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FINAL REPORT -

FULL-SCALE CRASH EVALUATION OF THE NETC 4-BAR SIDEWALK-MOUNTED STEEL BRIDGE RAILING

Research, Development, and Technology
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16. Abstract

This report presents the results of three NCHRP Report 350 type crash tests conducted on a sidewalk-mounted steel bridge railing designed by the New England Transportation Consortium (NETC). The test vehicles included an 820-kg small car, a 2,000-kg pickup truck, and an 8,000-kg single-unit van truck. Barrier performance was satisfactory for most of the test evaluation criteria of Report 350 with one exception - in the heavy vehicle (8,000-kg truck) test, the vehicle front axle assembly was dislodged in the impact sequence, allowing the vehicle's trajectory to intrude into adjacent traffic lanes.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

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INTRODUCTION

Three vehicle crash tests were performed by Southwest Research Institute, San Antonio, TX, to evaluate the performance of a 4-bar, sidewalk-mounted steel bridge railing which had been designed by the New England Transportation Consortium (NETC). Specifically, tests designated as types 4-10, 4-11, and 4-12 in NCHRP Report 350[1] were performed. This report summarizes those tests, but does not contain all the details found in the individual test reports. Instead, the reader is referred to Publication Nos. FHWA-RD-98-028[2], -029[3], and -030[4] for more detailed descriptions and applicable data.

Since the same barrier configuration was utilized in all three tests, the only variables between tests were the vehicle types and weights as well as the impact velocities and angles. These are shown in table 1 along with the warrant for each type of test.

The text in the following sections briefly describes the test installation, vehicles, test sequences, and resulting damage to both the installation and vehicle. In addition, conclusions regarding barrier performance during each of the individual tests as well as an overall evaluation will be offered.

TEST INSTALLATION

Facility

These tests were performed along and adjacent to the inactive East Runway at Brooks Air Force Base, San Antonio, Texas. As shown in figure 1, a concrete approach and 34.1-m-long sidewalk were constructed at an angle to the runway and a 32.9-m-long bridge rail test article erected on the sidewalk.

Test Article

Drawings describing an elevation and cross section of the test installation are shown in figures 2 and 3, respectively. Briefly, the steel-reinforced, concrete sidewalk was 2.0 m wide by 203 mm high on the traffic side which sloped upward to a level 229 mm high where the bridge rail was mounted. The bridge rail utilized W6 x 25 steel posts which were welded to 25-mm x 254-mm x 356-mm base plates, and these were attached to the concrete with 25-mm anchor bolts. Post spacing was 2.44 m. Four longitudinal rails fabricated from steel structural tubing were attached to the posts with 19.1-mm diameter studs; rail heights, measured from the concrete sidewalk to the top of the rails, were 229 mm, 475 mm, 813 mm, and 1168 mm. Further details of the installation and its components are shown in the drawing of Appendix A.

Photographs of details of the barrier installation are shown in figure 4. Table 2 summarizes the beam and post materials used in the installation and also lists dimensions of the key components of the system.

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[1]Ross, H.E., Jr., Sicking, D.L., Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," *NCHRP Report 350*, Washington, D.C., 1993.

[2]Kimball, C.E., and Mayer, J.B., "Full-Scale Crash Evaluation of Sidewalk-Mounted Steel Bridge Railing, NCHRP Test 4-10, SwRI Test No. NETC-1," Publication No. FHWA-RD-98-028, Federal Highway Administration, 1998.

[3]Kimball, C.E., and Mayer, J.B., "Full-Scale Crash Evaluation of Sidewalk-Mounted Steel Bridge Railing, NCHRP Test 4-11, SwRI Test No. NETC-2," Publication No. FHWA-RD-98-029, Federal Highway Administration, 1998.

[4]Kimball, C.E., and Mayer, J.B., "Full-Scale Crash Evaluation of Sidewalk-Mounted Steel Bridge Railing, NCHRP Test 4-12, SwRI Test No. NETC-3," Publication No. FHWA-RD-98-030, Federal Highway Administration, 1998.

TEST VEHICLE, CONTROLS, AND DATA SYSTEMS

Vehicle and Dummy

Pre-test photographs of the vehicles used are shown in Figures 5 through 7. For tests NETC-1 and NETC-2, an uninstrumented dummy was placed in the driver's seat of each vehicle and restrained with lap and shoulder belts; no dummy was used in test NETC-3.

Vehicle Controls

Target impact point of the vehicle for all tests was the centerline of post 6. Each vehicle was guided to that location using a 6.4-mm diameter x 457.2-m-long steel cable which passed through a guide tube/bracket attached to the left front wheel spindle. The cable was pretensioned and located alongside the run-up strip where it would not interfere with post-impact vehicle trajectory. Just prior to impact, the guide tube/bracket was sheared off allowing the vehicle free trajectory.

Braking of each test vehicle was accomplished by use of an air cylinder attached to its brake pedal. The air cylinder was activated by a gas-charged accumulator through an intermediate solenoid valve. The solenoid valve was remotely controlled by the test conductor.

Each test vehicle was towed into the barrier using a cable/pulley system for reverse towing, i.e., the tow vehicle moved away from the barrier as the test vehicle moved toward it. The tow cable was attached to the underside of the test vehicle and released just prior to impact. Vehicle impact speed control was achieved by means of an automatic controller attached to the engine distributor of the tow vehicle. After the tow vehicle accelerated to its predetermined test speed, the controller pulsed the ignition, maintaining the tow vehicle at that speed.

Electronic Data Acquisition

The test vehicles were instrumented with multiple accelerometers and one rate gyro; locations of these transducers in each vehicle are described in table 3. The accelerometers were oriented to obtain data in directions parallel to the longitudinal, lateral, or vertical axes of the vehicle, whereas the rate gyro was oriented to measure the yaw angular rate change the vehicle experienced during the impact sequence. All transducer data was recorded by a Pacific Instruments Model 5600 Data Acquisition System (DAS) which contained signal conditioners, amplifiers, appropriate SAEJ211 filters and digitizers with onboard memory for up to 32 data channels at programmable sample rates to 100 kilohertz per channel. Digitized data was recorded in solid state non-volatile memory with a capacity of 65,000 data points per channel.

In addition to the above, two accelerometers were mounted on the back flange of post 7 of the barrier installation. These were located 51 mm and 533 mm below the top of the post and were oriented to obtain data in a lateral direction to the barrier. These two transducers were connected to a signal conditioning unit for power, calibration and balancing, and their signals recorded during each test by digital computer at a rate of 1 kilohertz.

Film Data Acquisition

In addition to the electronic data, high-speed film coverage of all three tests included a camera onboard the vehicle (tests NETC-1 and NETC-2 only) as well as cameras adjacent to and overhead of the barrier installation (all tests).

Data Processing

Vehicle transducer data were downloaded to a personal computer after each test and processed through an Institute-developed computer program. This program utilized accelerometer and rate gyro data to determine vehicle acceleration (in longitudinal, lateral, and vertical directions), heading angle, velocity, and displacement as a function of time during each event. In addition, this data provided input to the program for calculation of the highest 50-millisecond average accelerations for the vehicle as well as occupant risk data, including impact velocities (with the interior of the vehicle) and 10-millisecond average ridedown accelerations. The output of this data was provided in both tabular or graphical form.

Data from the two accelerometers mounted on post 7 were transferred to a floppy disk after each test, and then imported to a Microsoft Excel spreadsheet. These data were then converted to standard engineering units (g's) and output in both tabular and graphical form.

TEST DESCRIPTION

Test NETC-1.

This was the first test of the series and utilized a small car as the test vehicle. As shown in the test summary diagram of figure 8, the vehicle traversed the sidewalk and impacted the barrier 610 mm downstream of post 6, maintaining contact with the longitudinal rails for 1.83 m as it was redirected, exiting the installation at a 6.6° angle (calculated from measured tire marks). Figures 9 and 10 show the redirection sequence of the vehicle from overhead as well as behind the barrier viewpoints. The post-impact trajectory of the vehicle was such that it traveled in a relatively straight line after loss of contact, coming to a stop 77 m downstream of initial impact point (brakes had been applied immediately after loss of contact with the barrier). Two of the vehicle accelerometers, the lateral accelerometer at the c.g. and the longitudinal accelerometer mounted on the instrument panel, malfunctioned at impact, resulting in no data on those channels. Data from film analysis indicated maximum 50 msec average accelerations of -3.4 g's in the longitudinal direction and 6.9 g's in the lateral direction. Occupant risk values showed that the dummy did not travel the required hypothetical distance in the longitudinal direction, and a value of 1.4 m/sec occupant impact velocity is reported at the maximum displacement of 0.2 m. Lateral impact velocity is calculated from film analysis as 6.4 m/sec. Maximum ridedown acceleration was 6.4 g's lateral.

Test NETC-2. In this pickup truck test, as shown in figure 11, the vehicle traversed the sidewalk and impacted the barrier 610 mm downstream of post 6, maintaining contact with the longitudinal rails for 3.96 m as it was redirected, exiting the installation at an 8.2 degree angle (calculated from measured tire marks). Figures 12 and 13 show the redirection sequence of the vehicle from overhead as well as behind the barrier viewpoints. The post-impact trajectory of the vehicle was such that it traveled in a relatively straight line after loss of contact, coming to a stop 62 m downstream of the initial impact point (brakes had been applied immediately after loss of contact with the barrier). Three of the vehicle accelerometers, the lateral accelerometer at the c.g. and the longitudinal accelerometers mounted on the instrument panel and bottom of the engine, malfunctioned at impact, resulting in no data on those channels. The net effect of the data loss from the lateral accelerometer was that the 50 msec average vehicle acceleration and occupant risk values in the lateral direction could not be calculated. However, the more important (for this test) longitudinal factors could be calculated and were as follows:

(1) maximum 50 msec average acceleration in the longitudinal direction was -6.12 g's, (2) the occupant impact velocity was 3.99 m/sec, and (3) the maximum occupant ridedown acceleration was -2.55 g's.

Test NETC-3. As shown in the test summary diagram of figure 14, the single-unit van truck traversed the sidewalk and impacted the barrier 610 mm upstream of post 6, deflecting the two top rails approximately 25 mm at the splice between posts 6 and 7 while maintaining contact with the longitudinal rails for 12.19 m as it was redirected. The vehicle then exited the barrier at a 4.1 degree angle (calculated from measured tire marks). Figures 15 and 16 show the redirection sequence of the vehicle from overhead as well as behind the barrier viewpoints. Since the front axle was dislodged during the impact, the vehicle veered hard to the right after exiting and stopped 84 m downstream and 91 m normal to the test installation. Although some of the vehicle accelerometers had interruptions in their data due to the impact, only one, the longitudinal accelerometer mounted on the bottom of the engine, suffered complete data loss. Maximum 50 msec average accelerations in the longitudinal and lateral directions were -2.72 g's and -5.79 g's, respectively. Occupant risk values were as follows: (1) the occupant impact velocities were 1.65 m/sec in the longitudinal direction and -2.89 m/sec in the lateral direction, and (2) the maximum occupant ridedown accelerations were -8.95 g's in the longitudinal direction and 14.30 g's in the lateral direction.

BARRIER DAMAGE

Test NETC-1. Damage to the barrier, as shown in figure 17, consisted of scuffing of the longitudinal rails which only required repainting prior to further testing. There was no measurable dynamic or permanent deflection of the barrier.

Test NETC-2. Damage to the barrier, as shown in figure 18, occurred mostly at post 7. The top of post 7 and the top rail section attached to it had 13 mm of permanent deflection, and the baseplate of the post was raised upward at the center approximately 3.5 mm. The remainder of the damage consisted of scuffing of the longitudinal rails which only required repainting prior to further testing. The top rail was straightened, but post 7 required replacement prior to subsequent testing.

Test NETC-3. Barrier damage is shown in figure 19. Maximum permanent rail deflection occurred at the splice upstream of post 7 and was measured as 13 mm. Two sections of the top rail had permanent deflection (deflection occurred between posts 6 and 7), and posts 6 and 7 were tilted back; the base plates of both posts were raised upward at the center approximately 3.5 mm. The remainder of the damage consisted of scuffing of all longitudinal rails between posts 6 and 11.

VEHICLE DAMAGE

Test NETC-1. As shown in figure 20, the test vehicle sustained damage to the left front fender and along the left side, as well as damage to headlight/grill area. The left side of the front bumper was deformed rearward, and the left front suspension/wheel/tire displaced rearward. All tires except the right rear were either blown out or deflated as a result of the impact. The exterior vehicle damage scale was estimated to be 11-FL-2 using the VDS system and 11FLEE2 using the CDC system. The interior deformation of the occupant compartment was LF0000000 using the OCDI system. There was no deformation or intrusion into the occupant compartment.

Test NETC-2. Figure 21 shows that the test vehicle sustained extensive damage to the left front fender and along the left side, as well as damage to the headlight/grille area. The left side of the front bumper was deformed rearward, and the left front suspension/wheel/tire displaced rearward. Contact with the edge of the sidewalk damaged the right front suspension also. All tires except the right rear were either blown out or deflated as a result of the impact. The exterior vehicle damage scale was estimated to be 11-FL-3 using the VDS system and 11FLEE3 using the CDC system. The interior deformation of the occupant compartment was LF0000000 using the OCDI system. There was no deformation or intrusion into the occupant compartment.

Test NETC-3. The test vehicle, as shown in figure 22, sustained extensive damage. As described previously, the entire front axle (axle/brakes/wheels/tires, etc.) was dislodged by the impact and later separated during vehicle run out. In addition, the left corner of the front bumper was deflected rearward, a portion of the left front fender was torn away (the vehicle had a one-piece, fiberglass front clip), the left step under the driver's door was torn away, the left rear, outside wheel was damaged, the cargo box was racked toward the left side, and the anti-underride assembly was fractured at the left rear corner. Since the exterior damage scales, i.e., the VDS system and the CDC system, are not applicable to this class of test vehicle, no assessment of that type was made. The OCDI system is also not applicable; however, there was no deformation or intrusion into the occupant compartment.

