# DYNAMIC TESTS OF THE CALIFORNIA TYPE 20 BRIDGE BARRIER RAIL

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The results of five full-scale vehicle impact tests on the California type 20 bridge rail are reported. The type 20 bridge rail is a rigid barrier system that incorporates a 27-in. high reinforced concrete parapet with a traffic-side contour very similar to that used for the New Jersey type of concrete median barrier. A 2- by 6-in. by ¼-in. thick structural steel tube rail is placed 12 in. above the top of this parapet, thus giving an overall barrier height of 39 in. Five tests were conducted at speeds of from 45 to 66 mph and at impact angles of 7, 15, and 25 deg. The test results indicated that this system will retain and redirect a 4,900-lb passenger vehicle impacting at speeds up to 65 mph and at angles of from 7 to 25 deg with the barrier. Vehicle damage varied from negligible at a 7-deg impact angle to severe at a 25-deg impact angle. The test results indicated that the vehicular decelerations sustained during 25-deg, 65-mph impacts into this system will result in occupant injuries varying from severe, if no restraints are used, to no more than moderate, if both a seat belt and a single diagonal shoulder harness are used. At impact angles of 7 deg and less, little or no injury will be sustained during a collision with this barrier regardless of the restraint system being used.

•THE FIRST vehicle impact tests of bridge barrier rails were conducted by the California Division of Highways in the mid-1950's (1, 2). These tests were initiated because of the serious operational deficiencies, primarily structural, that were developing with the bridge barrier rails then in use in California as heavier, high-speed vehicles took to the highways. As a result of these tests, the California Division of Highways adopted a design designated as the California type 1 bridge barrier rail (Fig. 1).

Subsequent vehicle impact tests of California bridge barrier rails (3, 4) have resulted in the development and adoption of the California types 8 and 9 bridge barrier rails (Figs. 2 and 3). Although these barriers have proved to be satisfactory, reports from New Jersey (5) and subsequent tests by the California Division of Highways in 1966-67 (6) indicated that the New Jersey concrete median barrier (Fig. 20, Appendix) showed definite promise of reducing the damage sustained by vehicles striking it at the more prevalent flat angles of impact. This characteristic was also reported by General Motors (7) in tests conducted on a bridge barrier containing a parapet contour similar to the New Jersey barrier (Fig. 20). The effectiveness of the lower sloped surface in reducing vehicle damage and decelerations had also been observed operationally in several experimental installations of the New Jersey concrete median barrier in California.

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Figure 1.

Figure 2.

Consequently, the Bridge Department of the California Division of Highways designed the California type 20 bridge barrier rail (Fig. 4 and Appendix Fig. 20). This design incorporates a single steel rail mounted 12 in. above the top of a 27-in. high concrete parapet. The rail is a rectangular tubing identical to that used in the type 9 design. The parapet wall has a traffic-side profile almost identical to the New Jersey median barrier.

The type 20 design provides better "see-through" characteristics than the General Motors design because the overall height is about 16 in. less, the concrete parapet is about 5 in. lower, and the steel rail is narrower. Visibility through the type 20 bridge rail is not as good as through the type 9 design. However, it appears to be adequate. Five full-scale vehicle impact tests of this type 20 bridge rail are reported herein.

## OBJECTIVES

The objectives of this research were as follows:

1. Test the ability of the California type 20 bridge barrier rail to (a) retain and redirect, in a stable manner, a medium-weight passenger car traveling 60 to 65 mph and impacting at angles of from 7 to 25 deg while sustaining little or no damage; (b) minimize the damage and deceleration sustained by the impacting vehicle during these collisions so that the injuries sustained by any vehicular occupants are minimized; and

Figure 3.

Figure 4.

(c) prevent excessive rebound of the vehicle back across the traveled way or other behavior hazardous to traffic near the point of impact.

2. Evaluate the aesthetic and visibility properties of the type 20 bridge barrier railing.

## TEST CONDITIONS

### Barrier Design and Construction

The design of the type 20 bridge rail was developed by the Bridge Department of the California Division of Highways. Prior to the construction of the test installation, a full-scale plywood mock-up was erected on an existing bridge next to some type 1 bridge barrier railing to compare the see-through qualities of the two designs (Fig. 5). After the mock-up was reviewed, the design details for the type 20 bridge barrier railing were finalized, and the test barrier was constructed.

The type 20 design consists of the current California standard type 9 bridge barrier rail posts and rail mounted on a reinforced-concrete parapet design adapted from the New Jersey median barrier. The steel rail portion of this barrier was fabricated with a 6- by 2-in. 12.02-lb structural steel tubing conforming to the requirements of ASTM Designation A 500, Grade B. The posts were fabricated using structural steel conforming to the requirements of ASTM Designation A 36.

The ¾-in. welded stud rail-to-post connector and the interior sleeve rail splice, proved effective in a previous test series (4), were again used. The fabricated steel posts were spaced at 10-ft centers and were secured to the concrete parapet with one ¾-in. diameter by 8-in. long and one 1-in. diameter by 12-in. long high-strength bolt cast in the concrete. These high-strength bolts conformed to the requirements of ASTM Designation A 325. The concrete portion of the barrier consisted of a 27-in. high by 67-ft long reinforced-concrete parapet constructed on a reinforced-concrete cantilevered deck. The total barrier height was 39 in. from the bridge deck to the top of the steel rail member. The deck and parapet reinforcing, as well as the other details of the type 20 bridge barrier rail design, are shown in Figure 21 in the Appendix.

This system was designed in accordance with the requirements of the Standard Specifications for Highway Bridges adopted by AASHO in 1969. The test section was built on an unused runway at a small airport near Lincoln, California.

### Test Vehicles

The test vehicles used in this study were 1966 Dodge sedans weighing approximately 4,900 lb, including two anthropometric dummies and on-board instrumentation. These vehicles were retired California Highway Patrol sedans and were modified for remote radio control as described elsewhere (8). Control of the vehicle during the approach was accomplished by an operator following approximately 200 ft behind the test vehicle in a control car equipped with a tone-transmission system.

Two anthropometric dummies were placed in the front seat of the test vehicle and restrained with conventional seat belts for all five tests. The driver, "Stan", weighed about 165 lb (50th percentile male); the passenger, "Sam", weighed about 210 lb (95th percentile male).

Figure 5.

### Photographic Coverage

All the tests were photographed with high-speed (250 to 400 frames per second) Photosonic cameras that were manually actuated from a central control console. These cameras were located to the front, rear, and side of the point of impact and on a tower directly above the point of impact. Most of the Photosonic data film had red-orange timing pips projected on it at a rate of 1,000 per second. These pips were then counted to determine the frame rates of the cameras. Targets were attached to the vehicle body, and a target board was bolted to the roof of the vehicle to facilitate data reduction of the film using a Vanguard motion analyzer. Another Photosonic camera was located in the rear of the vehicle to film movement of the dummies. This camera was actuated by a switch, mounted on the rear bumper of the test vehicle, that was tripped using a 50-ft length of nylon line anchored to the pavement behind the vehicle.

