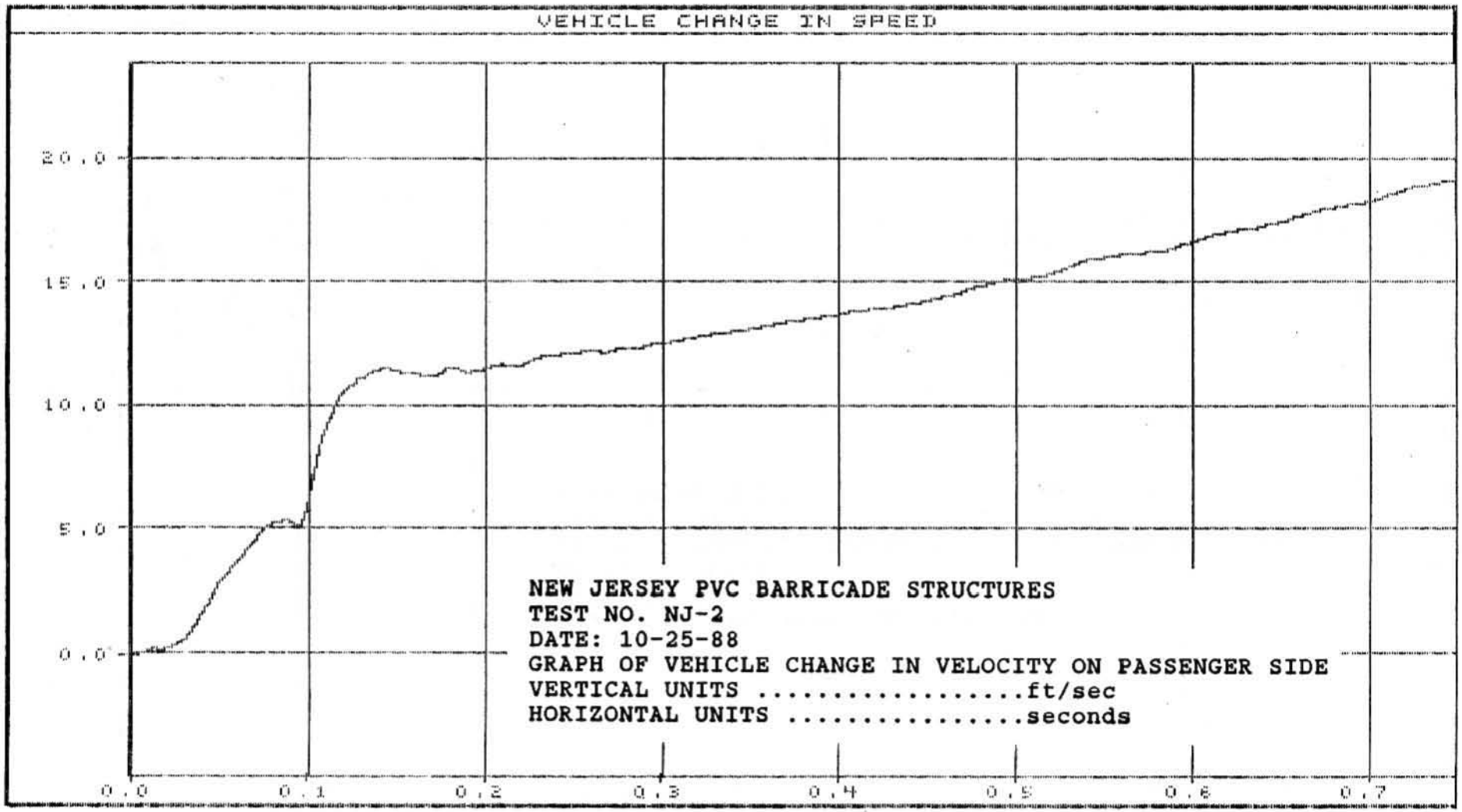
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds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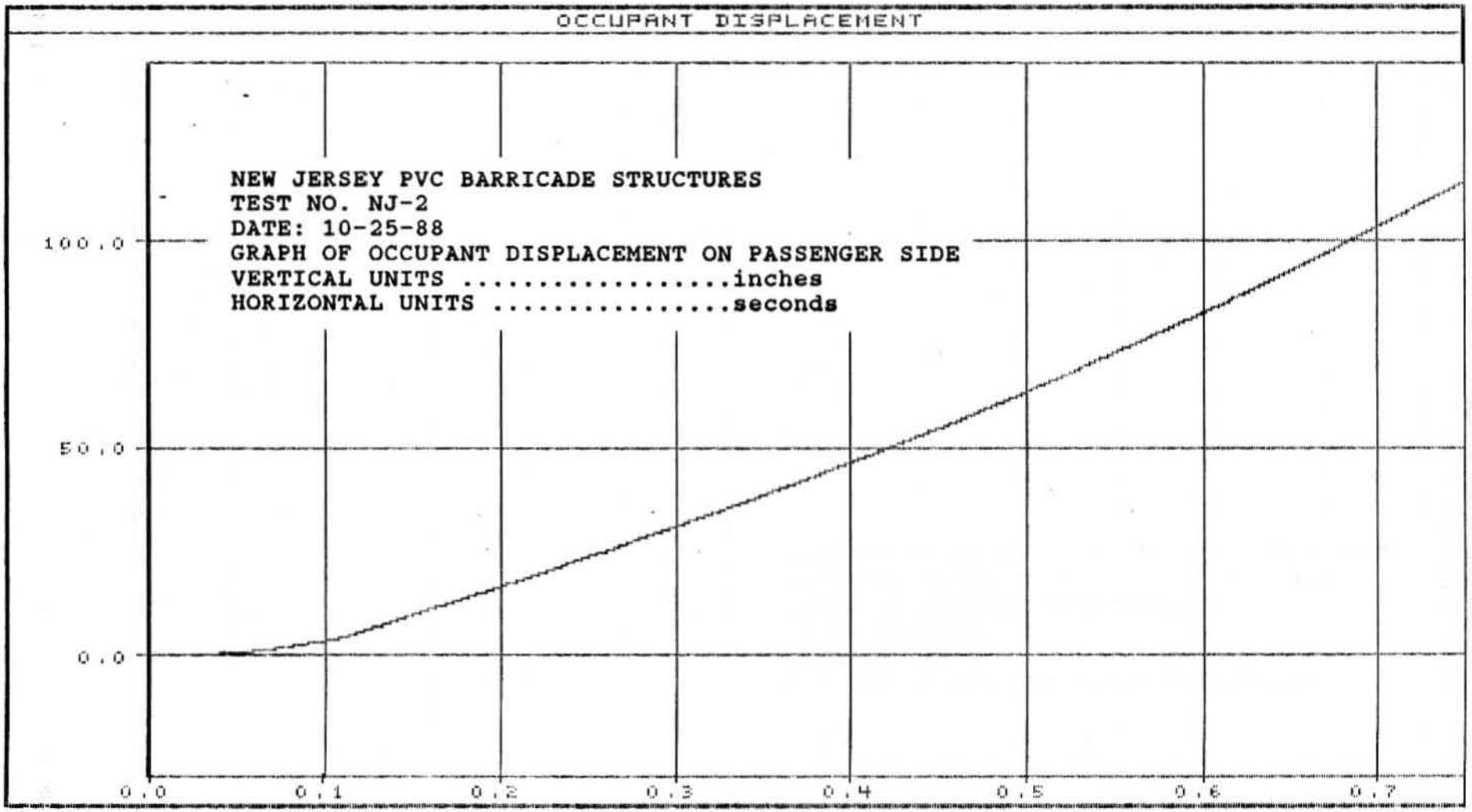
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds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TEST NO. NJ-2
DATE: 10-25-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
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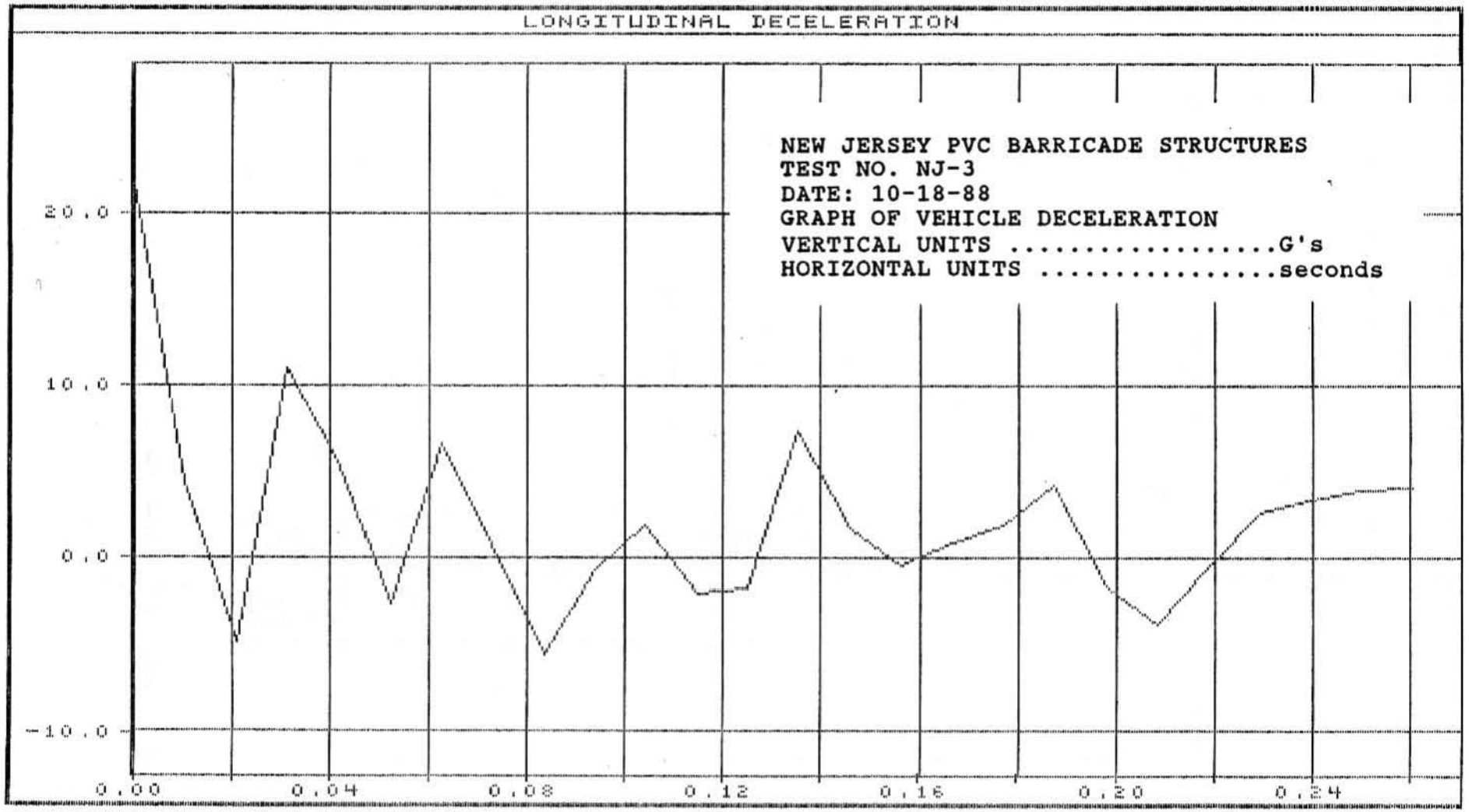
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


LONGITUDINAL DECELERATION
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TEST NO. NJ-3
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
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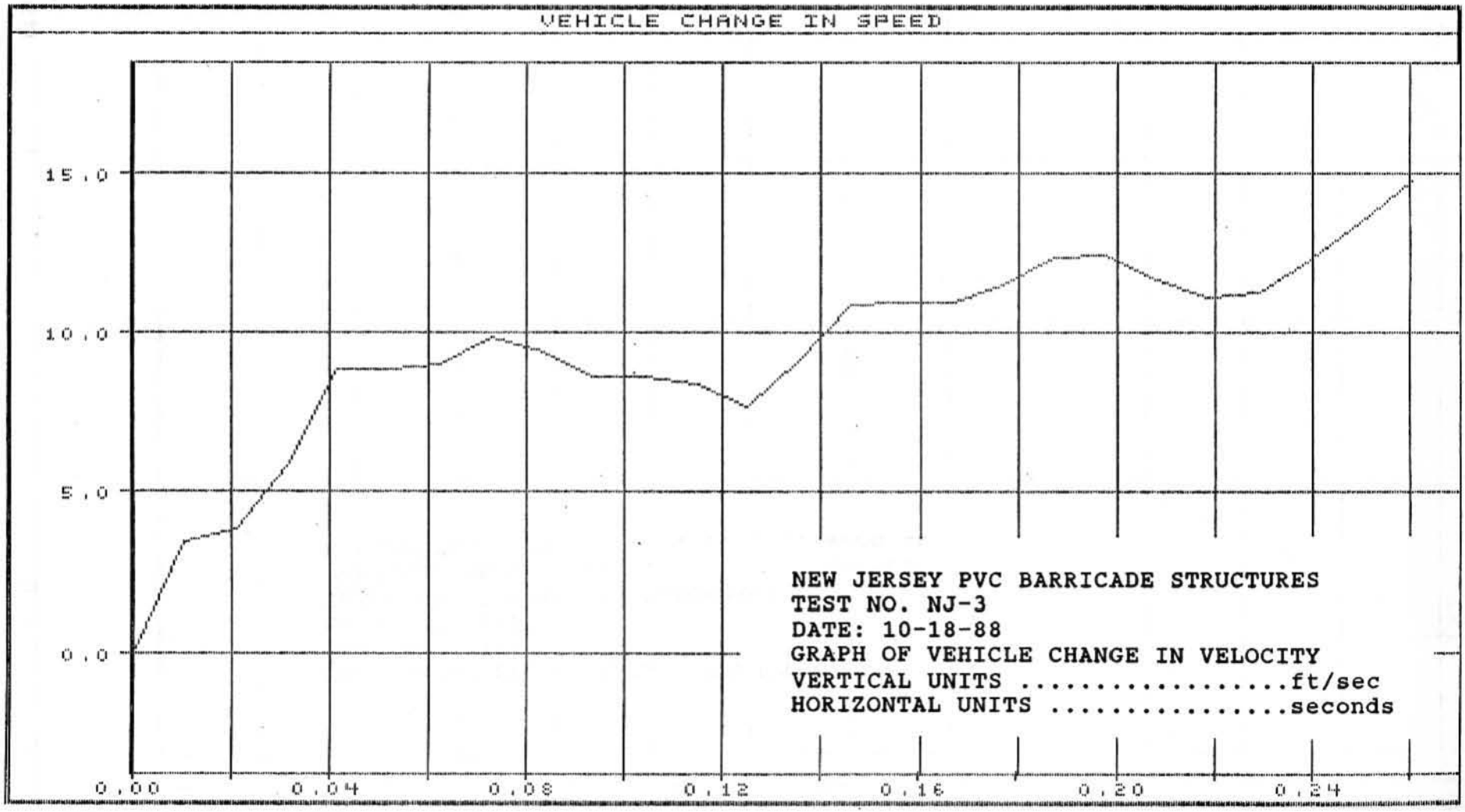
0.0
-10.0
0.00
0.04
0.08
0.12
0.16
0.20
0.24


VEHICLE CHANGE IN SPEED
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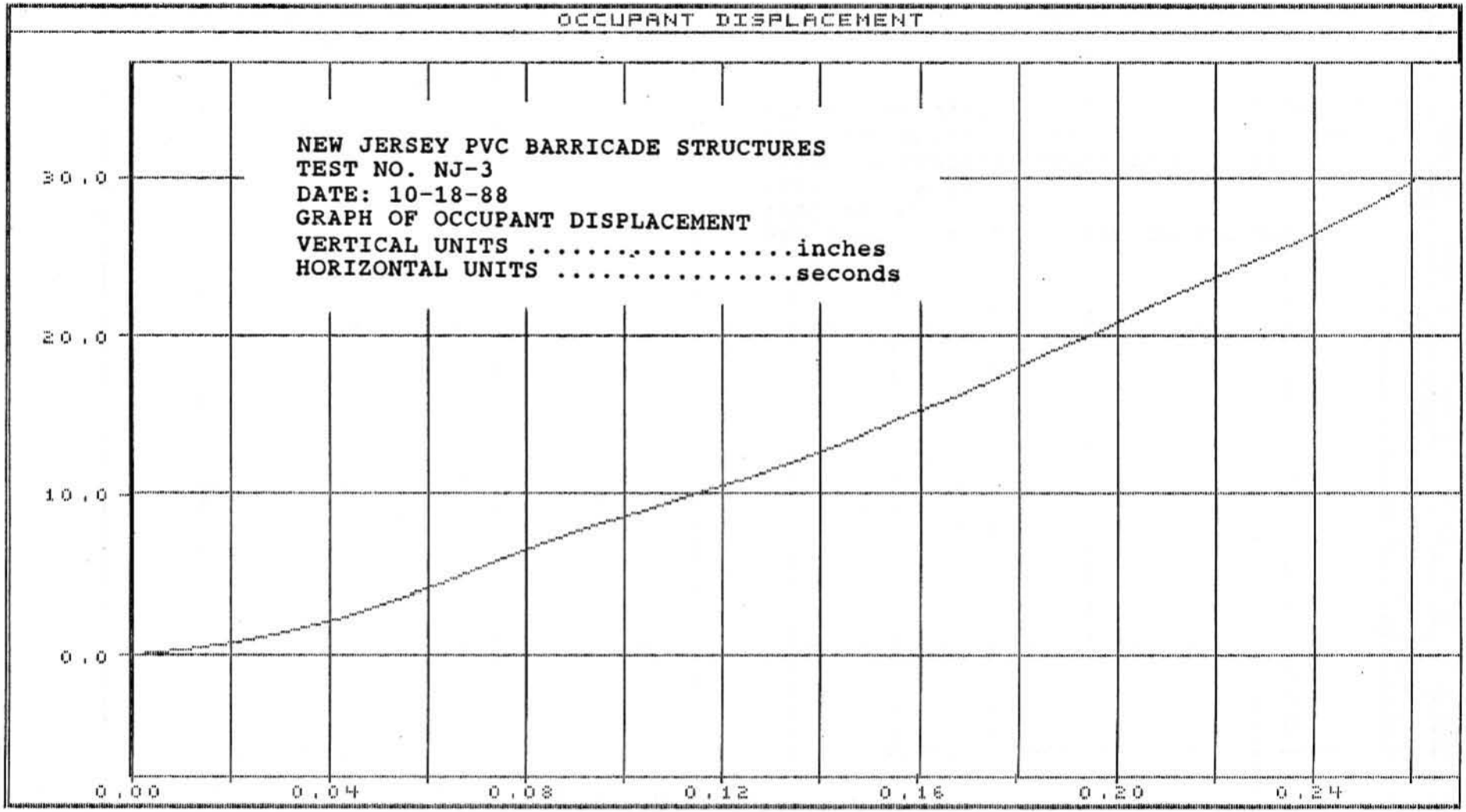
10.0
5.0
0.0
0.00
0.04
0.08
0.12
0.16
0.20
0.24
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-3
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds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TEST NO. NJ-3
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
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10.0
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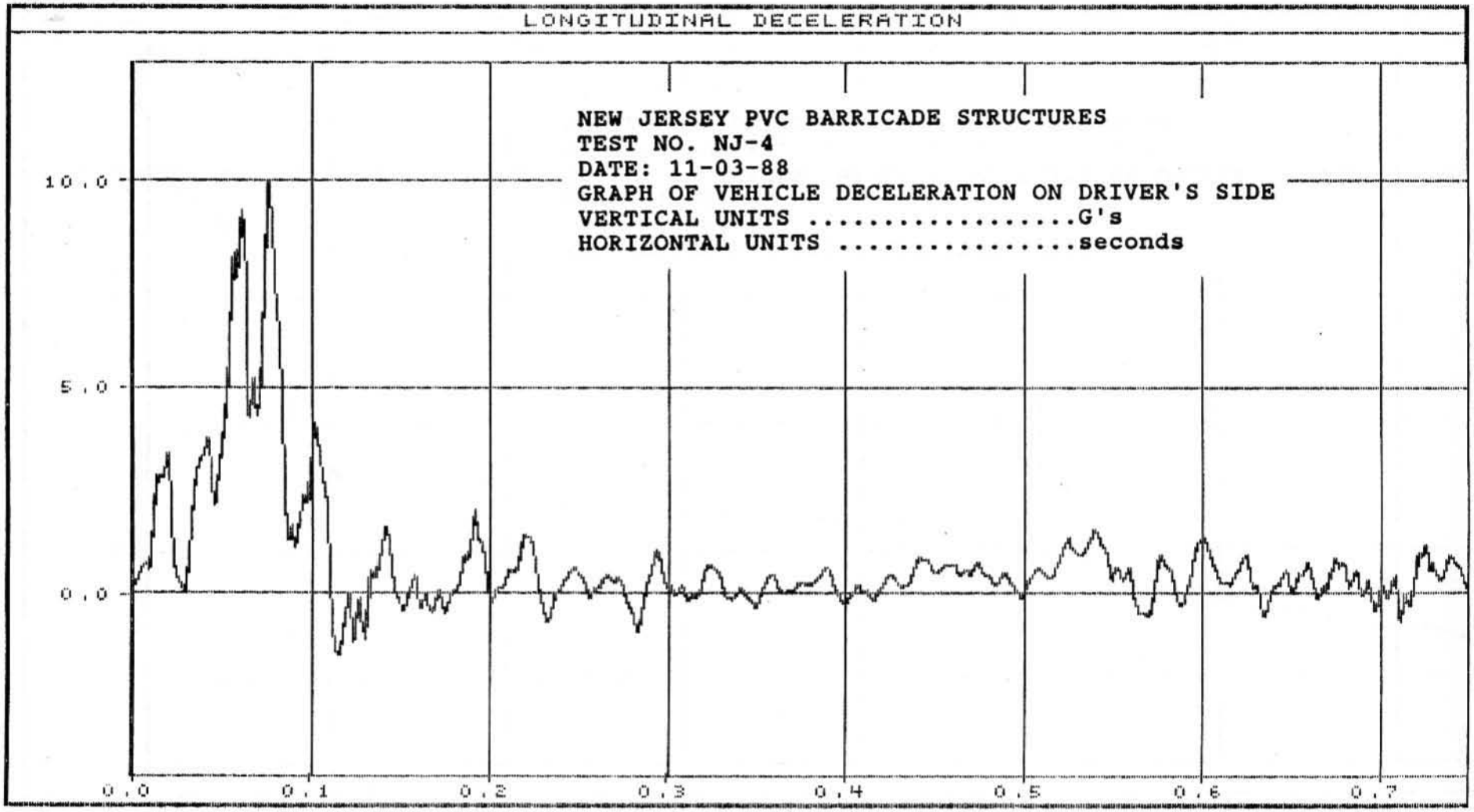
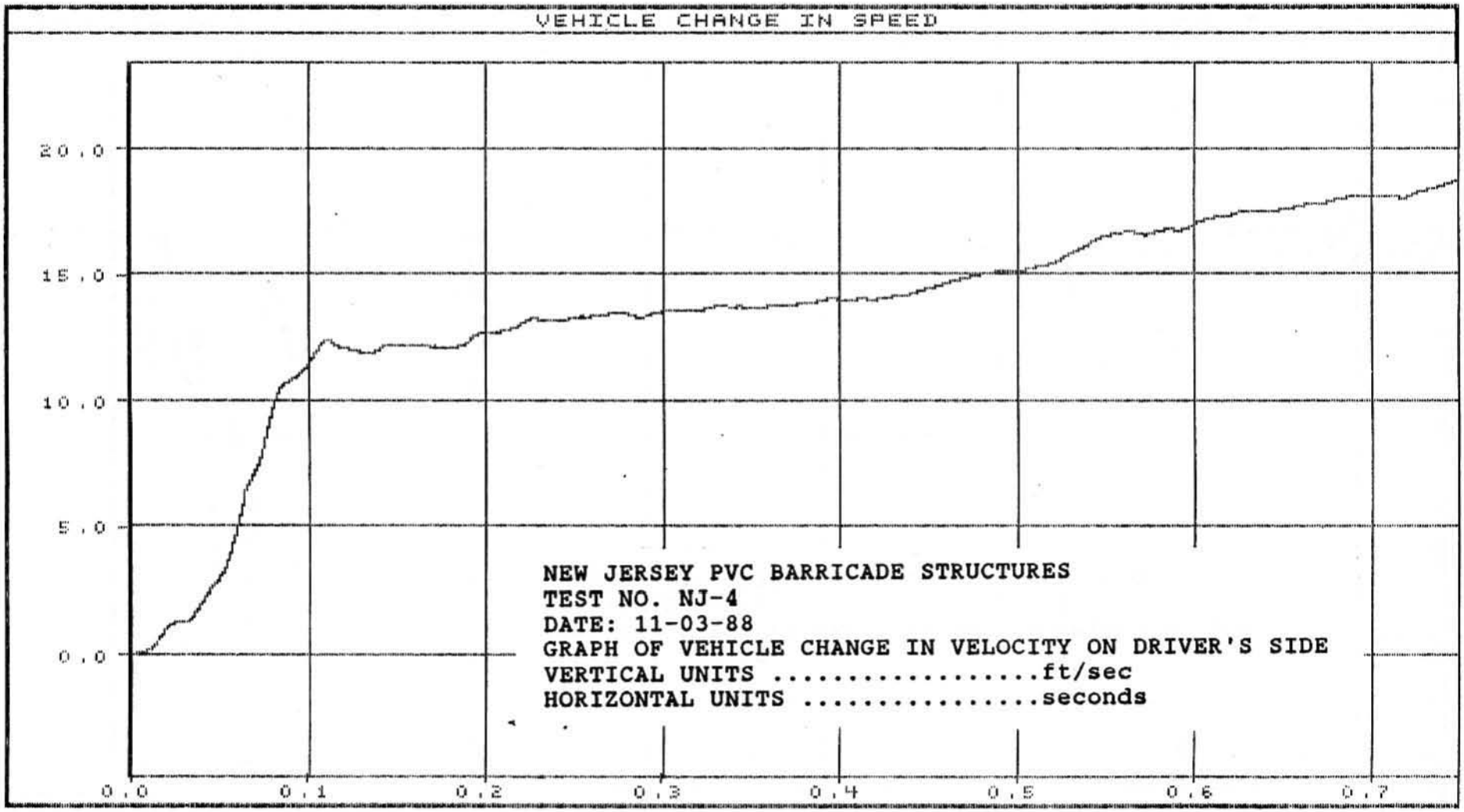
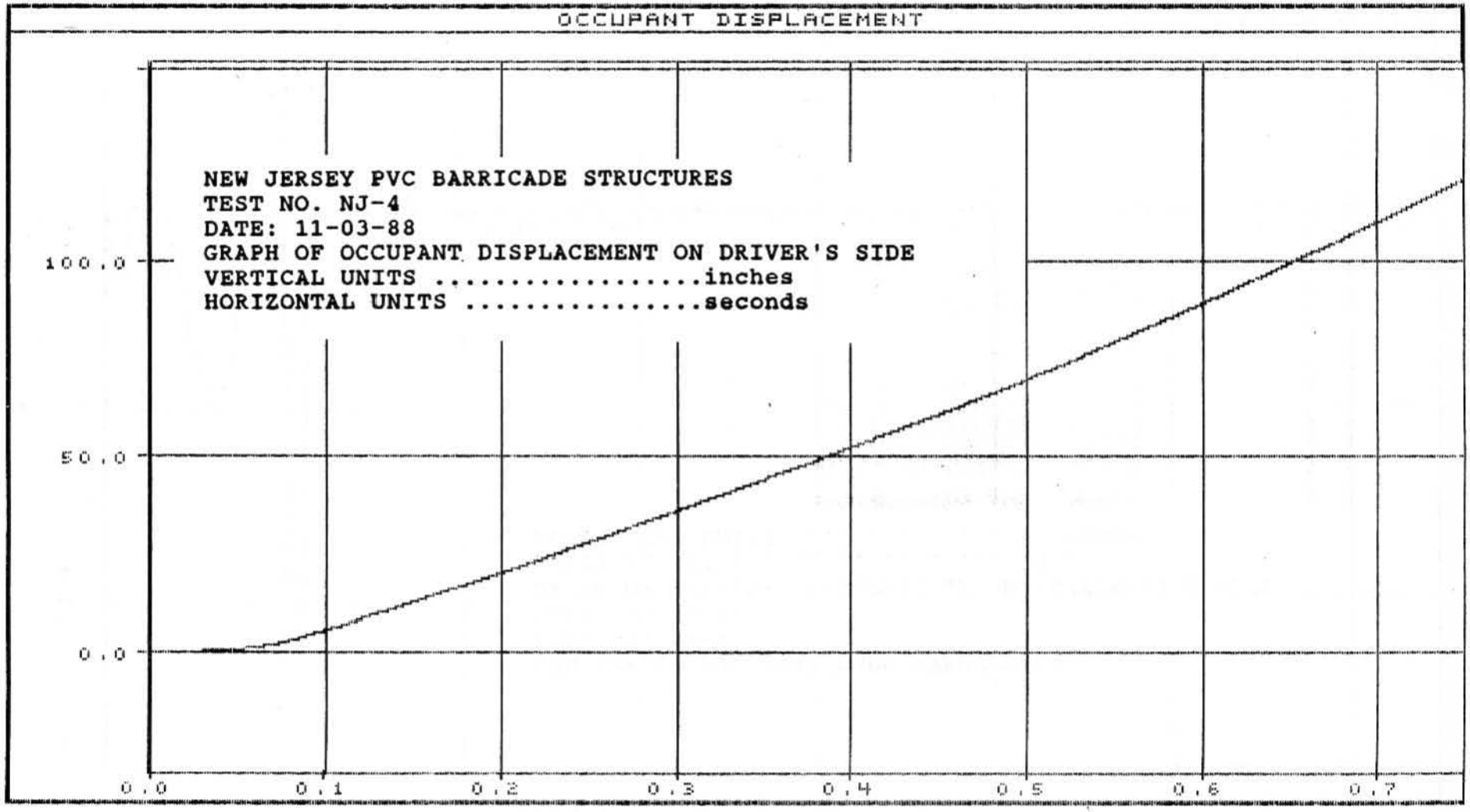
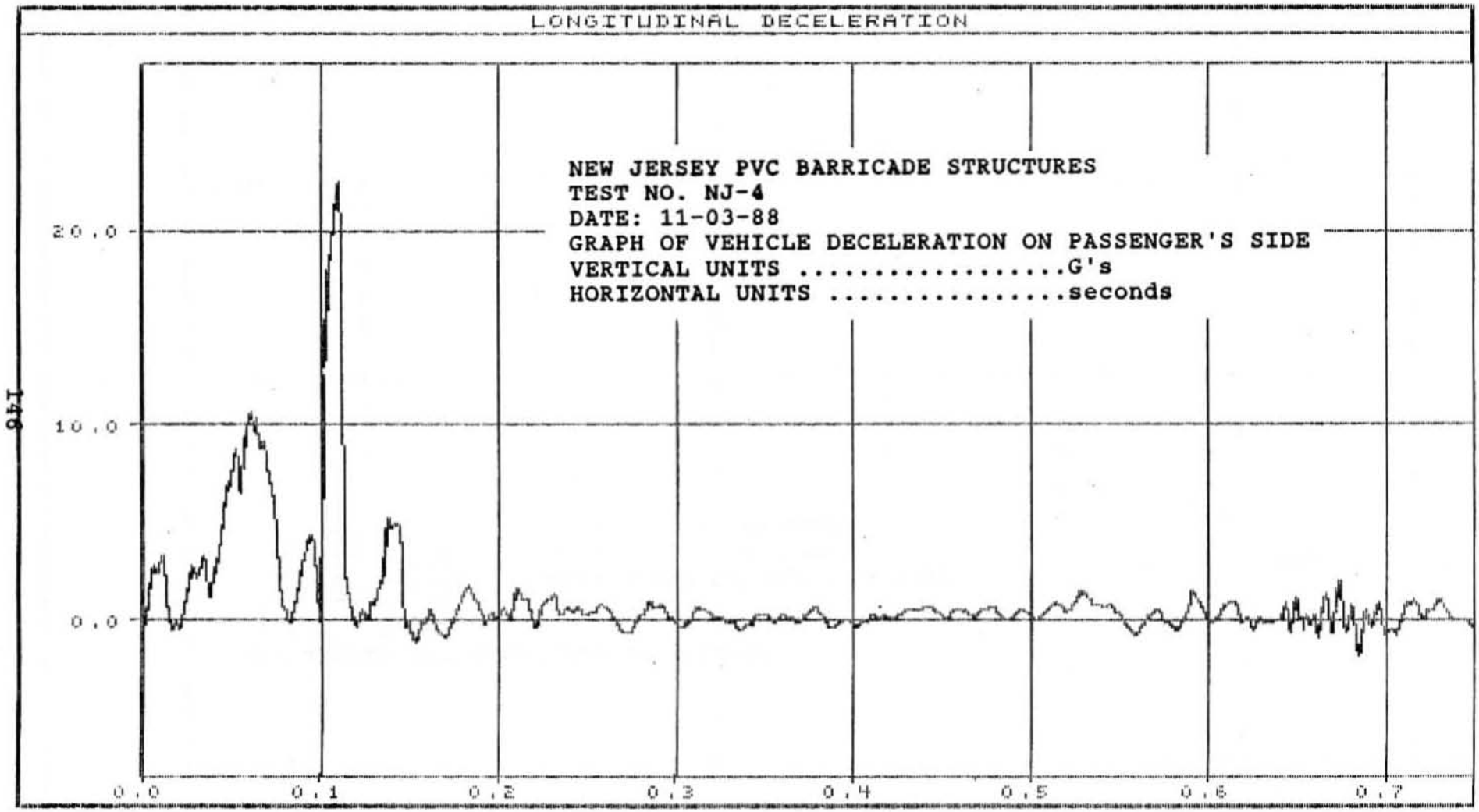
0.00
0.04
0.08
0.12
0.16
0.20
0.24


LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


VEHICLE CHANGE IN SPEED
20.0
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds


OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
100.0
50.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
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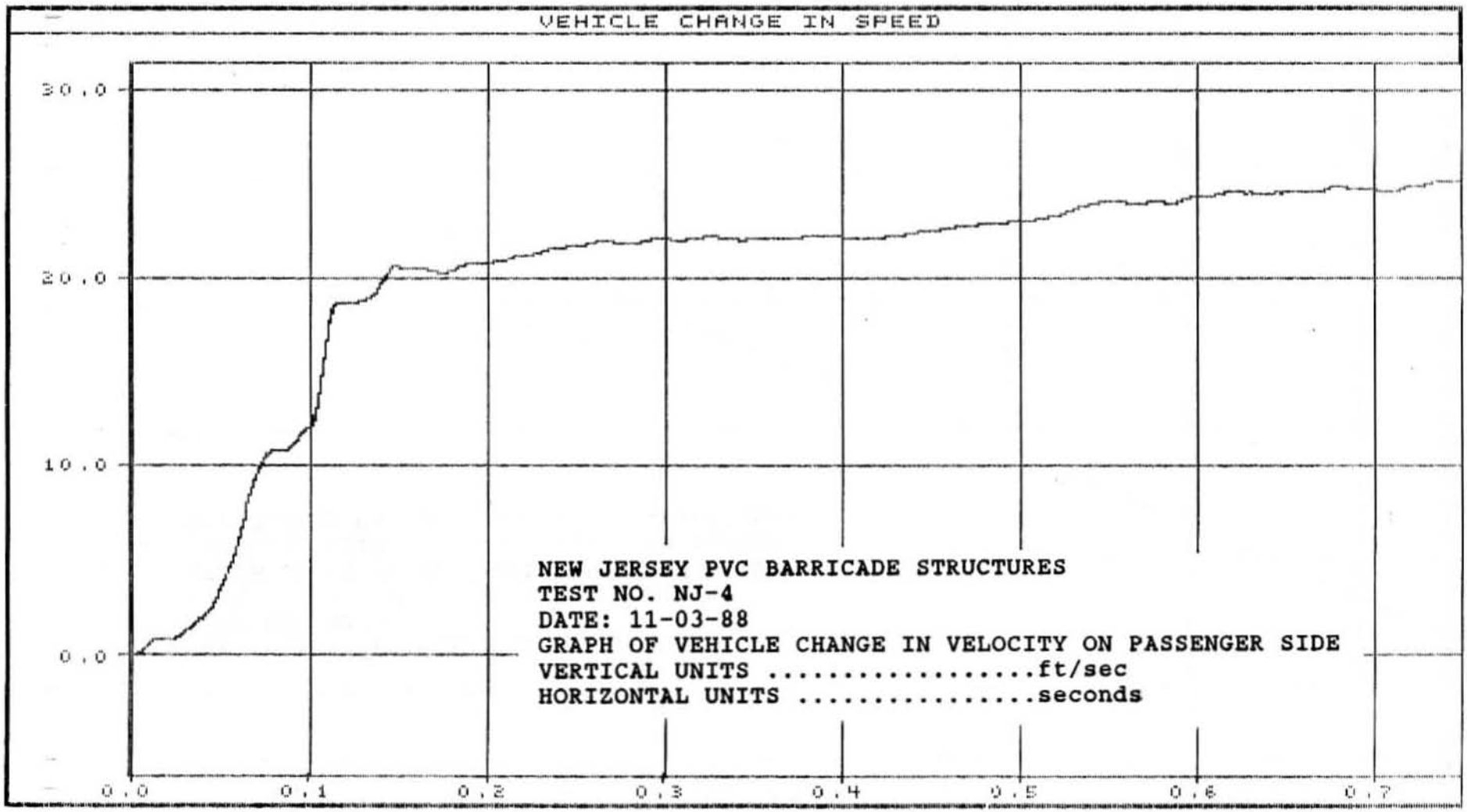
10.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


VEHICLE CHANGE IN SPEED
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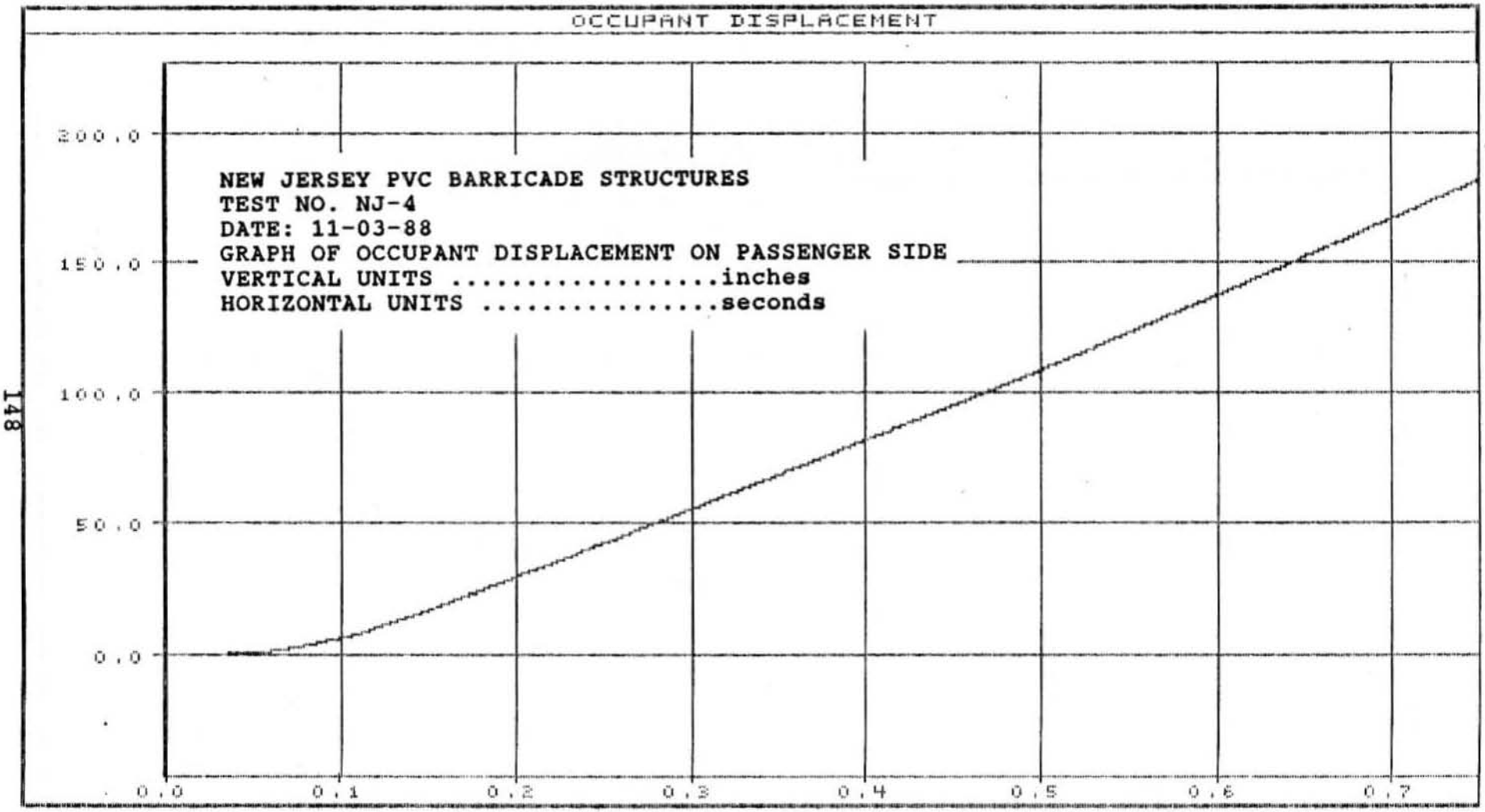
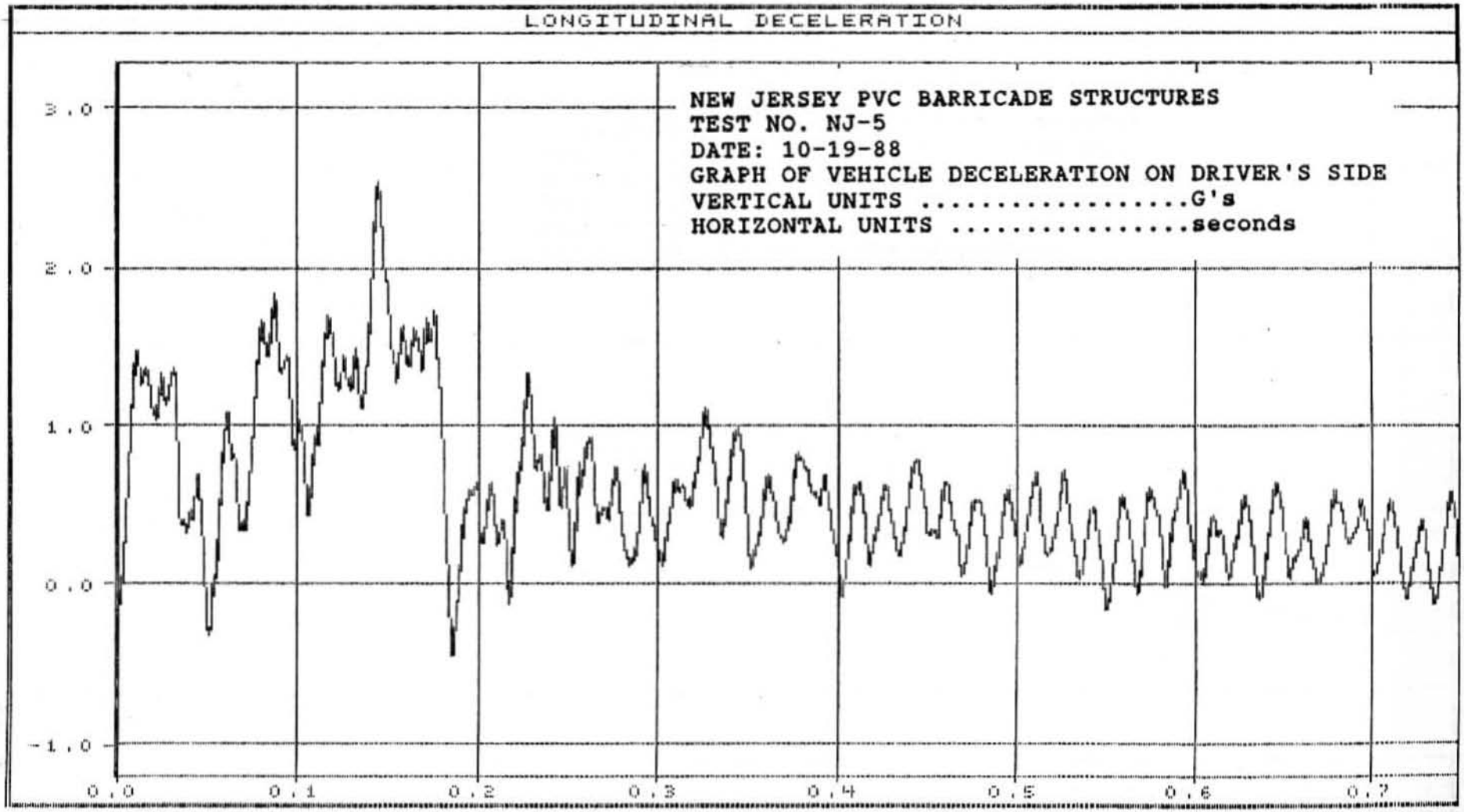
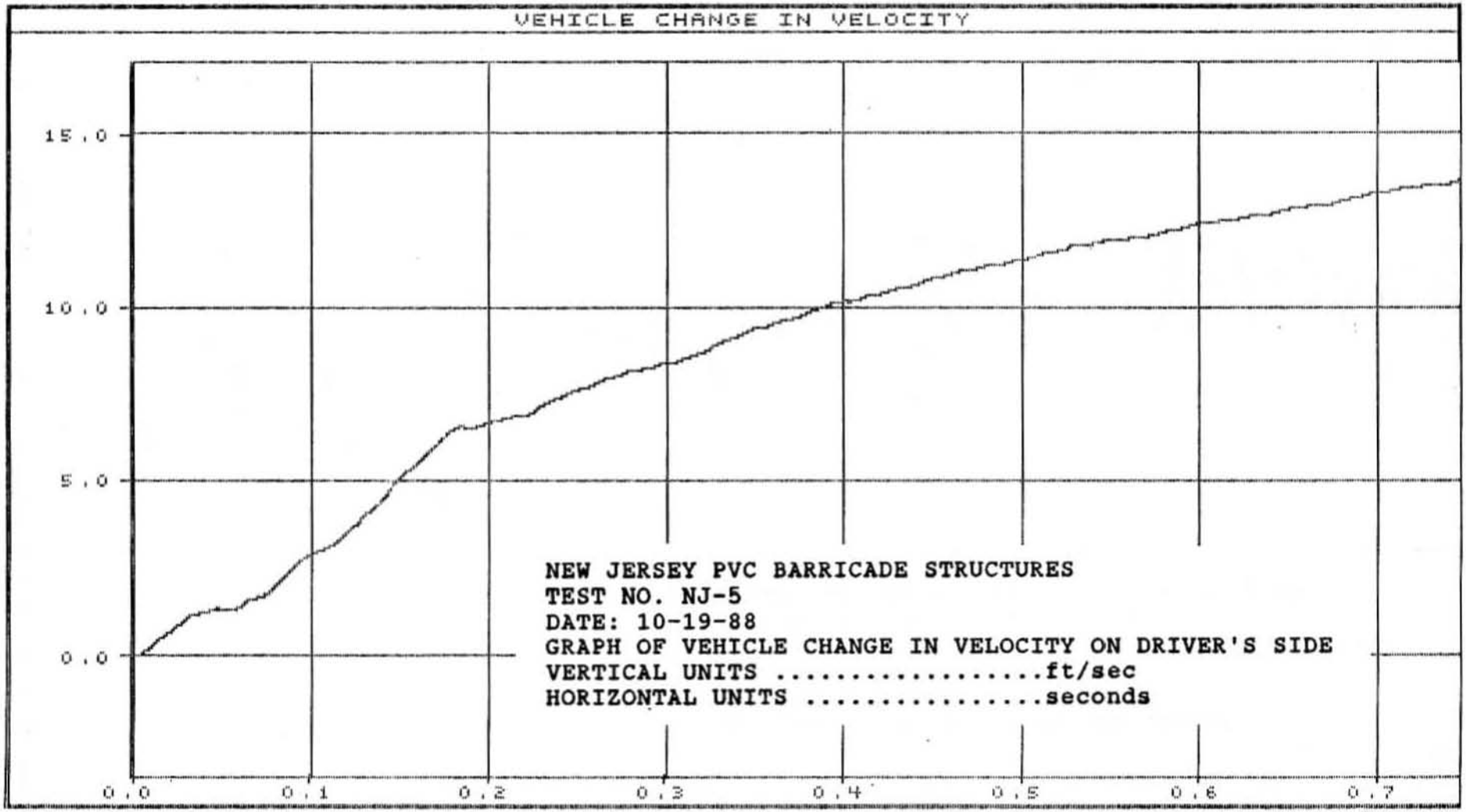
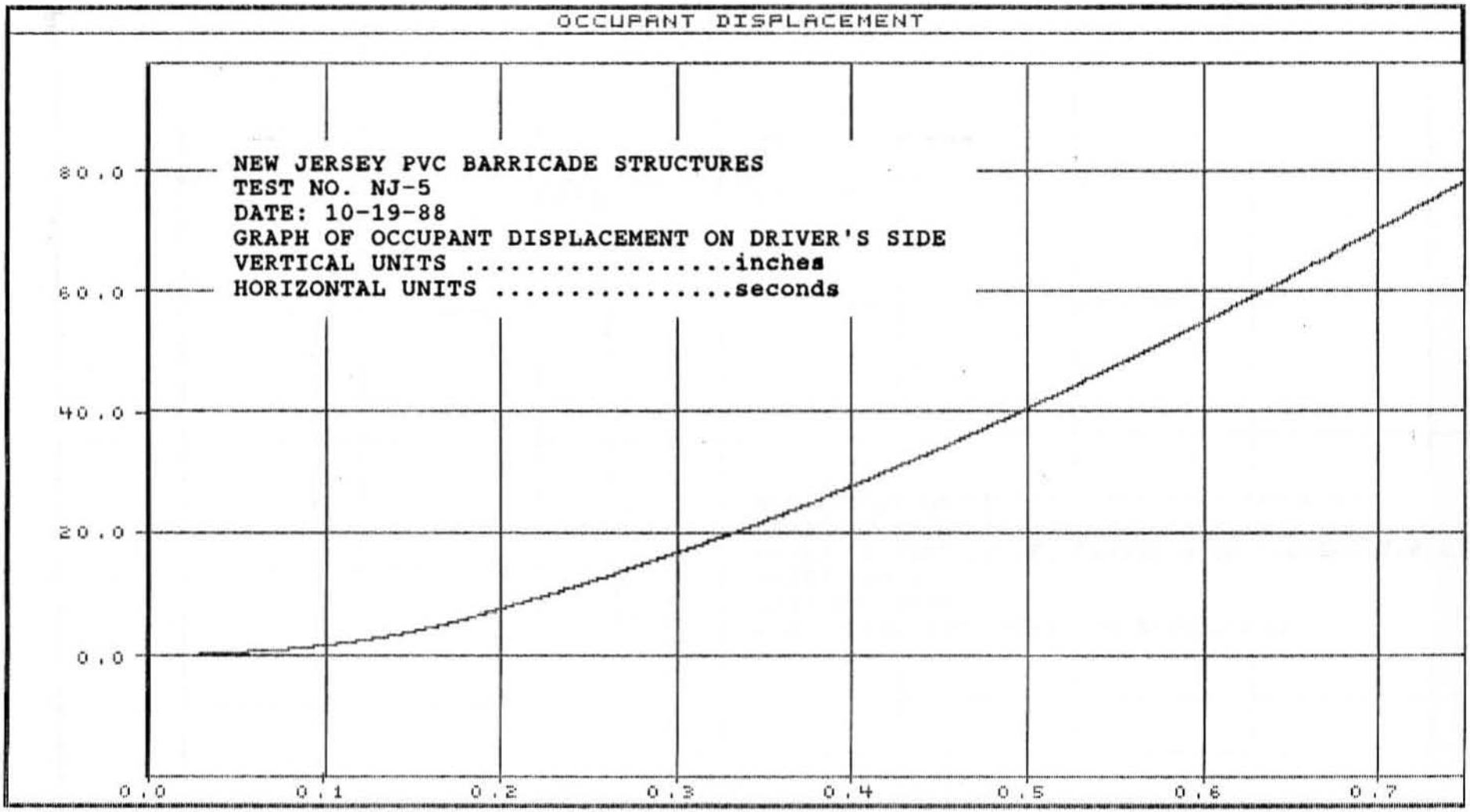
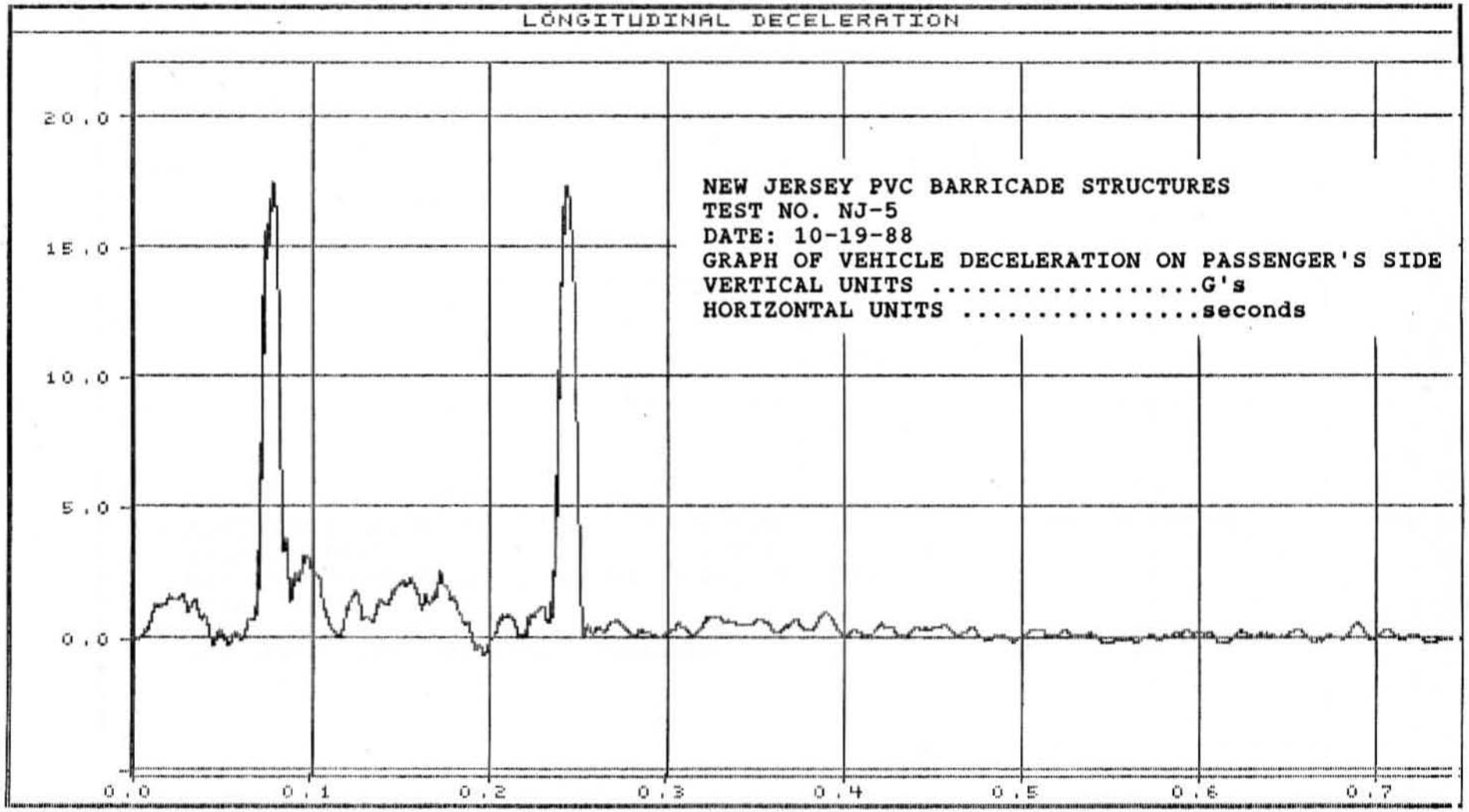
20.0
10.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

