RI-34-2

T. F. Willis

MISSOURI
STATE HIGHWAY DEPARTMENT

TESTS OF VARIOUS HIGHWAY GUARD RAILS

JEFFERSON CITY, MO.

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ARTHUR T. NELSON, Vice-Chairman
H. B. PYLE, Member
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CONDUCTED BY

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INTRODUCTION

As the main system of highways in Missouri nears completion, more money will probably be expended for the purpose of making the highways safer. One of the methods for accomplishing this purpose is the installation of guard rails at points where serious damage to car or occupants might result from a car leaving the roadway. There are several types of guard rail and numerous adaptations of these types manufactured; all of which have been used to greater or less extent by some of the states. Some of these guard rails have been tested by one or more agencies but others, including four manufactured in this state, have not been previously tested.

With the idea of supplementing the tests of other agencies and developing information about the untested guard rails, the Missouri State Highway Department performed the tests described in this report. The original series of impact tests (Test numbers 1 to 16) was made during June 1934 and this was followed by a supplementary series (Test numbers 18 to 24) in October 1934.

SCOPE, TEST CONDITIONS AND METHODS

Tests were made on the following guard rails:

1. Wire Rope, two strands
2. Page "Traffic Tape", two strands on Russell spring clip post mountings.
3. "Tyton" plate rail
4. "Flex-Beam", plate rail
5. "Tuthill", plate rail
6. "Page Traffic Tape", four strands on Page Type Post Mountings.
7. "Page Traffic Tape", two strands on Page Type Post Mountings.
8. "Truscon", plate rail
9. "Wej-Lock", plate rail
10. "Empire", plate rail
11. "Bente Phillips", plate rail
12. "Resiliflex", plate rail
13. "Glideplate", plate rail
15. Russell Plate and one strand wire rope
16. Wire Rope, two strands
18. Wire Rope, two strands (with light metal ties at center of each panel)
19. "Economy Products", plate rail
20. "Chain Link" fence
21. "Pittsburgh Safety Highway Guard"
22. "Pittsburgh Safety Highway Guard"
23. "Flex-Beam", plate rail
24. "Pittsburgh Safety Highway Guard"

The impact test consisted of striking a guard rail with an automobile at an angle of twenty degrees and a car speed of 32 to 35 miles per hour. The car attained its speed by coasting freely down an inclined runway.

The installation of each guard rail was supervised by the manufacturer's representative who also observed the test. Each installation was approximately one hundred feet long and so located, with respect to the foot of the runway, that initial contact between the rail and the right front wheel of the car occurred midway between the two center posts of the

Footnote: H. C. Medley and M. E. DeReus were the field engineers in charge of these tests and this report was prepared by F. V. Reagel, T. F. Willis and M. E. DeReus.

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installation. The guard rails were all erected along the same line which was on a vertical curve connecting a minus 12.8 per cent grade with a minus 2.6 per cent grade, the break in grade being about two feet uphill from the intended point of impact. While this vertical culve is sharper than any ordinarily found on highways, it was used with the idea that any rail which could be properly installed on it would be adaptable to any similar but less severe conditions which might be encountered in actual practice.

The cars used in these tests were, with two exceptions, Cadillac sedans or four passenger coupes weighing from 4800 pounds to 5100 pounds. The lighter cars were loaded with sand bags in sufficient quantities so that all cars, when used in the test, weighed 5100 pounds. In one test a taxicab of unknown make was used; and in another test, the purpose of which was to observe an impact with a light car, a Model A Ford was used. All of the cars were rather old but could and did run under their own power, and were in fair to good condition as far as the running gear, frame, axles and springs were concerned.

In addition to the impact tests, laboratory tests for the strength and chemical composition of the various rails are now being made. These will be reported as an appendix to this report at a later date.

During and after each impact test the following observations were made and each recorded.

1. Ease of erection of rail
2. Weight of car
3. Condition of car prior to test
4. Speed of car at impact
5. Path of car after impact of car with rail
6. Damage to rail
7. Damage to car
8. Repairs to rail necessary to put it in serviceable condition
9. Repairs to rail necessary to restore it to its original condition
10. Photographs were made of
    (a) Car before test
    (b) Rail before test
    (c) Impact of car with rail
    (d) Car after test
    (e) Rail after test
11. Moving pictures were taken
    (a) Front view, regular camera speed
    (b) Rear view, regular camera speed
    (c) Rear view, slow motion

The speed of the car was determined by measuring the time necessary for the car to traverse a distance of 13.2 feet just prior to impact with the rail. The timing device consisted of an electrically maintained tuning fork (100 vibrations per second), the vibrations of which were recorded on smoked, glazed paper mounted on the drum of a kymograph. Also recorded on the paper was the straight line mark of a stylus which could be displaced vertically by a solenoid in an electrical circuit with each of two switches on the runway. The last switch was located so that as the rear wheel of the car closed it the front end of the car was within a few inches of the rail, and the first switch was 13.2 feet further up the runway. When the wheels of the car passed over either switch, the stylus made a vertical jog in its record on the kymograph. By counting the vibrations the tuning fork registered between the two jogs made by a wheel of the car passing over the two switches, the time required for the car to travel 13.2 feet was determined. This time was determined for both a front wheel and rear wheel in each test and an average taken for the calculation of the car speed. The front wheel time was always a little greater than the rear wheel time, the difference indicating a car acceler-

ation of 2.7 feet per second per second. The speed determinations were accurate to ± 0.25 mile per hour.

An auxiliary and checking timing device consisted of a cycle counter connected to a sixty cycle alternating current and two runway switches. Closing the first switch started the counter and the second stopped it. In all cases the two methods of measuring speed checked within 0.5 mile per hour.

DISCUSSION OF RESULTS OF IMPACT TESTS

It is impossible to adequately describe, and difficult to fully interpret, the results of the impact tests through a verbal exposition and a compilation of data and still photographs. Probably the most important record made of these tests, the motion pictures, cannot be included in the report. After repeated observation of these, the attempt has been made to translate the impressions created by these pictures into the description of the test. However, a study of the motion pictures is recommended to anyone particularly interested in the tests.

Except for two tests (No. 7 and No. 23), the cars used for the tests were second-hand Cadillacs. These Cadillacs, which were models of about 1927, appeared to be exceptionally uniform in construction and ruggedness as they appeared upon the test field. In several of the tests the damage to the car was slight, in which event the car was repaired and used again. No doubt the car was strained in any test and was more susceptible to damage when reused in later tests. The damage inflicted on a car by any rail must be considered in this light.

It also appears probable that some of the cars had individual characteristics which influenced their behavior during the tests. The car used for tests No. 3, No. 4 and No. 8, in every case circled quite sharply to the left at some point in its course after impacting the rail. Another car was used for tests No. 9, No. 10, No. 12, No. 13 and No. 18. In test No. 9 the car ran through the rail and then circled slightly to the right. In test No. 10 and No. 12 the car circled quite sharply to the right after impacting and rebounding from the rail. However, in test No. 13 the car circled to the left after impacting the rail. The difference might have been due to a change in the front wheel alignment. On the other hand, the action of the rails might have been responsible. In this connection it should be noted that in tests No. 10 and No. 12 the rear end of the car rebounded quite forcibly from the rail. In no other test did the rear end of the car rebound as much as in these tests, and in no other tests did the car circle sharply to the right after impacting and rebounding from the rail.

The concensus of engineering opinion is that the primary function of a guard rail is to prevent a car from leaving the roadway and in so doing, cause a minimum of damage to car and occupants. Also, as a matter of economy, the rail itself should suffer as little damage, requiring maintenance or replacement, as possible. The results of these tests offer direct evidence of the ability of the rail to prevent a car from leaving the roadway, of the damage to the car, and of the damage to the rail. They do not offer direct evidence of the damage which would be done to occupants. However, there is inferential evidence on this point, i.e., the rate of deceleration of the car after impact with the rail. Certainly, there is a greater probability of injury to occupants of a car which becomes entangled with a rail and is decelerated from thirty miles an hour to a stop in a distance of from 0 to 30 feet, than to the occupants of a car which is deflected approximately parallel to the rail and rolls freely with gradual deceleration to a stop 70 to 150 feet away from the point of impact. From this viewpoint, the rails which prevented the cars from leaving the roadway fall into two classes, one of which covers the cases in

which the probability of injury to the occupants is small, and the other in which the probability of injury is considerably greater.

With the above in mind, the rails have been classified as follows:

CLASSIFICATION OF RAILS

I. Rails which prevented the car from leaving the roadway.

A. Rails which deflected the car with small probability of injury to occupants.

(1) With superficial damage to either the car or to the rail
"Empire"
"Flex-Beam"
"Glideplate"
"Resiliflex"
"Tyton"

(2) With appreciable damage to the car and more or less damage to the rail
"Duraguard"
"Page Traffic Tape", 4 strands
"Tuthill"

B. Rails which turned the car with considerably greater probability of injury to occupants.

(1) In which the car stopped against the rail.
"Page Traffic Tape", 2 strands (16' post spacing)
"Page Traffic Tape", 2 strands (10' post spacing)
"Pittsburgh Safety Highway Guard" (12' post spacing)

(2) In which the car stopped astride the rail.
"Pittsburgh Safety Highway Guard" (16' post spacing)
Russell plate and wire rope
Two strands, wire rope, (10' post spacing) with light ties

(3) In which the car mounted the rail but was not stopped by the rail. (See later discussion)
"Bente Phillips"

II. Rails which did not prevent the car from leaving the roadway.

"Chain Link"
Economy Products, plate rail
"Wej-Lock" Plate
Wire Rope, 2 strands (12' 8" post spacing)
Wire Rope, 2 strands (16' post spacing)

The above classification is based, in most instances on only one test. However, the rather close duplication of results where two or more tests were made on one rail, and the agreement between different tests on similar types of rail, indicate a considerable probability that duplicate tests on all rails would give similar results in all instances. It is conceded, however, that in some cases the classification may be incorrect. This is particularly true of the differentiation between the rails listed in Class I-A (1) and Class I-A (2).

Both of these groups of Class I-A satisfactorily performed the primary function of a guard rail in that they prevented the car from leaving

the roadway in such a manner that the safety of car occupants would probably have been protected. The difference between the two groups is found in the degree of damage to cars and rails. In group (1) there was little damage to either car or rail while in group (2) there was appreciable damage to the car. It is conceivable that some invisible or unobserved defect in some of the cars, prior to their use in the tests, was responsible for part of the damage noted after the tests; and that repetition of the tests with other cars might have resulted in reclassification of some of the rails. This possibility is greatest in the case of the Duraguard and Tuthill tests, both of these test cars having been used in prior tests.

The rails of Class I-B prevented the car from leaving the roadway but the manner in which this was done promoted, in the minds of the authors, the idea that there was considerably greater probability of injury to car occupants than was the case with the rails of Class I-A. In all the tests of Class I-B rails, the cars become entangled with the rails to some extent and were stopped abruptly within 45 feet, or less of the point of impact. Apparently violent impacts were made with one or more posts. In the tests of rails of group (1), the cars stayed in contact with the rail from the point of contact and stopped at a point near the end of the installation. In the group (2) tests, the cars straddled the line of the rail and were stopped in this position much sooner than those of group (1), with sufficient abruptness to throw the rear ends off the ground. The group (3) rail was bent over when struck and the car straddled and rode the rail to the end of the installation where it slid off and turned over.

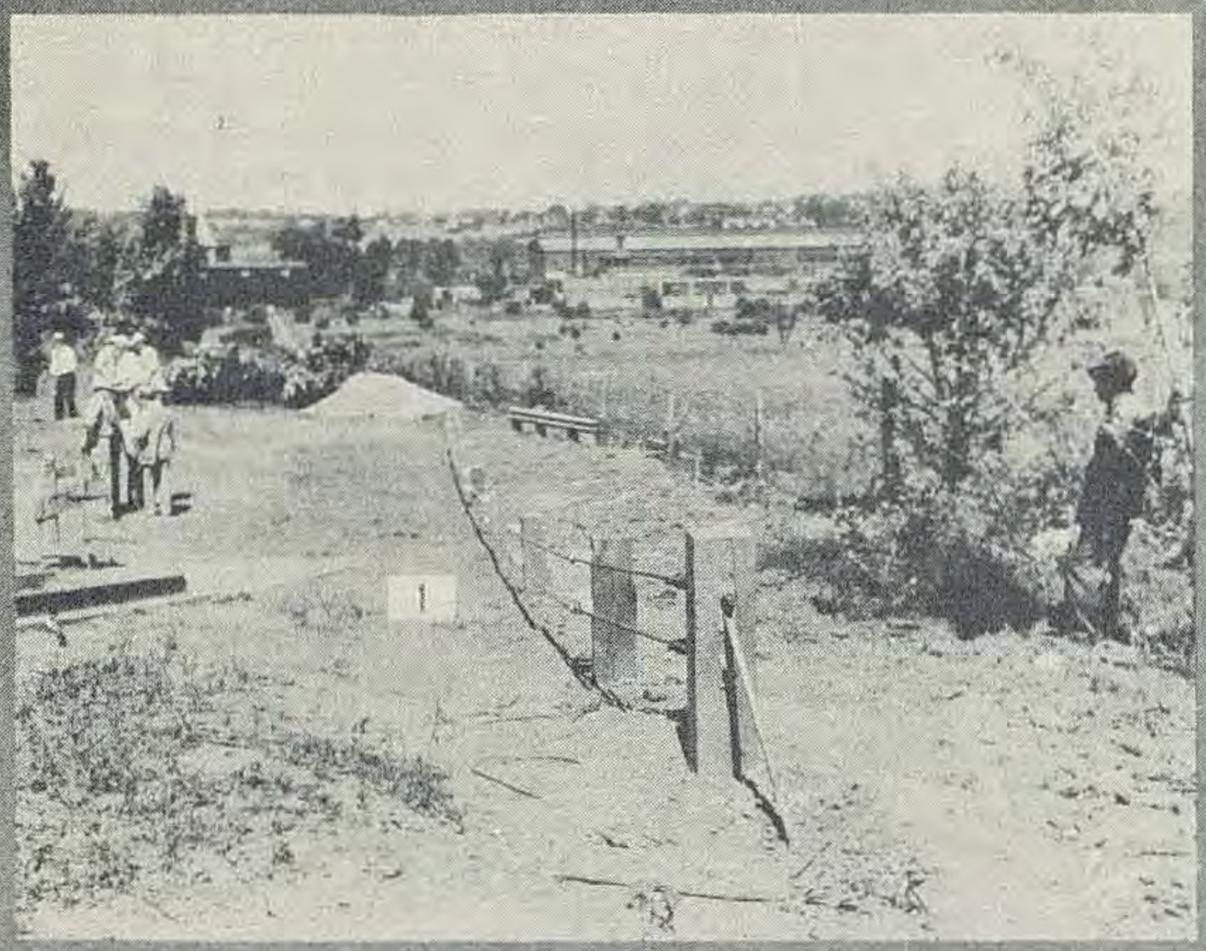
The Class II rails were simply not strong enough to withstand the impact force applied in these tests, the car going through the rail with little diminution of speed in each case.

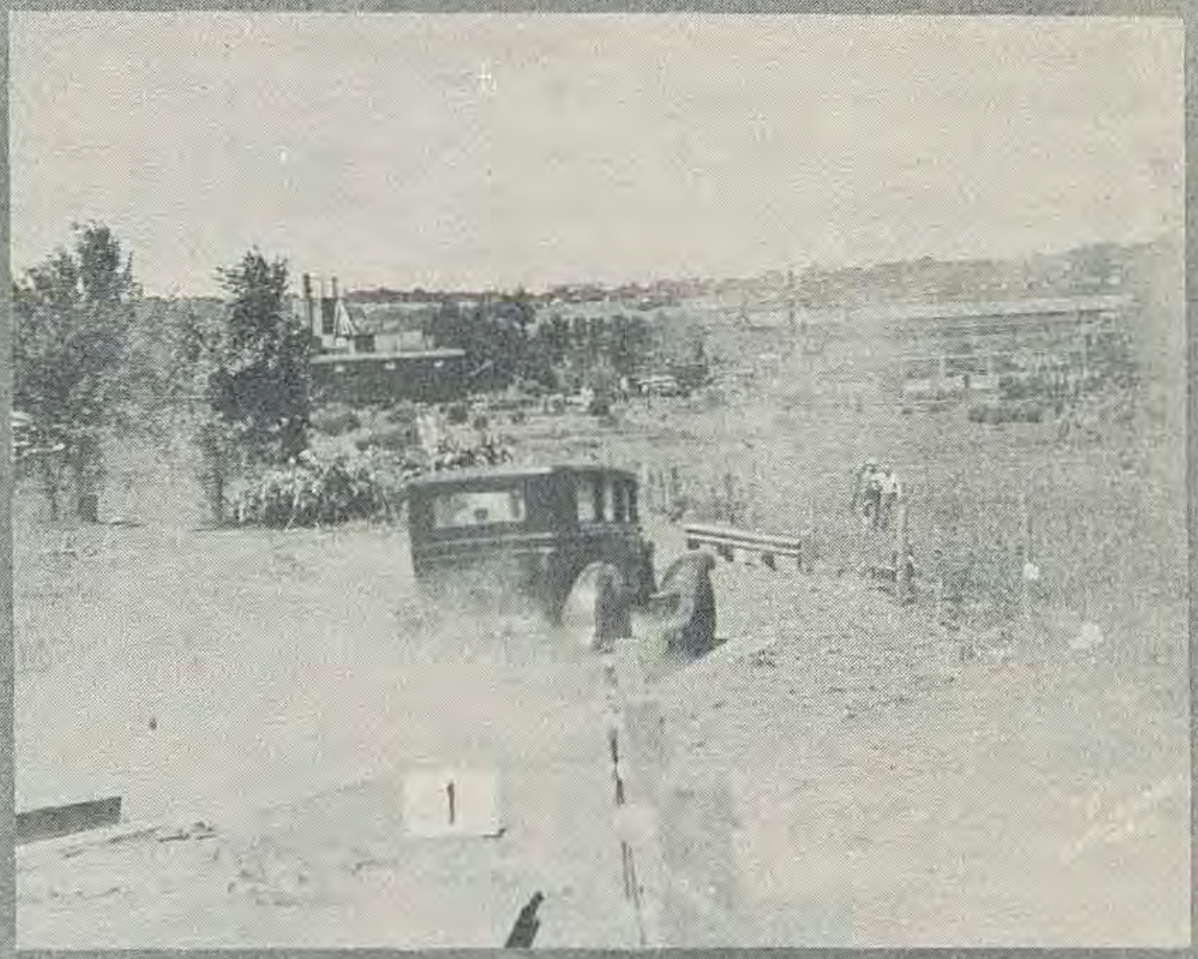
It should be stressed that the results of these tests, and deductions therefrom, pertain only to the conditions obtaining in these tests. With different kinetic energies of the impacting vehicle different results might be obtained. In fact the authors know of several tests of some of the same rails, performed by other agencies under different conditions, where the results were different. Certainly, however, rails which were not satisfactory under the conditions of these tests would not be so under more severe conditions, although they might have served their purpose under less severe impacts.

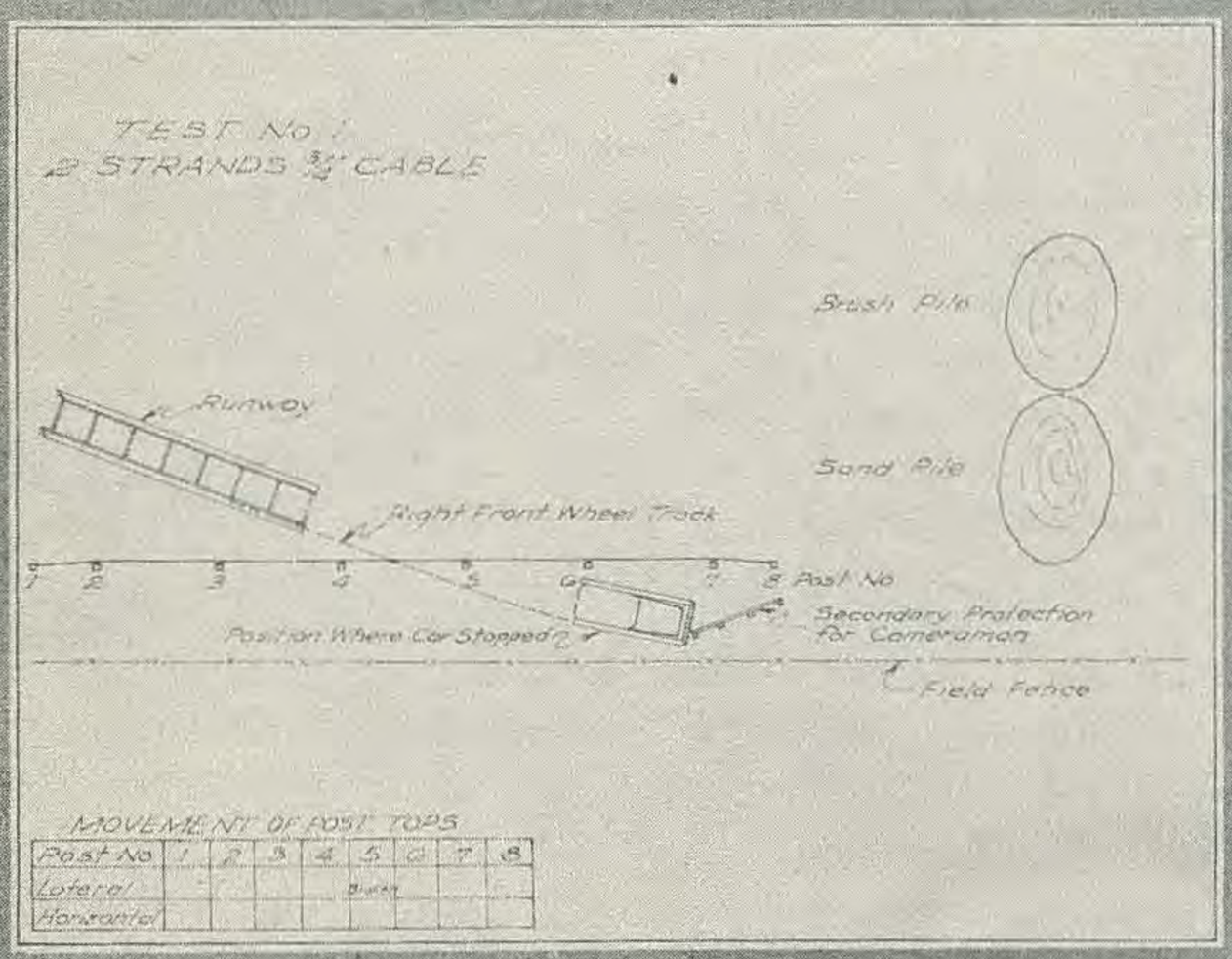
CONCLUSION

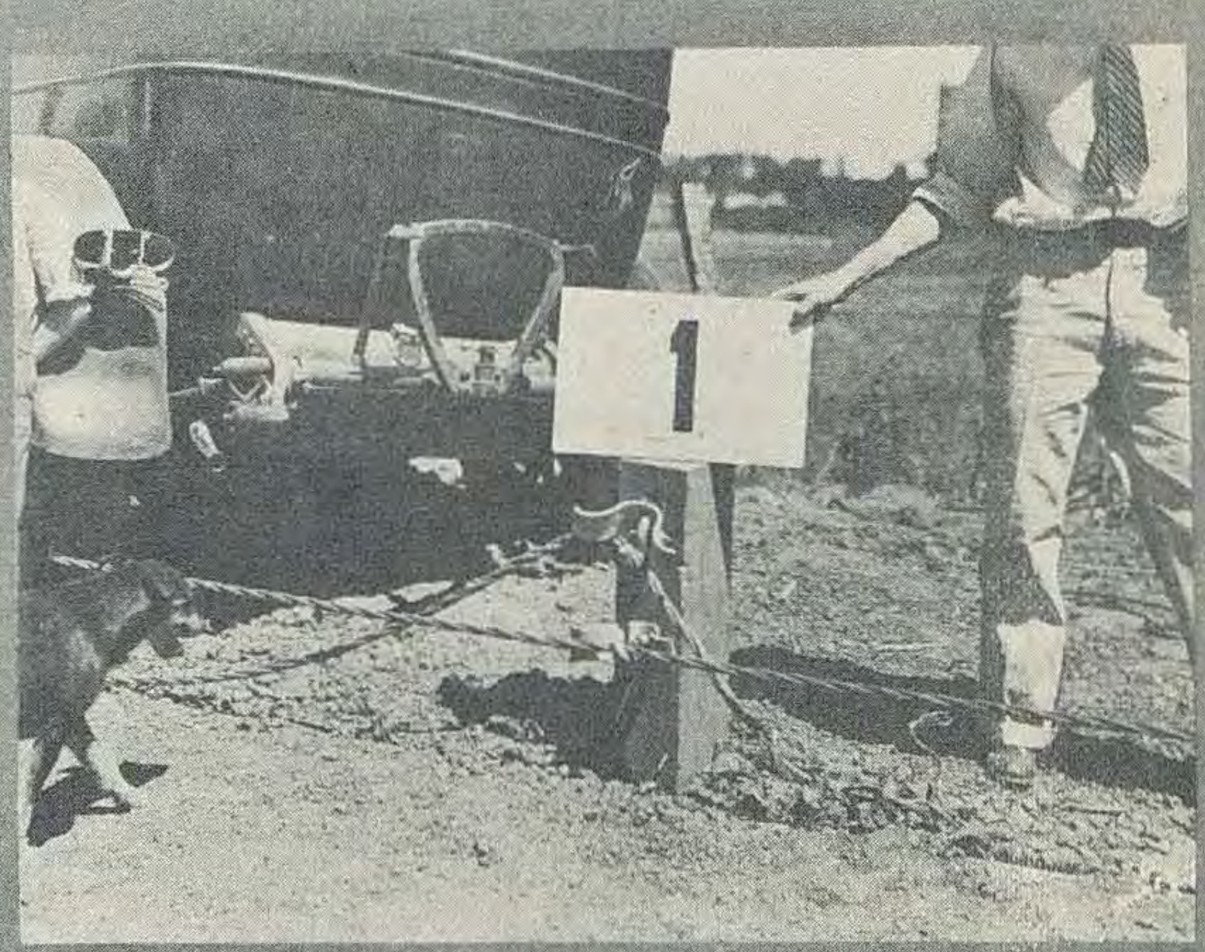
Under the conditions of these tests, the single element steel plate rails which were sufficiently strong to withstand the impact force applied were the most satisfactory. These rails prevented the cars from leaving the roadway, deflected them into a path parallel to the rail for a sufficient interval to give the driver some chance to regain control of the car, and decelerated the cars gradually enough that there was small probability of serious injury to the occupants. Furthermore, they did the least damage to the car and seemed to be in more serviceable condition after one impact.

There is an indicated difference in the serviceability of these plate rails, relative to each other, but corroborative tests would be necessary before this difference could be evaluated or considered a proven fact.






TEST No 1
2 STRANDS 3/4" CABLE
Brush Pile
Runway
Sand Pile
Right Front Wheel Track
1 2 3 4 5 6 7 8 Post No
Position Where Car Stopped
Secondary Protection For Cameraman
Field Fence
MOVEMENT OF POST TOPS
Post No 1 2 3 4 5 6 7 8
Lateral
Horizontal



TEST NO. 1

Description of Rail - The rail used for this test was made up of two strands of 3/4" wire rope (Missouri Highway Department Specification). The strands of rope were mounted on 6" x 8" pine posts which were set 4 feet in the ground, 16 feet center to center by means of 2-1/2" x 5/16" Russell Highway Guard Company spring clips. The rope and spring clip were fastened to the intermediate posts by a 3/4" hook bolt. Each rope was connected to each end post by means of a 1" eye bolt and three rope clips and each end post was anchored to a dead man. The distance from the ground to the lower rope was 11" and the distance between ropes was 9".

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 34.2 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, hit post No. 5 hard, breaking it off; then, without deflection, ran over the lower strand of rope, pulled the top strand in two in panel 5-6, and crashed into the end of a secondary rail. This secondary rail had been erected for the protection of one of the photographers but was removed before further tests were made.

Damage to Rail - The impact of the car with the rail pulled the top rope in two, broke off post No. 5 and bent the top hook bolt on post No.6.

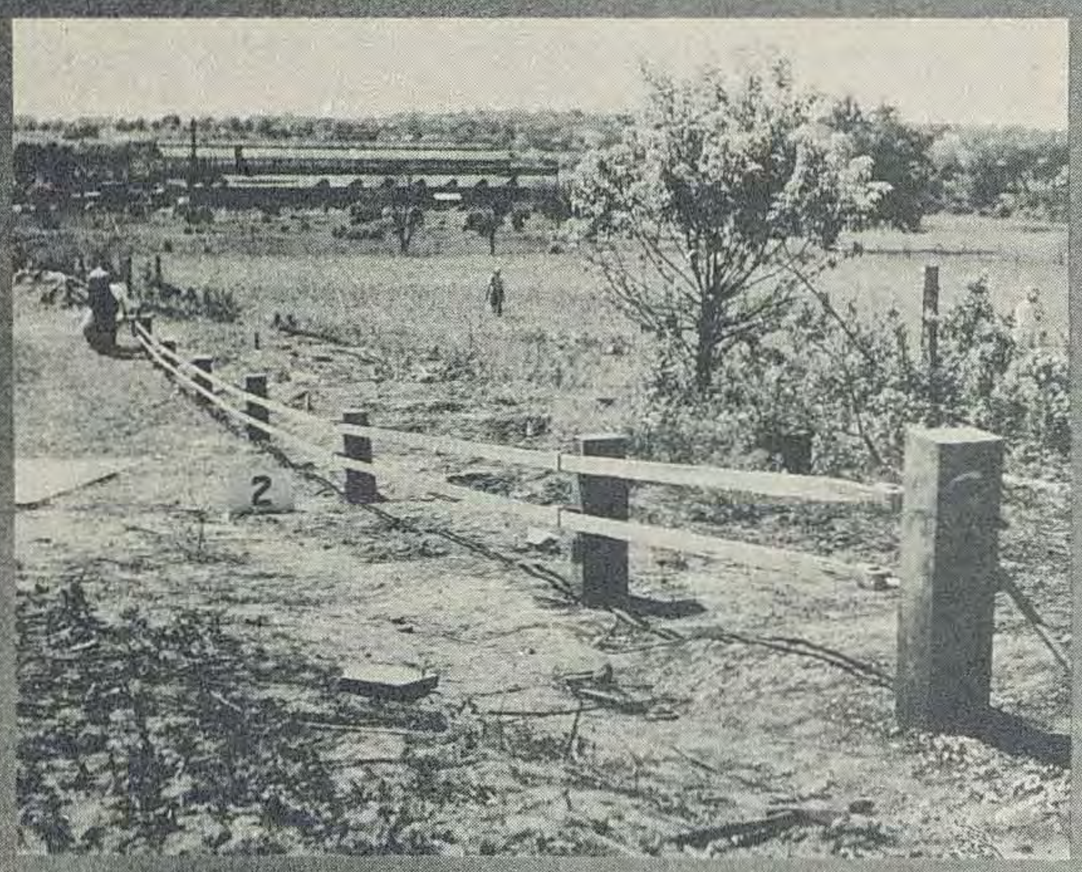
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to splice the top rope and to replace one post and one hook-bolt.

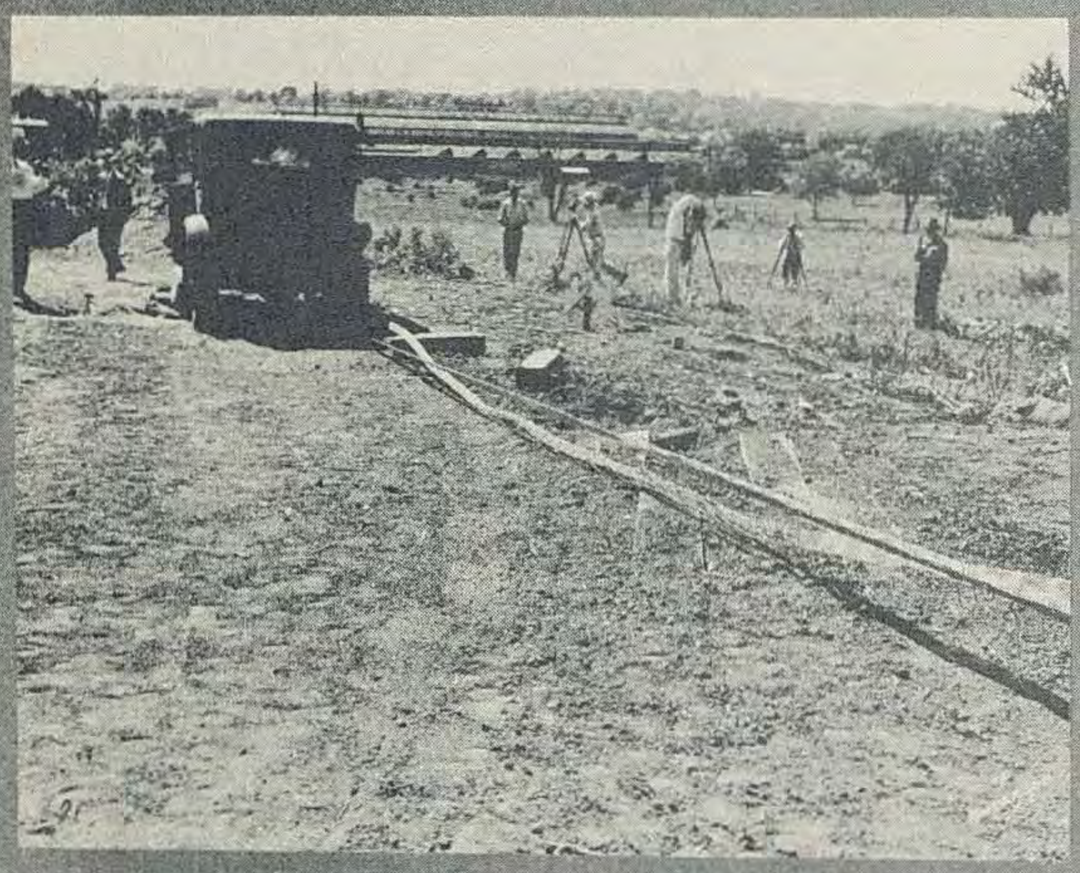
Damage to Car - It was impossible to ascertain the damage to the car caused by this rail, as most of the damage was caused by the secondary protection rail.