Documentary coverage consisted of high-speed and normal-speed motion-picture coverage during the tests plus motion pictures, still photographs, and slides taken before and after each test. A scaffold-mounted Hulcher camera with a speed of 20 frames per second was also used for documentary coverage of the tests. Five tape switches, placed perpendicular to the vehicle path at 10-ft intervals leading into the point of impact, were actuated by the tires of the test vehicle and triggered a series of flashbulbs located in view of all the data cameras. These flashbulbs were used for correlation between all stationary cameras and for the determination of the impact velocity.

Flashbulbs mounted on top of the rear fenders of the test vehicle were used to establish the vehicle location and the time at which the brakes were applied. The bulbs also served to alert the control car driver that the test car's brakes had been applied. These flashbulbs were fired when the brake-actuating relay was closed by either radio equipment failure or the remote operator.

### Instrumentation

The instrumentation system used for all five tests was the Wyle Accident Simulation Measurement System on loan from the Federal Highway Administration (9). It consisted of seven channels of FM telemetry for the crash vehicle and dummies and seven channels of hardwire equipment for the barrier. The system included seven accelerometers, two seat-belt force transducers, and all the necessary signal-conditioning equipment. The dynamic data from these transducers were recorded on a 14-channel analog magnetic tape recorder that was also a part of the system.

The location and description of the instrumentation of the test vehicle for tests 232, 234, and 235 are shown in Appendix Figure 22. The instrumentation layouts for tests 231 and 233 are not included because the accelerometer records for these tests were considered invalid.

The time at which impact occurred was established from the high-speed movies and then was located on the record of accelerometer data. The cause of accelerometer data events could then be determined, at least in some cases, through study of the vehicular and dummy kinematics recorded on the film at the same point in time.

### Test Parameters

The test guidelines established by the Highway Research Board Committee on Guardrails and Guide Posts (10) specify the use of a 4,000-lb vehicle, an impact velocity of 60 mph, and impact angles of 7 and 25 deg. A heavier vehicle (4,900 lb) traveling at approximately 65 mph was used for these tests because it was felt that these higher values more nearly represented the more severe conditions now being encountered on California highways. The five tests were identical except for the differences given in Table 1.

## TEST RESULTS

Descriptions of the five full-scale tests are included in the following data. In all these tests, the point of impact was within 6 ft of the concrete parapet expansion joint to test this critical point of discontinuity.

Tire skid marks and other scuff marks on the barrier parapet were studied after each test to determine vehicle behavior. After this examination, the marks were covered with white paint to prepare the barrier for the next test.

TABLE 1

TEST PARAMETERS

| Test No. | Impact Speed (mph) | Angle of Impact (deg) |
|---|---|---|
| 231 | 45 | 7 |
| 232 | 66 | 7 |
| 233 | 64 | 15 |
| 234 | 64 | 7 |
| 235 | 66 | 25 |

TABLE 2

DECELERATION LIMITS (g)

| Occupant Restraint | Lateral | Longitudinal | Total |
|---|---|---|---|
| Unrestrained | 3 | 5 | 6 |
| Seat belt | 5 | 10 | 12 |
| Seat belt and shoulder harness | 15 | 25 | 25 |

Note: Highest 50 msec average, vehicle passenger compartment.

The decelerations reported in the descriptions of each test are averages of the highest average decelerations sustained over a 50-msec period. The measurements were taken using Statham strain-gage accelerometers mounted on the floor of the passenger compartment and in back of the dummy chest cavity. A discussion of the processing and interpretation of these data is included elsewhere (8).

The vehicular decelerations measured during tests 232, 234, and 235 were interpreted using the tolerance limits given in Table 2. Nordlin, Woodstrom, and Hackett (8) discuss deceleration tolerances and the reasoning behind the choice of these values. These limits define what would be, in the authors' opinion, a survivable environment under almost all circumstances.

## Test 231

Test 231 was conducted to evaluate the effectiveness of the type 20 bridge barrier rail when impacted at a flat approach angle and a moderate speed. The vehicle impacted the barrier approximately 27.5 ft from the upstream end at a speed of 45 mph and at an approach angle of 7 deg. After impacting the barrier, the test vehicle was smoothly redirected parallel to the barrier. Vehicle barrier contact was maintained for the remaining 40 ft of barrier, after which the vehicle traveled an additional 150 ft before coming to a stop (Appendix Fig. 23).

Maximum vehicular rise was approximately 16 in. There was minor sheet-metal damage sustained by the test vehicle and slight surface cracks sustained by the barrier (Figs. 6 and 7). No determination of the electronically measured deceleration could be made due to the poor quality of the instrumentation data.

## Test 232

The same vehicle used for test 231 was used for test 232 with no repairs. Test 232 also involved a 7-deg impact, but the impact velocity was increased to 66 mph. Impact was again about 27.5 ft from the upstream end of the test barrier. After impact, the vehicle traveled along the barrier for 27 ft and then left the barrier at an exit angle of


Figure 6.

Figure 7.


Figure 8.

Figure 9.

1 deg (Appendix Fig. 24). During this test the maximum vehicle rise was 16 in. Vehicle damage was very minor, and there was no significant structural damage sustained by the barrier (Figs. 8 and 9). The damaged windshield and grill were caused by a second collision with a section of scaffold. A maximum 50-msec average deceleration of 4.8 g laterally (average of 2 data channels) was measured on the floor of the passenger compartment. This deceleration did not exceed the tolerance level for a seat-belted occupant. None of the longitudinal deceleration data was considered accurate.

Test 233

The vehicle used for tests 231 and 232 was used again for test 233, a 64-mph, 15-deg impact. Impact occurred about 27.5 ft from the upstream end of the barrier. After maintaining contact with the barrier for approximately 19 ft, the test vehicle left the barrier at an exit angle of 10 deg (Appendix Fig. 25). Vehicle rise was small; it appeared that the steel railing held the test vehicle down during the redirection. This penetration underneath the steel railing is indicative of the decreasing effect of the contoured concrete surface at larger impact angles. There was no tendency for the vehicle to roll or jump. The left front end and undercarriage of the vehicle were severely damaged (Fig. 10). Minor spalling of the concrete parapet also occurred (Fig. 11). No measurement of vehicular or dummy deceleration was obtained because of an apparent instrumentation malfunction.

Test 234

Test 234 was performed to substantiate the results of test 232. This correlation was felt necessary because the vehicular rise noted during test 232 (16 in.) was sub-


Figure 10.

Figure 11.

Figure 12.