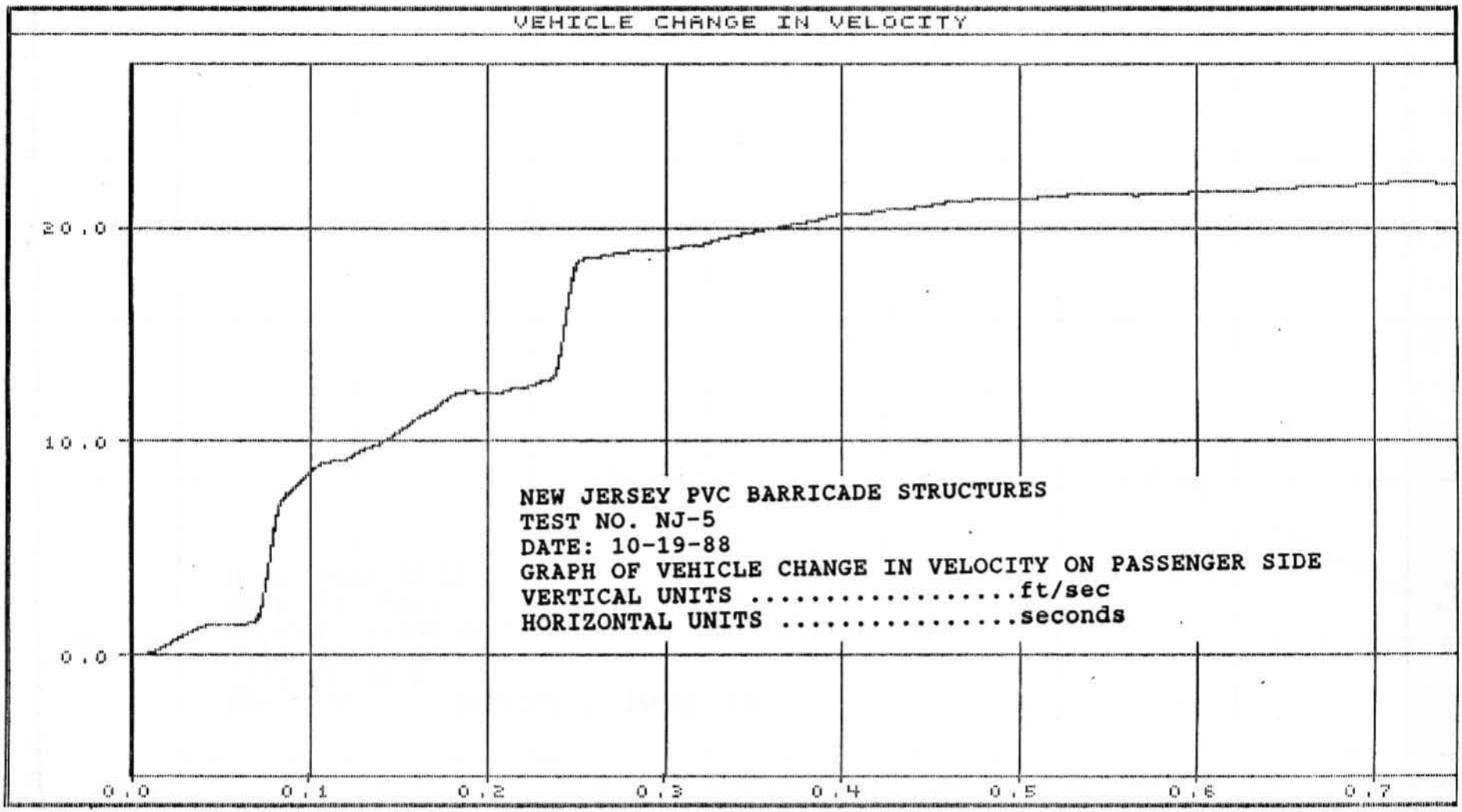

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-4
DATE: 11-03-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
200.0
150.0
100.0
50.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

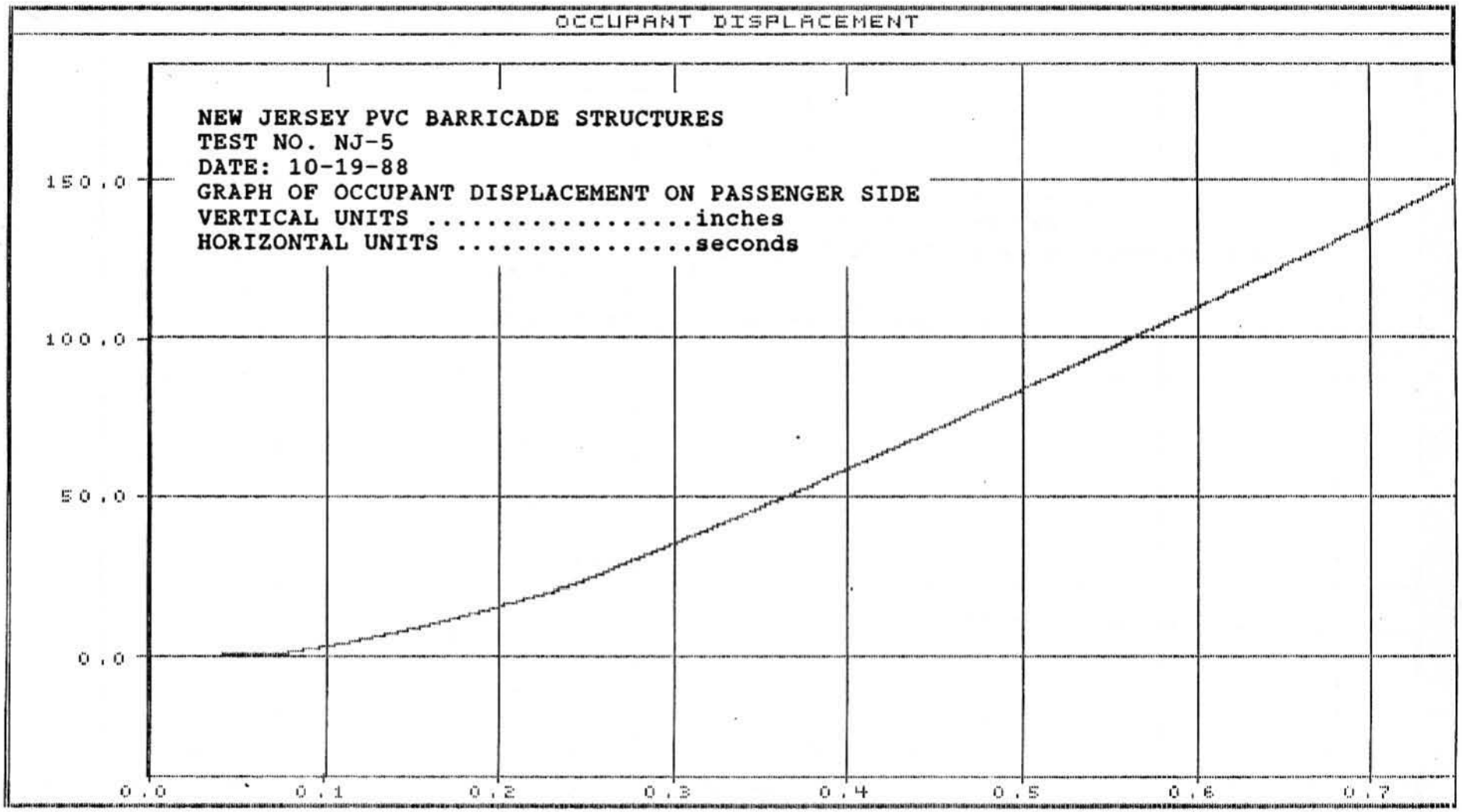

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

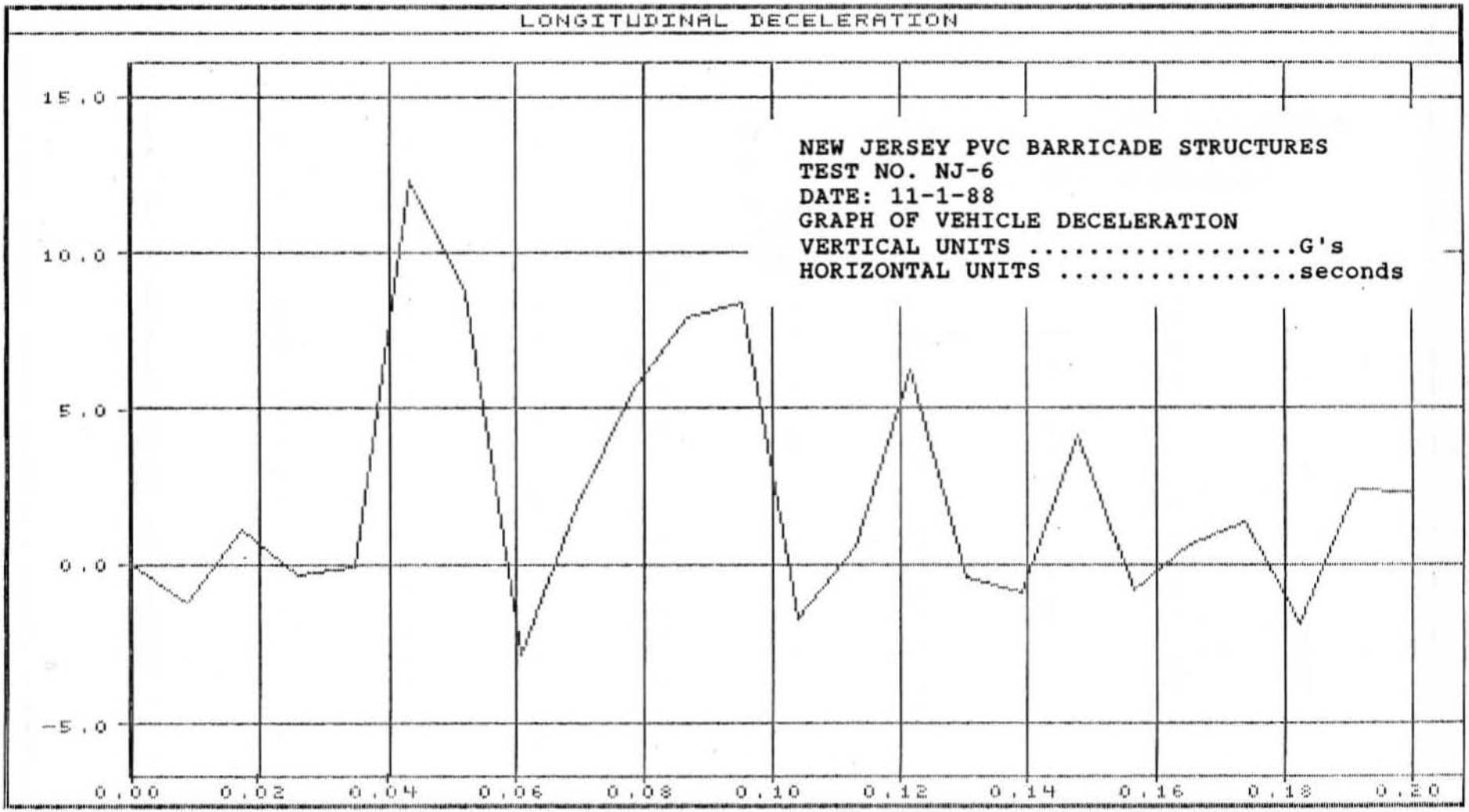

VEHICLE CHANGE IN VELOCITY
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

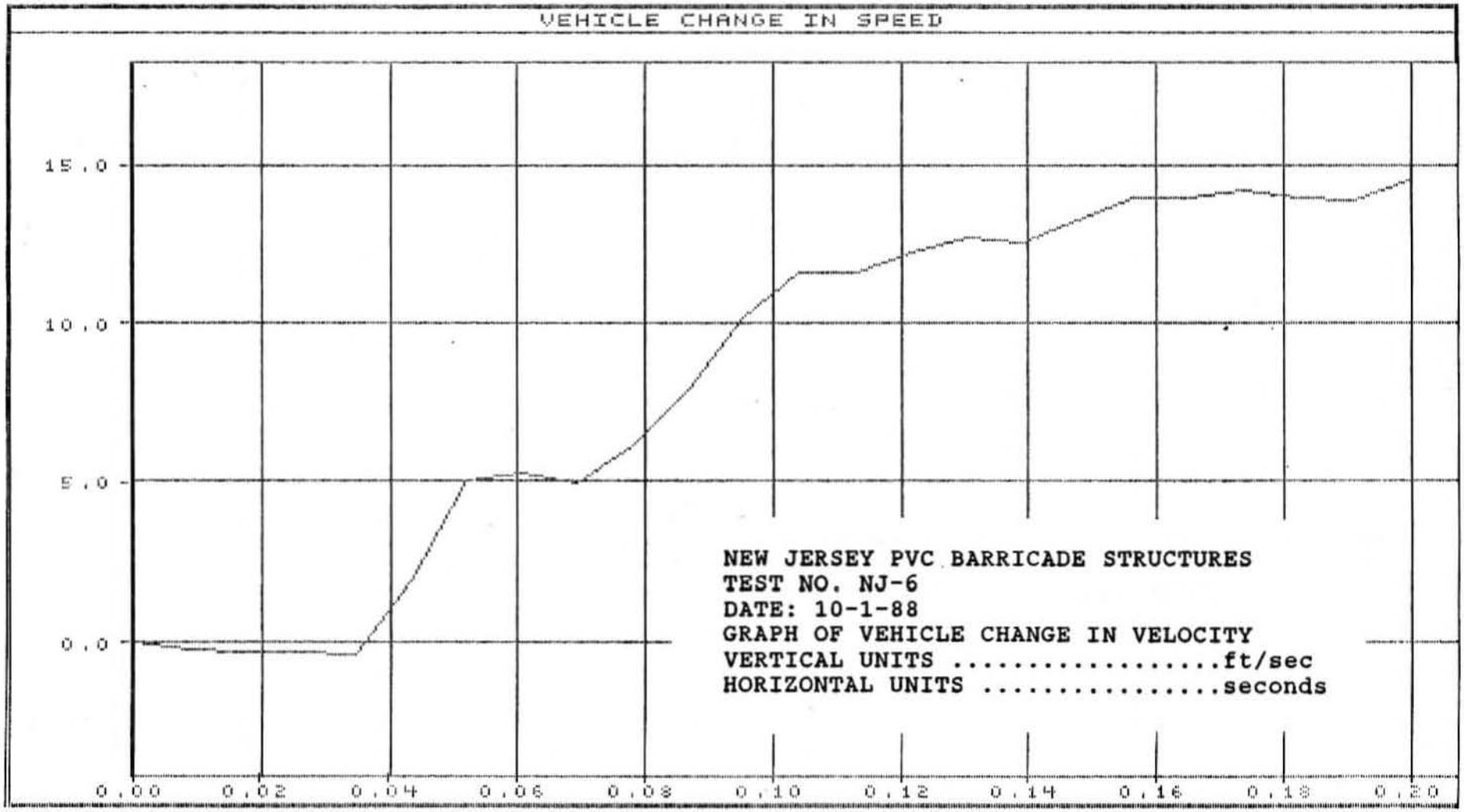

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

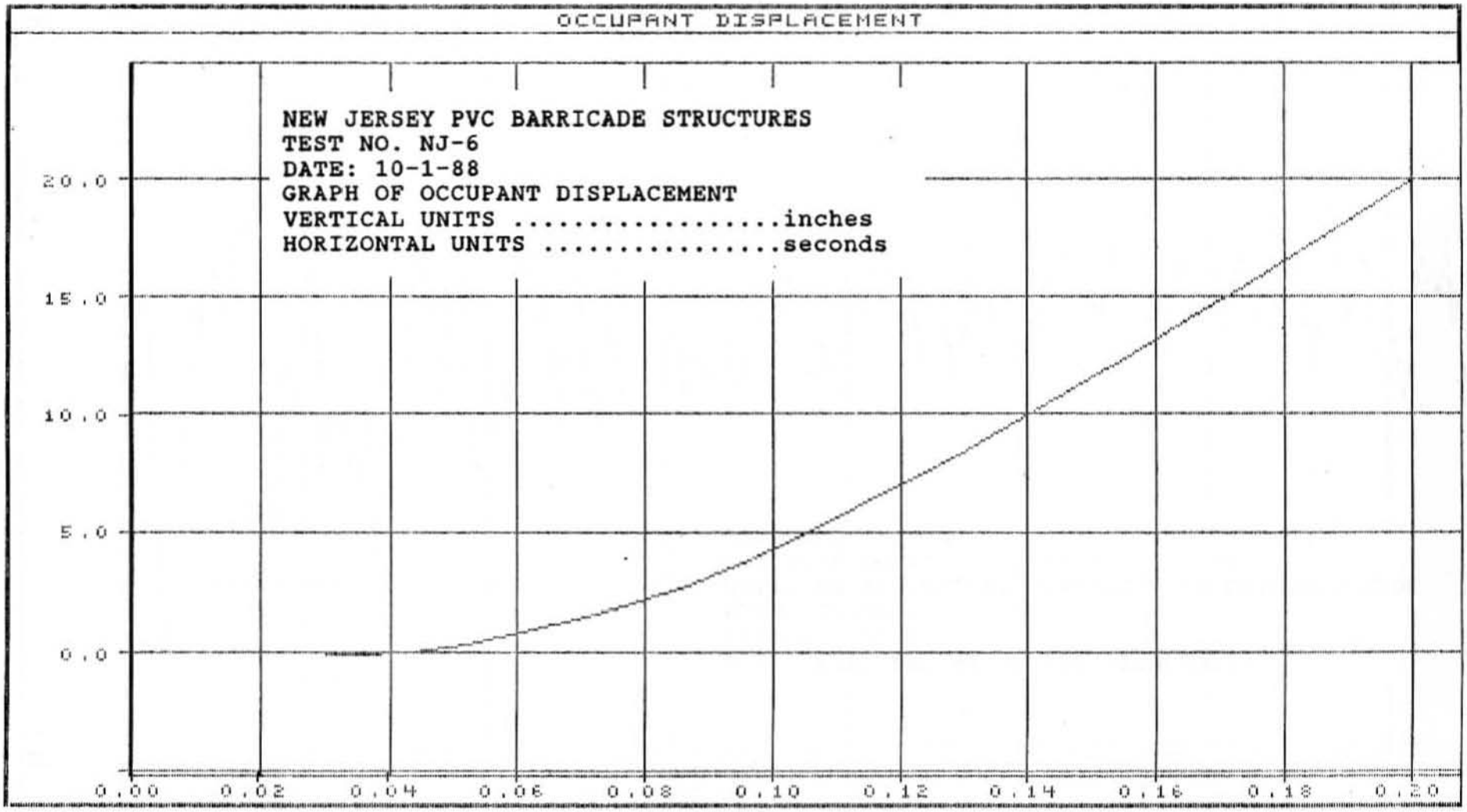

LONGITUDINAL DECELERATION
20.0
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds

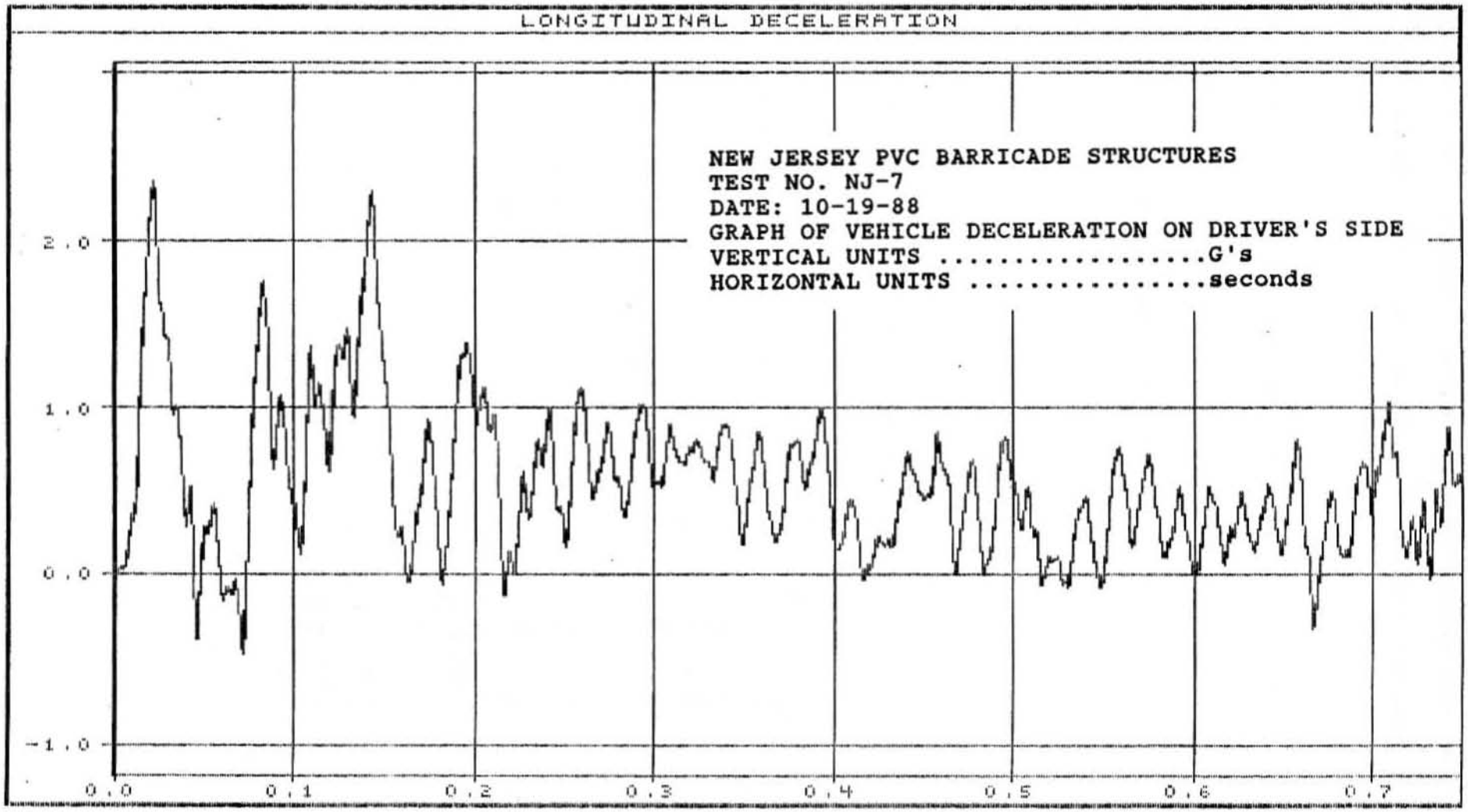

VEHICLE CHANGE IN VELOCITY
20.0
10.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

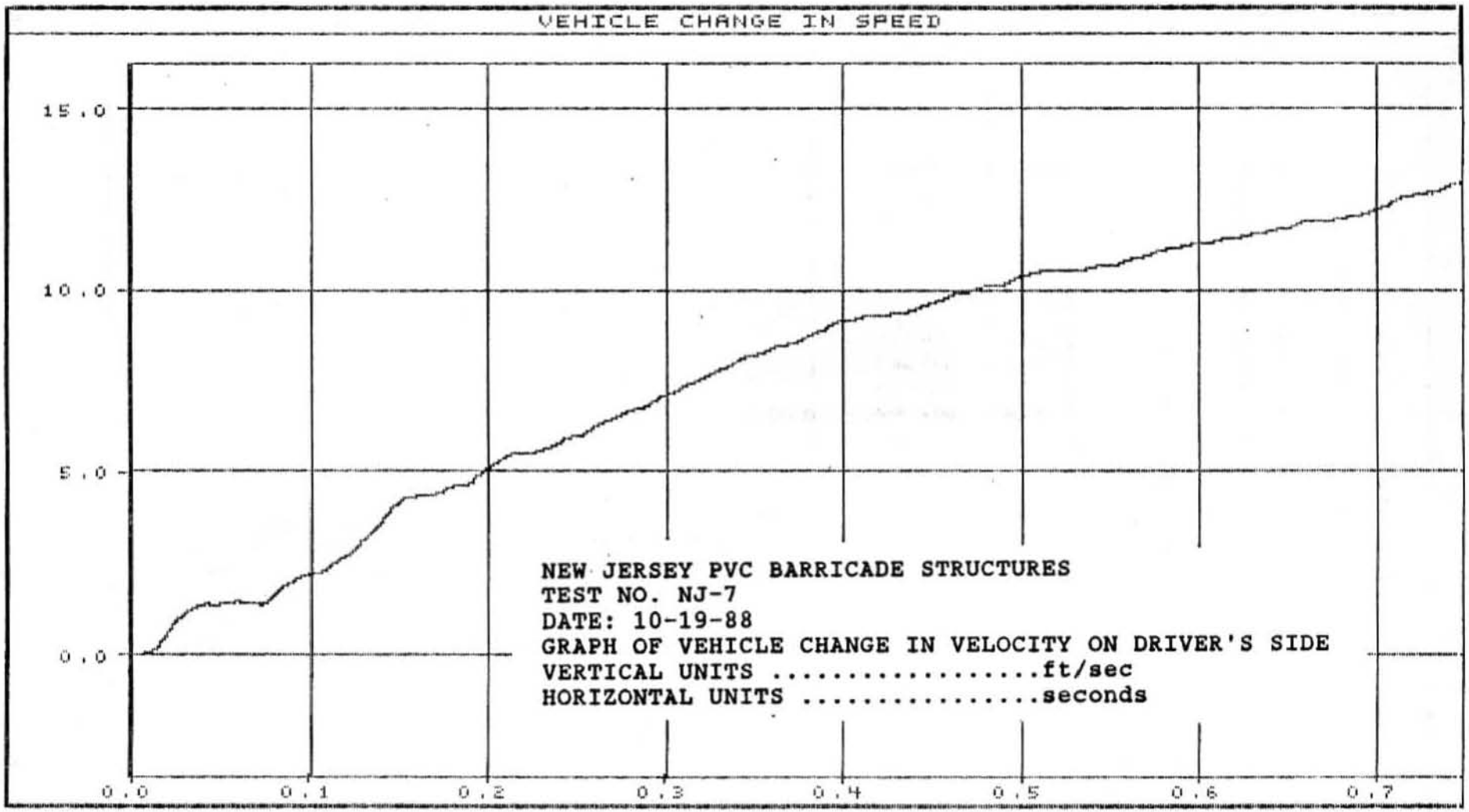

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-5
DATE: 10-19-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
150.0
100.0
50.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

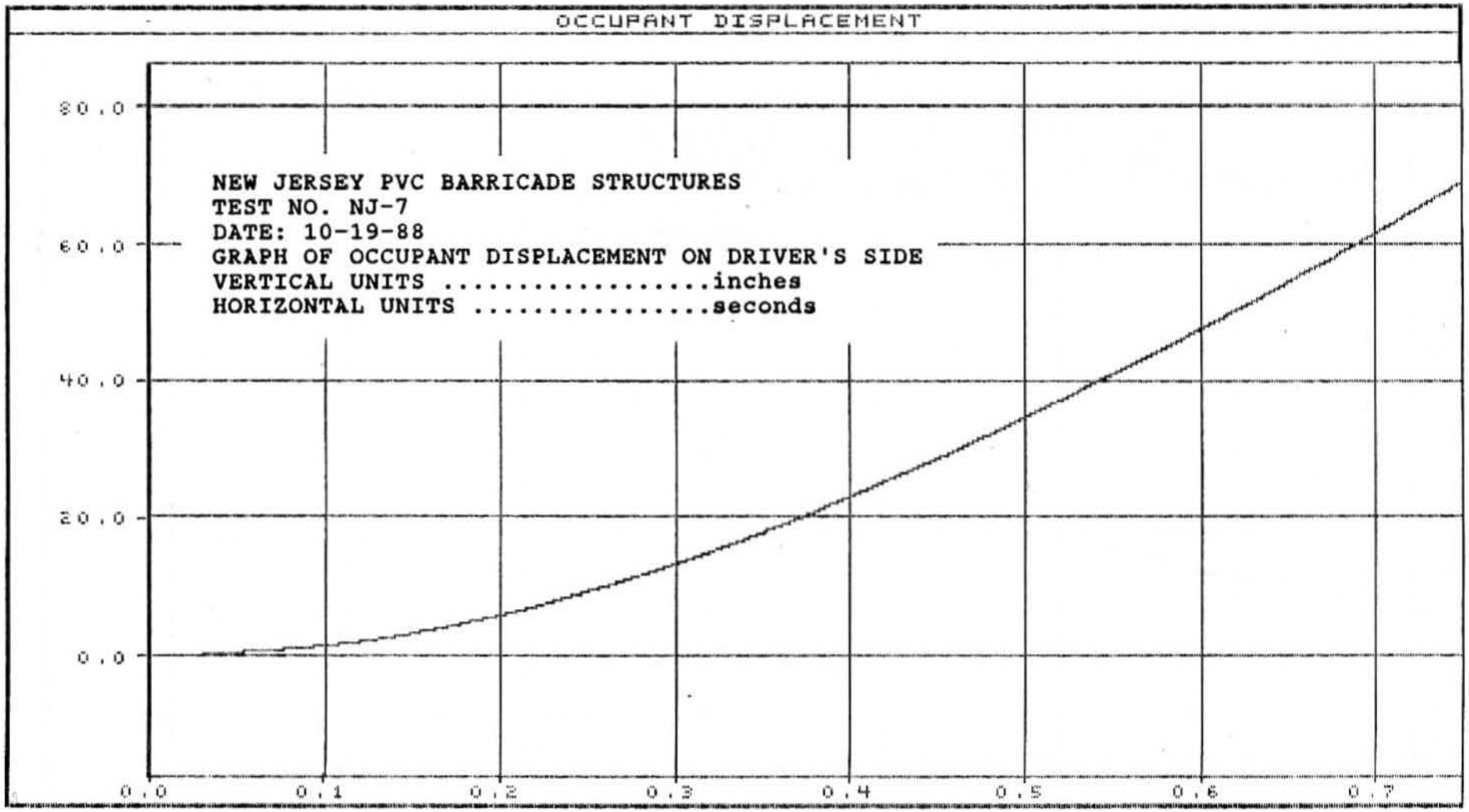

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-6
DATE: 11-1-88
GRAPH OF VEHICLE DECELERATION
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
15.0
10.0
5.0
0.0
-5.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

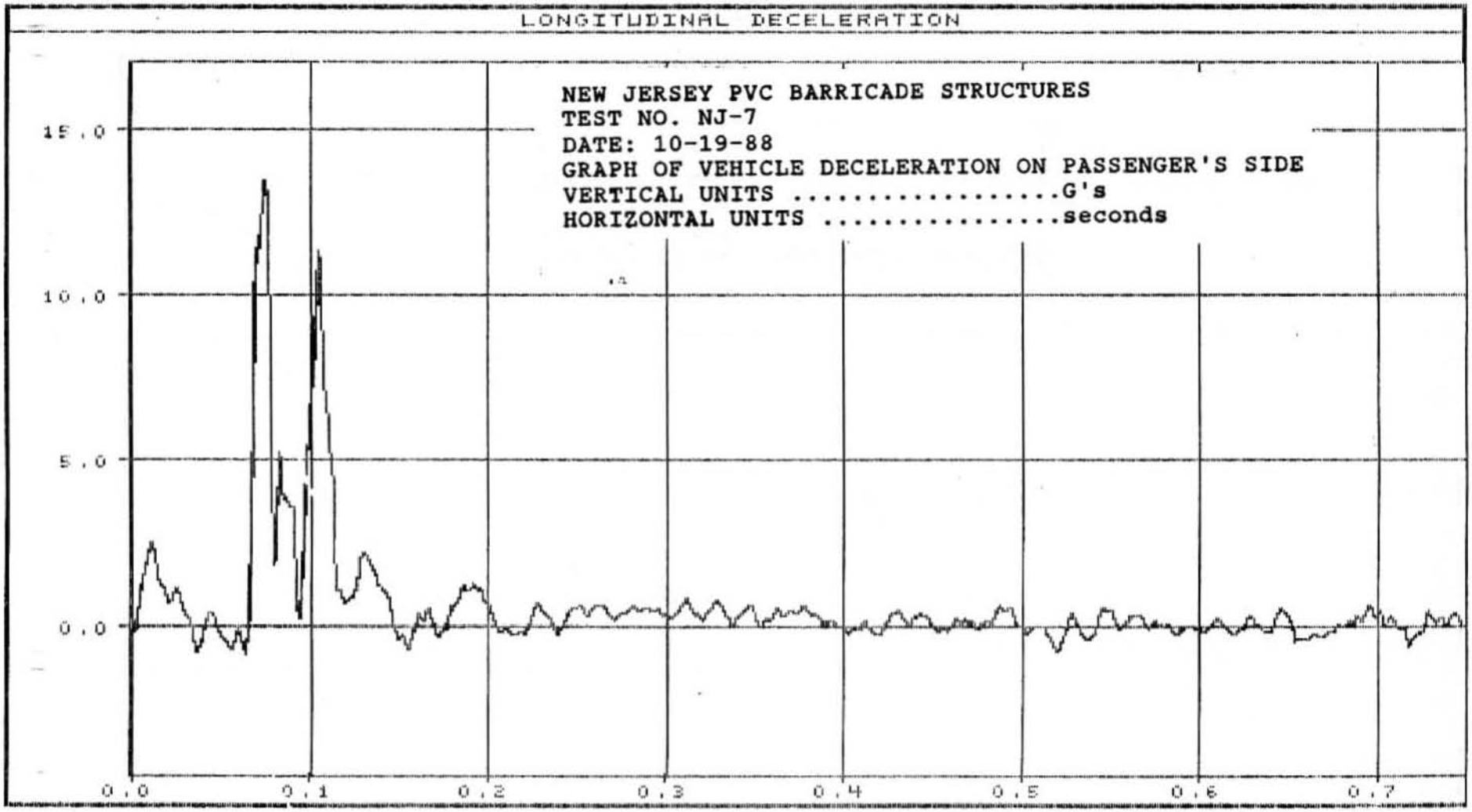

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-6
DATE: 10-1-88
GRAPH OF VEHICLE CHANGE IN VELOCITY
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

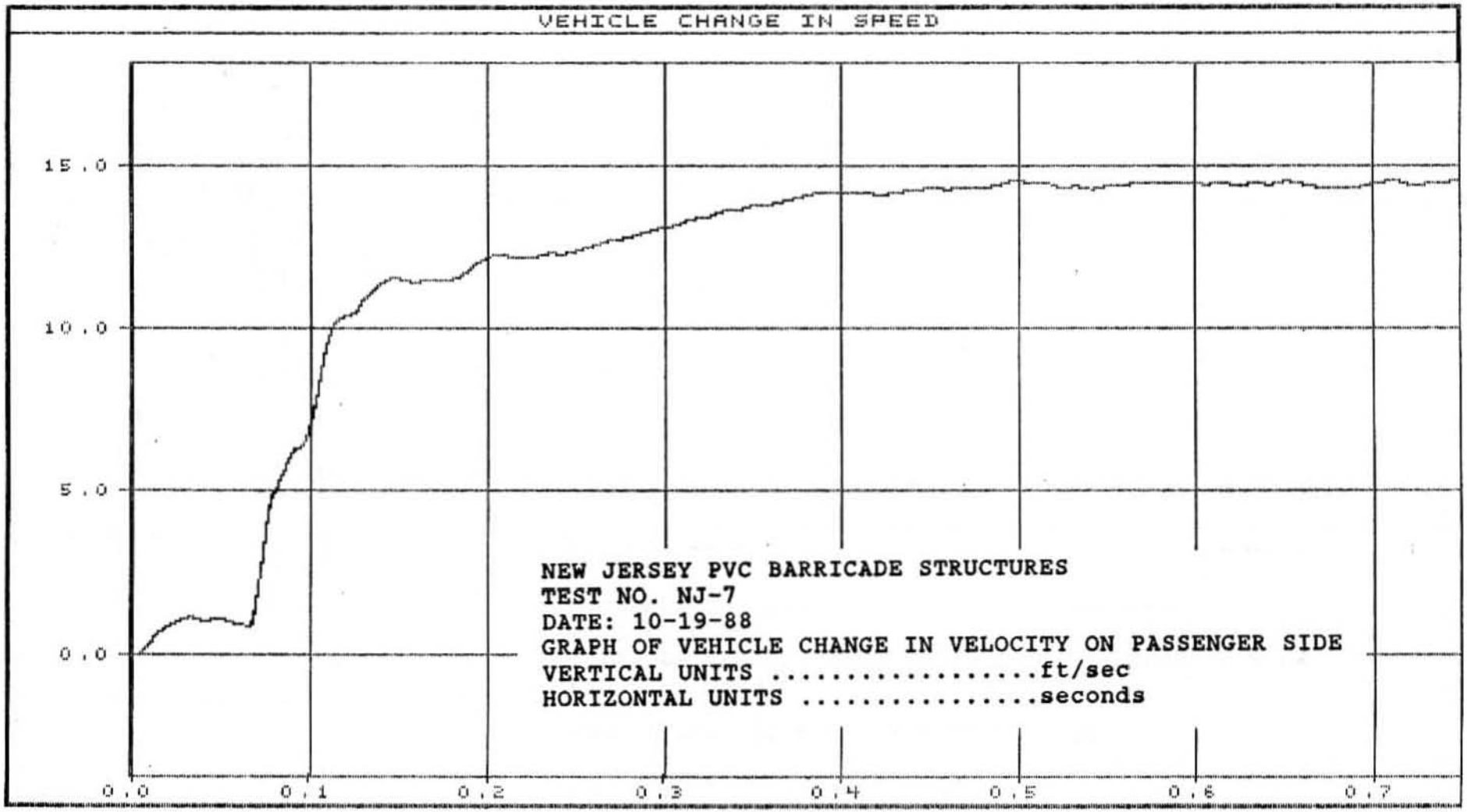

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-6
DATE: 10-1-88
GRAPH OF OCCUPANT DISPLACEMENT
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
20.0
15.0
10.0
5.0
0.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

