Dynamic Full-Scale Tests of Median Barriers

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Full-scale dynamic tests were made of 15 proposed designs of traffic barriers for use in median areas. Of these, two proved to be worthy of trial installations.

This report describes the procedure used in testing median barriers by oblique, high-speed collisions with passenger vehicles and a 17,000-lb bus, and outlines the extensive instrumentation used in this test series.

Specific recommendations are made for use of a flexible-type barrier in wide medians and a semi-rigid type in narrow medians.

●THE ADVENT of the 4-lane highway and particularly the divided expressway and freeway has reduced the frequency of the deadly head-on collisions that were so prevalent on the 2-lane- and 3-lane-type highway. Unfortunately, this type accident has not been eliminated entirely, in that occasionally an out-of-control car will pass over even a wide median between the opposing roadways and may be involved in a head-on collision in the opposite roadway, resulting in the death of the majority of the occupants of both cars.

As outlined in the Report on Median Accidents (1) 20 percent of the fatal accidents that occur on freeways are the result of cross-median accidents.

It is the purpose of this report to outline the results of a test program to develop a median barrier that will prevent even a high-speed automobile from getting into the opposite lane while at the same time reducing so far as possible the severity of accidents that result from a vehicle striking the barrier.

After attaining operating experience with several types of median barriers in many locations, the Division of Highways launched an extensive study in an attempt to develop the optimum design for such barriers and to establish the conditions that justify their use. The Materials and Research Department was assigned the problem of making full-scale dynamic tests of various barrier systems so as to determine or develop the most efficient system for use as a barrier in a median strip.

In order of importance the following three functions were considered to be primary essentials of a median barrier: (1) positiveness of preventing crossing of median, (2) minimizing reflection of offending vehicle back into traffic stream, and (3) minimizing injury to occupants of offending vehicle.

In order that all pertinent factors would be considered, a median barrier committee was formed consisting of the Traffic, Design, Bridge, and Materials and Research Departments of the Division of Highways. In

April 1958 this committee met and approved for testing 12 basic designs of median barriers (Fig. 1). This original action was later revised by dropping one and adding four new designs making a total of 15 median barrier designs tested. The results of the tests are shown on the individual test data sheets (Figs. 3 through 22) in the Appendix.

TEST PROCEDURE

All the preliminary tests were conducted by driving a medium weight 4-passenger sedan automobile into the various test barriers at a speed of approximately 60 mph and an angle of collision of 30 deg. This same weight of car, speed, and approach angle were used to obtain as good a comparison as possible between the various designs. Final tests were made on the two designs, which were judged to be the most efficient after the preliminary program, by driving a 34-passenger bus into collision with them at 40 mph and an angle of 30 deg. (The bus at 40 mph represented slightly more than twice the kinetic energy developed by the cars at 60 mph.) One collision with a passenger car (Fig. 9) was made at a 20-deg angle of approach and was intended to determine the difference between a 20- and 30-deg angle of approach to the same type of barrier rather than as a comparative test of the barrier systems.

The 60-mph speed and the 30-deg angle of approach combination was selected as representative of the more severe type of oblique accident with a median barrier. (The primary aim was to test the resistance of the barrier.) This speed and angle were selected after studying the results of several actual cross-median accidents as well as analyzing this department's past experience with many different speeds and angles of approach used during the testing of bridge curbs and rails reported previously (2, 3).

Movements of the vehicle and barrier at the time of collision were recorded by a series of high- and normal-speed cameras placed approximately as shown on the typical test site layout diagram (Fig. 2) in the Apendix. Dynamic data were reduced from the film. These data were supplemented by deceleration recordings taken from accelerometers located in an anthropometric dummy restrained by a seat belt and located in the driver's seat of the test car. In addition to this, various dynamic strains were recorded by the use of SR4 gages located on some of the barrier systems. All physical changes in dimensions and condition of the barrier systems were listed as well as the observations and appraisals of damage to the car and visual action during and after the collision as recorded by trained observers at the site.

DISCUSSION

The reason for placing a barrier in a median between the opposing roadways of a divided highway is to prevent the crossing of that median by any traffic. However, it appears that such a barrier in order to be most effective must not only prevent crossing of the median but when struck by a car must minimize occupant injury and must minimize the tendency of the offending vehicle to be bounced back into the traffic stream.

Before discussing the findings of this study, the purpose of which was to develop a barrier that would be the most effective considering the foregoing three criteria, the attention of the reader should be directed to the fact that because of the cost of such a test program, it was necessary to hold the number of tests to the very minimum needed to provide a proper guide to engineering judgment rather than to attempt to collect sufficient information to develop mathematical parameters of all details. The following discussion of the test program is therefore tempered by the actual operating experience of the Division of Highways with several median barrier designs as well as a series of dynamic tests performed on barrier curbing and bridge rails during the years 1953, 1954, and 1955. Studies indicated in general that there are probably three broad classifications into which the various designs of median barrier can be placed. These are the (1) flexible type, (2) semi-rigid type, and (3) rigid type.

Flexible Barriers

The criteria used in this study for a flexible-type barrier was a design that would fulfill the barrier concept while at the same time flex and deform under collision such that the deceleration of the colliding car would be tolerable to its occupants and would provide safe maneuvering time and space for any cars in its own traffic stream. This being a new concept insofar as median barriers were concerned, no practical working designs could be found. During the study period prior to actual testing, several different designs were considered by the median barrier committee but were discarded for various reasons. The one design considered worthwhile for immediate testing was a combination of chain link fencing and wire rope cable properly anchored at the ends.

As shown in Figures 14, 16, 17, 18, 19, and 21, several tests were made to determine the proper details for such a system. The combination of 9-gage chain link fabric on 2 1/4-in. by 4.1-lb steel H posts seems to be reasonably well balanced in that during failure it provided sufficient resistance to decelerate both the test car and bus within a reasonable distance, while at the same time it allowed a deceleration rate tolerable to the occupants of the car.

It is of significance that transverse deceleration during test collision was in most cases less than longitudinal deceleration on this cable-chain link design. This illustrates the efficient trapping action of this design which brings the vehicle to a stop with a gradual transverse deceleration, not subjecting the occupants to the high transverse Gs usually resulting in ejections. The exception to this was Figure 18 which was a test of the proposed anchor and closure design. The results of this latter test proved that the anchorages immediately trap a car and cause a violent accident.

The deflection-time curves (Figs. 32 and 33) indicate the duration of encroachment on the opposing traffic lanes if this barrier is installed on median strips less than 16 ft between edges of pavement.

One of the secondary benefits of this design is that it will support a growth of ivy or other vines to serve as a headlight screen. It is probable that in some areas vines will not grow. It is suggested in these areas that wood or light metal strips could be inserted in the chain link fabric. In this case it is probable that the chain link fabric should be 48 in. wide rather than the 36 in. used in this series of tests. Indications are that this additional foot in height will not seriously affect the operation of the design as a barrier as long as the cable system remains undisturbed.

The lower cable has a double purpose of serving to distribute the collision load to the back posts, thereby stiffening the system in general, while at the same time allowing the wheel to pass over during initial impact and then serving as a trap to prevent the return of the front wheel and so helping to retain the car in the median area. The 9-in. height seems to be about right for this purpose.

The top cable is the most important structural item in this system. Its placement with respect to height is critical and its attachment to the post is critical. If the cable is placed too low, it will either permit the car to pass over the system or it will force the car to bounce back into its traffic stream. If placed too high, it might tend to slip over the car permitting it to pass on through and perhaps sever the superstructure.

This series of tests indicates that 30 in. above the ground is about the proper height for this top cable. This height is well above the center of gravity of most cars and pickups on the road today and therefore tends to prohibit any tendency for the car to roll. At the same time insofar as the average passenger car is concerned the cable will cut through the body sheet metal and slip over the colliding wheel; this helps to retain the car in the median area throughout and after collision. Figure 21 also shows this height to be effective in stopping a bus. Test No. 12 (Fig. 14) on a single top cable with load cells in the cable system indicates that a single cable will probably serve in this design. However, to be most effective a cable should be located on the collision side; this requires two cables. In addition, the risk involved in cutting one cable during collision is such that the factor of safety of having two cables is well worth the slight additional cost.

The fittings used to fasten the cable to the post must be so designed that they will clamp the cable firmly in place but, under collision loading, they will slip off the end of the post acting as a series of friction brakes. There should be no tendency to fix the cable to the post. If the cable were fixed to the posts, this would result in tripping the car rather than gradually snubbing it through a tolerable deceleration.

The effect of end anchorages is a definite problem. An anchorage strong enough to develop the strength of the cable is so strong that when struck it trips the car rather than snubs it to a gentle stop. This tends to cartwheel the colliding car in an uncontrolled manner with the possible unfortunate result that the car could pass on over the barrier, although it did not during the test of the anchorage system in this study. Under operating conditions the anchors should be placed at a point where other fixed objects occupy the median area. Insofar as distance between anchors is concerned, it has been determined that when subjected to a 60-mph passenger vehicle collision no permanent set occurred in the posts 150 ft behind impact and that the stress became negligible about 400 ft behind impact. The only practical limits to length would be those determined by the effects of temperature, topography or physical obstructions.

The cable should be placed and maintained in a snug condition but should contain little or no stress. To maintain the cable in this condition, turnbuckles should be placed about every 500 ft to provide for average seasonal changes as well as reasonable lengths for construction and replacement.

Semi-Rigid Barriers

The criteria used in this study for a semi-rigid-type barrier was a design that would be strong enough to fulfill the barrier concept, while at the same time capable of deforming into a smooth curve without pocketing under collision, such that a change of direction of the offending car would not be as abrupt as if the barrier were as completely rigid as a concrete wall. This would provide some opportunity for the occupants of the offending car to survive and allow a reflection of the car rapid enough for evasive action by close following cars.

During the study period prior to actual testing, many different designs were considered by the median barrier committee. A selection of designs shown in Figures 3-11, and 13 were selected to best investigate this general classification. These designs were selected for two reasons. The first was that almost all were already in use either in California or in other states or toll road authorities throughout the United States. The other was that the selection represented a good opportunity to investigate both types and spacing of posts as well as types and heights of rails. The results that came from testing this series of designs indicated that a composite design as shown in Figure 24 should be most successful. The two tests (Figs. 15 and 22) confirmed these findings.

The efficiency of the design used for Test No. 13 (Fig. 15) in lessening the chances of injury-producing impacts apparent in other tests on corrugated-beam guardrail mounted 30 in. above the ground is illustrated by the deceleration patterns shown in Figure 30. Note that the moderately high transverse Gs on the dummy occur when the vehicle is still in contact with the rail. It is apparent that the human body can sustain these moderate transverse Gs, taking the full load against the shoulder and arm, with less chance of critical injuries than the high longitudinal Gs which usually throw the occupant against the steering column and windshield.

Tests No. 1 and 2 (Figs. 3 and 4) were typical highway guardrail installations. In neither of these tests did the car pass over the barrier; however, the collision with the spring-mounted, curved-beam type resulted in the test car rolling along the top of the rail. Indications were that the car could have bounced across as well as coming to rest on the rail. The curved beam (Fig. 4) tended to pocket the car during impact whereas the corrugated beam (Fig. 3) formed a smooth curve and reflected the test car away from the rail. The necessity for good beam strength in metal-beam guardrails was well illustrated by these two tests which coincide with the findings of others (4).

In both of these tests the car rolled over after impact. This was caused by the rail, which was mounted at a 25-in. height (19 in. to center of rail), being forced back and downward under impact. This tended to impart a rolling motion to the car. This same action occurred at all mounting heights of rail, whenever no provision was made to prevent the rail from following the posts downward. At a 30-in. height the car tends to get under the rail forcing it upwards. This minimizes the tendency of the car to roll.

Test No. 3 (Fig. 5) was used to study the effect of steel spring posts. It was determined that the flexible posts deflected excessively under impact so that they formed the rail into a pocketed ramp, and the car passed on over the barrier. This system has no value as a barrier to high-speed vehicles.

Tests No. 4 and 5 (Figs. 6 and 7) were similar designs used to investigate the effect of doubling the number of posts at a 25-in. mounting height of rail. This height of barrier gave identical results as the guardrail Test No. 1 (Fig. 3) insofar as the reflected rollover-type accident was concerned in spite of the additional stiffness of adding the back rail in Test No. 4 and then doubling the posts in Test No. 5. The only effect of stiffening the system by doubling the number of posts was that, in the stiffer system, the car was reflected back more positively into the same traffic side of the rail.

Tests No. 6 and 7 (Figs. 8 and 9) duplicate barrier designs located in both the Los Angeles and San Francisco areas on existing freeways. These systems used the 30 in. mounting height above a 6-in. curb. One design is the corrugated-section beam and the other the curved-beam rail. Because these rails have approximately equivalent section modulus and were rigidly mounted on steel posts at 6-ft 3-in. centers, it was decided in advance that rather than using the exact speed and angle of approach for both designs, the angle of approach would be varied so as to note the difference between the two angles of approach. Both tests indicated that the railing was mounted at a proper height to provide positive barrier action and to prevent the rollover-type reflection. Unfortunately, this mounting height, with no means provided to prevent the offending car from going under the rail, results in the car colliding with the posts.

In Test No. 6 (Fig. 8), the 30-deg angle of approach, the car collided so hard with the post that it was trapped within 23 ft, resulting in decelerations far in excess of those that could possibly be tolerated by the occupants of the car, and in addition would give a following car little opportunity for evasive action. At the flatter angle of 20 deg in Test No. 7 the car again went under the rail, but due to the flat angle the frame of the car did not contact the post. The post severed the front wheel which went on through the barrier into the opposing traffic lane while the car reflected at a flat angle on its own side of the barrier. The free wheel itself could have caused a head-on collision.

These tests indicated that while the 30-in. mounting height was undoubtedly a workable height, if the normal 12-in. wide rail is used, there should be a means provided to prevent the undercarriage from being entrapped on the posts.

Test No. 8 (Fig. 10) made use of a double corrugated-metal rail mounted at an over-all height of 34 in. on each side of the steel post system so as to solve the entrapment problem. It did, but at the same time imparted a corkscrew rolling action to the car which resulted in the car tumbling on down the roadway similar to the 25-in. mounting height. This test seemed to verify that when no provision is made to prevent the rail from being downed with the posts, no matter what the height, it will impart a rolling tendency to the vehicle. In other words, to prevent roll the car must go under the rail so that the reaction of the rail on the car is downward.

There has been some belief that a spring system for mounting a guardrail would tend to minimize damage to the offending car. It may be true under light collisions; however, under heavy collisions as presented by Test No. 9 (Fig. 11), a flexible mounting tends to allow the rail to pocket between the posts. This results in a rail failure and the car passing on through the railing, thus it has little value as a positive barrier.

The designs shown in Figures 13 and 7 are identical except for height, so they can be considered as comparison of the effect of the change of height. There were two significant observations from these comparative tests. The first was that while there was some question from the action of the car whether or not it would pass on over the rail in Test No. 5 (Fig. 7), there was no question in Test No. 11 (Fig. 13). However, it was definitely shown that a 30-in. height of a single rail mounted directly to posts would result in a severe collision with the posts during high-speed, high-angle collisions.

These observations, coupled with the apparent operational success of blocked out guardrails used on the New Jersey Turnpike, led to the design shown in Figure 24. Here the rail is blocked out on timber posts and has a lower rail to prevent undercarriage entrapment. The 30-in. high blocked out design minimizes the rollover tendency of the car by allowing it to force under the metal guardrail, thus maintaining rail elevation, while the lower rail prevents the car from being trapped by the posts. Figures 15 and 22 show this design to be a success.

The decision to use timber posts was based on the observation that the timber post in earth under dynamic loading was more resilient and tended to give a smoother deceleration than did the steel post set in concrete. This was verified by static cantilever tests showing the 8- by 8-DF post to be nearly equivalent in strength to the 6-in.-wide flange 15.5-lb steel post with approximately twice the deflection. This resilience would be lost if the timber were set in concrete so it is suggested that in going over structures or in other areas where earth is not available, then either steel posts or a concrete wall barrier could be used.

The over-all width of this barrier design is about 27 in., and its deflection under heavy dynamic collision is about 3 ft. This design is efficient in narrow medians as a positive barrier. The reflection angle and speed of the offending car is such that evasive action is possible by following cars. The collision decelerations and the after travel of the offending car are such that the occupants have an opportunity of survival as long as there are no stalled vehicles in the road ahead.

Rigid Barriers

Rigid barriers are represented in this series by only one test (Fig. 20), but this test was supplemented by information gained during dynamic tests of five bridge rails performed and reported in 1955 and two concrete bridge rails tested during this series. As shown by the test data sheet, this design failed during tests.

Indications from the results of Test No. 22 (Fig. 20) are that the design of this rail needs only a slight amount of stiffening to make it serve under heavy collisions. Previous tests on bridge rails indicate that a wall as low as 27 in. in height could be effective as long as it did not fail. The reflective action from a properly designed concrete wall, as indicated by previous tests conducted on bridge rails, shows that the offending vehicle will reflect from the concrete wall with an abrupt change in direction and with high decelerations caused by the extremely rapid reflection of the vehicle from the non-deflecting surface. There is good opportunity, however, for evasive action by following cars in that the reflection angle is normally flat and due to the damaged colliding wheel the car tends to curve back into the rail and come to rest against it. There is even less opportunity of evading stalled traffic ahead after collision than there is with the semi-rigid-type barrier.

This rigid barrier is probably the only type that can be considered for those center strips where little or no space for a median barrier is available. In areas where it is felt that a great many brushing-type collisions will occur with such a center barrier, then consideration should be given to facing the rail with an undercut base or rubbing curb, as shown in the alternate design B in Figure 25. This undercut-type rubbing curb was found to be exceedingly efficient in controlling an offending car when subjected to low angles of collision (3).

The failure of the light concrete wall used in Test No. 22 served to illustrate again the fact that when a rail "lays over" during a heavy collision, no matter what the height, a high-speed colliding vehicle will tend to roll after reflecting from the barrier. Thus it is evident that any barrier design in which it is expected that measurable downward deflection will take place, then provision must be made to hold the restraining unit (rail, cable, etc.) at or above the center of gravity of the vehicle at the first instant of and throughout collision.

One other concrete median barrier was tested during this study. This barrier is shown in Figure 12 and consists of a series of truncated cone concrete posts placed at 5-ft centers. This design was not effective as a positive barrier.

Curbs

This series of tests included only two cases involving curbs placed in front of the test barriers. However, these two test supplemented by some 200 previous full-scale tests (3) performed on highway bridge curbing, are considered to be sufficient to support firm conclusions as to the effect of curbing in front of a median barrier. At high speeds the 6-in. high type of curb seems to have little effect on either the rise or deflection of the collision car. This is explained by the fact that the wheels and springs of the car were deflected over the 6-in. high curb with little appreciable change in elevation of the car itself. In other words, the center of gravity of the car and the frame of the car maintained their traveling elevation while the raise of the curb was taken up in the deflection of the tire and the springing system of the car. This effect would only be true for narrow medians and high angles of collision. At flatter angles of collision or wider medians, the rebound of the springing system would have time to lift a car to its new traveling elevation which would be 6 in. above its roadway elevation and due to spring reaction for a short period probably somewhat higher than this. Previous tests (3) indicate that this effect would no longer hold true for curbs 8 in. and higher. These higher curbs cause an immediate dynamic jump by the car. If such roadway curbs exist, then provision must be made in the design of the barrier to contain the dynamic jump.