Figure 13.

stantially less than that noted during a previous 7-deg, 65-mph test (test 161B) of the New Jersey type of concrete median barrier (6). The two tests are shown in Figures 12 and 13.

During test 234 (7 deg, 64 mph), impact was again located approximately 27.5 ft from the upstream end of the barrier. The maximum rise of the test vehicle was approximately 18 in. After impacting the barrier, the vehicle traveled along the barrier for approximately 30 ft before exiting at an angle of 1 deg (Appendix Fig. 26).

Vehicle damage was limited to minor scrapes along the left side (Fig. 14). Barrier damage was very minor (Fig. 15). The maximum 50-msec average decelerations measured on the floor of the passenger compartment were 4.8 g laterally (average of two data channels) and less than 1 g longitudinally (average of three data channels). These vehicular decelerations did not exceed the tolerance levels for a seat-belted occupant. Thus, a belt-restrained occupant would have sustained little or no injury. The maximum 50-msec dummy decelerations measured were 6.5 g laterally and 2.3 g longitudinally.

Test 235

Test 235, the most severe impact into the barrier, was conducted using the same vehicle used for test 234. The test vehicle struck the barrier 27.5 ft from the upstream


Figure 14.

Figure 15.

Figure 16.

Figure 17.

end at 66 mph and at an angle of 25 deg. After impact, the vehicle remained in contact with the barrier for approximately 12 ft before leaving the barrier at a 3-deg angle (Appendix Fig. 27). Vehicular rise was minimal as the steel rail restricted the tendency to ride up on the barrier parapet. This was also observed in test 233 (15 deg impact angle) but was not observed during tests 231, 232, and 234 (7 deg impact angle), as minimal contact with the steel rail occurred at the shallower impact angle.

Spalling of the concrete in the vicinity of impact and a slight permanent deflection (0.1 ft) of the steel railing indicated the severity of the impact (Fig. 16). The concrete portion of the barrier railing sustained a vertical crack approximately $1/16$ in. wide that extended from the deck to the top of the parapet. This crack was at a point just upstream from impact. Displacement of the concrete parapet was approximately $1/8$ in. at the top of the expansion joint. As could be expected with any 25-deg impact into a rigid barrier, vehicular damage was severe (Fig. 17).

The maximum 50-msec decelerations measured on the floor of the passenger compartment were 9.1 g laterally (average of two accelerometers) and 14.8 g longitudinally (average of four accelerometers). This lateral deceleration exceeds the tolerance level for a seat-belted occupant. Thus, an occupant restrained by a seat belt would have sustained moderate to severe injury. Both values, however, are below the tolerance level of an occupant restrained by both a seat belt and a shoulder harness and indicate that a fully restrained occupant would sustain no more than moderate injury. The maximum 50-msec average decelerations measured in the dummy driver's chest cavity were 9.2 g longitudinally and 16.9 g laterally.

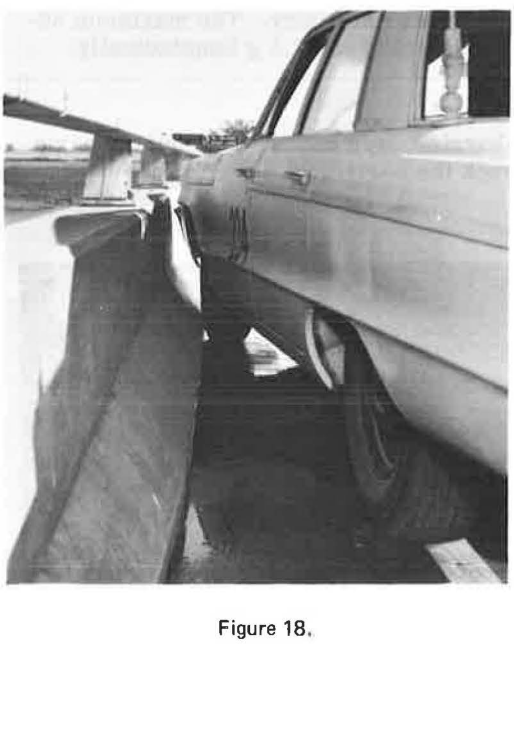

Figure 18.

## DISCUSSION OF RESULTS

The results of these tests indicated that the effectiveness of sloping the traffic side of the barrier parapet diminished as the angle of impact increased. This is not surprising in that the point of initial vehicle-barrier contact shifts from the tire sidewall at a 7-deg impact angle (Fig. 18) to the body sheet metal at a 15-deg impact angle (Fig. 19).

Thus, at the greater angle, a smaller proportion of the vehicle kinetic energy is absorbed within the vehicular suspension system, and a proportionally greater amount is absorbed through deformation of the vehicle body and chassis, thus resulting in increased vehicle damage and passenger-compartment decelerations. As the impact angle approaches 25 deg, the vehicular damage sustained approaches that sustained when impacting the vertically faced type 1 bridge barrier rail. However, an excerpt in a recent study reported elsewhere (11) indicates that approximately 75 percent of the vehicles departing from the traveled way do so at an angle of 15 deg or less. Almost 60 percent depart at 10 deg or less; this indicates that, in a majority of the collisions that will probably occur with the type 20 barrier, the sloped parapet face will be beneficial.


Figure 19.

## CONCLUSIONS

The following conclusions are based on an analysis of the results of the full-scale vehicle impact tests conducted during this test series:

1. The type 20 bridge barrier rail will retain and redirect a 4,900-lb passenger car impacting at speeds up to 65 mph and approach angles up to 25 deg. The vehicle will remain stable and upright during redirection, and little or no barrier damage will be sustained.
2. In the more common shallow angle impacts such as 7 deg, little or no vehicular damage will be sustained. Occupant injuries will vary from minor (seat belt and shoulder harness) to moderate (no restraint). Thus, the contoured traffic face of the type 20 bridge barrier rail parapet definitely minimizes the collision severity at shallow angles of impact. As the angle of impact increases above approximately 10 deg, the colliding vehicle will become increasingly involved with the upper surface of the barrier. When the angle of impact is 25 deg, a vehicle striking the type 20 bridge rail at a speed of 64 mph or greater will sustain severe damage, and occupant injuries will vary from minor to moderate, if a seat belt and shoulder harness are used, and to severe, if no restraints are used. The type 20 bridge barrier rail appears to offer little or no advantage over other rigid bridge barrier rails now in use in California when impacted at these larger approach angles.
3. The impacting vehicle tended to hug the bridge rail in all tests rather than rebound sharply off the rail. This was particularly true at the 7-deg impact angle. In four of the five tests, the exit angle was 3 deg or less. Thus, the type 20 rail appears to be equal or superior to other types of rigid bridge barrier rails in eliminating the secondary hazard of excessive rebound.
4. The type 20 bridge rail offers no aesthetic improvements over those types of bridge rails now in use in California, and its see-through properties are not as good as those of at least one bridge rail now in use in California. However, the use of this barrier design seems to be justified by the significantly decreased collision severity that will occur at flat impact angles.
5. No design modifications were made to the test barrier during the tests and none is recommended.