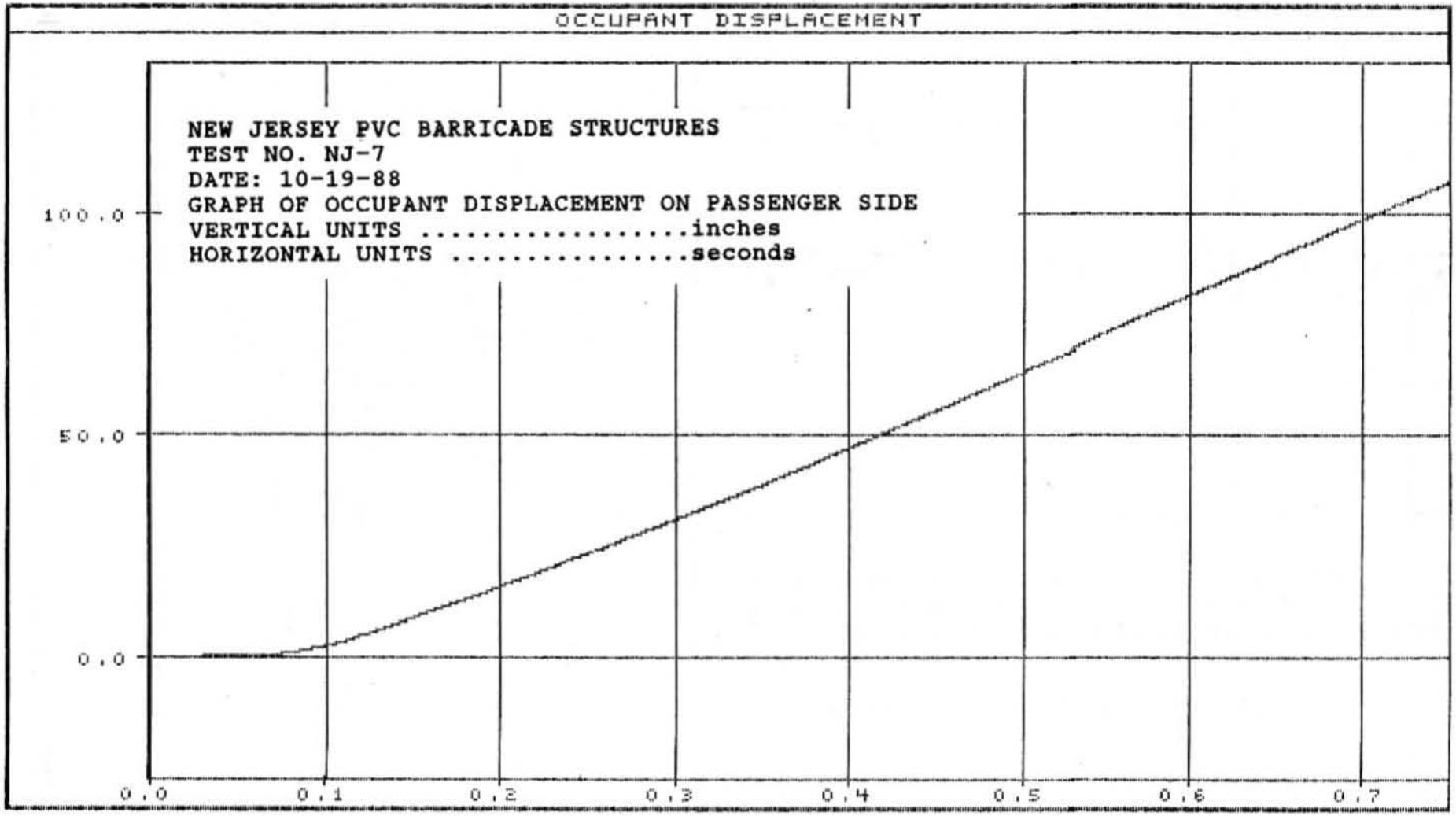

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

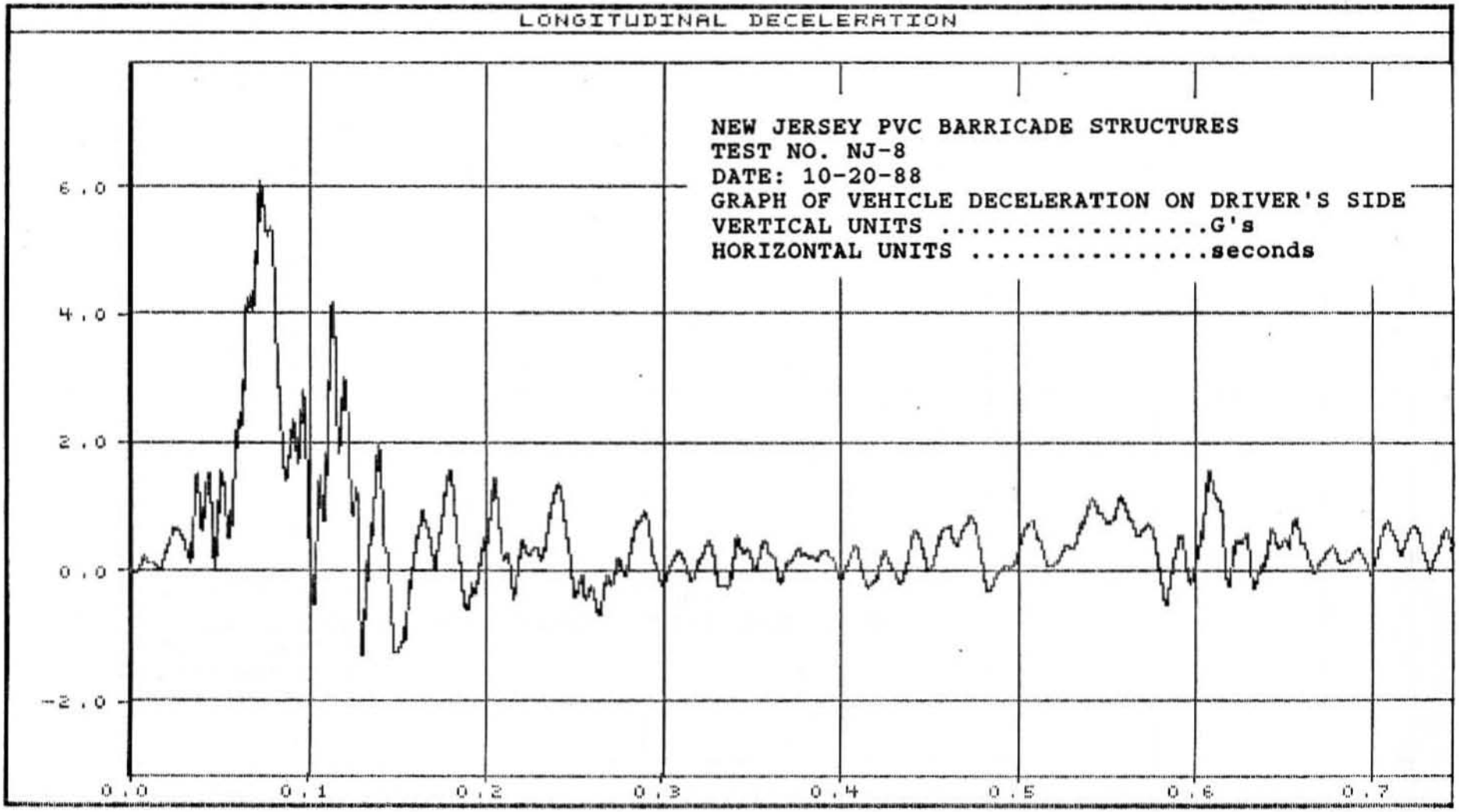

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

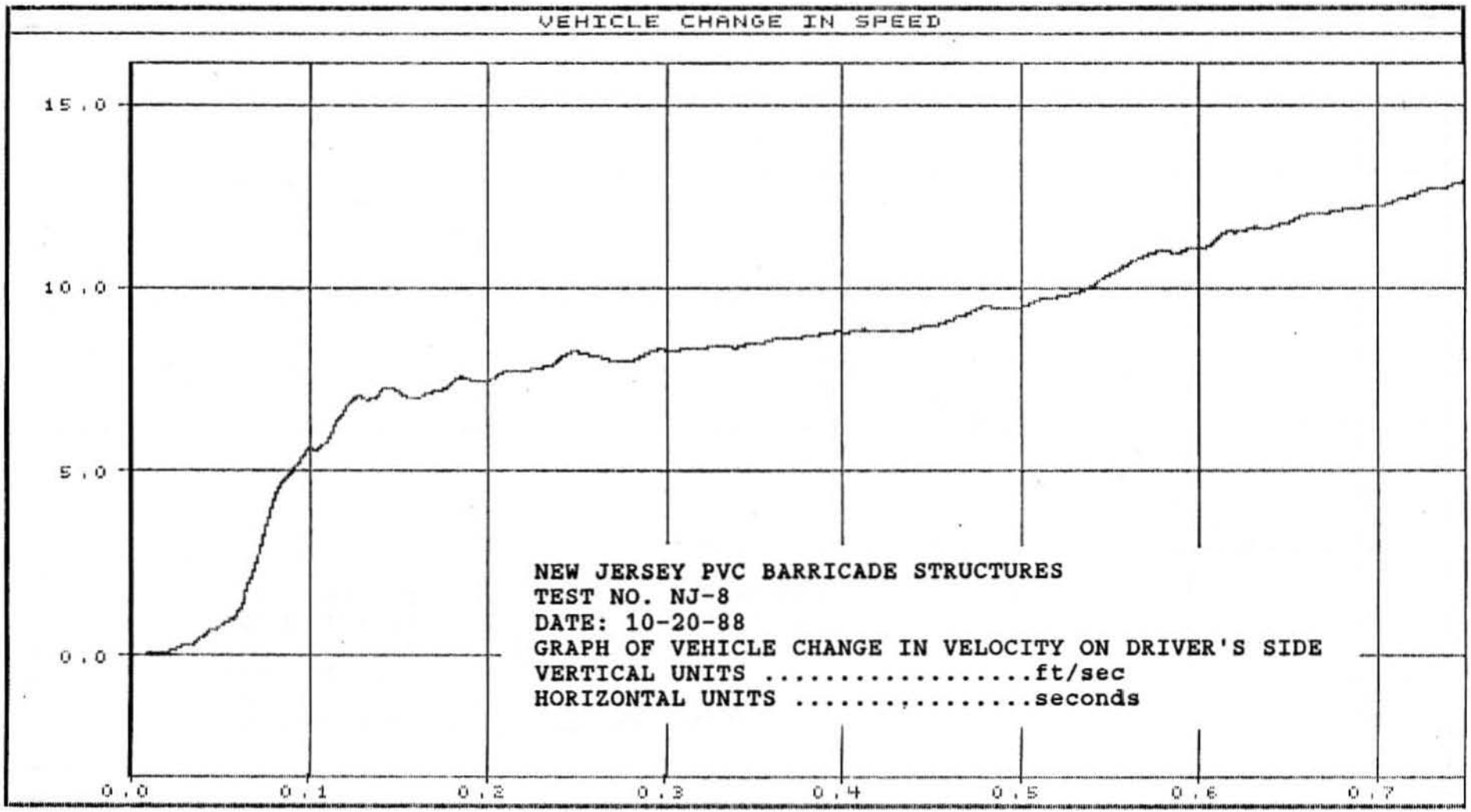

OCCUPANT DISPLACEMENT
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds

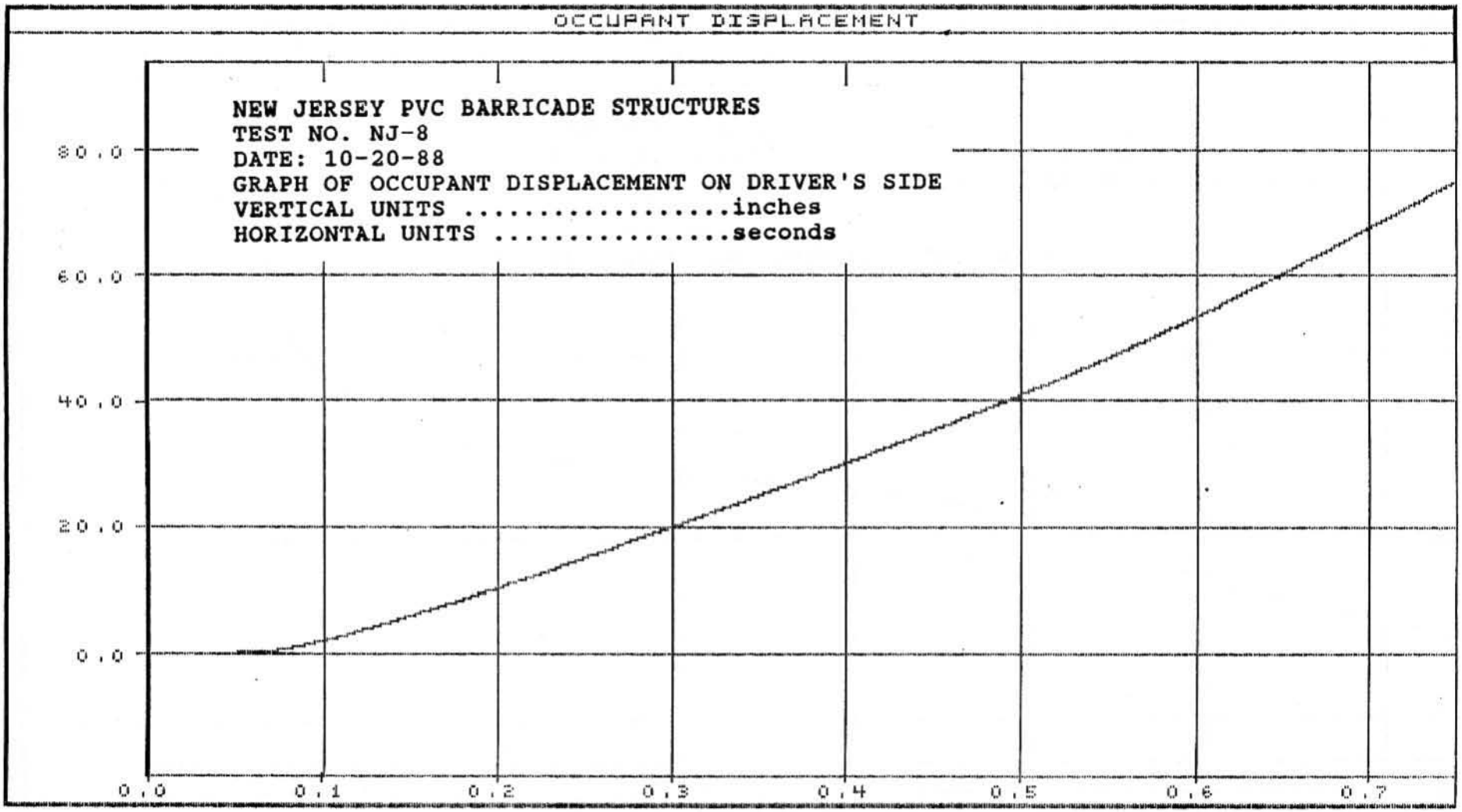

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

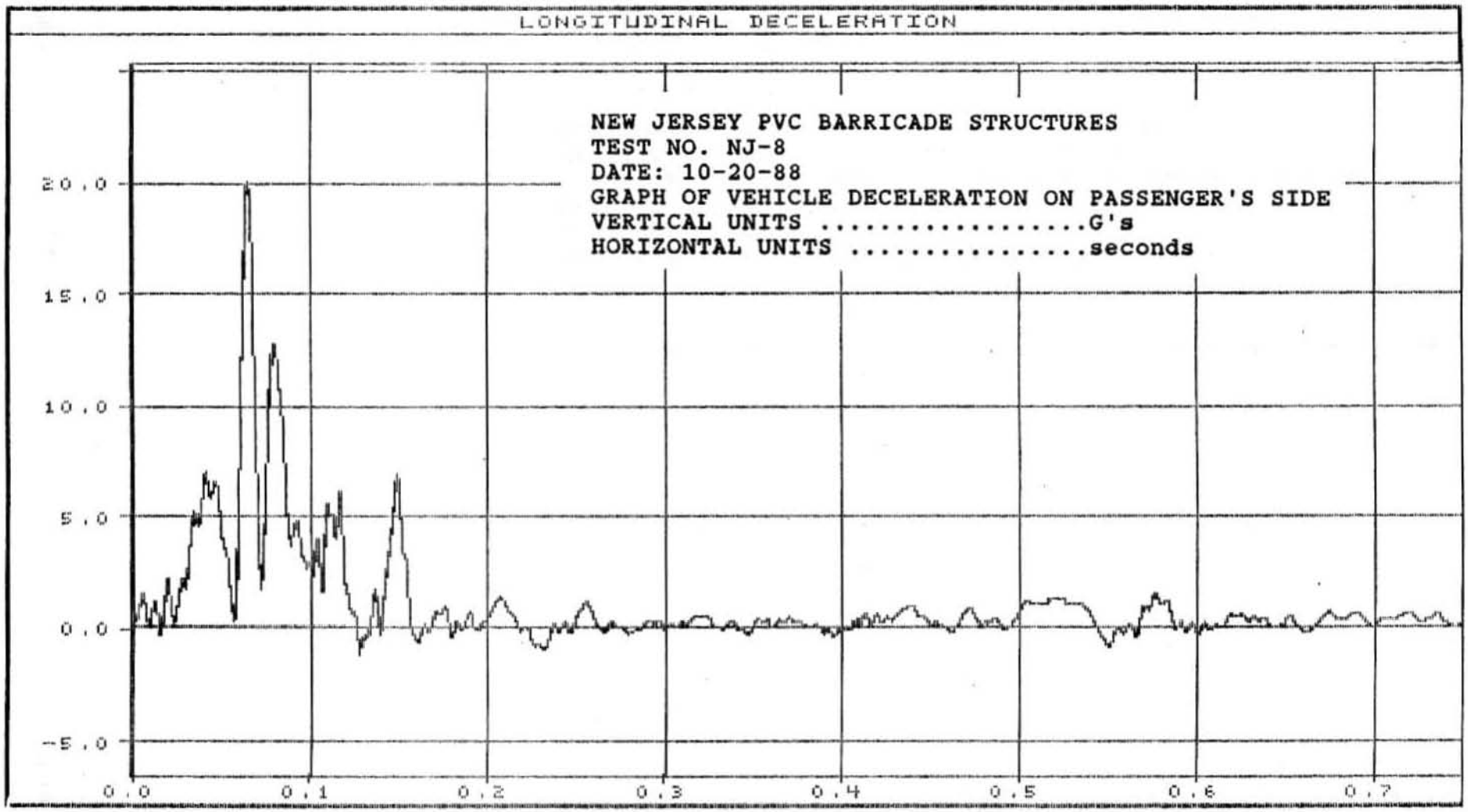

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

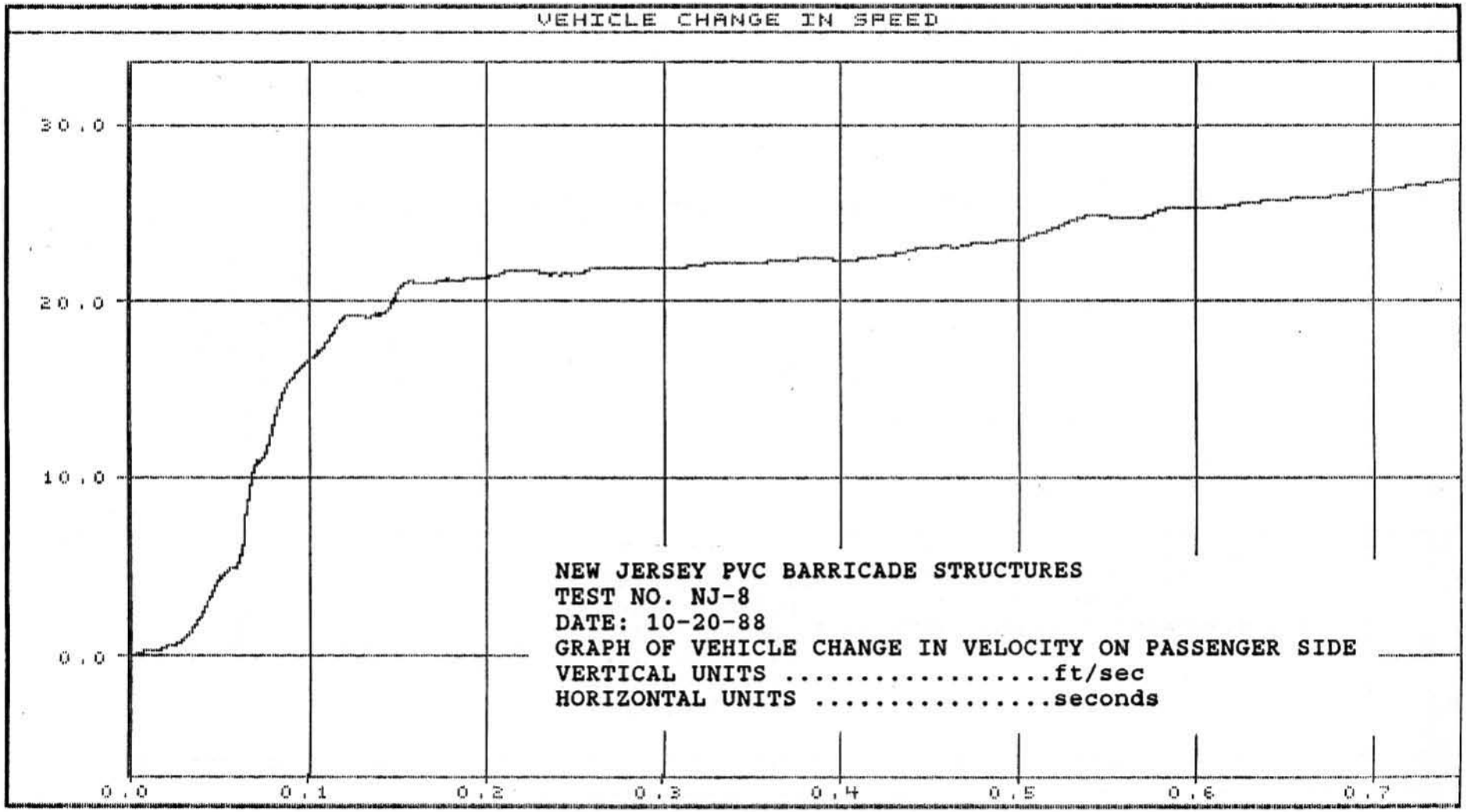

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-7
DATE: 10-19-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
100.0
50.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

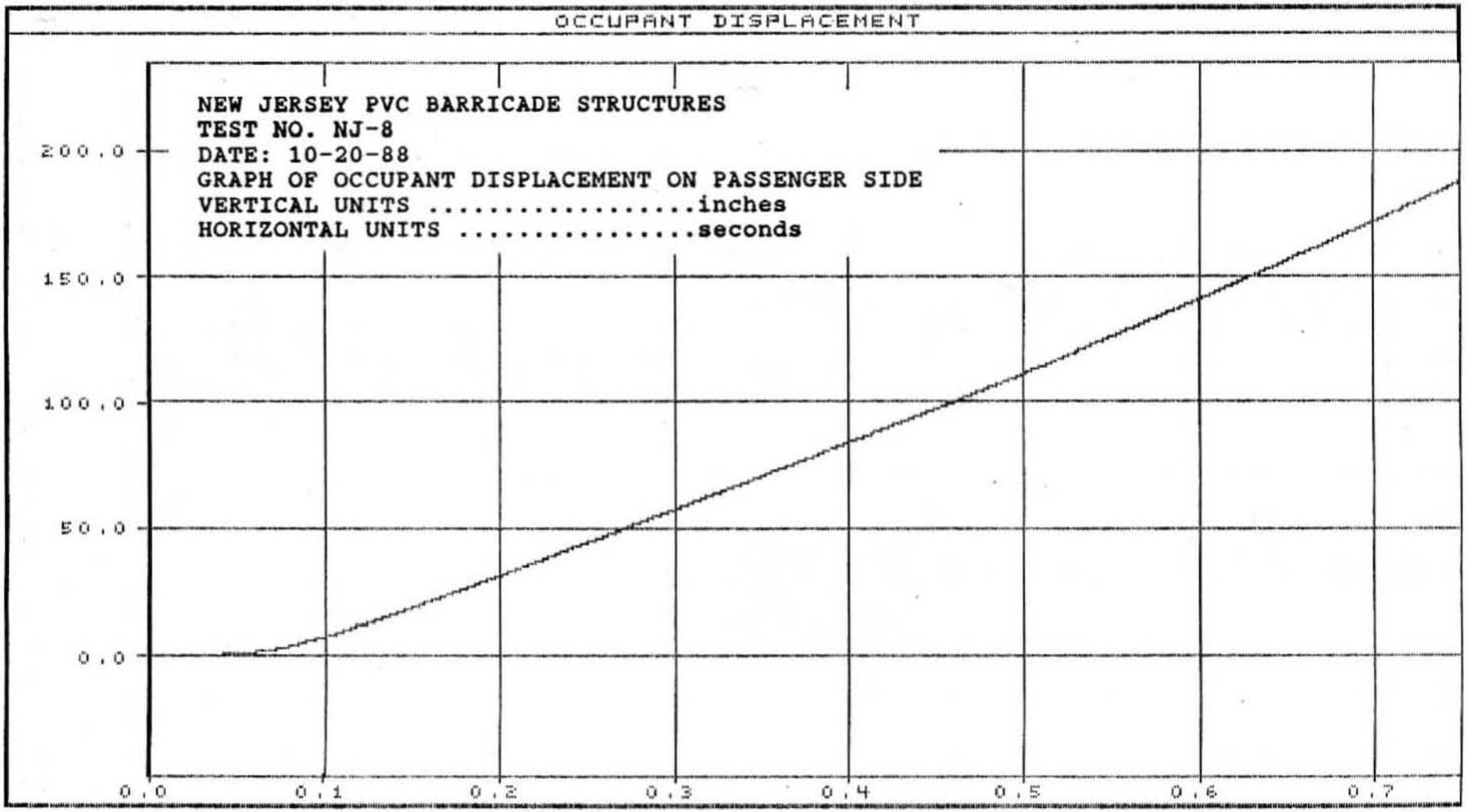

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
6.0
4.0
2.0
0.0
-2.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