EVALUATION OF TEST RESULTS

Performance evaluation of the barrier design is based on the criteria shown in table 5.1 titled "Safety Evaluation Guidelines," of NCHRP Report 350. The specific requirements applicable for each of the test types, i.e. 4-10, 4-11, and 4-12, are shown in tables 4 through 6 together with the test results. Although the data loss of the vehicle lateral accelerometer during test NETC-1 (small car) precluded any occupant risk calculations and subsequent assessments (see table 4) from those calculated values, it was conjectured by SwRI project personnel that the barrier performance would have passed those criteria also. This was based on a comparison of vehicle damage and shallow exit angle for this test with those tests performed previously. Table 5 for test NETC-2 (pickup truck) indicates that the barrier passed in all categories of assessment, but table 6 for test NETC-3 (single-unit van truck) indicates a failure in the category applicable to vehicle intrusion into adjacent traffic lanes. This was a result of the loss of the front axle assembly causing the vehicle to veer sharply to the right, and it would have been a hazard to adjacent traffic.

CONCLUSIONS

From these tests and the evaluations described in the preceding section, the NETC 4-bar, sidewalk-mounted steel bridge railing appears to meet most of the requirements for a longitudinal barrier. The exception being, of course, the intrusion by the vehicle into adjacent traffic lanes as described for test NETC-3 in the previous section.

Table 1. Summary of test conditions.

Test Designation and NCHRP 350 Test Type	Vehicle Type	Vehicle Weight (kg)	Impact Velocity (km/h)	Impact Angle (deg)	Barrier Evaluation
NETC-1 (4-10)	Small Car (1991 Ford Festiva)	820	100	20	Length of need; occupant risk
NETC-2 (4-11)	Pickup Truck (1991 Ford F-250)	2000	100	25	Barrier strength
NETC-3 (4-12)	Single-Unit Van Truck (1993 IH 4600-LP)	8000	80	15	Barrier strength (heavy vehicle)

Table 2. Installation bill of material.

Bill of Material

Item	Quantity
TS 4 x 4 x 1/4 - 7.31 M long rail	12
TS 8 x 4 x 5/16 - 7.31 M long rail	4
TS 4 x 4 x 1/4 - 3.66 M long rail	3
TS 8 x 4 x 5/16 - 3.66 M long rail	1
W6 x 25 - 1.05 M high post	14

Table 3. Vehicle data transducer locations.

Type	Location	Orientation	Applicability
Accelerometer	Center of gravity	Longitudinal axis	All tests
Accelerometer	Center of gravity	Lateral axis	All tests
Accelerometer	Center of gravity	Vertical axis	All tests
Rate Gyro	Center of gravity	Longitudinal axis	All tests
Accelerometer	Over rear axle	Longitudinal axis	All tests
Accelerometer	Over rear axle	Lateral axis	All tests
Accelerometer	Over rear axle	Vertical axis	All tests
Accelerometer	Top engine block	Longitudinal axis	All tests
Accelerometer	Bottom of engine block	Longitudinal axis	All tests
Accelerometer	Right front disc brake caliper	Longitudinal axis	All tests
Accelerometer	Left front disc brake caliper	Longitudinal axis	All tests
Accelerometer	Center of instrument panel	Longitudinal axis	All tests
Accelerometer	Right rear brake backing plate	Vertical axis	Test NETC-3 Only
Accelerometer	Left rear brake backing plate	Vertical axis	Test NETC-3 Only

Table 4. Test assessment summary - NCHRP Report 350 test designation 4-10 - SwRI test number NETC-1.

Designation	Factor	Description			Test Results	Assessment
C	Structural Adequacy	Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.			Vehicle contained and redirected.	**PASS**
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries shall not be permitted.			This article and its elements did not penetrate the occupant compartment or present undue hazard to adjacent traffic or others. There was no deformation or intrusion into the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	**PASS**
H	Occupant Risk	Occupant impact velocities should satisfy the following: Occupant Impact Velocity Limits (m/s)				
		Component	**Preferred**	**Maximum**		
		Longitudinal	9	12	1.4	**PASS**
		Lateral	9	12	6.4	**NONE**
I	Occupant Risk	Occupant ridedown accelerations should satisfy the following: Occupant Ridedown Acceleration Limits (G's)				
		Component	**Preferred**	**Maximum**		
		Longitudinal	15	20	0*	**PASS**
		Lateral	15	20	6.4	**PASS**
K	Vehicle Trajectory	After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			Vehicle exit angle was 6.6 degrees.	**PASS**

*Occupant did not travel required hypothetical distance.

Table 5. Test assessment summary - NCHRP Report 350 test designation 4-11 - SwRI test number NETC-2.

Designation	Factor	Description	Test Results	Assessment
A	Structural Adequacy	Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	Vehicle contained and redirected.	**PASS**
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries shall not be permitted.	This article and its elements did not penetrate the occupant compartment or present undue hazard to adjacent traffic or others. There was no deformation or intrusion into the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.	Vehicle remained upright during and after the collision.	**PASS**
L	Vehicle Trajectory	Occupant longitudinal impact velocity and ridedown acceleration should satisfy the following:	Occupant longitudinal impact velocity and ridedown acceleration values were:	
		Component / **Maximum**		
		Longitudinal impact velocity / 12 m/sec	3.99 m/sec	**PASS**
		Longitudinal ridedown acceleration / 20 G's	2.55 G's	**PASS**
K	Vehicle Trajectory	After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	Vehicle did not intrude into adjacent traffic lanes.	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.	Vehicle exit angle was 6.6 degrees.	**PASS**

Table 6. Test assessment summary - NCHRP Report 350 test designation 4-12 - SwRI test number NETC-3.

Designation	Factor	Description	Test Results	Assessment
A	Structural Adequacy	Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	Vehicle contained and redirected.	**PASS**
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries shall not be permitted.	This article and its elements did not penetrate the occupant compartment or present undue hazard to adjacent traffic or others. There was no deformation or intrusion into the occupant compartment.	**PASS**
G	Occupant Risk	It is preferable, although not essential, that the vehicle remain upright during and after the collision.	Vehicle remained upright during and after the collision.	**PASS**
K	Vehicle Trajectory	After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	Vehicle intruded into adjacent traffic lanes.	**DID NOT PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.	Vehicle exit angle was 4.1 degrees.	**PASS**

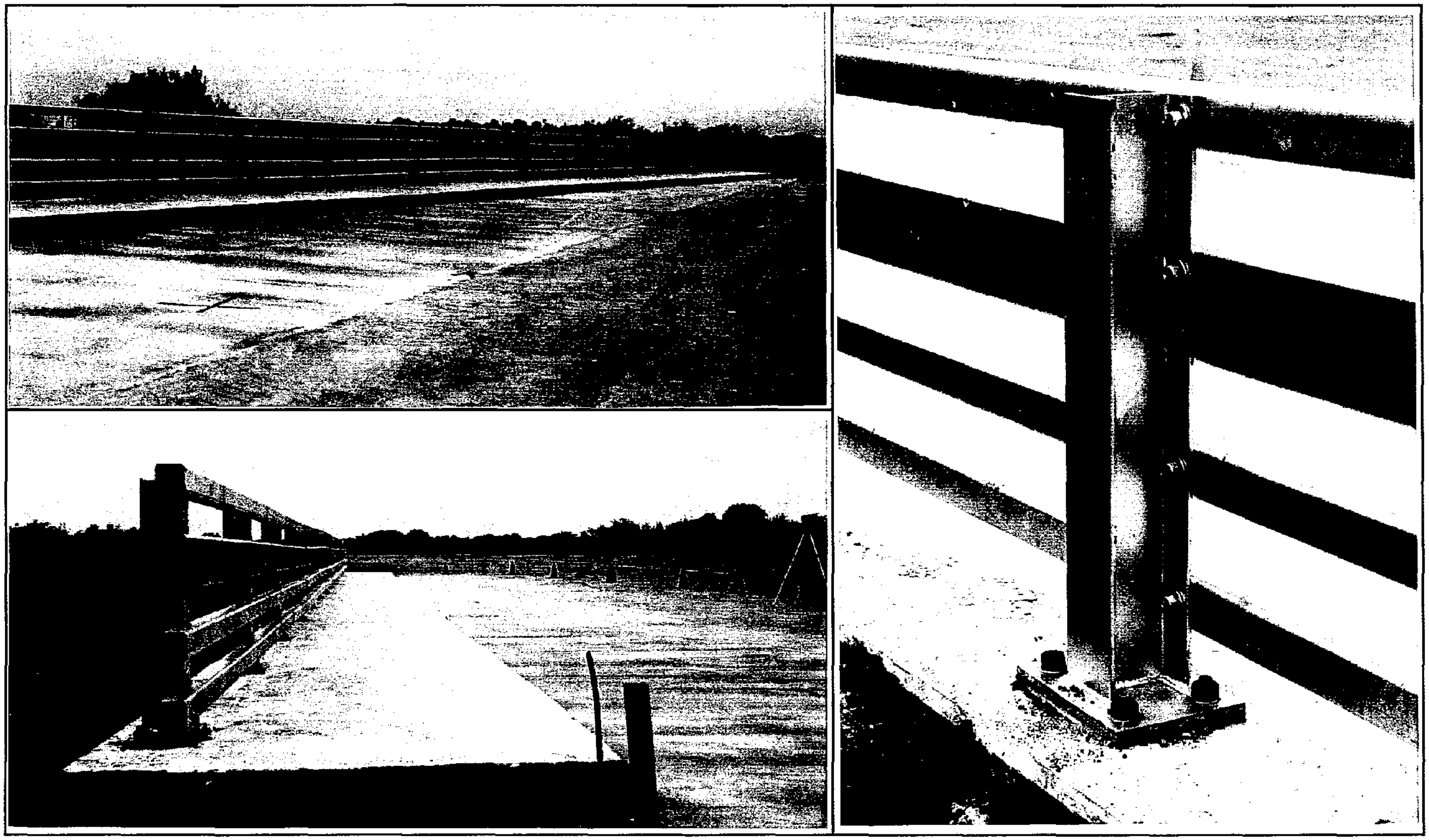


Figure 1. Barrier installation.

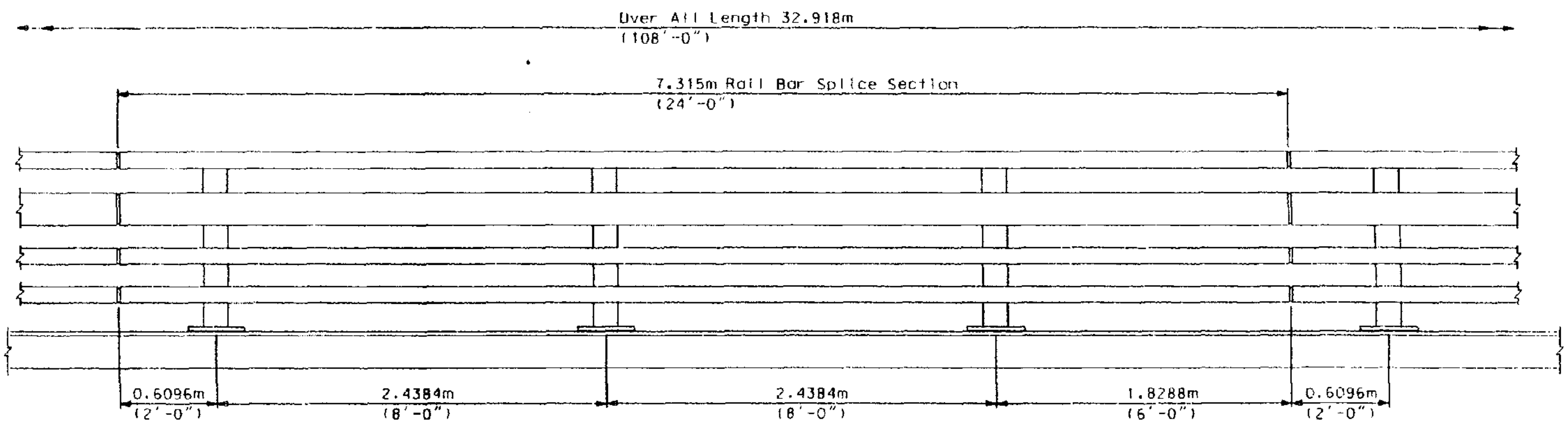


Figure 2. Barrier elevation drawing.

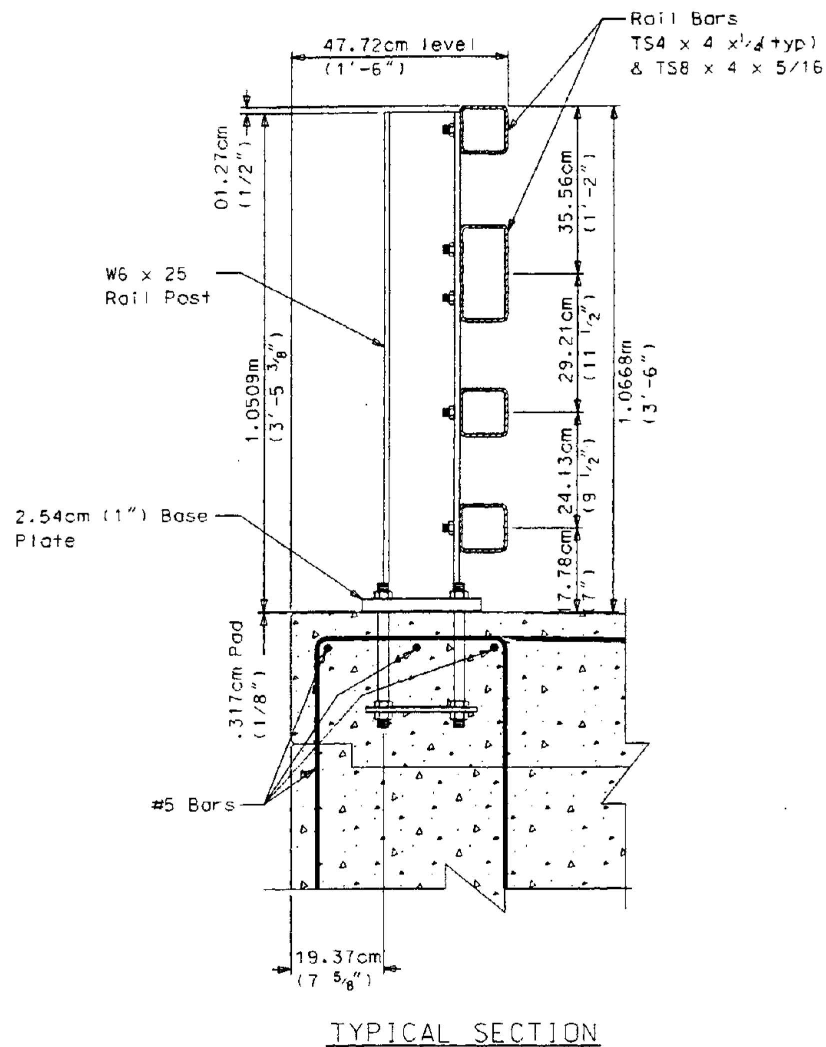


Figure 3. Barrier cross-section drawing.