ACKNOWLEDGMENT

This work was accomplished in cooperation with the Federal Highway Administration. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Federal Highway Administration.

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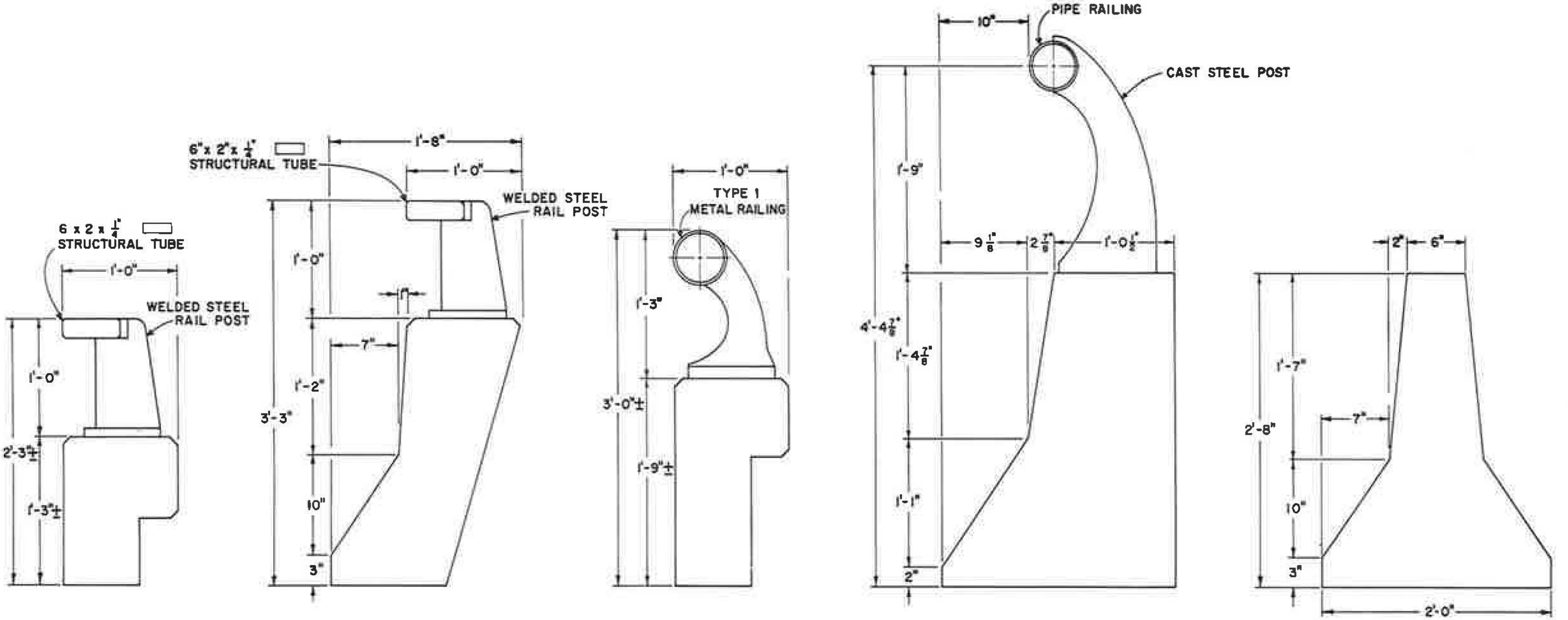
## Appendix

DETAILS OF BARRIER DESIGN AND PERFORMANCE

The following figures contain pertinent data and photographs of the impact tests discussed in this report.




TYPE 9 BRIDGE BARRIER RAILING

TYPE 20 BRIDGE BARRIER RAILING

TYPE 1 BRIDGE BARRIER RAILING

GENERAL MOTORS BRIDGE BARRIER RAILING

NEW JERSEY CONCRETE MEDIAN BARRIER

Figure 20.