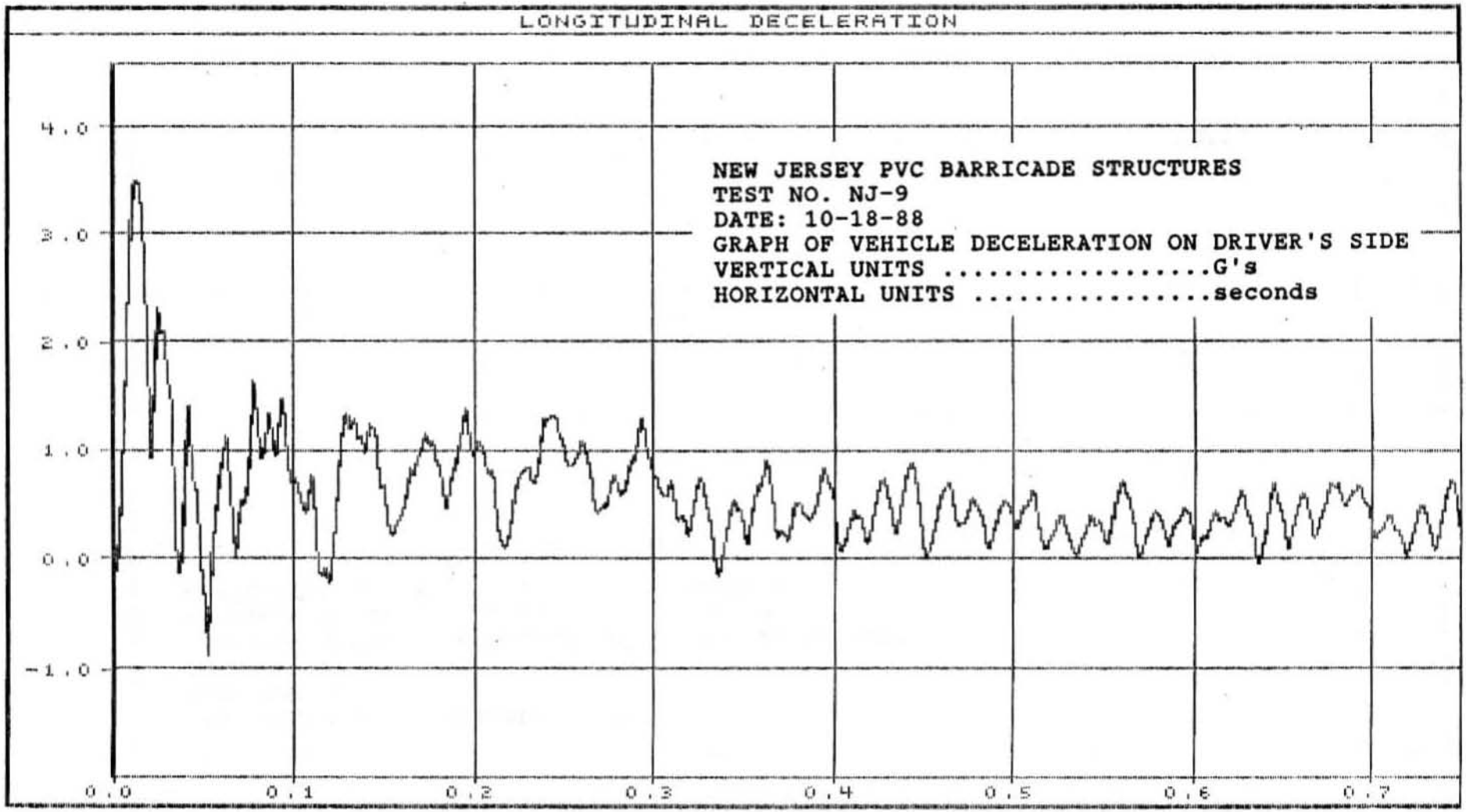

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....,.....seconds

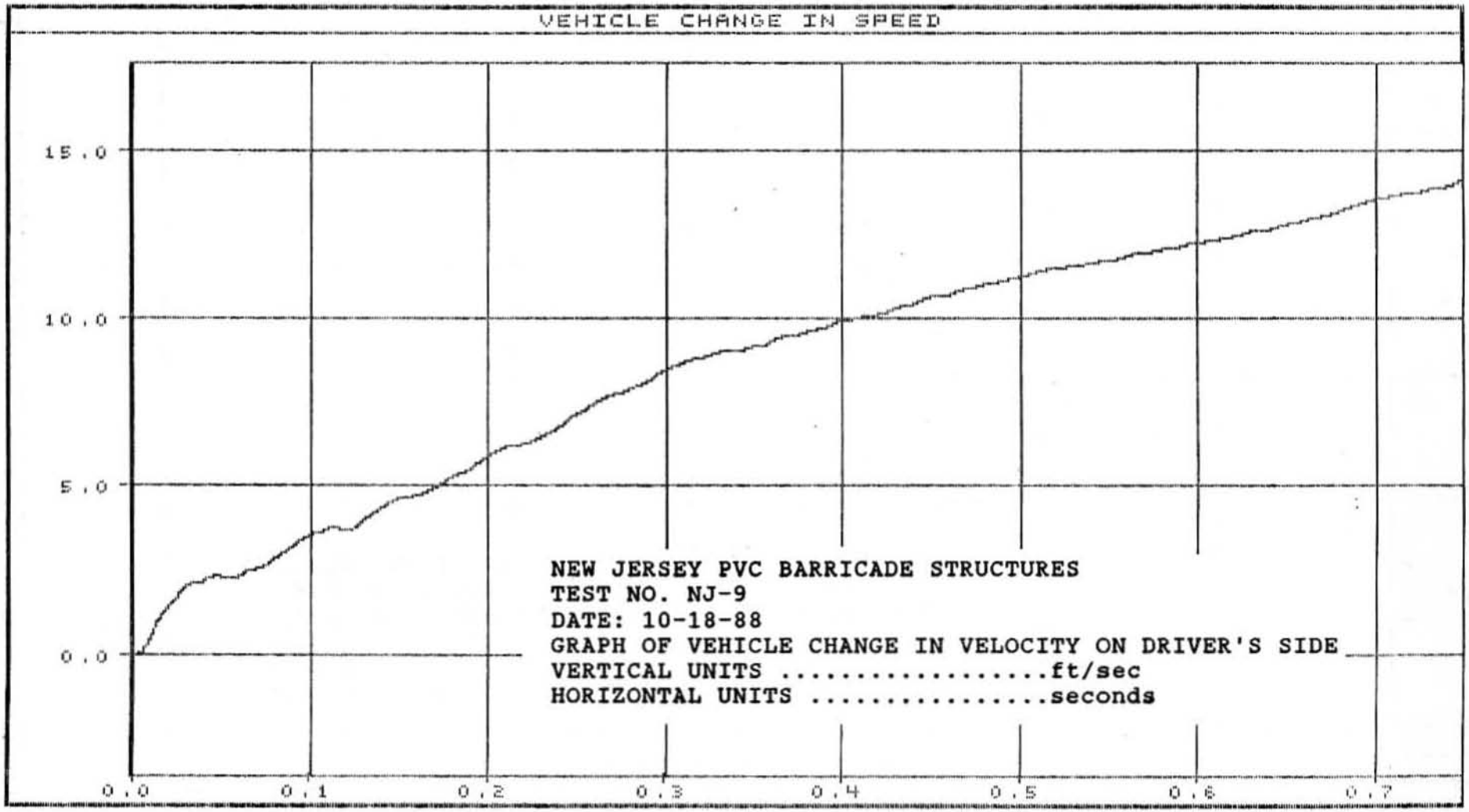

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

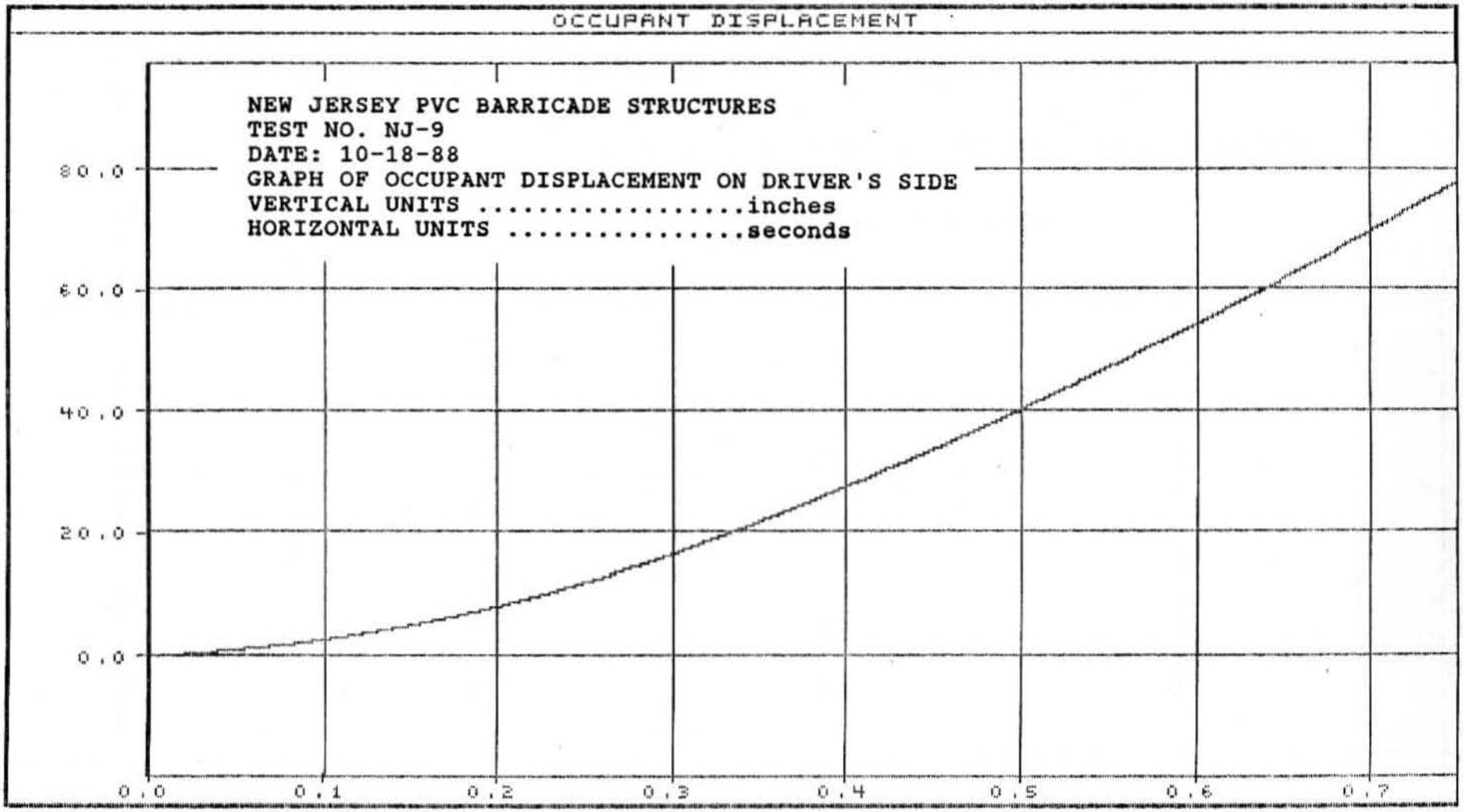

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
20.0
15.0
10.0
5.0
0.0
-5.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

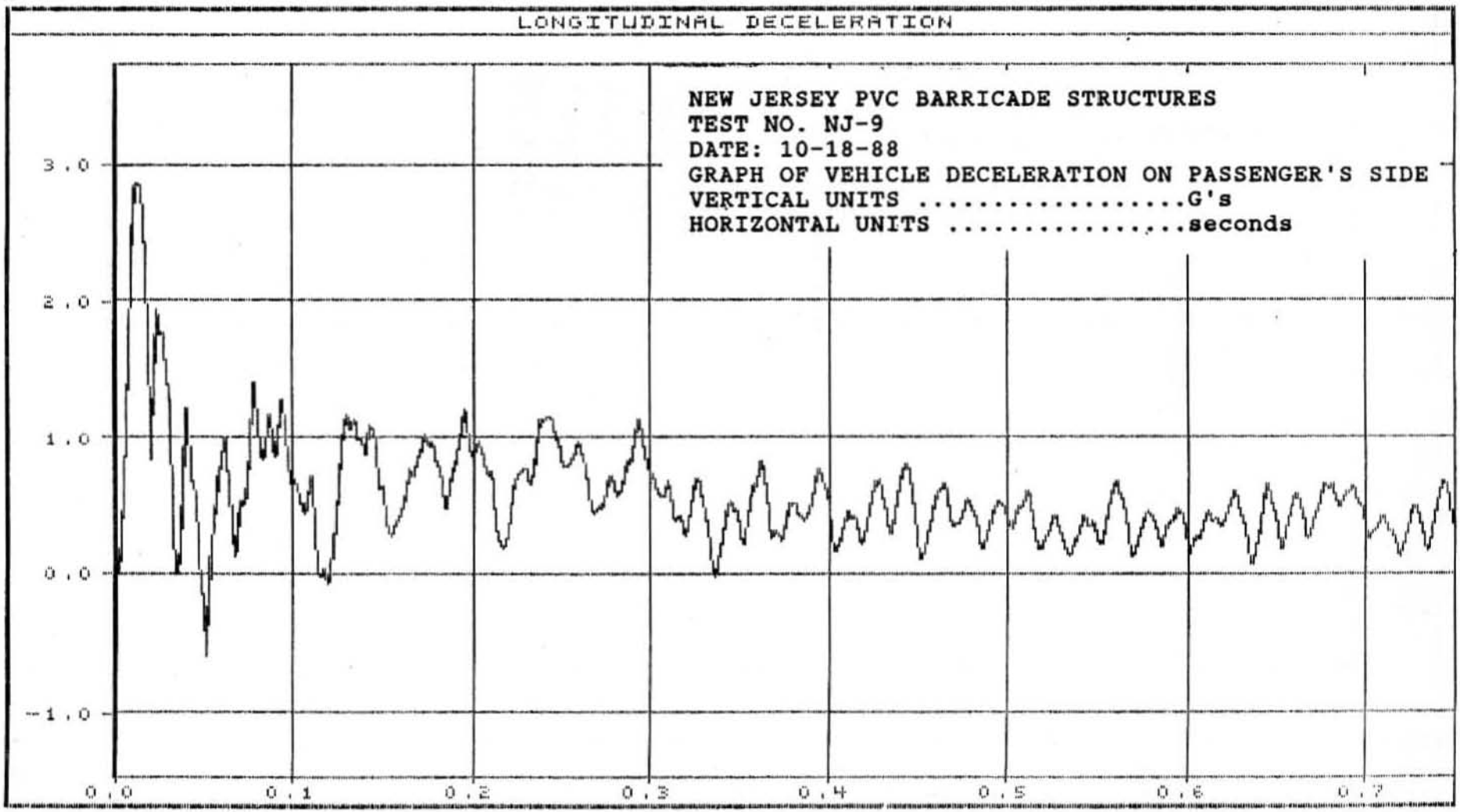

VEHICLE CHANGE IN SPEED
30.0
20.0
10.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

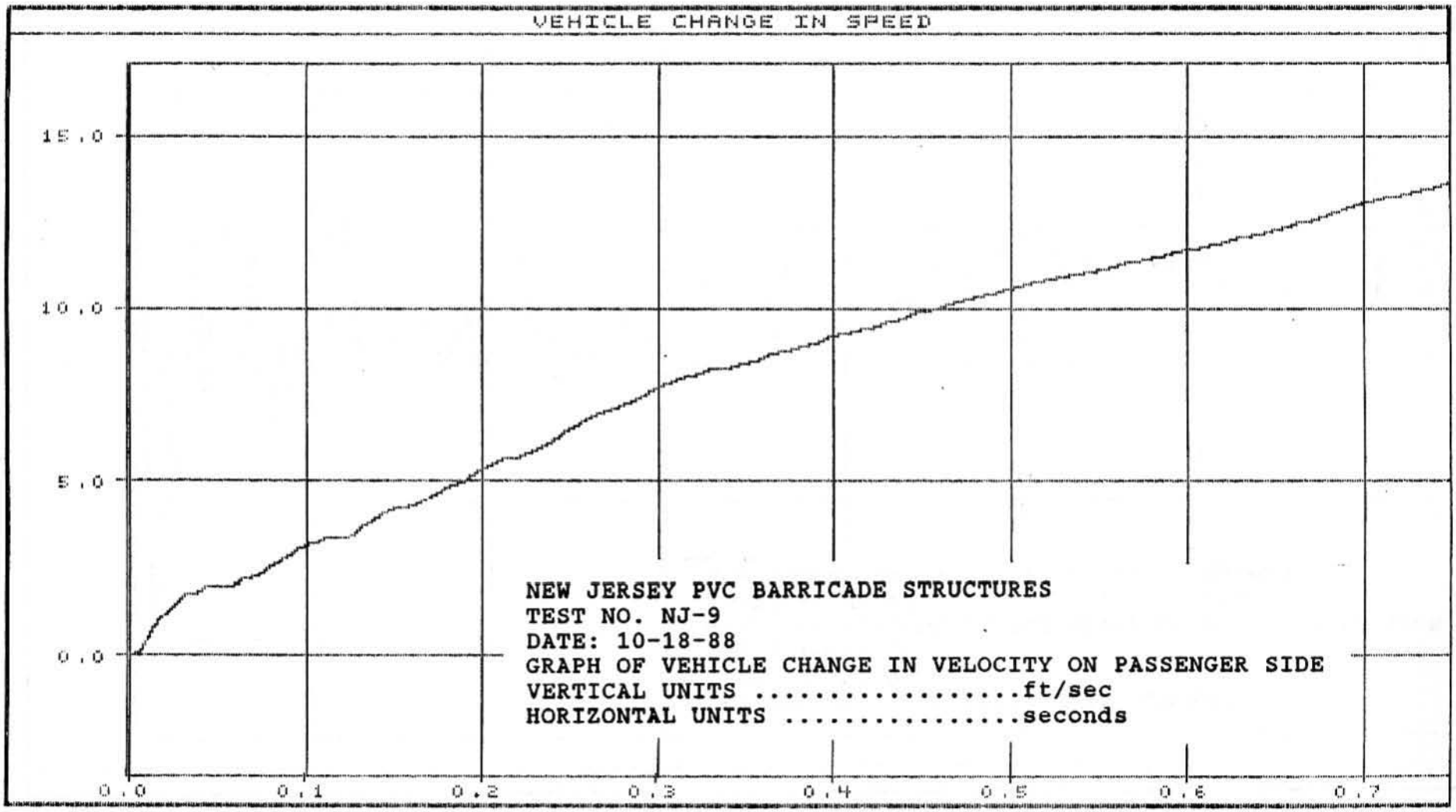

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-8
DATE: 10-20-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
200.0
150.0
100.0
50.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

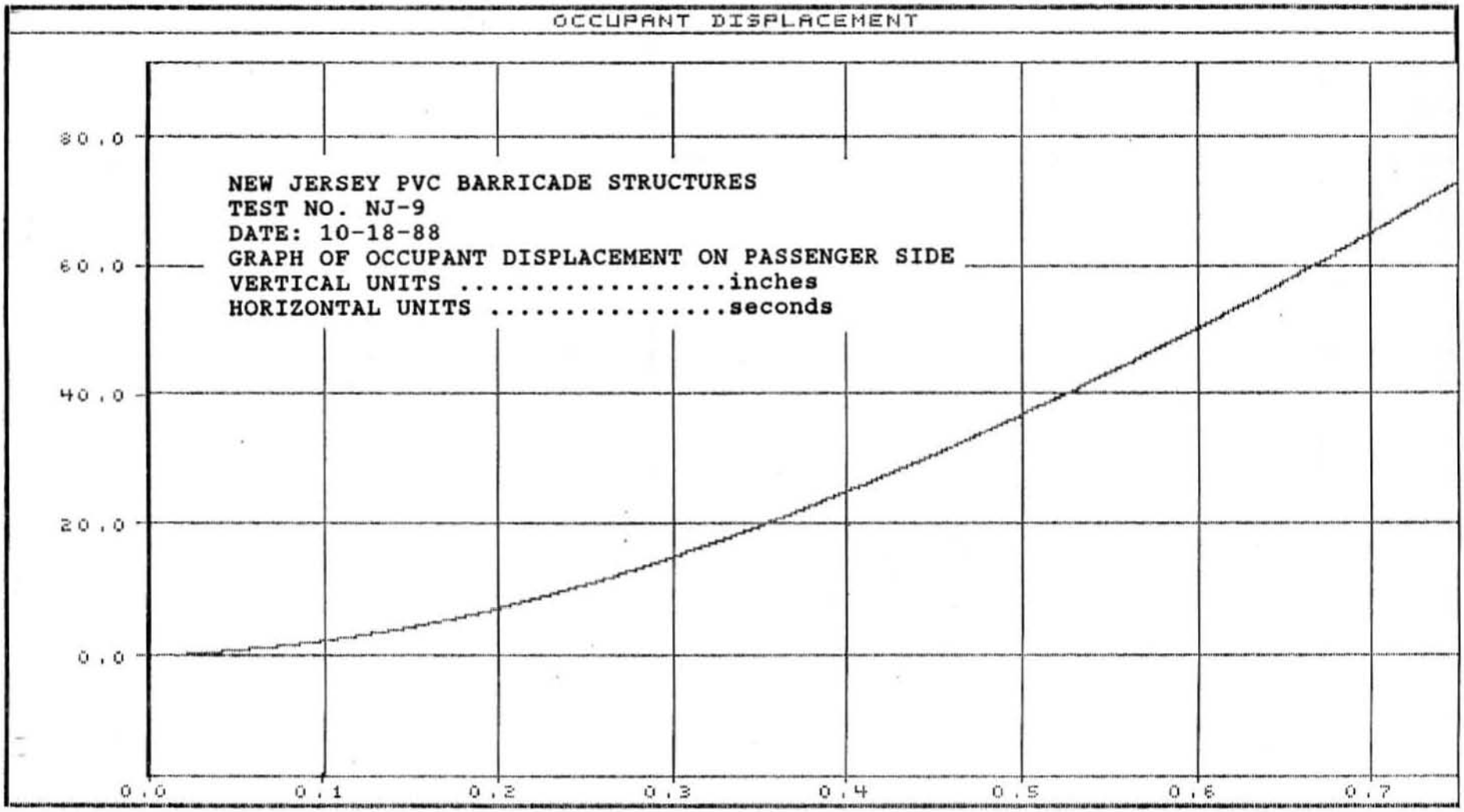

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
4.0
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