Figure 4. Barrier photographs.

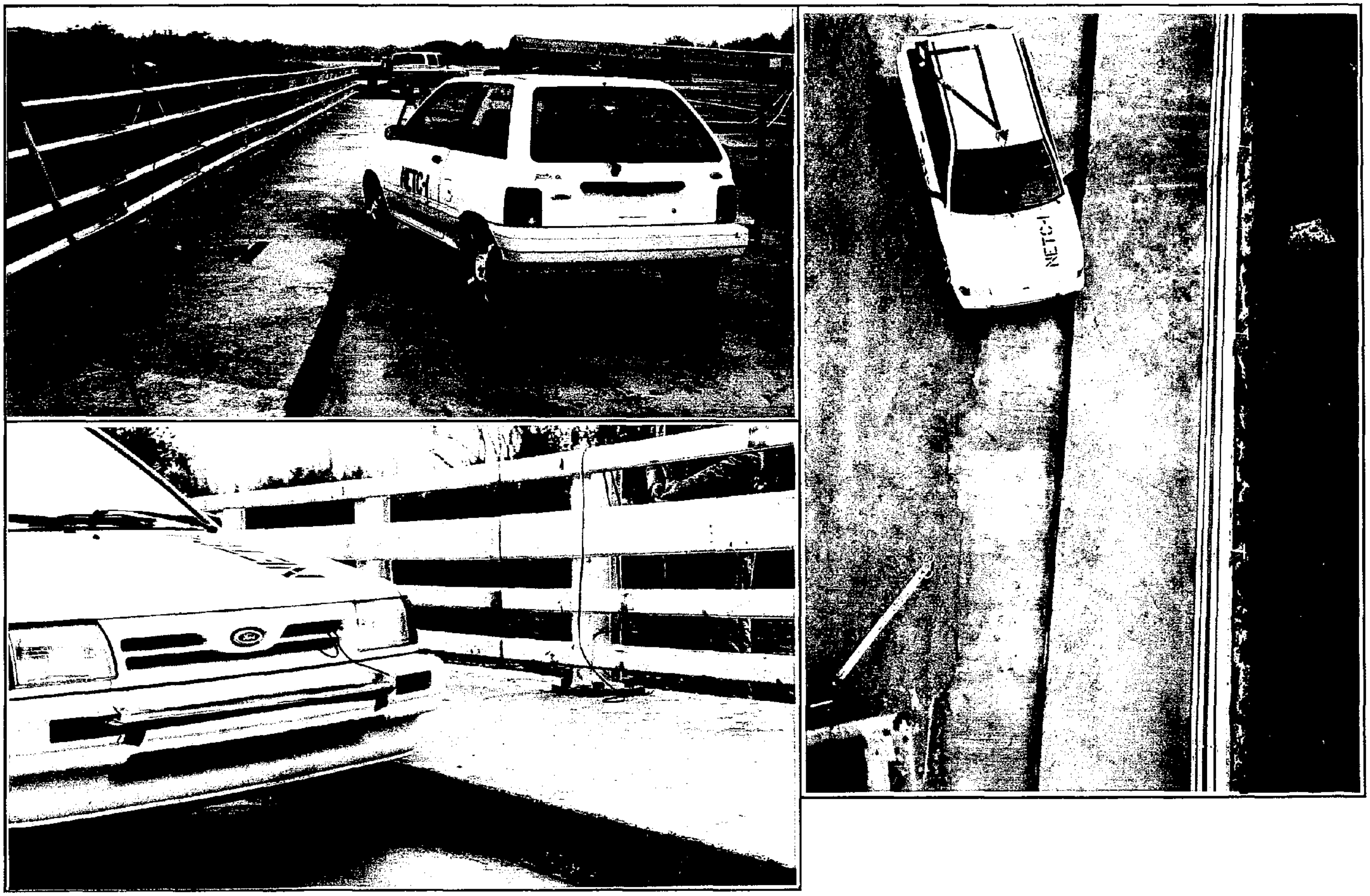


Figure 5. Vehicle photographs - Test NETC-1.

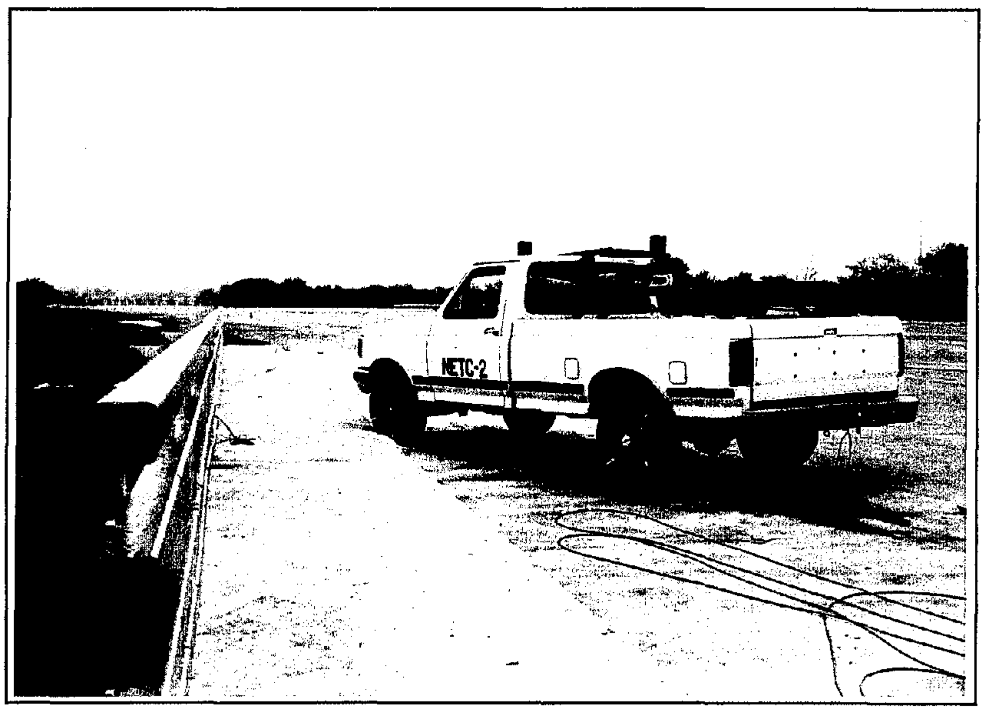


Figure 6. Vehicle photographs - Test NETC-2.

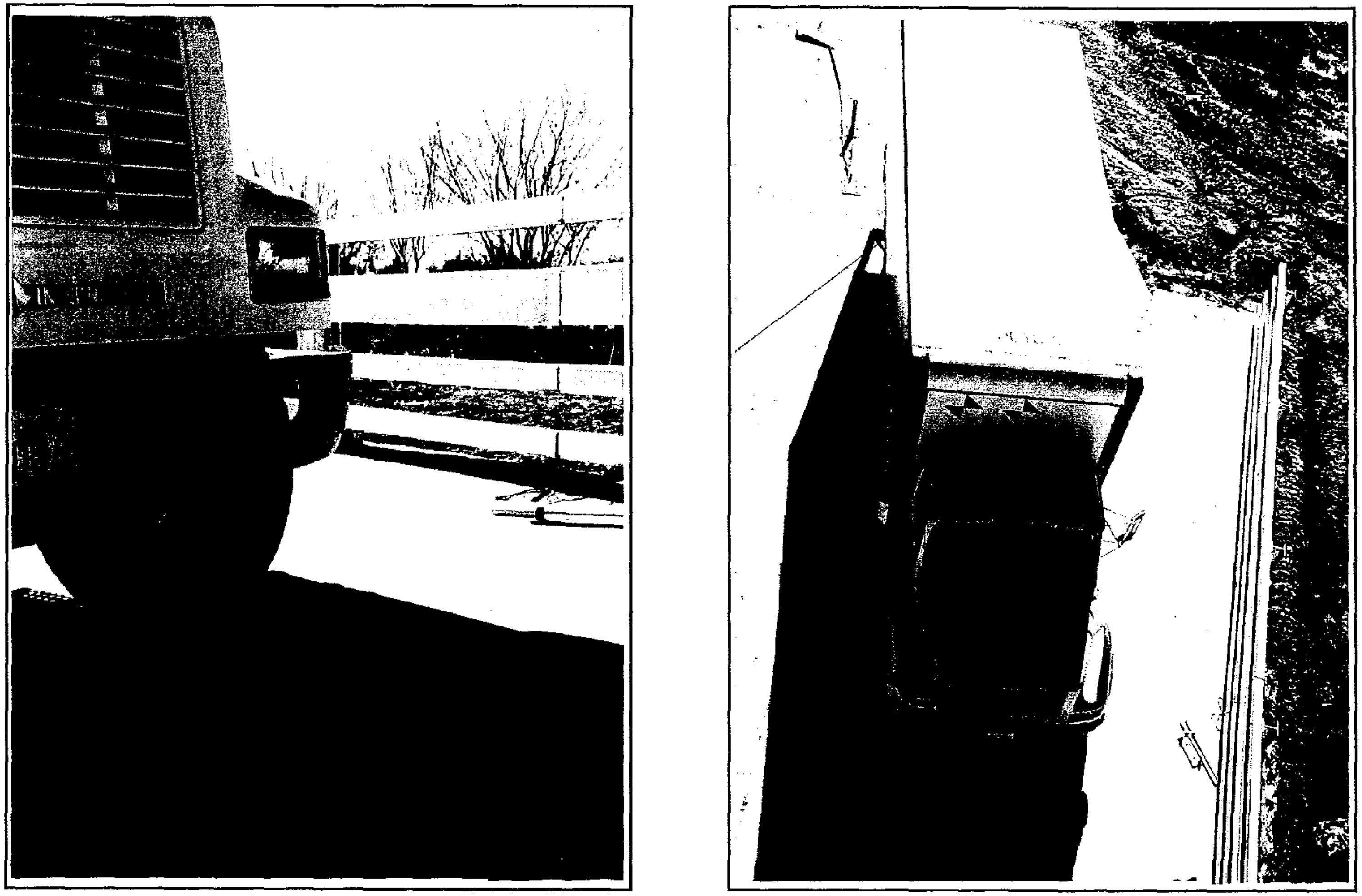
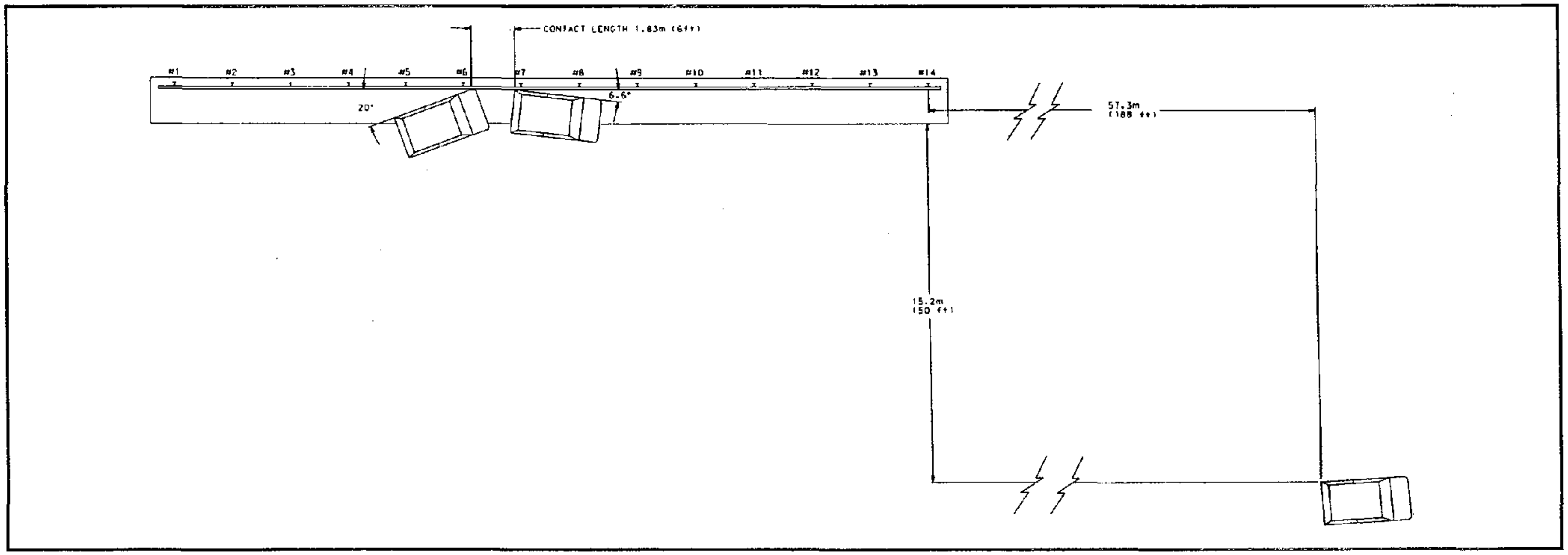


Figure 7. Vehicle photographs - Test NETC-3.