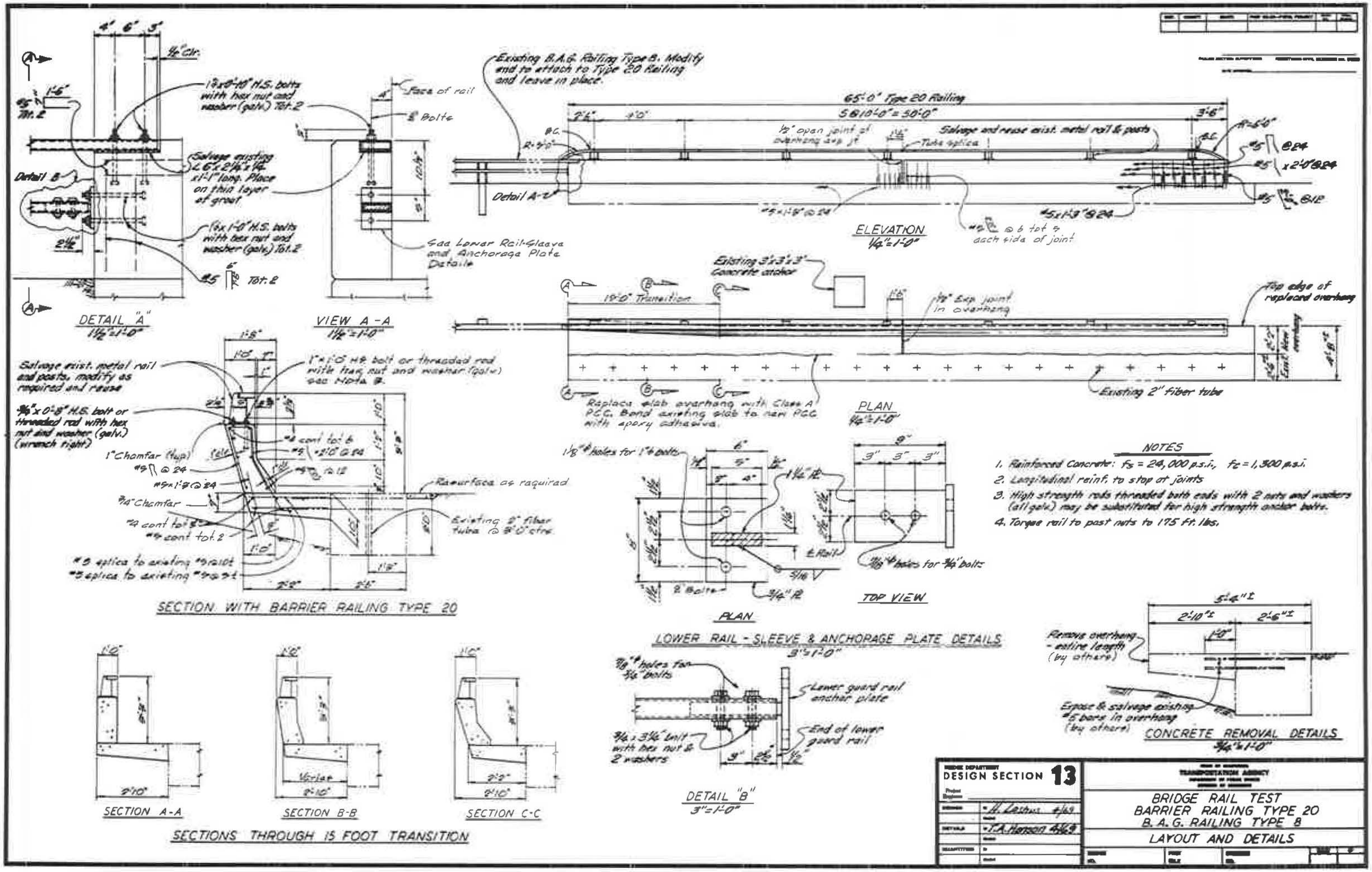
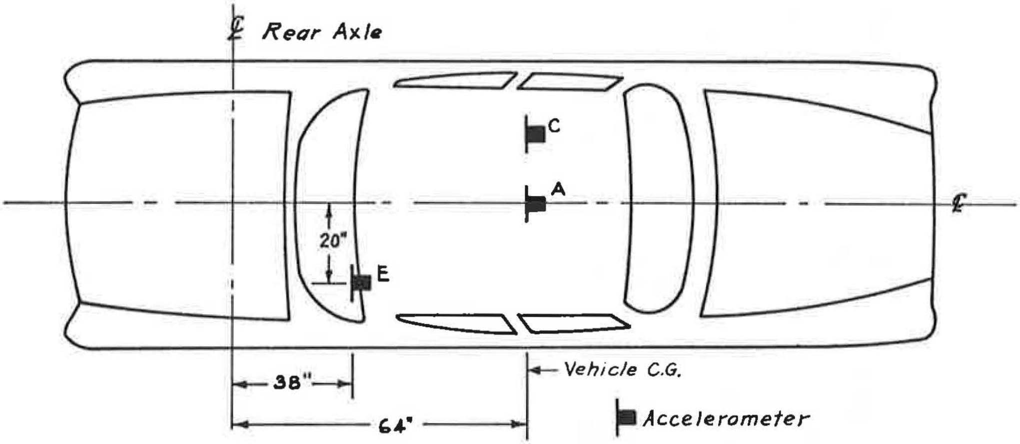

DETAIL "A"
1½"=1'-0"
VIEW A-A
1½"=1'-0"
Existing B.A.G. Railing Type 8. Modify end to attach to Type 20 Railing and leave in place.
65'-0" Type 20 Railing
5 @ 10'-0" = 50'-0"
Salvage and reuse exist. metal rail & posts
ELEVATION
¼"=1'-0"
Existing 3'x3'x3' Concrete anchor
15'-0" Transition
Top edge of replaced overhang
Existing 2" fiber tube
Replace slab overhang with Class A P.C.C. Bond existing slab to new P.C.C. with epoxy adhesive.
PLAN
¼"=1'-0"
SECTION WITH BARRIER RAILING TYPE 20
PLAN
TOP VIEW
LOWER RAIL - SLEEVE & ANCHORAGE PLATE DETAILS
3"=1'-0"
NOTES
1. Reinforced Concrete: fs = 24,000 p.s.i., fc = 1,300 p.s.i.
2. Longitudinal reinf. to stop at joints
3. High strength rods threaded both ends with 2 nuts and washers (all galv.) may be substituted for high strength anchor bolts.
4. Torque rail to post nuts to 175 ft. lbs.
CONCRETE REMOVAL DETAILS
¾"=1'-0"
SECTION A-A
SECTION B-B
SECTION C-C
SECTIONS THROUGH 15 FOOT TRANSITION
DETAIL "B"
3"=1'-0"
DESIGN SECTION 13
BRIDGE RAIL TEST
BARRIER RAILING TYPE 20
B. A. G. RAILING TYPE 8
LAYOUT AND DETAILS

Figure 21.

CALIFORNIA DIVISION OF HIGHWAYS

VEHICLE INSTRUMENTATION

TYPE 20 BRIDGE BARRIER RAIL TESTS




Test #232

| CHANNEL NO. | LOCATION[1] | DESCRIPTION[2,3] |
|---|---|---|
| 1 | A | 100 "G" longitudinal accelerometer (T) |
| 2 | A | 100 "G" lateral accelerometer (T) |
| 3 | E | 100 "G" longitudinal accelerometer (T) |
| 4 | E | 50 "G" lateral accelerometer (T) |
| 5 | C | 50 "G" longitudinal accelerometer (T) |
| 6 | C | 50 "G" lateral accelerometer (T) |
| 7 | C | 50 "G" vertical accelerometer (T) |
| 8 | E | 100 "G" longitudinal accelerometer (U) |
| 9 | E | 100 "G" lateral accelerometer (U) |

Tests #234 & #235

| CHANNEL NO. | LOCATION[1] | DESCRIPTION[2,3] |
|---|---|---|
| 1 | A | 100 "G" longitudinal accelerometer (T) |
| 2 | A | 100 "G" lateral accelerometer (T) |
| 3 | E | 100 "G" longitudinal accelerometer (T) |
| 4 | | Same as Channel 3 |
| 5 | E | 50 "G" lateral accelerometer (T) |
| 6 | C | 50 "G" lateral accelerometer (T) |
| 7 | C | 50 "G" longitudinal accelerometer (T) |
| 8 | E | 100 "G" longitudinal accelerometer (U) |
| 9 | E | 50 "G" lateral accelerometer (U) |

Notes:

[1] A and E on vehicle floor; C on back of dummy's chest cavity.

[2] (T) = telementry, (U) = umbilical cord.

[3] All transducers were unbonded strain gage type accelerometers. Channels 1-7 were Statham Model A514TC and Channels 8 and 9 were Statham Model A400TC.

Figure 22.