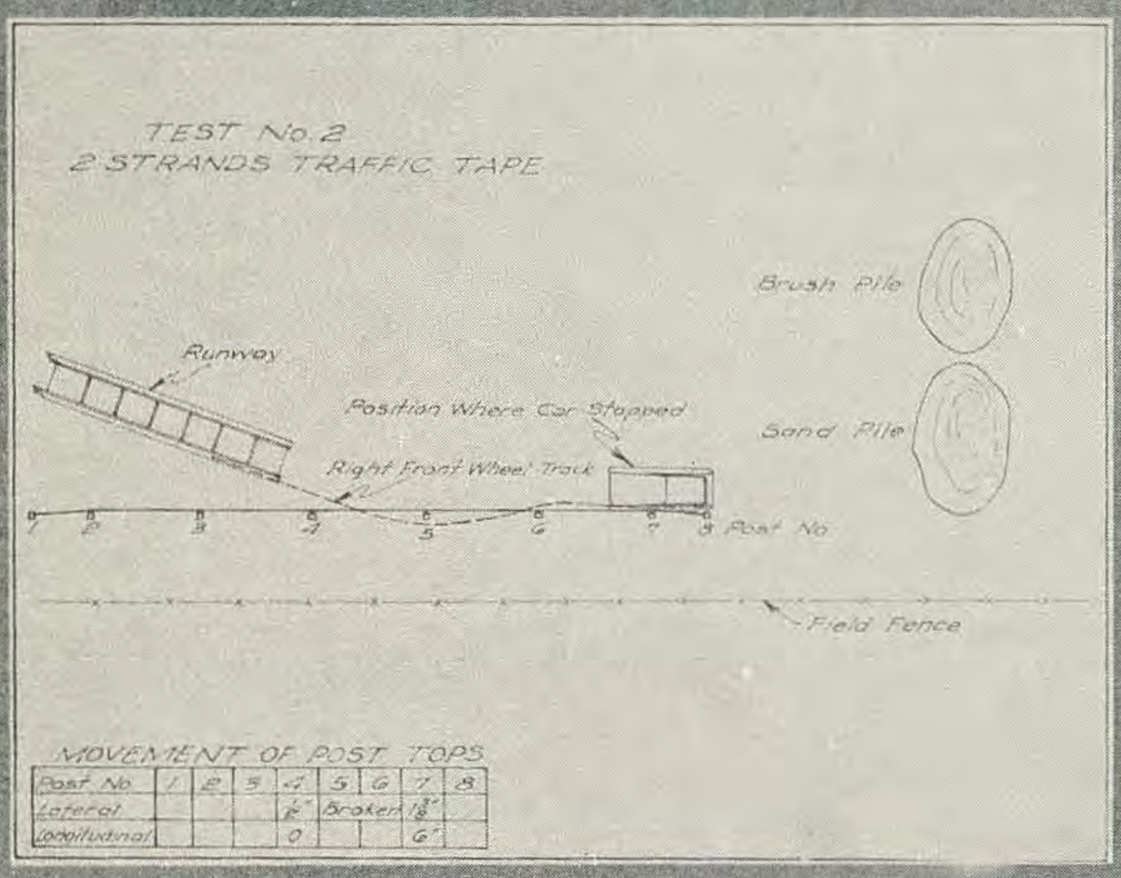
Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - The condition of the rope at the point of breakage shows that some portion of the car struck it at this point. A number of the wires were seriously abraded, reducing their section but the remainder of the wires showed true tension failure, being well necked at the point of failure.

Results - The guard rail, as constructed for this test, did not prevent the car from leaving the roadway.

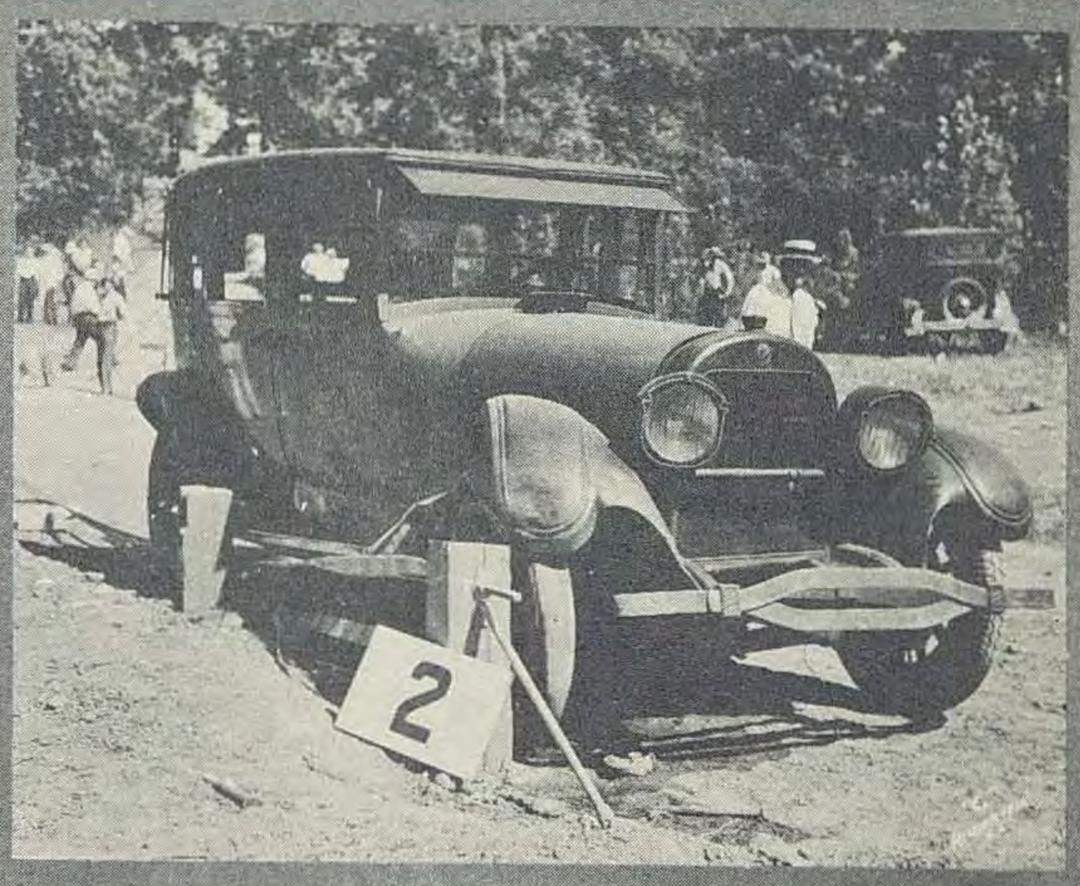






MOVEMENT OF POST TOPS

Post No	1	2	3	4	5	6	7	8
Lateral				1/2"	Broken		1 3/8"	
Longitudinal				0			6"	



TEST NO. 2

Description of Rail - The rail used in this test was made up of two strands "Traffic Tape" (Page Steel and Wire Company). Each strand of tape, 2-1/2" wide, was composed of 21 wires, .118 of an inch in diameter, and was mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. Each strand of tape was connected to each end post by means of a Page E-11-35 end take-up, which employs the wedge principle for holding the wires and each end post was anchored to a dead man. The tape was fastened to the intermediate posts by means of the Page Type-A line post offset with a 2-1/2" x 5/16" Russell spring clip substituted for the regular back block. The distance from the ground to the center of the lower tape was eleven inches and the distance between centers of tape was nine inches.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 33.3 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5 and was turned parallel to the rail. As the rear end of the car swung into and impacted the rail, the car tipped approximately five degrees from the vertical. The car rammed into and broke post No. 5, and rolling along in contact with the rail, struck and broke post No. 6, struck and loosened post No. 7 and finally stopped against the rail with the front wheel about even with end post No. 8. At some point during contact with the rail, the right rear wheel climbed over the lower strand of tape, although the front wheel did not do so. Two 150-200 pound bags of sand were thrown from the car through the left rear door.

Damage to Rail - The upper strand of tape was deformed at the point of impact and at post No. 7, and sixteen wires of this strand were pulled out of the end fitting at post No. 1 while three wires were pulled out of the end fitting at post No. 8. The lower strand of tape was deformed at post No. 7 and the post-bolts at post No. 7 were bent. Posts No. 5 and No. 6 were broken, post No. 7 was loosened and post No. 4 was moved slightly.

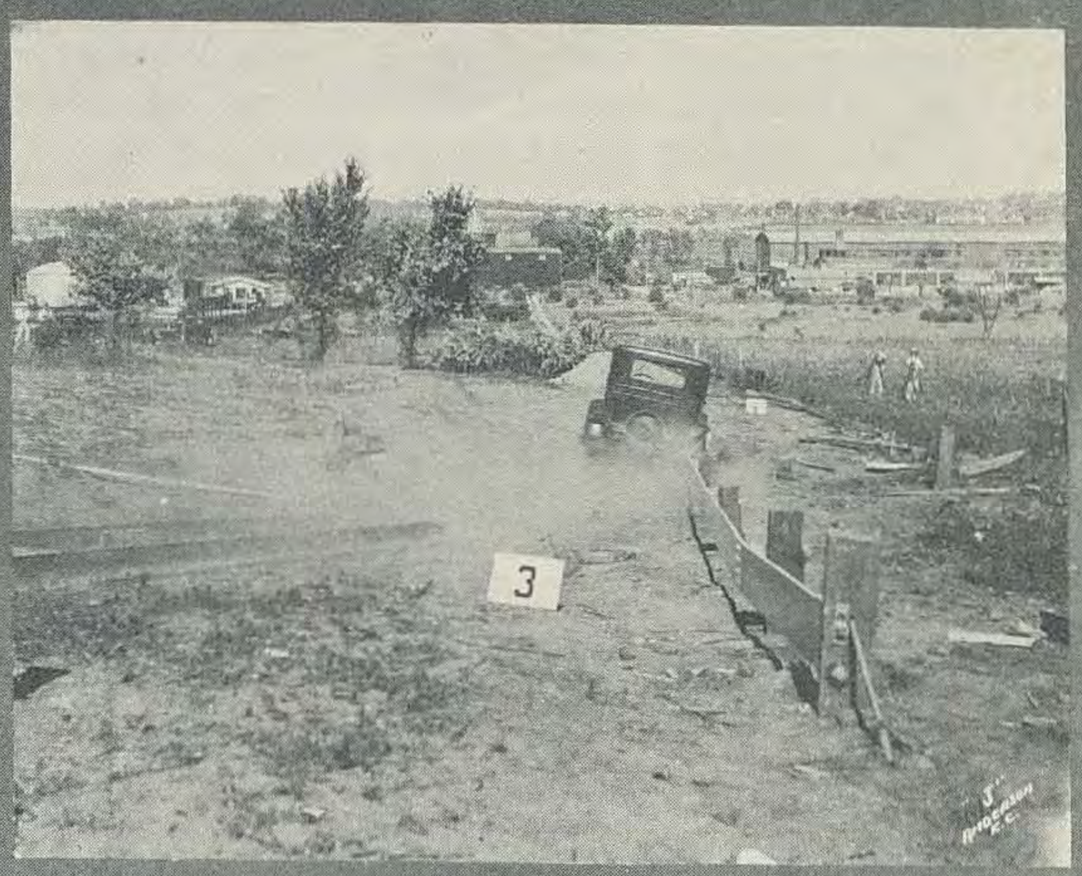
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace both strands of tape, two posts and two bolts in post No. 7, and to retamp one post. If the installation had been a long one, the damaged sections of tape could have been cut out and new pieces spliced in.

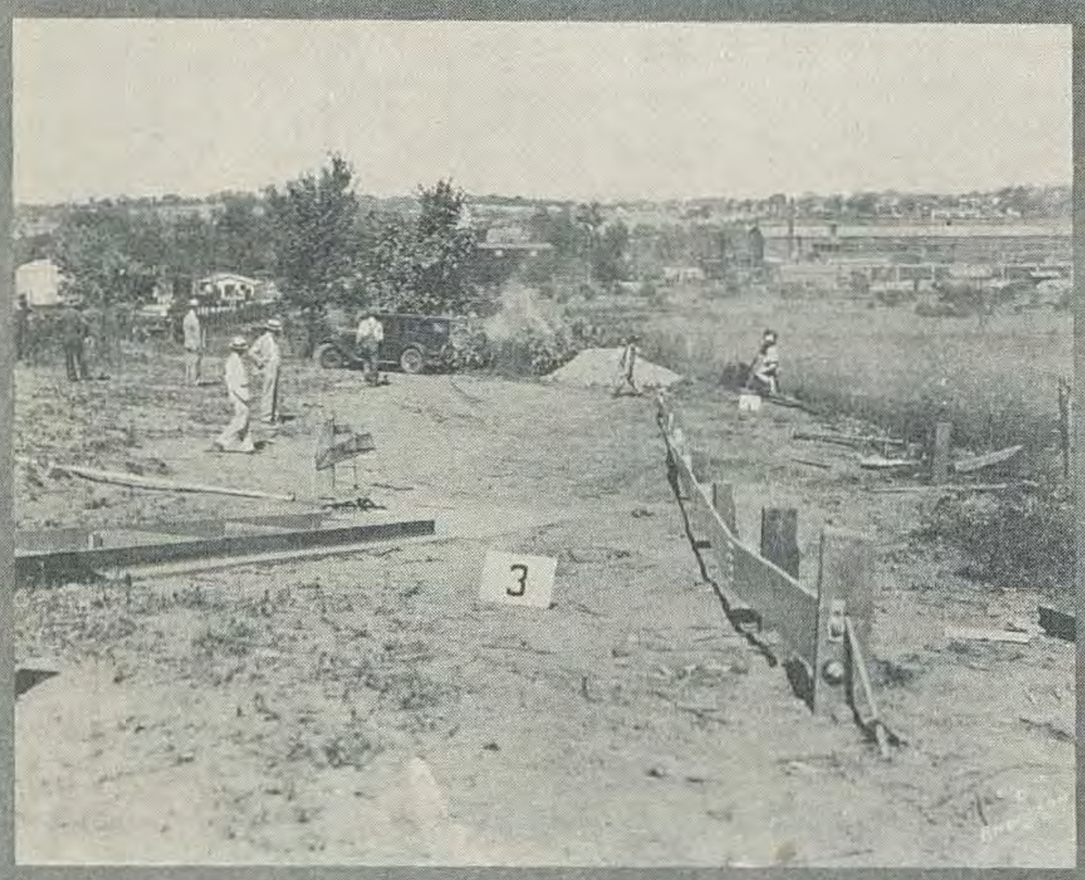
Damage to Car - the impact of the car with the rail crumpled both fenders on the right side. The left rear door was knocked open and the glass broken by a bag of sand. The carcass of the right front casing was torn in one spot, but no blowout occurred. The engine pen was bent and the water pump broken off.

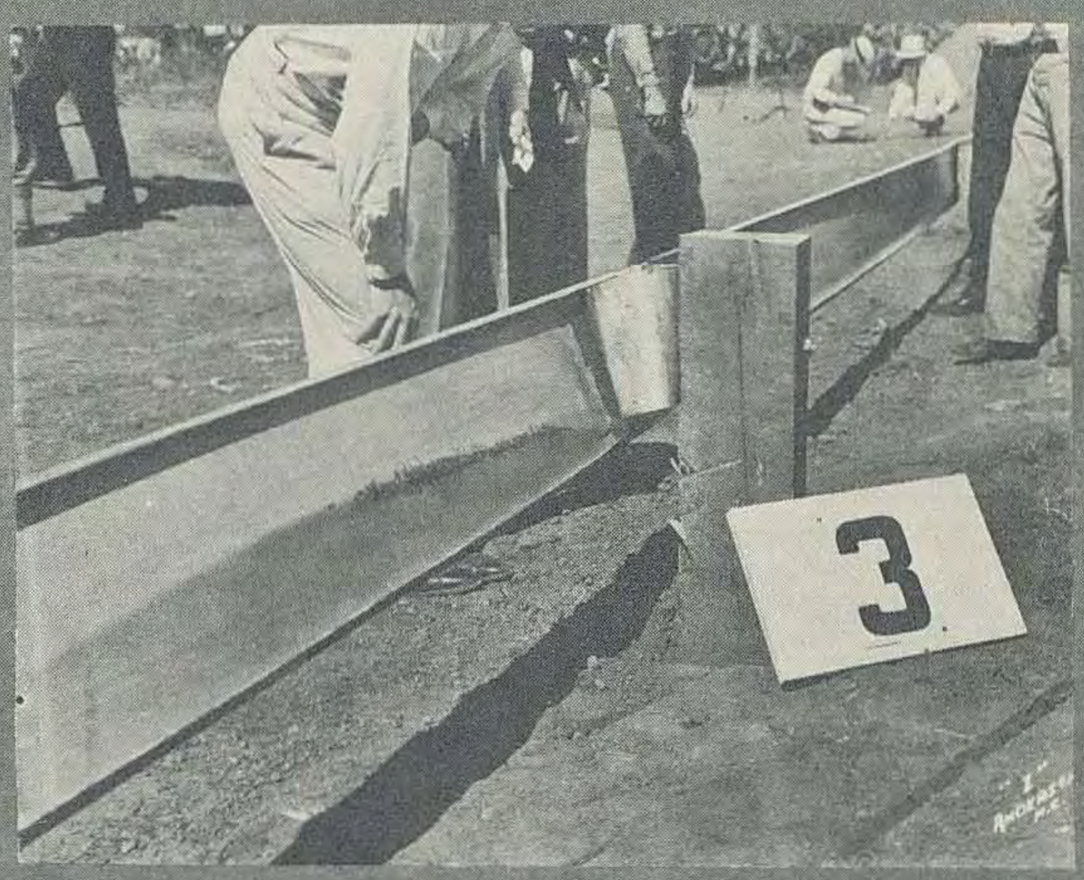
Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

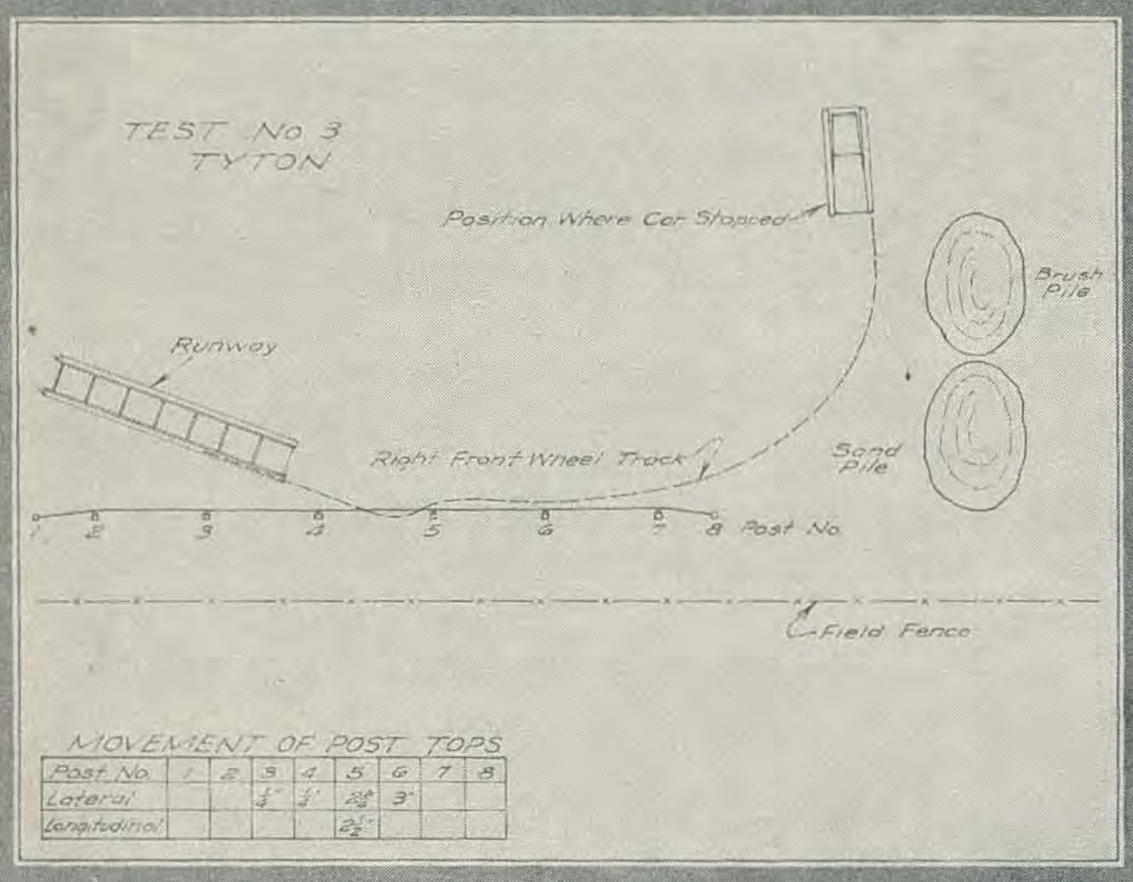
General Remarks - The test on this rail gave the best performance of any two element rail tested.

Results - This rail turned the car but the car was not kept away from the posts and stopped against the rail with some probability of injury to occupants. The impacts of the car with the rail caused no appreciable damage to the car but did seriously damage the rail.



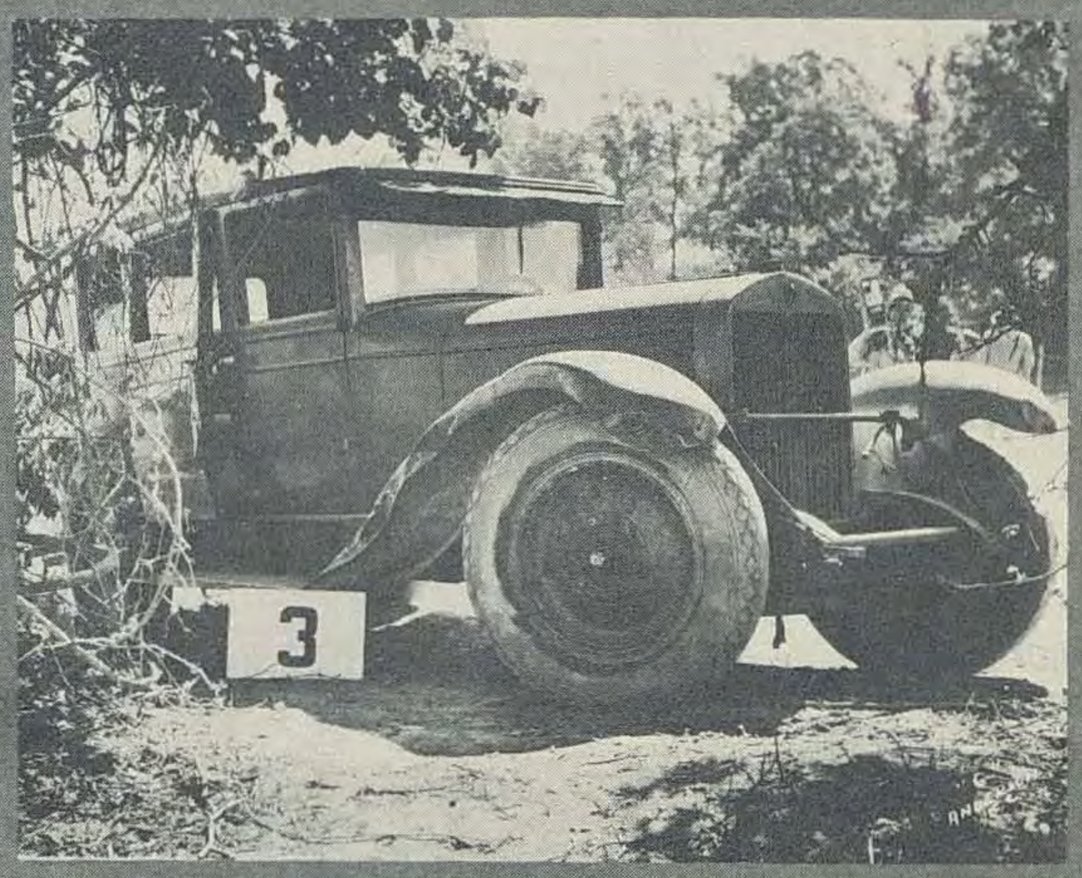






MOVEMENT OF POST TOPS

Post No.	1	2	3	4	5	6	7	8
Lateral			1/4"	1/4"	2 5/8"	3"		
Longitudinal					2 1/2"			



TEST NO. 3

Description of Rail - The rail used in the test was "Tyton" (Toncan Culvert Manufacturers' Ass'n). It consisted of a plate, 0.125" thick, with 1" rolled edges. The vertical projection of the plate was twelve inches. The rail was mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The end sections were 8' x 6" long. The rail was connected to each end post by two 1" bolts on which were mounted helical compression springs, and each end post was anchored to a dead man. The rail was mounted on the intermediate posts by means of a spring offset, formed of a twelve inch plate rolled to an oblong closed curve with a projection for connecting the rail to the spring, which was connected to the post with a single 5/8" bolt. Adjoining rail panels were connected by a single lap splice which was made with twelve 1/2" carriage-bolts, four of which passed through slots in the post spring. The center of the plate was set eighteen inches above the ground.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 34.5 miles per hour. This car had been used for some previous tests performed by the Sheffield Steel Corporation; however, except for some superficial body injuries, the car was in good condition.

Behavior of Car and Rail - The car struck the rail, between posts No. 4 and No. 5, approximately six feet from post No. 5. The front end of the car was deflected. As the rear end of the car impacted the rail, the car tipped approximately ten degrees from the vertical after which the rear end of the car rebounded slightly from the rail. The car then rolled along the rail to post No. 6 where it parted contact and rolled free at an angle of about nine degrees with the rail. When the car had rolled well beyond the end of the test section, it turned sharply to the left and rolled uphill until it came to rest. Due to the unevenness of the ground and side hill location of the car's path after leaving the rail, there was a tendency for the car to turn over, but it righted itself. The final position of the car was some fifty feet away from and substantially at a right angle to the line of the rail.

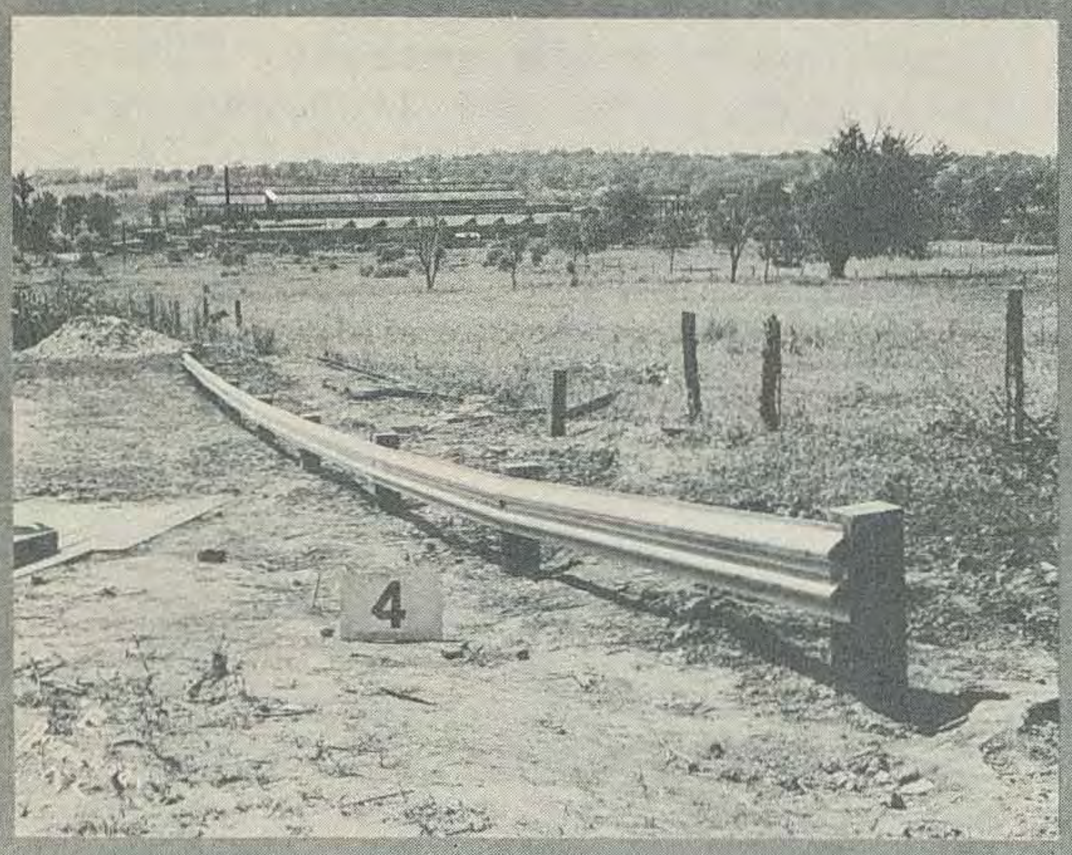
Damage to Rail - The impact of the car with the rail bent the rail in panel 4-5, also creased the rail from the point of impact to post No. 5 and bent the rail somewhat in panel 5-6. The spring offset at post No. 5 was deformed beyond repair. Posts No. 3 and No. 4 were moved slightly and posts No. 5 and No. 6 were loosened in the ground.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to retamp two posts and to replace one spring offset; that is, the rail would probably have functioned efficiently without replacing either of the two bent panels. In order to have restored the rail to its original condition, replacement of two rail panels, in addition to the other repairs, would have been necessary.

Damage to Car - The collision of the car with the rail crumpled both fenders on the right side and tore off the light bumper which had been welded on. It caused the bags of sand to spring out the bottom of the right rear door. This door had been previously damaged and was held shut by a 2" x 1/8" bar.

Erection Notes - Some difficulty was encountered in erecting the rail to conform to the vertical curve. This difficulty was due to the fact that the splice holes of adjoining rail panels did not match well, however, the condition of the rail as erected was satisfactory.

Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.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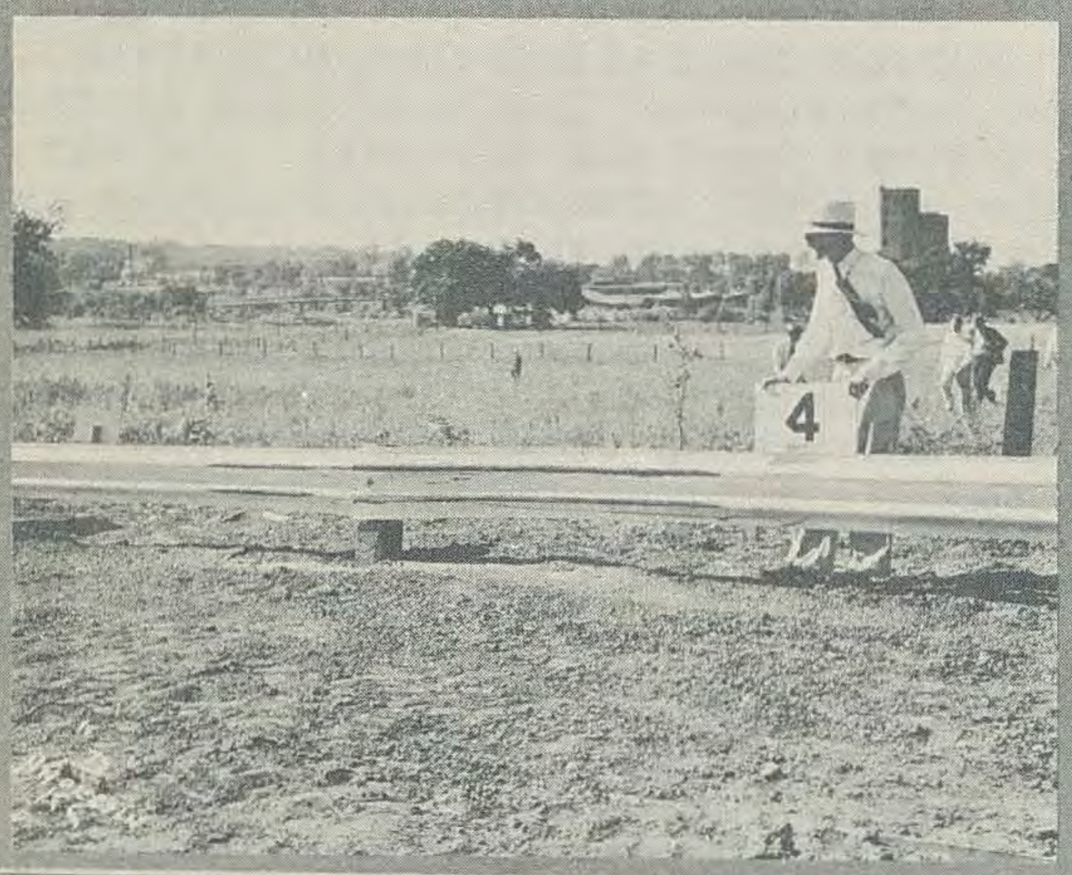
4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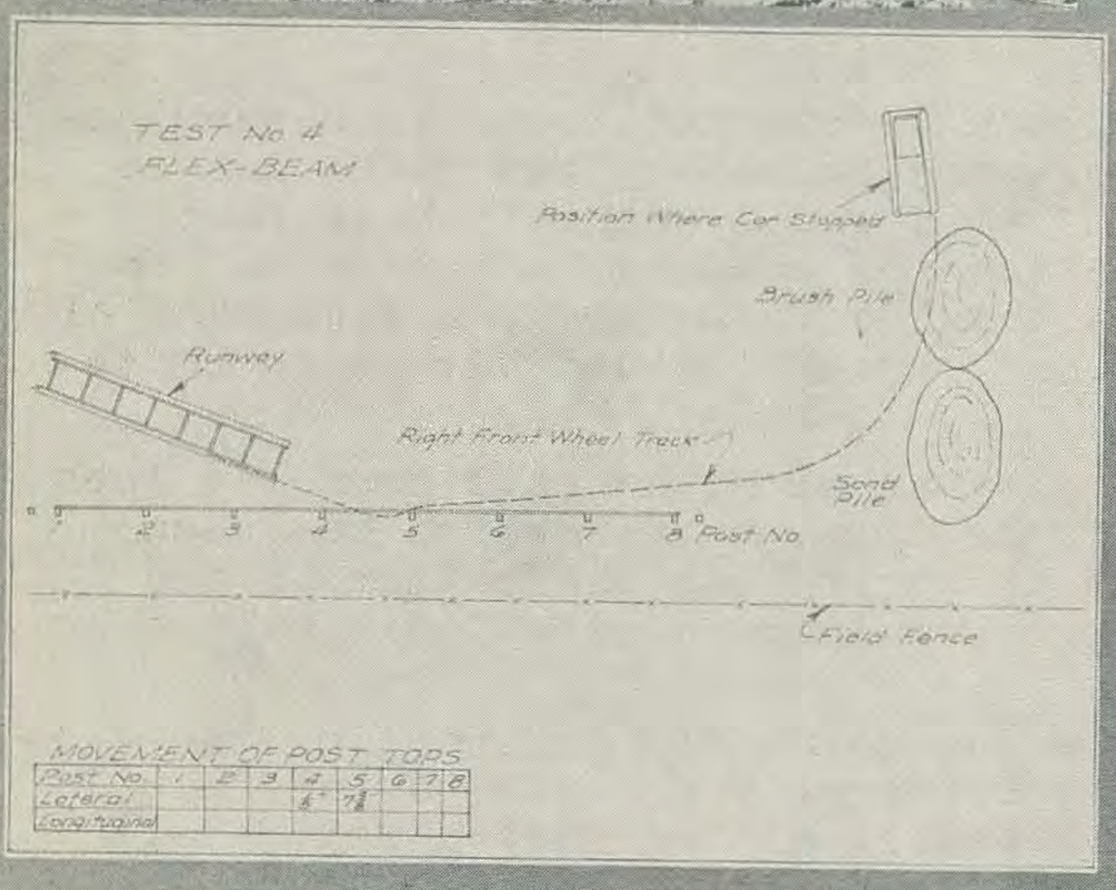
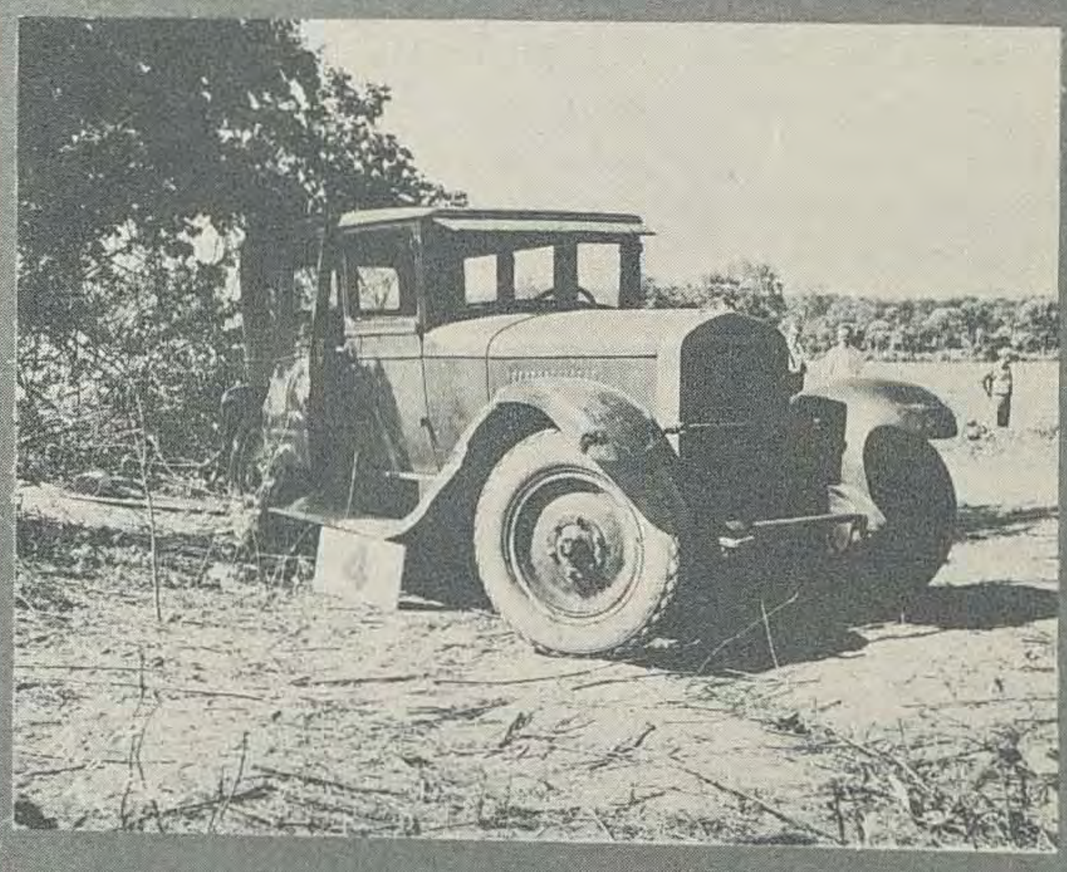

TEST No. 4
FLEX-BEAM
Position Where Car Stopped
Brush Pile
Runway
Right Front Wheel Track
Sand Pile
1 2 3 4 5 6 7 8 Post No.
Field Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral 6" 7½
Longitudinal



TEST NO. 4

Description of Rail - The rail used in this test was "Flex-Beam" (Sheffield Steel Corporation). It consisted of a plate 18" x 0.142" corrugated 3" deep. The projected width of the corrugated plate was 12 1/2". Panels of the rail were mounted directly on 6" x 8" pine posts which were set four feet in the ground, twelve feet, eight inches center to center. The end posts were not anchored. Adjoining panels were connected to each other by a single lap splice which was made with a 1" bolt which also passed through the post. The center of the rail was set 16" above the ground.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 33.1 miles per hour. This car has been used previously for test No. 3 and had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail, between posts No. 4 and No. 5, approximately five feet from post No. 5. The front end of the car was deflected. The rear end of the car was thrown against the rail and rebounded from it. As the rear end of the car impacted the rail, the car tipped approximately fifteen degrees from the vertical. The car rolled along the rail until it was approximately three feet beyond post No. 5, where it parted contact and rolled free at an angle of about five degrees with the rail. When the car was well beyond the end of the test section, it turned sharply to the left and rolled uphill until it came to rest. The final position of the car was some fifty feet away from and substantially at a right angle to the line of the rail.