4. **General Information**		7. **Test Vehicle (Continued)**		10. **Ridedown Acceleration (g's)**	
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	*
Test Number	NETC-1	Mass (kg) Gross Static	902	**11. Test Article Deflection (m)**	
Test Date	11/18/97	**8. Impact Conditions**		Dynamic	0
5. Test Article		Speed (km/h)	100.0	Permanent	0
Type	Bridge Rail	Angle (deg)	20.0	**12. Vehicle Damage**	
Installation Length (m)	32.9	**9. Exit Conditions**		Exterior	
Barrier	4 Steel Rails	Speed (km/h)	18.3	VDS	11-FL-2
6. Soil Type and Condition	N/A	Angle (deg)	6.6	CDC	11FLEE2
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production	Impact Velocity (m/s)		OCDI	LF0000000
Designation	820C	x-direction	*	**13. Post-Impact Vehicular Behavior**	
Model	1991 Ford Festiva	y-direction	*	Maximum Roll Angle (deg)	10 Approximate
Mass (kg) Curb	827	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Approximate
Mass (kg) Test Inertial	827	X-direction	*	Maximum Yaw Angle (deg)	34 Approximate

*No occupant risk data - lateral accelerometer malfunctioned during test.

Figure 8. Impact sequence and summary of test conditions and results - Test NETC-1.

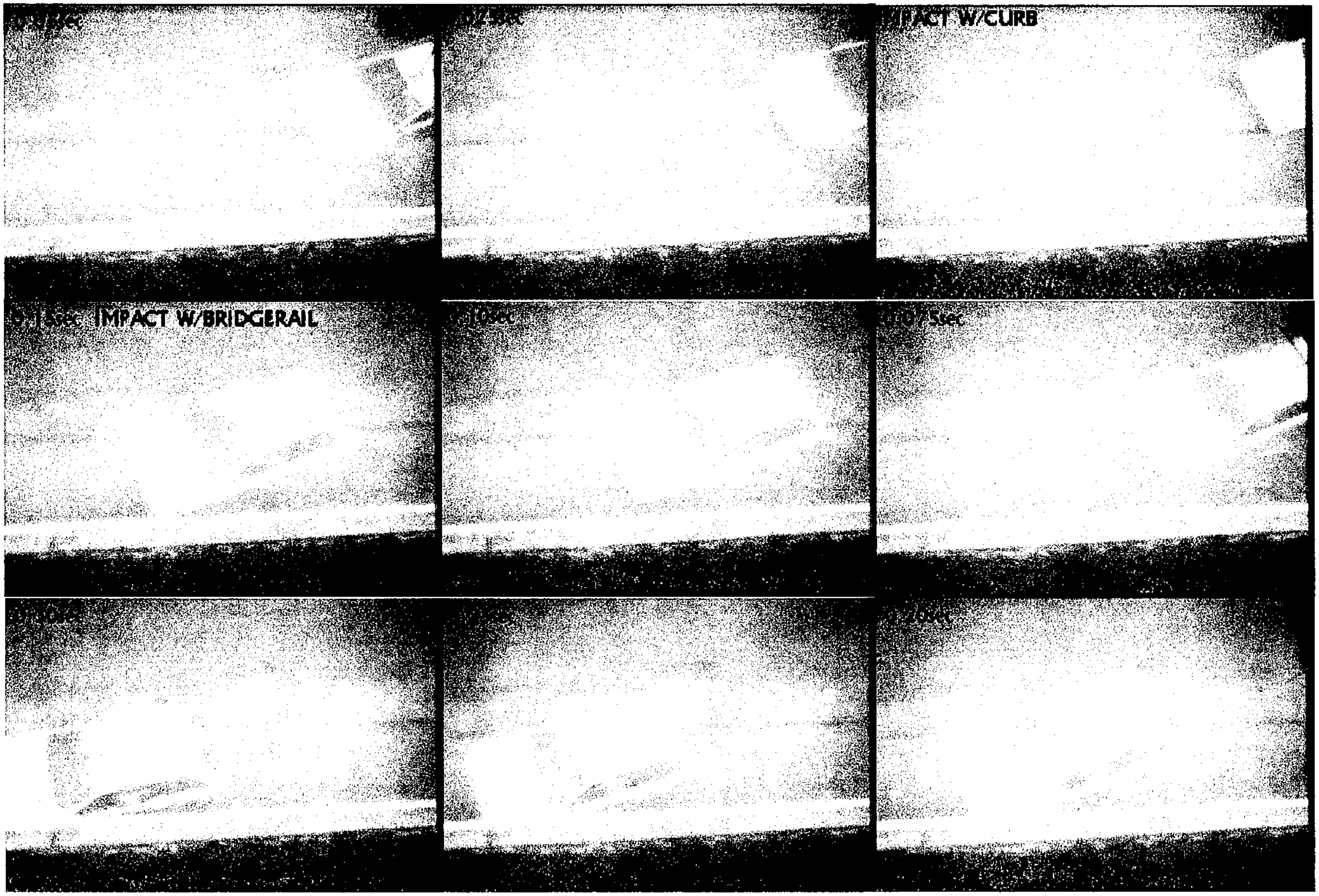


Figure 9. Overhead sequential photographs - Test NETC-1.

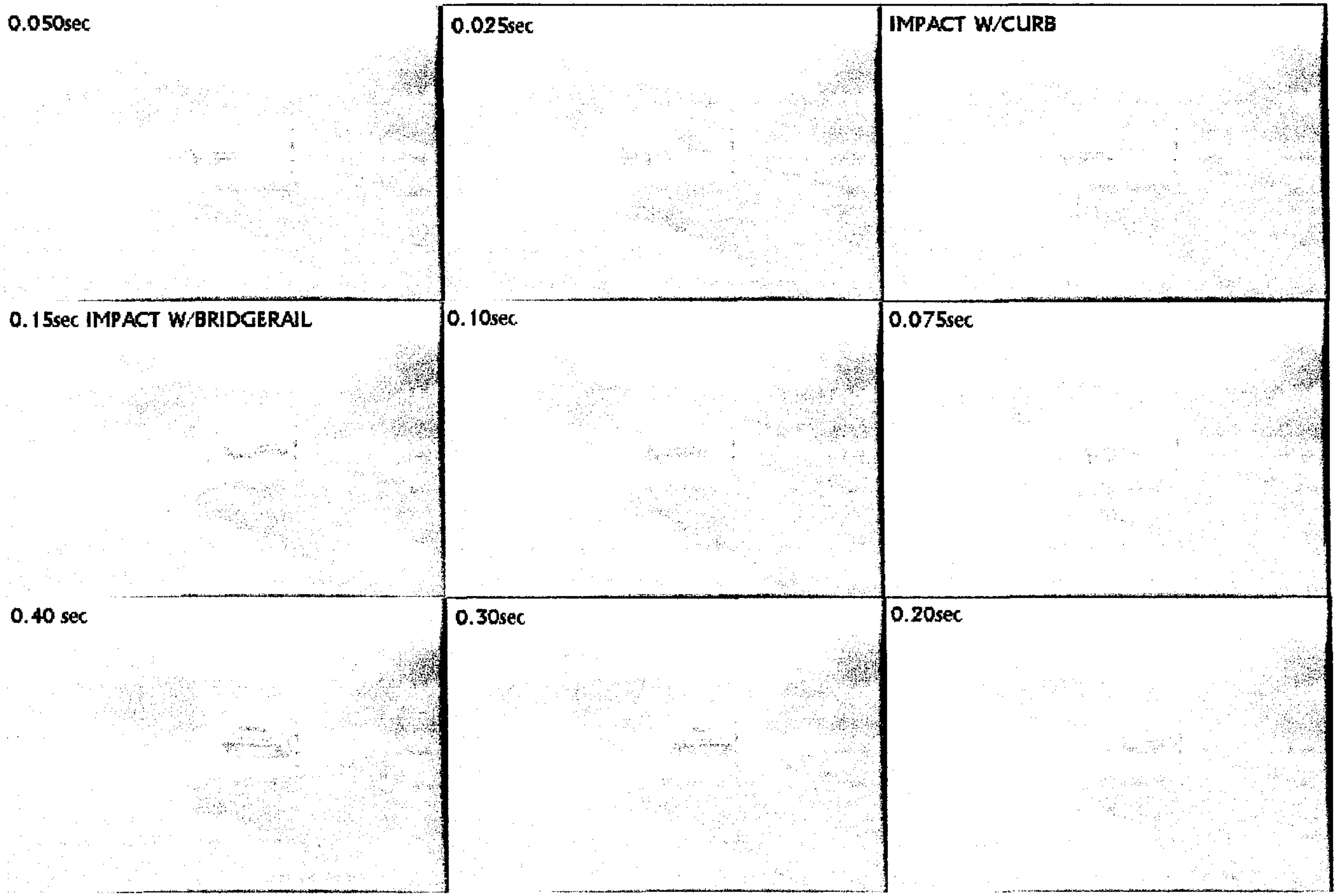
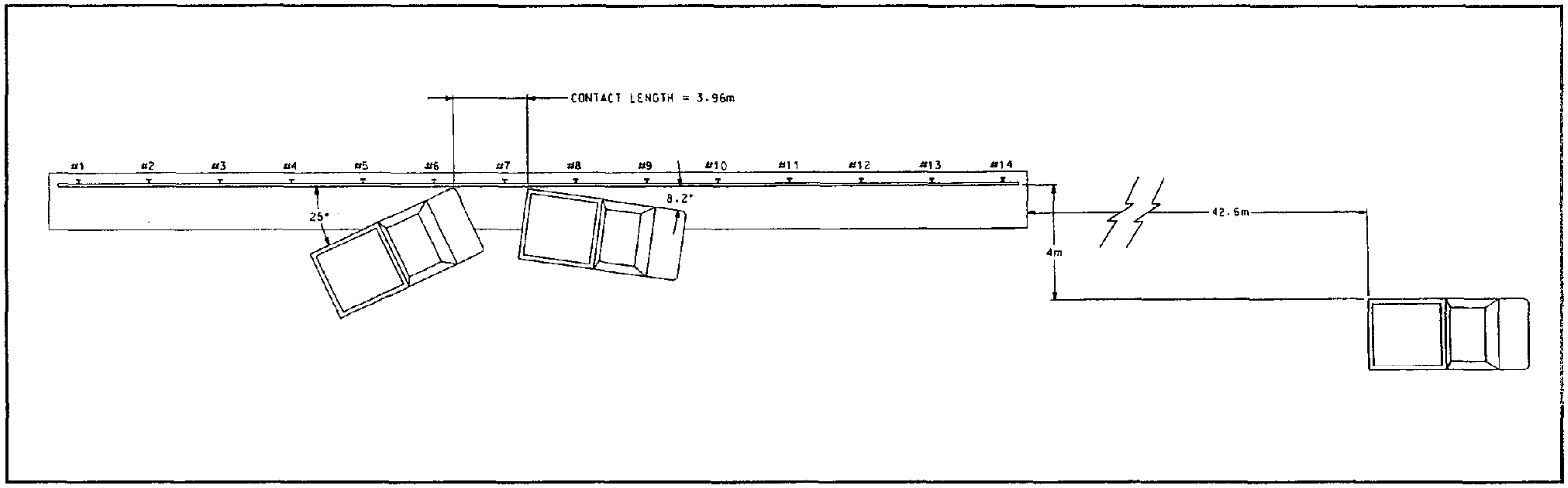


Figure 10. Sequential photographs - Test NETC-1.



4. General Information		**7. Test Vehicle (Continued)**		**10. Ridedown Acceleration (g's)**	
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	*
Test Number	NETC-2	Mass (kg) Gross Static	2,109	**11. Test Article Deflection (mm)**	
Test Date	11/20/97	**8. Impact Conditions**		Dynamic	25 (est.)
5. Test Article		Speed (km/h)	100.0	Permanent	13
Type	Bridge Rail	Angle (deg)	25.0	**12. Vehicle Damage**	
Installation Length (m)	34.1	**9. Exit Conditions**		Exterior	
Barrier	4 Bar, Sidewalk-Mounted	Speed (km/h)	17	VDS	11-FL-3
6. Soil Type and Condition	N/A	Angle (deg)	8.2	CDC	11FLEE3
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production	Impact Velocity (m/s)		OCDI	LF0000000
Designation	2000P	x-direction	3.99	**13. Post-Impact Vehicular Behavior**	
Model	1991Ford F-250	y-direction	*	Maximum Roll Angle (deg)	20 Approximate
Mass (kg) Curb	2,034	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	15 Approximate
Mass (kg) Test Inertial	2,034	X-direction	-2.55	Maximum Yaw Angle (deg)	N/A

*No data - vehicle lateral accelerometer malfunctioned during test.

Figure 11. Impact sequence and summary of test conditions and results - Test NETC-2.