INSTRUMENTATION

Collision Vehicles

The vehicles used for this 1959 Test Series were standard 4-door sedans, 1951 to 1955 models, supplemented by one 34-passenger 17,000-lb bus. The center of gravity of the various passenger cars was determined to be about the same and was between 21 and 23 in. above the pavement. The average weight of the vehicles with dummy and instrumentation was 4,000 lb. The rear seat and spare tire were removed to facilitate installation of the control instruments. The following modifications and installations were made in the test vehicles:

1. A Bendix Hydrovac booster was attached to the master brake cylinder for radio remote operation of the brakes.
2. The ignition system was bypassed and wired into the remote-radio control panel.
3. The gas tank was drained and the gas line rerouted into a 1-gal. tank mounted over the spare tire well. This tank was equipped with a relief valve and cut-off valve to prevent leakage of fuel when the vehicle rolled.
4. A mounting plate was welded to the floorboard in the front seat compartment for installation of the steering motor (Fig. 34).

5. Storage batteries and the steering pulser were bolted to the rear seat floorboard.

6. The remote radio control equipment was bolted to trunk compartment deck (Fig. 34). Whip antennae were mounted on the rear body of vehicle.

7. A seat belt was installed on the driver's side.

8. An adjustable pulley was clamped to steering wheel for control of vehicle through the steering motor.

Approximately 2 man-days' labor were required to modify each stock passenger vehicle to radio control.

Radio control of the vehicle along the 2,000-ft collision path was accomplished by means of 3 modulated tones and the R.F. carrier from a transmitter installed in the control truck (Fig. 35).

The five basic functions considered necessary for complete and flexible control of the test vehicles were: ignition on, ignition off, steer right, steer left, and brakes on. The accelerator linkage was wired in the full throttle position before push off. The vehicles attained a peak speed of 58 to 62 mph on impact, with a 2,000-ft collision path.

The ignition system was energized through a relay controlled by the R.F. carrier from the control truck transmitter. A failure in any of the radio control equipment opened the ignition relay allowing the car to stop under compression.

A signal to the steering motor pulser actuated the steering motor in incremental steps, variable in each direction from 1/8 to 1 in. per pulse. The pulse rate was variable from 2 to 20 pulses per second. The steering pulser was set after determining the amount of correction necessary to the steering of each vehicle by several trials before the actual test.

Deceleration Instrumentation

1. Two unbonded uni-axial strain-gage-type accelerometers were mounted on the right side of the vehicle frame at Station 10 (10 ft to the rear of the front bumper) for comparison to studies by others (5). The accelerometers are positioned with their axes 90 deg opposed to provide bi-axial sensing of the longitudiinal and transverse decelerations of the vehicle frame. Peak G readings are difficult to reduce from these oscillograph records because of high amplitude traces caused by the transient ringing inherent in the vehicle frame on impact with a semi-rigid object. Peak vehicle deceleration as reported on the data sheets represents an average of the peak decelerations recorded.

2. A Sierra Engineering Company, Model 157, 6-ft 0-in. 220-lb. anthropometric dummy positioned in the driver's seat was restrained by a conventional lap belt. The dummy was also instrumented with two accelerometers mounted in the chest cavity in the relative position of the heart, with the axes sensitive to the longitudinal and transverse deceleration of the upper torso. Deceleration readings from the dummy indicate the severity of injury-producing collisions as well as the general body areas injured on impact with the door or steering column of the crash vehicle, and can in most tests be considered the maximum Gs deceleration sustained during impact. This information may also be used for correlation to the work of others (5, 6).

Because of unforeseen failures due to the high "G" loading sustained by the accelerometer recording equipment mounted in the collision vehicles during the first ten tests, consistent deceleration readings could not be produced. Therefore "G" readings from the first ten test collisions were not considered valid and are omitted from this report. On subsequent tests a 300-ft tether line was connected from the accelerometers in the collision vehicle to the recording equipment in an instrument truck. The instrument truck followed parallel to and 30 to 50 ft behind the collision vehicle on the approach path. During two tests the tether line was severed a few milliseconds after impact; however, complete data were obtained on most of the Tests 11 through 22. In addition to the accelerometer data, the kinematics of the dummy under collision conditions were observed from the high-speed tower camera on the first seven tests.

The top of the vehicle from the windshield to 6 in. behind the driver's seat was cut away to allow total photographic coverage of the dummy reaction. It was apparent after an analysis of the data film records of these first seven tests that the kinematic pattern of the dummy was very similar during all of the semi-rigid barrier collisions.

Additional data of this type were not considered to be of enough significance to justify removal of the vehicle top on subsequent tests.

In all tests on semi-rigid and rigid barriers where the vehicle was not trapped by the posts, the vehicle was subjected to high transverse decelerations. The dummy was forced against the left door with sufficient energy to break the latching mechanism. On tests where those high transverse decelerations were imparted to the dummy while the side of the vehicle was not in contact with the barrier, the head and shoulders of the dummy protruded from the car. Had the dummy not been restrained with a lap belt, it would have been ejected from the vehicle. However, in cases where the dummy contacted the door at a time when the side of the car was in firm contact with the barrier, exemplified by Test No. 8, the rail prevented the door from opening completely.

An examination of the sequence photographs from the 25-in. high barrier tests as exemplified by Test No. 2 (Fig. 4) revealed that the rail retained only the lower portion of the door and allowed the top of the door to be forced open as much as 1 ft. In these cases the head of the dummy protruded from the vehicle, which resulted in critical head injuries.

When the dummy experienced excessive longitudinal decelerations, such as in Test No. 6 (Fig. 8) the torso of the dummy pivoted about the femur, striking the head and chest violently against the steering wheel, windshield, and instrument panel. This action was typical on all tests where the front wheel assembly was trapped by the posts.

Deceleration data from all tests of cable-chain link barriers show very low transverse decelerations (2-9 Gs) and low longitudinal deceleration (3-7 Gs). If the dummy did impart a loading great enough to spring the door latching mechanism, the door did not open because the vehicle was firmly against the upper cables when peak transverse decelerations occurred.

Photographic

This department has determined from experience on previous collision tests that photographic coverage of this type event will yield the maximum of significant data for the lowest initial investment. As it was necessary that the final analysis and presentation be in the form of a film report in addition to a written report, the data cameras had to function also as documentary cameras. A frame rate of 1200 per second was used for the tower mounted camera to record information on impact velocity, approach angle, and average vehicle deceleration. The field of view from this camera was 30 by 40 ft covering from 20 ft before impact to 20 ft beyond impact parallel to the rail. To provide documentary coverage, a 200 frame per second camera with the same field of view was mounted adjacent to the data camera. The field of view from this camera covered from 10 ft behind to 30 ft beyond impact parallel to the rail.

Due to the variable post collision trajectories of the test vehicles, it was found necessary to orient all but the tower-mounted data cameras at different locations for each test. The relative location of the cameras, barrier, collision vehicles, control and instrument vehicles for a typical test are shown in Figure 1. This was varied to meet the expected reflection action of each test. Standard photographic coverage of each collision included: one turret-mounted front data camera, one rear data camera, two overhead data cameras, and two documentary cameras panning the vehicle through collision to the terminal point. In addition to the foregoing photographic coverage, a 70-mm sequence camera operating at 20 frames per second was used to record a documentary series that could be enlarged and analyzed for details. The pictures exhibited at the top of each test data sheet are reproductions of the most significant frames from this sequence camera coverage.

Following is a description of the data and documentary cameras:

Camera Number	Type	Frames /Sec	Lens	Film	Location	Function
1	Fastax	1200	12.5mm	16mm 100-ft roll	Tower	Data
2	Gordent 200	200	13 mm	16mm 100-ft mag.	Tower	Data
3	Gordent 200	200	4 in.	16mm 100-ft mag.	Front turret	Data
4	Gordent 200	200	4 in.	16mm 100-ft mag.	Rear	Data
5	Hulcher 70	20	6.5 in.	70mm 100-ft roll	Rear platform	Doc. sequence
6	Bolex 16	24	Zoomar	16mm 100-ft roll	Various	Doc. pan
7	Bell & Howell	24	1 in.	16mm 100-ft roll	Various	Doc. pan
8	G.S.A.P.	64	1 in.	16mm 50-ft mag.	Various	Doc.

As each type camera motor required a different time interval to reach operating speed and each camera had a different operating frame speed, it was necessary to control them manually and in sequence from the camera control center.

A typical sequence for camera and flash bulb operation follows:

Impact minus 3 sec, camera #8
Impact minus 2 sec, cameras #2, 3, 4
Impact minus 1 sec, camera #1
Impact minus 200 millisec, flash bulb #4

For certain barrier tests additional data cameras were positioned at strategic points to cover wheel or front suspension reaction, post and rail reaction.

For a closer view of the dummy reaction during the two bus tests, a 200-fps data camera was rigidly mounted above the rear window of the collision vehicle to record a full kinematic study of dummy reaction. This camera was connected to a 10-sec time delay relay starting the camera when the collision vehicle was within 10 sec of impact. A spring loaded microswitch mounted on the rear bumper actuated the time delay relay when the power assist truck released the collision vehicle on the collision path.

As data camera #1 was the only camera with 1000 cycle timing pips, it was necessary to provide a method of timing the other data cameras. A segmented drum revolving at approximately 1600 rpm was mounted directly below the tower in view of all data cameras. Analysis of the revolving drum image and the timing pips on the film from camera #1 provided a time-in-space correlation for all data cameras. It was thus possible to correlate the information from any film frame on the data cameras with the film from the #1 camera.

Two pressure sensitive electrical switches were mounted on the pavement on the collision path and positioned 5 and 15 ft before the collision point. As the vehicle passed over the switches, flash bulbs positioned behind the barrier in view of the high-speed overhead data camera were fired. By analysis of the flash bulb images and the 1000 cycle timing pips on the high-speed data film from camera #1, the average speed of the test vehicle 10 ft before impact was determined.

A third flash bulb mounted on the collision vehicle was fired on impact by a "G" switch set to close when the deceleration approached 2 "G". A photocell mounted adjacent to the flash bulb transmitted this event marker pulse to the instrument truck accelerometer recorder through the tether line and onto the oscillograph recorder film. This pulse provided a correlation pip between the high-speed data camera and the deceleration recordings.

When strain gages were mounted on the barrier rails to measure the transmission of stress through the rail members, it was possible to correlate the stress recording oscillograph to the data cameras through a similar flash bulb/photocell unit positioned behind the barrier and in view of data camera #1. This flash bulb was triggered manually from the camera control center a few milliseconds prior to impact. This report does not contain the complete stress and strain information. This data was used merely to verify existing specification joint requirements.

TRIAL INSTALLATIONS

The barriers (Table 1) conforming to the recommendations of this report either have been or are being placed on California freeways. These installations are considered to be experimental and will be carefully observed under operating conditions.

CONCLUSIONS

Of the 15 median barrier designs tested, only two barriers satisfied to some degree all essential requirements for an efficient barrier when subjected to high-speed collision. The preferred barrier design to be used is determined primarily by the width between edges of pavement.

The combination cable-chain link barrier (Fig. 23) is over-all the most effective barrier but is limited to use in median strips where a deflection of about 8 ft can be tolerated. This barrier met all three requirements.

1. It acted as a positive barrier.
2. It minimized the possibility of the overtaking-type accident by retaining the vehicle within the median.
3. It decelerated the colliding vehicle gradually and so minimized the probability of injury to the occupants.

TABLE 1

MEDIAN BARRIER INSTALLATIONS

Contract	Location	Barrier	Length (ft)	Median Width E.P. to E.P. (ft)	1958 ADT
60-7VC-29FI	Santa Ana Freeway VII-LA-166-A	Cable-chain link	16,835	12	98,878
60-7VC-29FI	Santa Ana Freeway VII-LA-166-A	Blocked out rail	11,357	8 to 12	98,878
60-7VC-29FI	Hollywood Freeway VII-LA-2-D	Blocked out rail	7,138	12	130,500
60-7VC-15	Ventura Freeway VII-LA-2-LA	Cable-chain link	12,500	22	New construction
60-4TC-42	Bayshore Freeway IV-SF-68-SF	Blocked out rail	7,484	Curbed 6 to 16	86,100
60-4TC-40	Nimitz Freeway IV-Ala-69-C	Cable-chain link	20,200	12	82,400
60-4TC-40	Nimitz Freeway IV-Ala-69-C	Blocked out rail	14,797	2.5 to 12	82,400

Note: LA—Los Angeles County;
SF—San Francisco County;
Ala—Alameda County.

The blocked out metal beam barrier design shown in Figure 24 is the most effective for narrow medians and traffic conditions where deflections allowed by the cable-chain link type could not be tolerated. During the tests this barrier satisfied all three criteria to some degree.

1. It acted as a positive barrier.
2. Although it reflected the colliding vehicle back into its traffic stream, the exit speed and angle were such that close following traffic would have had some opportunity for evasive action.
3. It resulted in decelerations of the colliding car which, while high, would be within the possible limits of human tolerance. There would be a good probability of surviving a severe collision with this barrier.

RECOMMENDATIONS

Results of Test Program

The two designs shown in Figures 23 and 24 are recommended for use as traffic barriers between divided roadways subject to the following:

1. The cable-chain link barrier shown in Figure 23 be used as a barrier in medians where the width available will allow for at least 8-ft deflection of the barrier. It could be used in a median of lesser width depending on the degree of risk involved in allowing a momentary encroachment into the opposing roadway.
2. The blocked-out metal beam barrier shown in Figure 24 be used in narrow medians down to 3 ft when the space is insufficient for the cable-chain link barrier. By eliminating the metal beams and the wood block from one side of this design, it could be used where a definite barrier-type guardrail is needed, such as at bridge ends, tight curves, or other hazardous areas.

Future Study Suggestions

1. In medians where a rigid barrier is needed, such as between undivided multilane roads, tests performed on bridge rails during this program and in the past (2) indicate concrete to be the most efficient ma-

terial. No attempt was made to develop final details of such a barrier in this program; however, tests to date indicate Designs A and B in Figure 25 might be effective.

It is therefore suggested that if a study is undertaken to develop a rigid barrier, Designs A and B be included in such a program.

2. The limited tests of guardrail performed during this study indicated a definite need for the dynamic development of a guardrail design. Such a study should include both posts and rails. Post studies should include both dimensional and material design for each of the major construction materials: wood, steel, and reinforced and prestressed concrete. Rail studies should include not only geometric design but also materials other than steel, such as fiberglass reinforced plastics and aluminum.

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1. "Median Accident Study: 1958." Traffic Department, California Division of Highways.
2. Beaton, J.L., "Full-Scale Tests of Concrete Bridge Rails Subjected to Automobile Impacts." HRB Proc., 35:251-267 (1956).
3. "Final Report of Full-Scale Dynamic Tests of Bridge Curbs and Rails." Materials and Research Department, California Division of Highways.
4. Lundstrom, L.C., and Skeels, P.C., "Full-Scale Appraisals of Guardrail Installations by Car Impact Tests." HRB Proc., 38:353-355 (1959).
5. Severy, D.M., Mathewson, J.H., and Siegel, A.W., "Automobile Head-on Collisions, Series II." Univ. of California, Institute of Transportation and Traffic Engineering. (Presented at SAE meeting, Detroit, Mich., March 4-6, 1958).
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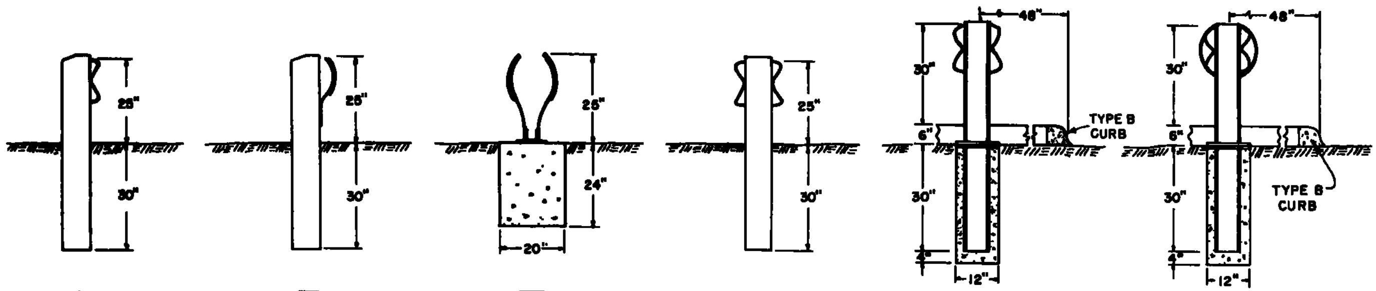
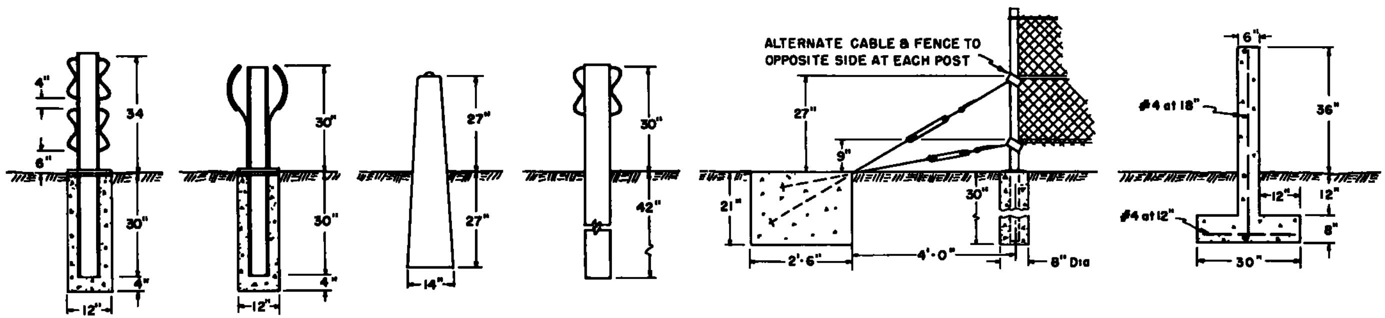
HRB:OR-375



	I	II	III	IV	V	VI
RAIL	CORRUGATED BEAM	CURVED BEAM	CURVED BEAM	CORRUGATED BEAM	CORRUGATED BEAM	CURVED BEAM
BRACKET	NONE	HG15N	HG 26 N	NONE	NONE	HG 32 N
POST	8" x 8" D F	8" x 8" D F	HG 26N	8" x 8" D F	6" WF 15 5 #	6" WF 15.5 #
POST SPACING	12'-6" CTRS.	10' CTRS	6'-3" CTRS	12'-6" CTRS	6'-3" CTRS	6'-3" CTRS



	VII	VIII	IX	X	XI	XII
RAIL	CORRUGATED BEAM	CURVED BEAM	NONE	CORRUGATED BEAM	2-3/4" CABLE & CHAIN LINK	6" RIENF CONC.
BRACKET	NONE	HG15N	NONE	NONE	NONE	NONE
POST	6" WF 15 5 #	6" WF 15 5 #	P C C	8" x 8" D F	2 1/4" H 4 1 #	NONE
POST SPACING	6'-3" CTRS	6'-3" CTRS	5' CTRS	6'-3" CTRS	8' CTRS	NONE

Figure 1. Trial designs.