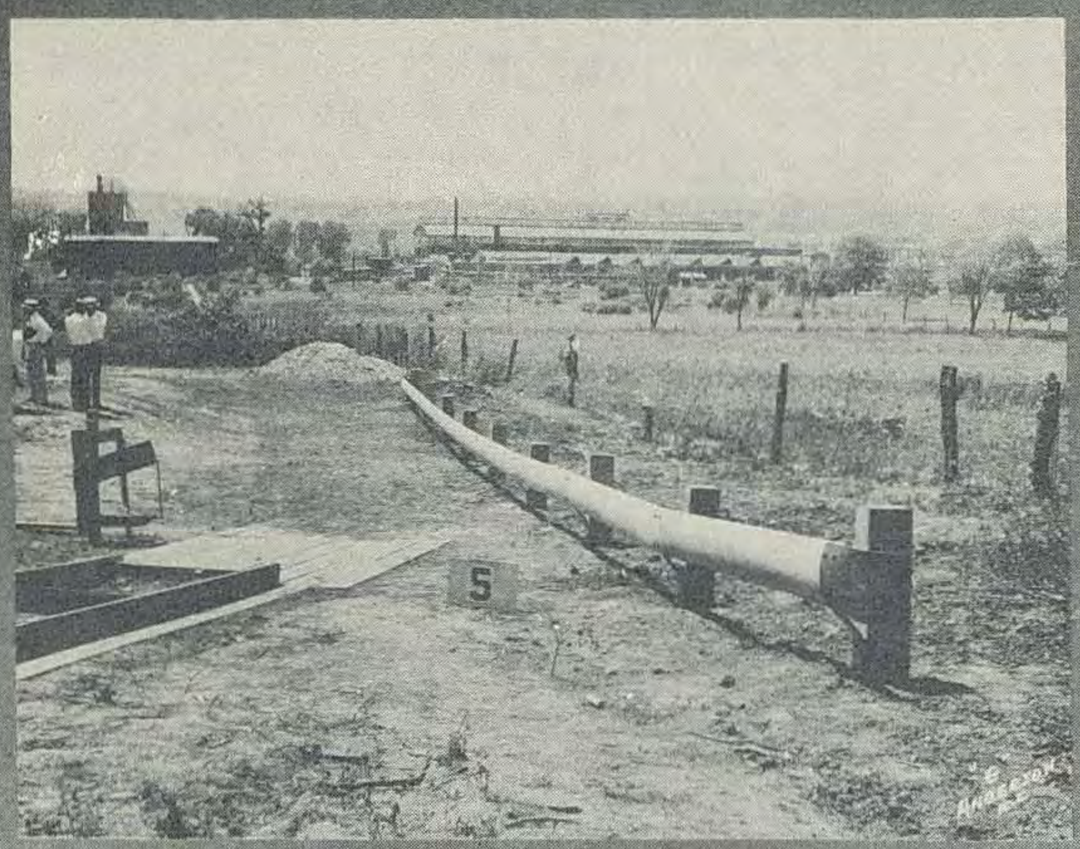
Damage to Rail - The impact of the car with the rail bent the rail in panel 4-5, causing a permanent set of 4-3/4", bent the bolt in post No. 5 slightly and loosened post No. 5 in the ground.

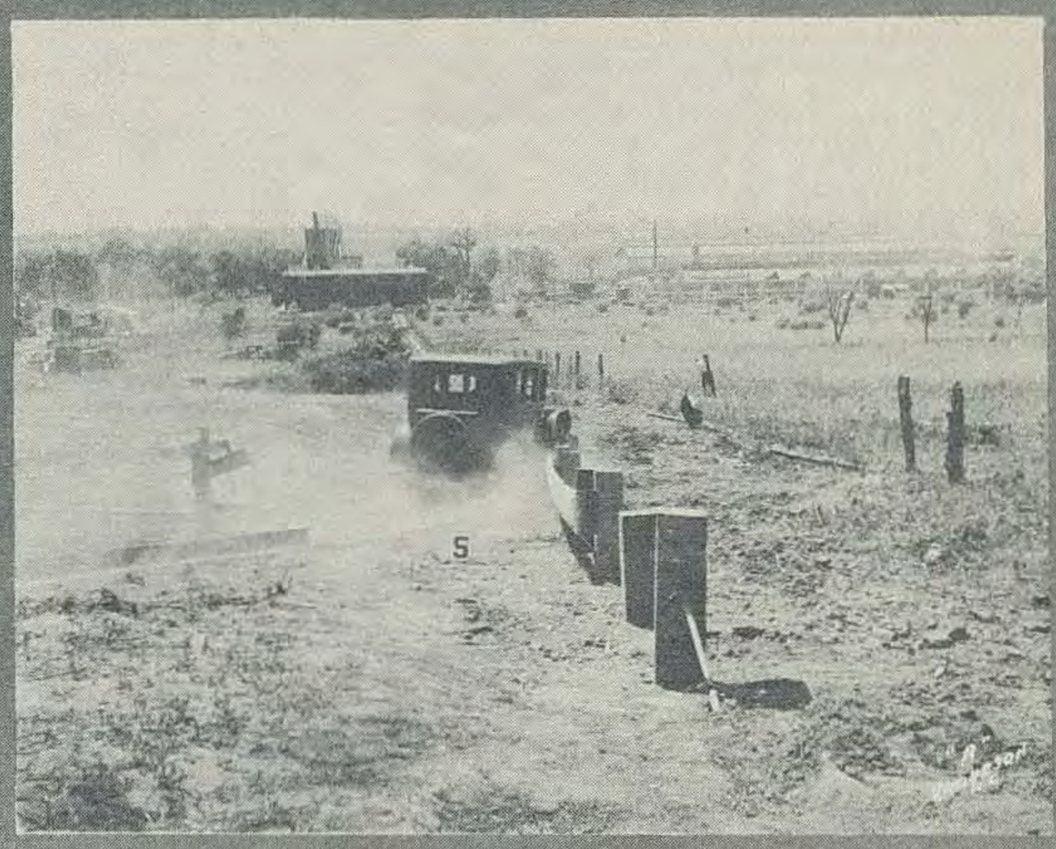
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would only have been necessary to retamp post No. 5; that is, the rail would probably have functioned efficiently without replacing the bent panel. In order to have restored the rail to its original condition, it would have been necessary to replace one rail panel in addition to retamping one post.

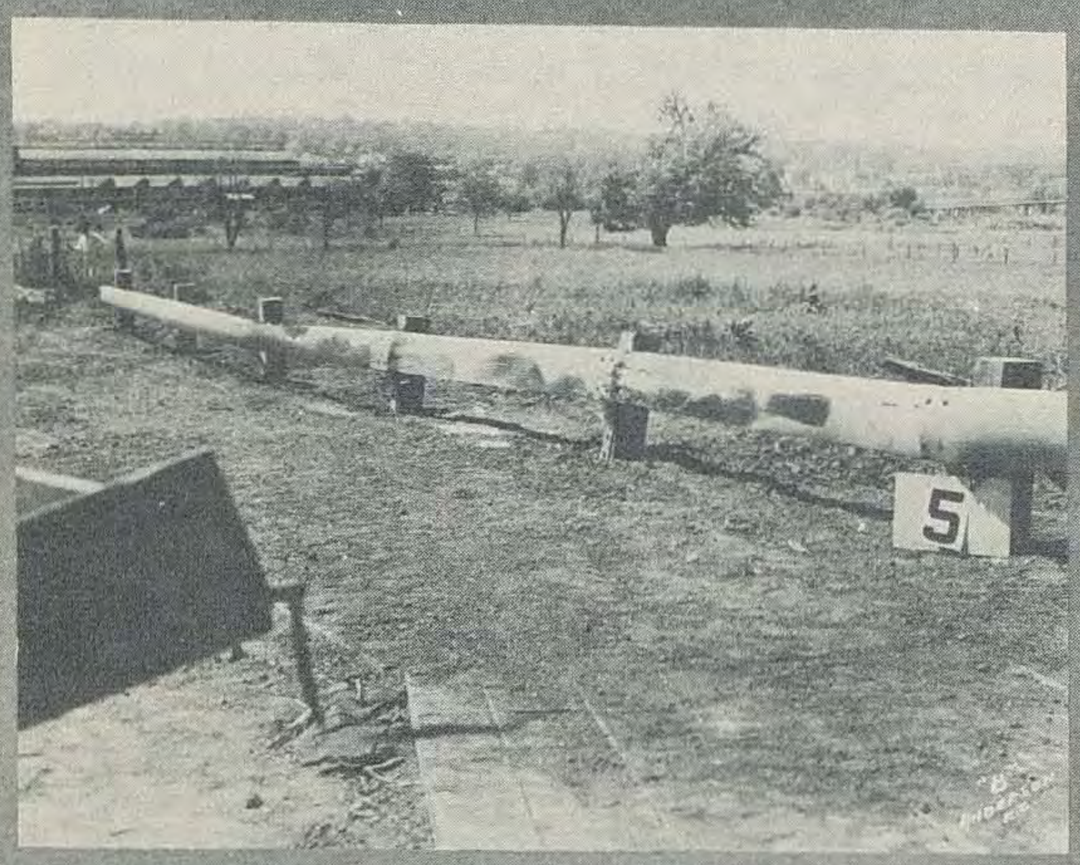
Damage to Car - The collision of the car with the rail bent the right rear fender and tore off the light bumper which had been welded on. It caused the bags of sand to spring out the bottom of the right rear door. This door had been damaged previously and was held shut by a 2" x 1/8" bar.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

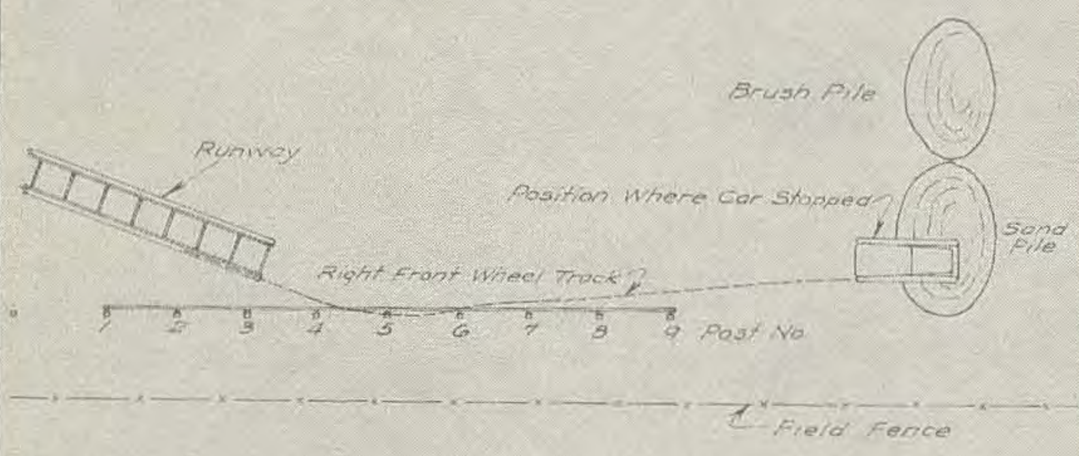
Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.







TEST No. 5
TUTHILL HIGHWAY GUARD



MOVEMENT OF POST TOPS

Post No.	1	2	3	4	5	6	7	8	9
Lateral					1½"	6"			
Longitudinal					8½"	1"			

TEST NO. 5

Description of Rail - The rail used in this test was "Tuthill Highway Guard" (Tuthill Spring Company). It consisted of a plate 12" x 0.161", which was rolled convex to the roadway and had a vertical projection of 11 1/2". The rail was mounted on 6" x 8" pine posts which were set four feet in the ground, ten feet center to center. The end posts were not anchored. The rail was supported by 4" x 7/16" cantilever spring offsets which were attached to the bottom of the posts with two 5/8" bolts. Adjoining rail panels were connected by a single lap splice which was made with four 5/8" bolts. These bolts also connected the rail to the cantilever spring offset.

Description of Car - The car used for the test was a Cadillac sedan which weighed 5,100 pounds. The speed of the car was 34.3 miles per hour. This car had been used previously for test number 2 but had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, approximately three feet from post No. 4. The front end of the car was deflected. The rear end of the car was thrown in against the rail and rebounded slightly from it. As the rear end of the car impacted the rail, the car tipped approximately 20 degrees from the vertical. The car rolled along the rail until just before post No. 7 was reached, where it parted contact and rolled free at an angle of about six degrees with the rail. The car continued to roll forward until it lodged on a sandpile about thirty feet beyond the end of the test section.

Damage to Rail - The impact of the car with the rail bent panels 4-5, 5-6, and 6-7, the plate in panel 5-6 being virtually flattened. Also a hole was gouged in the plate of panel 4-5 at post No. 5 and a splice bolt in the joint at post No. 4 was sheared. The cantilever spring offsets at posts No.5 and No. 6 were bent and all the spring offsets back of the point of impact were moved longitudinally. Posts No. 5 and No. 6 were loosened in the ground.

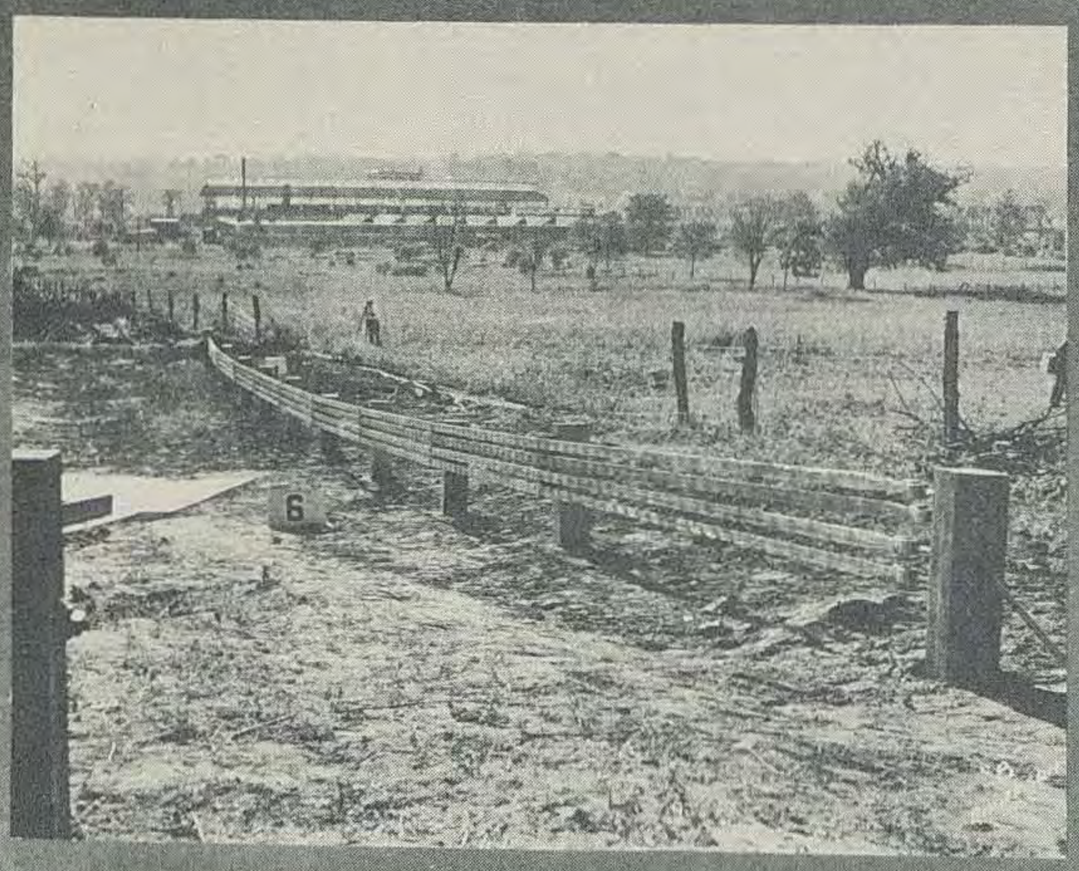
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace two rail panels, two spring offsets and to retamp two posts. Were it not too difficult to straighten, a third panel, panel 6-7, could probably have been reused.

Damage to Car - The car was damaged to the following extent: Both fenders on the right were crumpled, the bumper was bent, the headlights were bent, the running board was mashed its full length, the front axle was loosened on the right spring and the right front wheel forced back about eighteen inches. Also, four spokes in the right rear wheel were splintered.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - In considering the damage to the car, some allowance should be made for the fact that this car had been used for a previous test.

Results - This rail deflected the car with small probability of injury to occupants although the impact of the car with the rail caused an appreciable damage to the car and some damage to the rail.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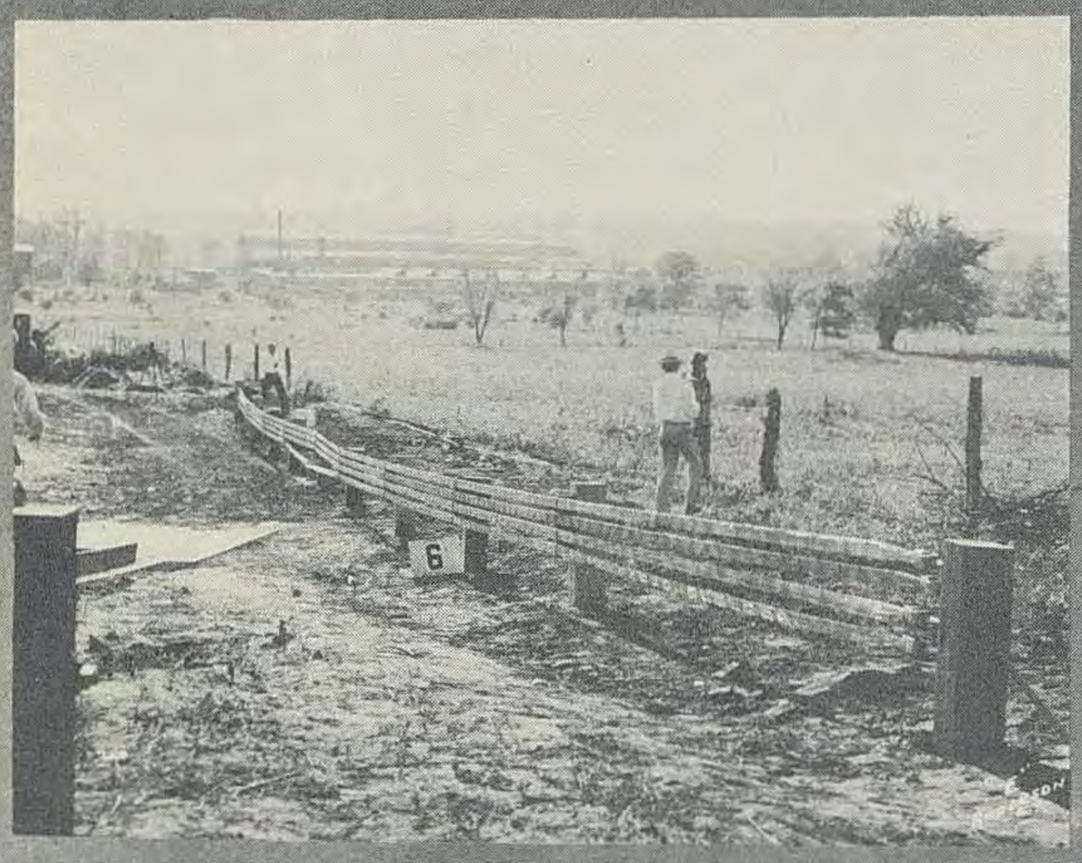
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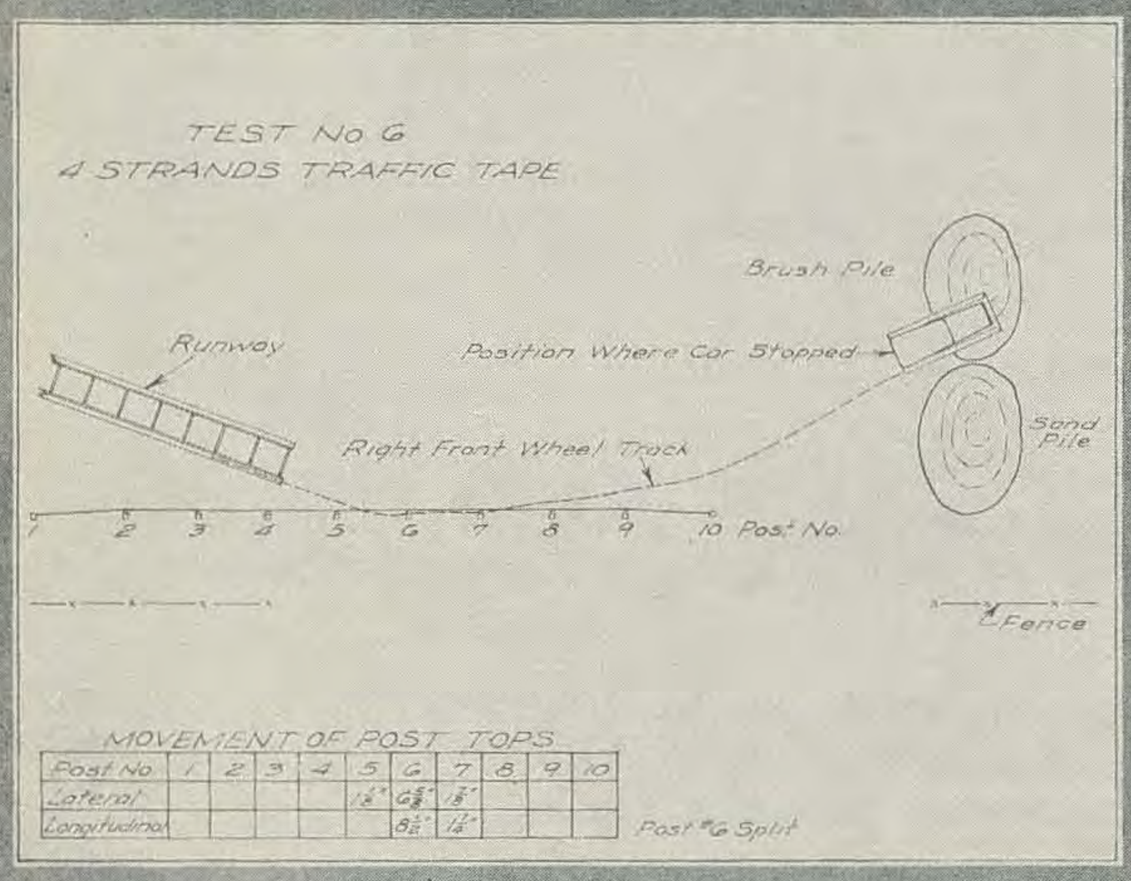
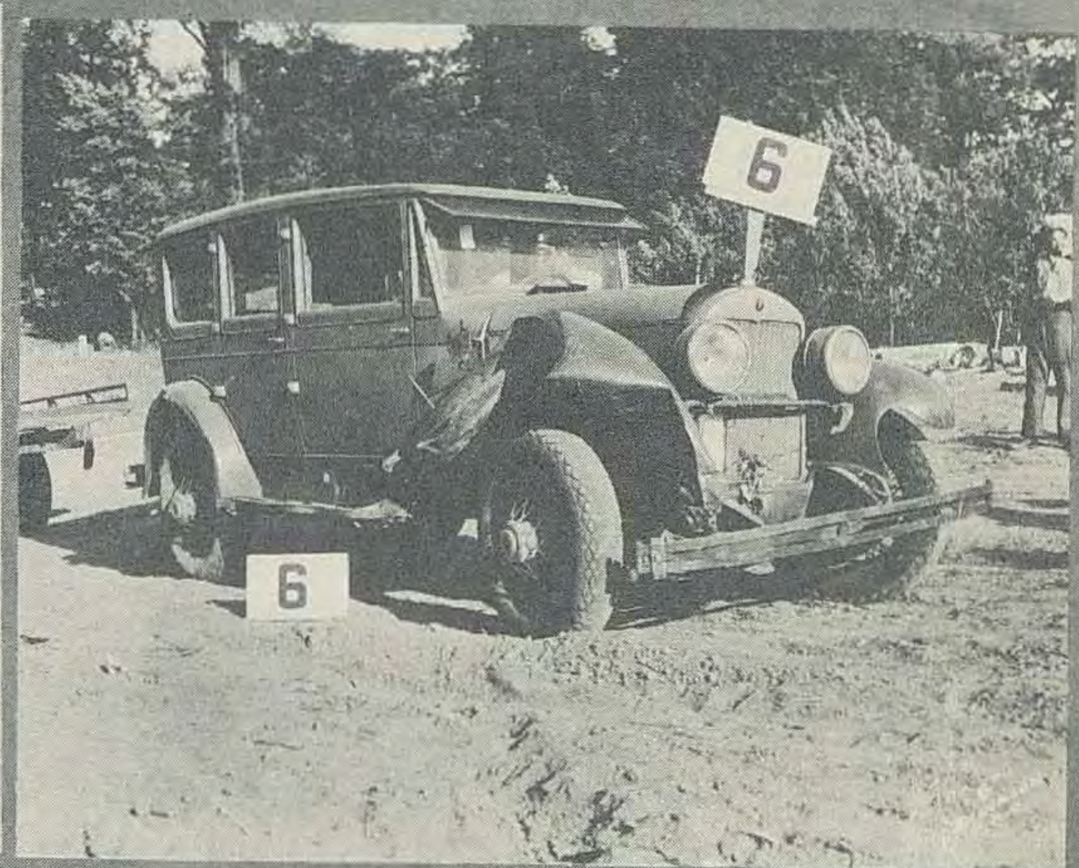

TEST No 6
4 STRANDS TRAFFIC TAPE
Brush Pile
Runway
Position Where Car Stopped
Sand Pile
Right Front Wheel Track
1 2 3 4 5 6 7 8 9 10 Post No.
Fence
MOVEMENT OF POST TOPS
Post No 1 2 3 4 5 6 7 8 9 10
Lateral 1 1/8" 6 5/8" 1 3/8"
Longitudinal 8 1/2" 1 1/4"
Post #6 Split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6

TEST NO. 6

Description of Rail - The rail used in this test was composed of four strands of "Traffic Tape" (Page Steel and Wire Company). Each strand of tape, 2-1/2" wide, was composed of twenty-one wires, .118 of an inch in diameter and was mounted on 6" x 8" pine posts, which were set four feet in the ground, ten feet center to center, by means of a "U"-shaped spring offset which was attached to the post with two 5/8" bolts. Each strand of tape was connected to each end post by means of a Page E-11-35 end take-up, which employs the wedge principle for holding the wires and each end post was anchored to a dead man. The distance from the ground to the center of the lowest strand was fifteen inches and the overall width of the four strands was fourteen inches with the four strands equally spaced.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 31.9 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No. 5 and No. 6. The front end of the car was deflected. The rear end of the car was thrown into the rail and, as it impacted the rail, the car tipped approximately ten degrees from the vertical. The car rammed into post No. 6, splitting it, and then rolled along in contact with the rail to a point just beyond post No. 7 where it parted contact and rolled free at an angle of about eight degrees with the rail. The car then turned to the left and stopped in a brushpile some thirty feet beyond the end of the test section.

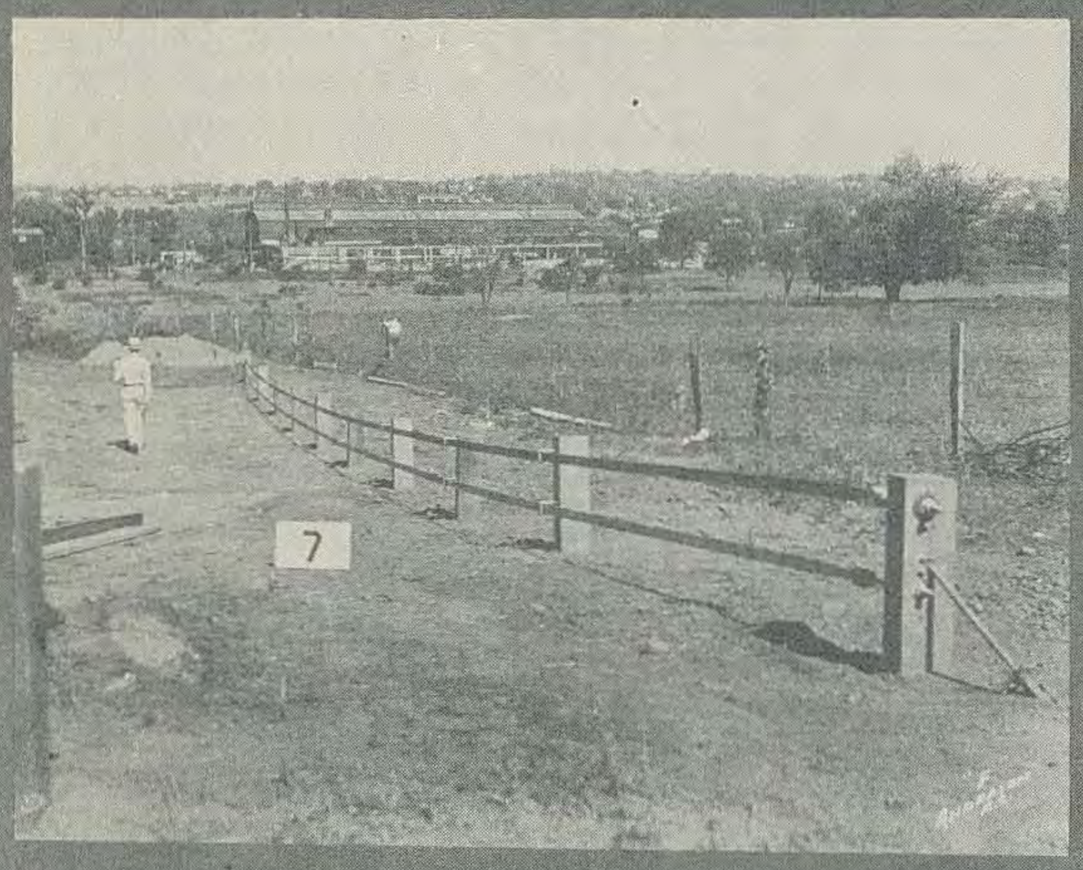
Damage to Rail - The bottom strand of tape was deformed at posts No. 6 and No. 7 and one wire of the strand was broken at post No. 6. The strand next to the bottom was also deformed at post No. 6 but the two upper strands, except for some torn spacer wires, were practically undamaged. Post No. 6 was split and posts No. 4, No. 6 and No. 7 were loosened in the ground. The spring offset at post No. 6 was slightly bent.

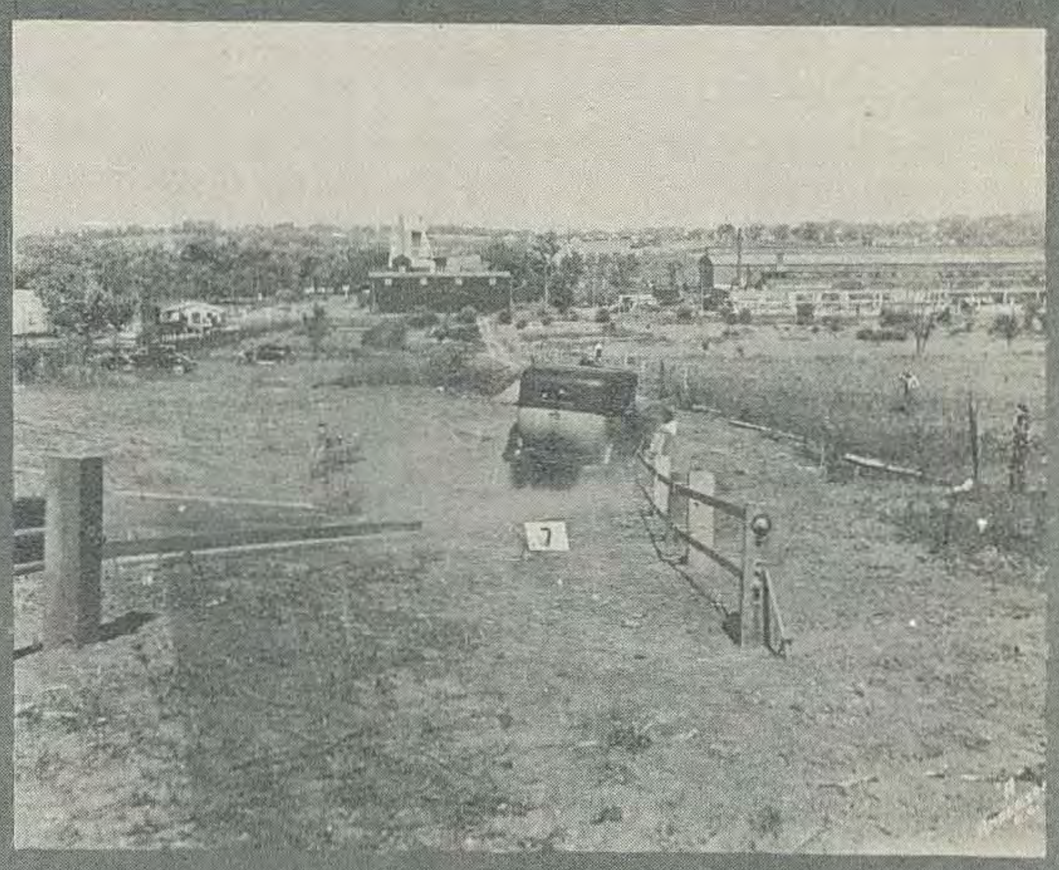
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace one post and three 1/4" clip bolts, to retamp two posts, and to straighten one spring offset. The rail would have remained reasonably effective by merely tightening the two lower strands of tape, but in order to have restored the rail to its original condition, the two lower strands would have had to be replaced. In a longer installation, about 25 feet of tape in the two lower strands could be cut out and the tapes spliced.