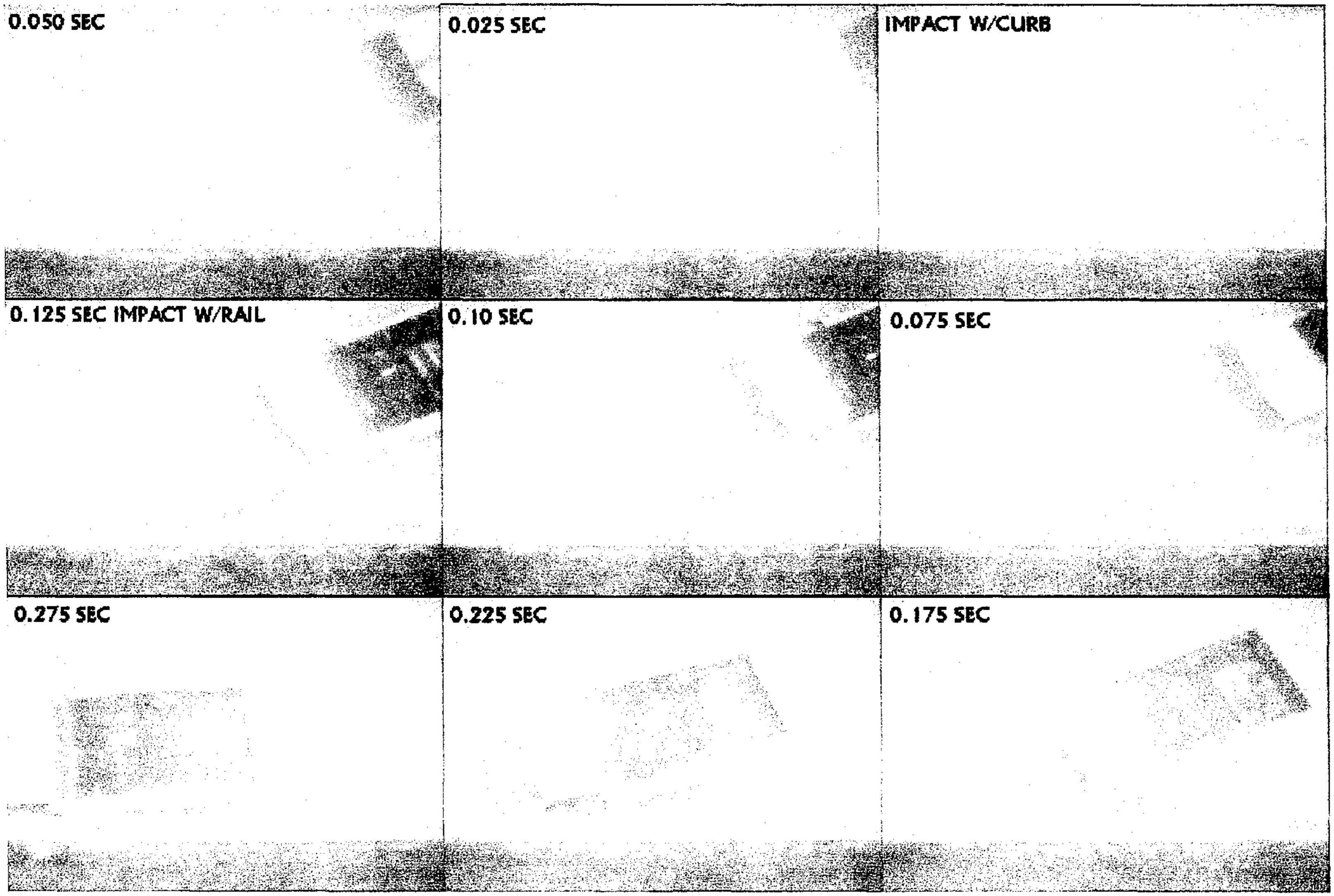


Figure 12. Overhead sequential photographs - Test NETC-2.

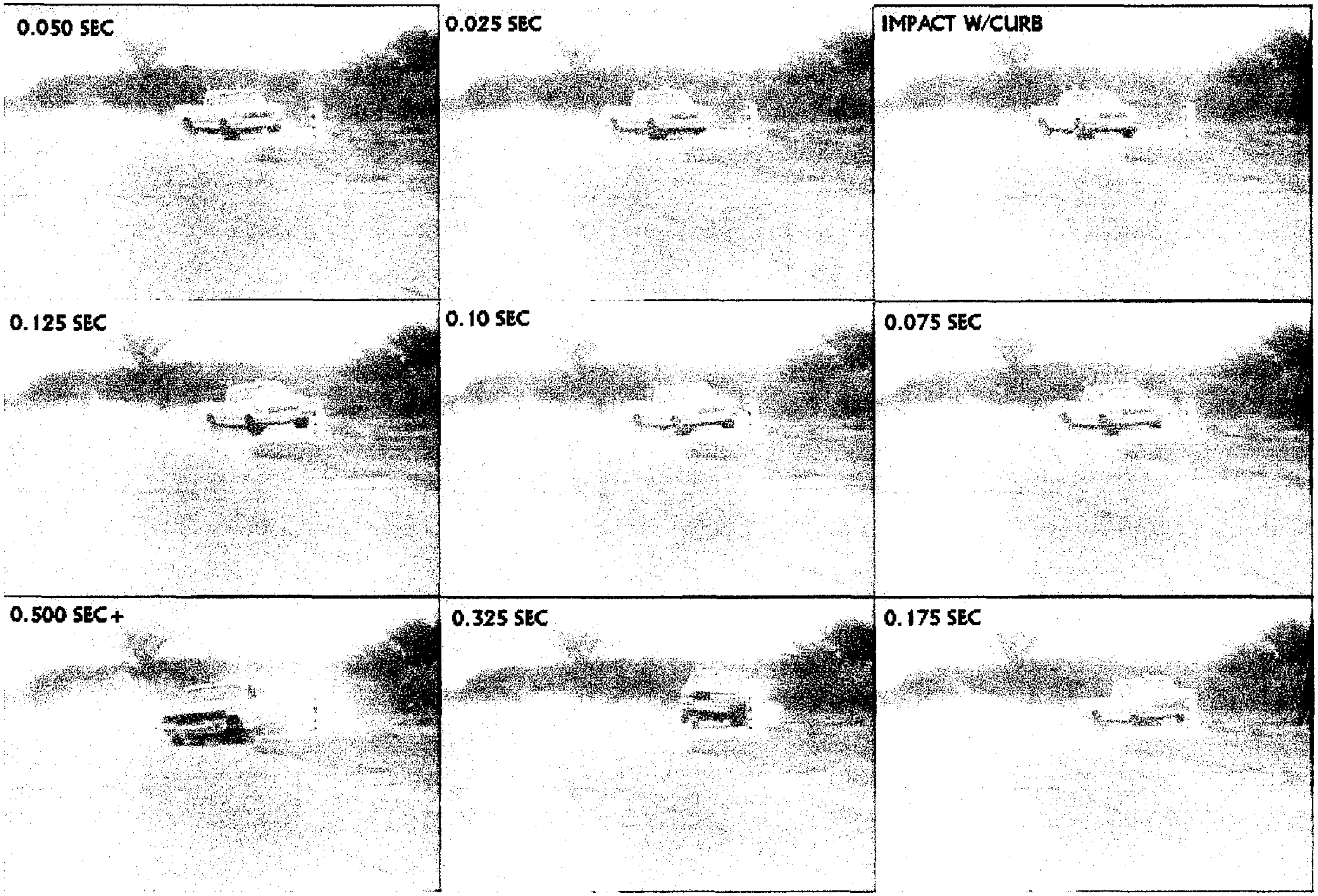
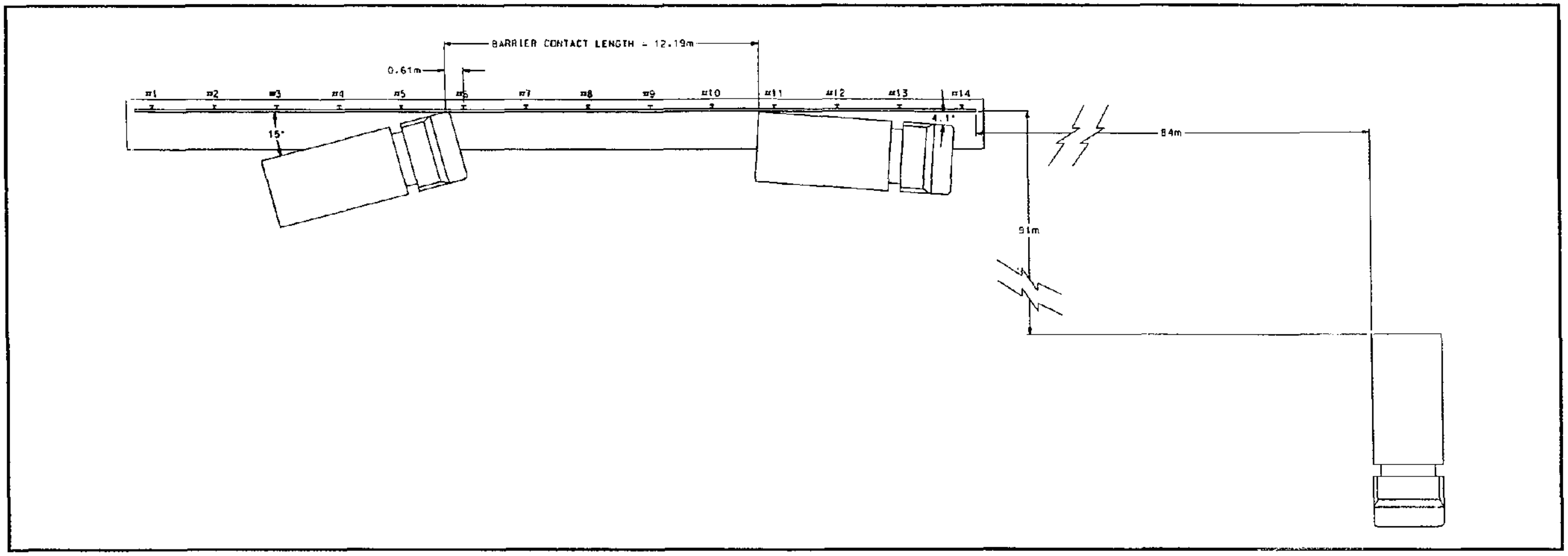


Figure 13. Sequential photographs - Test NETC-2.



4. General Information		**7. Test Vehicle (Continued)**		**10. Ridedown Acceleration (g's)**	
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	N/A	y-direction	14.30
Test Number	NETC-3	Mass (kg) Gross Static	8,108	**11. Test Article Deflection (mm)**	
Test Date	12/18/97	**8. Impact Conditions**		Dynamic	25
5. Test Article		Speed (km/h)	80	Permanent	13
Type	Bridge Rail	Angle (deg)	15.0	**12. Vehicle Damage**	
Installation Length (m)	34.1	**9. Exit Conditions**		Exterior	
Barrier	4 Rails, Sidewalk-Mounted	Speed (km/h)	57.6	VDS	N/A
6. Soil Type and Condition	N/A	Angle (deg)	4.1	CDC	N/A
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production	Impact Velocity (m/s)		OCDI	N/A
Designation	8000S	x-direction	1.65	**13. Post-Impact Vehicular Behavior**	
Model	1993 International 4600 LP	y-direction	-2.89	Maximum Roll Angle (deg)	20 Approximate
Mass (kg) Curb	8,108	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Approximate
Mass (kg) Test Inertial	8,108	X-direction	-8.95	Maximum Yaw Angle (deg)	N/A

Figure 14. Impact sequence and summary of test conditions and results - Test NETC-3.

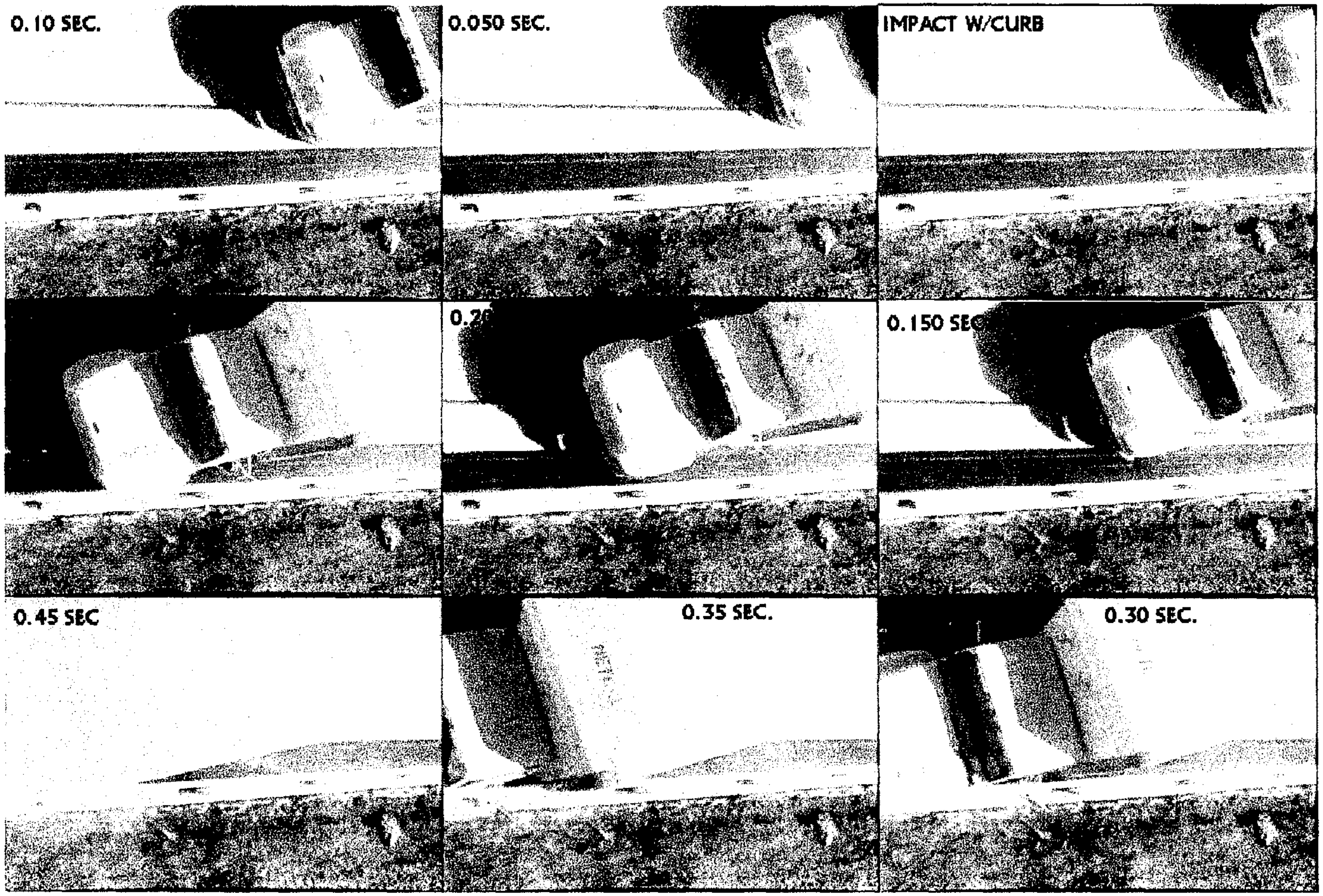


Figure 15. Overhead sequential photographs - Test NETC-3.