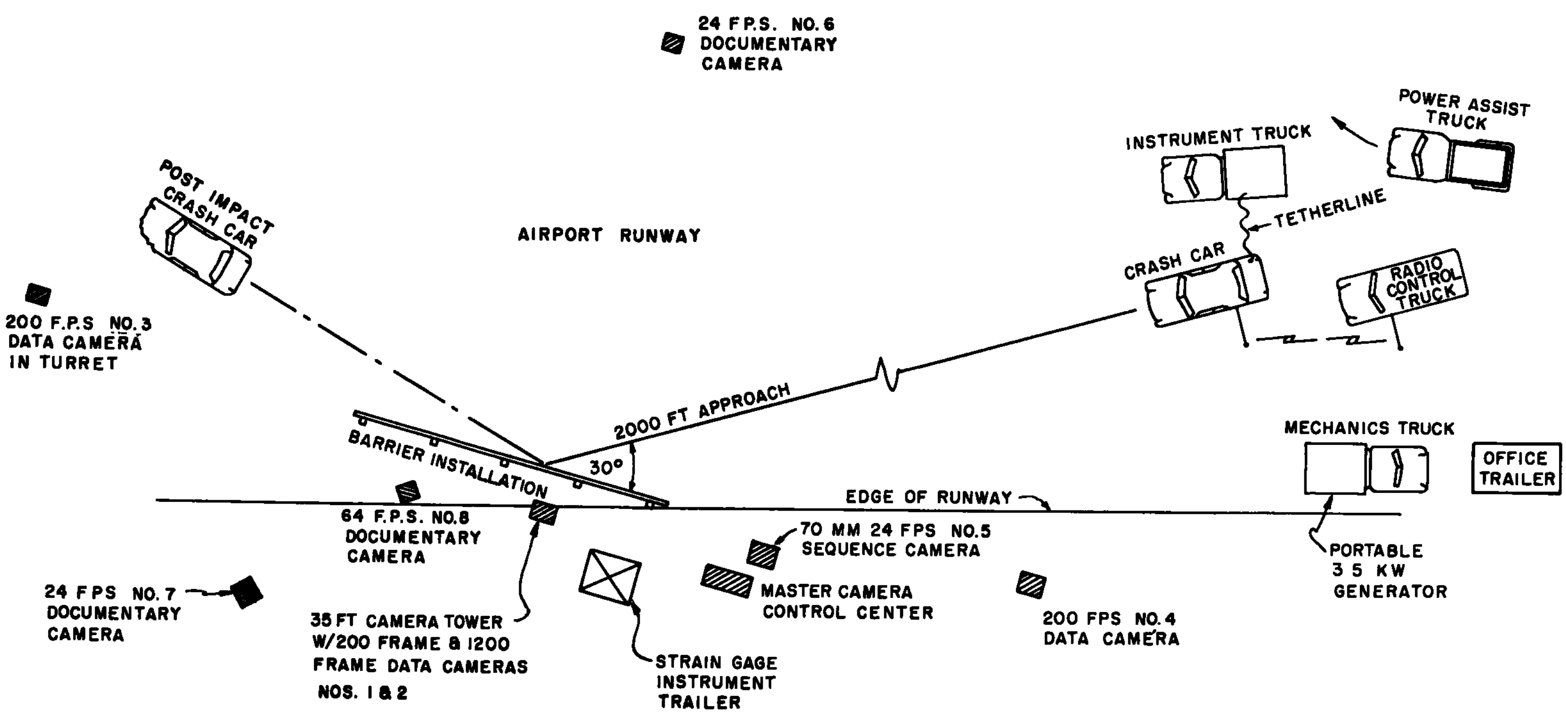
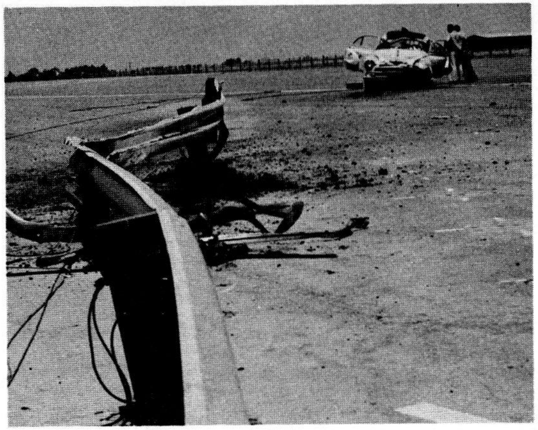


Figure 2. Plan view of test site.



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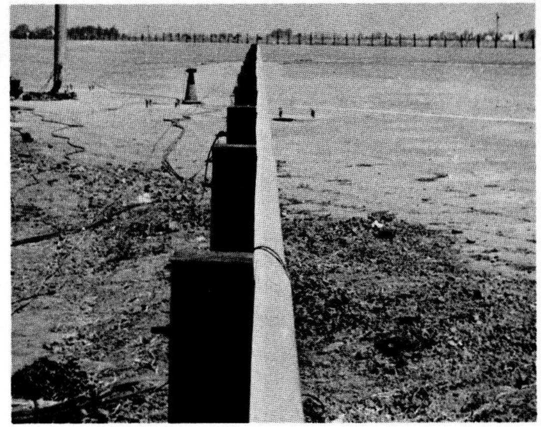

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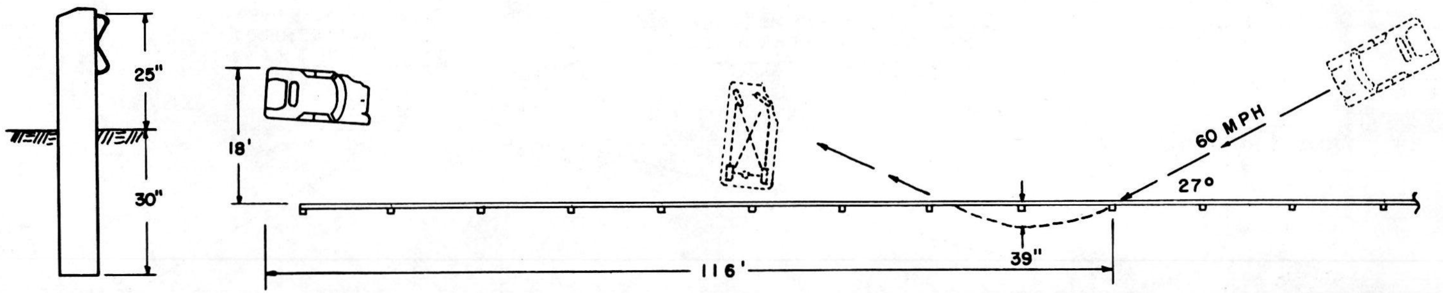
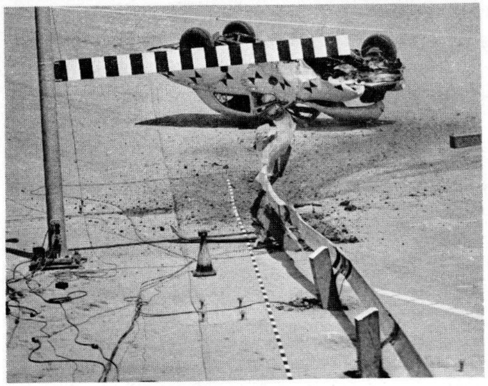


GUARDRAIL .... W Section
BRACKET .... None
POST .... 8x8 D.F.
POST SPACING............. 12'-6" O.C.
LENGTH OF INSTALLATION... 212.5'
GROUND CONDITION .... Dry

DUMMY INJURY....................... Left shoulder & side injuries. Possible concussion.
GUARDRAIL DAMAGE .... 3 Sections damaged beyond repair.
POST DAMAGE .... 2 Posts damaged beyond repair.
12 Posts out of alignment.
VEHICLE DAMAGE .... Total loss
MAX. DYNAMIC DEFLECTION OF RAIL... 48"

TEST NO. 1
DATE 7-10-58
VEHICLE .... Chev. 52 Sedan
SPEED .... 60 MPH
IMPACT ANGLE...... 27°
VEHICLE WEIGHT... 3980
(W/DUMMY & INSTRUMENTATION)

Figure 3. Test data information sheet.



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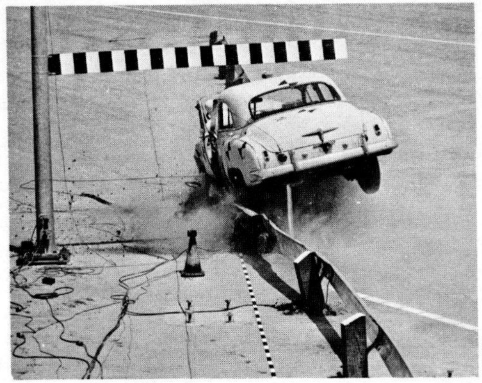

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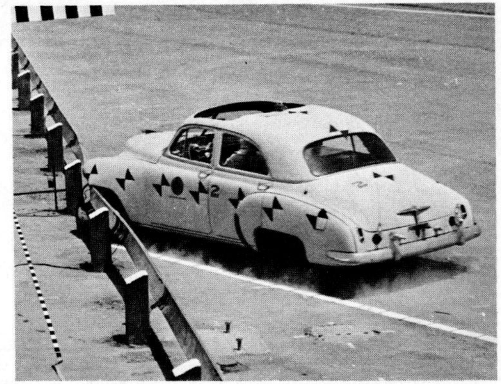

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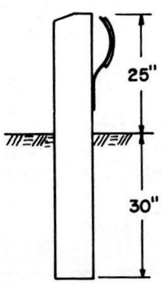
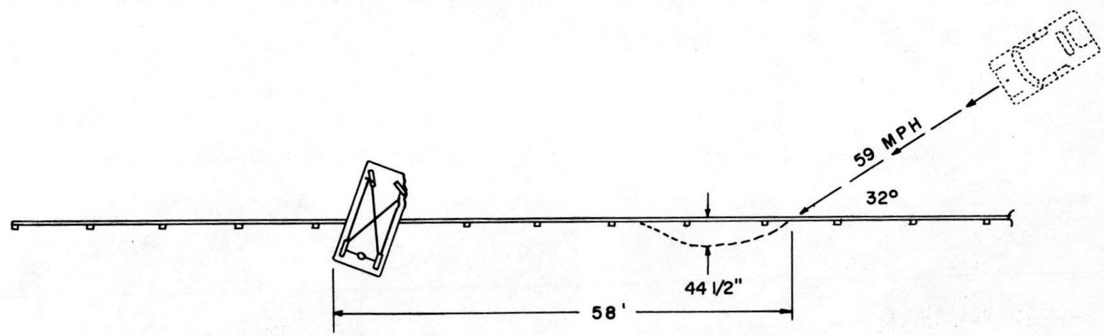


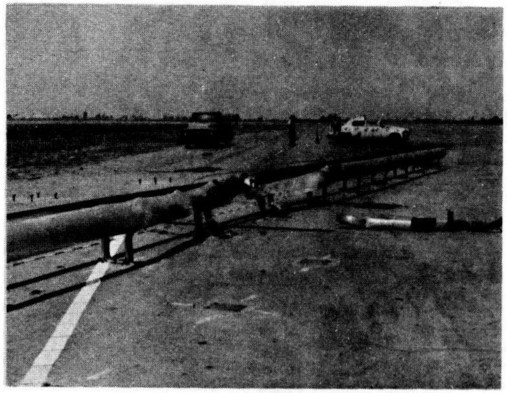


GUARDRAIL .... Tuthill
BRACKET HG15N
POST .... 8 x 8 D.F.
POST SPACING .... 10' O.C.
LENGTH OF INSTALLATION ... 200'
GROUND CONDITION .... Dry

DUMMY INJURY .... Severe head, neck, chest, & internal injuries.
GUARDRAIL DAMAGE .... 4 Sections damaged beyond repair.
POST DAMAGE .... 5 Posts damaged beyond repair.
10 Posts out of alignment.
VEHICLE DAMAGE .... Total loss
MAX. DYNAMIC DEFLECTION OF RAIL ... 55 1/2"

TEST NO. 2
DATE 7-23-58
VEHICLE .... Chev. 50 Sedan
SPEED .... 59 MPH
IMPACT ANGLE ..... 32 °
VEHICLE WEIGHT.... 3980
(W/DUMMY & INSTRUMENTATION)

Figure 4. Test data information sheets.



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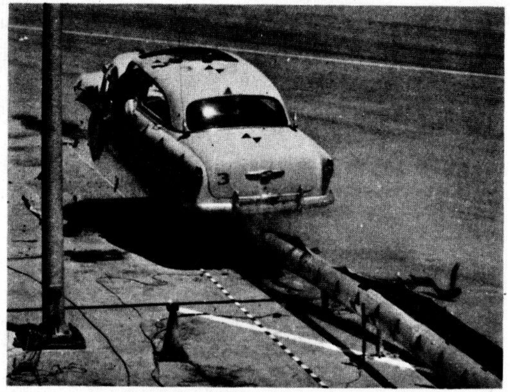

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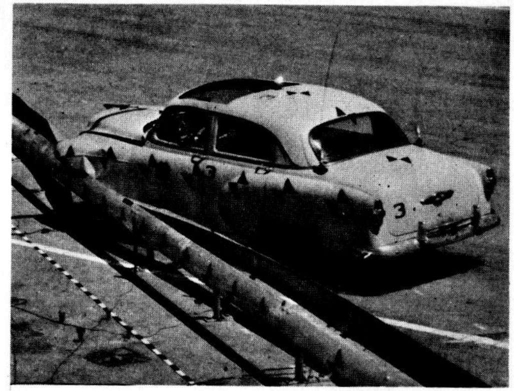
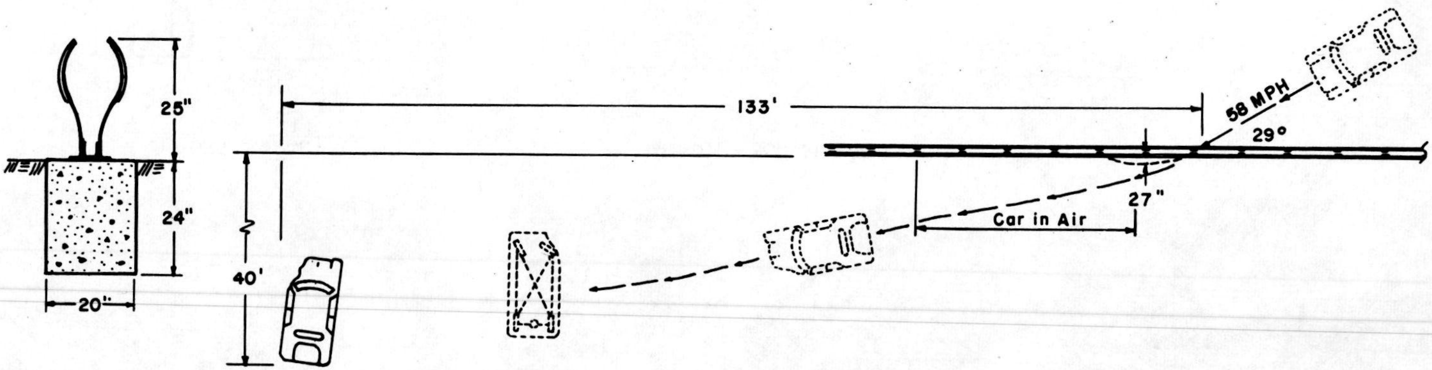


IMPACT + 75 M SEC.



GUARDRAIL ....Tuthill
BRACKET .... HG 26 N
POST ....HG26 N
POST SPACING ....6'-3" O.C.
LENGTH OF INSTALLATION... 100'
GROUND CONDITION ....Dry

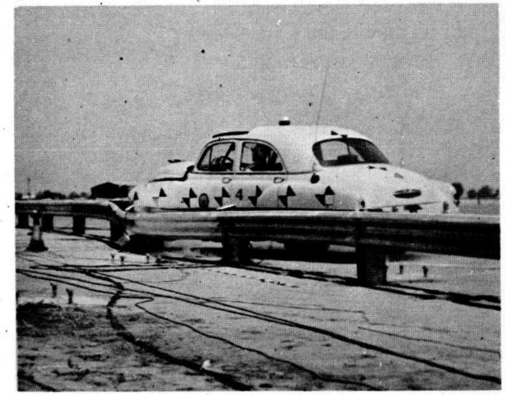
DUMMY INJURY ....Left shoulder & side injuries. Possible concussion.
GUARDRAIL DAMAGE ....4 Sections damaged beyond repair. Inside rail failed.
POST DAMAGE ....6 Brackets damaged beyond repair.
VEHICLE DAMAGE ....Total loss
MAX. DYNAMIC DEFLECTION OF RAIL... 27" Before failure.

TEST NO. 3
DATE 8-6-58
VEHICLE ....Chev. 53 Sedan
SPEED ....58 MPH
IMPACT ANGLE ..... 29°
VEHICLE WEIGHT... 3980
(W/DUMMY & INSTRUMENTATION)

Figure 5. Test data information sheets.

POST IMPACT

IMPACT + 450 M SEC.



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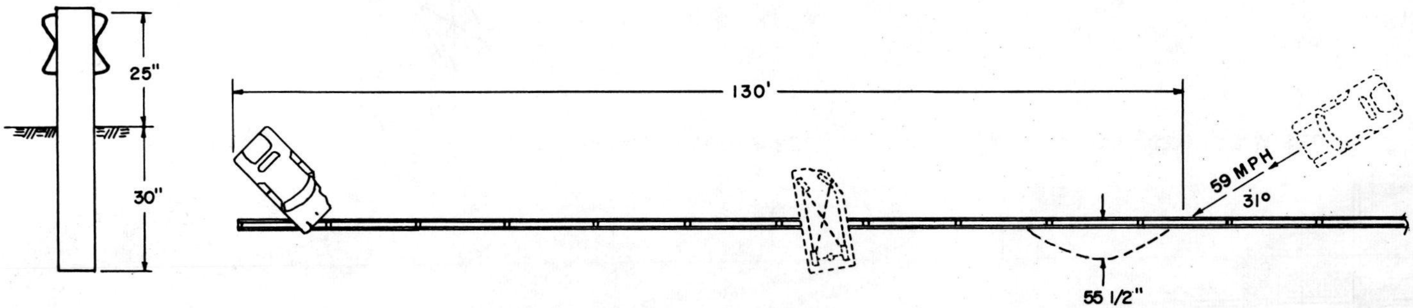


GUARDRAIL .... W Section
BRACKET .... None
POST .... 8x8 D.F.
POST SPACING .... 12'-6" O.C.
LENGTH OF INSTALLATION ... 200'
GROUND CONDITION .... Dry

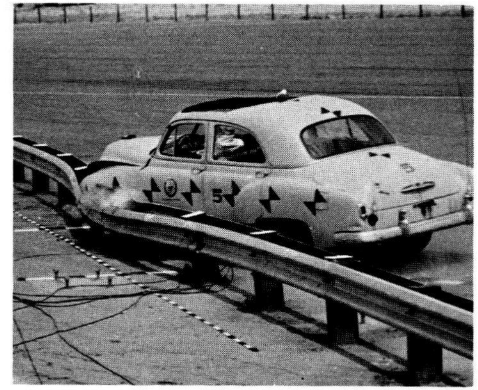
DUMMY INJURY .... Severe neck, head & left shoulder injuries.
GUARDRAIL DAMAGE .... 3 Sections damaged beyond repair.
POST DAMAGE .... 1 Post damaged beyond repair.
7 Posts out of alignment.
VEHICLE DAMAGE .... Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL ... 60"

TEST NO. 4
DATE 8-20-58
VEHICLE .... Chev. 51 Sedan
SPEED .... 59 MPH
IMPACT ANGLE ..... 31°
VEHICLE WEIGHT ... 3980
(W/DUMMY & INSTRUMENTATION)

Figure 6. Test data information sheets.