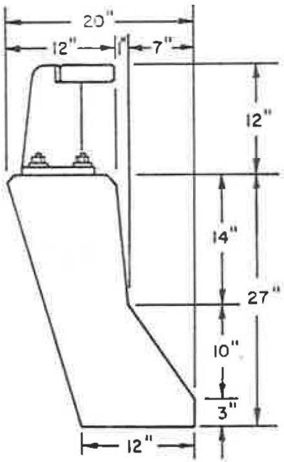
TEST 231

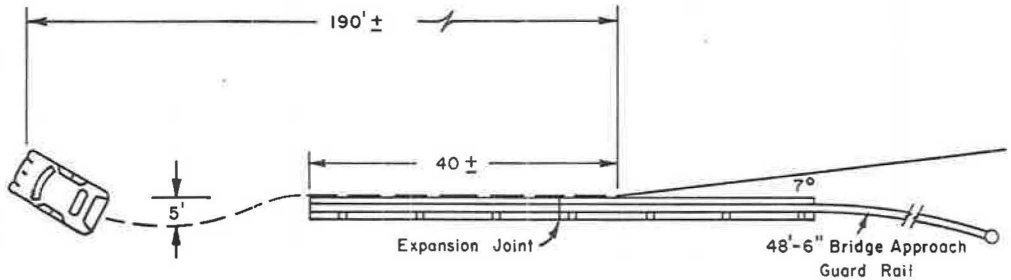

Impact +0.02 Sec.


I + 0.21 Sec.


I + 0.53 Sec.


I + 0.62 Sec



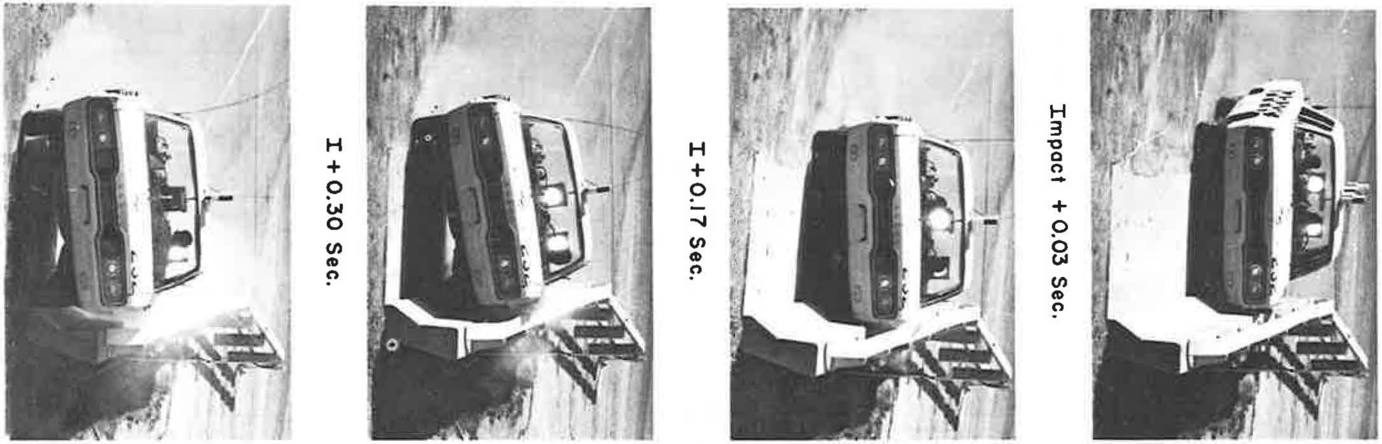




| | | |
|---|---|---|
| BARRIER TESTED | | Type 20 Bridge Rail |
| LENGTH OF INSTALLATION | | 67' ± |
| PASSENGER COMPARTMENT DECEL. (Highest 50 ms average) | Long. | * |
| | Lat. | * |
| MAXIMUM VEHICLE RISE | | 16" |
| EXIT ANGLE | | 0° |
| BARRIER DAMAGE | | Negligible |

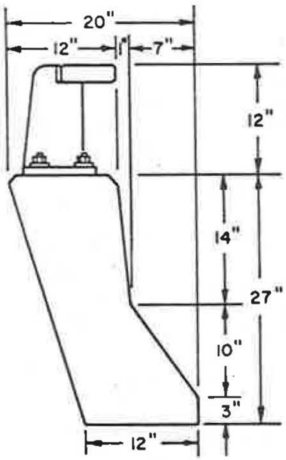
*EXCESSIVE INTERFERENCE IN SIGNAL.

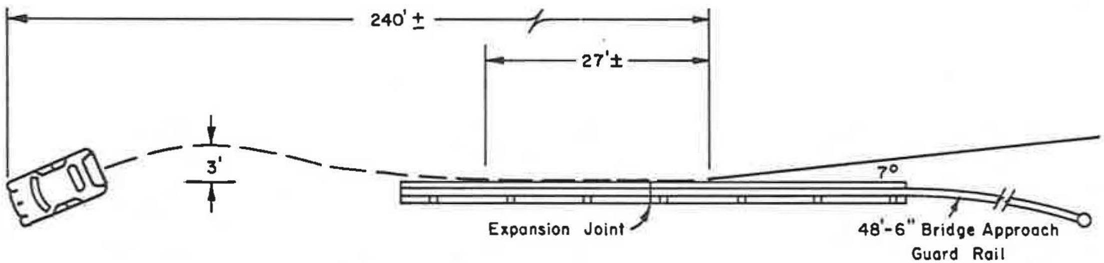
| | |
|---|---|
| TEST NO. | 231 |
| DATE | 10-2-69 |
| VEHICLE | 1966 Dodge Sedan |
| SPEED | 45 mph |
| IMPACT ANGLE | 7° |
| VEHICLE WEIGHT (Incl./dummys & instrumentation) | 4980 Lbs |
| DUMMY RESTRAINT | Lap Belt |

Figure 23.