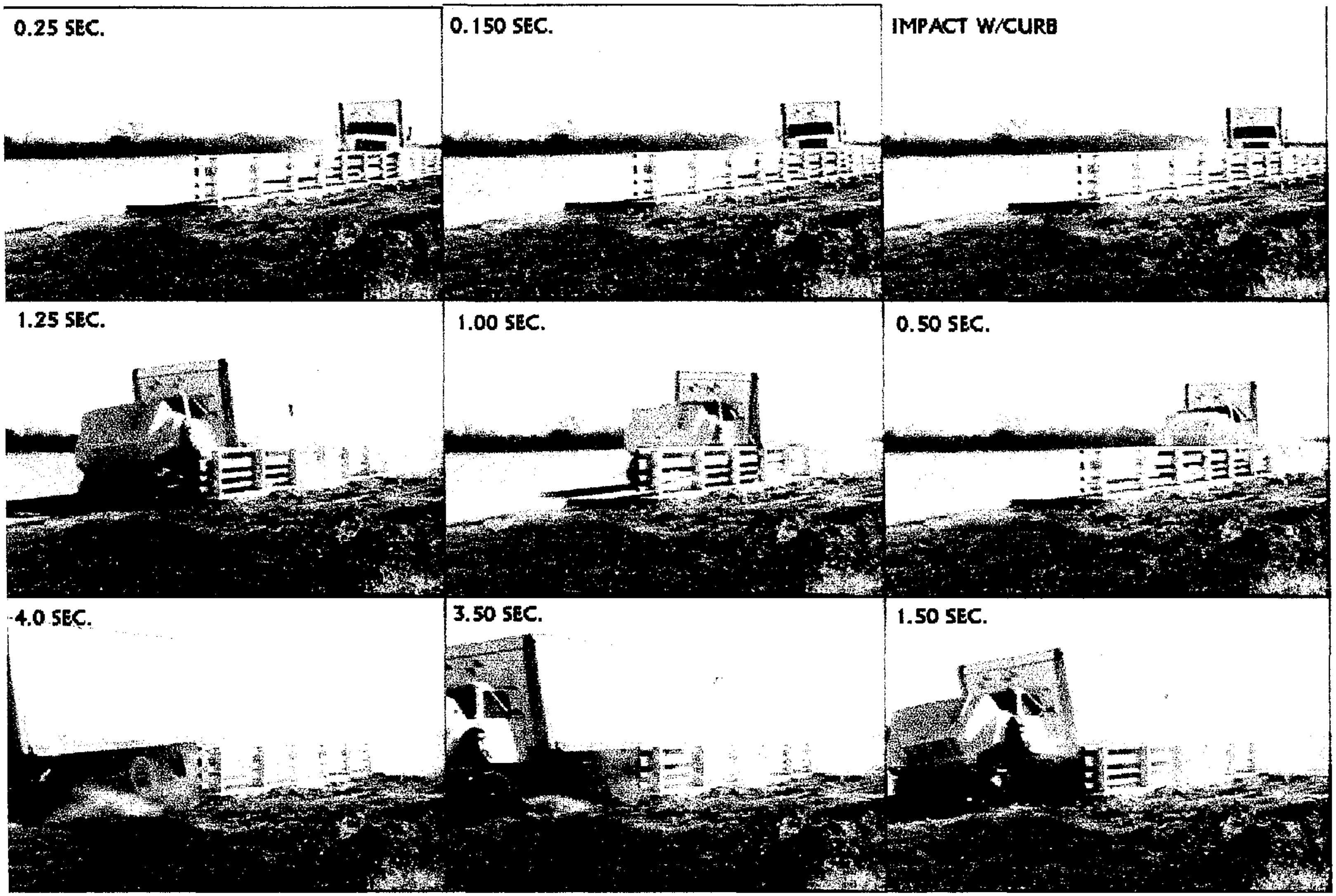


Figure 16. Sequential photographs - Test NETC-3.

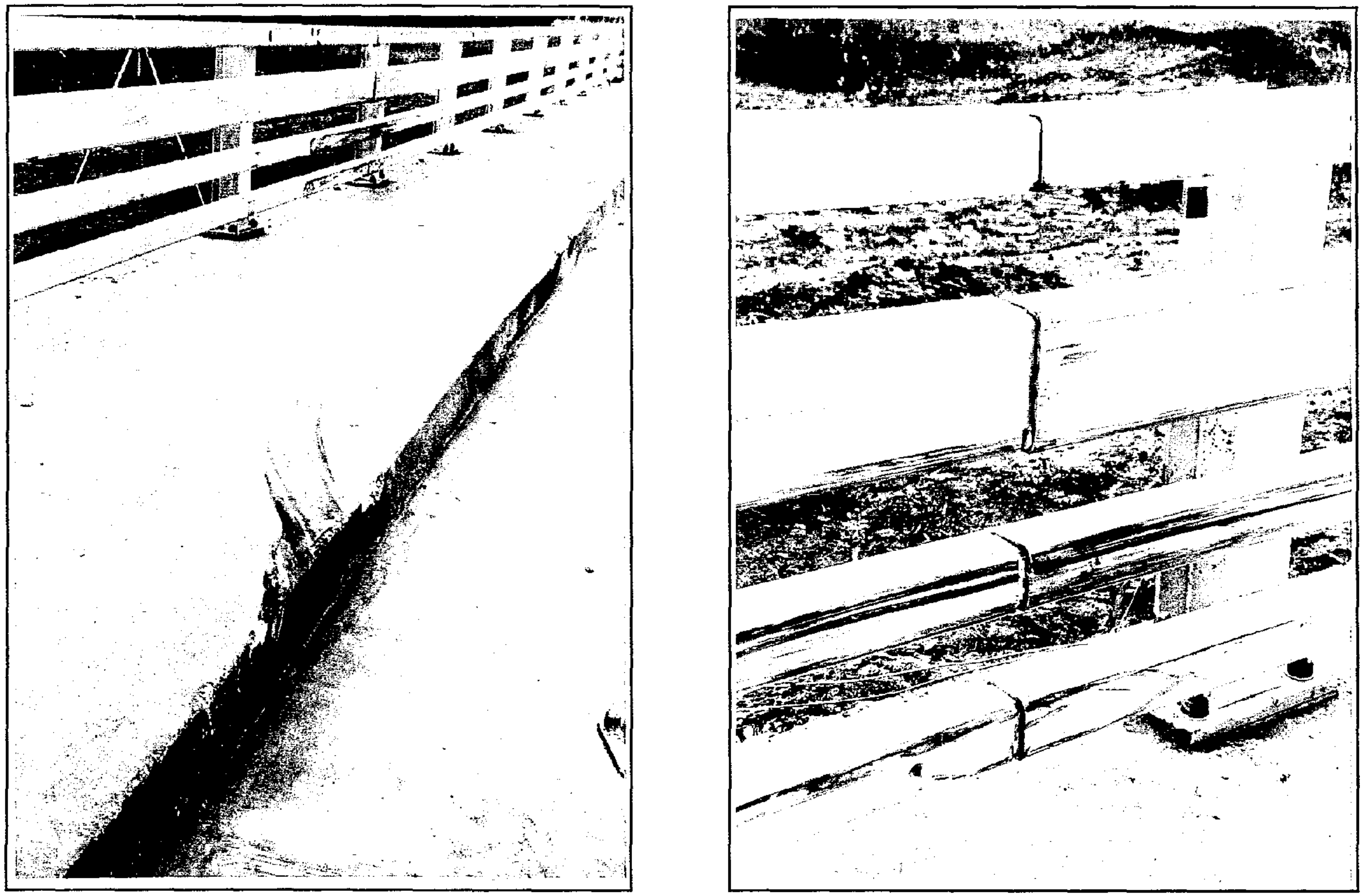
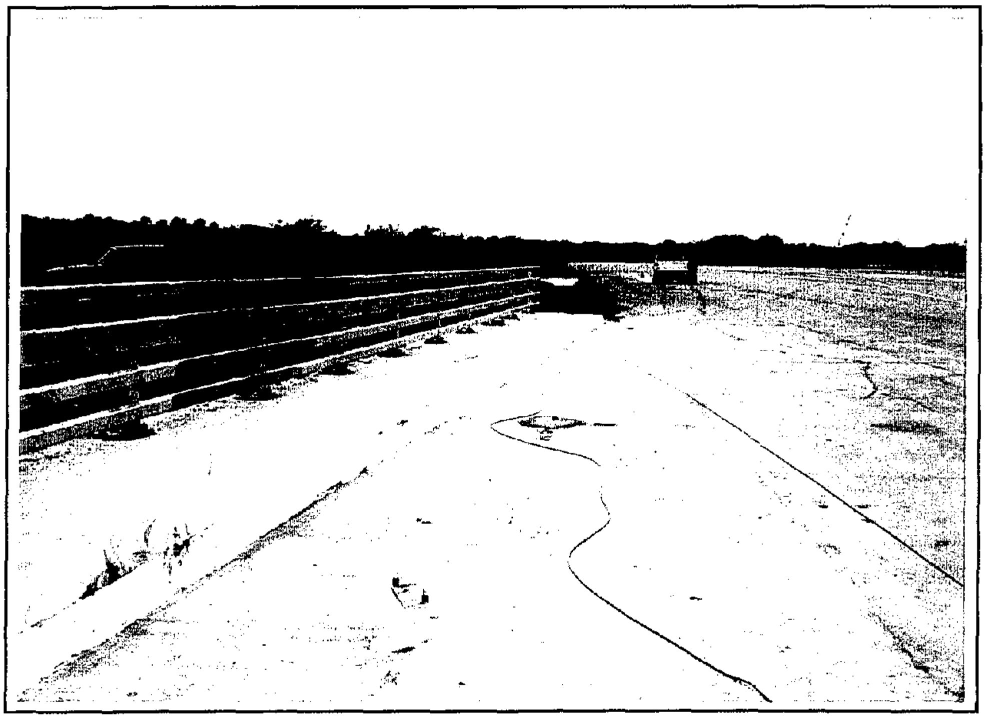


Figure 17. Barrier damage photographs - Test NETC-1.



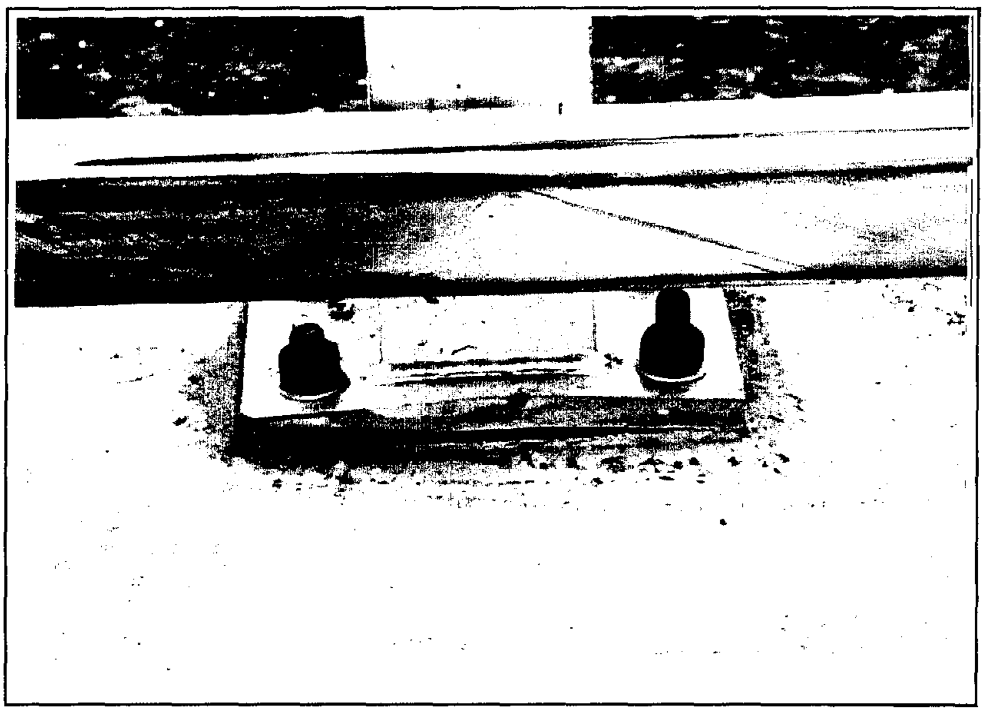
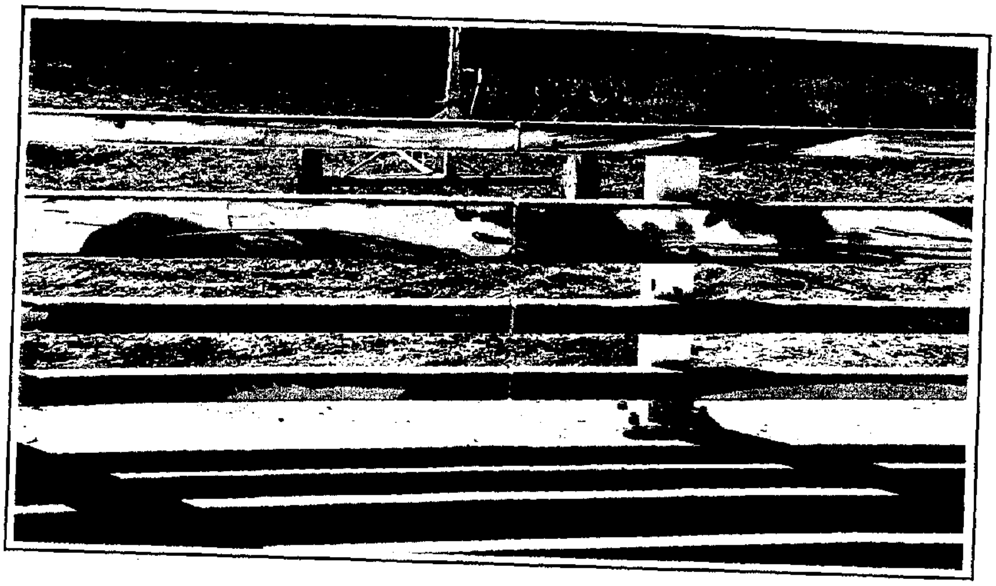


Figure 18. Barrier damage photographs - Test NETC-2.