POST IMPACT

IMPACT + 500 M SEC.



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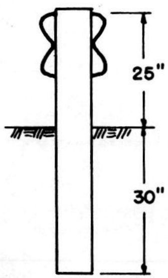
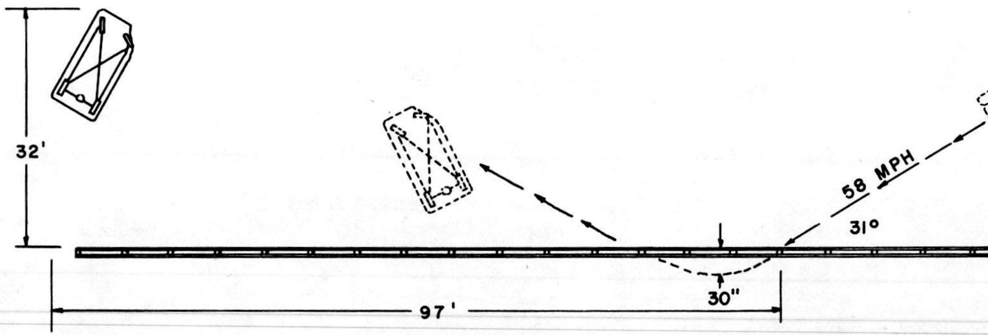


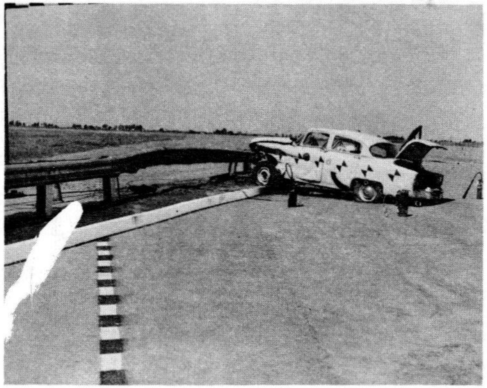


GUARDRAIL .... W Section
BRACKET .... None
POST .... 8x8 D.F.
POST SPACING .... 6'-3" O.C.
LENGTH OF INSTALLATION... 200'
GROUND CONDITION .... Dry

DUMMY INJURY .... Severe left shoulder & arm, head & neck injuries
GUARDRAIL DAMAGE .... 2 Sections damaged beyond repair.
POST DAMAGE .... 3 Posts damaged beyond repair.
5 Posts out of alignment.
VEHICLE DAMAGE .... Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL... 40.5"

TEST NO. 5
DATE 8-27-58
VEHICLE .... Chev. 51 Sedan
SPEED.............. 58 MPH
IMPACT ANGLE ...... 31°
VEHICLE WEIGHT... 3980
(W/DUMMY & INSTRUMENTATION)

Figure 7. Test data information sheets.



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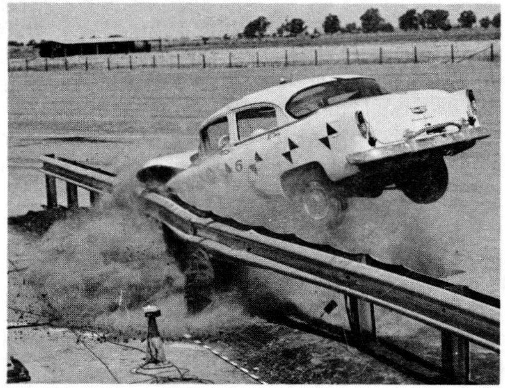

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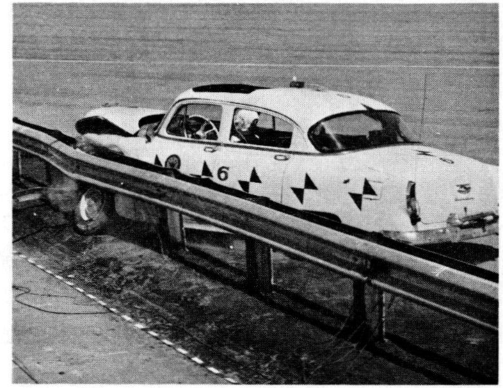

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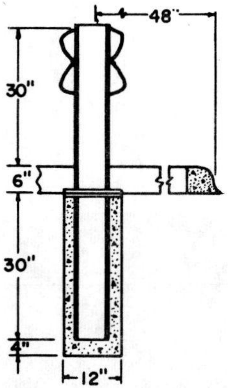
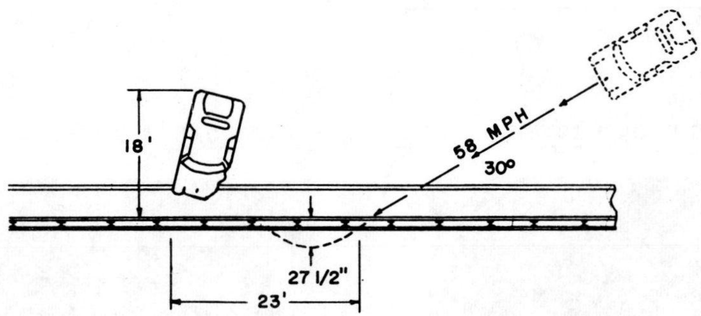




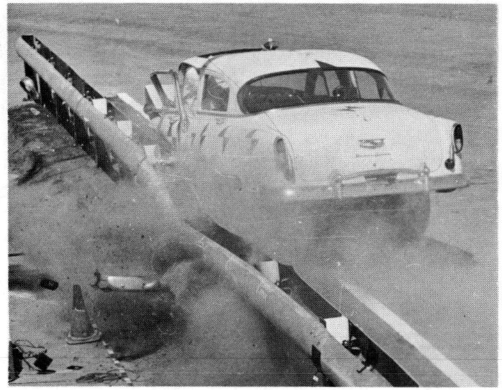
GUARDRAIL .... W Section
BRACKET .... None
POST .... 6" WF 15.5 #
POST SPACING.............. 6'-3" O.C.
LENGTH OF INSTALLATION... 100'
GROUND CONDITION .... Dry

DUMMY INJURY .... Severe head, chest & neck injuries.
GUARDRAIL DAMAGE .... 4 Sections damaged beyond repair.
POST DAMAGE .... 3 Posts knocked out.
2 Posts out of alignment.
VEHICLE DAMAGE .... Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL ... 36"

TEST NO. 6
DATE 9-10-58
VEHICLE .... Chev. 54 Sedan
SPEED .... 58 M P H
IMPACT ANGLE ...... 30°
VEHICLE WEIGHT.... 4000
(W/DUMMY & INSTRUMENTATION)

Figure 8. Test data information sheets.

POST IMPACT



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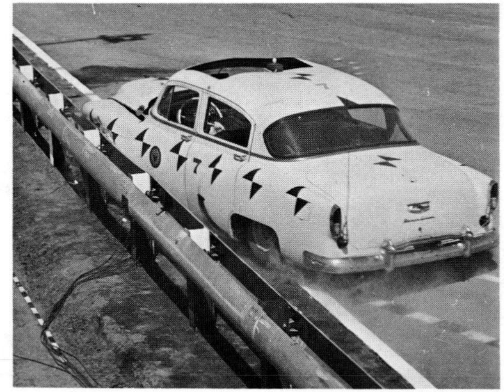

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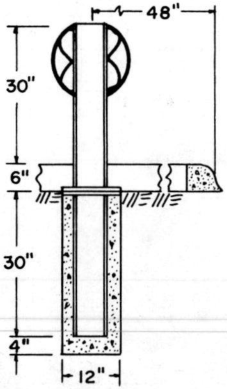
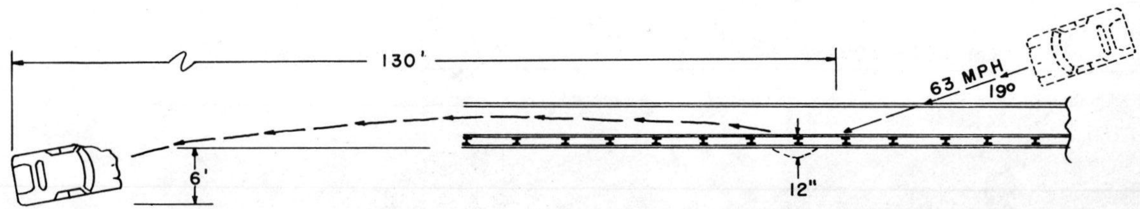




GUARDRAIL................Tuthill
BRACKET.................HG 32 N
POST ....6" WF 15.5 #
POST SPACING ....6'-3" O.C.
LENGTH OF INSTALLATION...100'
GROUND CONDITION.........Dry

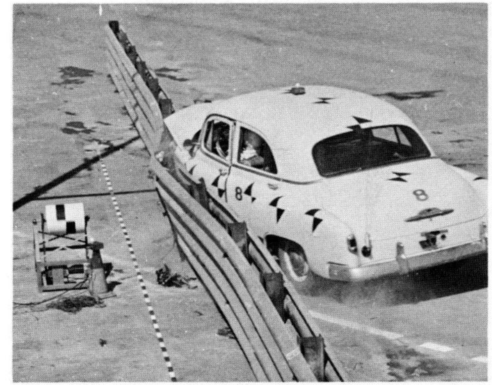
DUMMY INJURY.......................Severe head, chest & internal injuries.
GUARDRAIL DAMAGE ....2 Sections damaged beyond repair.
POST DAMAGE ....2 Posts damaged beyond repair.
2 Posts out of alignment.
VEHICLE DAMAGE ....Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL...19"

TEST NO.............7
DATE..............9-18-58
VEHICLE..........Chev. 54 Sedan
SPEED ....63 M PH
IMPACT ANGLE......19°
VEHICLE WEIGHT....4050
(W/DUMMY & INSTRUMENTATION)

Figure 9. Test data information sheets.

POST IMPACT

IMPACT + 500 M SEC.



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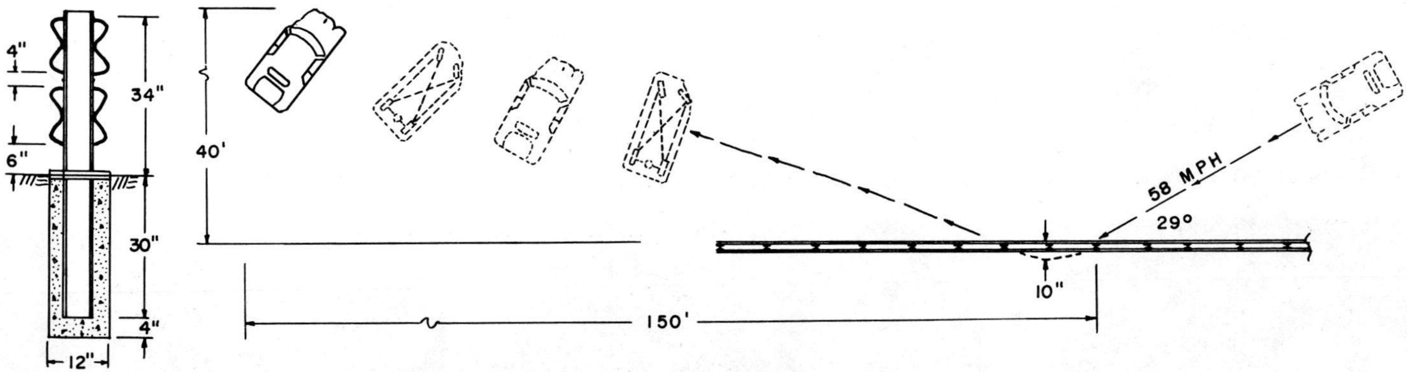
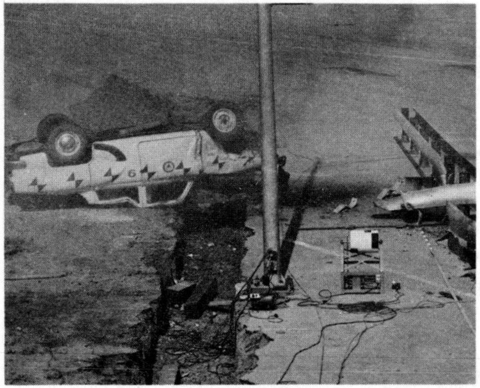


GUARDRAIL .... W Section
BRACKET .... None
POST .... 6" WF 15.5 #
POST SPACING .... 6'-3" O.C.
LENGTH OF INSTALLATION... 100'
GROUND CONDITION .... Dry

DUMMY INJURY .... Severe head, shoulder & arm injuries. Multiple lacerations & concussion.
GUARDRAIL DAMAGE .... 2 Sections damaged beyond repair.
POST DAMAGE .... All can be repaired. 5 Posts out of alignment.
VEHICLE DAMAGE .... Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL... 15"

TEST NO 8
DATE 10-2-58
VEHICLE .... Chev. 52 Sedan
SPEED .... 58 M.PH
IMPACT ANGLE ...... 29°
VEHICLE WEIGHT... 4050
(W/DUMMY & INSTRUMENTATION)

Figure 10. Test data information sheets.



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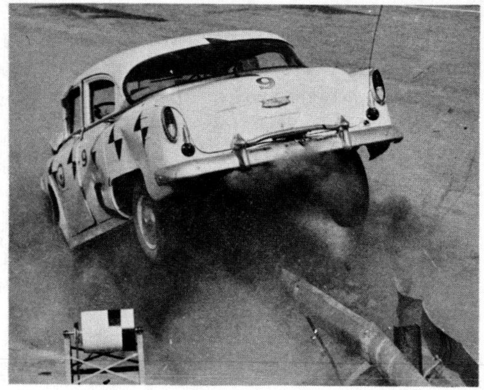
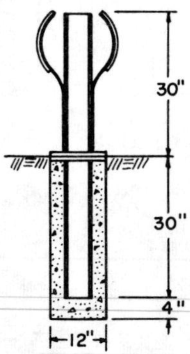
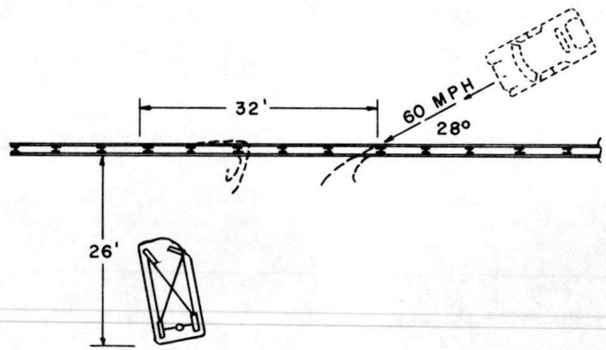


IMPACT + 450 M SEC.

IMPACT + 100 M SEC.





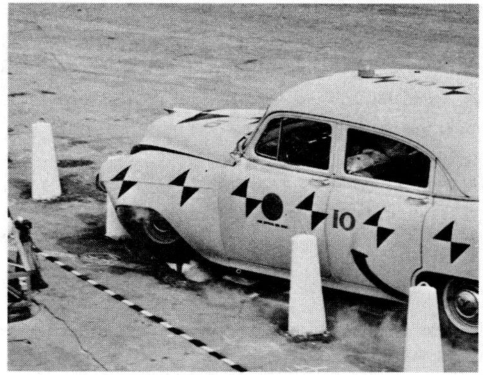
GUARDRAIL ....Tuthill
BRACKET HG15N
POST ....6" WF 15.5 #
POST SPACING ....6'-3" O.C.
LENGTH OF INSTALLATION...100'
GROUND CONDITION ....Dry

DUMMY INJURY ....Head, neck, chest & possible internal injuries.
GUARDRAIL DAMAGE ....4 Sections damaged beyond repair. Both rails failed.
POST DAMAGE ....2 Posts damaged beyond repair. 2 Posts out of alignment.
VEHICLE DAMAGE ....Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL... 15" Before failure.

TEST NO. 9
DATE 10-15-58
VEHICLE ....Chev. 54 Sedan
SPEED ....60 MPH
IMPACT ANGLE.....28°
VEHICLE WEIGHT...3970
(W/DUMMY & INSTRUMENTATION)

Figure 11. Test data information sheets.

POST IMPACT



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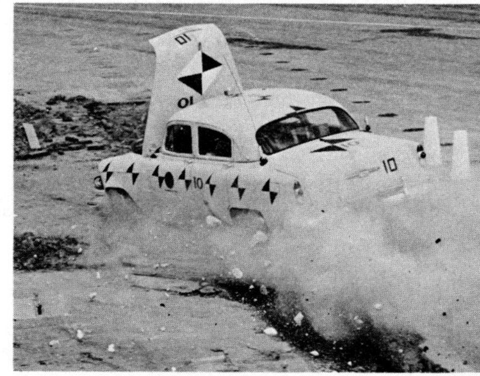
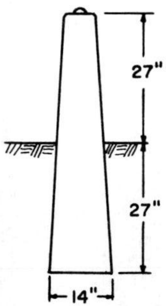
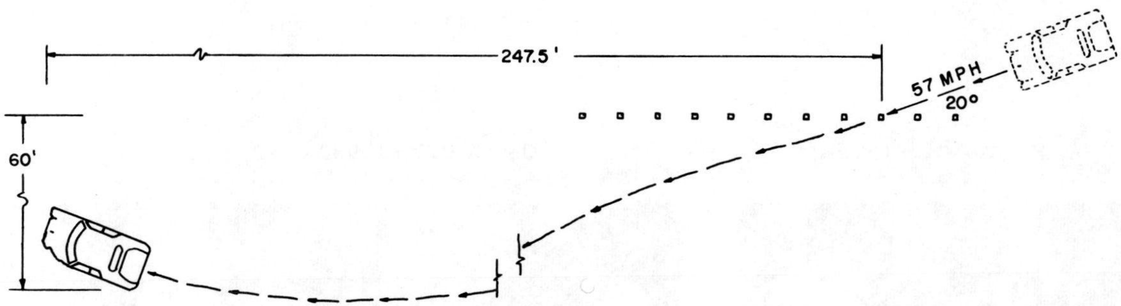


IMPACT + 25 M SEC.





GUARDRAIL ....None
BRACKET ....None
POST ....................P.C.C.
POST SPACING ....5' O.C.
LENGTH OF INSTALLATION...60'
GROUND CONDITION ....Dry

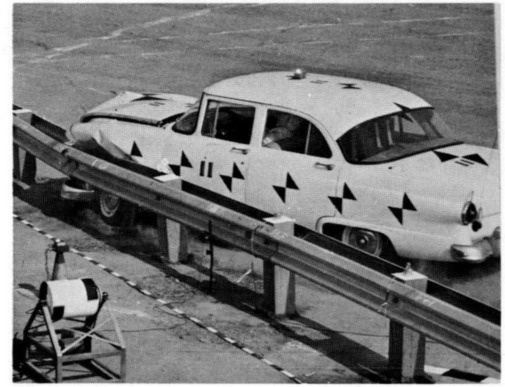
DUMMY INJURY ....Minor Bruises
GUARDRAIL DAMAGE ....No rail.
POST DAMAGE ....3 Posts demolished.
1 Post out of alignment.
VEHICLE DAMAGE ....Est. $500.
MAX. DYNAMIC DEFLECTION OF RAIL...No rail.