TEST 232

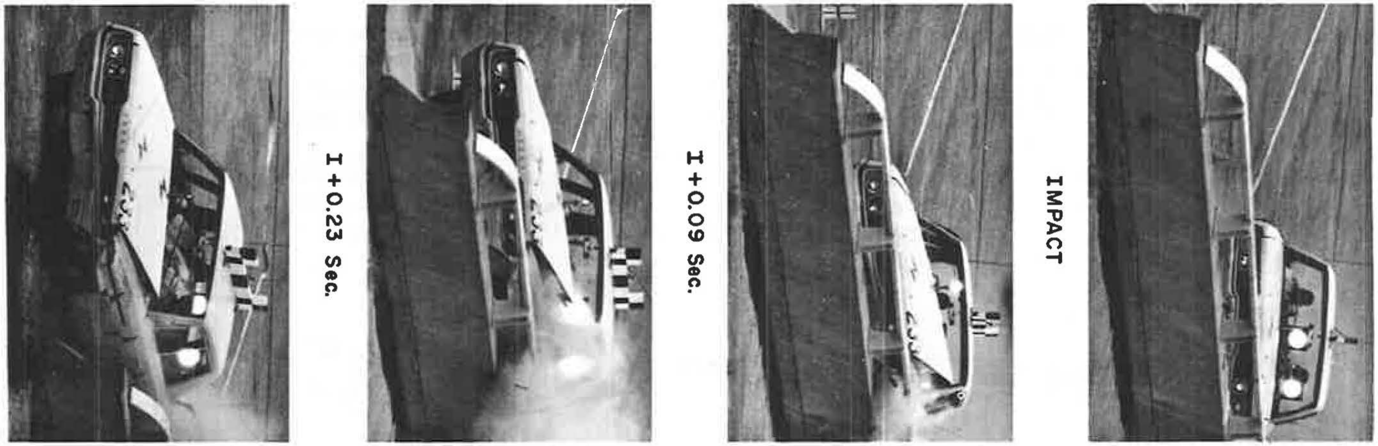


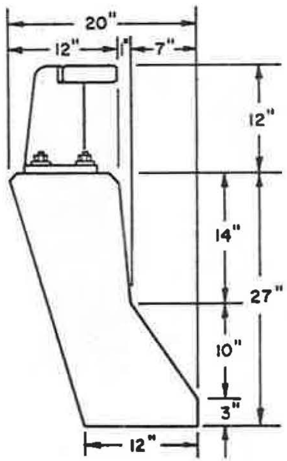



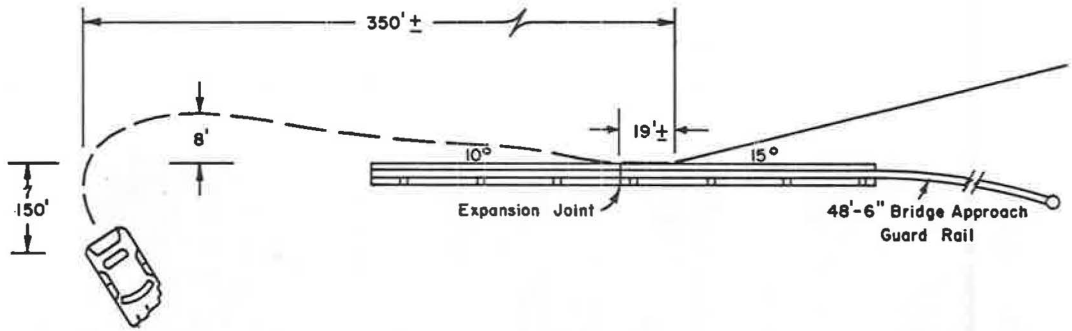

| | | | |
|---|---|---|---|
| BARRIER TESTED | Type 20 Bridge Rail | TEST NO. | 232 |
| LENGTH OF INSTALLATION | 67'± | DATE | 10-2-69 |
| PASSENGER COMPARTMENT DECEL. (Highest 50 ms average) | Long. * <br> Lat. 4.8 G's | VEHICLE | 1966 Dodge Sedan |
| | | SPEED | 66 mph |
| MAXIMUM VEHICLE RISE | 16" | IMPACT ANGLE | 7° |
| EXIT ANGLE | 1° | VEHICLE WEIGHT (Incl./dummys & instrumentation) | 4980 Lbs |
| BARRIER DAMAGE | Negligible | | |
| * ERRONEOUS DATA | | DUMMY RESTRAINT | Lap Belt |

Figure 24.

# TEST 233




| | |
|---|---|
| BARRIER TESTED | Type 20 Bridge Rail |
| LENGTH OF INSTALLATION | 67'± |
| PASSENGER COMPARTMENT DECEL. (Highest 50 ms average) | Long. * / Lat. * |
| MAXIMUM VEHICLE RISE | Negligible |
| EXIT ANGLE | 10° |
| BARRIER DAMAGE | Negligible |

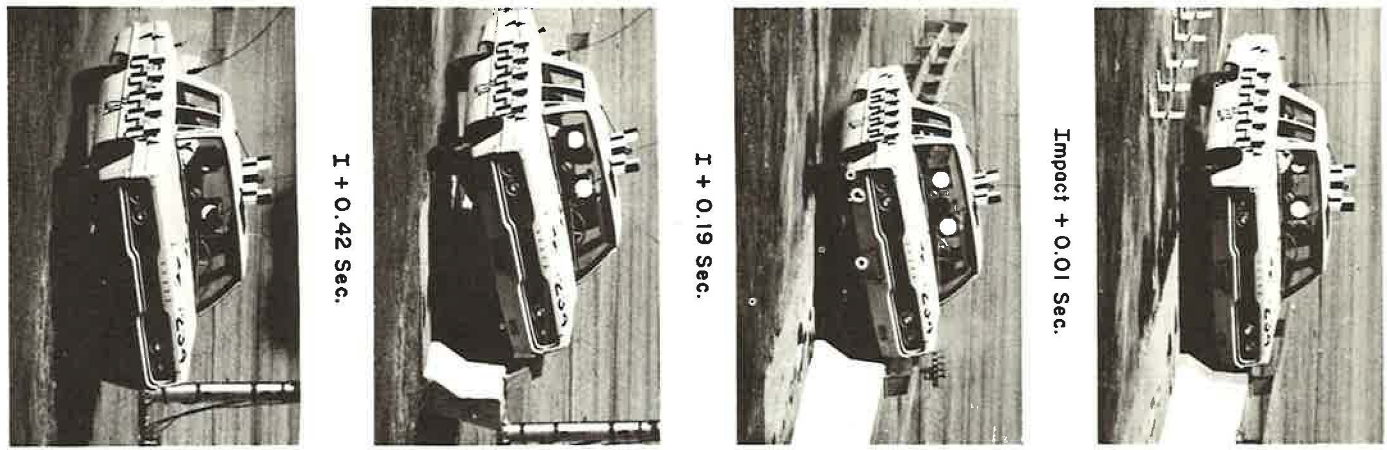
* INSTRUMENTATION MALFUNCTION

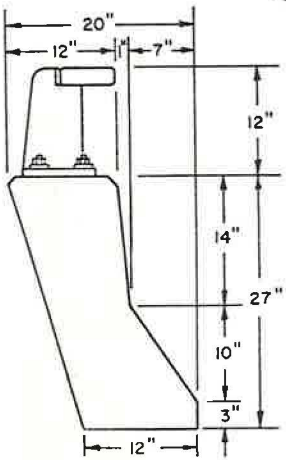
† VEHICLE GAS TANK REMOVED

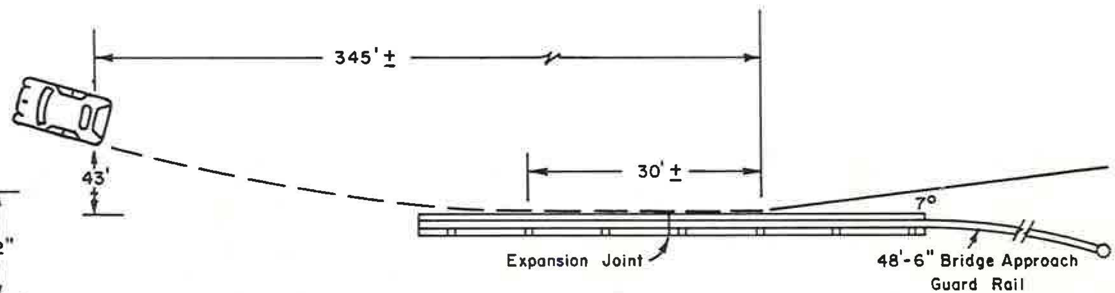
| | |
|---|---|
| TEST NO. | 233 |
| DATE | 10-8-69 |
| VEHICLE | 1966 Dodge Sedan |
| SPEED | 64 mph |
| IMPACT ANGLE | 15° |
| VEHICLE WEIGHT (Incl. / dummys & instrumentation) | 4900 Lbs.† |
| DUMMY RESTRAINT | Lap Belt |

Figure 25.