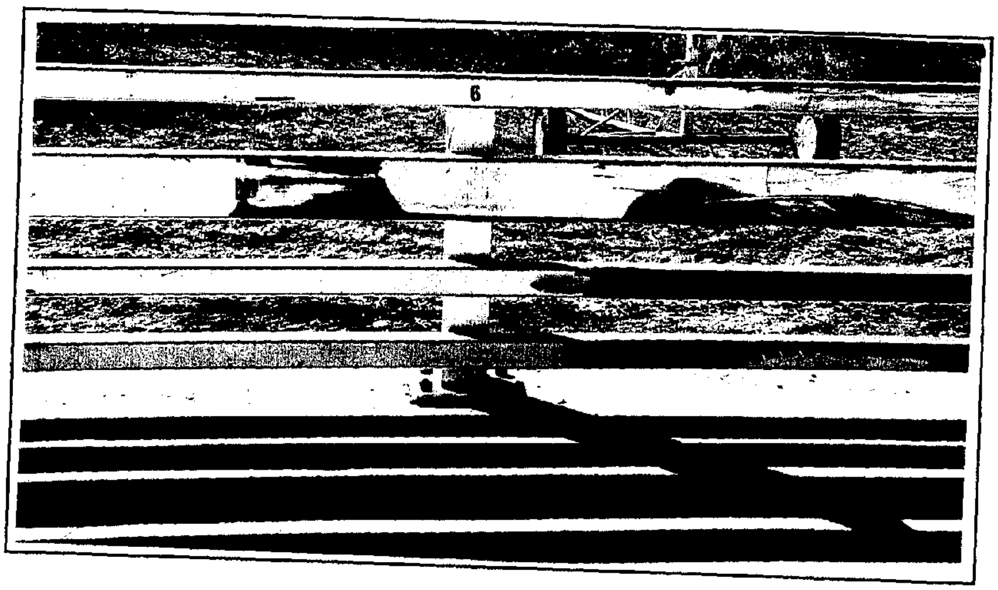


Figure 19. Barrier damage photographs - Test NETC-3.

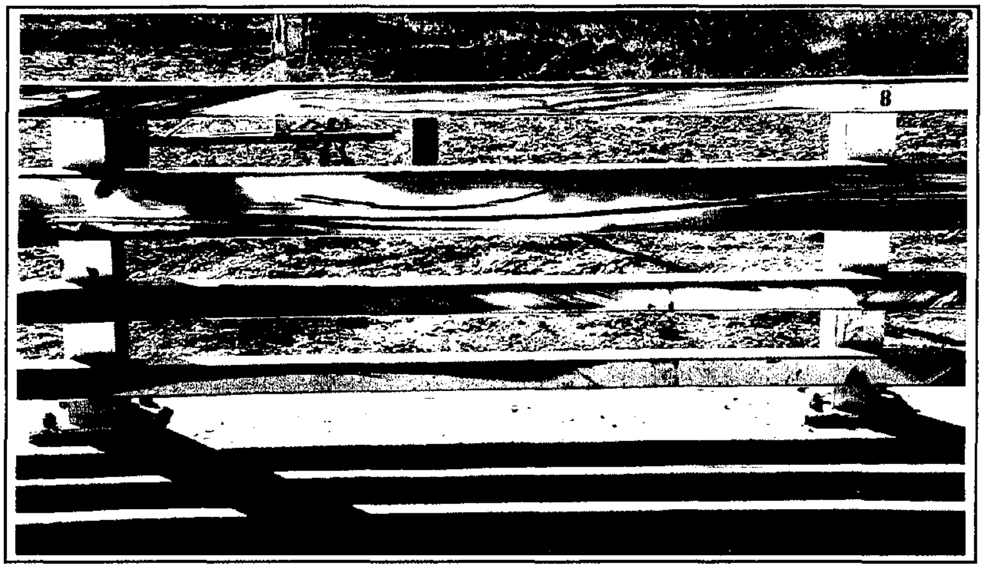


Figure 19. Barrier damage photographs - Test NETC-3 (continued).

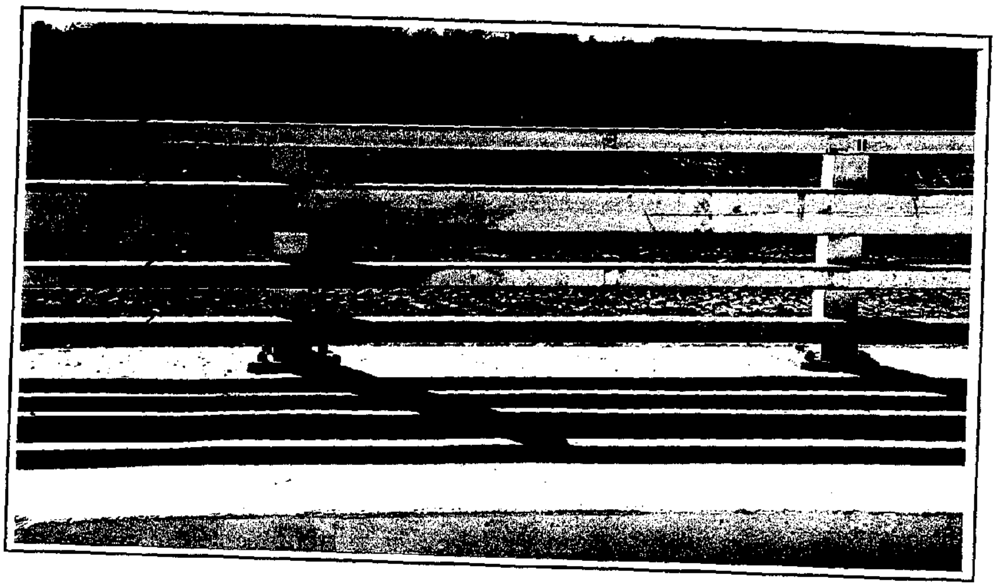


Figure 19. Barrier damage photographs - Test NETC-3 (continued).

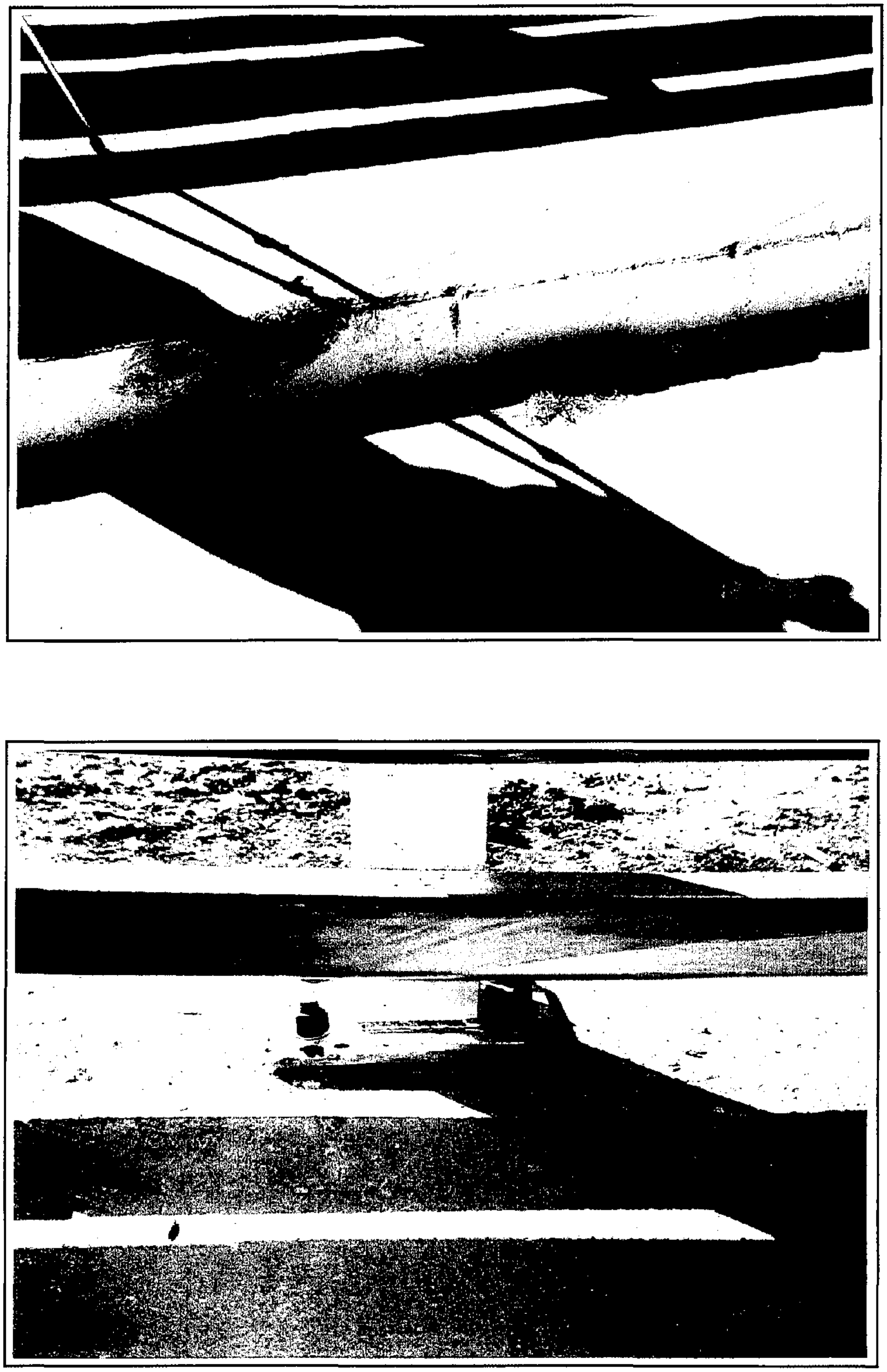
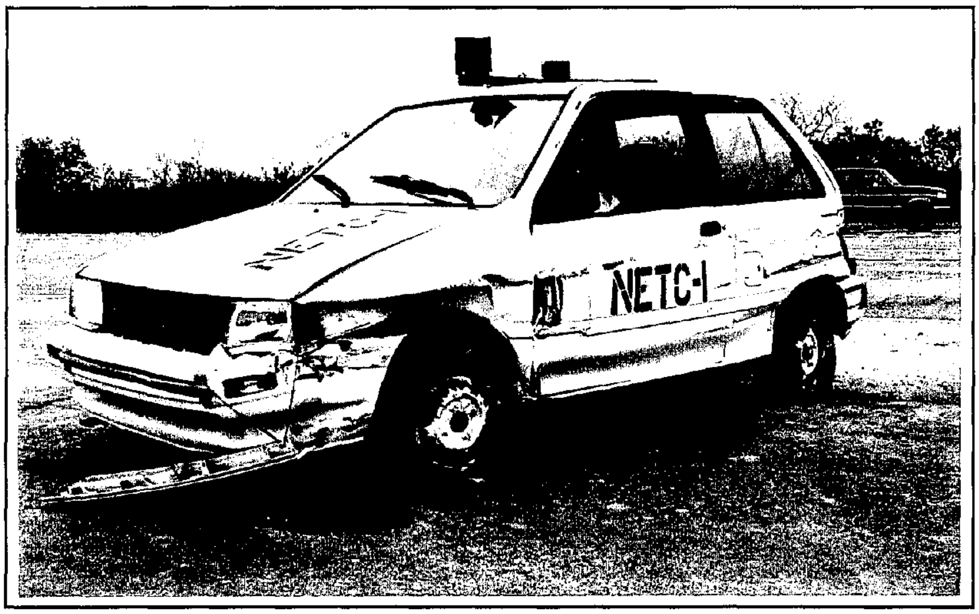


Figure 19. Barrier damage photographs - Test NETC-3 (continued).



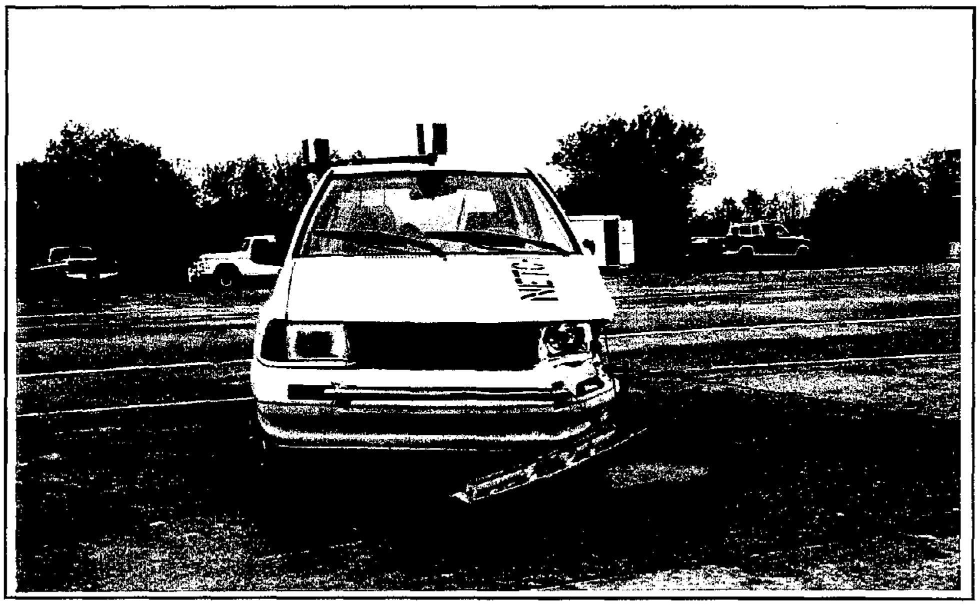


Figure 20. Vehicle damage photographs - Test NETC-1.