TEST NO. 10
DATE 10-23-58
VEHICLE ....Chev. 53 Sedan
SPEED ....57 MPH
IMPACT ANGLE.... 20°
VEHICLE WEIGHT...3970
(W/DUMMY & INSTRUMENTATION)

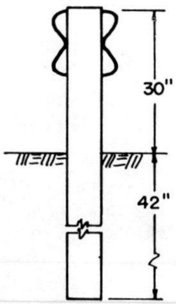
Figure 12. Test data information sheets.

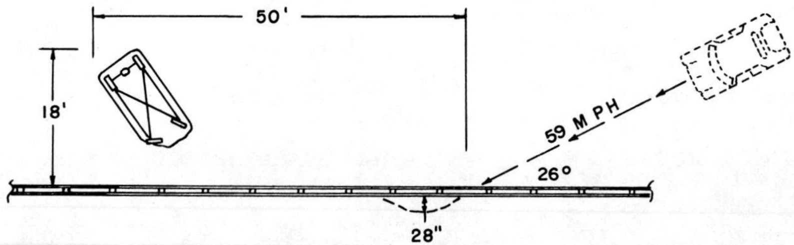
POST IMPACT

IMPACT + 450 M SEC.



IMPACT + 50 M SEC.





GUARDRAIL .... W Section
BRACKET .... None
POST .... 8x8 D.F.
POST SPACING .... 6'-3" O.C.
LENGTH OF INSTALLATION... 200'
GROUND CONDITION .... Dry

DUMMY INJURY .... Left shoulder & side, chest & internal injuries.
GUARDRAIL DAMAGE .... 6 Sections damaged beyond repair.
POST DAMAGE .... 3 Posts damaged beyond repair.
3 Posts out of alignment.
VEHICLE DAMAGE .... Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL... 40"

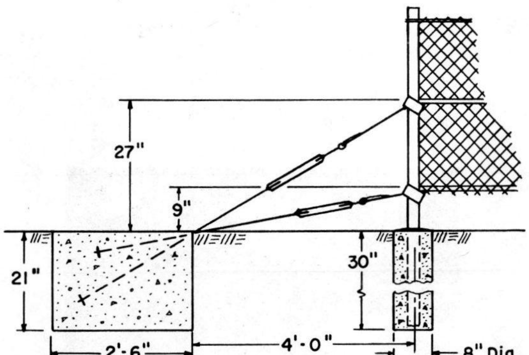
TEST NO. 11
DATE 10-30-58
VEHICLE .... Ford 55 Sedan
SPEED .... 59 MPH
IMPACT ANGLE ..... 26°
VEHICLE WEIGHT... 4050
(W/DUMMY & INSTRUMENTATION)

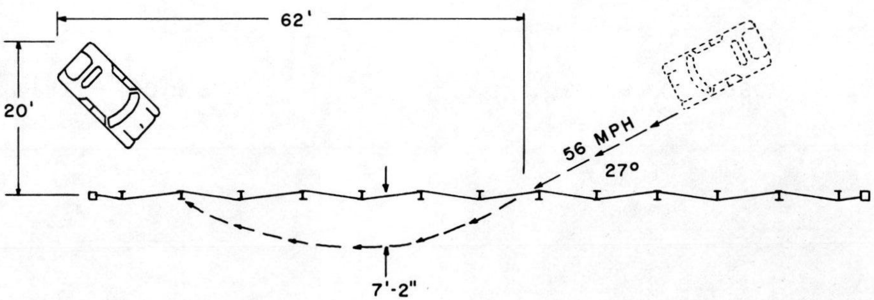
Figure 13. Test data information sheets.

POST IMPACT

IMPACT +500 M SEC.

IMPACT + 50 M SEC.



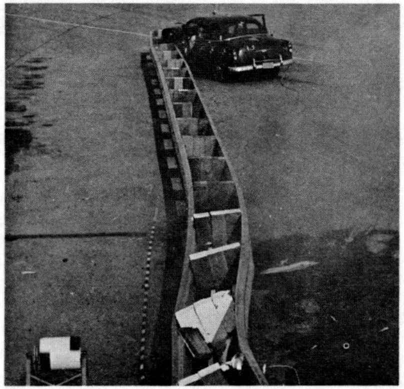


GUARDRAIL .... Chain Link Fence w/ 3/4" cables 9" & 27" above Pvmt.
POST .... 2 1/4"-4.1 # H Section Fence Post.
POST SPACING .... 8' O.C.
LENGTH OF INSTALLATION... 96'
GROUND CONDITION .... Dry

DUMMY INJURY .... Possible neck injuries & minor bruises.
GUARDRAIL DAMAGE .... 50' of Fence knocked out. No damage to Cable.
POST DAMAGE .... 7 Posts damaged beyond repair. 6 Posts Bent.
VEHICLE DAMAGE .... $ 600.
MAX. DYNAMIC DEFLECTION OF RAIL .. 7'-2"
VEHICLE DECELERATION (PEAK)..... Long. 69 G ... Transv. 154 G
DUMMY DECELERATION (PEAK)..... Long 7 G ... Transv. 9.5 G

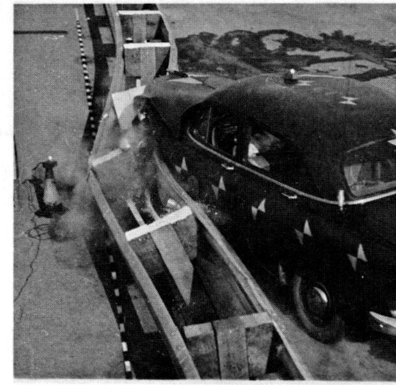
TEST NO. 12
DATE 11-13-58
VEHICLE .... Ford 52 Sedan
SPEED .... 56 MPH
IMPACT ANGLE .... 27 °
VEHICLE WEIGHT... 4002 (W/DUMMY & INSTRUMENTATION)

Figure 14. Test data information sheets.

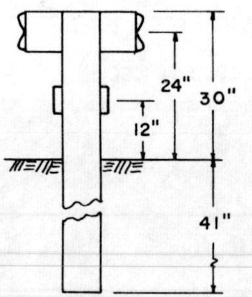


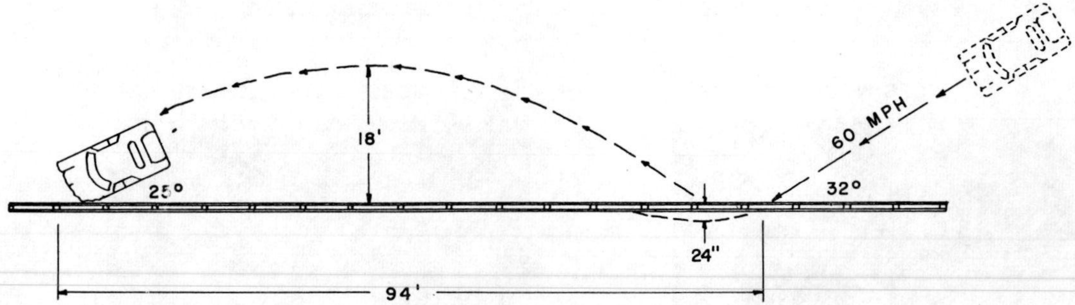
POST IMPACT

IMPACT + 500 M SEC.



IMPACT + 100 M SEC.





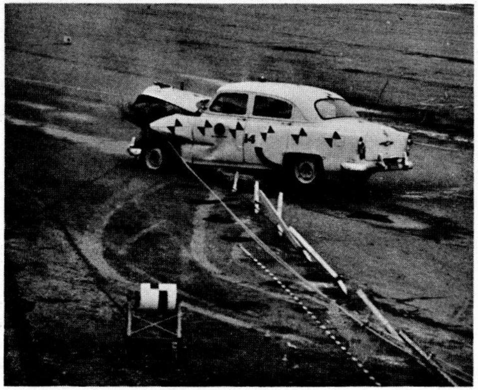
GUARDRAIL .... W Section
CHANNEL .... 6" ⊓ 8.2 #
BRACKET .... 8x8x12 D.F Block
POST .... 8x8 D.F.
POST SPACING .... 6'-3" O.C.
LENGTH OF INSTALLATION ... 125'
GROUND CONDITION .... Dry

DUMMY INJURY .... Possible left shoulder, arm & side injuries.
GUARDRAIL DAMAGE .... 4 Sections damaged beyond repair.
CHANNEL DAMAGE .... 4 Sections damaged beyond repair.
POST DAMAGE .... 3 Posts damaged beyond repair.

VEHICLE DAMAGE .... $ 900
MAX. DYNAMIC DEFLECTION OF RAIL ... 37"
VEHICLE DECELERATION (PEAK) .... Long. 104 G ... Transv. 198G
DUMMY DECELERATION (PEAK) .... Long. 16 G ... Transv. 18G

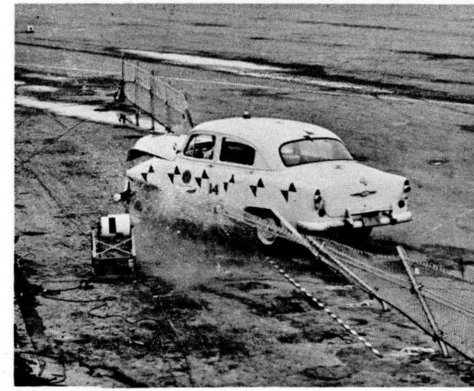
TEST NO. 13
DATE 12-18-58
VEHICLE .... Chev. 53 Sedan
SPEED .... 60 MPH
IMPACT ANGLE .... 32°
VEHICLE WEIGHT ... 4000
(W/DUMMY & INSTRUMENTATION)

Figure 15. Test data information sheets.

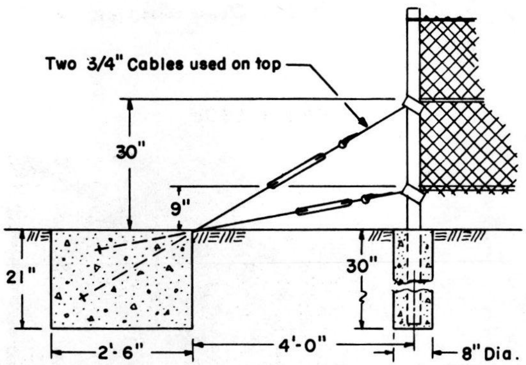


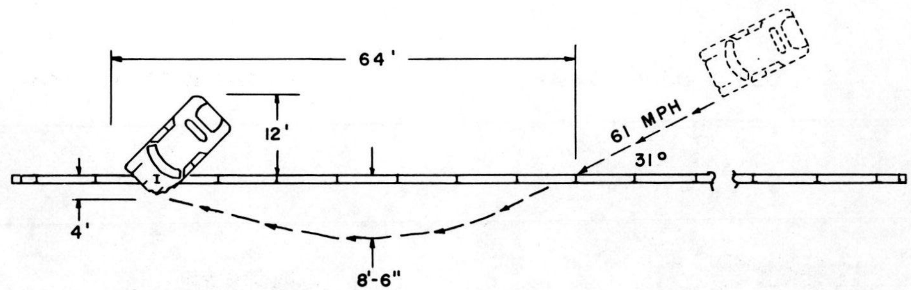
POST IMPACT

IMPACT + 400 M SEC.



IMPACT + 150 M SEC.



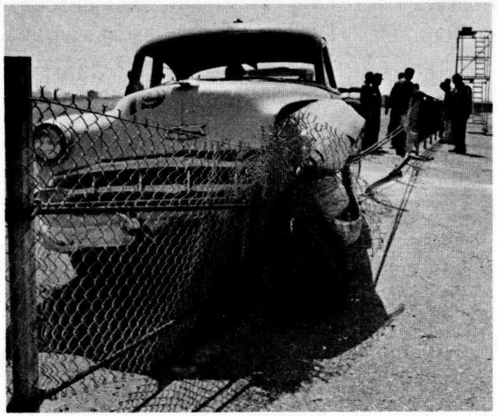


GUARDRAIL .... Chain Link Fence w/ 3/4" cables 9" & 30" above Pvmt.
POST .... 2 1/4"-4.1# H Section Fence Post.
POST SPACING .... 8' O.C.
LENGTH OF INSTALLATION ... 192'
GROUND CONDITION ...... Dry

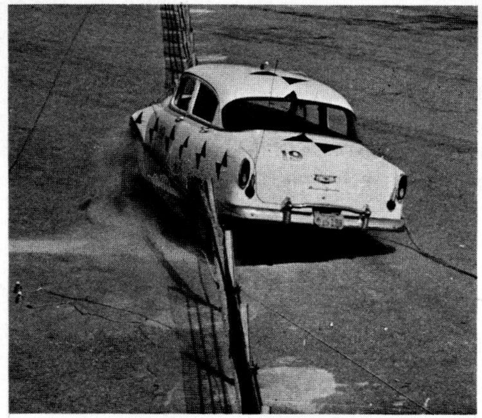
DUMMY INJURY .... Minor Bruises & possible neck injuries.
GUARDRAIL DAMAGE .... 80' of Fence knocked out. No damage to Cables.
POST DAMAGE .... 11 Posts damaged beyond repair.
VEHICLE DAMAGE .... $600.
MAX. DYNAMIC DEFLECTION OF RAIL ... 8'-6"

TEST NO. 14
DATE 12-26-58
VEHICLE .... Chev. 53 Sedan
SPEED .... 61 MPH
IMPACT ANGLE .... 31 °
VEHICLE WEIGHT ... 4000 (W/DUMMY & INSTRUMENTATION)

Figure 16. Test data information sheets.

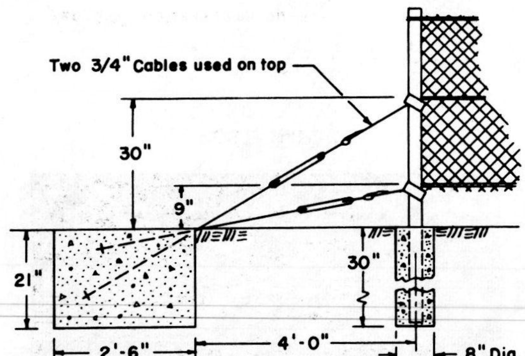


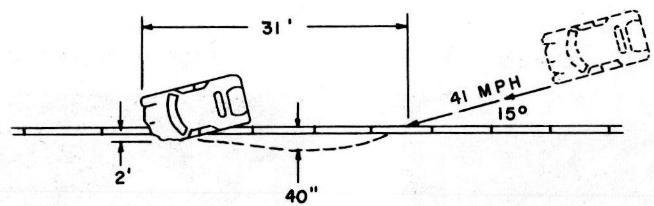
POST IMPACT



IMPACT + 350 M SEC.

IMPACT + 100 M SEC.



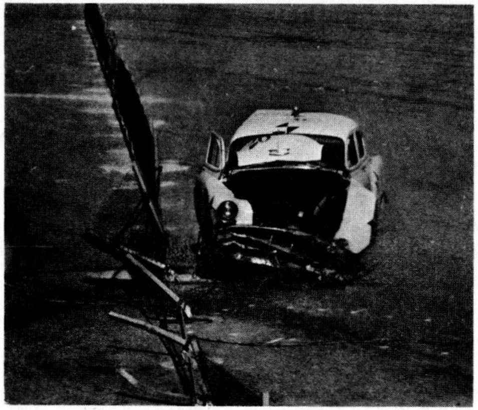


GUARDRAIL .... 36" Chain Link Fence w/3/4" cables 9" & 30" above pvmt.
POST .... 2 1/4"-4.1 # H Section Fence Post
POST SPACING .... 8' O.C.
LENGTH OF INSTALLATION ... 400'
GROUND CONDITION .... Dry

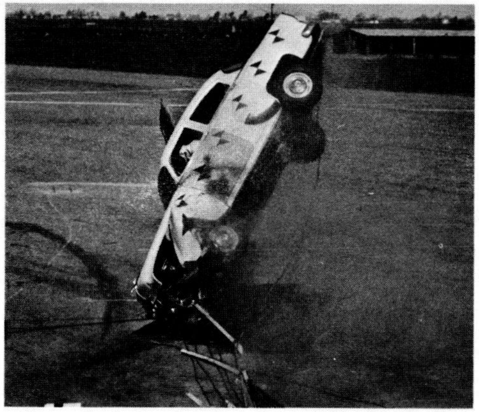
DUMMY INJURY .... Minor Bruises
GUARDRAIL DAMAGE .... 35' of Fence knocked out. No damage to cables.
POST DAMAGE .... 4 Posts damaged beyond repair.
VEHICLE DAMAGE .... $ 400.
MAX. DYNAMIC DEFLECTION OF RAIL ... 40"
VEHICLE DECELERATION (PEAK) ... Long. 55 G ... Transv. 22 G
DUMMY DECELERATION (PEAK) ..... Long. 3 G ... Transv. 2 G

TEST NO 19
DATE 3-5-59
VEHICLE .... Chev. 53 Sedan
SPEED .... 41 MPH
IMPACT ANGLE ..... 15°
VEHICLE WEIGHT .... 3700 (W/DUMMY & INSTRUMENTATION)

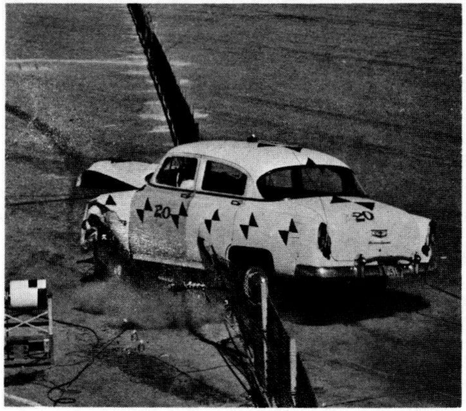
Figure 17. Test data information sheets.



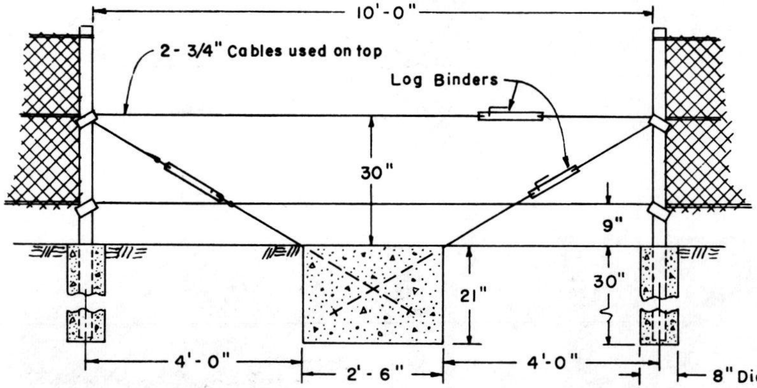
POST IMPACT

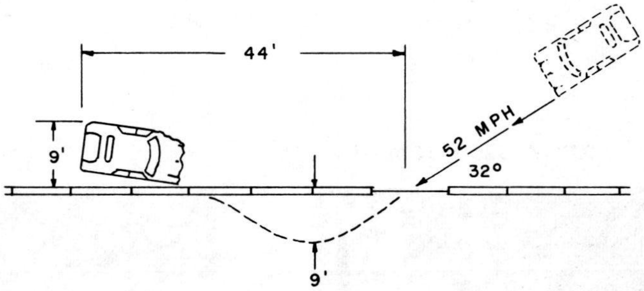


IMPACT + 1000M SEC.



IMPACT + 150 M SEC.





GUARDRAIL .... 36" Chain Link Fence w/ 3/4" cables 9" & 30" above pvmt. Impact point at center of emergency crossover.