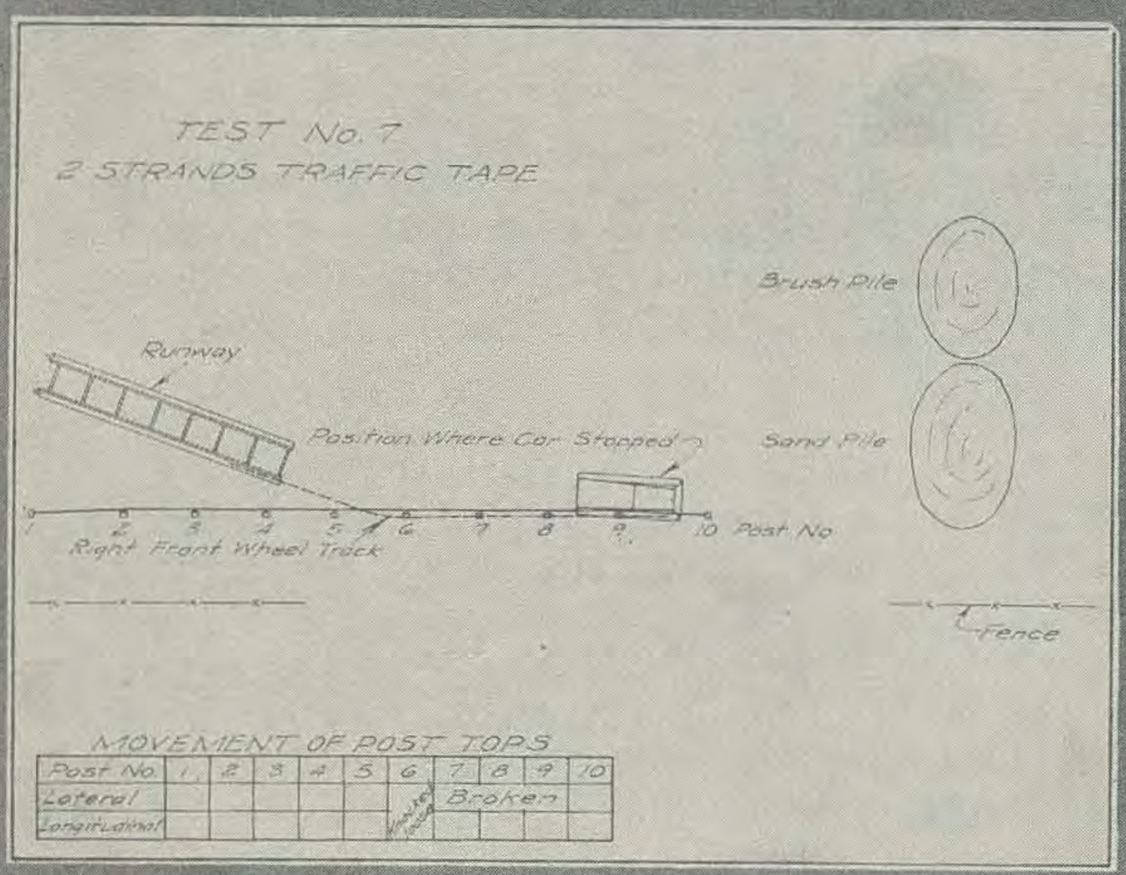
Damage to Car - The right running board was damaged somewhat and the right front fender of the car was crumpled. The bumper was bent and broken but remained on the car. The front axle was torn loose from the right spring and was bent so that the wheels toes out, and the frame was bent and shoved back on the right.

Erection Notes - The rail was easily erected, and no trouble was caused by the vertical curve. In erecting this type of rail, care must be taken in assembling the end fittings to insure that the tape does not pull out. In this test, all of the end fittings held.

Results - This rail deflected the car with small probability of injury to occupants although the impact of the car with the rail caused an appreciable damage to the car and some damage to the rail.






TEST No. 7
2 STRANDS TRAFFIC TAPE
Brush Pile
Runway
Position Where Car Stopped
Sand Pile
1 2 3 4 5 6 7 8 9 10 Post No
Right Front Wheel Track
Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Broken

TEST NO. 7

Description of Rail - The rail used for this test was made up of two strands of "Traffic Tape" (Page Steel and Wire Company). Erection details were the same as for test No. 6 except that the strands of tape were mounted on the intermediate posts with Page type "A" line post offsets. The distance from the ground to the center of the lower strand was 15" and the centers of the two strands were placed 12" apart. These tapes had been used as the two top strands of the four strand "Traffic Tape" rail in test No. 6. Some of the spacer wires had been torn and moved but, otherwise, the tapes were in good condition.

Description of Car - A taxicab (make unknown) loaded to weigh 5,100 pounds, was used for this test. The speed of the car was 33.1 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6. The front end of the car was turned into the line of posts. As the rear end of the car impacted the rail, the car tipped approximately five degrees from the vertical. The car hit post No. 6 hard, knocking it loose in the ground and shoving it back, then climbed over the lower strand and continued on down the line of posts, breaking off posts No.7, No.8 and No.9. The car finally stopped about three feet from the end post with both right wheels over the lower strand of tape.

Damage to Rail - Both strands of tape were deformed from the point of impact to the point where the car stopped. Post No.6 was knocked loose in the ground and posts No.7, No.8 and No.9 were broken off. The offsets on posts No.6, No.7, No.8 and No.9 were damaged beyond repair.

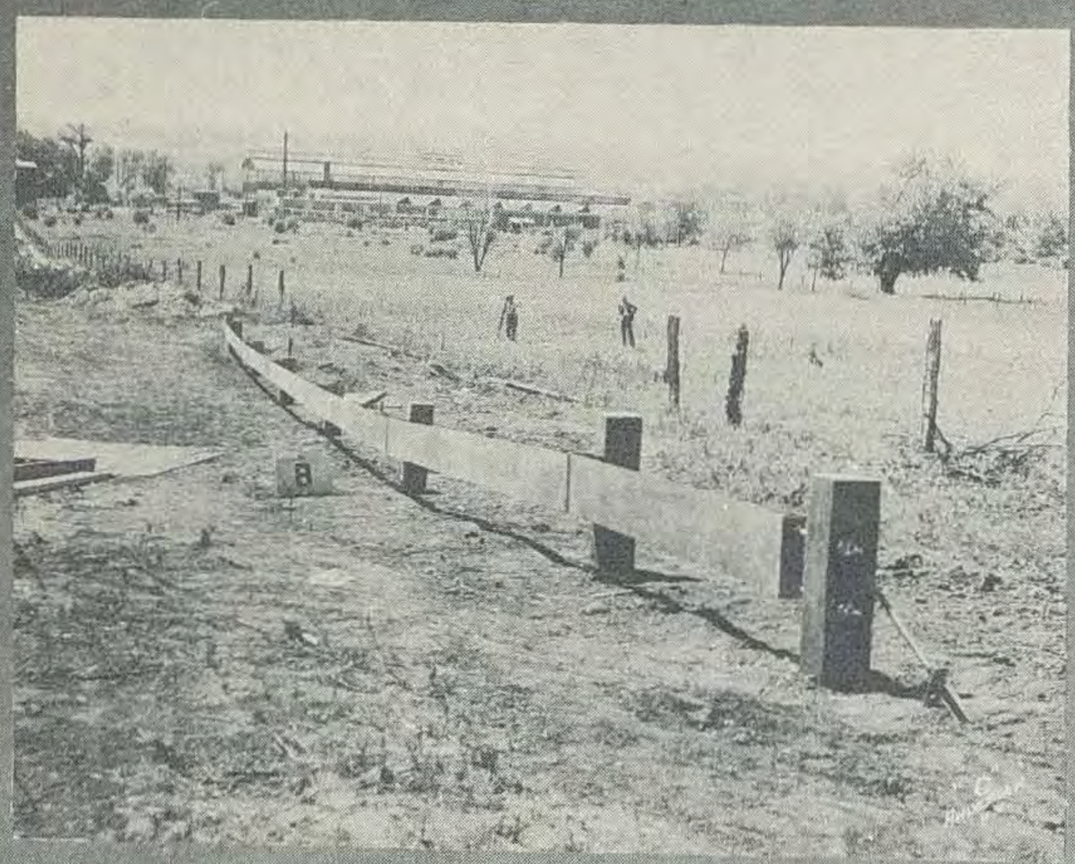
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to retamp one post and to replace three posts, both strands of tape and the offsets on four posts.

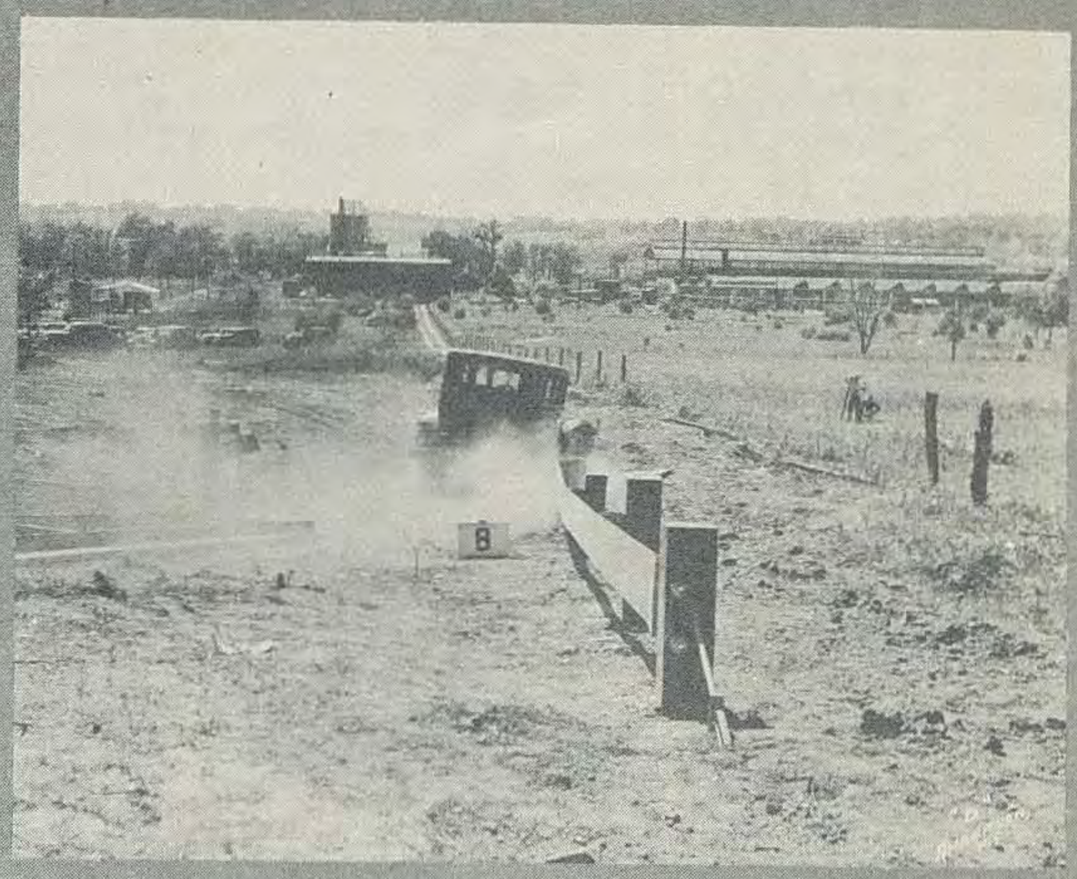
Damage to Car - The right front fender of the car was crumpled, the bumper was broken, and the right front tire was badly torn. The right front spring was broken and the right front wheel was shoved back about eighteen inches. The axle was also twisted.

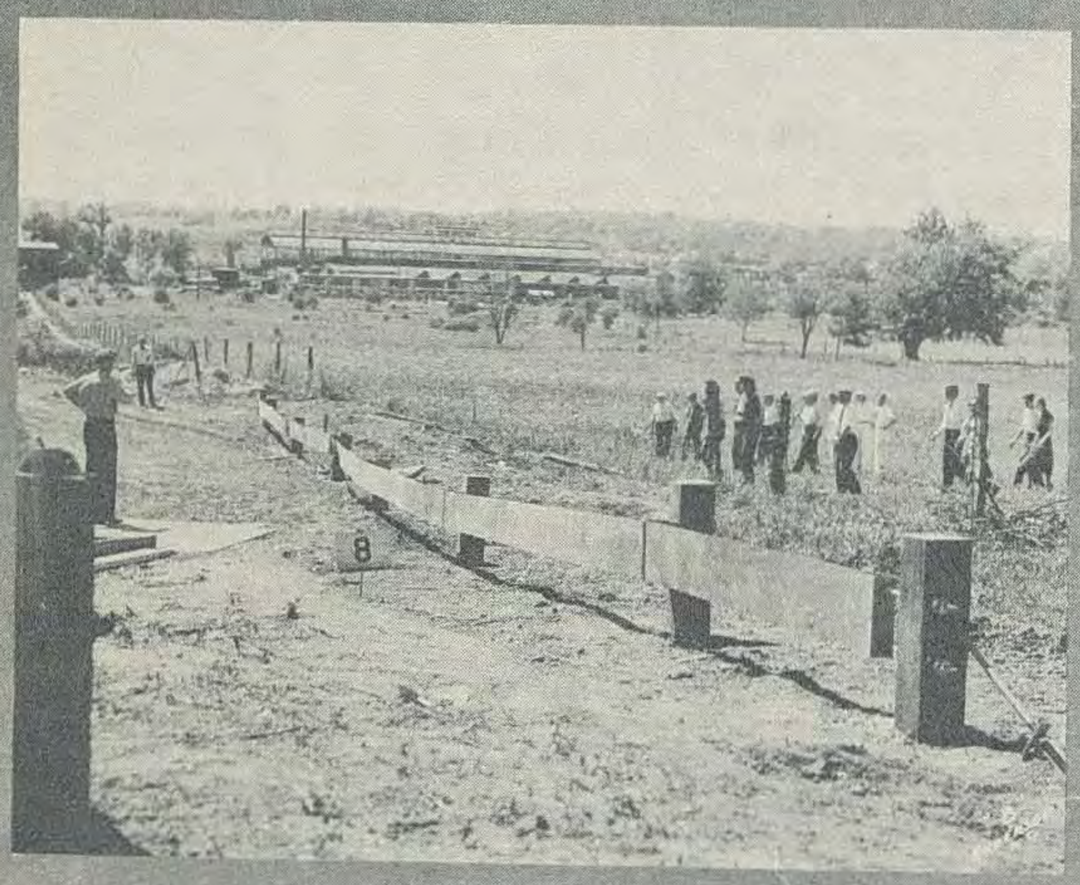
Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

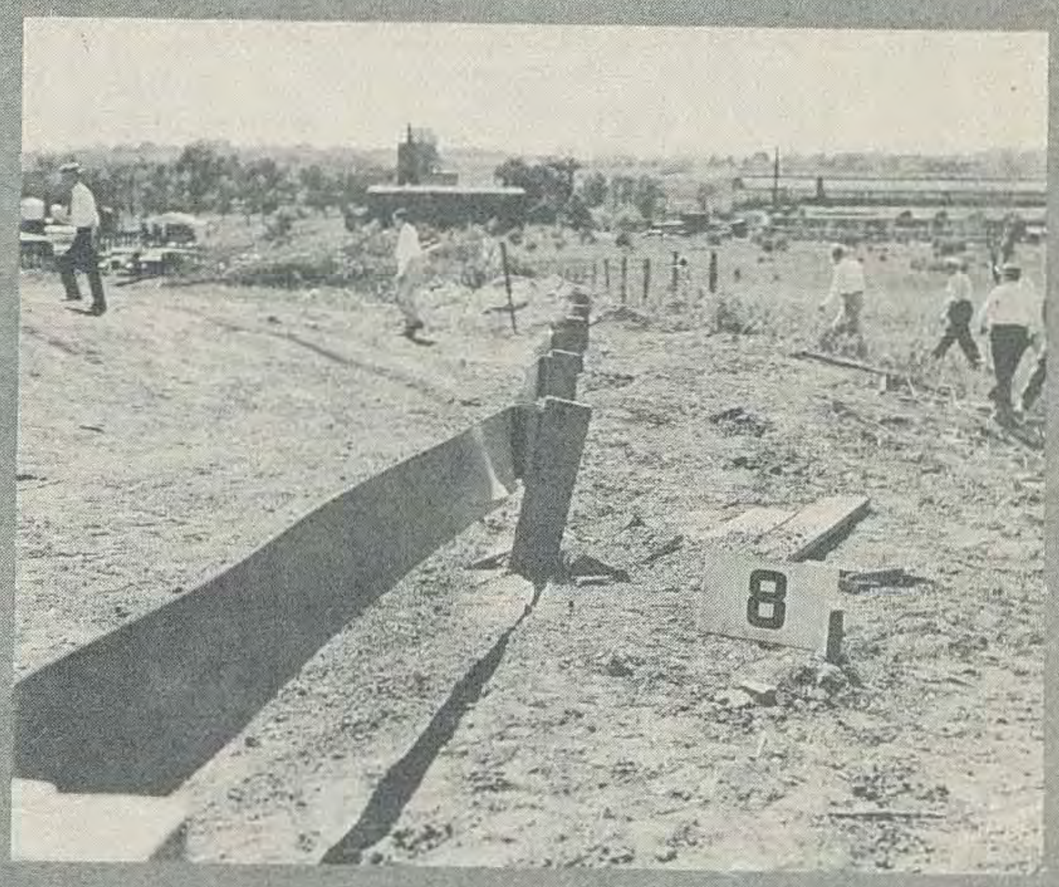
General Remarks - The car used for this test was of a type of construction inferior to that of the Cadillac. Consideration should be given to this fact when comparing the damage to the car caused by the two strands of Traffic Tape to the damage caused by the other types of rail. The performance of the rail in this test was very similar to that in test No.2 but the damage inflicted on the car in this case was in excess of that in test No.2. Since the post spacing, post mounting and spacing of the strands differed from those in test No.2, no conclusion can be drawn as to which factor, the different spacings or the less rugged construction of the car, was most influential in the increased car damage.

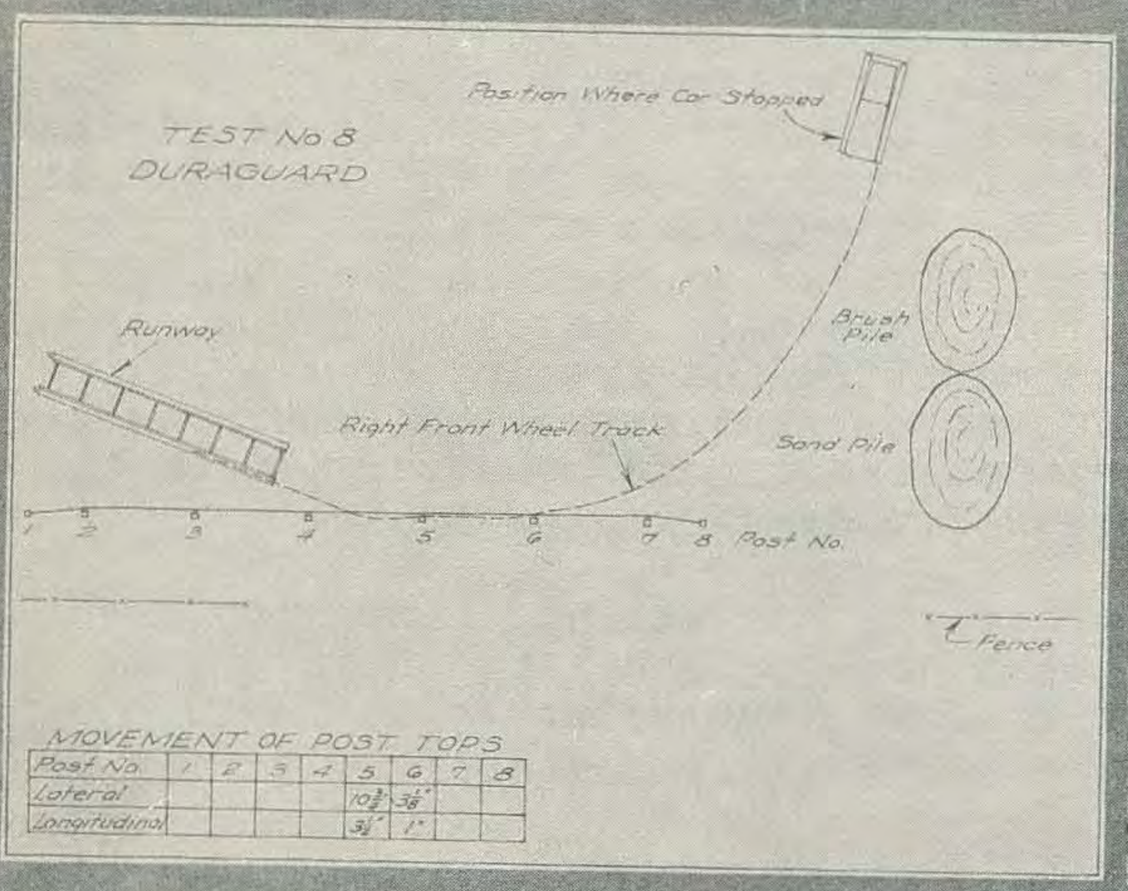
Results - This rail turned the car but the car was not kept away from the posts and stopped against the rail with some probability of injury to occupants. The impacts of the car with the rail caused an appreciable damage to both the car and the rail.











MOVEMENT OF POST TOPS

Post No.	1	2	3	4	5	6	7	8
Lateral					$10\frac{3}{4}''$	$3\frac{1}{8}''$		
Longitudinal					$3\frac{1}{2}''$	$1''$		

TEST NO. 8

Description of Rail - The rail used for the test was "Duraguard" (Truscon Steel Company). It consisted of a plate 12" wide x 0.108" thick, mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The end panels were eight feet long. The rail was connected to each end post with two 3/4" bolts and each end post was anchored to a dead man. The rail was mounted on the intermediate posts by means of a spring offset formed of a 12" plate rolled to an oval curve with the vertical edges flanged inward. The flanged ends of the rail sections were held between the flanged edges of the offset and were connected with three 1" bolts. The spring offset was connected to the post by a single 5/8" bolt. The center of the plate was set 18" above the ground.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 33.7 miles per hour. This car has been used previously for test No.3 and test No.4 but had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail between posts No.4 and No.5. The front of the car was deflected. The rear end of the car was thrown against the rail and as it impacted the rail, the car tipped approximately twenty degrees from the vertical. The car rammed into post No.5, loosening it in the ground, continued along the rail to post No.6, which is also hit and loosened. At a point just beyond post No.6, the car parted contact with the rail and rolled ahead in a curve to the left stopping approximately fifty feet away from and at substantially a right angle with the line of the rail.

Damage to Rail - The rail was bent at post No.5 and at post No.6 and was creased in panel 4-5. The spring offsets at posts No.5 and No.6 were bent out of shape and posts No.5 and No.6 were loosened in the ground.

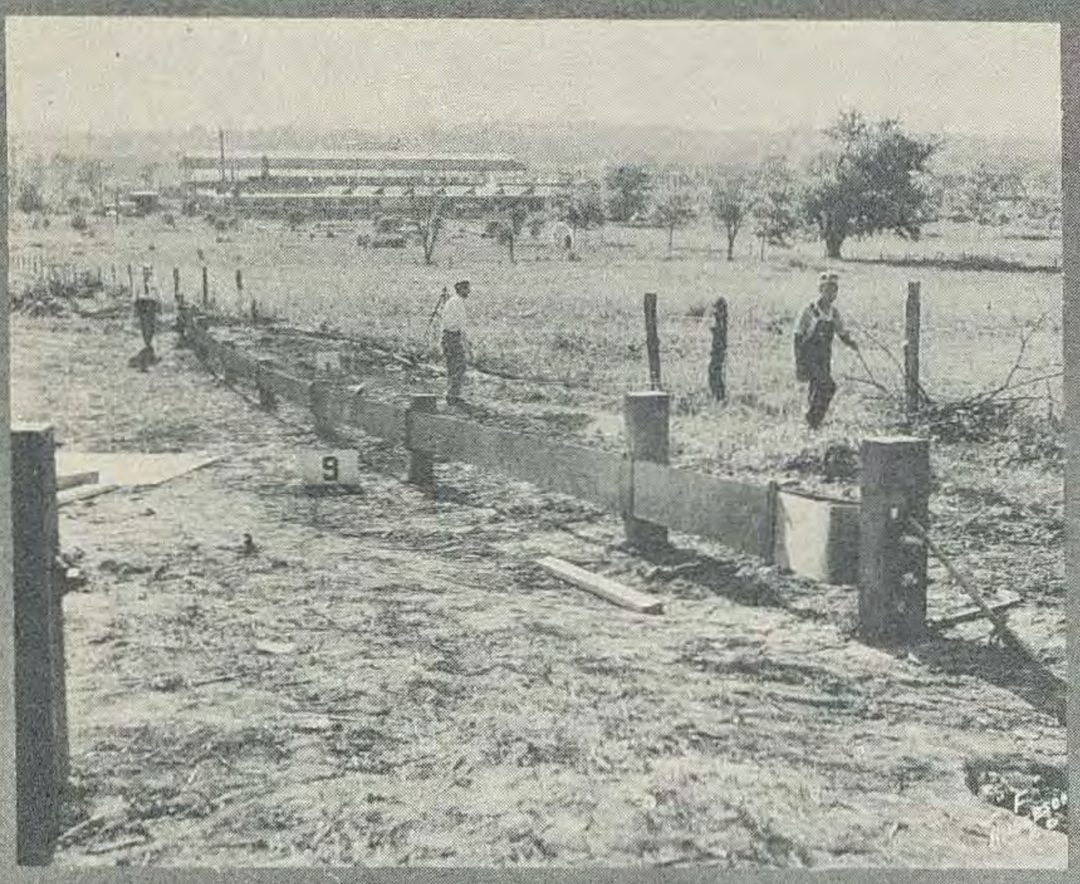
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to retamp two posts and to replace the spring offsets on two posts. Two panels of the rail, at least the flanged end connections, would have had to be straightened. Were that not too difficult, the rail would probably have functioned efficiently without the replacement of any rail panels. In order to have restored the rail to its original condition, however, it would have been necessary to replace two rail panels in addition to the other repairs.

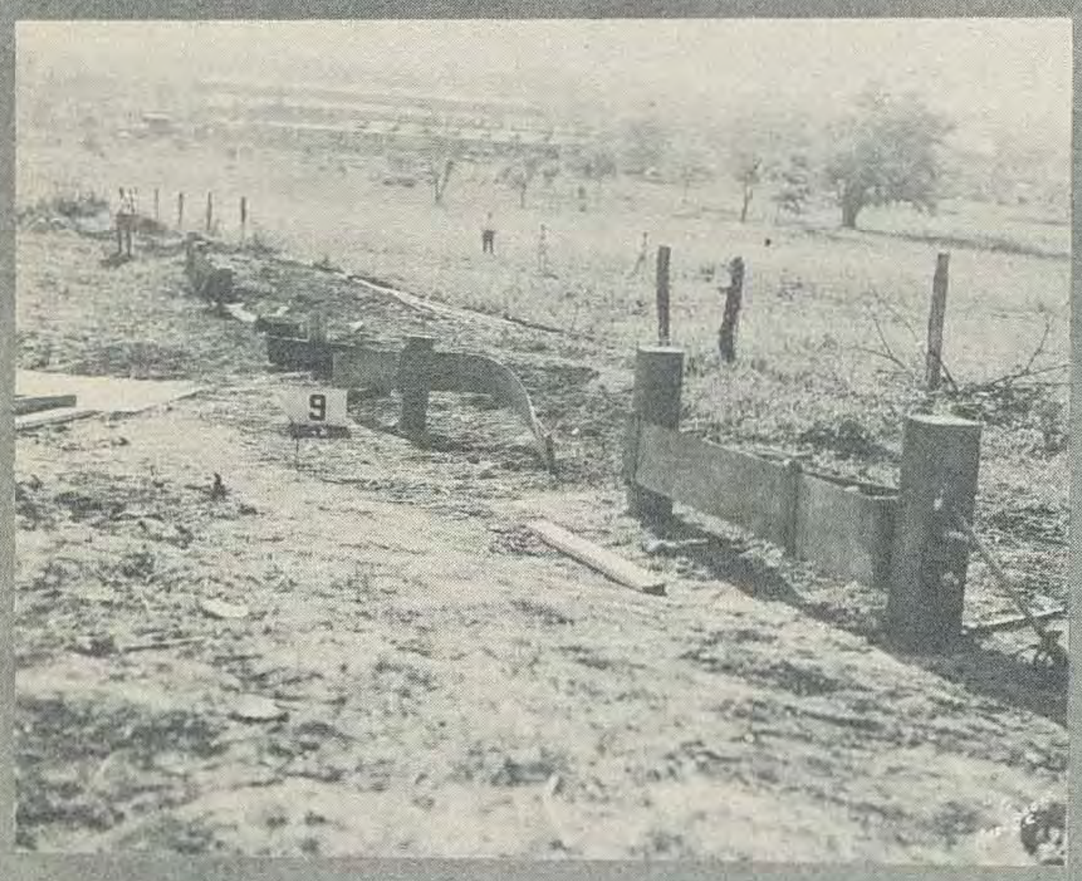
Damage to Car - The light bumper which had been welded on was broken and torn loose from the frame on the right side. The running board was demolished and both fenders on the right side were crumpled. The bottom of the right rear door which had been previously damaged and was held shut by a 2" x 1/8" bar was sprung out by the bags of sand. The right front spring was broken, the axle twisted and the right front wheel shoved back.

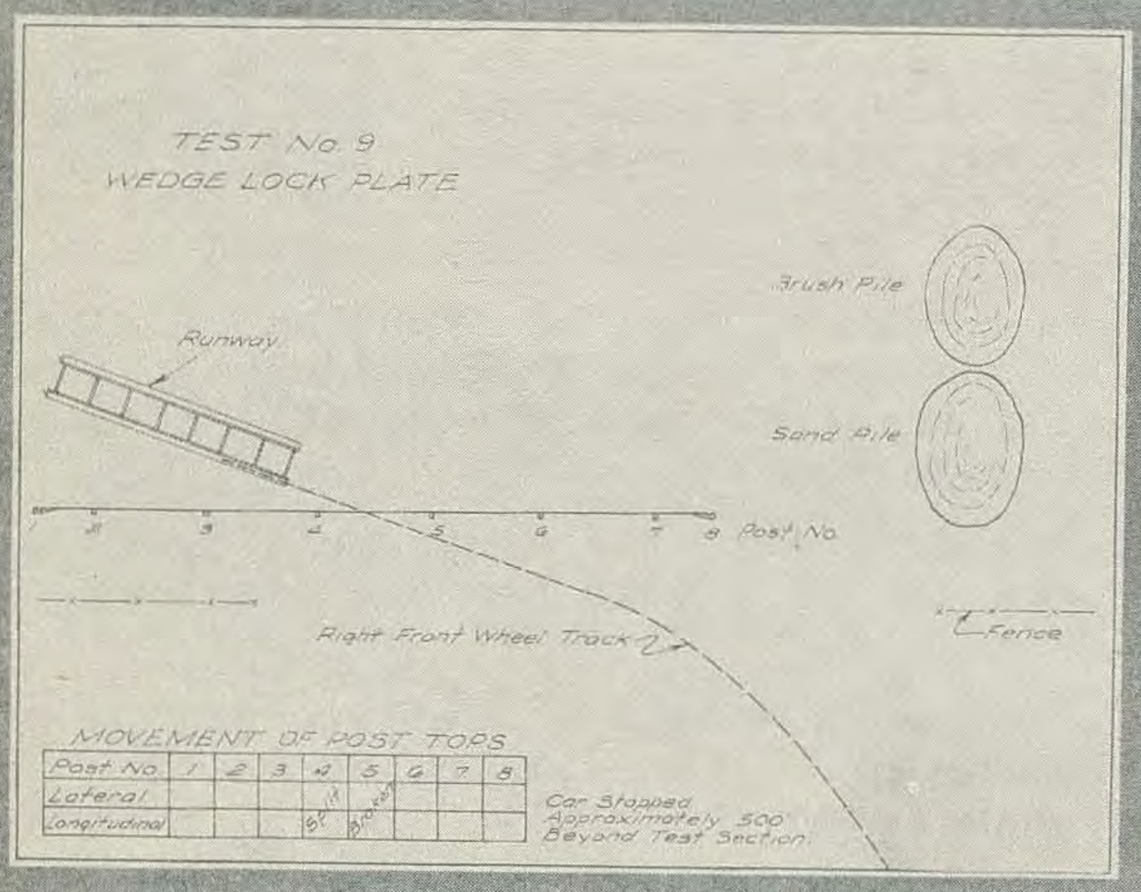
Erection Notes - Special tools are required for the erection of this rail. Although the rail was erected to conform to the vertical curve, some difficulty was encountered and as finally erected the top edge of the rail plate was somewhat less taut than the bottom edge.

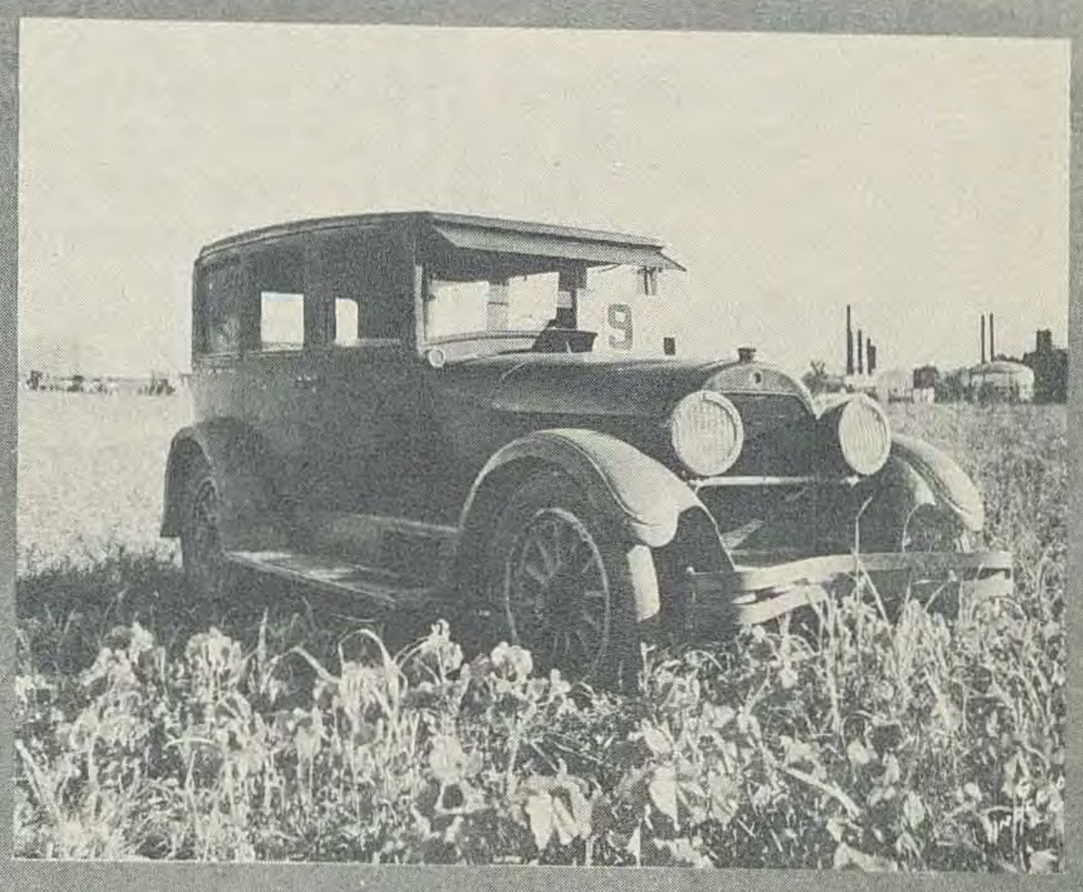
General Remarks - In considering the damage to the car some allowance should be made for the fact that this car had been used for two previous tests.