# TEST 234



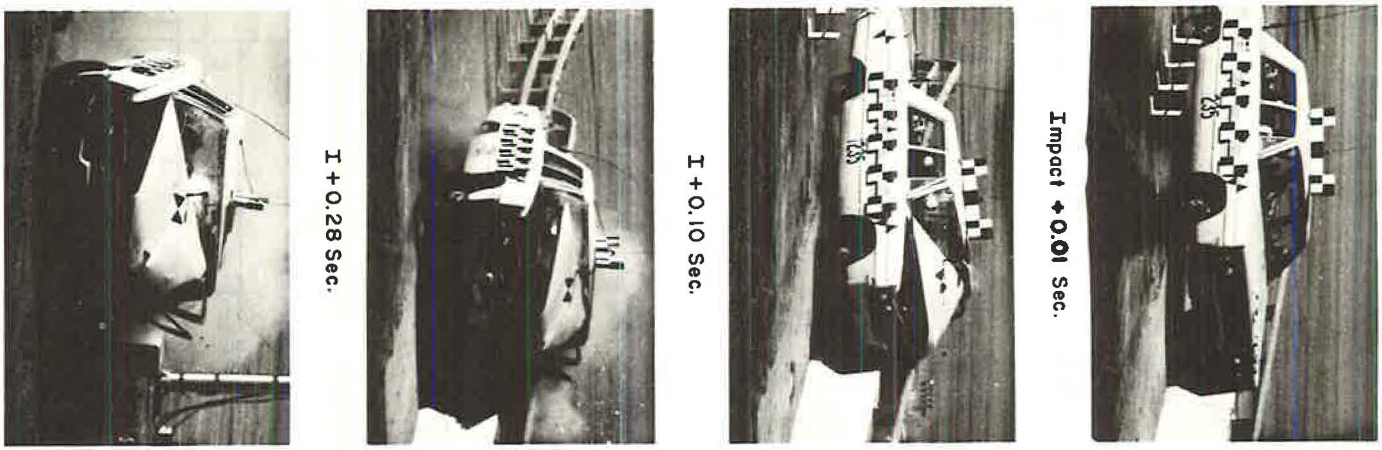

| | |
|---|---|
| BARRIER TESTED | Type 20 Bridge Rail |
| LENGTH OF INSTALLATION | 67' ± |
| PASSENGER COMPARTMENT DECEL. (Highest 50 ms average) | Long. * <br> Lat. 4.8 G's |
| MAXIMUM VEHICLE RISE | 18" |
| EXIT ANGLE | 1° |
| BARRIER DAMAGE | Negligible |

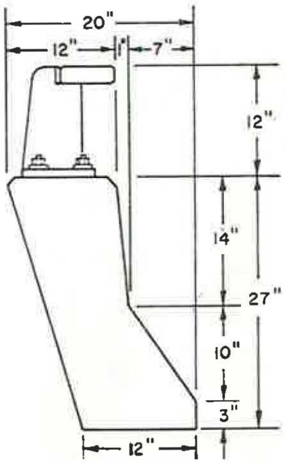
*LESS THAN 1 G

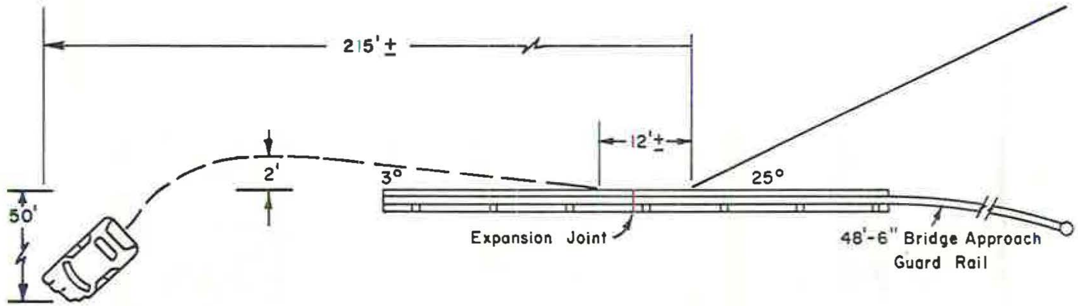
| | |
|---|---|
| TEST NO. | 234 |
| DATE | 10-29-69 |
| VEHICLE | 1966 Dodge Sedan |
| SPEED | 64 mph |
| IMPACT ANGLE | 7° |
| VEHICLE WEIGHT (Incl./dummys & instrumentation) | 4980 Lbs |
| DUMMY RESTRAINT | Lap Belt |

Figure 26.

## TEST 235




BARRIER TESTED . . . . . . . . . Type 20 Bridge Rail
LENGTH OF INSTALLATION . . . . . . . . . . . 67'±
PASSENGER COMPARTMENT DECEL. (Highest 50 ms average) Long. 14.8 G's Lat. 9.1 G's
MAXIMUM VEHICLE RISE . . . . . . . . . . . Negligible
EXIT ANGLE . . . . . . . . . . . . . . . . . . . . . 3°
BARRIER DAMAGE . . . . . . . . . . . . . . . . . Minor
† VEHICLE GAS TANK REMOVED

TEST NO. . . . . . . . . . . . . . . . . . . . . . . . 235
DATE . . . . . . . . . . . . . . . . . . . . . . 10-29-69
VEHICLE . . . . . . . . . . . . . . . . . 1966 Dodge Sedan
SPEED . . . . . . . . . . . . . . . . . . . . . . . 66 mph
IMPACT ANGLE . . . . . . . . . . . . . . . . . . . . 25°
VEHICLE WEIGHT . . . . . . . . . . . . . . . 4900 Lbs†
(Incl./dummys & instrumentation)
DUMMY RESTRAINT . . . . . . . . . . . . . . . Lap belt

Figure 27.