POST .... 2 1/4"-4.1 # H Section Fence Post

POST SPACING .... 8' O.C.

LENGTH OF INSTALLATION ... 400'

GROUND CONDITION ..... Dry

DUMMY INJURY .... Severe Chest & Internal Injuries

GUARDRAIL DAMAGE .... 24' of Fence knocked out. 10' of Cable damaged.

POST DAMAGE .... 4 Posts damaged beyond repair. 2 Posts Bent.

VEHICLE DAMAGE .... Total Loss

MAX. DYNAMIC DEFLECTION OF RAIL .. 9'

VEHICLE DECELERATION (PEAK) .... Long. 53 G ... Transv. 34 G

DUMMY DECELERATION (PEAK).... Long. NG ... Transv. 6 G

TEST NO. 20

DATE 3-10-59

VEHICLE .... Chev. 54 Sedan

SPEED .... 52 MPH

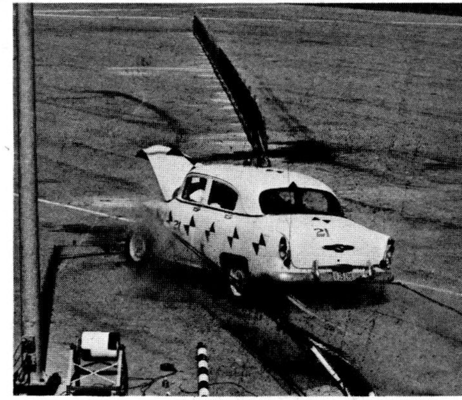
IMPACT ANGLE .... 32°

VEHICLE WEIGHT ... 3700 (W/DUMMY & INSTRUMENTATION)

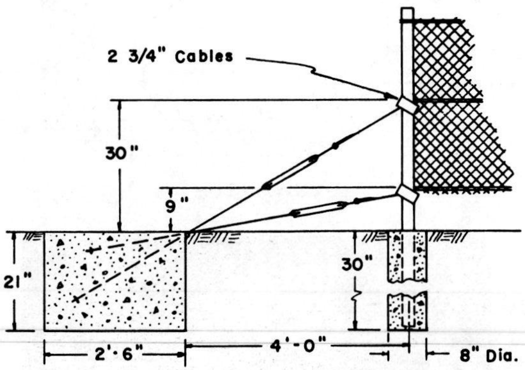
Figure 18. Test data information sheets.

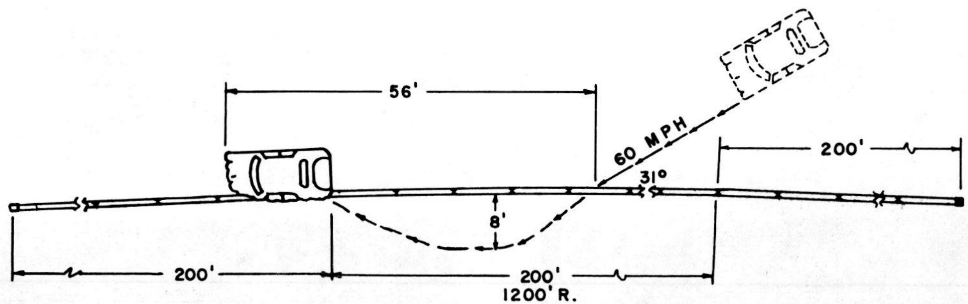
POST IMPACT

IMPACT + 750 M SEC.



IMPACT + 225 M SEC.



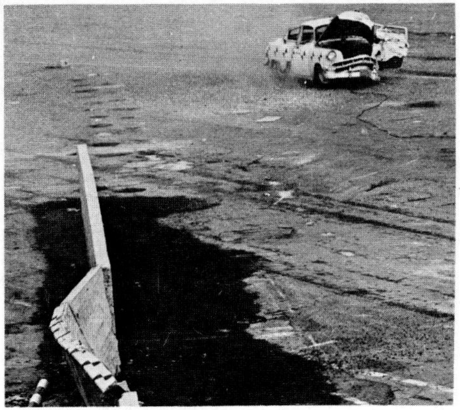


GUARDRAIL . . . . 36" Chain Link Fence w/2 3/4" cables 9" & 30" above pvmt.
POST . . . . 2 1/4" - 4.1 # H Section Fence Post.
POST SPACING . . . . 8' O.C.
LENGTH OF INSTALLATION. . . 600'
GROUND CONDITION . . . . Wet

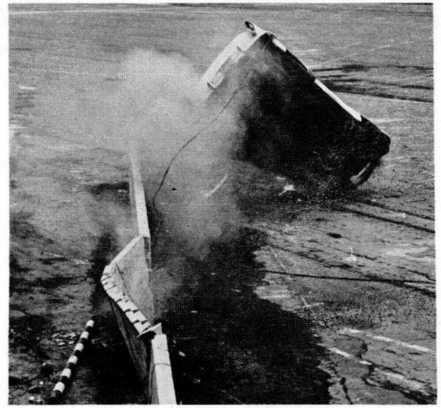
DUMMY INJURY . . . . Scalp laceration, possible chest injuries.
GUARDRAIL DAMAGE . . . . 56' of fence knocked out. No damage to cables.
POST DAMAGE . . . . 12 posts damaged beyond repair.
VEHICLE DAMAGE . . . . Total loss.
MAX. DYNAMIC DEFLECTION OF RAIL . . . 8'
VEHICLE DECELERATION (PEAK) . . . Long. NG . . . Transv. NG
DUMMY DECELERATION (PEAK) . . . . . Long. 6G . . . Transv. 4G

TEST NO. 21
DATE 3-20-59
VEHICLE . . . . Chev. 53 Sedan
SPEED . . . . 60 MPH
IMPACT ANGLE . . . 31°
VEHICLE WEIGHT . . . 3850 (W/ DUMMY & INSTRUMENTATION)

Figure 19. Test data information sheets.

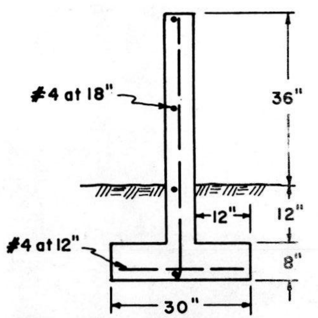


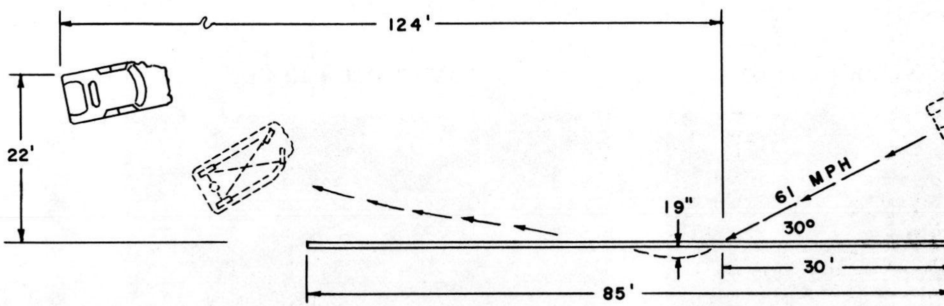
POST IMPACT



IMPACT + 750 M SEC.

IMPACT + 150 M SEC.





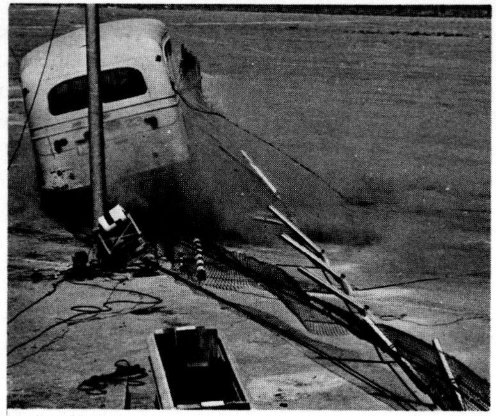
GUARDRAIL .... 36" Conc. Wall, 6" Thick.
REINFORCING BAR SPACING.. #4 at 12" Vert. #4 at 18" Horiz.
LENGTH OF INSTALLATION ... 85'
GROUND CONDITION ...... Wet

DUMMY INJURY .... Concussion, severe shoulder & chest injuries.
GUARDRAIL DAMAGE .... 20' Wall broken
VEHICLE DAMAGE .... Total loss
MAX. DYNAMIC DEFLECTION OF RAIL.. 22"
VEHICLE DECELERATION (PEAK) ..... Long. 112G ... Transv. 72G
DUMMY DECELERATION (PEAK) .... Long. 21G ... Transv. 25G

TEST NO. 22
DATE 3-30-59
VEHICLE .... Chev. 53 Sedan
SPEED .... 61 MPH
IMPACT ANGLE ... 30°
VEHICLE WEIGHT ... 3850
(W/DUMMY & INSTRUMENTATION)

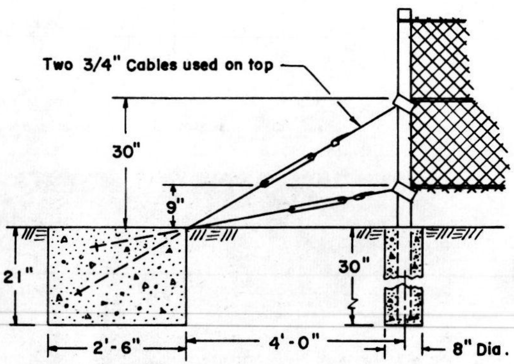
Figure 20. Test data information sheets.

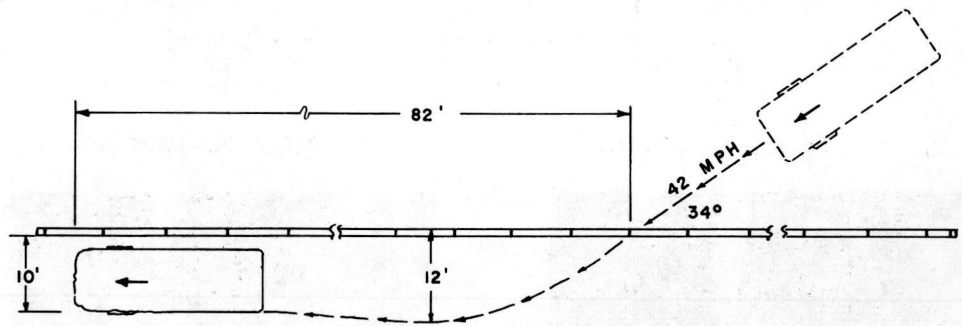
POST IMPACT



IMPACT + 900 M SEC.

IMPACT + 100 M SEC.



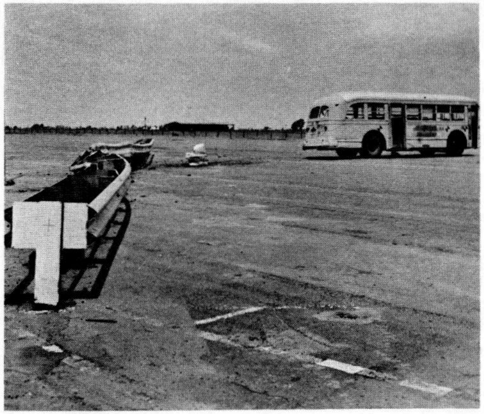


GUARDRAIL ....36" Chain Link fence w/ 3/4" cables 9" & 30" above pvmt.
POST ....2 1/4"-4.1# H Section Fence Post.
POST SPACING .... 8' O.C.
LENGTH OF INSTALLATION... 304'
GROUND CONDITION ....Dry

DUMMY INJURY .... Left shoulder injuries.
GUARDRAIL DAMAGE .... 90' of fence knocked out. No damage to cables.
POST DAMAGE .... 23 Posts damaged beyond repair.
VEHICLE DAMAGE .... $ 1200
MAX. DYNAMIC DEFLECTION OF RAIL . .. 12'
DUMMY DECELERATION (PEAK) .... Long. 2.8 G .. Transv. 9.3 G

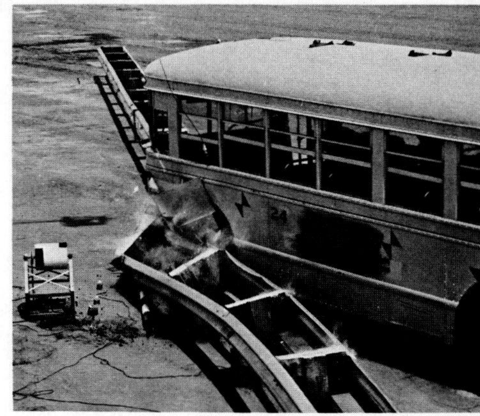
TEST NO. 23
DATE 4-21-59
VEHICLE .... 1937-40 pass. Bus
SPEED........... 42 MPH
IMPACT ANGLE ..... 34°
VEHICLE WEIGHT ...17,500
(W/DUMMY & INSTRUMENTATION)

Figure 21. Test data information sheets.

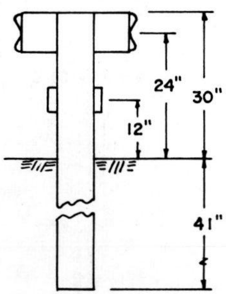


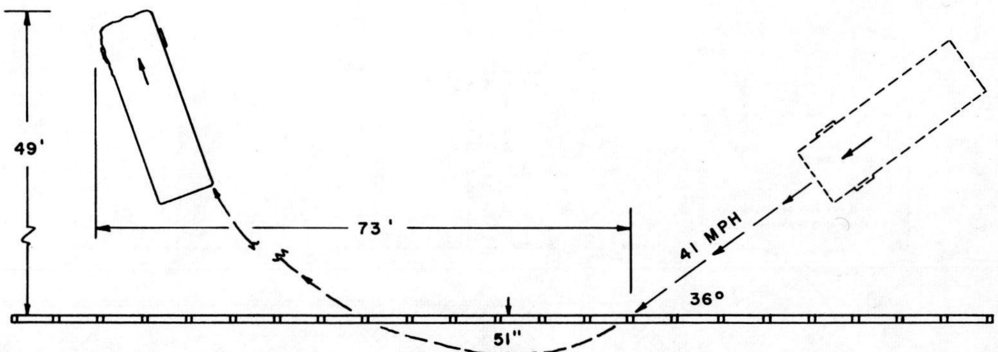
POST IMPACT

IMPACT + 800 M SEC.



IMPACT + 150 M SEC.





GUARDRAIL	W Section	DUMMY INJURY	Critical head, neck & shoulder injuries; severe body bruises.	TEST NO.	24
CHANNEL	6" ⊓ 8.2 #	GUARDRAIL DAMAGE	7 Sections damaged beyond repair.	DATE	4-30-59
BRACKET	8x8x12 D.F. Block	CHANNEL DAMAGE	4 Damaged beyond repair.	VEHICLE	1937-40 pass. Bus.
POST	8 x 8 D.F.	POST DAMAGE	5 Damaged beyond repair.	SPEED	41 MPH
POST SPACING	6'-3" O.C.	VEHICLE DAMAGE	$ 1,500	IMPACT ANGLE	36°
LENGTH OF INSTALLATION	125'	MAX. DYNAMIC DEFLECTION OF RAIL	58"	VEHICLE WEIGHT	17,500
GROUND CONDITION	Dry	DUMMY DECELERATION (PEAK)	Long. 6G ... Transv. 25 G	(W/DUMMY & INSTRUMENTATION)	

Figure 22. Test data information sheets.

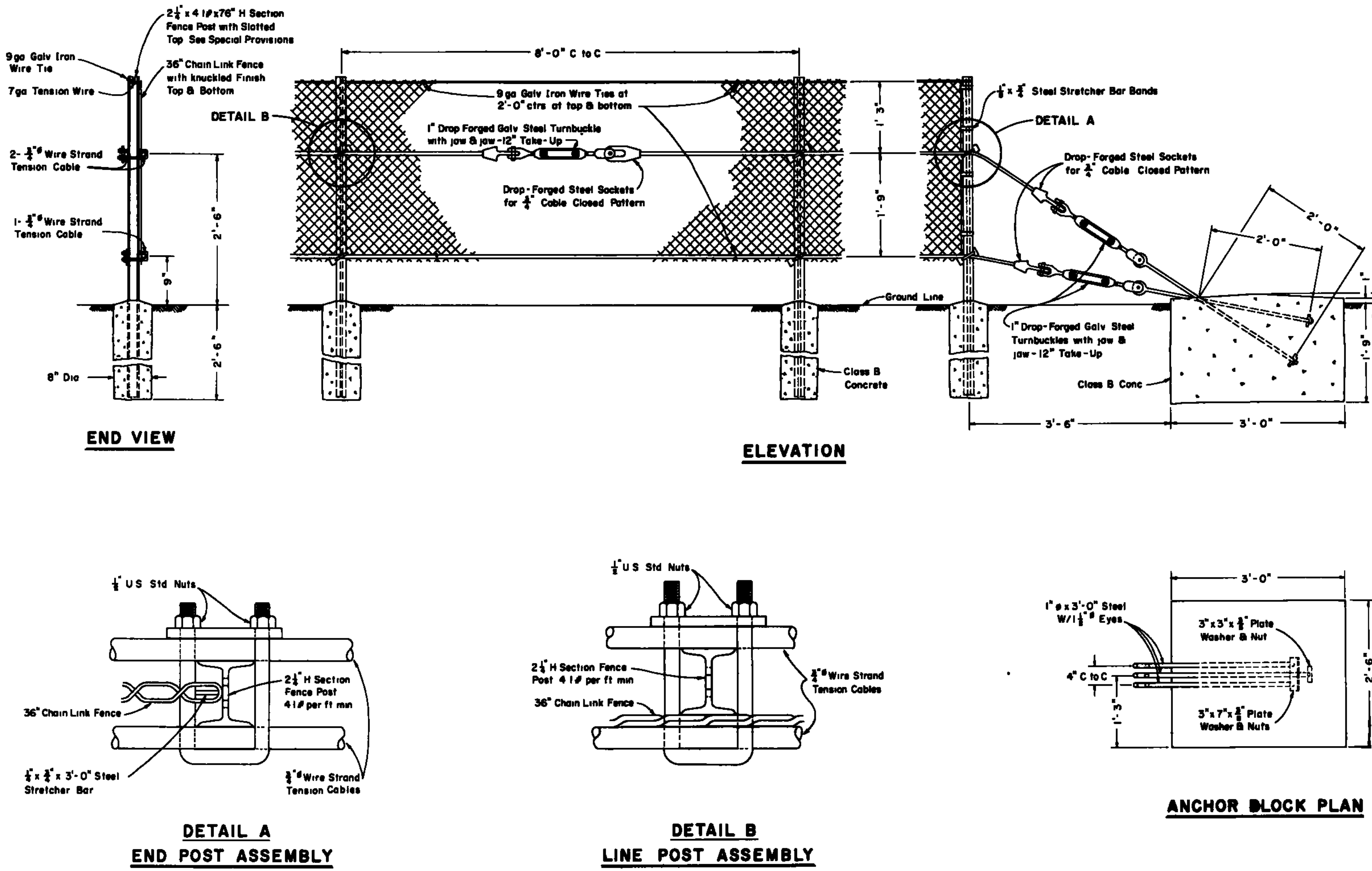


Figure 23. Cable-chain link barrier.