Results - This rail deflected the car with small probability of injury to occupants although the impact of the car with the rail caused an appreciable damage to the car and some damage to the rail.






TEST No. 9
WEDGE LOCK PLATE
Brush Pile
Runway
Sand Pile
Post No.
Right Front Wheel Track
Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral
Longitudinal
Car Stopped Approximately 500' Beyond Test Section



TEST NO. 9

Description of Rail - The rail used in this test was Wej-Lock Plate. The plate rail, 12" wise x 0.065" thick, was mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The rail was connected to each end post by two 3/4" bolts on which helical compression springs were mounted and each end post was anchored to a dead man. The rail was mounted directly on the intermediate posts by means of two clamp plates. The ends of adjoining panels were interlocked by a folded connection which was held by the clamp plates. The center of the plate was set eighteen inches above the ground.

Description of Car - A Cadillac sedan which weighed 5,100 pounds was used for the test. The speed of the car was 34.6 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No.4 and No.5. The impact of the car with the rail split post No. 4 and the car ran into post No. 5, breaking it and shearing the plate in panel 4-5 at post No. 5. After this the car ran over the rail, there being no deflection and little deminution in speed of the car.

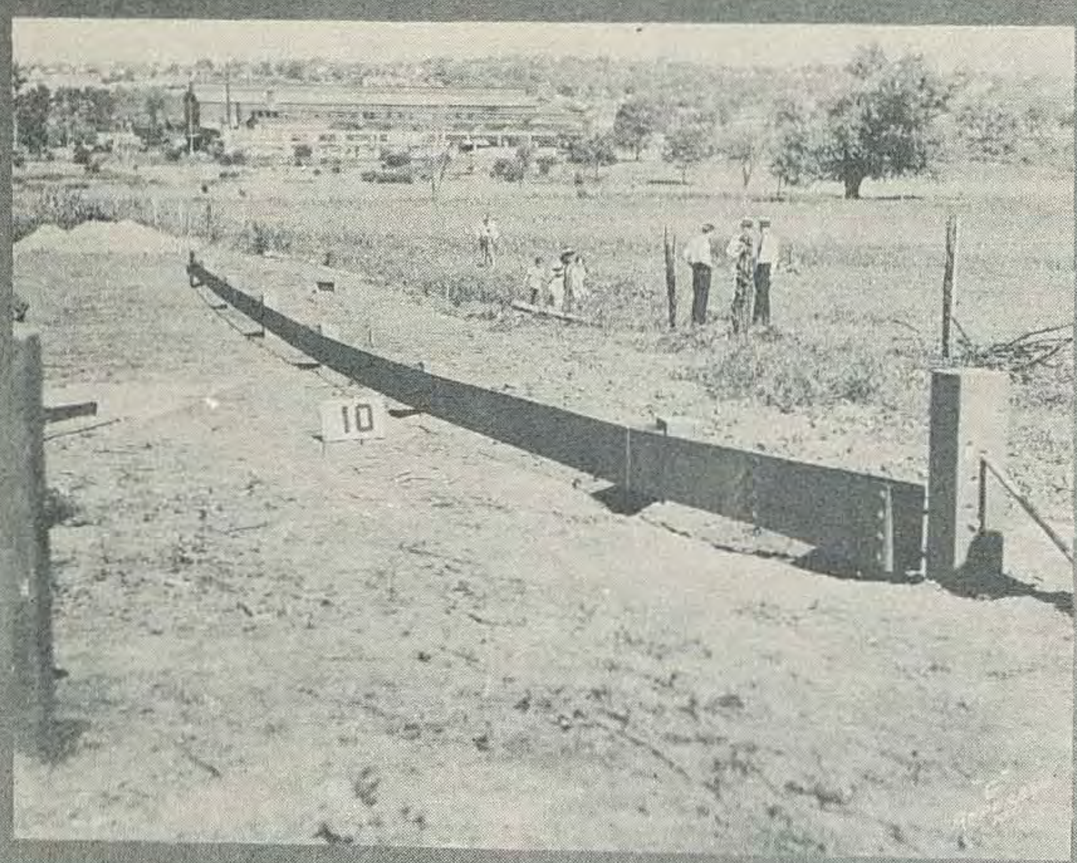
Damage to Rail - The joint at post No. 2 was pulled apart and the plate in panel 4-5 was cleanly sheared in two at post No. 5. Panels 4-5 and 5-6 were badly crumpled and twisted. Post No. 4 was split and post No. 5 was broken off.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace two posts and two rail panels.

Damage to Car - The only damage suffered by the car was a bent bumper caused by running over post No. 5. The photographs show broken glass in the lower section of the windshield. This was caused by running through a fence in an adjoining field.

Erection Notes - The rail was not adapted to the vertical curve and the top edge of the plate was quite loose.

Results - This rail did not prevent the car from leaving the roadway.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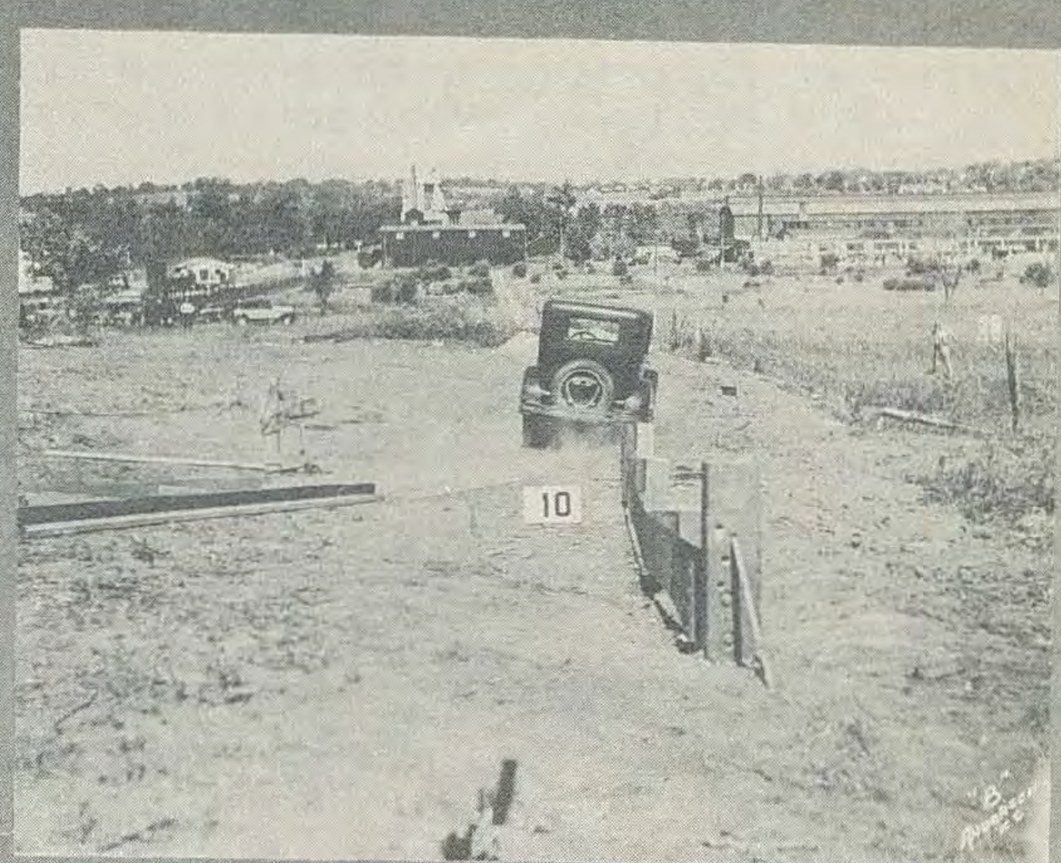
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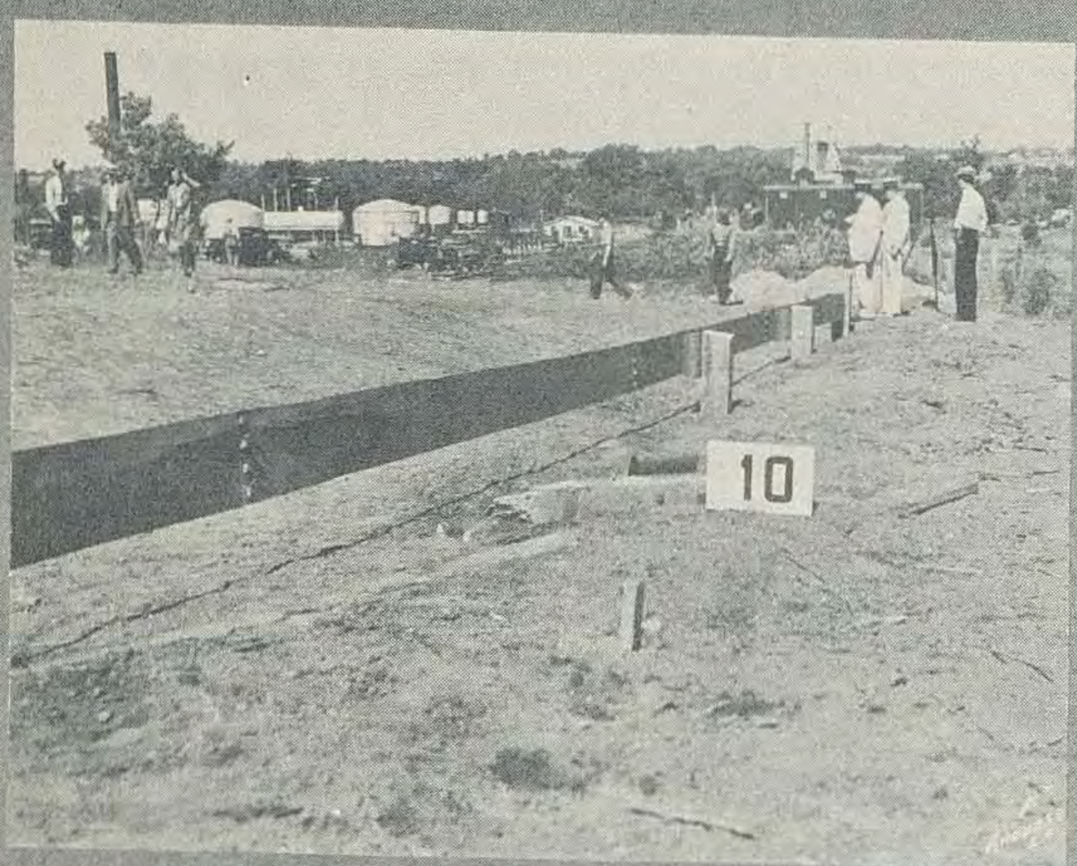
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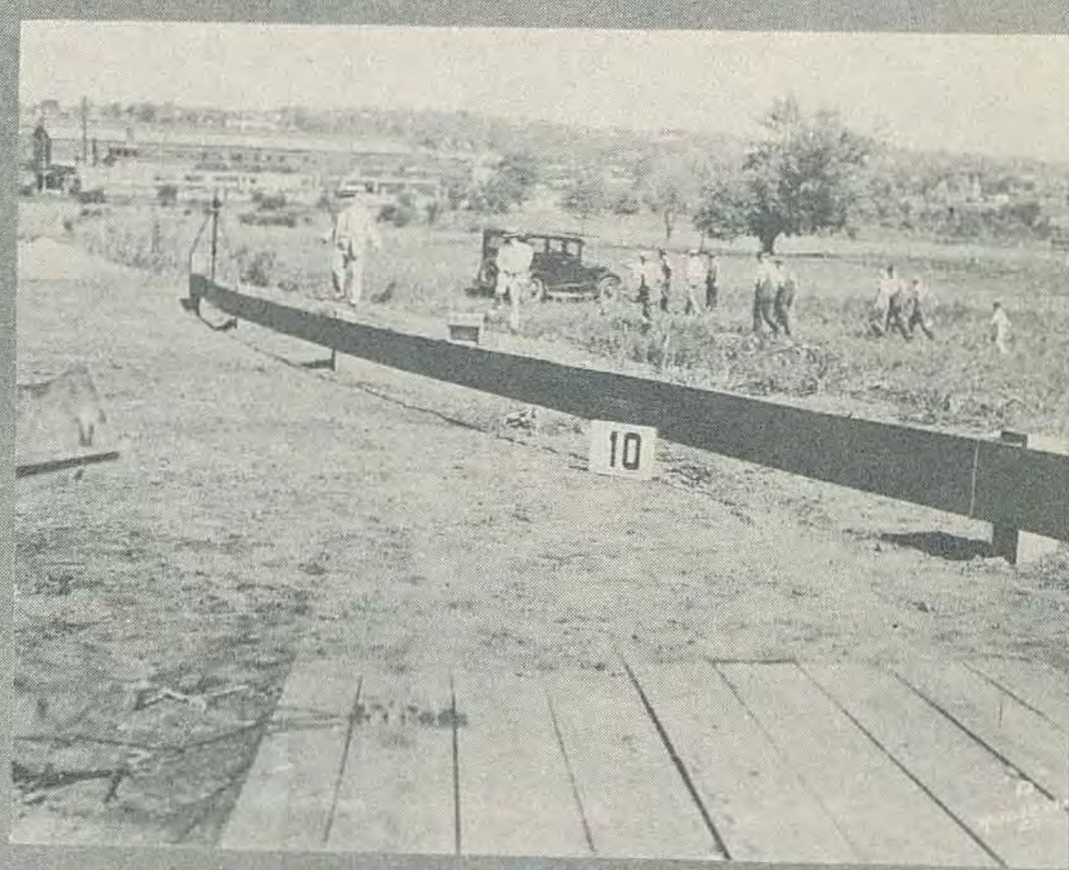
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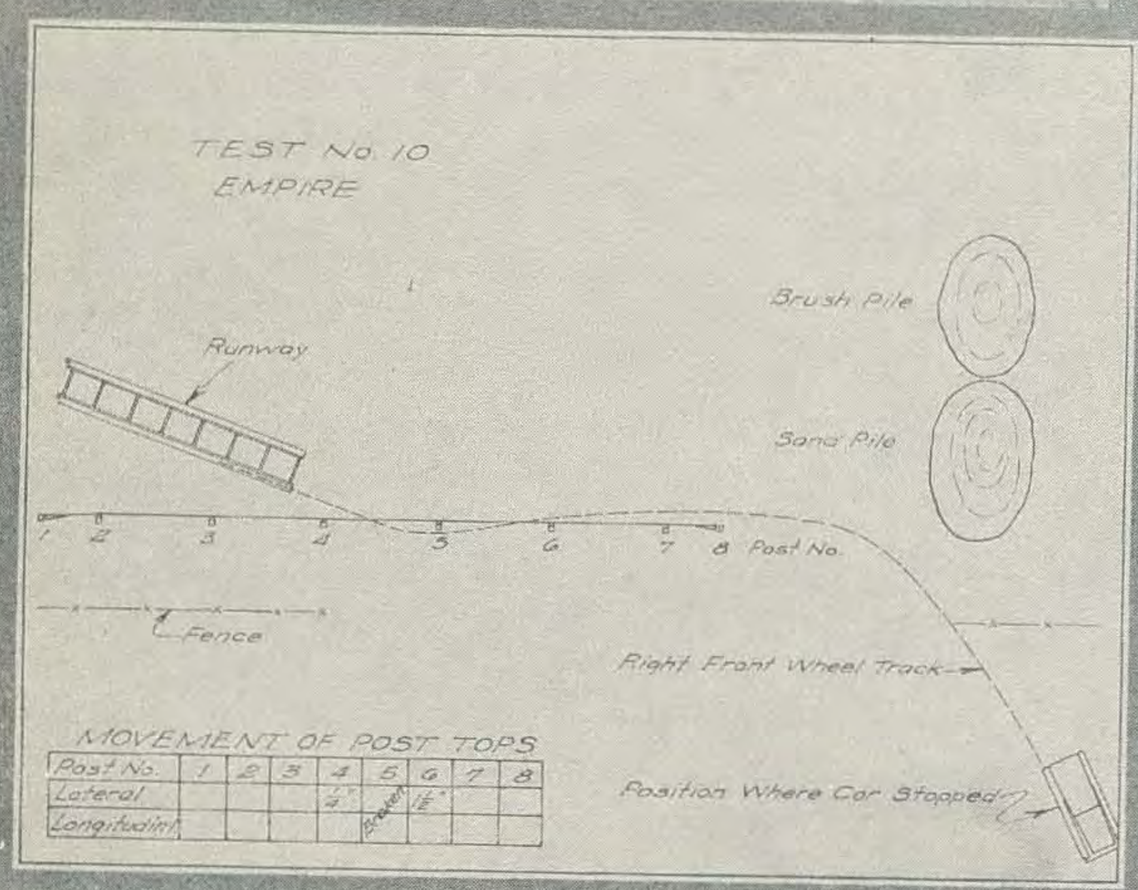
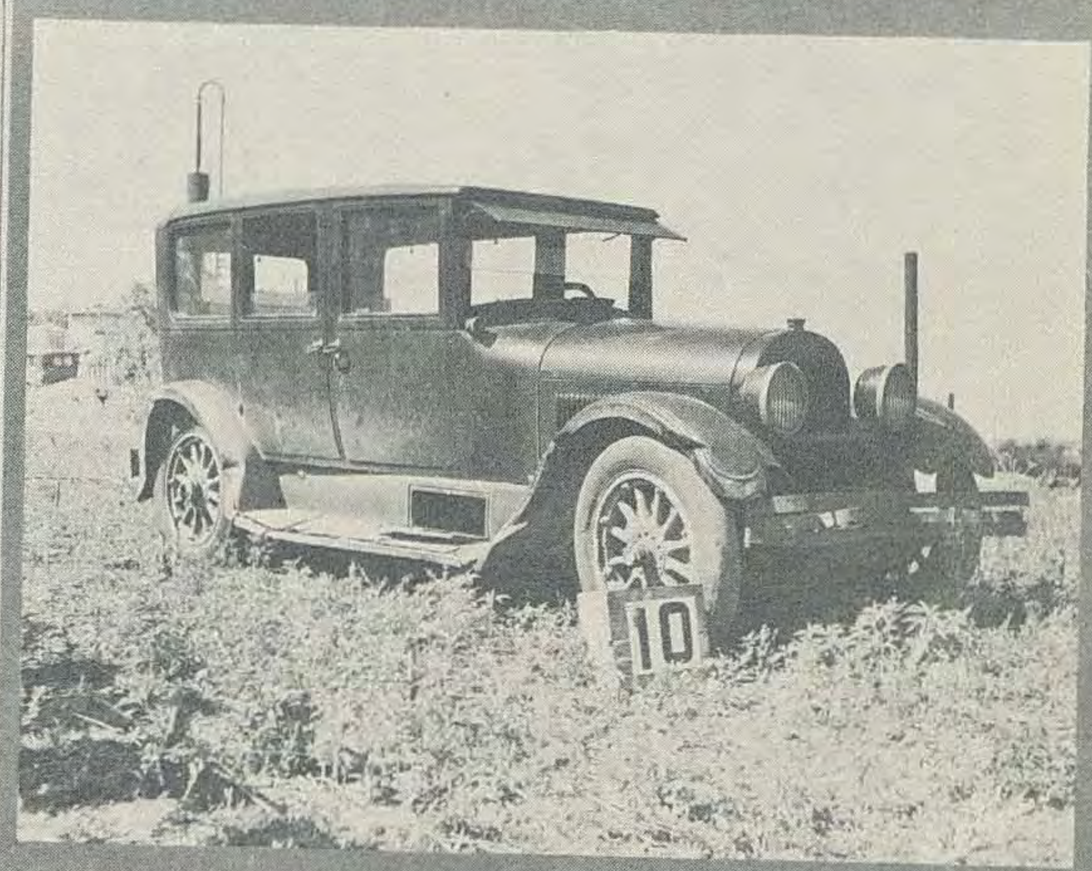

TEST No. 10
EMPIRE
Runway
Brush Pile
Sand Pile
1 2 3 4 5 6 7 8 Post No.
Fence
Right Front Wheel Track
Position Where Car Stopped
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral
Longitudinal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TEST NO. 10

Description of Rail - The rail used for the test was "Empire" (General Wheelbarrow Company). It consisted of a plate, 12" x 0.076", mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The end panels were eight feet long. The rail was connected to the end posts with two 3/4" bolts, on which were mounted helical compression springs, and each end post was anchored to a dead man. The rail was mounted on the intermediate posts by means of a spring offset which was formed of a 12" plate rolled into a cylinder and was fastened to the post by means of two 5/8" bolts. The plate section was held to the spring offset by a band which allowed the plate to move longitudinally. Adjoining panels of the rail were connected together by means of a single lap splice which was made with seven 1/2" pan head bolts. The center of the plate was set eighteen inches above the ground.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 34.0 miles per hour. This car has been used previously for test No. 9 but had suffered no serious damage.

Behavior of Car and Rail - The car hit the rail between posts No.4 and No.5, approximately seven feet ahead of post No.4. The front of the car was deflected. The rear end of the car was thrown in against the rail and rebounded forcibly from it, the right rear wheel landing almost three feet from the original rail line on the rebound. As the rear end of the car impacted the rail, the car tipped approximately twenty degrees from the vertical. The car hit post No.5 hard, breaking it off, and then rolled along the rail to post No.6. There it parted contact and ran parallel with the rail for about thirty feet, at which point it curved to the right, crossed the line of the rail and ran down hill into an adjoining field. Had the rail been two panels longer, the car would have hit the rail a second time.

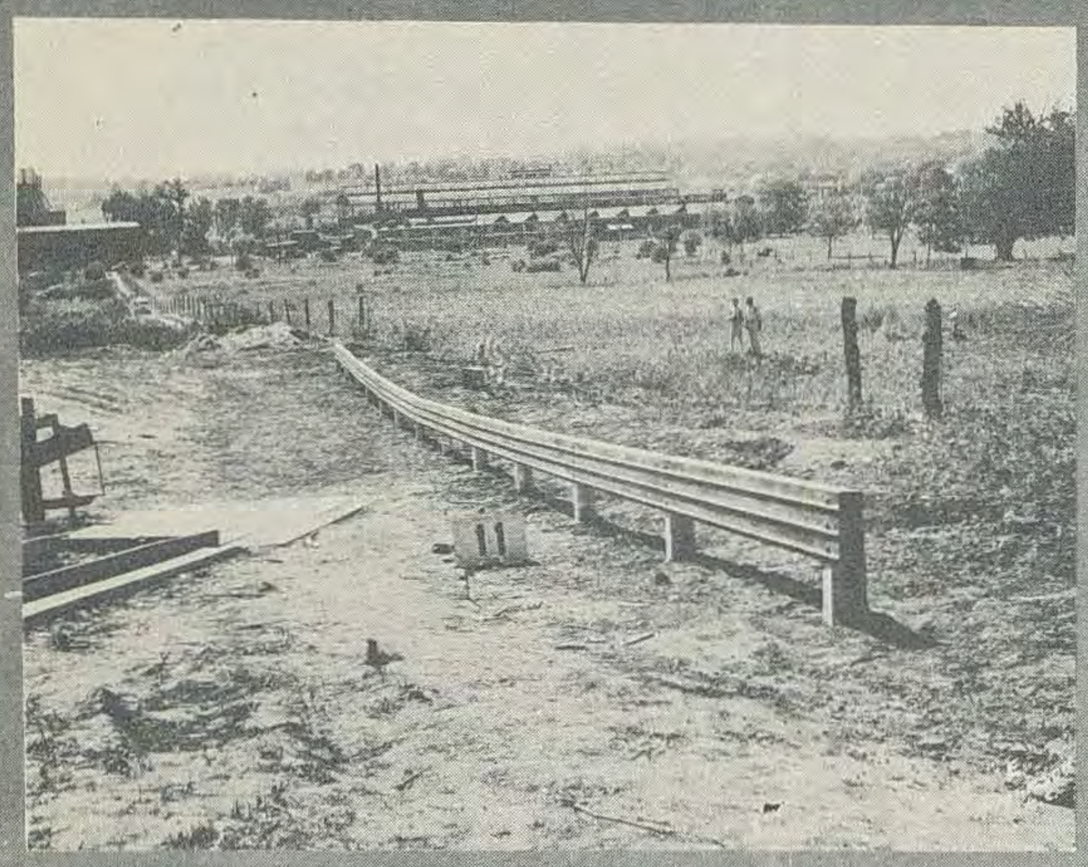
Damage to Rail - Two plate panels were creased and slightly bent and another panel had a wavy bend on the top edge. The rail was torn loose from the spring offset, which was bent, at post No.6 and the spring offset at post No.5 was flattened. Post No.5 was broken off, and post No.6 was loosened in the ground.

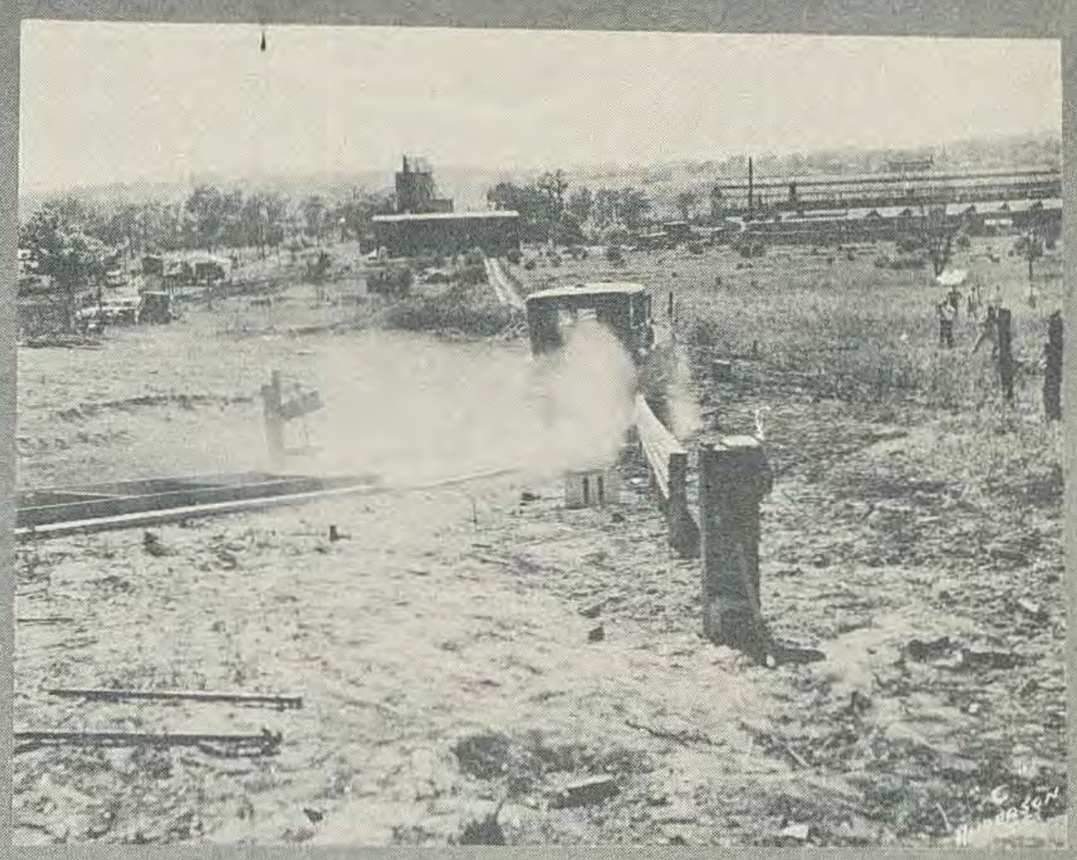
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to retamp one post and to replace one post and the spring offsets on two posts. While none of the plate panels were badly deformed, yet it would have been necessary to replace one of them, in order to slip it under the band on the spring offset. Otherwise, the rail would probably have functioned efficiently without replacing any rail panels.

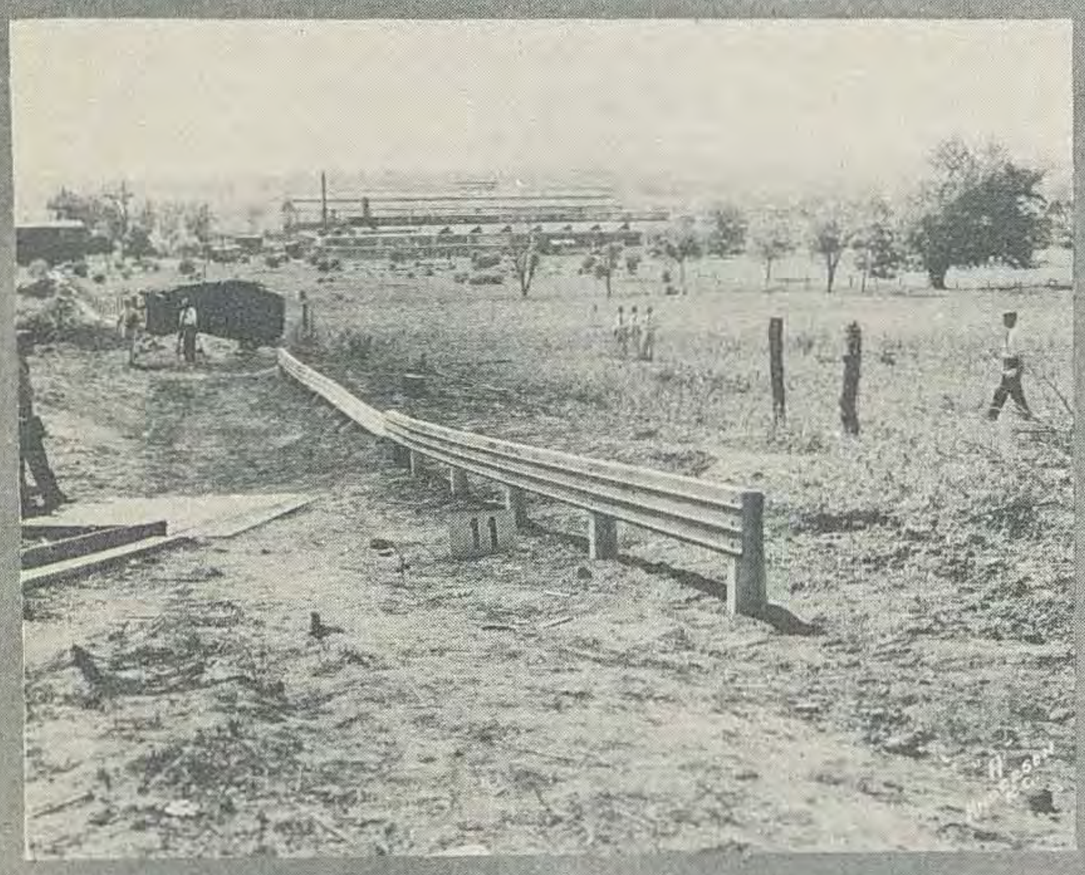
Damage to Car - The bumper was bent, the fenders on the right side were bent, the running board was bent and the right rear hub cap was knocked off.

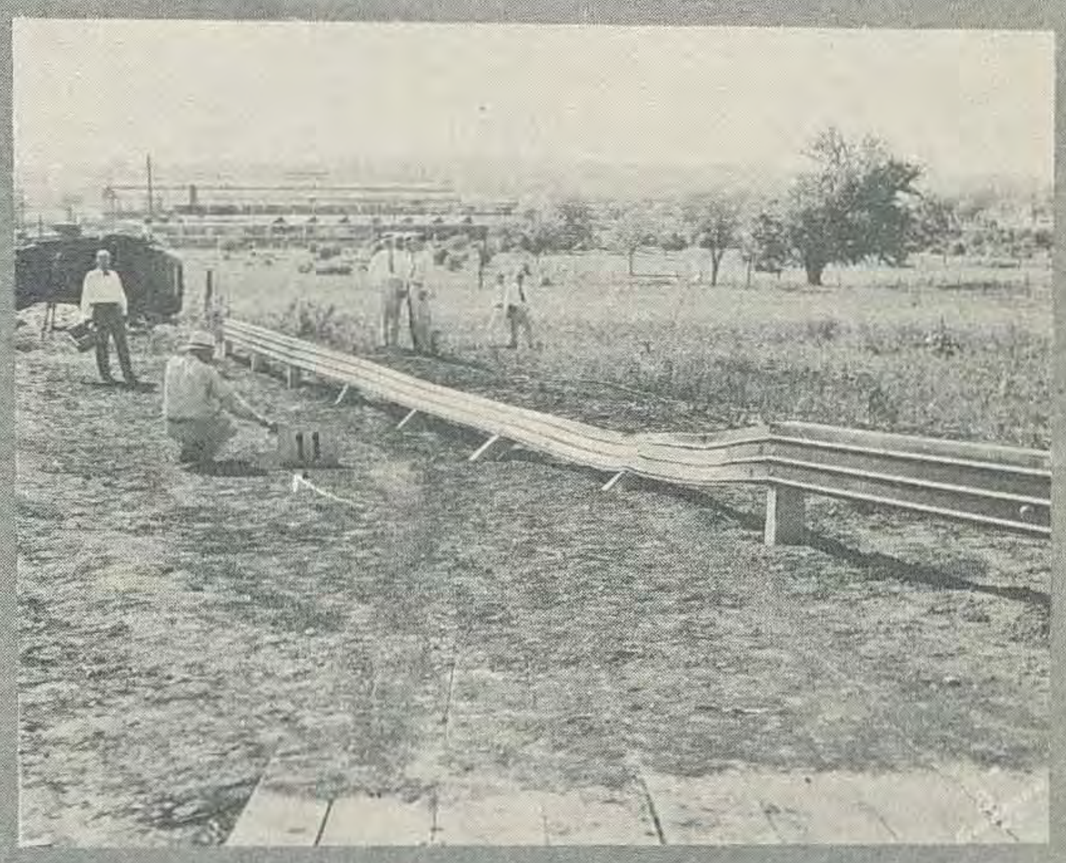
Erection Notes - Considerable difficulty was encountered in erecting this rail. This difficulty was due to the fact that the rail was not able to accommodate itself to a vertical curve as sharp as that on the test section location. The company's erector made no attempt to place the rail so that it could have been continued back from post No.1; in fact, at that point, the rail was set directly on the ground. Later experience showed that this type of rail could be made to accommodate the vertical curve by reaming the splice holes of the joints between panels.