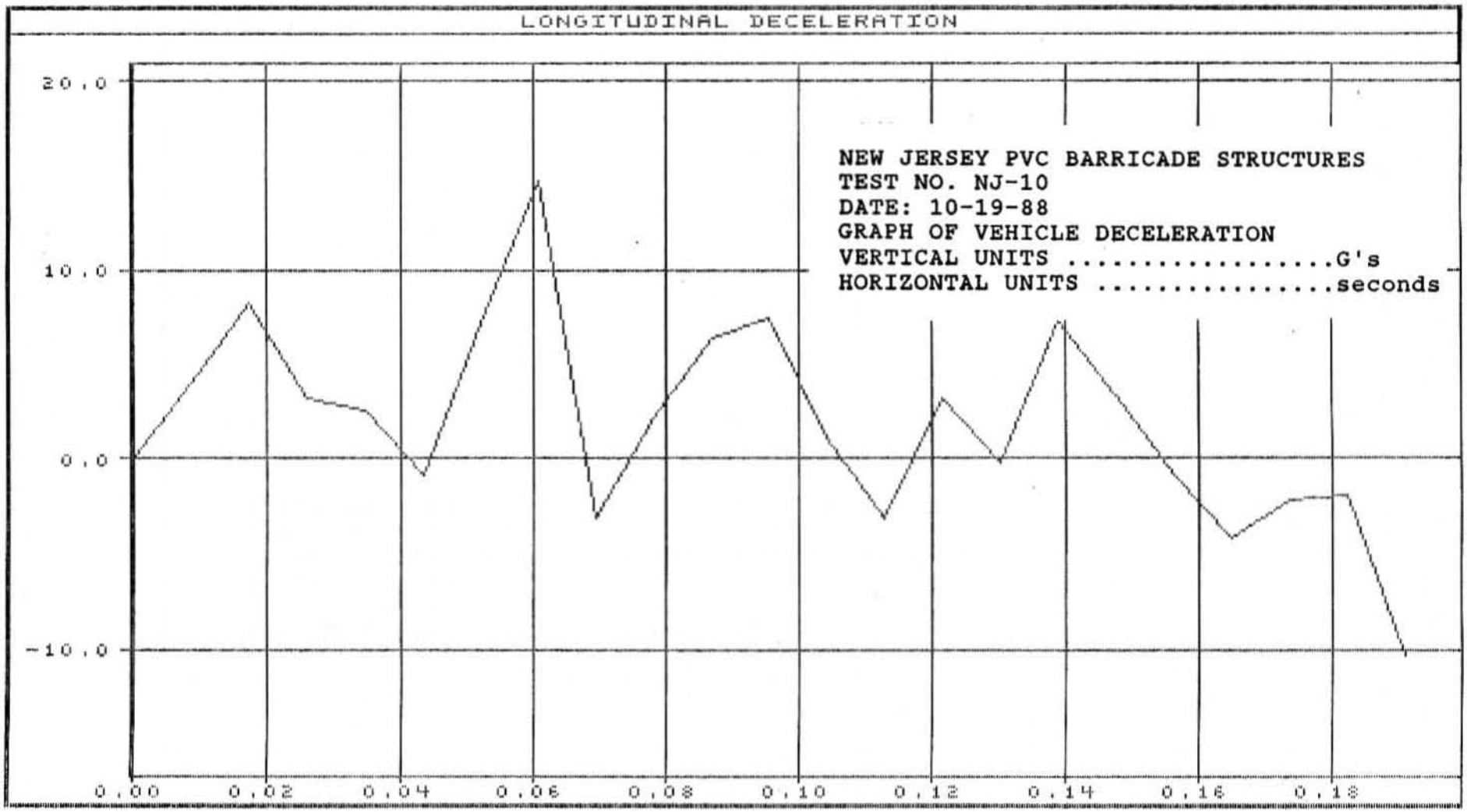

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

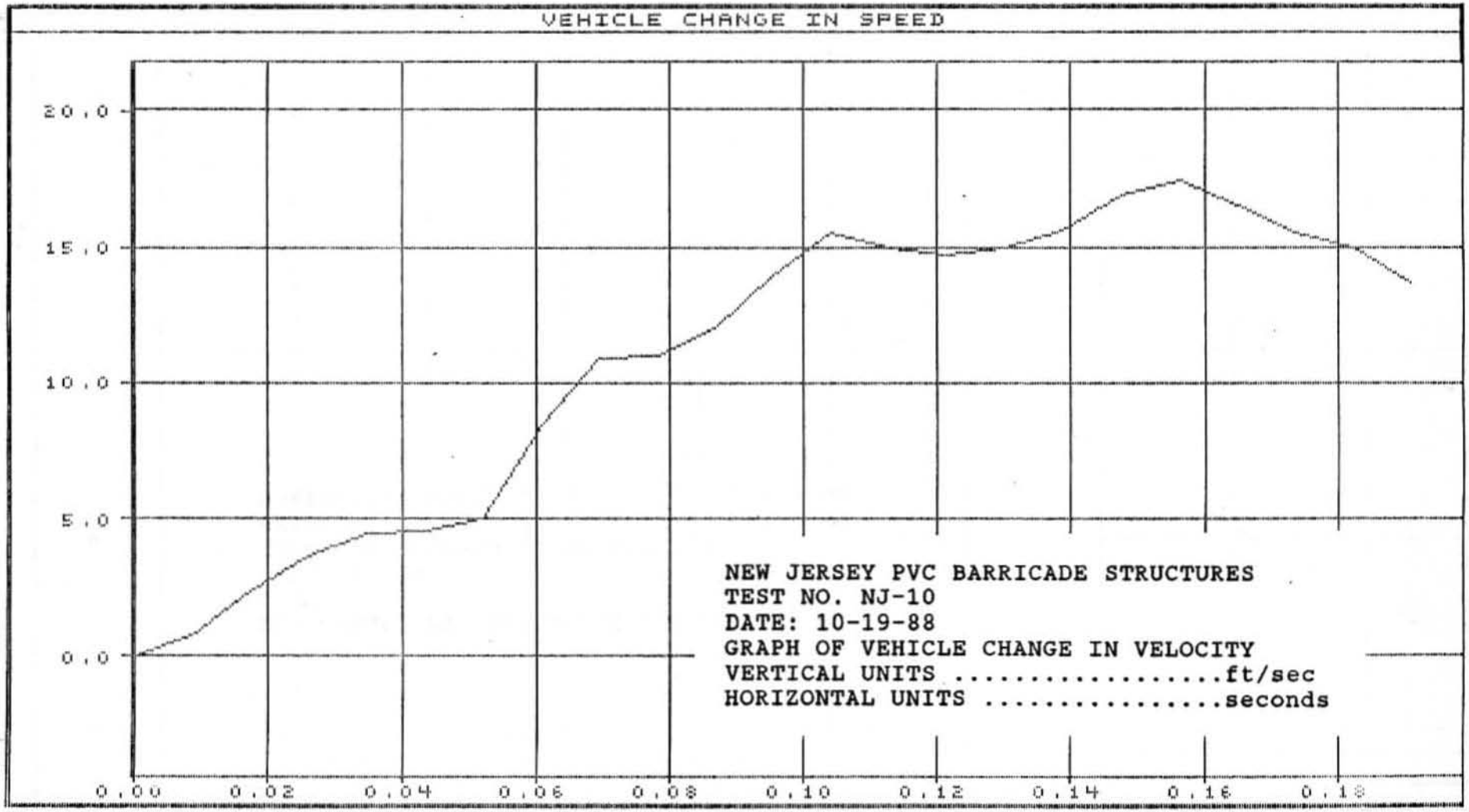

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

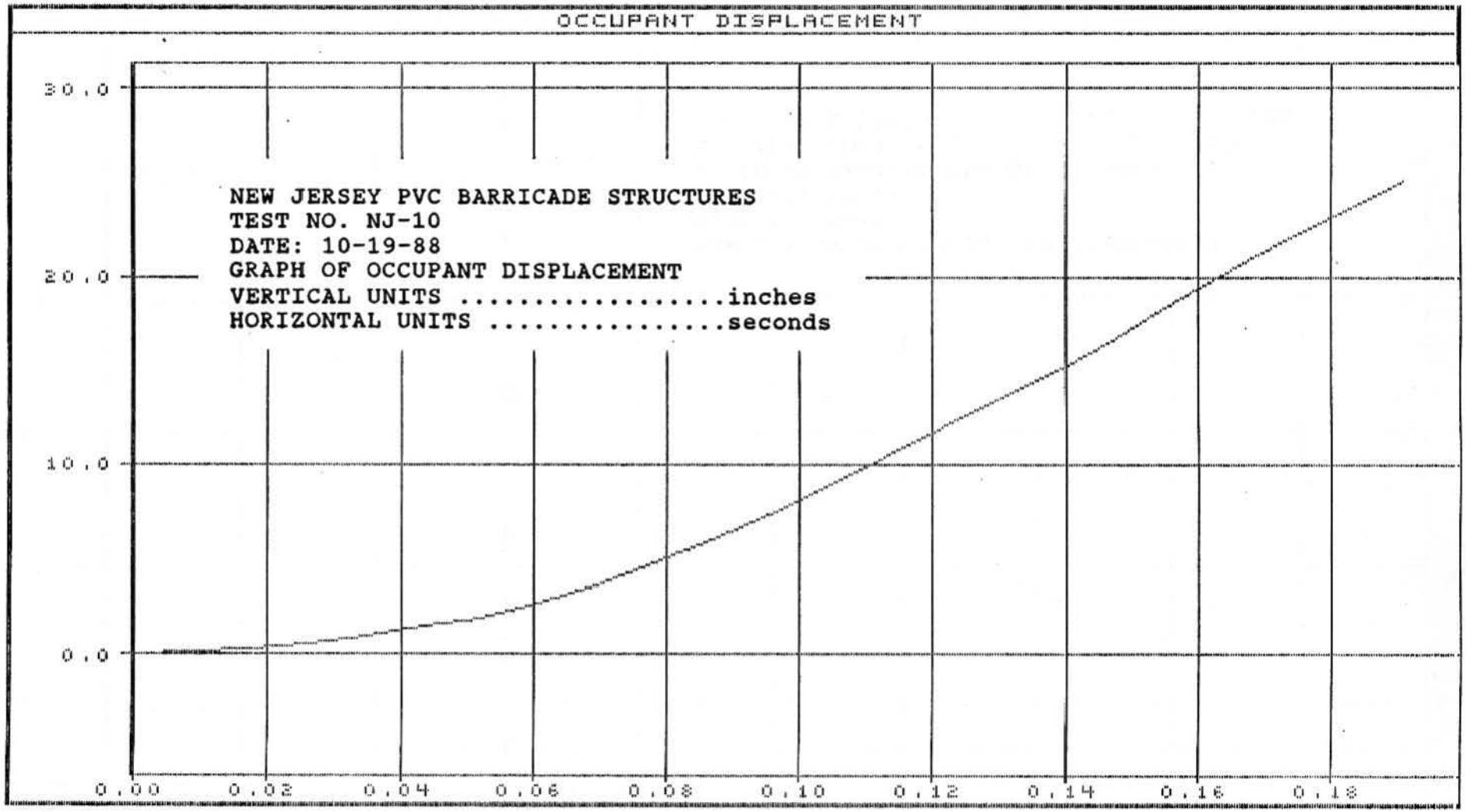

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

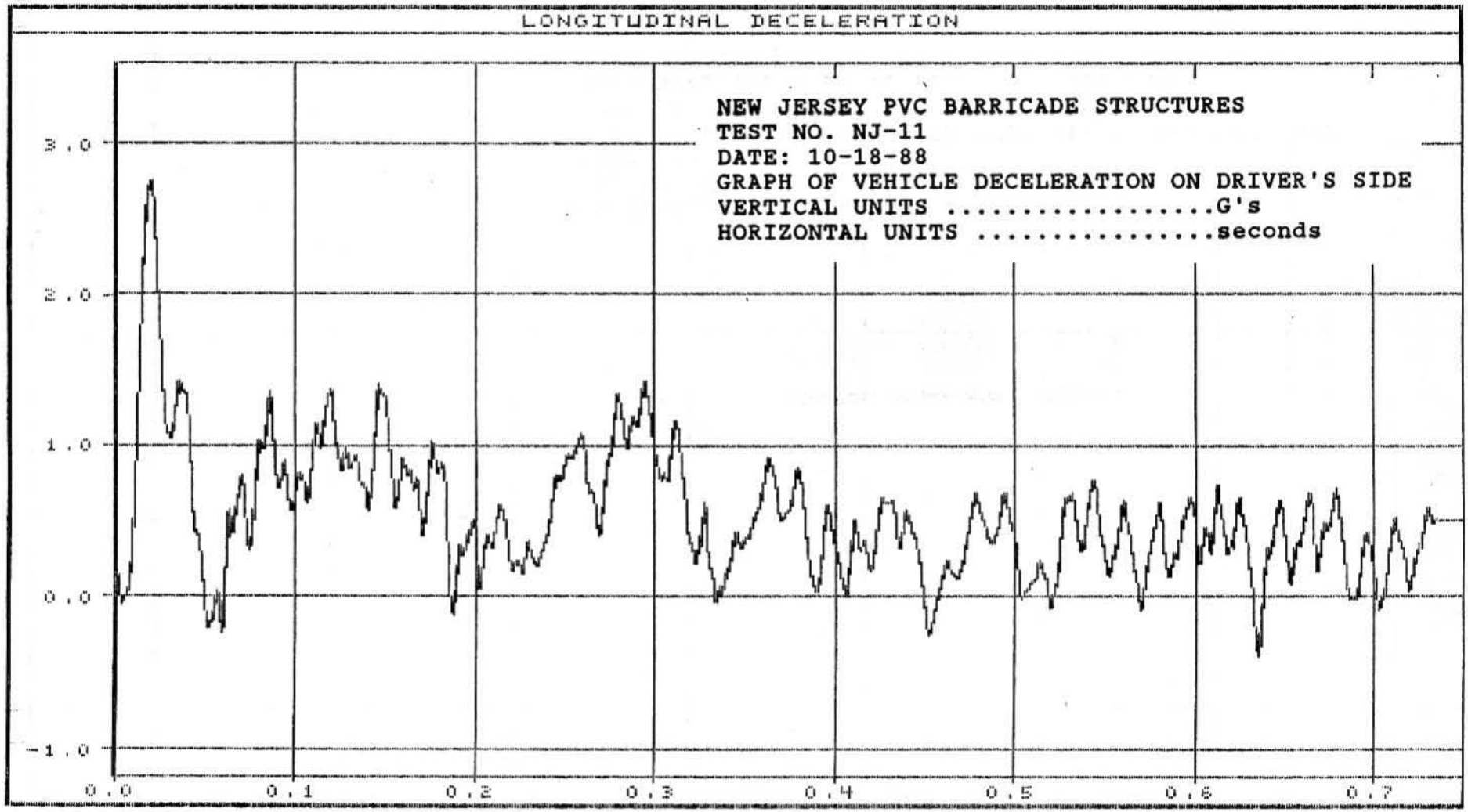

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

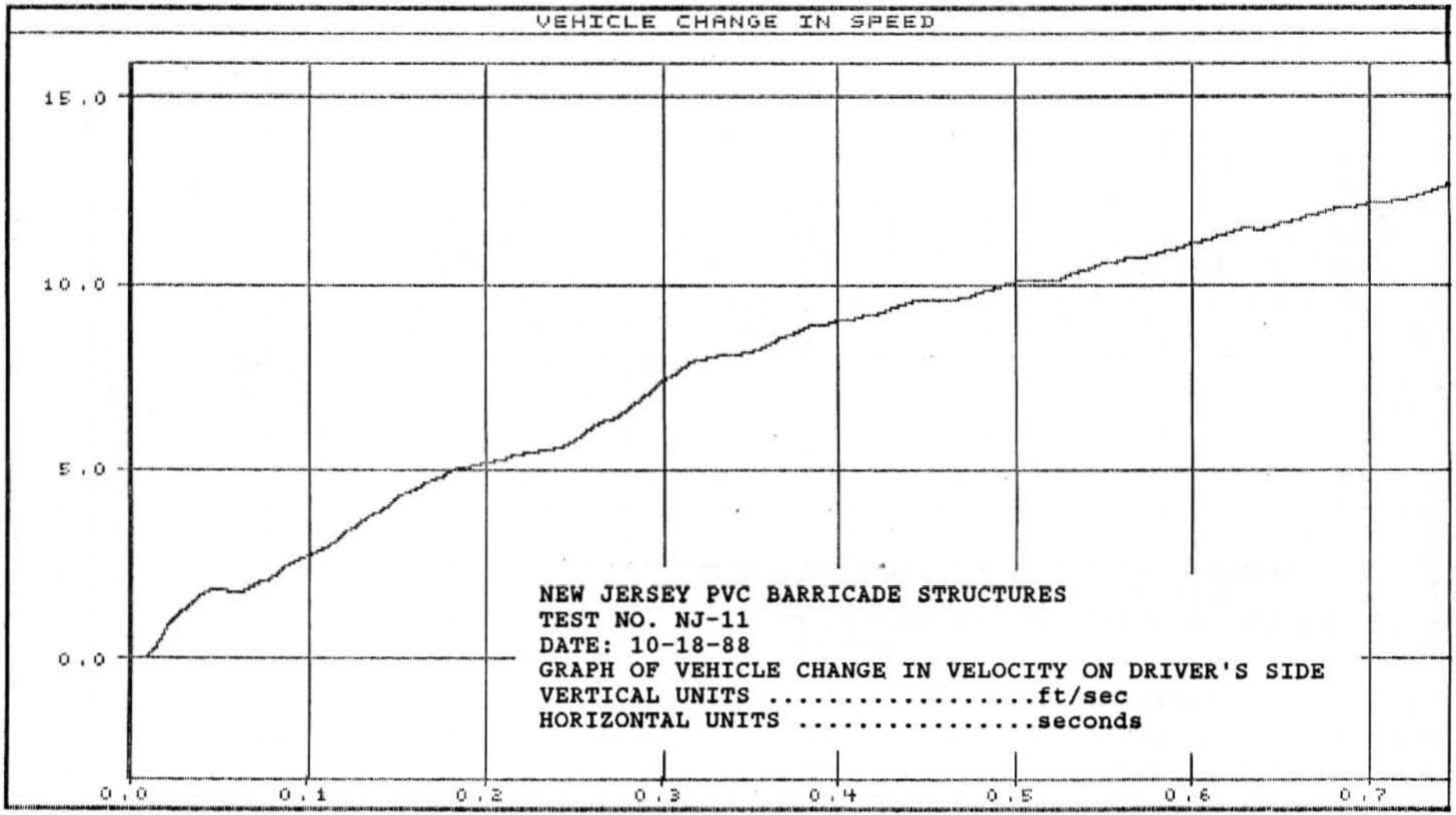

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-9
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

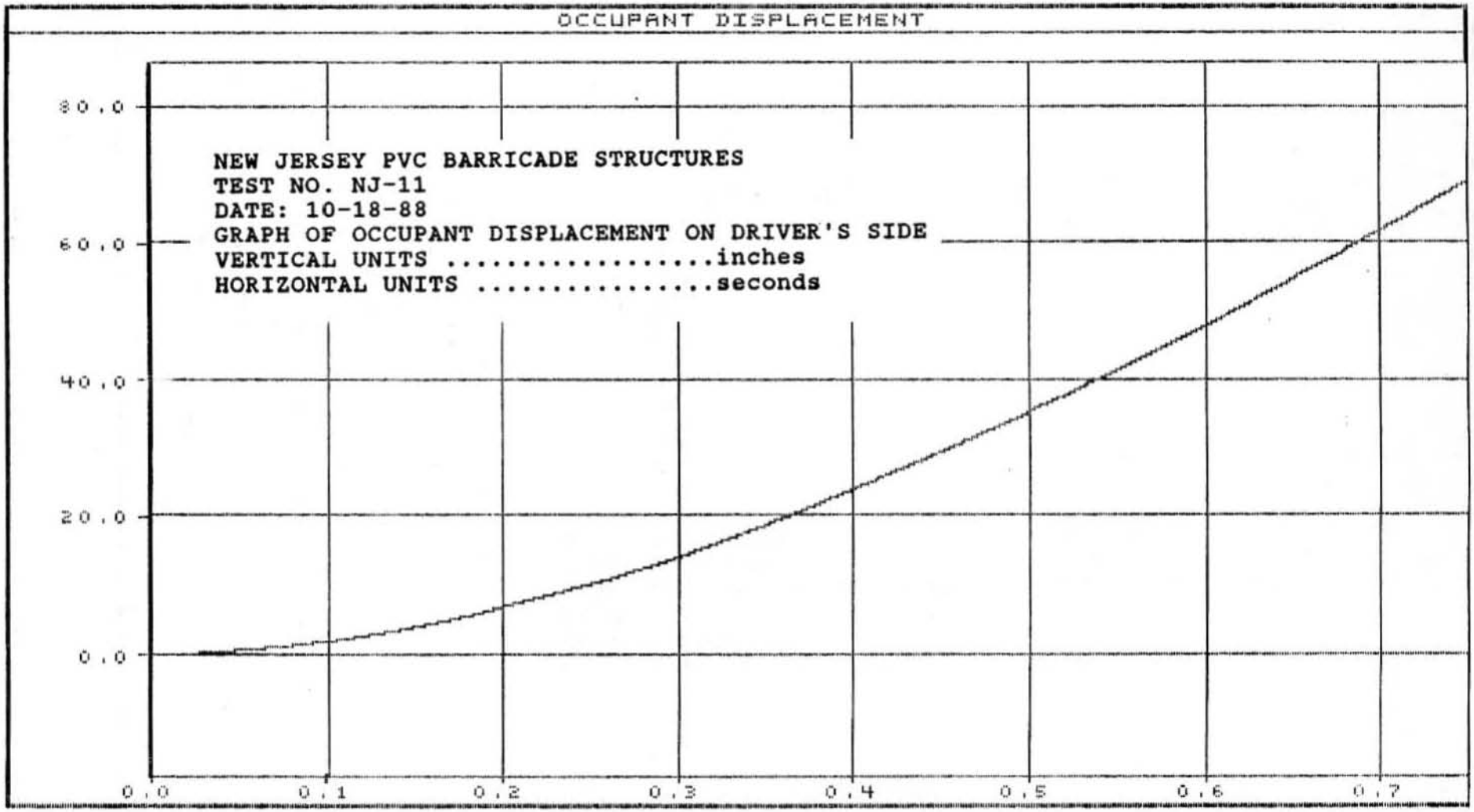

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-10
DATE: 10-19-88
GRAPH OF VEHICLE DECELERATION
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
20.0
10.0
0.0
-10.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18

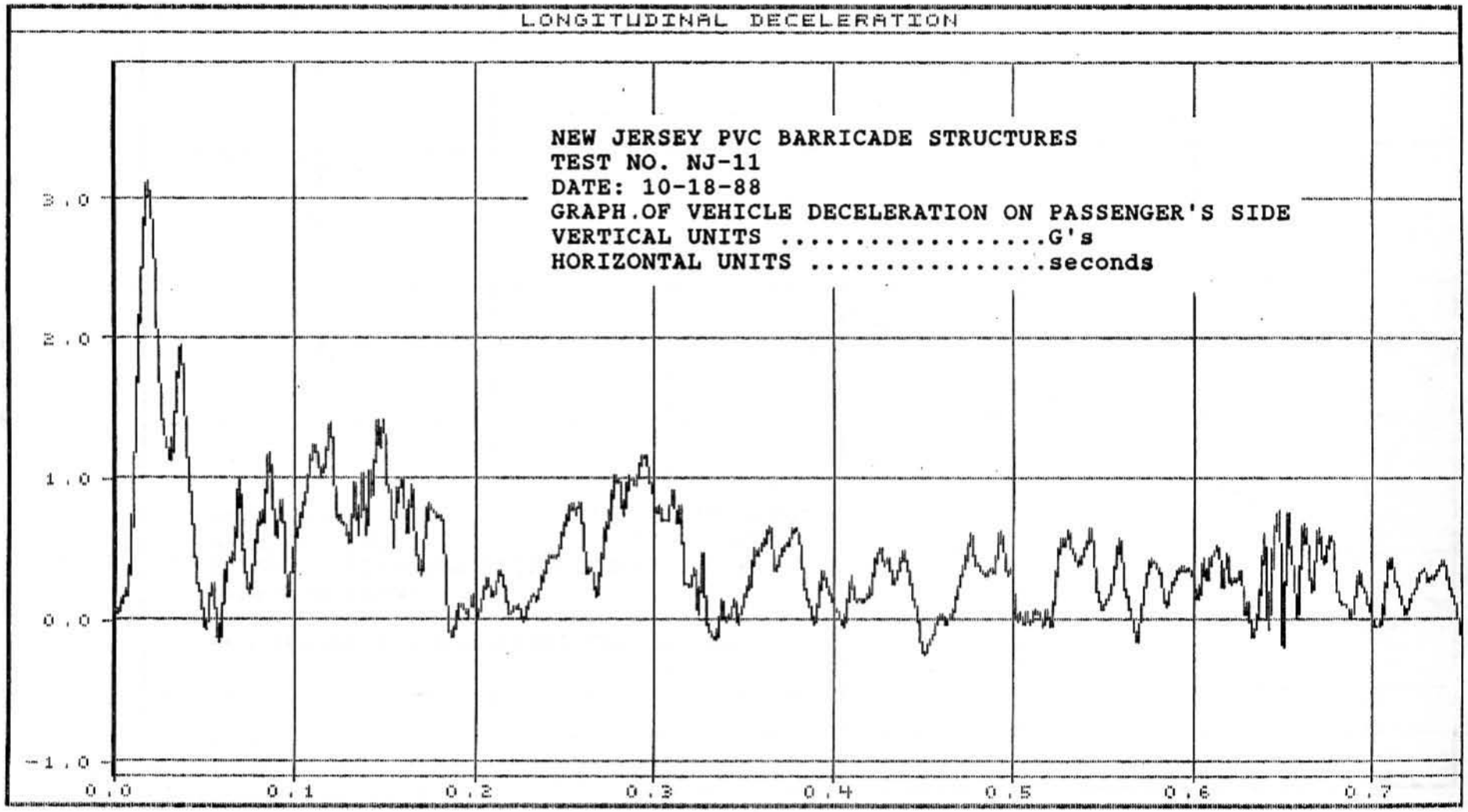

VEHICLE CHANGE IN SPEED
20.0
15.0
10.0
5.0
0.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-10
DATE: 10-19-88
GRAPH OF VEHICLE CHANGE IN VELOCITY
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

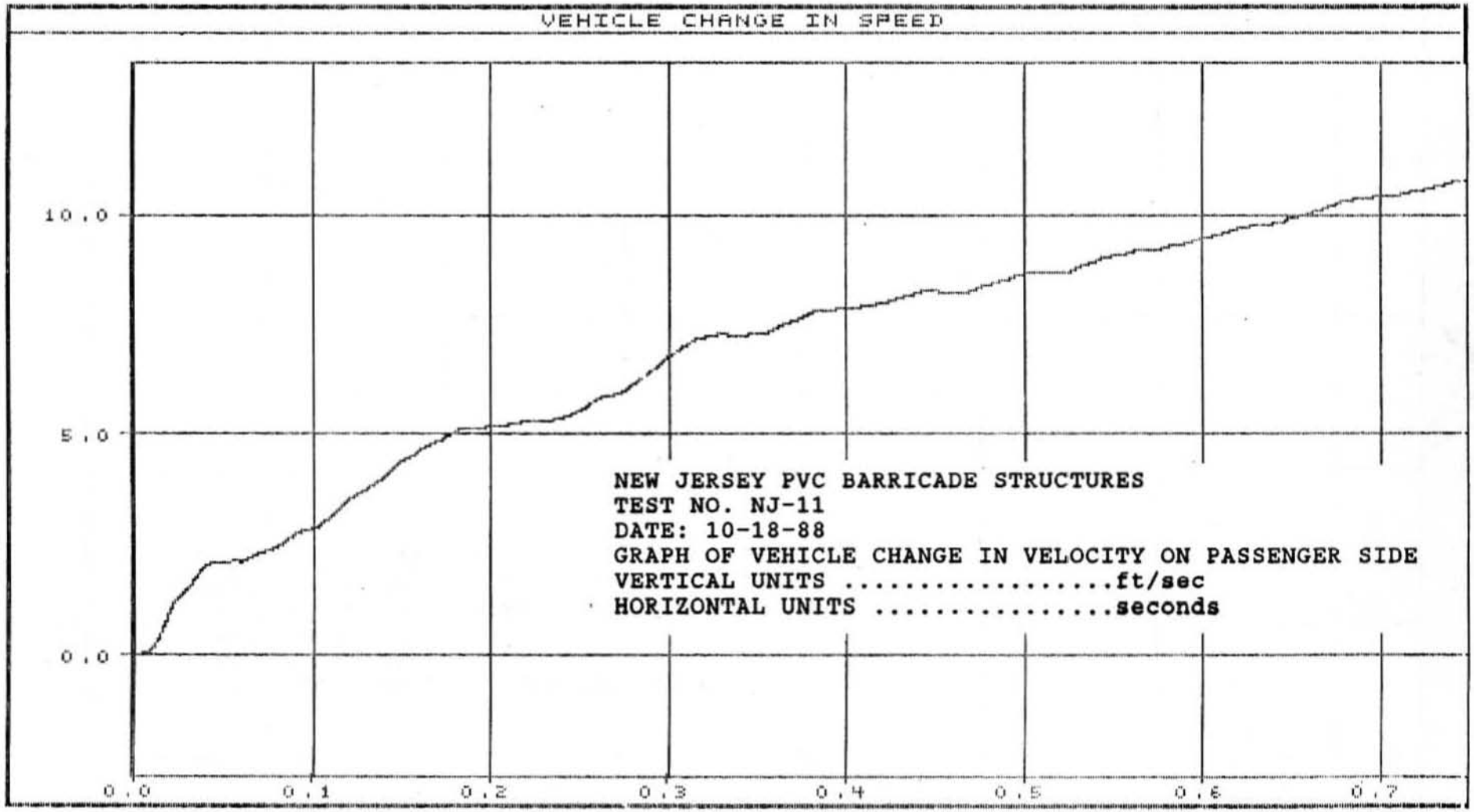

OCCUPANT DISPLACEMENT
30.0
20.0
10.0
0.0
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-10
DATE: 10-19-88
GRAPH OF OCCUPANT DISPLACEMENT
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18