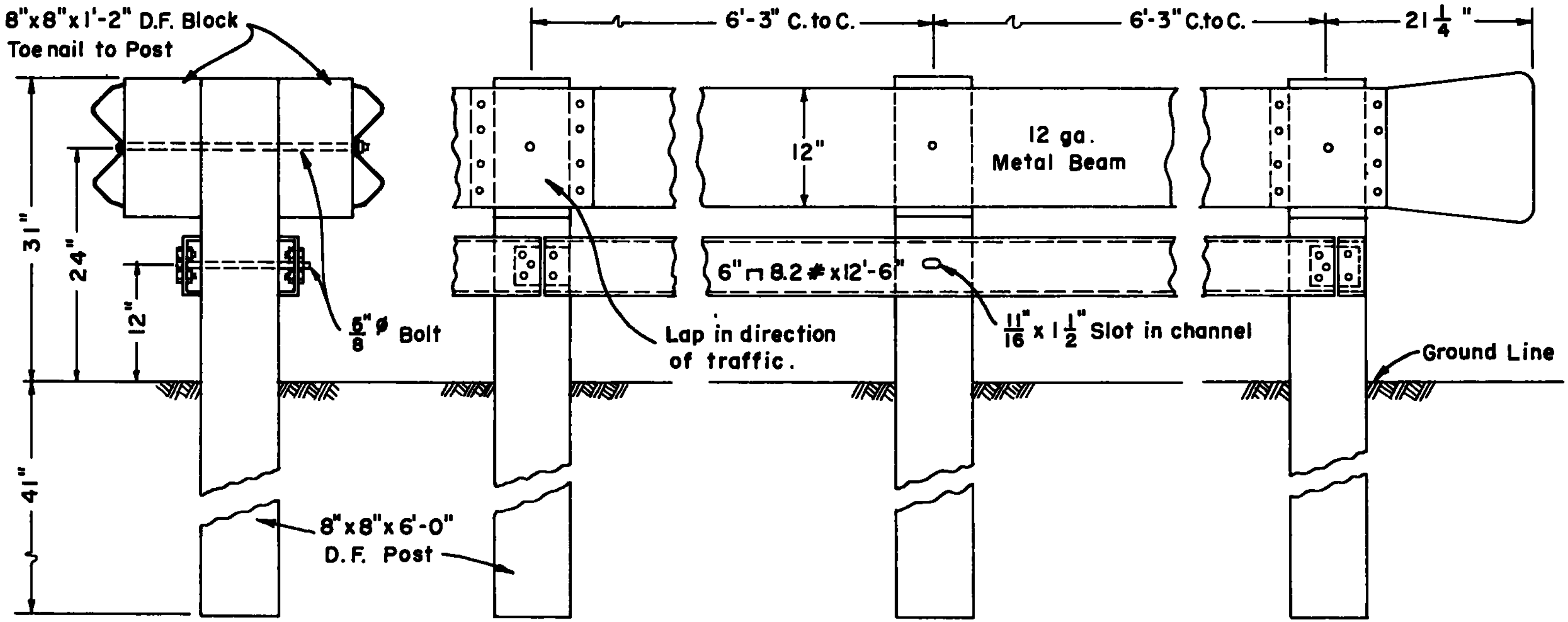


Figure 24. Blocked out metal beam barrier.

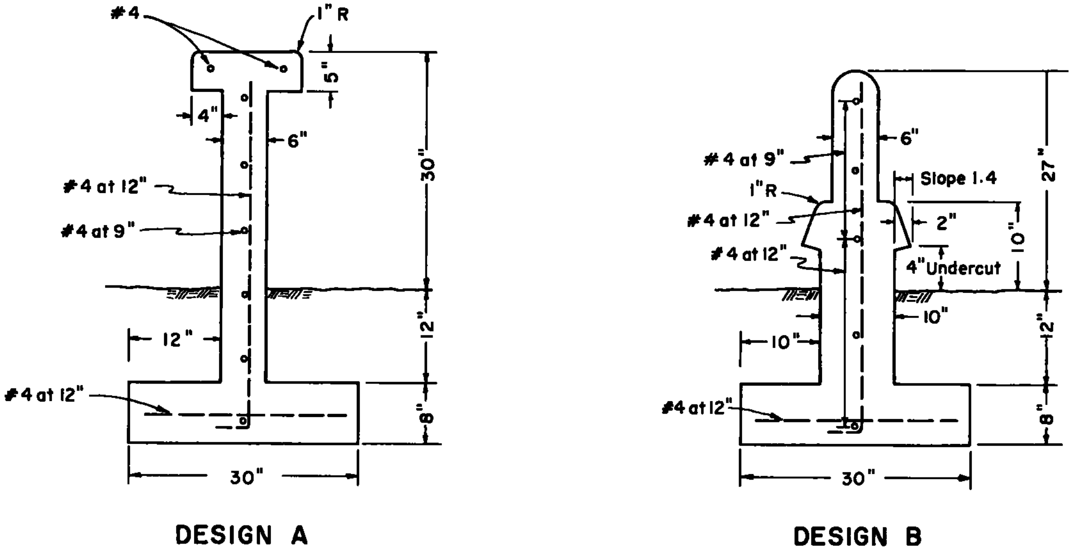


Figure 25. Concrete wall barrier.

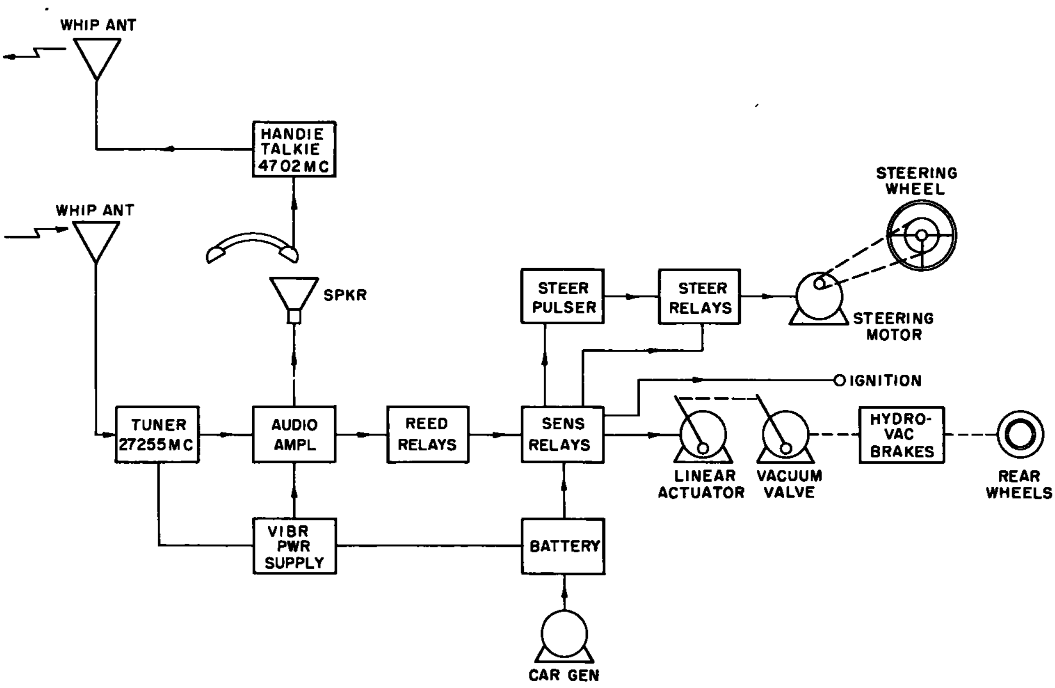


Figure 26. Block diagram—crash car remote controls.

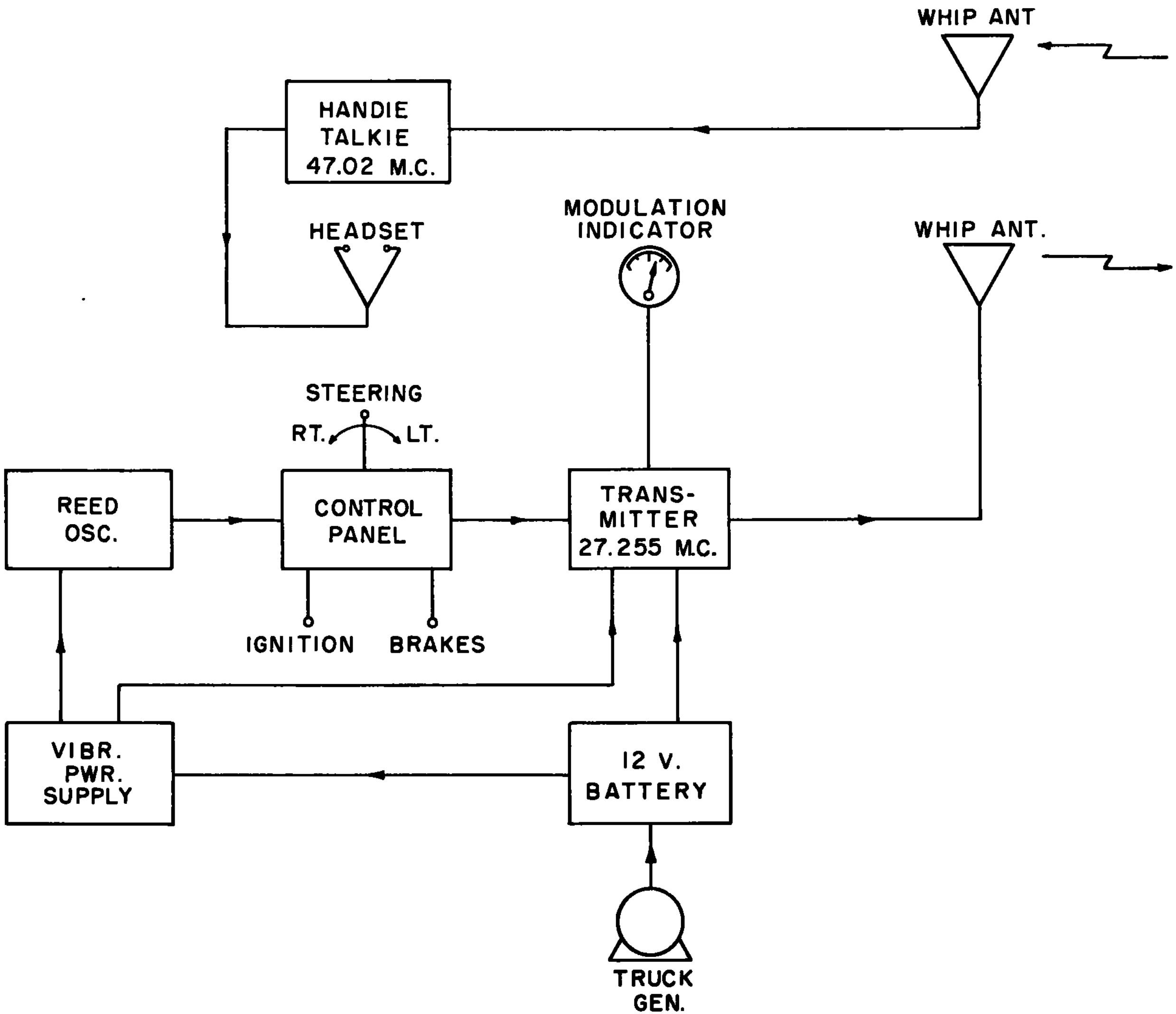


Figure 27. Block diagram—control car radio control.

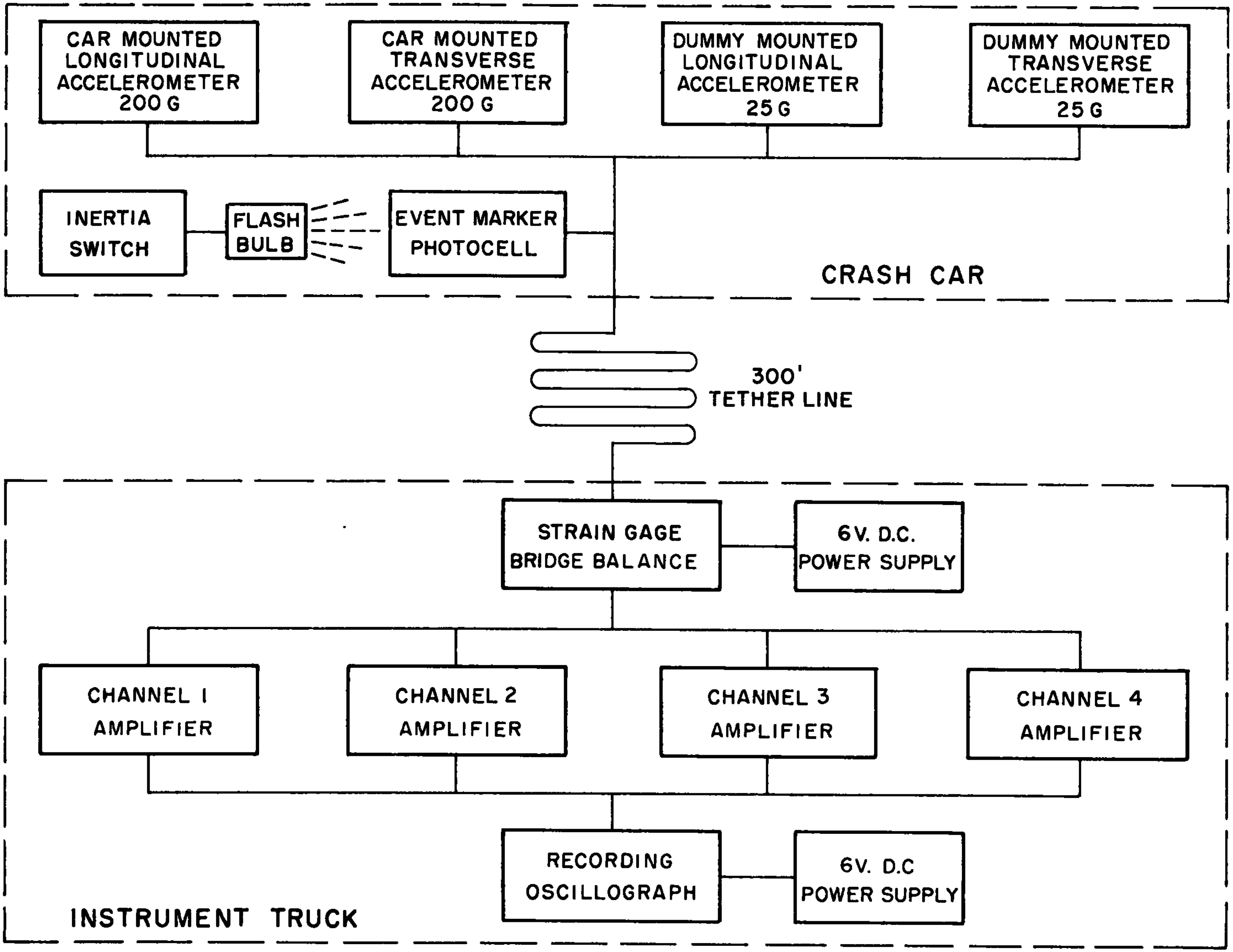


Figure 28. Deceleration instrumentation.

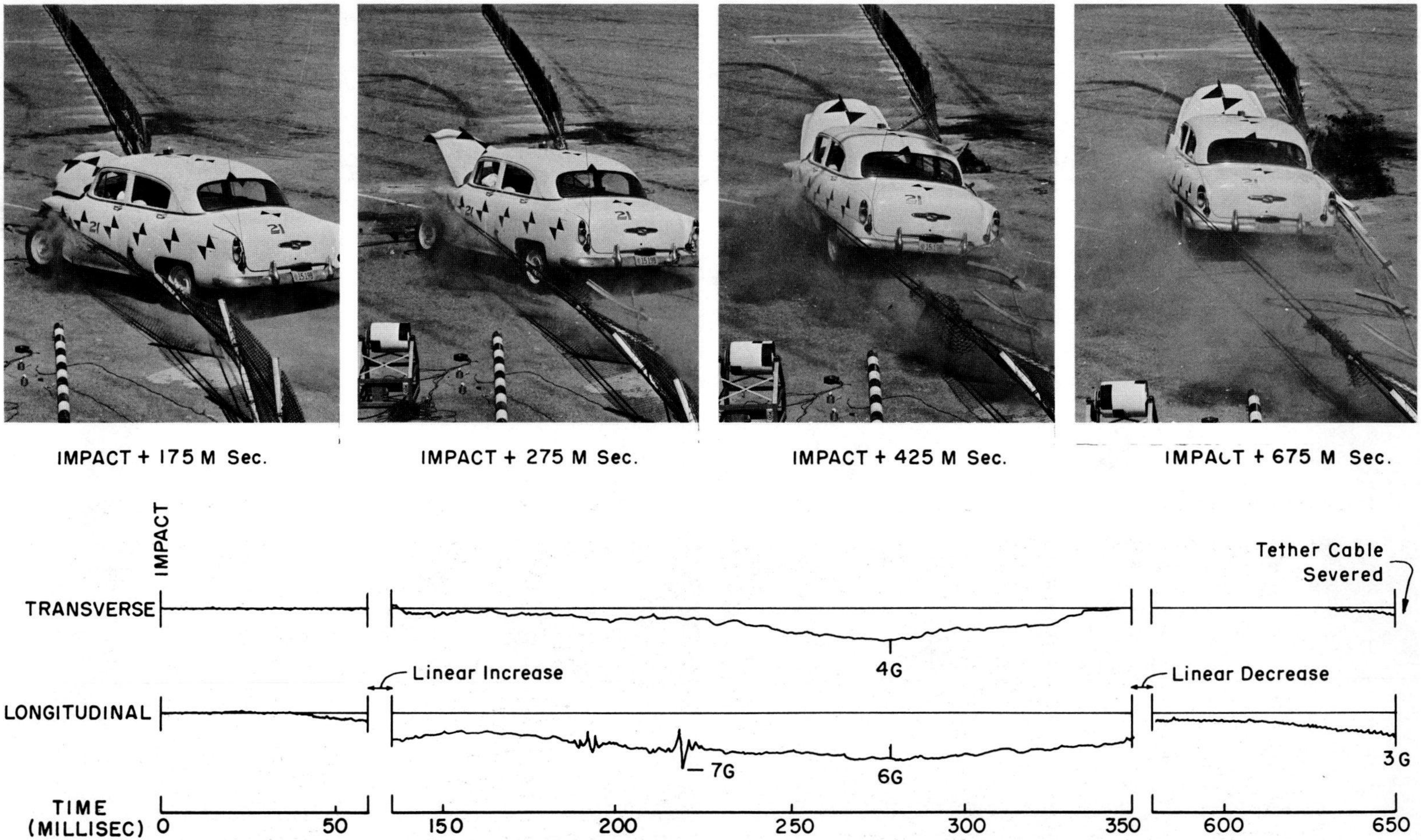


Figure 29. Deceleration record of cable-chain link (Test 21) barrier.

IMPACT + 200 M Sec. IMPACT + 250 M Sec. IMPACT + 800 M Sec. IMPACT + 3050 M Sec.