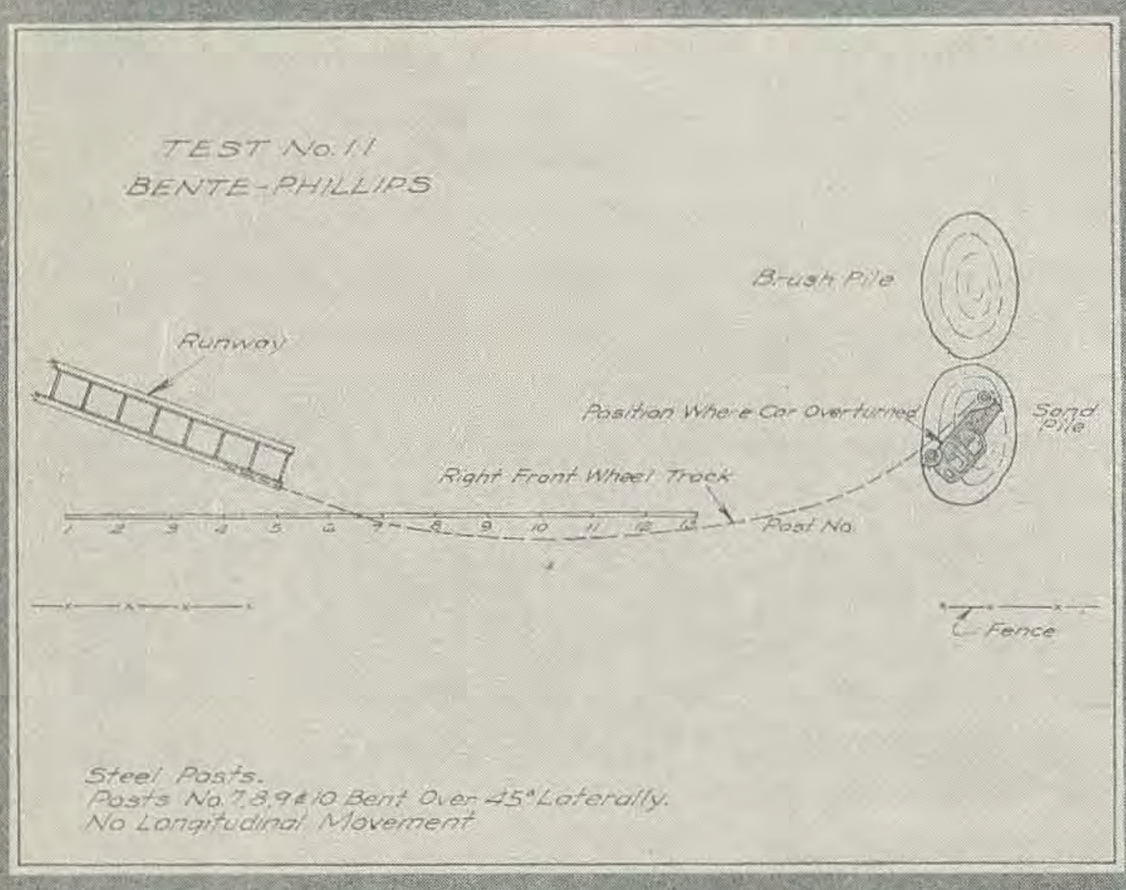
Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.

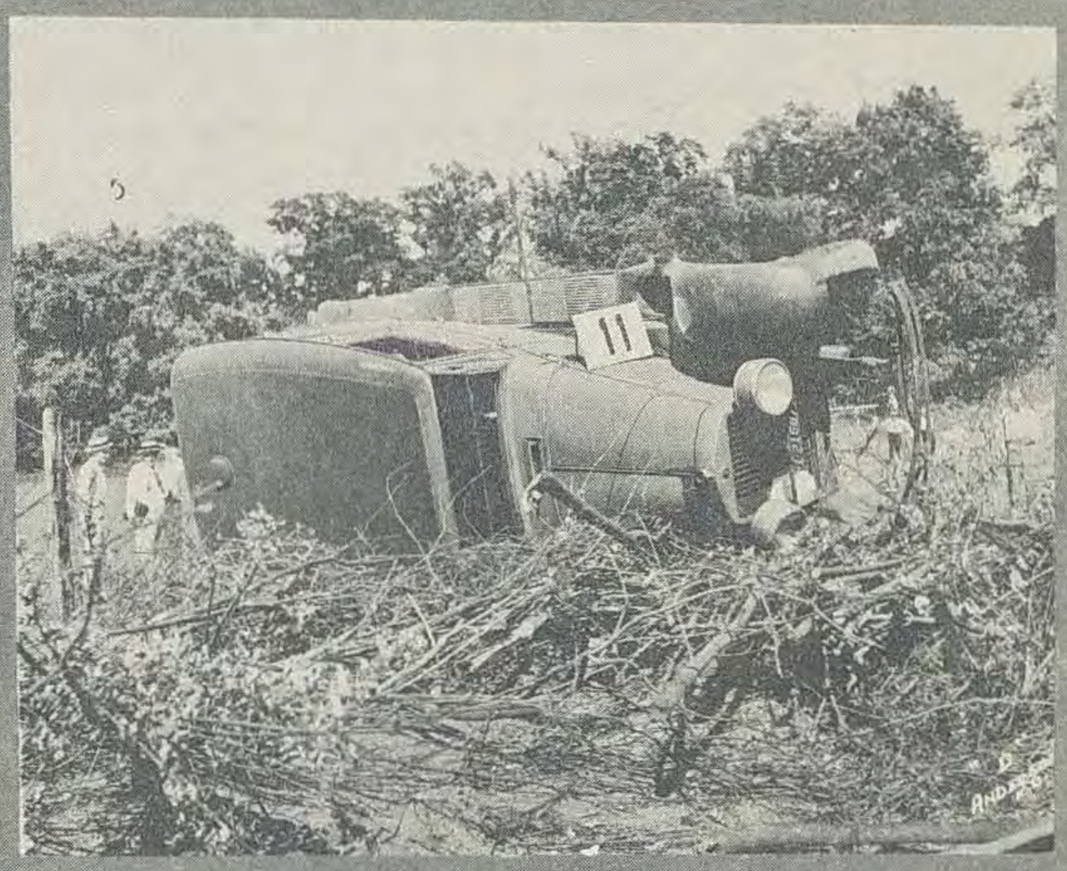









TEST No. 11
BENTE-PHILLIPS
Brush Pile
Runway
Position Where Car Overturned
Sand Pile
Right Front Wheel Track
1 2 3 4 5 6 7 8 9 10 11 12 13
Post No.
Fence
Steel Posts.
Posts No. 7, 8, 9 & 10 Bent Over 45° Laterally.
No Longitudinal Movement


11

TEST NO. 11

Description of Rail - The rail used for the test was "Bente Phillips" (Bente Phillips Metal Products Company). It consisted of a plate, 20" x 0.109", bent to a box top section with a 12" vertical projection on the face, a 4-3/16" horizontal projection across the top, and a 3-1/16" vertical projection in the rear. In the face, there were three corrugations, 3/8" deep, spaced 4" center to center. The rail was mounted on "Z" type metal posts, 0.109" thick, with the depth of post at the top such that the rail just fitted over it. These posts were five feet long and were set three feet in the ground, seven feet five inches center to center. The end posts were not anchored. Adjoining panels were connected by a single lap splice which was made with four 1/2" carriage bolts and these bolts also fastened the rail to the post. The center of the rail was set eighteen inches above the ground.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 34.1 miles per hour. This car had been used previously for test No.6 and in that test the front axle had been torn loose from the right spring.

Behavior of Car and Rail - The car struck the rail between posts No.6 and No.7. As the car struck the rail it bent and pushed over post No.7 which enabled the right front wheel to climb over the rail. When the left front wheel struck the rail the car turned and posts No.8, No.9 and No.10 were bent and pushed over. The right rear wheel followed the right front wheel over the rail and as the right front wheel touched the ground back of the rail, the car tipped approximately thirty degrees from the vertical. However, the car righted itself, continued on down the rail, astraddle it, and then ran off the end of the test section onto the sand pile where it turned over.

Damage to Rail - Posts No.7, No.8, No.9 and No.10 were badly bent. Panels 6-7 and 7-8 were bent and dented. Panel 10-11 was twisted. Panels 8-9 and 9-10 were practically undamaged.

Repairs for Rail - In order to have placed this rail in a serviceable condition, it would have been necessary to replace four posts and three panels of rail.

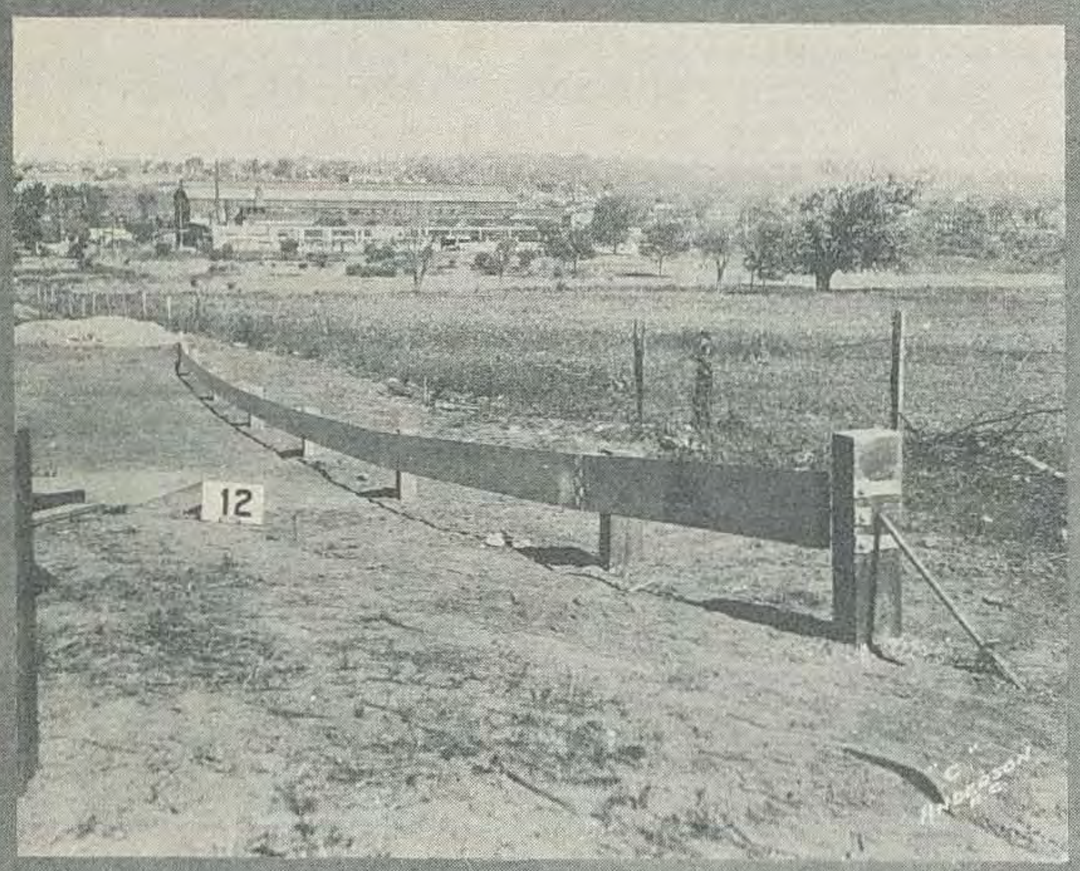
Damage to Car - The collision of the car with the rail pushed the axle back on the right front spring. The car's passage along the top of the rail ripped a hole in the gasoline tank and cut the battery holder. The overturning of the car crumpled the fenders and running board on the right side.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - It was impossible to ascertain at just which point the front axle of the car was damaged, whether this occurred when the car struck the rail or when the car overturned. If it is assumed that the impact of the car with the rail was the cause, then, due to the fact that in a previous test the front axle of the car had been torn loose from the righ spring and due to the apparent ease with which four of the steel posts were pushed over, it appears doubtful that a car in better condition would have been as seriously damaged.

Whether or not the car would have overturned, had the sand pile not obstructed its path, is problematical.

Results - The steel posts failed to hold the rail erect at the time of impact, allowing the car to mount the rail. The car was turned but its path was so erratic that there was at least some probability of injury to occupants. Both the car and the rail were appreciably damaged.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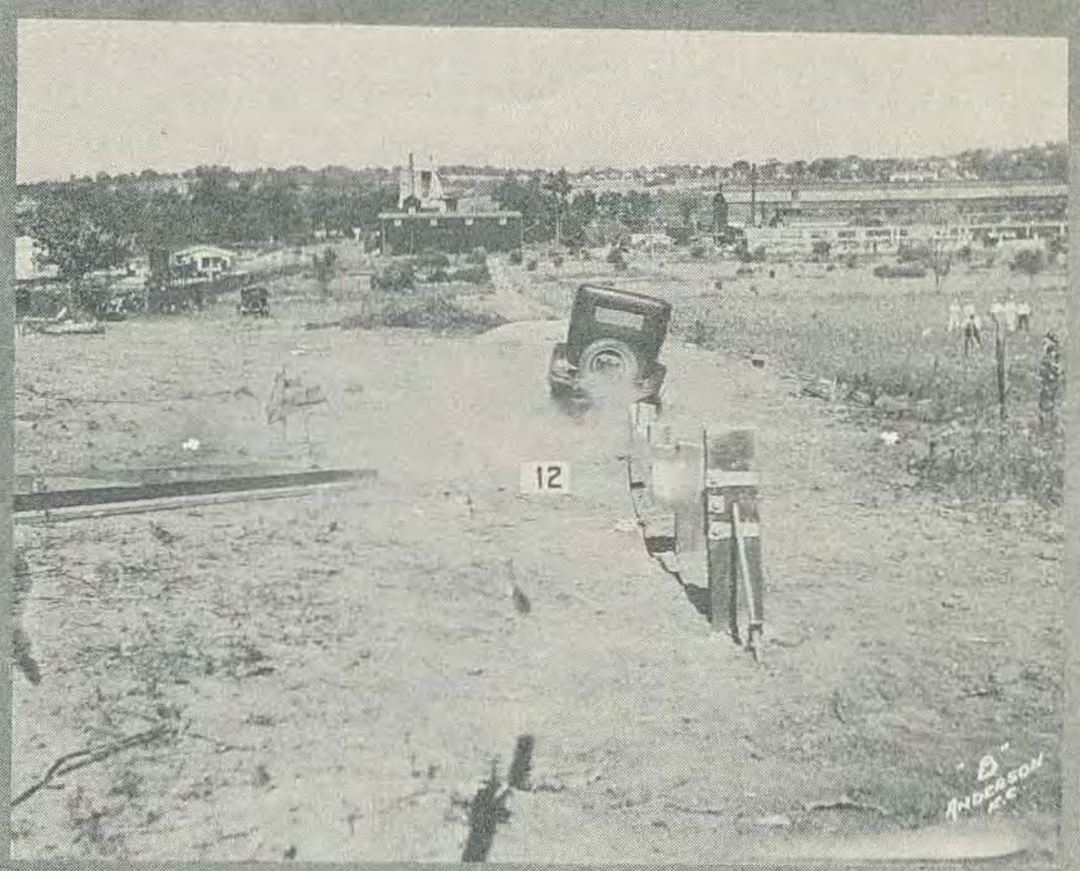
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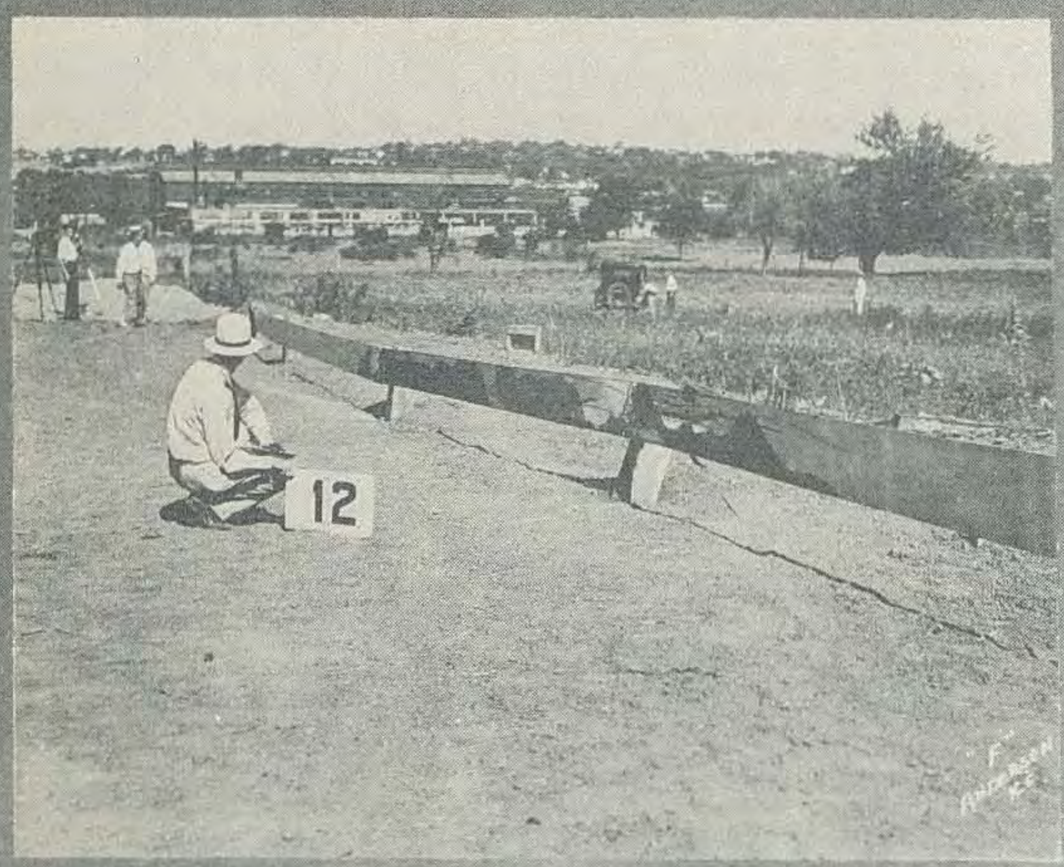
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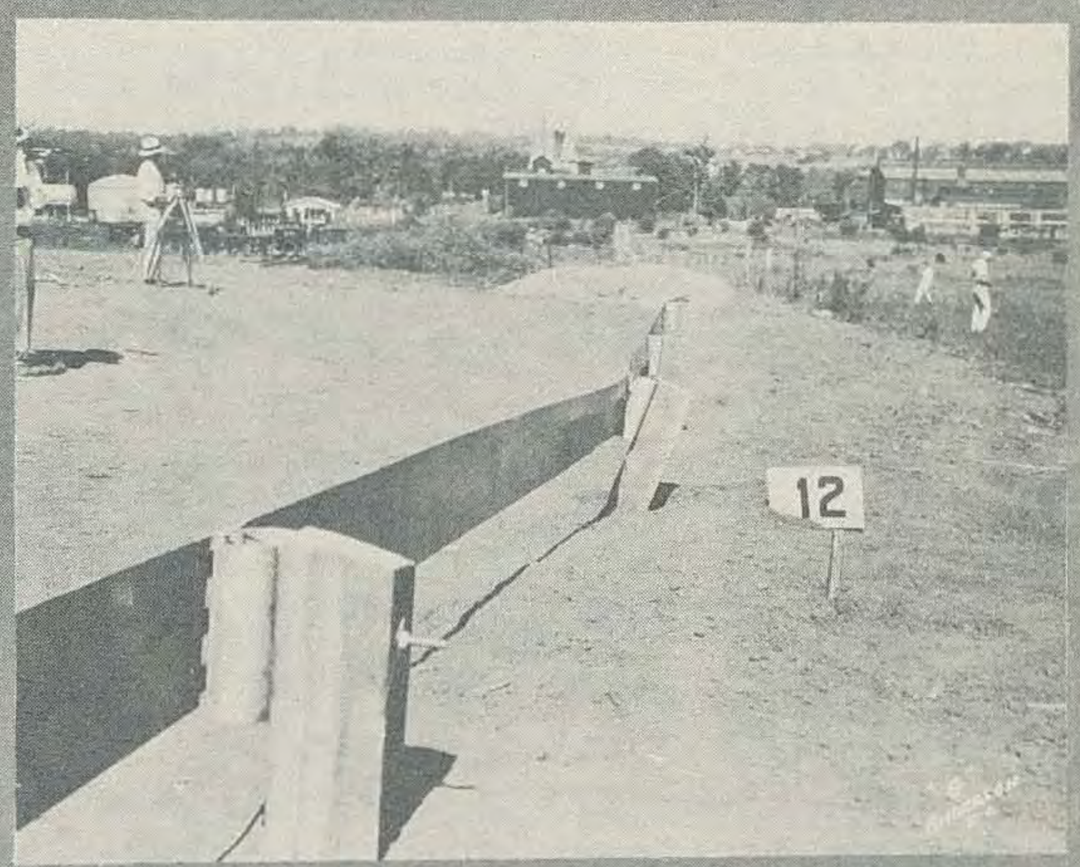
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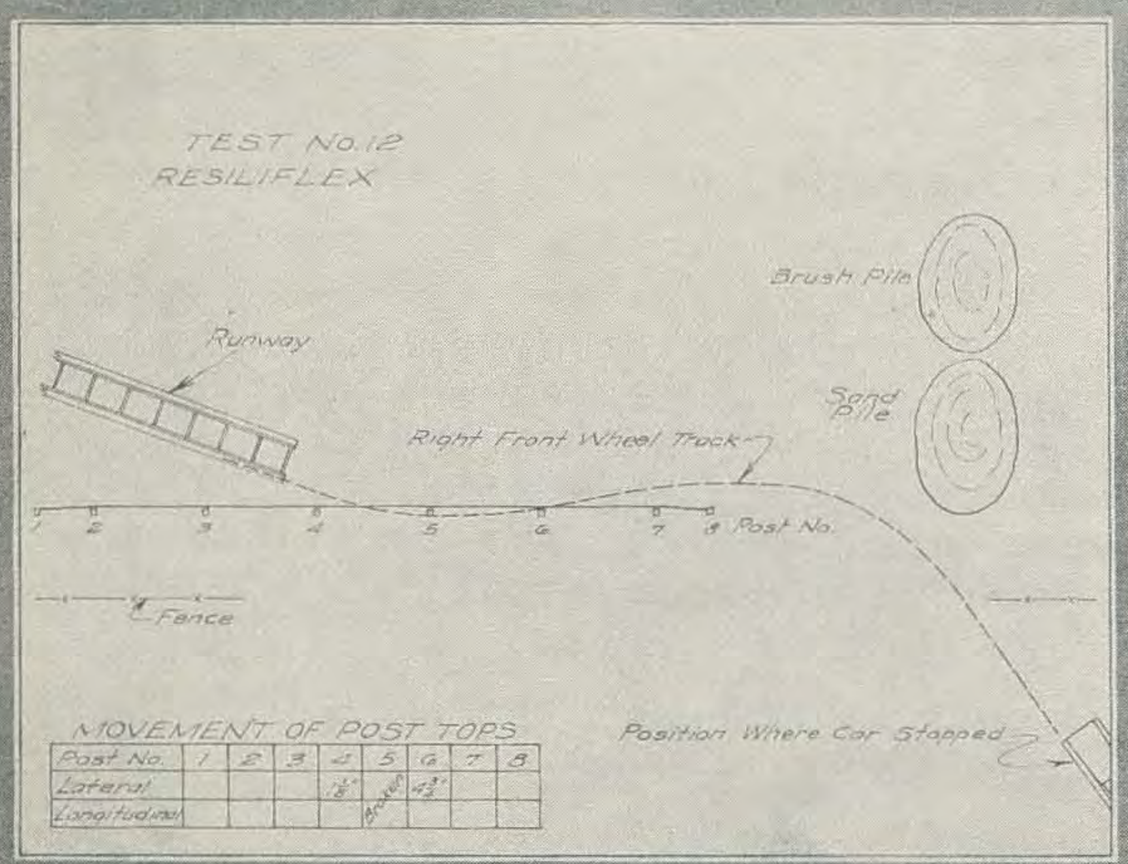
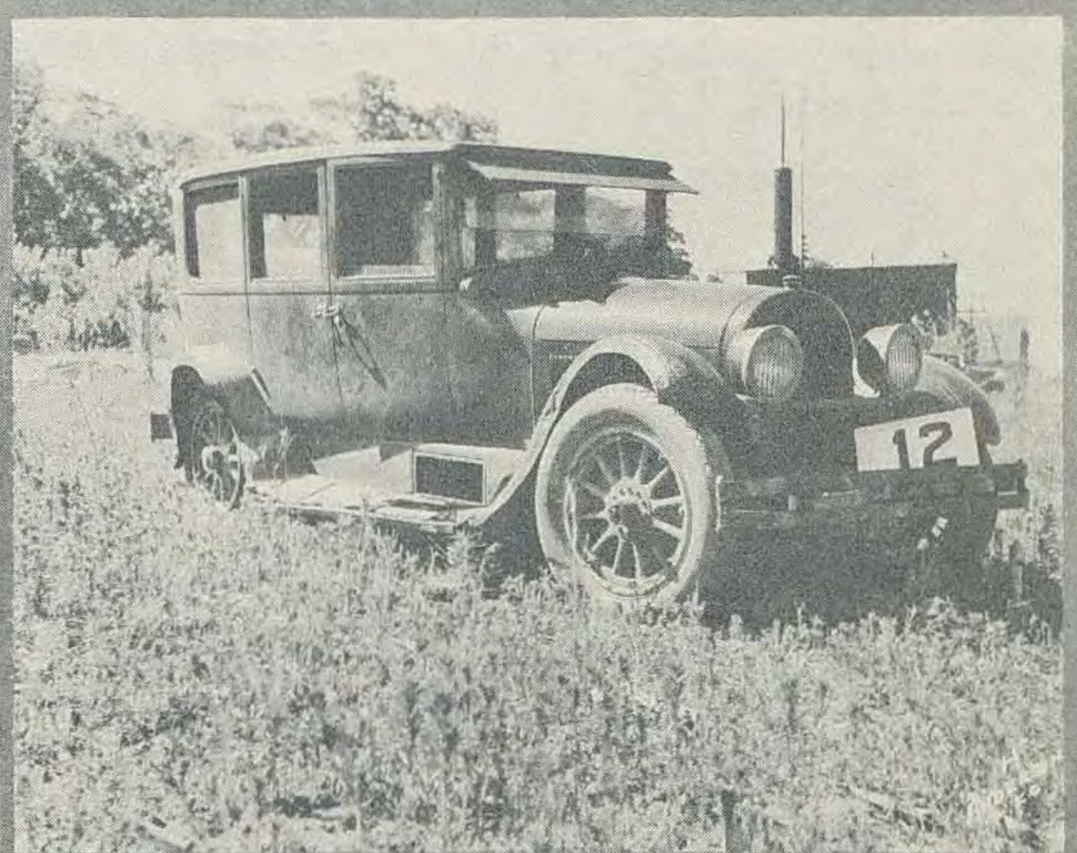

TEST No. 12
RESILIFLEX
Brush Pile
Runway
Sand Pile
Right Front Wheel Track
1 2 3 4 5 6 7 8 Post No.
Fence
Position Where Car Stopped
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral
Longitudinal


12

TEST NO. 12

Description of Rail - The rail used for the test was "Resiliflex" (National Traffic Guard Company). It consisted of plates, 12" x 0.109", mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The end panels were eight feet long. Each end of the rail was connected to the end post with three 3/4" bolts and each end post was anchored to a dead man. The rail was mounted on the intermediate posts by means of a four-leaf spring offset which was fastened to the post with a 5/8" bolt. There was no direct connection between adjoining panels of the rail, the end of each panel being connected to the spring offset by means of an interlocking finger arrangement which was held with a 5/8" pin. The distance from the ground to the center of the plate was eighteen inches.

Description of Car - A Cadillac sedan, which weighed 5,100 pounds, was used for the test. The speed of the car was 34.4 miles per hour. This car had been used previously for tests number 9 and number 10 but had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail between posts No.4 and No.5 and was deflected. The rear end of the car was thrown in against the rail and rebounded forcibly from it, the right rear wheel landing almost three feet from the original rail line on the rebound. As the rear end of the car impacted the rail, the car tipped approximately twenty degrees from the vertical. The car hit post No.5 hard, breaking it below the ground, and then rolled along the rail to post No.6. Just beyond post No.6, the car left the rail at a small angle and then curved back to the right and crossed the line of the rail a short distance beyond end post No.8 and ran downhill into an adjoining field. Had the rail been two panels longer, the car would have hit it again.

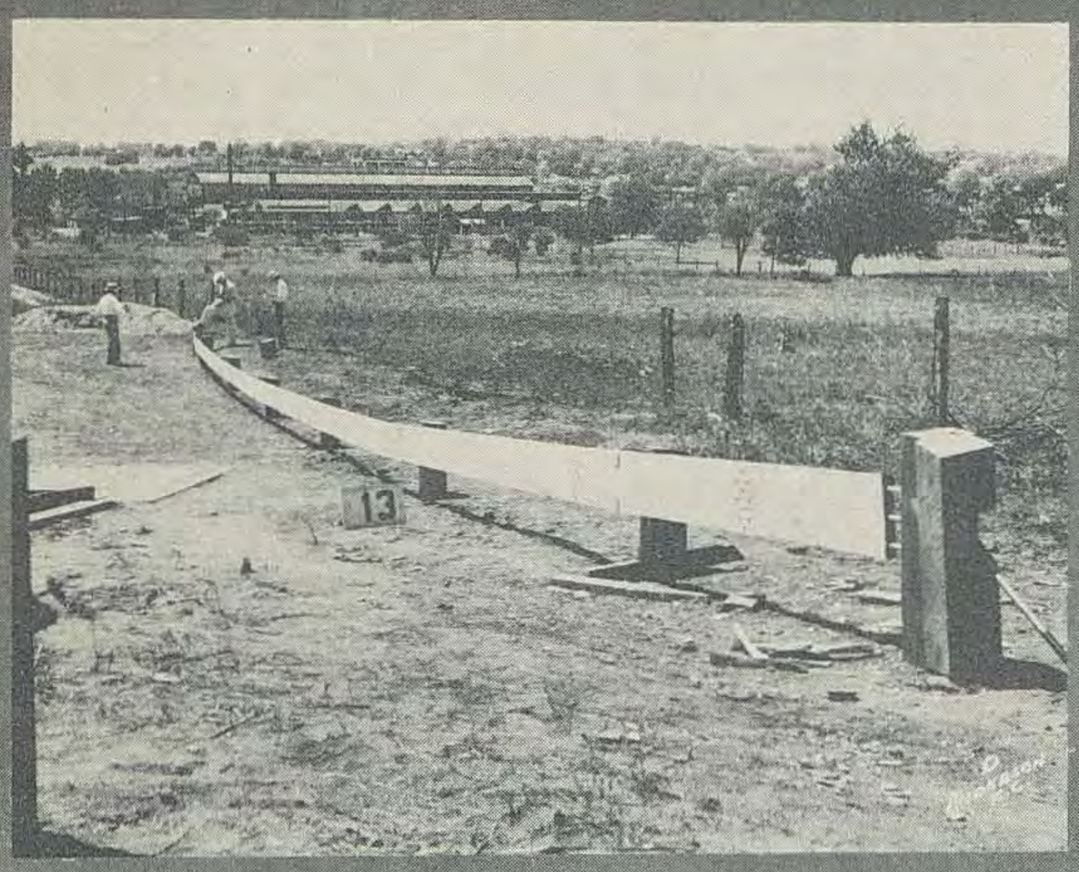
Damage to Rail - The impact of the car with the rail bent panels 4-5 and 5-6 and also creased panel 4-5 from the point of impact to post No.5. It broke post No.5 below the ground and loosened posts No.4 and No.6 in the ground. The spring offset at post No.5 was bent slightly and all the bolts connecting the spring offsets to the posts above the point of impact were slightly bent.

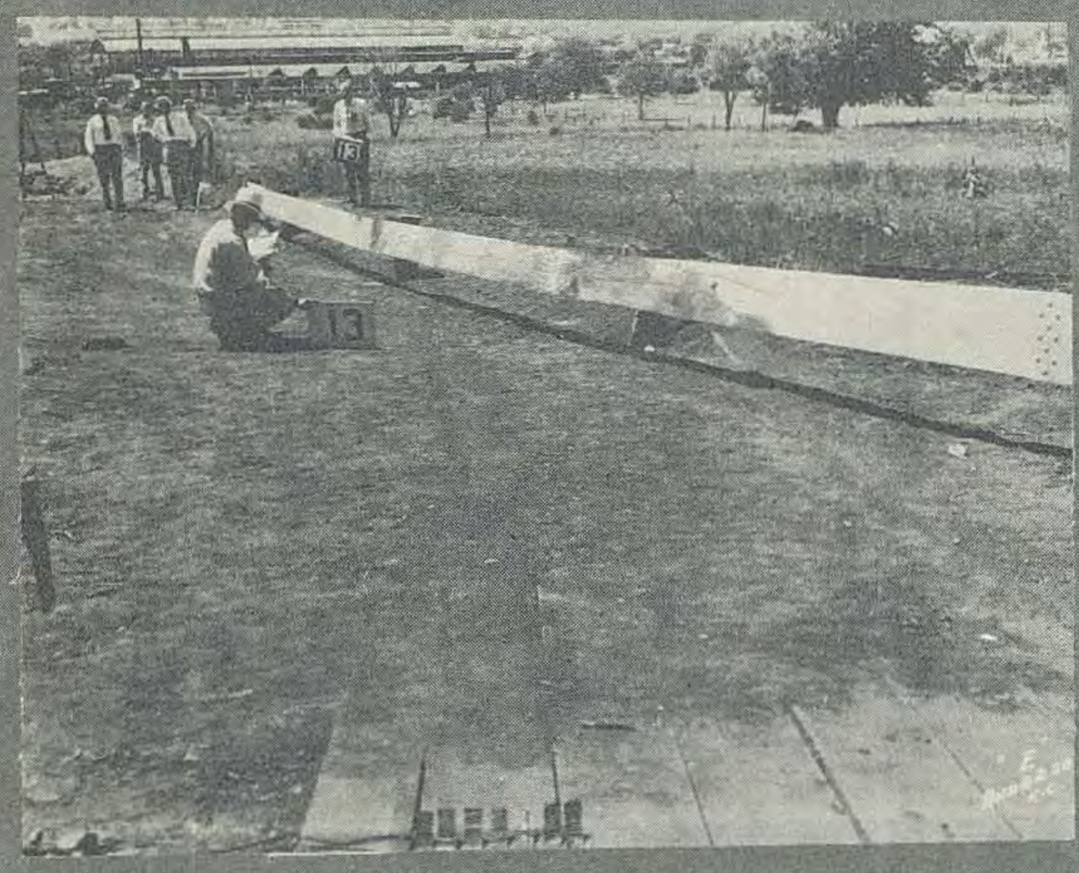
Repairs for Rail - In order to have placed this rail in a serviceable condition, it would have been necessary to replace one post and to retamp two posts. The rail would probably have functioned efficiently without the replacement of any rail panels or spring offsets. By running the post bolt through from the back of the post, it would have been possible to replace post No. 5 without disconnecting the rail. In order to have restored the rail to its original condition, however, it would have been necessary to replace two rail panels and one spring offset in addition to the other repairs.

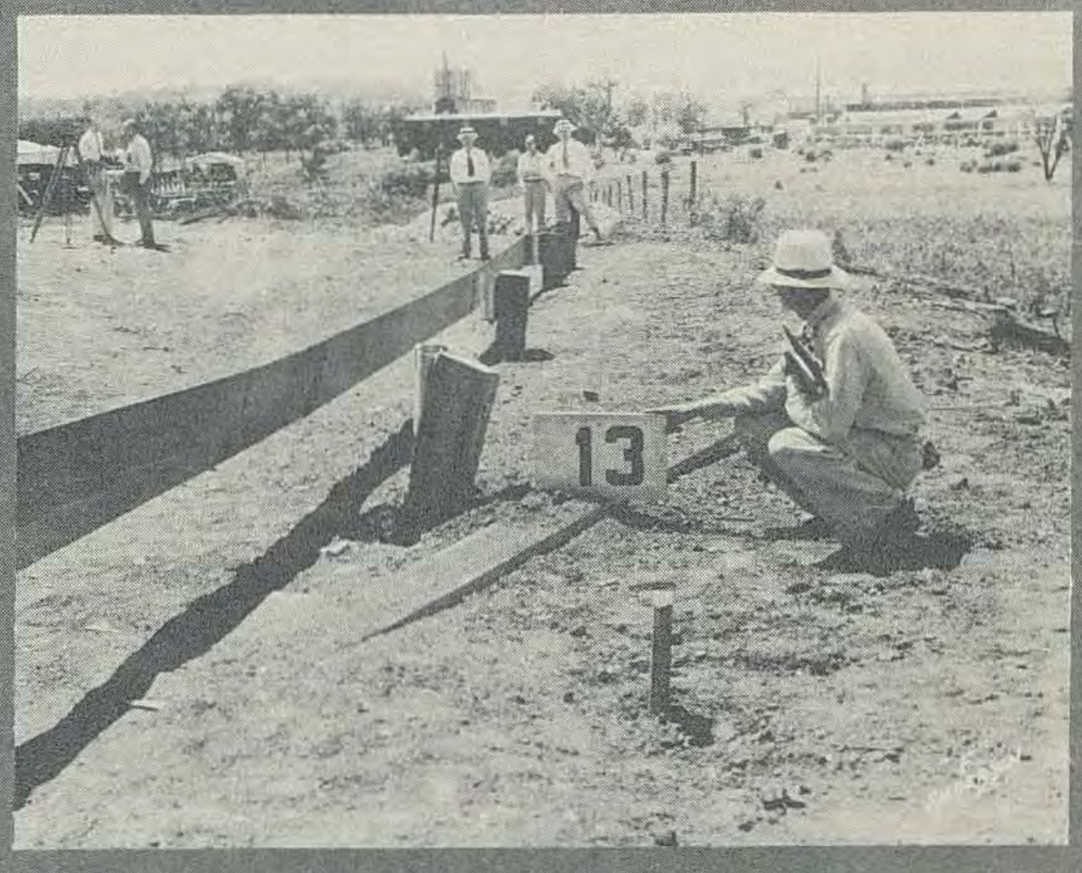
Damage to Car - The collision of the car with the rail crumpled both fenders on the right, bent the bumper, and caused the radiator to leak. It also caused a blowout of the right rear tire and knocked the hub cap off the right front wheel.