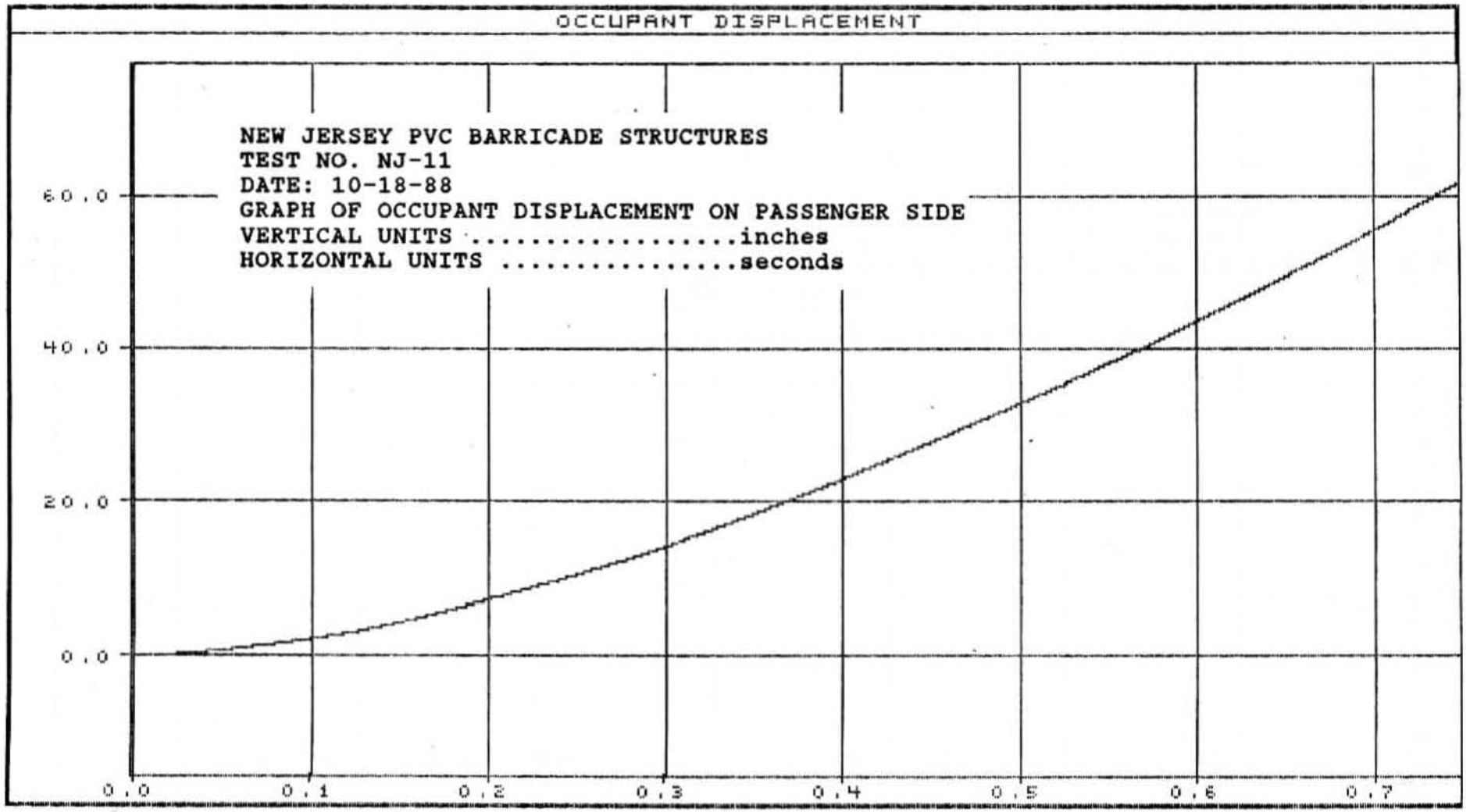

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

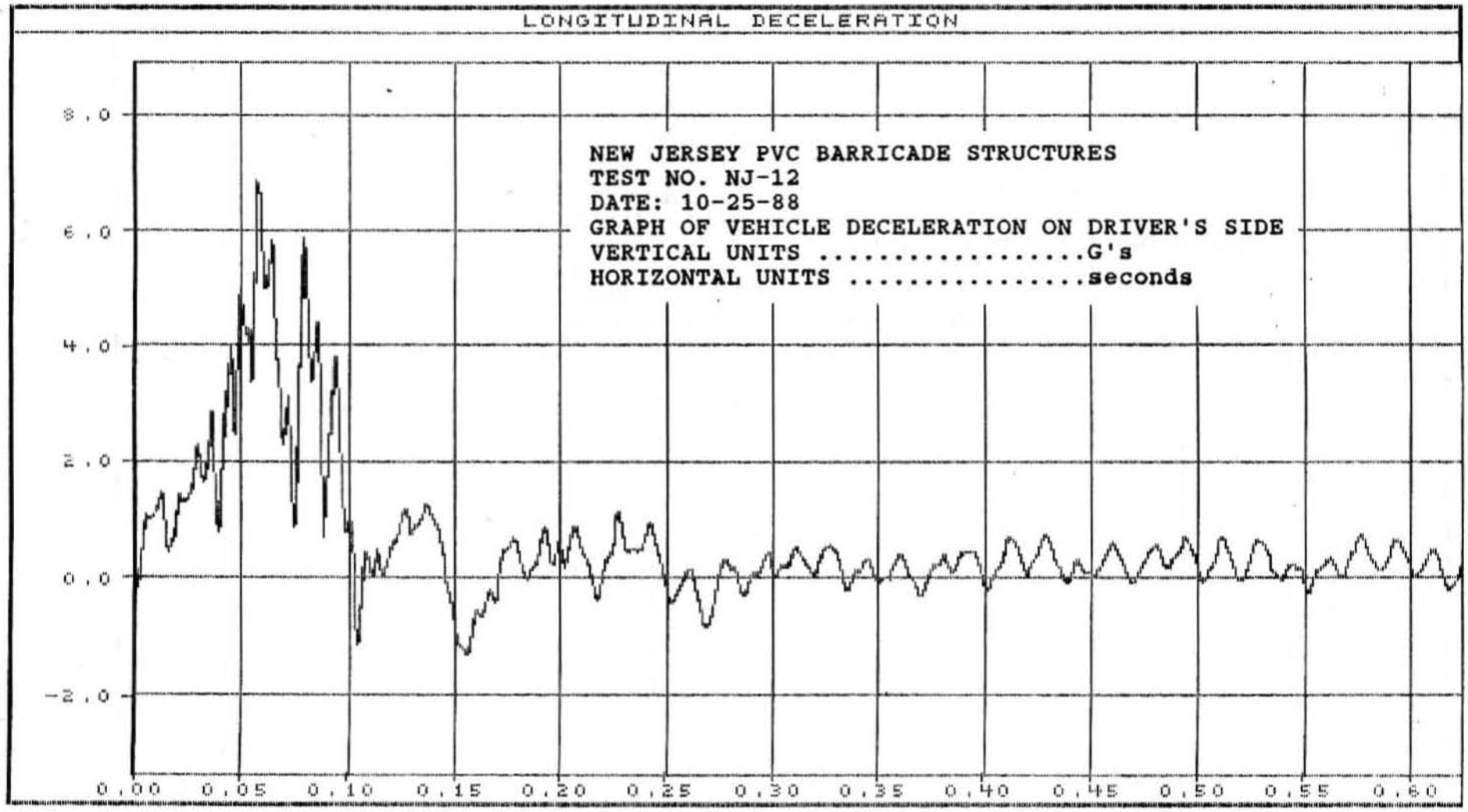

VEHICLE CHANGE IN SPEED
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

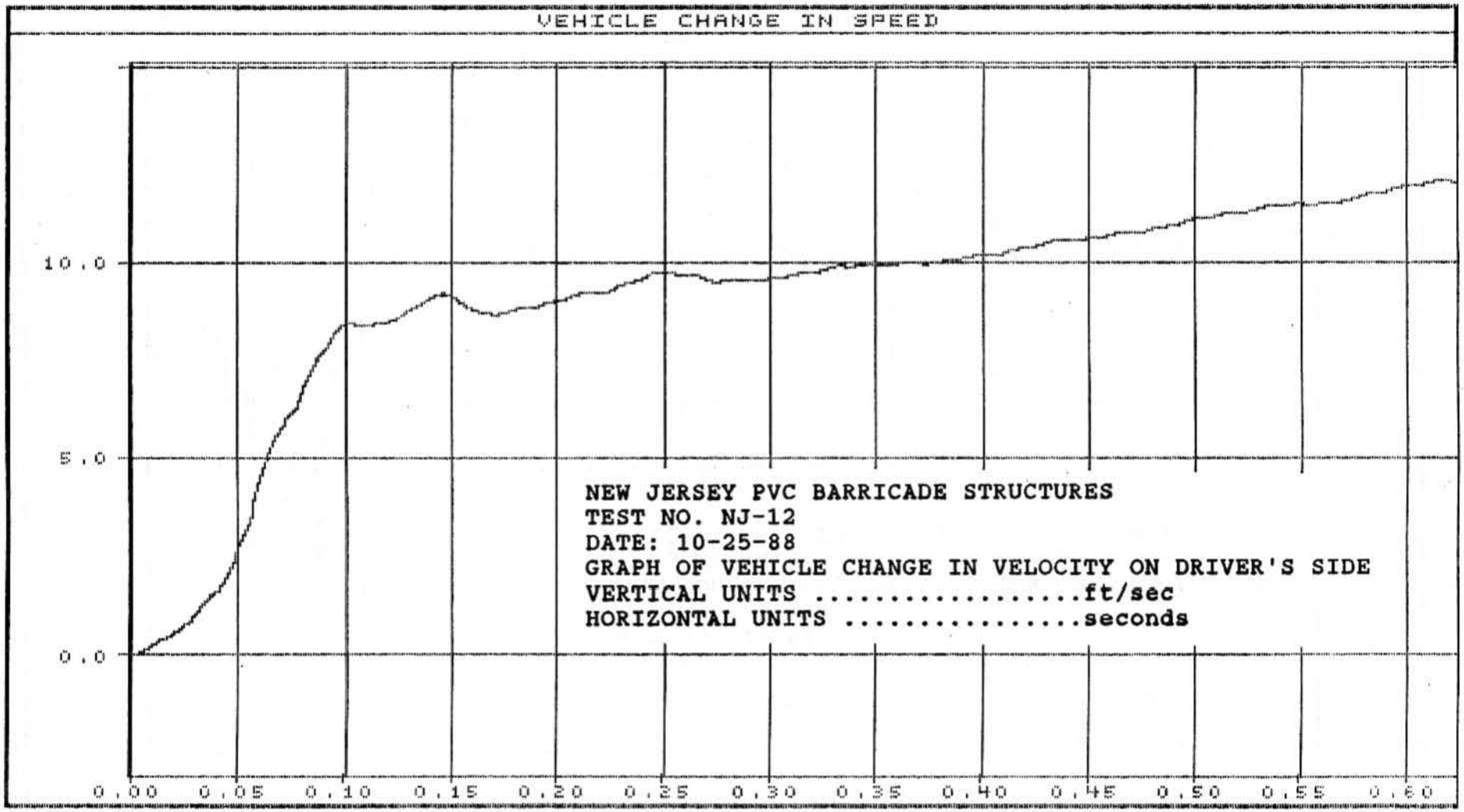

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

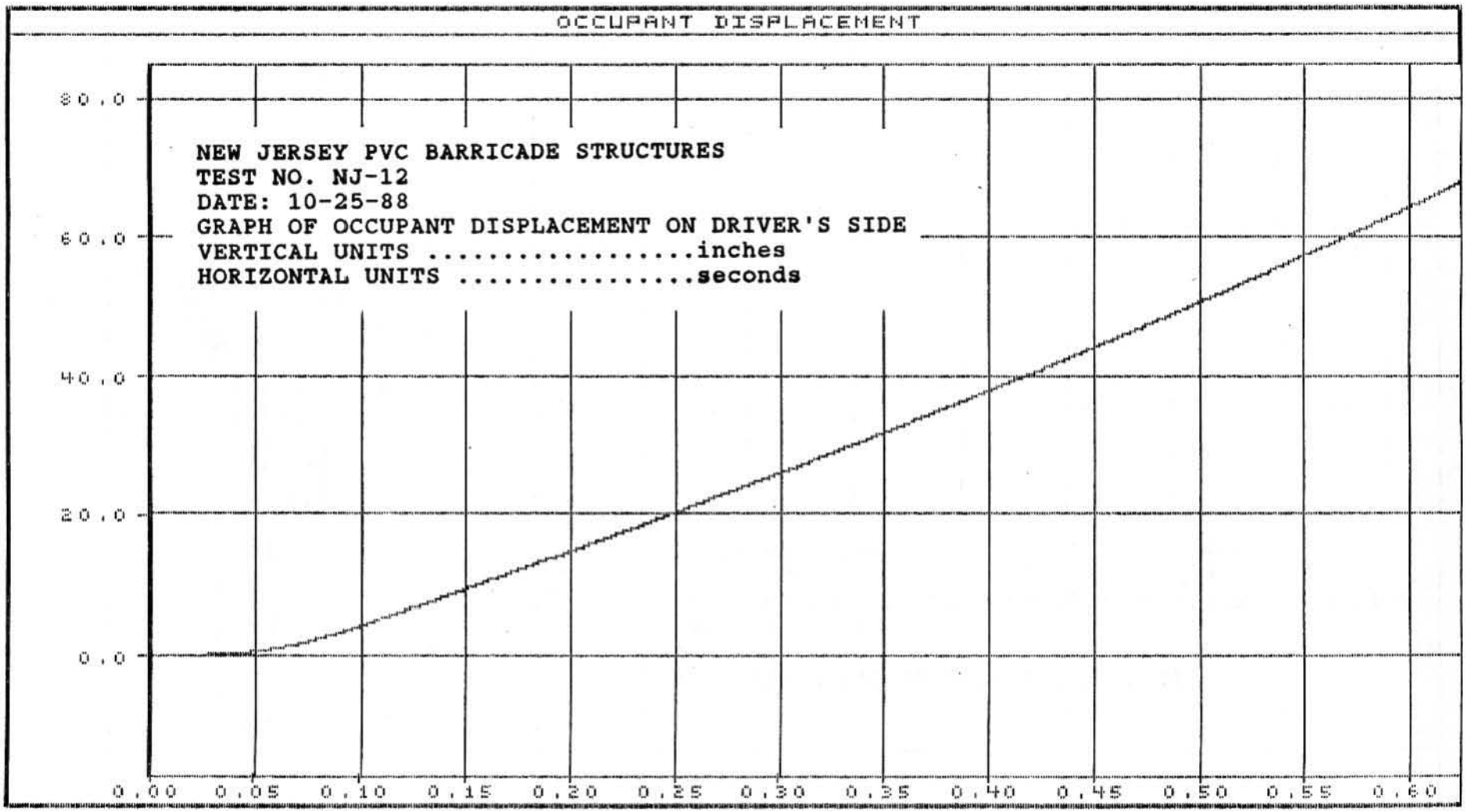

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH.OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
3.0
2.0
1.0
0.0
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

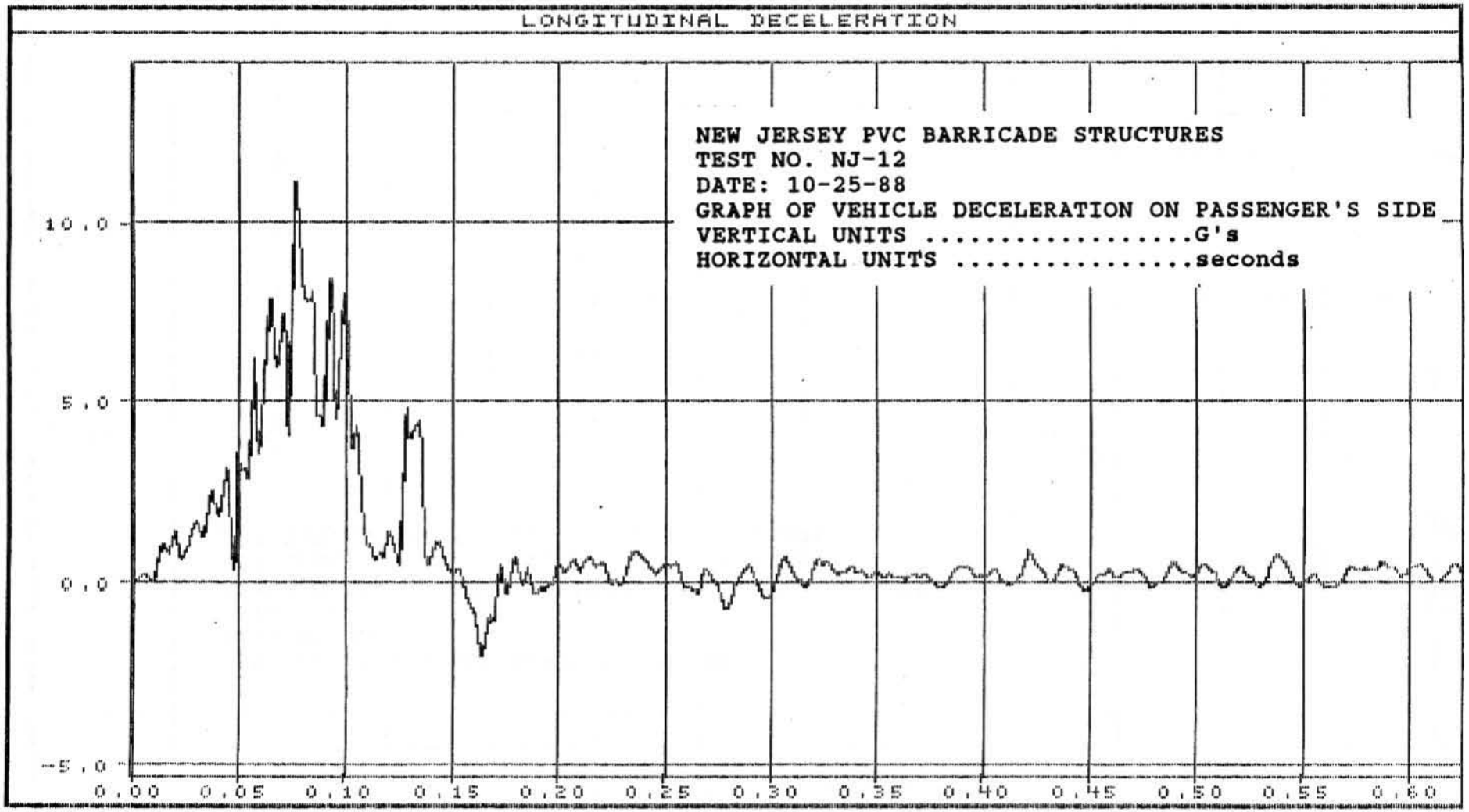

VEHICLE CHANGE IN SPEED
10.0
5.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds

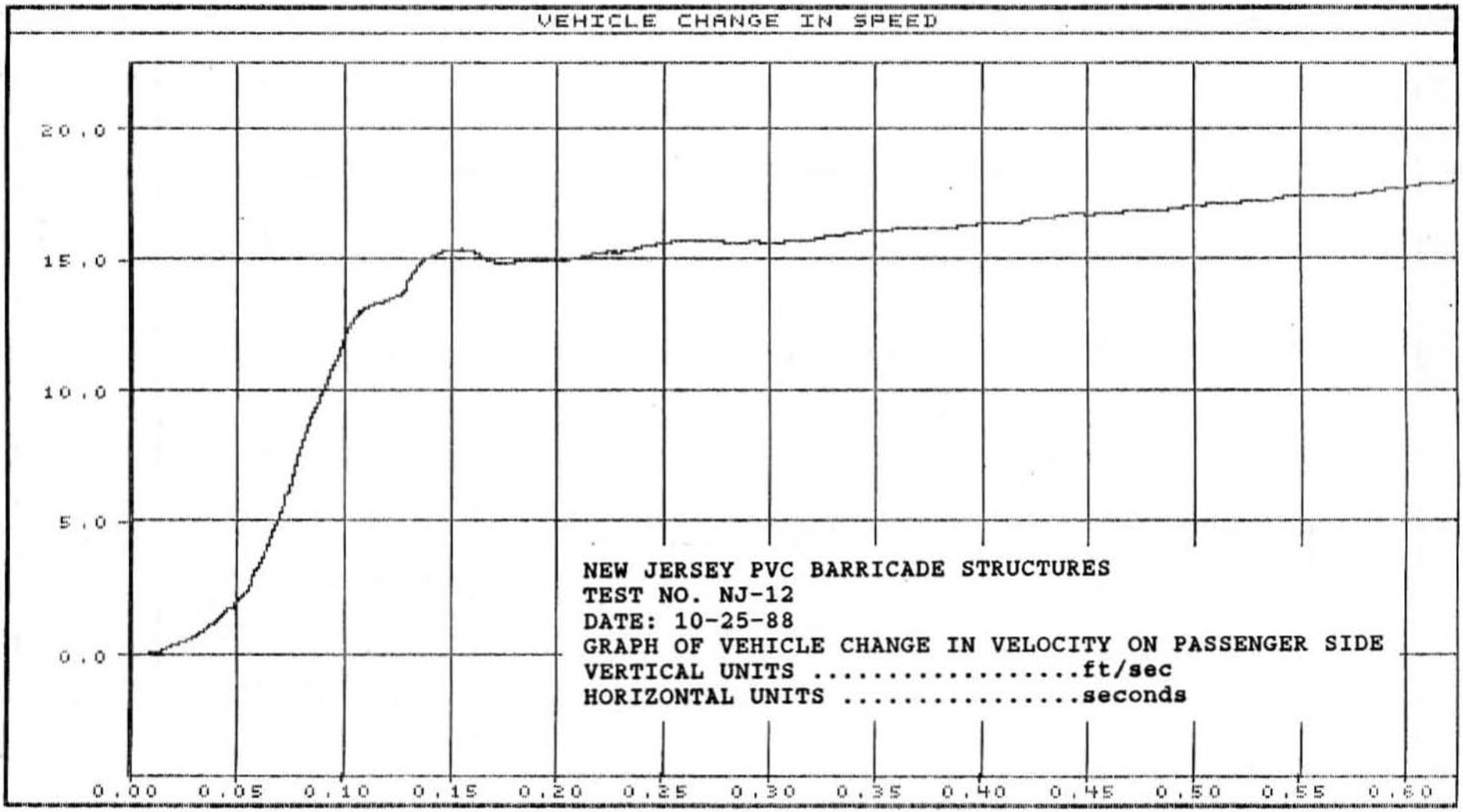

OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-11
DATE: 10-18-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
60.0
40.0
20.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

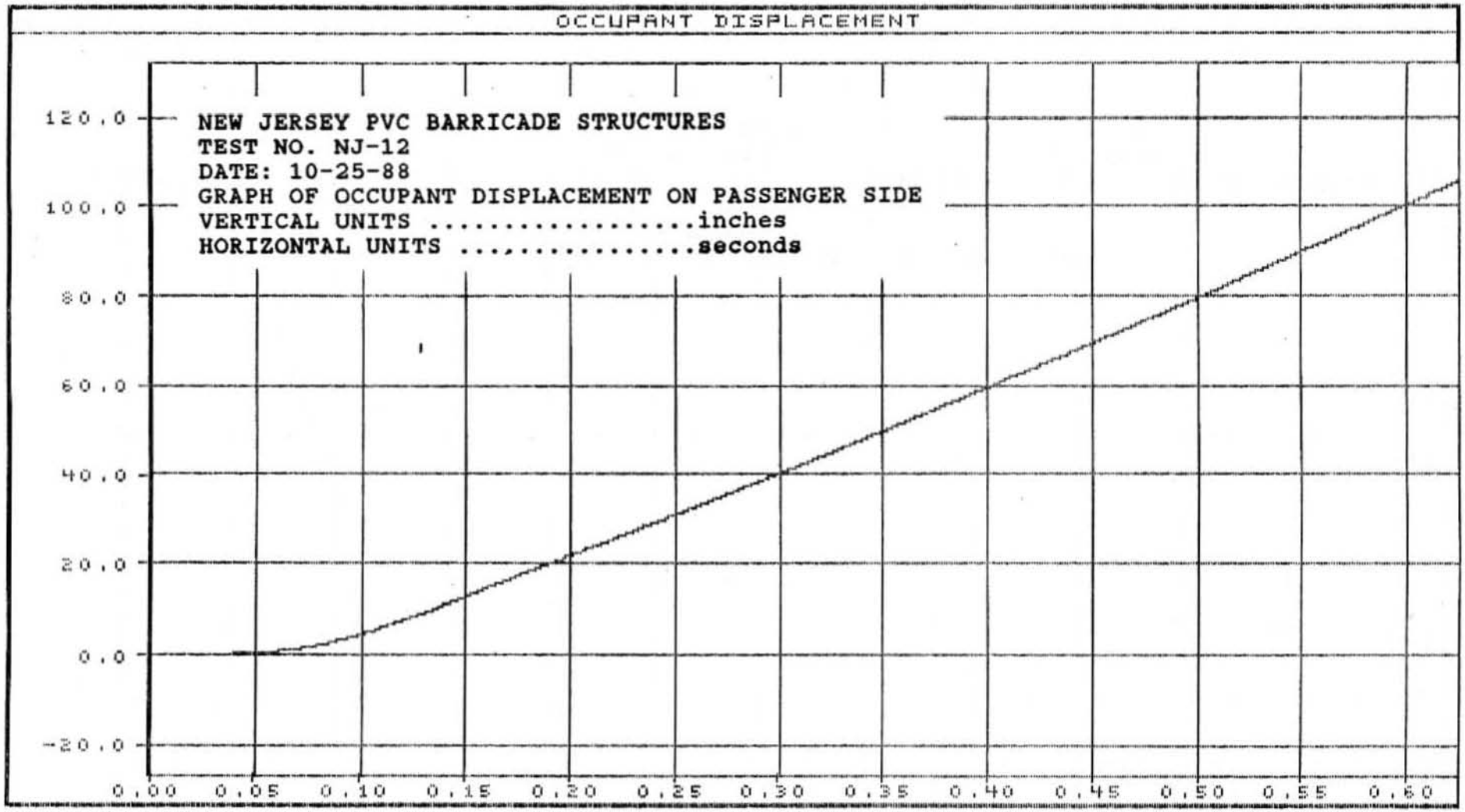

LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF VEHICLE DECELERATION ON DRIVER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
8.0
6.0
4.0
2.0
0.0
-2.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60


VEHICLE CHANGE IN SPEED
10.0
5.0
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON DRIVER'S SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds


OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF OCCUPANT DISPLACEMENT ON DRIVER'S SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
80.0
60.0
40.0
20.0
0.0
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60


LONGITUDINAL DECELERATION
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF VEHICLE DECELERATION ON PASSENGER'S SIDE
VERTICAL UNITS .....G's
HORIZONTAL UNITS .....seconds
10.0
5.0
0.0
-5.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60


VEHICLE CHANGE IN SPEED
20.0
15.0
10.0
5.0
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF VEHICLE CHANGE IN VELOCITY ON PASSENGER SIDE
VERTICAL UNITS .....ft/sec
HORIZONTAL UNITS .....seconds


OCCUPANT DISPLACEMENT
NEW JERSEY PVC BARRICADE STRUCTURES
TEST NO. NJ-12
DATE: 10-25-88
GRAPH OF OCCUPANT DISPLACEMENT ON PASSENGER SIDE
VERTICAL UNITS .....inches
HORIZONTAL UNITS .....seconds
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60