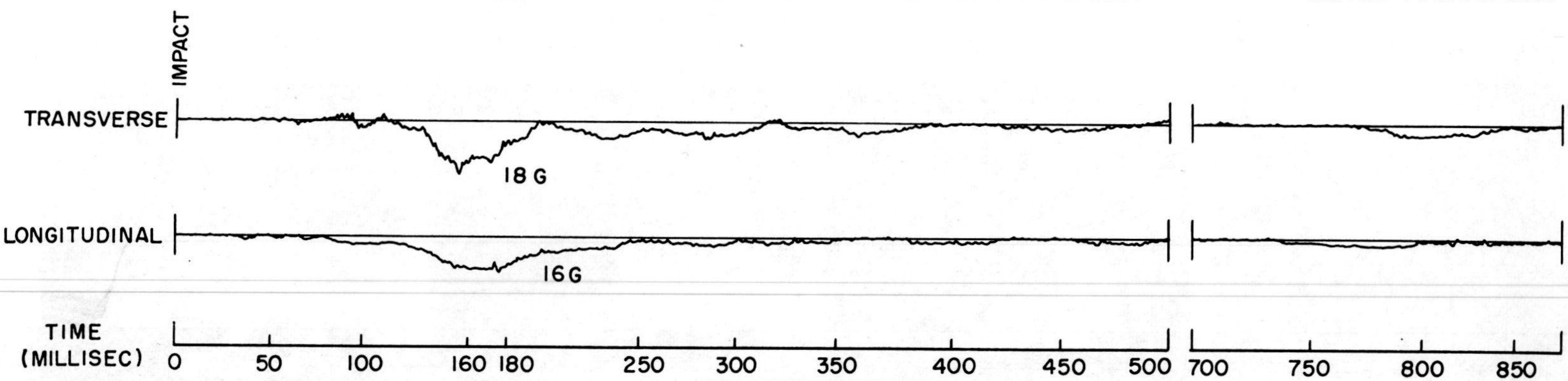


Figure 30. Deceleration record of blocked out metal beam (Test 13) barrier.

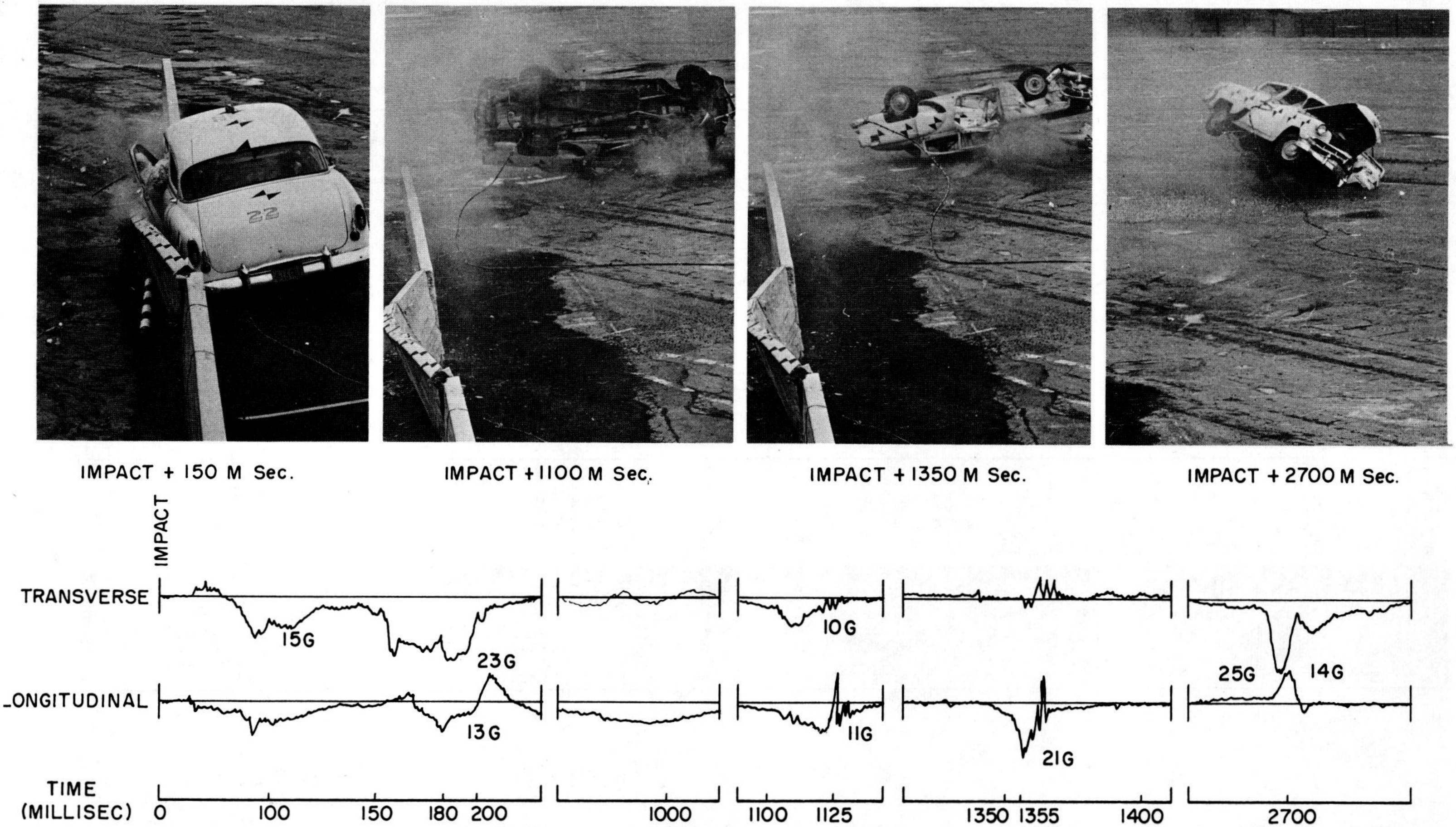
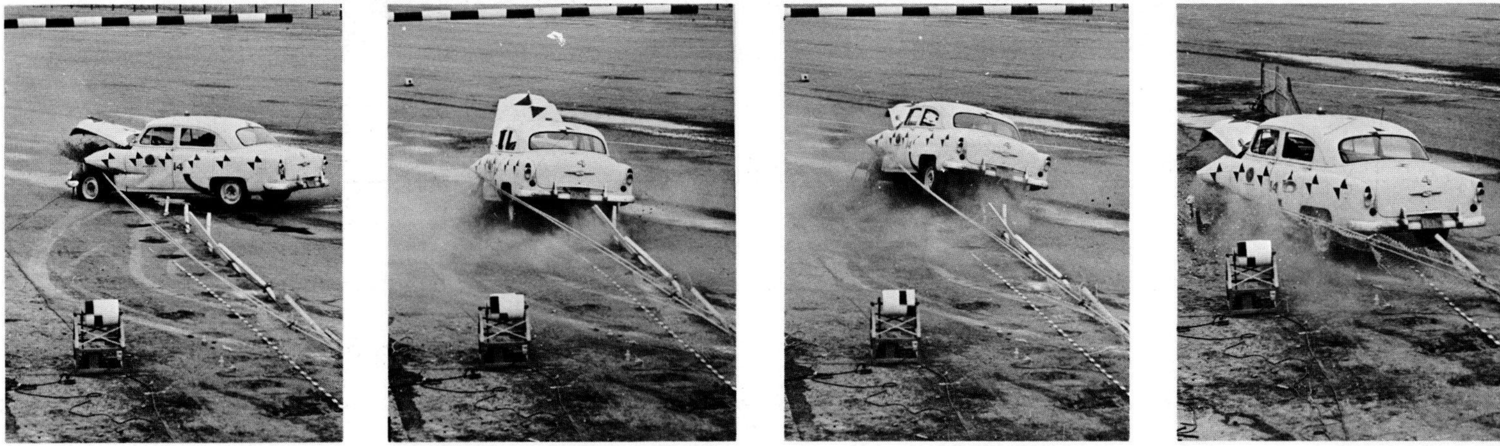


Figure 31. Deceleration record of concrete wall (Test 22) barrier.



400 ms | 600 ms | 1150 ms | Post Impact

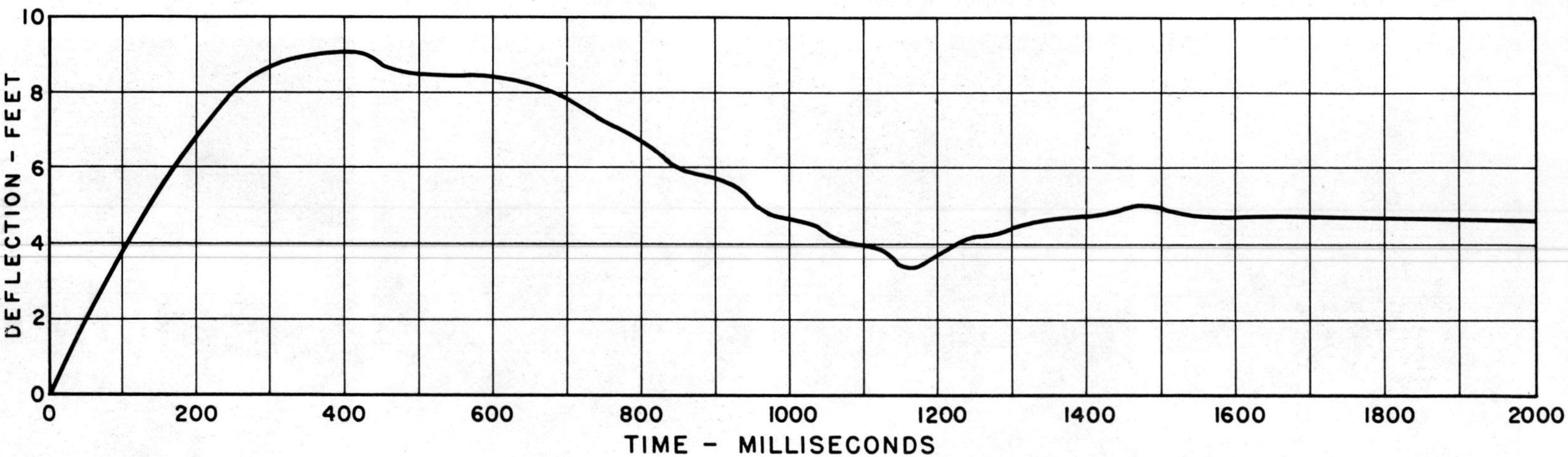
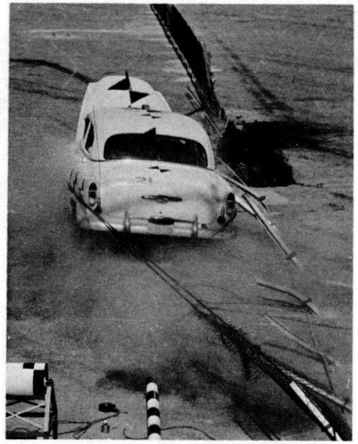


Figure 32. Time-deflection graph cable-chain link barrier (Test 14).

300 ms



800 ms

1000 ms

Post Impact

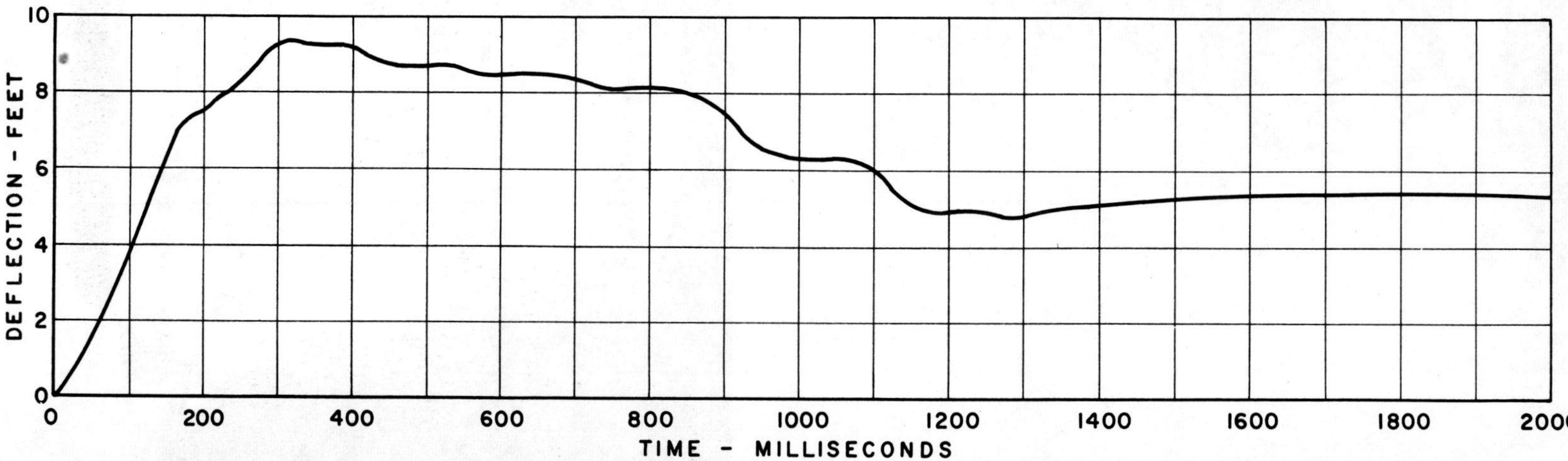
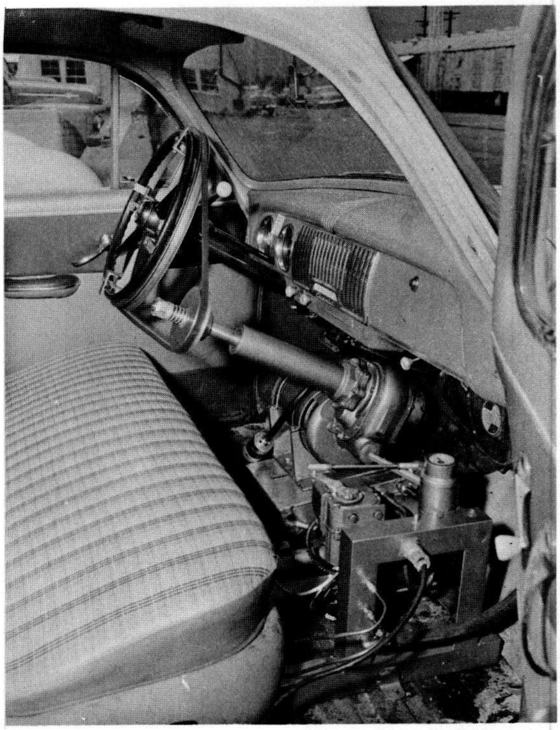


Figure 33. Time-deflection graph cable-chain link barrier (Test 21).



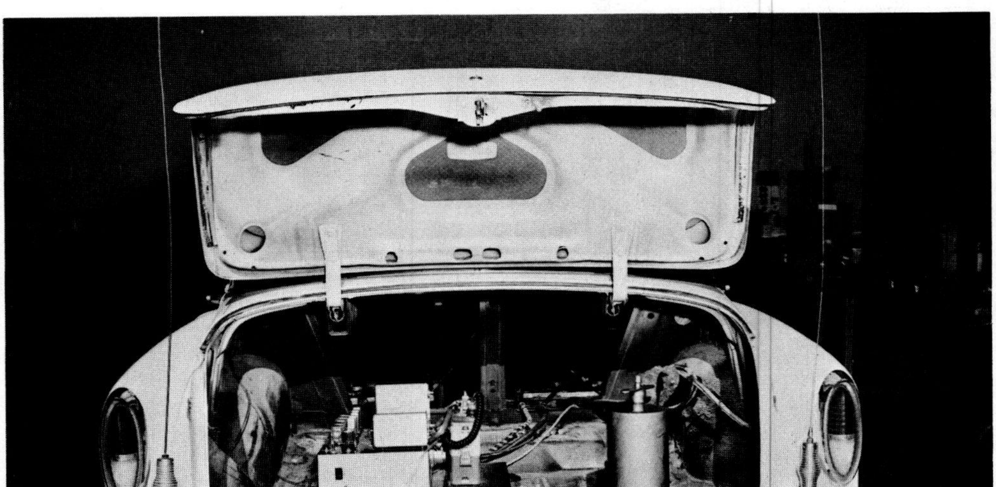


Figure 34. Photographs of crash car instruments.

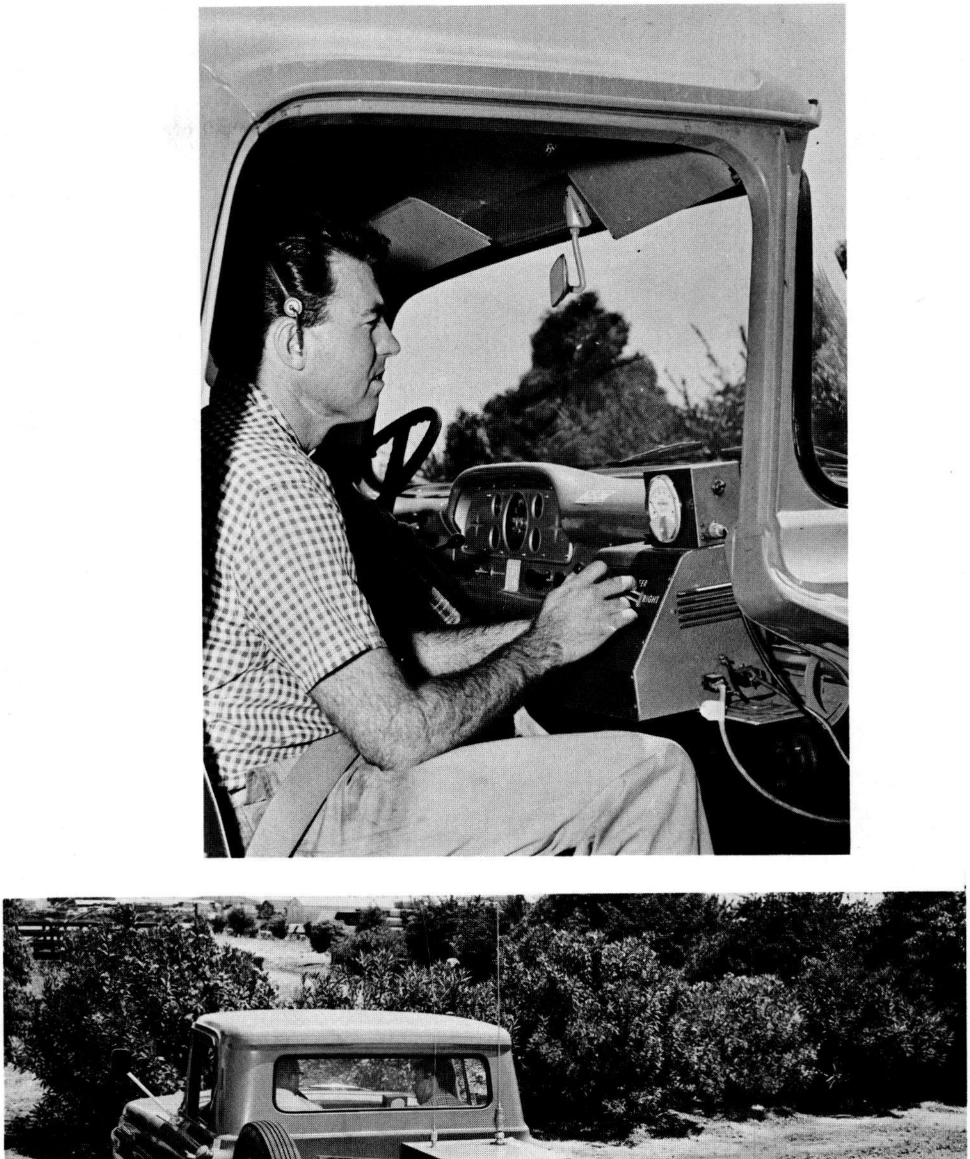


Figure 35. Photographs of control car instruments.