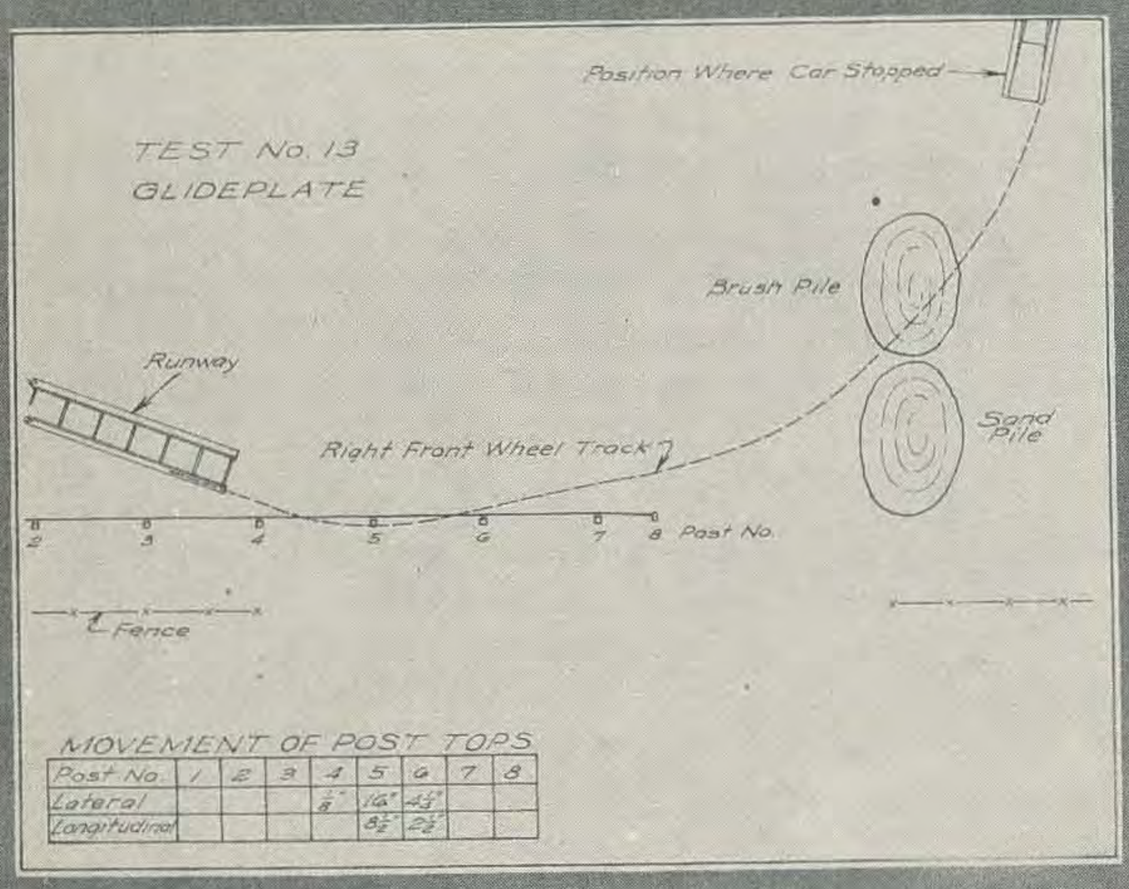
Erection Notes - The rail was erected with no difficulty except that it was necessary to keep the three advance posts knee-braced as the work progressed. The rail easily adapted itself to the vertical curve. For this test the posts were not tamped as solidly as were the posts in previous tests.

Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.



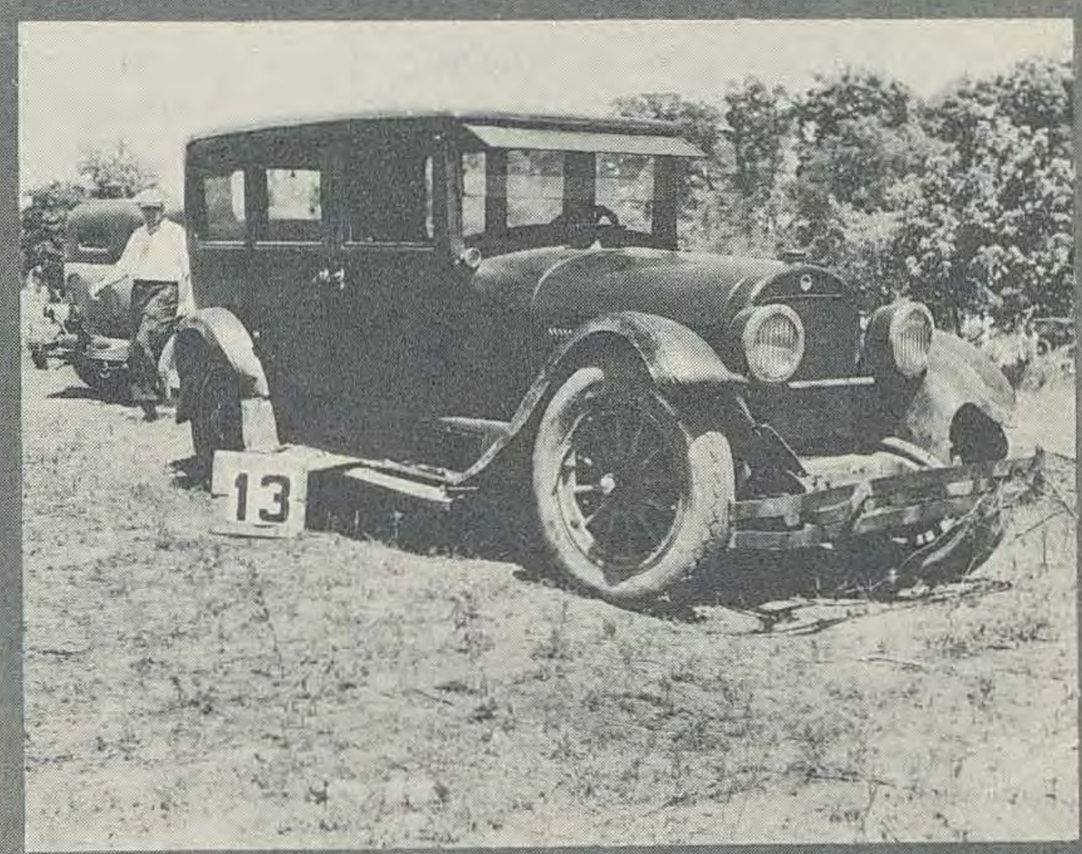






MOVEMENT OF POST TOPS

Post No.	1	2	3	4	5	6	7	8
Lateral				1/8"	16"	43"		
Longitudinal					8 1/2"	2 1/2"		



TEST NO. 13

Description of Rail - The rail used for the test was "Glide Plate" (National Traffic Guard Company). It was made up of a plate, 12" x 0.110", mounted on 6" x 8" pine posts which were set four feet in the ground, sixteen feet center to center. The end panels were eight feet long. Each end of the rail was connected to the end posts by three 3/4" bolts, on which were mounted helical compression springs and each end post was anchored to a dead man. The rail was mounted on the intermediate posts by means of a cylindrical plate spring offset which was fastened to the post with a single 5/8" bolt. The rail was held to the spring offsets by straps which allowed the rail to move longitudinally. Adjoining panels of the rail were connected to each other by a single lap splice which was made with ten 1/2" panhead bolts. The distance from the ground to the center of the plate was eighteen inches.

Description of Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 34.1 miles per hour. This car had been used previously for tests No.9, No.10 and No.12, but had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail between posts No.4 and No.5 and was deflected. The rear end of the car was thrown into the rail and rebounded slightly from it. As the rear end of the car impacted the rail, the car tipped approximately twenty degrees from the vertical. The car hit post No.5 hard, knocking it loose in the ground, and then ran along in contact with the rail to post No.6. There, the car rolled free at an angle of about eleven degrees with the rail, curved to the left, and ran about 75 feet, rolling through the brushpile, before it stopped.

Damage to Rail - The impact of the car with the rail bent rail panels 4-5 and 5-6, bent two spring offsets and loosened two posts in the ground.

Repairs for Rail - In order to have placed this rail in a serviceable condition, it would have been necessary to replace two spring offsets and to retamp two posts. The rail would probably have functioned efficiently without the replacement of any rail panels; however, in order to have restored the rail to its original condition, it would have been necessary to replace two rail panels in addition to the other repairs.

Damage to Car - The collision of the car with the rail bent the bumper and both right fenders.

Erection Notes - Some difficulty was encountered in erecting this rail. In order to make it conform to the vertical curve, it was necessary to ream the holes in two joints. After this was done the rail fit the curve well and was pulled tight. For this test, the posts were not tamped as solidly as were the posts in the first eleven tests.

Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.

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15

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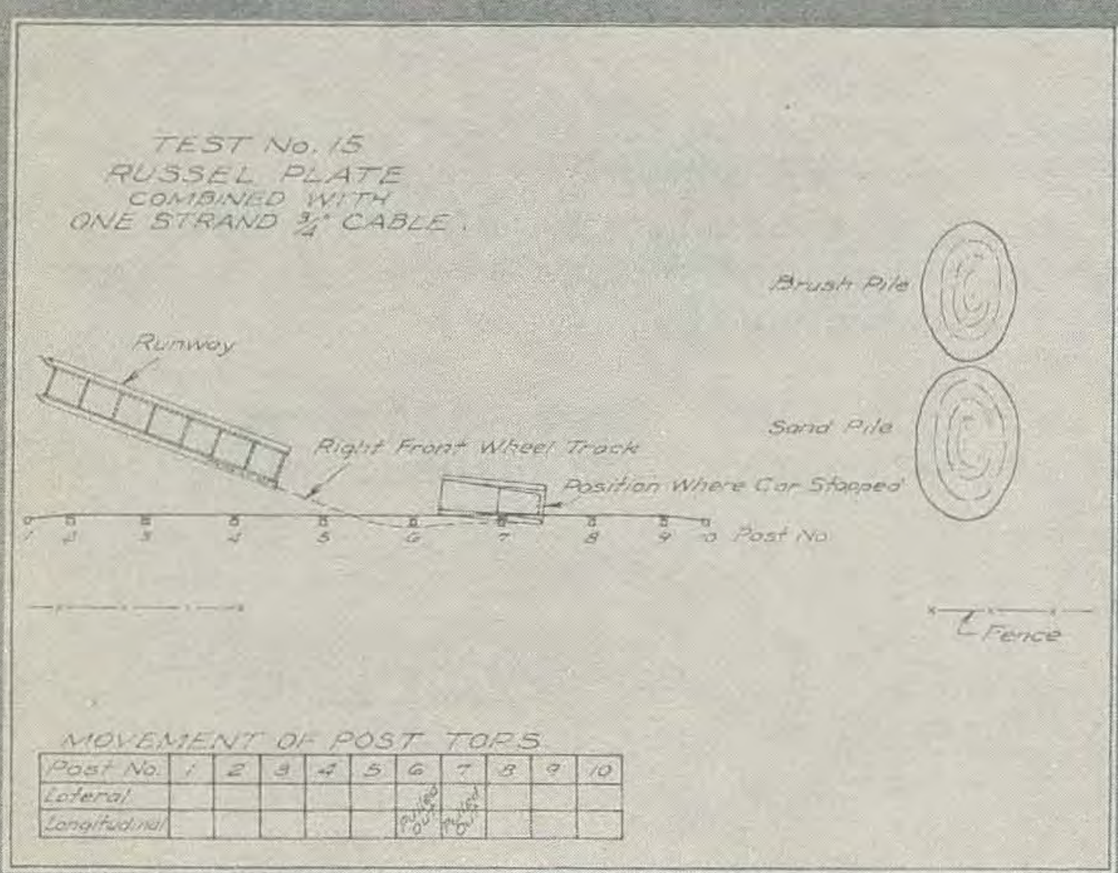
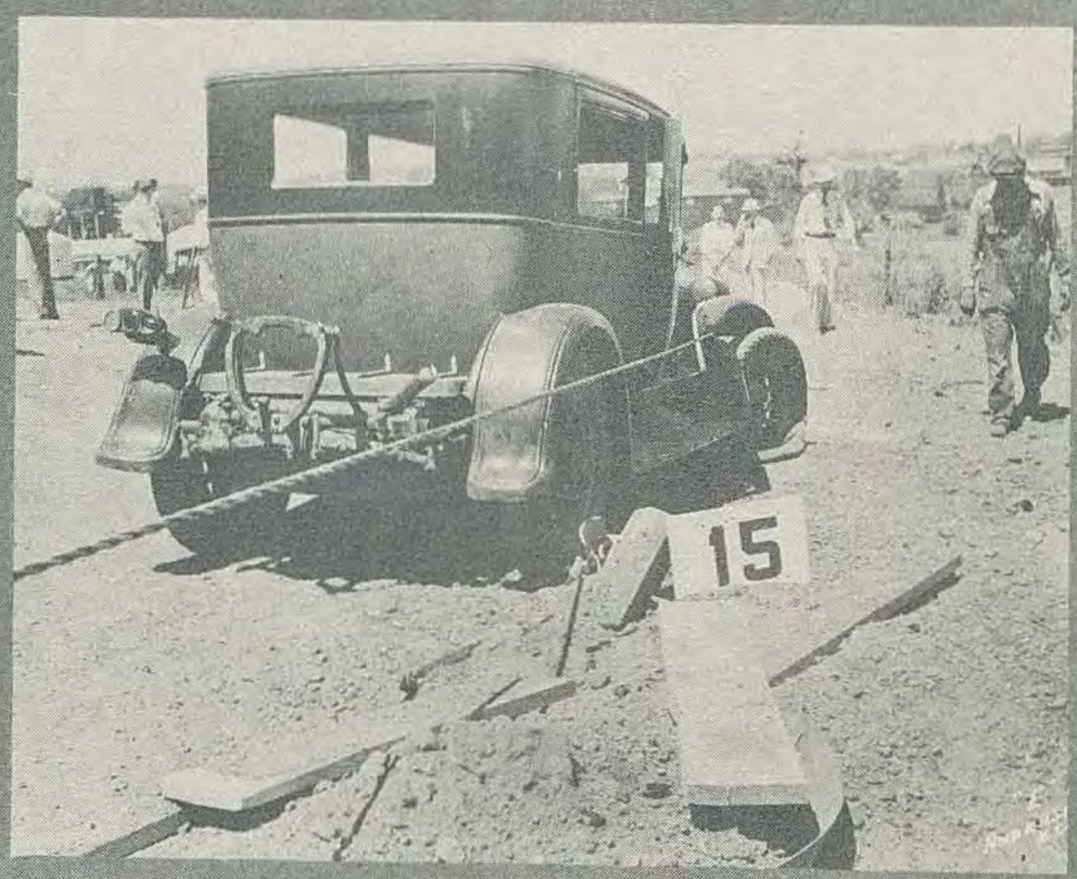
15


TEST No. 15
RUSSEL PLATE
COMBINED WITH
ONE STRAND 3/4" CABLE.
Brush Pile
Runway
Sand Pile
Right Front Wheel Track
Position Where Car Stopped
1 2 3 4 5 6 7 8 9 10 Post No.
Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Pulled Out
Pulled Out


15

TEST NO. 15

Description of Rail - The rail used for the test was composed of a 10 gauge plate, 5" wide, set with its center 14" above the ground and a 3/4" wire rope (Missouri Highway Department Specification) set 10" above the center of the plate. The rail was mounted on 6" x 8" pine posts which were set four feet in the ground, 12 feet, 8 inches center to center. Both the rope and the plate were connected to the end posts by single 1" bolts on which were mounted compression springs and each end post was anchored to a dead man. The wire rope and the plate were mounted on the intermediate posts by Russell Highway Guard Company spring-clips. The ends of adjoining plate panels were held by a wedge which forced them into a rectangular cast collar, around which they were bent and crimped and this fitting was fastened to the post with a 1" bolt. The rope was held to the post by a 3/4" hook bolt. The wire rope had been marked by the impact of test No.14 but was not seriously damaged.

Description of Car - The car used for the test was a Cadillac coach which weighed 5,100 pounds. The speed of the car was 34.6 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6. The front end of the car was turned and as the rear end of the car impacted the rail the car tipped approximately ten degrees from the vertical. The car hit post No. 6 hard, the failure of the post connection allowed the plate to drop, and the right front wheel ran under the cable. Post No. 6 was pulled out of the ground and the cable then headed the car directly into post No.7 which was hit and pulled out of the ground. The added resistance offered by post No. 7 was sufficient to stop the car at this point, after having traveled only twenty feet from the point of impact. A two hundred pound bag of sand was thrown up and forward from the floor in the rear of the car onto the cowl.

Damage to Rail - The clamp casting at post No. 5 was cracked and the castings at posts No. 6 and No. 7 were badly deformed. The ends of three plate sections were badly deformed. Two posts were pulled out of the ground. The wire rope was slightly elongated.

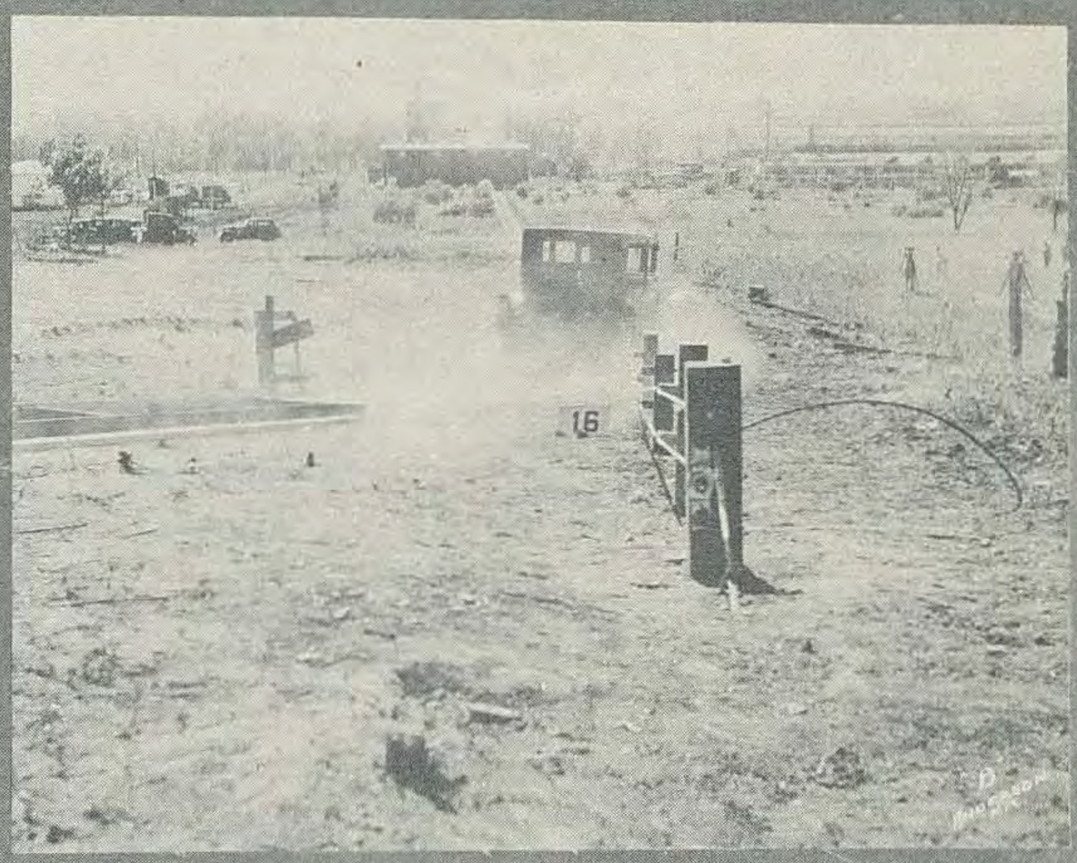
Repairs for Rail - In order to have placed this rail in a serviceable condition, it would have been necessary to retamp two posts, and to replace three plate sections, and three clamp castings. In order to replace the plate sections, it is necessary to dismantle all plates to the nearest end post.

Damage to Car - The bumper was broken and torn from the right side of the frame. The right front fender was crumpled and the right front tire was badly cut and blown out.

Erection Notes - The erection of this rail presents some difficulty since great care must be taken to insure that the holes in the post for the plate are bored horizontal. Some difficulty was also encountered in correctly placing the wedges. The rail easily accomodated itself to the vertical curve. For this test, the posts were not tamped as solidly as were the posts in the first eleven tests.

Results - This rail turned the car but the car was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impacts of the car with the rail caused no appreciable damage to the car but did seriously damage the rail.

16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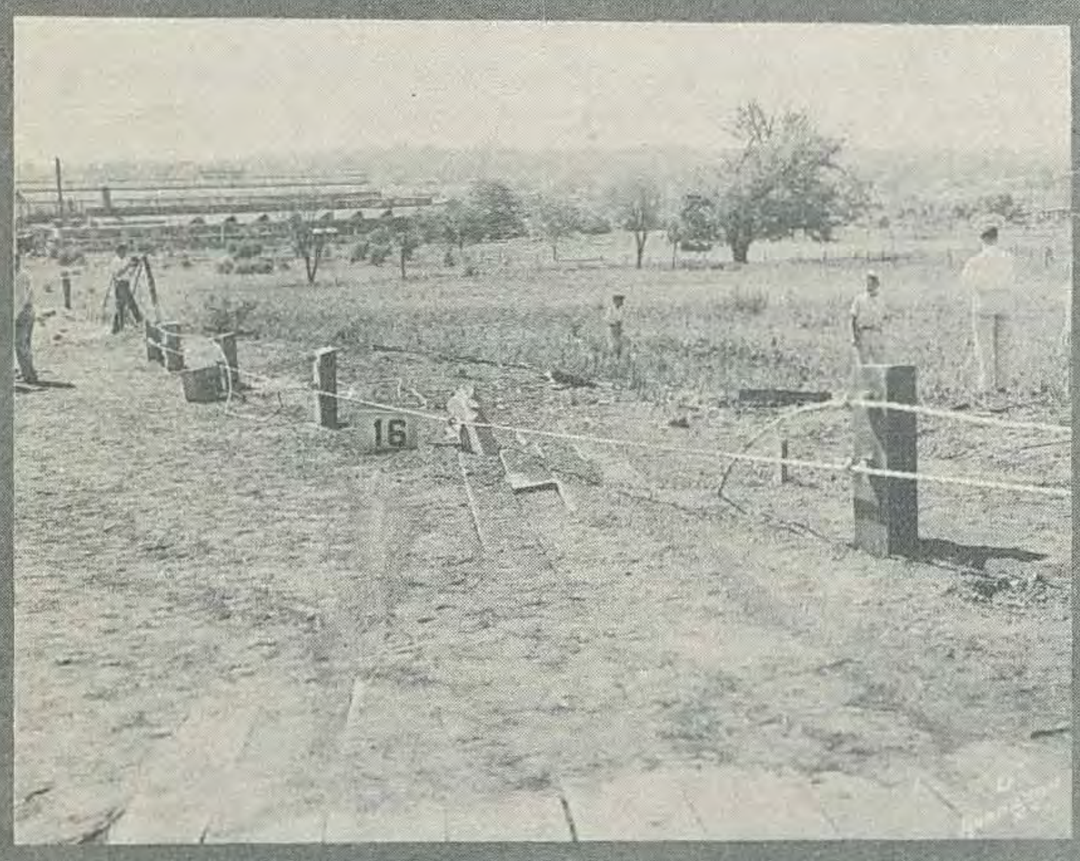
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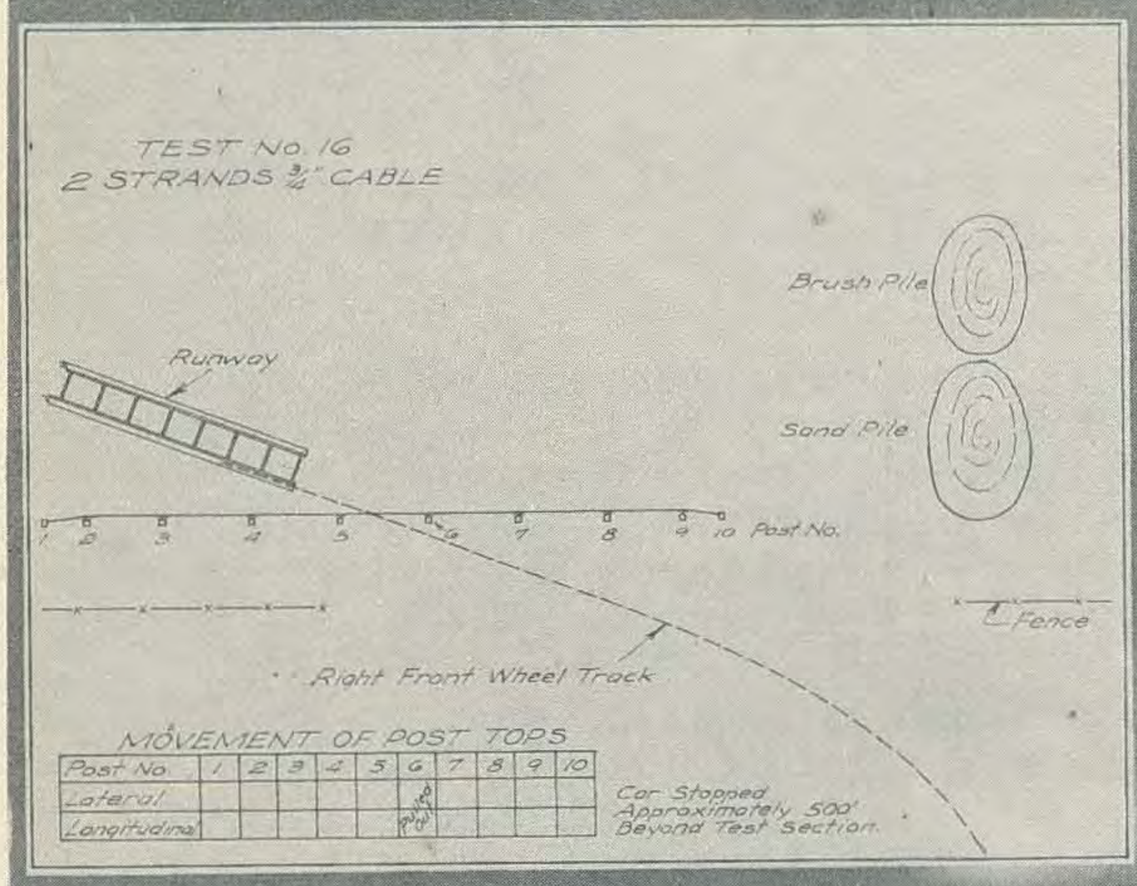

TEST No. 16
2 STRANDS 3/4" CABLE
Brush Pile
Runway
Sand Pile
1 2 3 4 5 6 7 8 9 10 Post No.
Fence
Right Front Wheel Track
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Car Stopped Approximately 500' Beyond Test Section.

16

TEST NO. 16

Description of Rail - The rail used for the test was made up of two strands of 3/4" wire rope (Missouri Highway Department Specification). Erection details were the same as for test No. 1, except that the intermediate post spacing was reduced to 12 feet 8 inches and the rope spacing changed to 14" above the ground for the lower strand and 10" between the strands.

Description of Car - The car used for the test was a Cadillac coach which weighed 5,100 pounds. The speed of the car was 32.2 miles per hour. This car had been used previously for test No.15 but had suffered no serious damage.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6, ran over the lower strand of rope and rammed into post No.6, knocking it loose in the ground. The top strand of rope was broken at the point of impact, and the car continued on over the rail with no deflection and very little diminution of speed, finally stopping against a field fence some 500 feet away.

Damage to Rail - The top strand of wire rope was broken, post No.6 was loosened and knocked over, and the hook bolt at post No. 6 was bent.

Repairs for Rail - In order to have put this rail in a serviceable condition, it would have been necessary to splice the top strand of rope, to retamp post No.6, and to replace one hook bolt in post No.6.

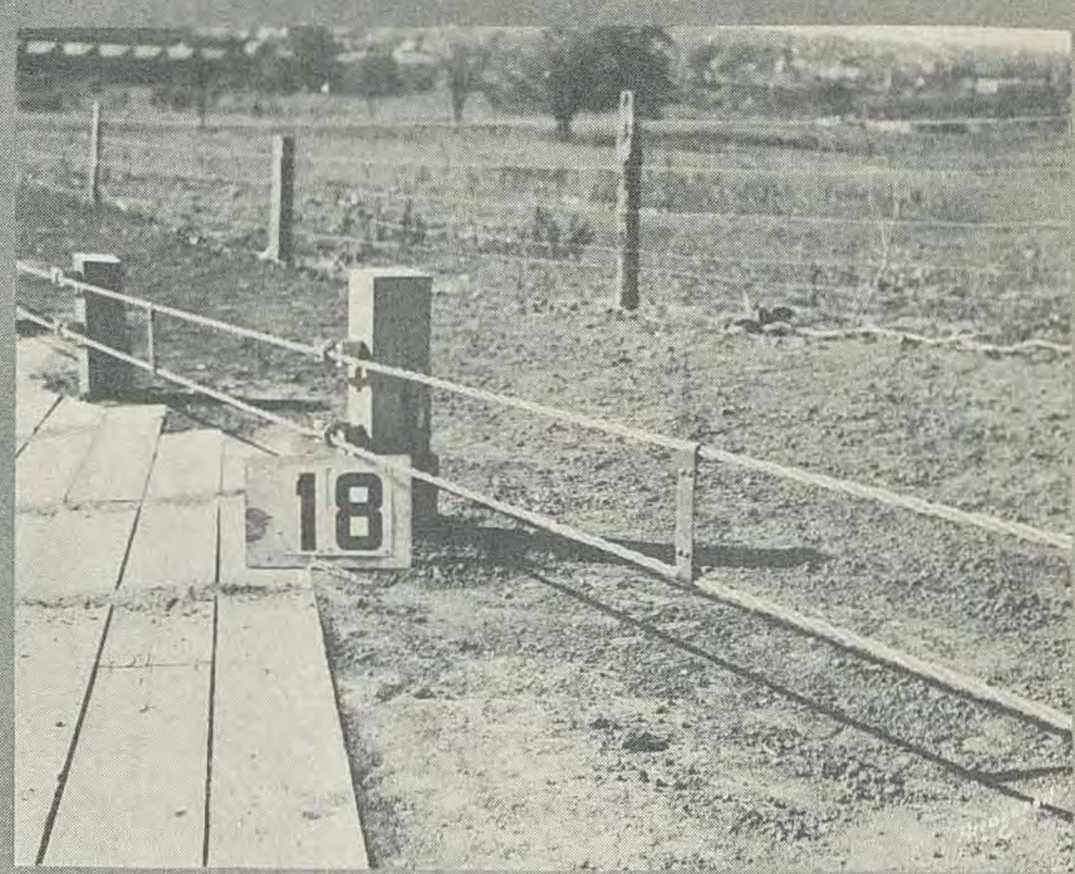
Damage to Car - The damage to the car was negligible.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve. For this test the posts were not tamped as solidly as were the posts in the first eleven tests.

General Remarks - The top rope in this test had also been used in tests No.14 and No.15. It had been marked by the impact of test No.14, but the failure took place at an undamaged point. The top of post No. 6 was sawed off too short by an unskillful workman and as a result, the hook bolt pulled partly out, but that this had any effect on the test result is problematical.

Results - This rail did not prevent the car from leaving the roadway.

18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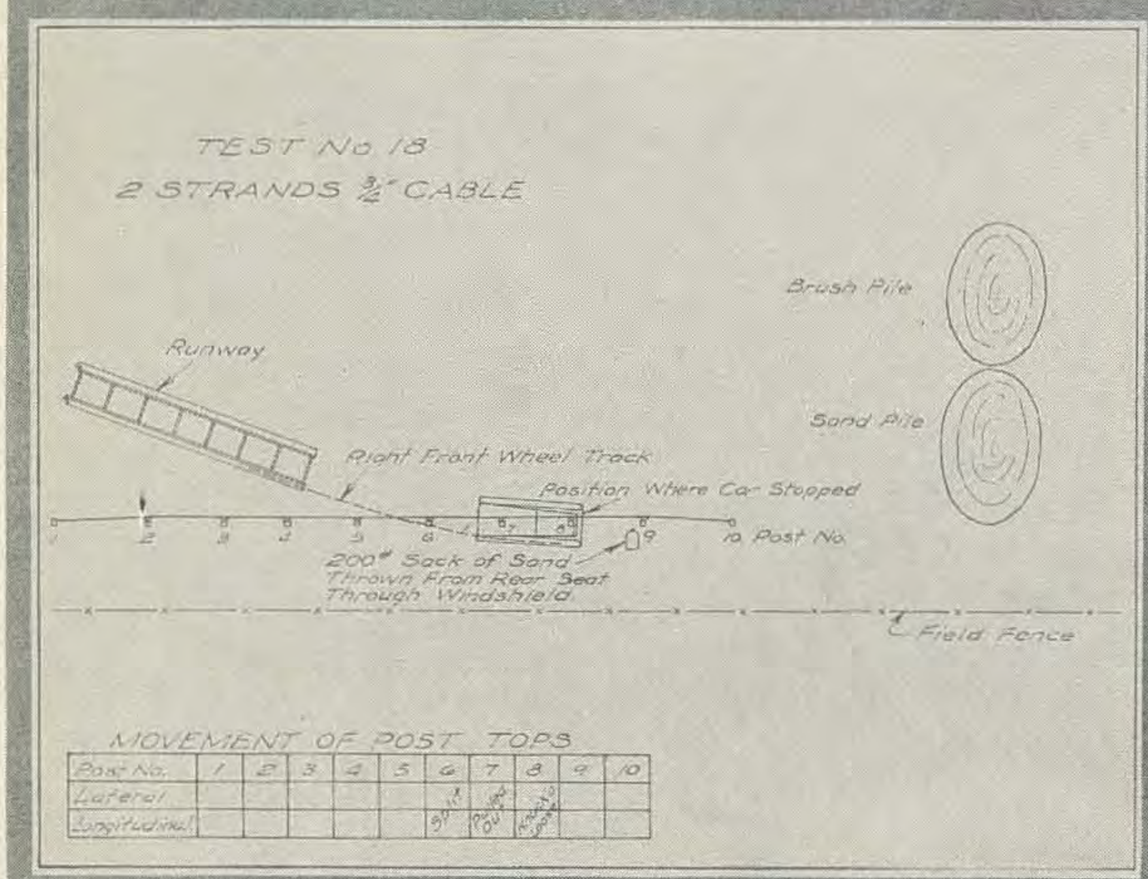
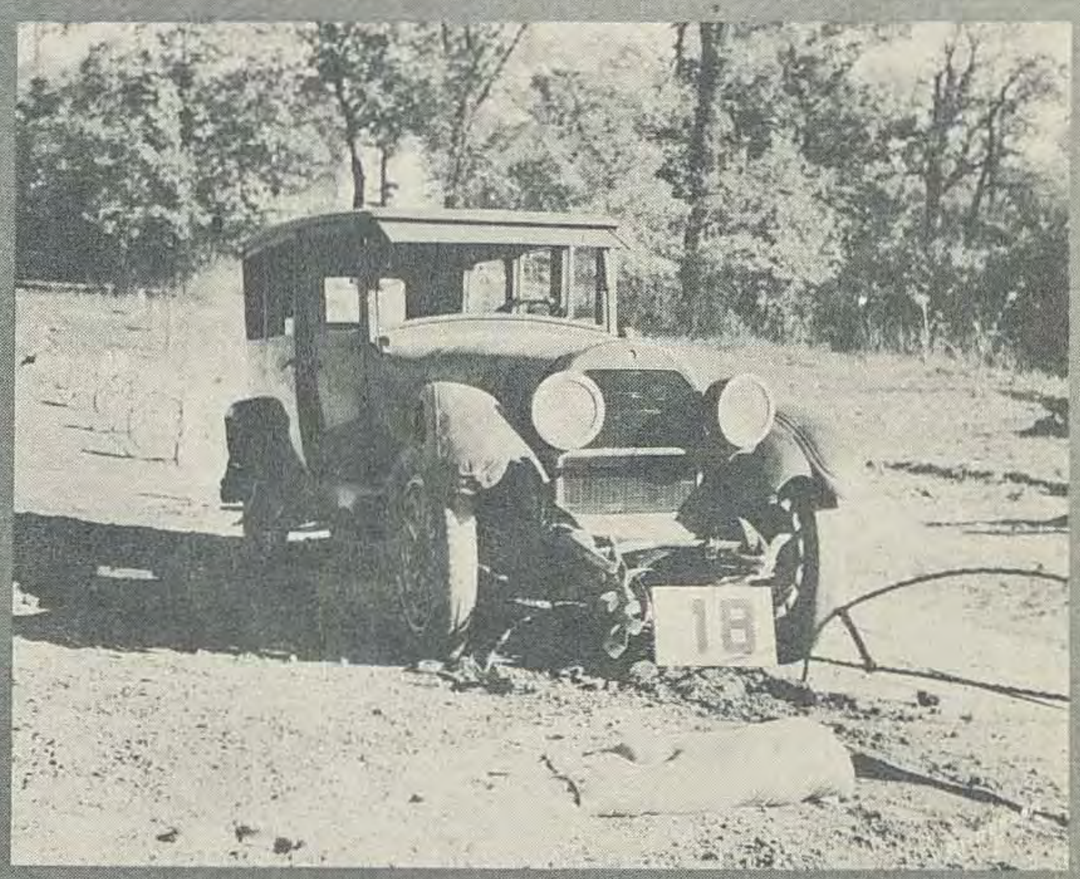

TEST No 18
2 STRANDS 3/4" CABLE
Brush Pile
Runway
Sand Pile
Right Front Wheel Track
Position Where Car Stopped
to Post No.
200# Sack of Sand Thrown From Rear Seat Through Windshield
Field Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
9"
Pushed Over
Broken Off


18

TEST NO. 18

Description of Rail - The rail used for this test was made up of two strands of 3/4" wire rope (Missouri Highway Department Specifications). Erection details were the same as for test No.1, except that the post spacing was reduced to ten feet and the top rope was placed 22" above the ground and the bottom rope was placed 13" above the ground. The two strands of rope were connected midspan of the posts by light ties. These ties were made of 12 gauge metal, 1-3/4" wide, were fastened over each rope by means of two 1/4" bolts, and were free to move longitudinally on the wire ropes. The tension of both the top and bottom strands was such that a normal load of 100 pounds midspan of the posts caused a deflection of 2-3/4".