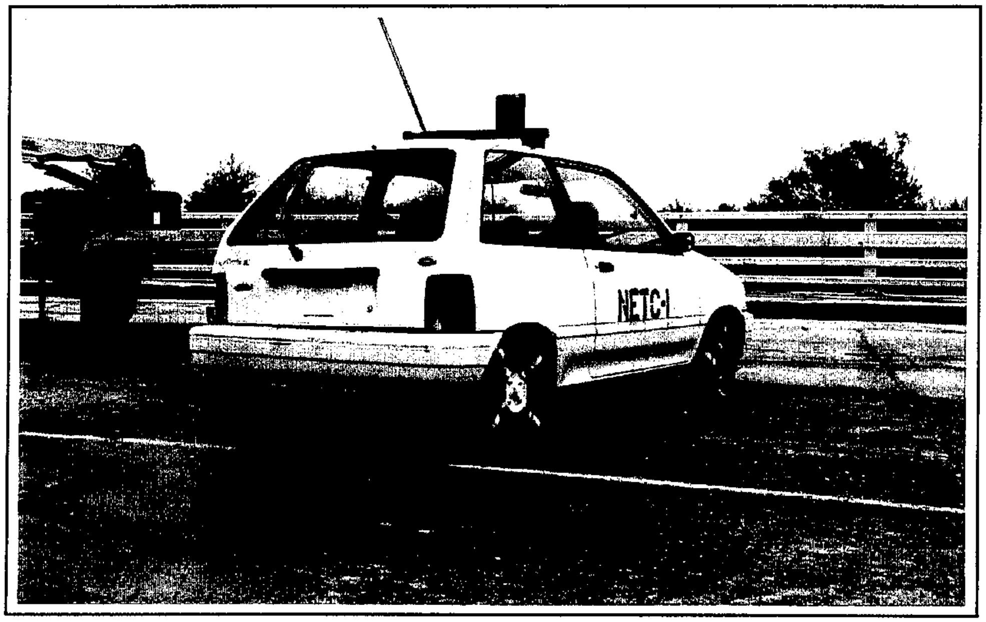
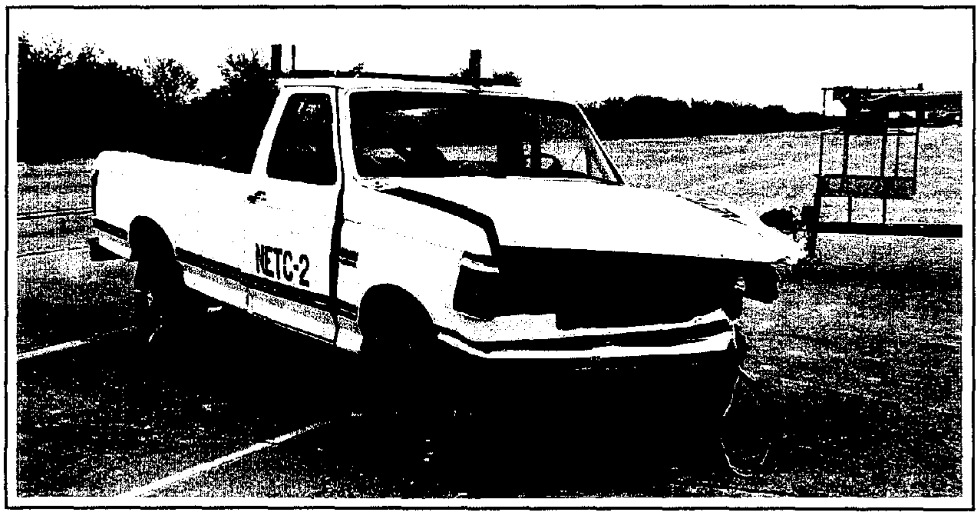


Figure 20. Vehicle damage photographs - Test NETC-1 (continued).



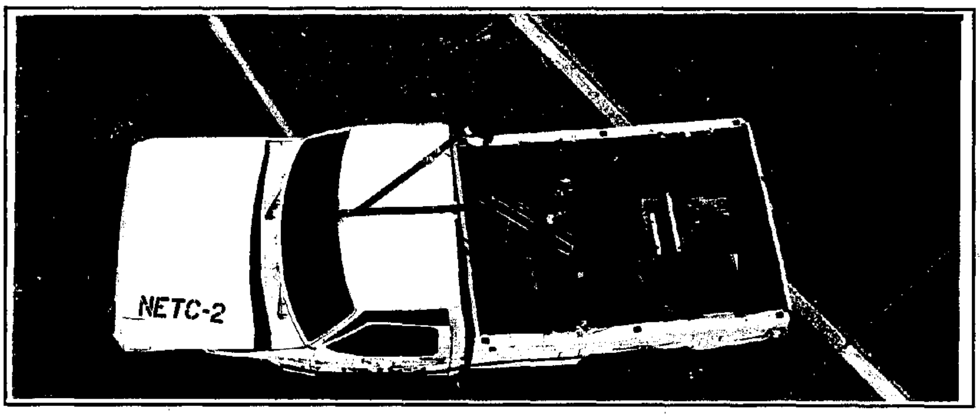


Figure 21. Vehicle damage photographs - Test NETC-2.

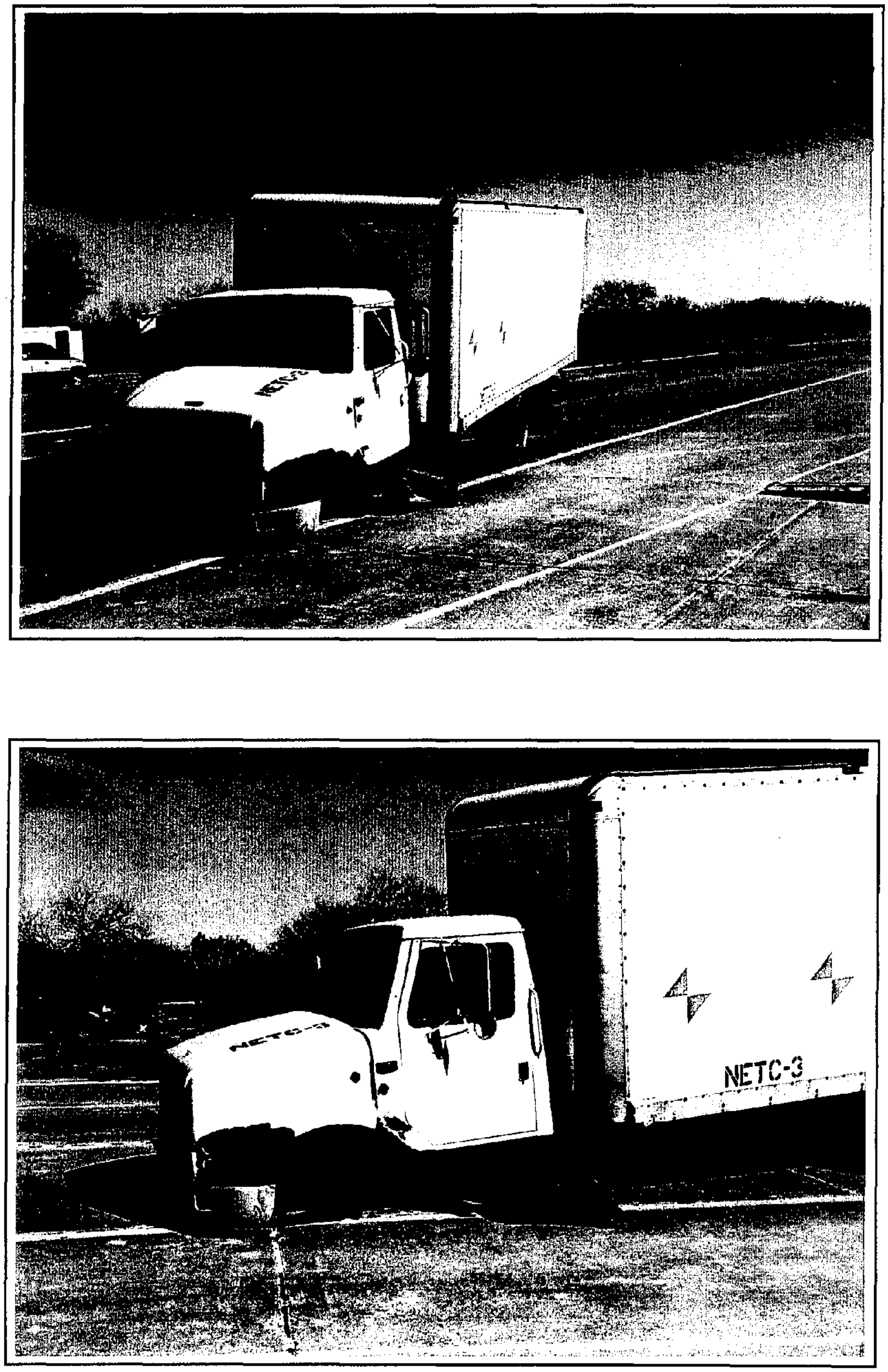


Figure 22. Vehicle damage photographs - Test NETC-3.

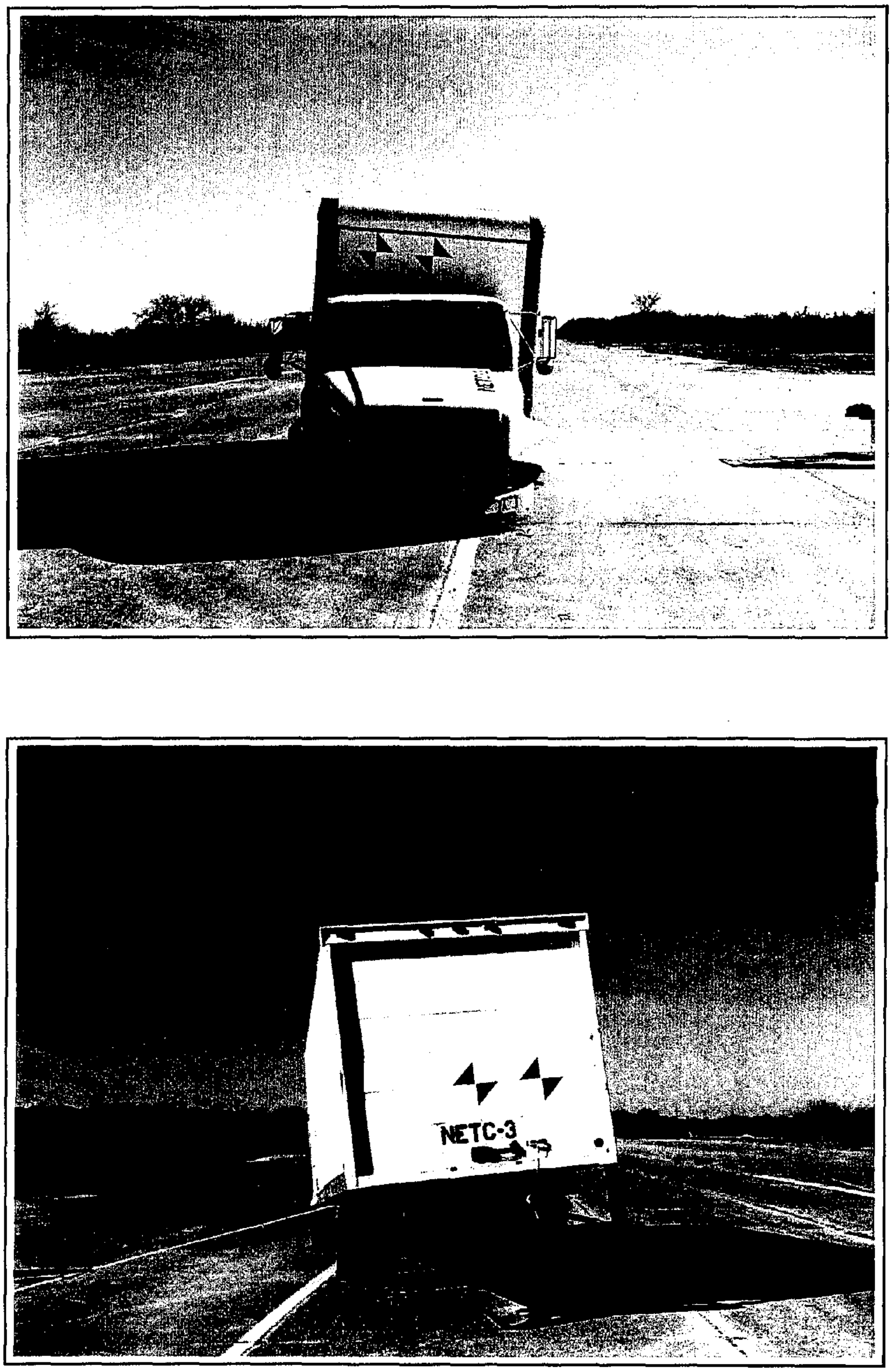


Figure 22. Vehicle damage photographs - Test NETC-3 (continued).

APPENDIX A - NETC CRASH TEST STEEL BRIDGE RAILING DRAWING