Description of Car - The car used for the test was a Cadillac sedan which weighed 5,100 pounds. The speed of the car was 33.5 miles per hour. This car had been used previously for tests No.9, No.10, No.12 and No.13.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6, three feet back of post No.6, and the front end of the car was turned. The car caught the upper post fitting at post No.6, splitting the post, freeing both post fittings from the post and loosening post No.6 in the ground. The car then shoved post No.6 back, climbed over the lower strand of rope, headed directly into the line of posts and ran over post No.7, pulling it out of the ground and loosening it from the lower strand of rope. In the meantime the top strand of rope had broken at post No.6. The car then ran into post No.8 and was stopped abruptly, a 200 pound bag of sand being thrown from the rear seat through the windshield and landing about eight feet in front of the car. The car had come to rest with the front axle supported by post No. 8, which had been pushed forward to an angle of forty-five degrees, with the left front wheel three inches off the ground. The car had carried post No.7 along to post No.8 and had also carried the cable ties for panels 6-7 and 7-8 along on the lower cable to post No.8.

Damage to the Rail - The top strand of rope was broken, post No. 6 was split open, post No. 7 was pulled out of the ground and post No. 8 was knocked loose in the ground. The top hook bolt at post No. 6 was bent.

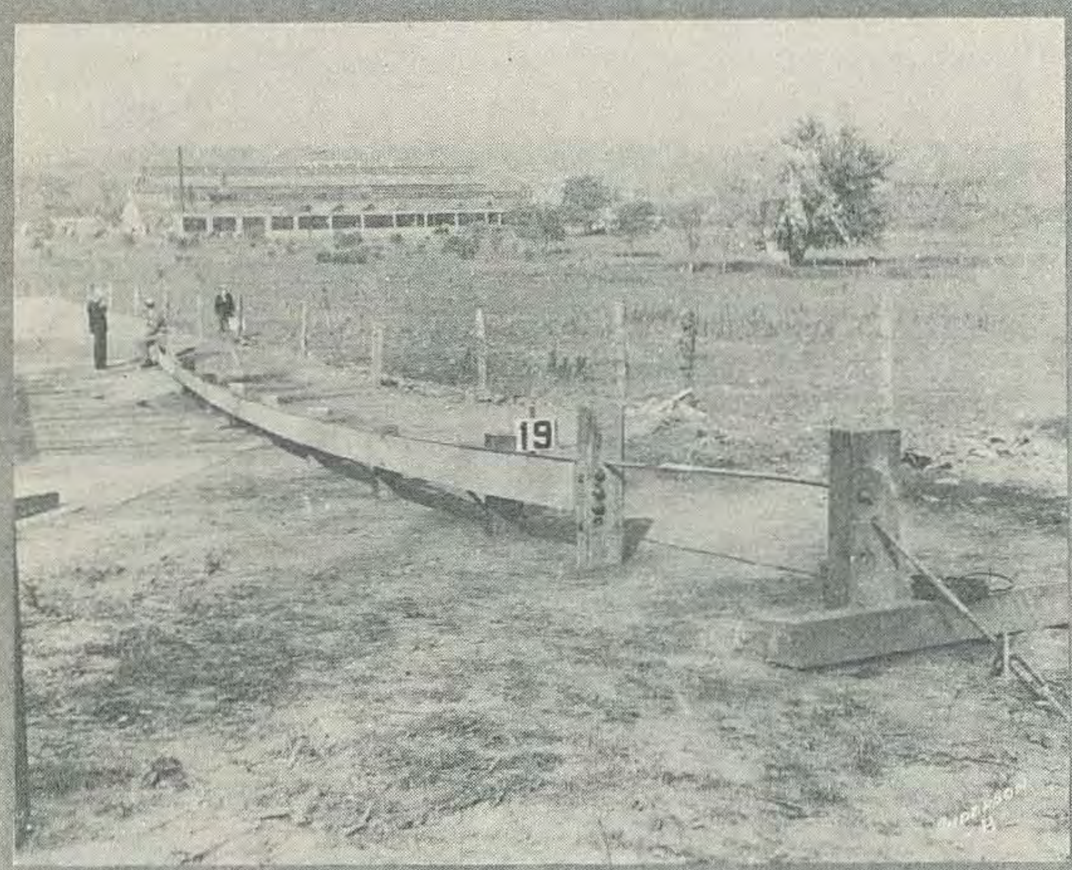
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to splice the top rope, to replace one post fitting and one post, and to retamp two posts.

Damage to the Car - The bumper was bent, the right front fender was bent, and the left headlight lens was broken. The frame was twisted so that the car could not be steered and the engine pan was torn loose in front allowing the oil to run out.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - This test gave the best performance of any of the wire rope rails tested and this was apparently due to the fact that the light metal ties enabled the separate strands to act together. However, the breaking of the top cable indicates that the car may not be turned or stopped in every instance.

Results - This rail turned the car but the car was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impacts of the car with the rail caused an appreciable damage to both the car and the rail.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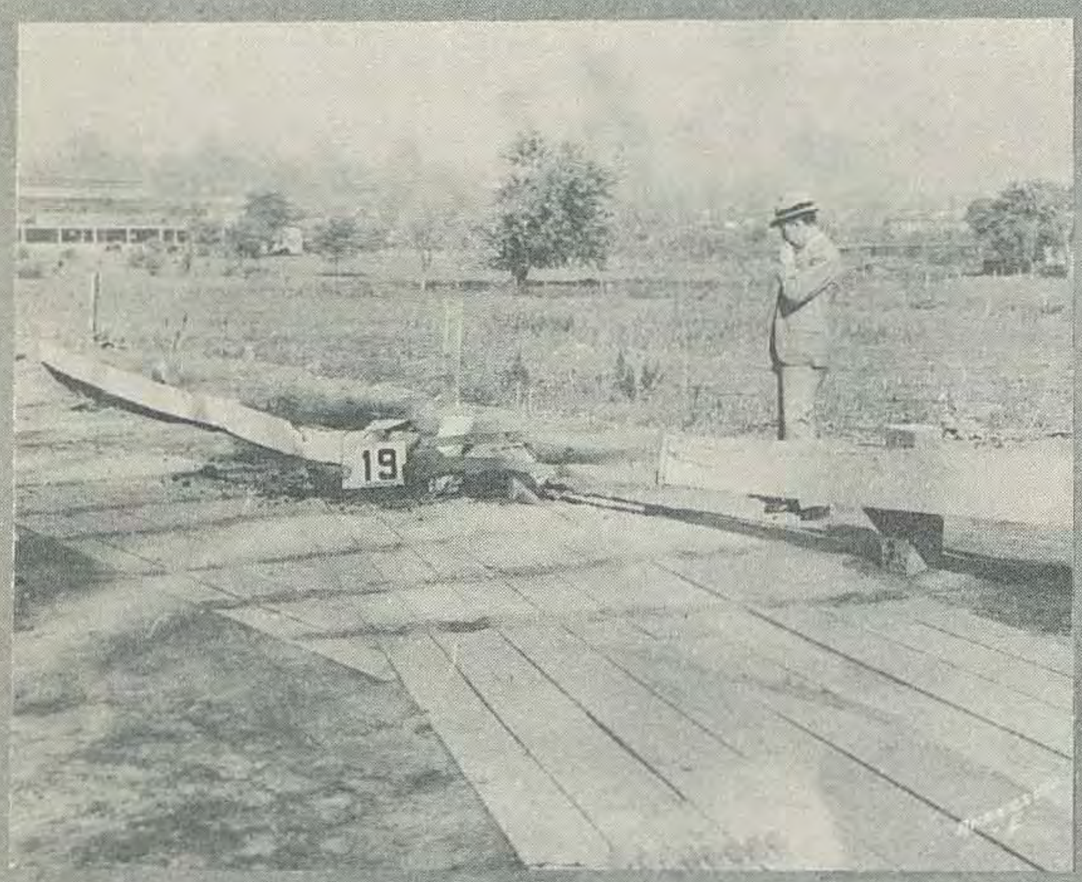
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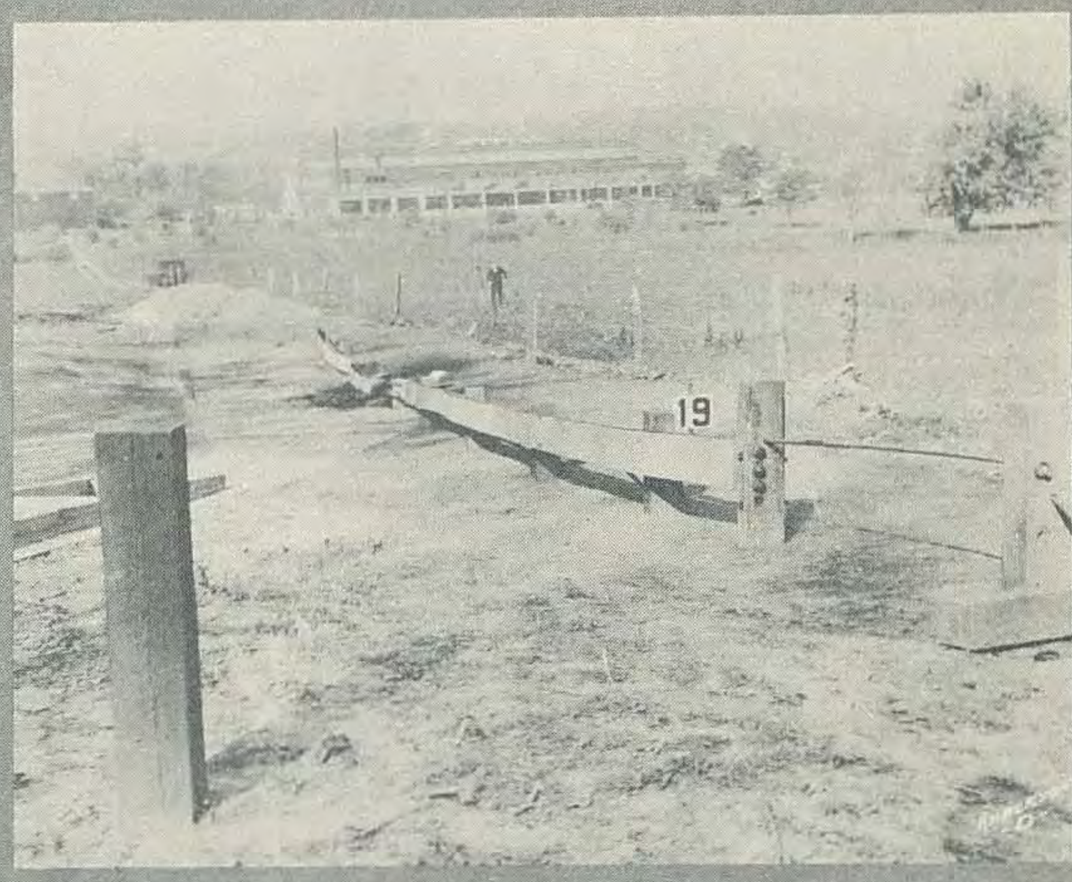
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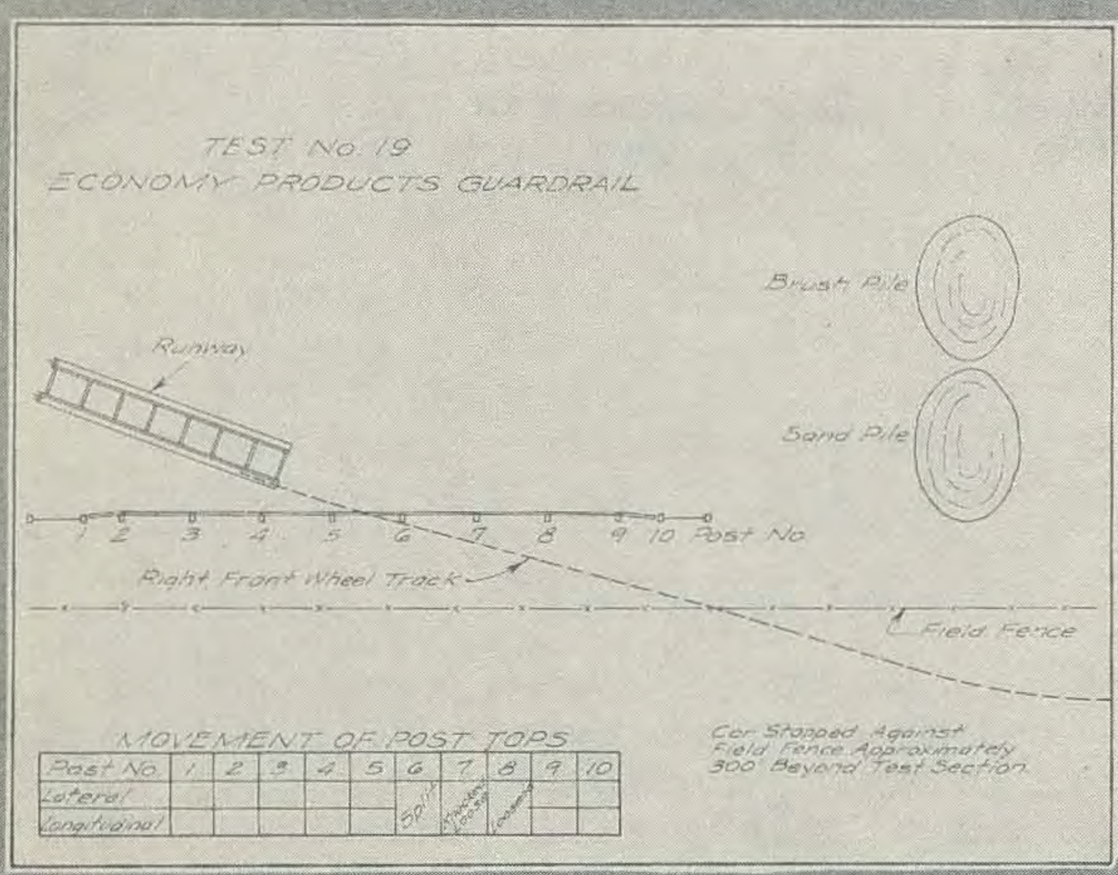
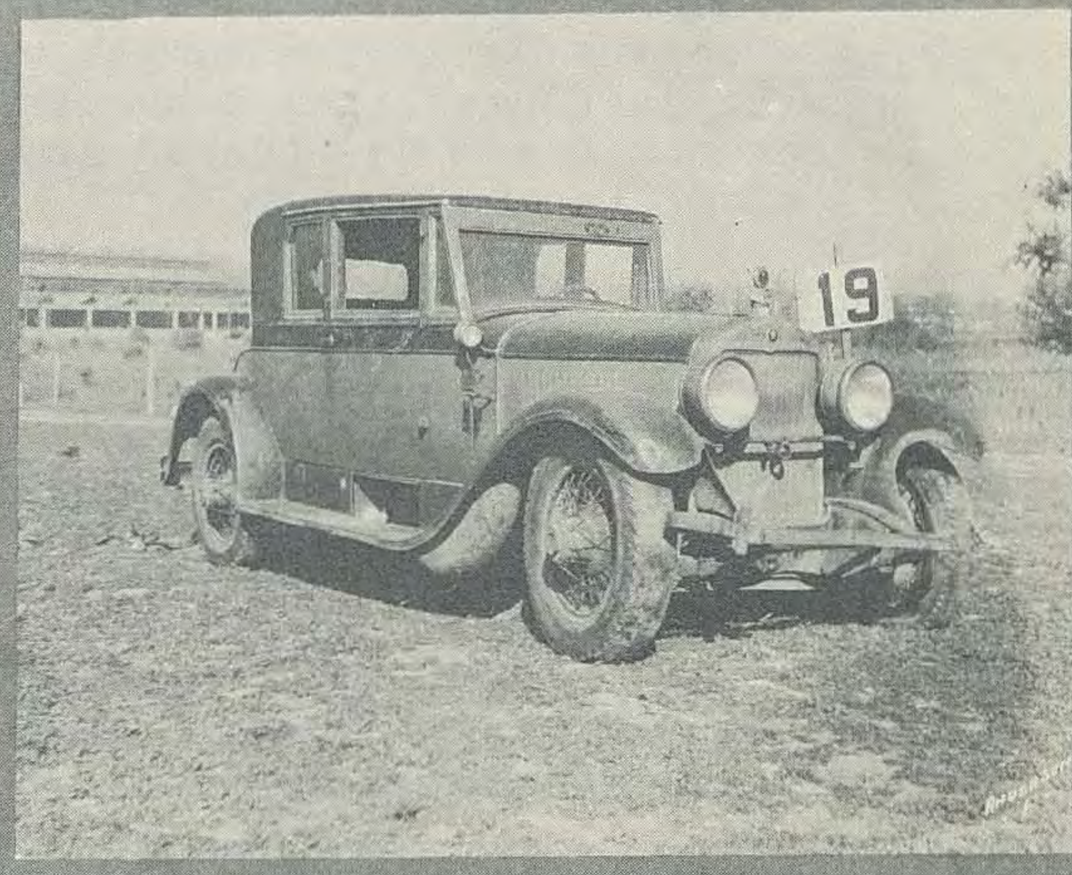

TEST No. 19
ECONOMY PRODUCTS GUARDRAIL
Brush Pile
Runway
Sand Pile
1 2 3 4 5 6 7 8 9 10 Post No.
Right Front Wheel Track
Field Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Car Stopped Against Field Fence Approximately 300' Beyond Test Section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TEST NO. 19

Description of Rail - The rail used for this test was manufactured by Economy Products Company. This rail consists of a face plate 10" x .110", and a two 3" x .110" bands placed four inches to the rear of the face plate. The rail is spliced midspan of the posts by butting two fillets, which are formed by bending the face plate, are 4" deep and are reinforced by filler plates. The splice is made by means of five 1/2" x 1" bolts and the 3" bands are bolted to the back of the joint. The rail is supported by means of two 1-1/2" strap hangers, welded on the rear of the face plate, which slip over cantilever spring offsets attached to the bottom of the posts. The posts were 6" x 8" pine posts, set four feet in the ground, ten feet center to center. The end of the rail was fastened to the end posts with three 3/4" bolts and each end post was anchored to a dead man. The distance from the ground to the center of the rail was 17". The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 7/8".

Description of Car - The car used for the test was a five passenger Cadillac coupe which weighed 5,100 pounds. The speed of the car was 34.0 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6, three and one-half feet beyond post No.5. The car shoved the rail hard up against post No.6 and caught the cantilever spring offset at post No.6 wrenching it from the post and splitting the post. Apparently the car was not turned, however, it must have been turned slightly, as, instead of running directly over post No.6, the car passed along side of post No. 6 sideswiping and loosening it in the ground. The face plate of the rail sheared in two at the splice in panel 6-7 and the rail hangers at posts No.6 and No. 7 were torn loose allowing the rail to drop. The car then with no further deflection ran over post No. 7, knocking it loose in the ground and the left wheel of the car grazed post No. 8, loosening it in the ground. After passing through the rail, the car turned to the left ran down hill about 300 feet and finally stopped against a field fence.

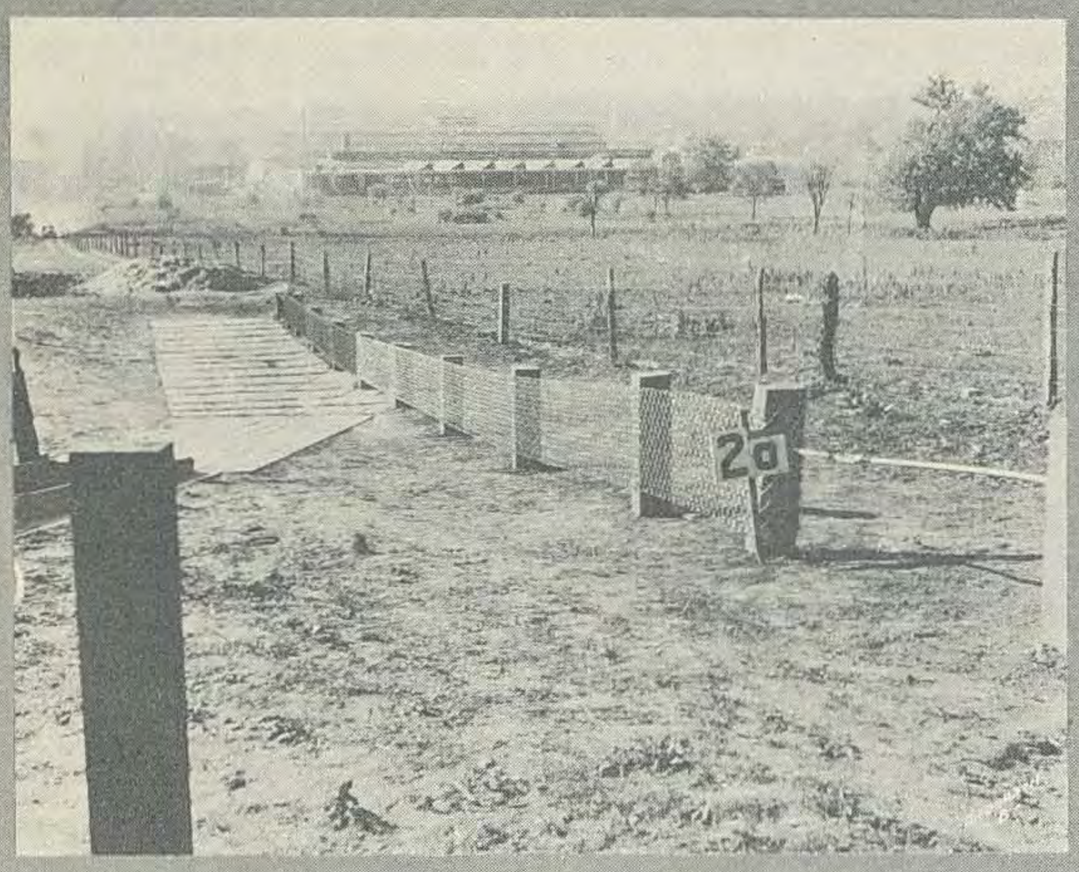
Damage to Rail - The cantilever spring offset at post No. 6 was pulled loose from the post. The rail hangers at posts No.6 and No. 7 and the bottom hanger at post No. 8 were torn loose. The face plate was sheared at the rail splice between posts No. 6 and No. 7 and a small hole was punched in the rail plate at post No. 6. Post No. 6 was split and posts No. 7 and No. 8 were loosened in the ground. All rail joints behind the point of impact were opened 1/8" to 1/4" at the face of the rail and the two bolts next to the face of the rail, at the joint between posts No.6 and No.7, failed in tension.

Repairs to Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace three rail panels and to straighten three additional rail joints. One post would have had to be replaced and two posts retamped.

Damage to the Car - The right front fender was bent and the bumper was bent and broken. The left front tire was slightly cut and punctured and one wire spoke was broken in the right rear wheel.

Erection Notes - The rail was easily erected. However, the bottom of the face plate was more taut than the top and also the two 3" bands were quite loose.

Results - The results of this test showed that the rail splice and the strap hangers were far too weak to withstand the impact received in this test. The fact that the plate was sheared in one place and punctured in another place indicates that the steel in this rail was not of sufficient strength to withstand the impact received. This rail did not prevent the car from leaving the roadway.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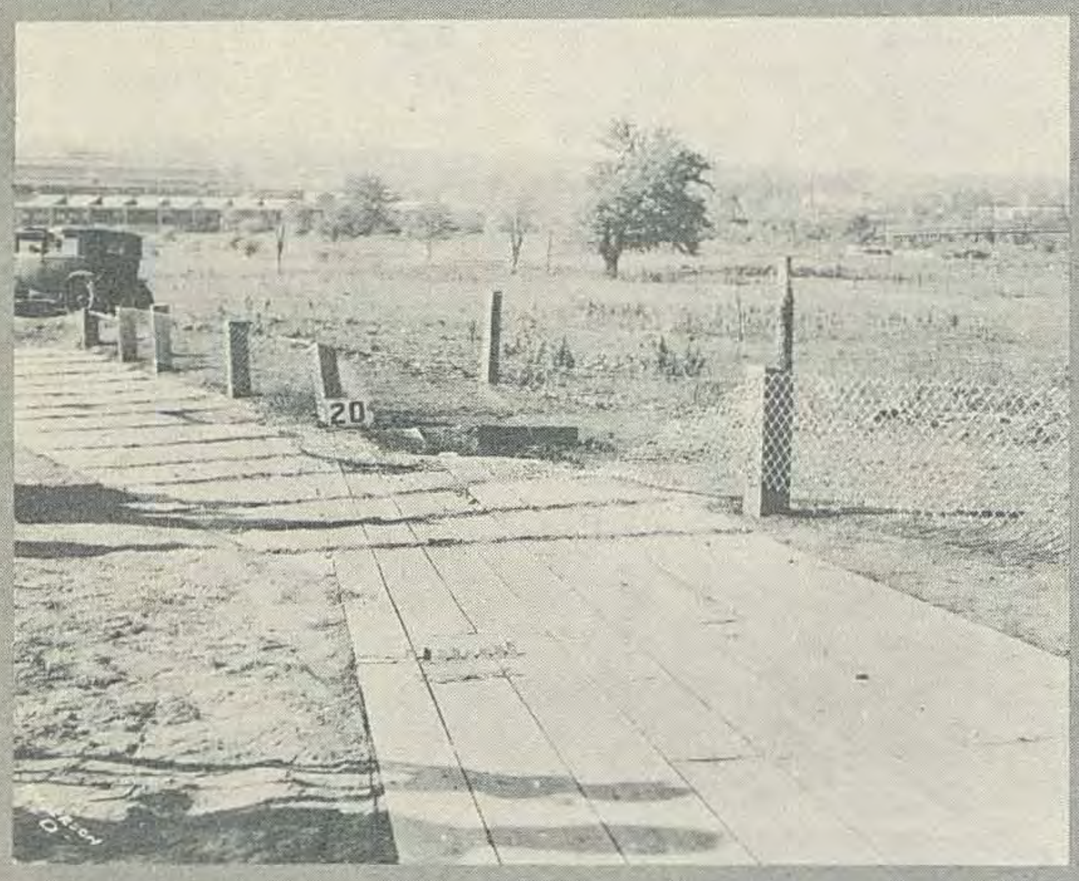
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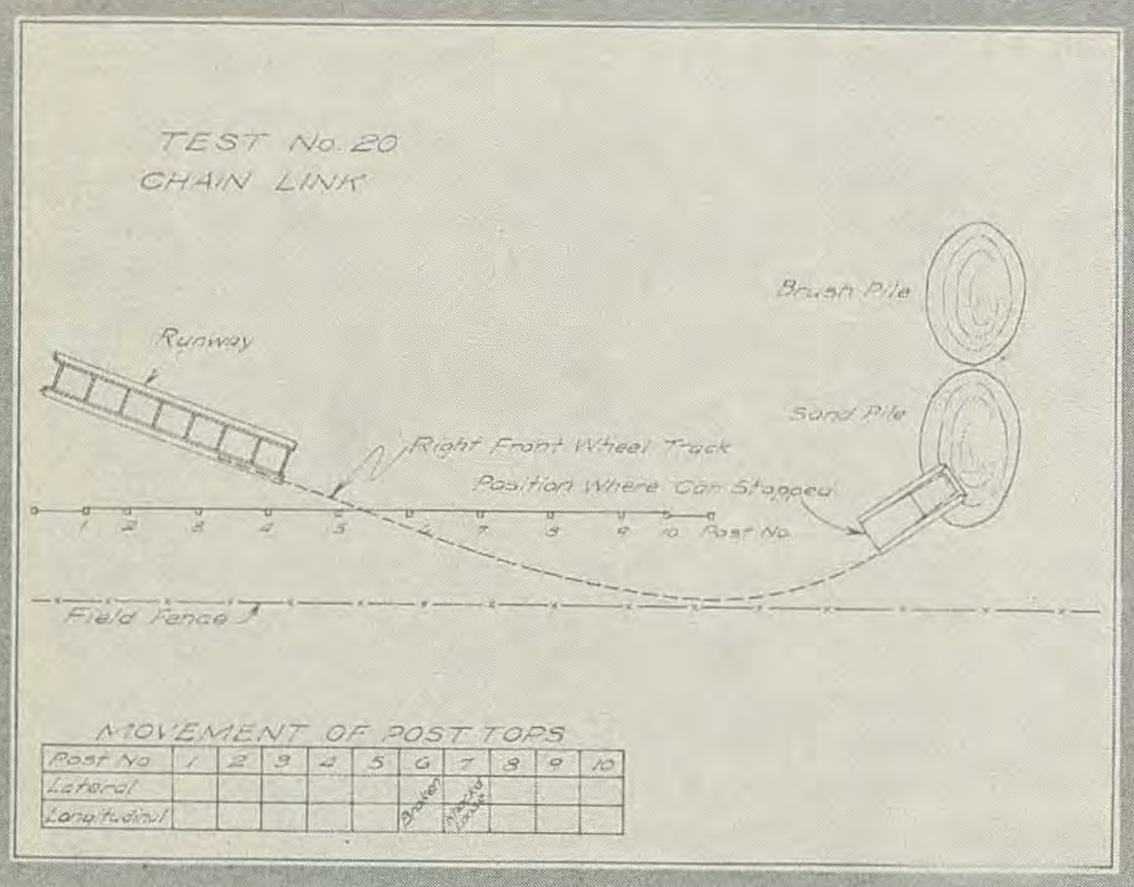
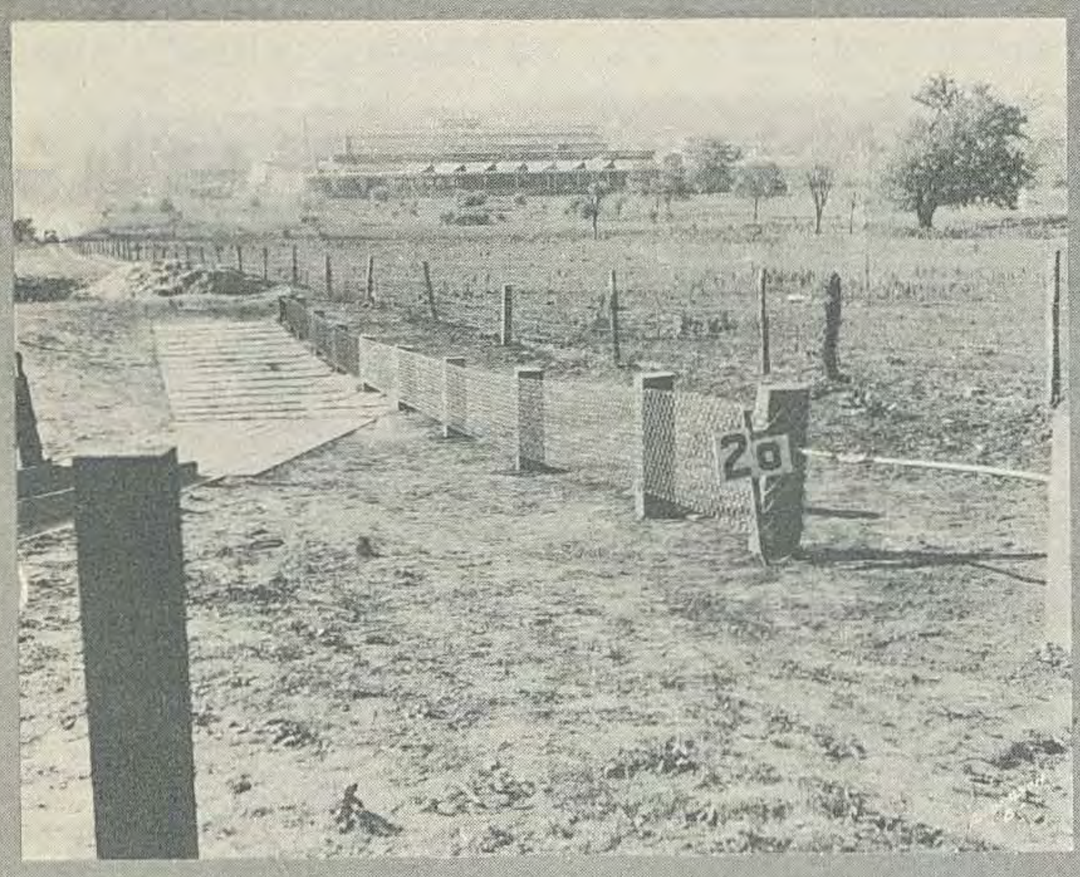

TEST No. 20
CHAIN LINK
Runway
Brush Pile
Sand Pile
Right Front Wheel Track
Position Where Car Stopped
1 2 3 4 5 6 7 8 9 10 Post No.
Field Fence
MOVEMENT OF POST TOPS
Post No 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Broken
Middle Third

20
ANDERSON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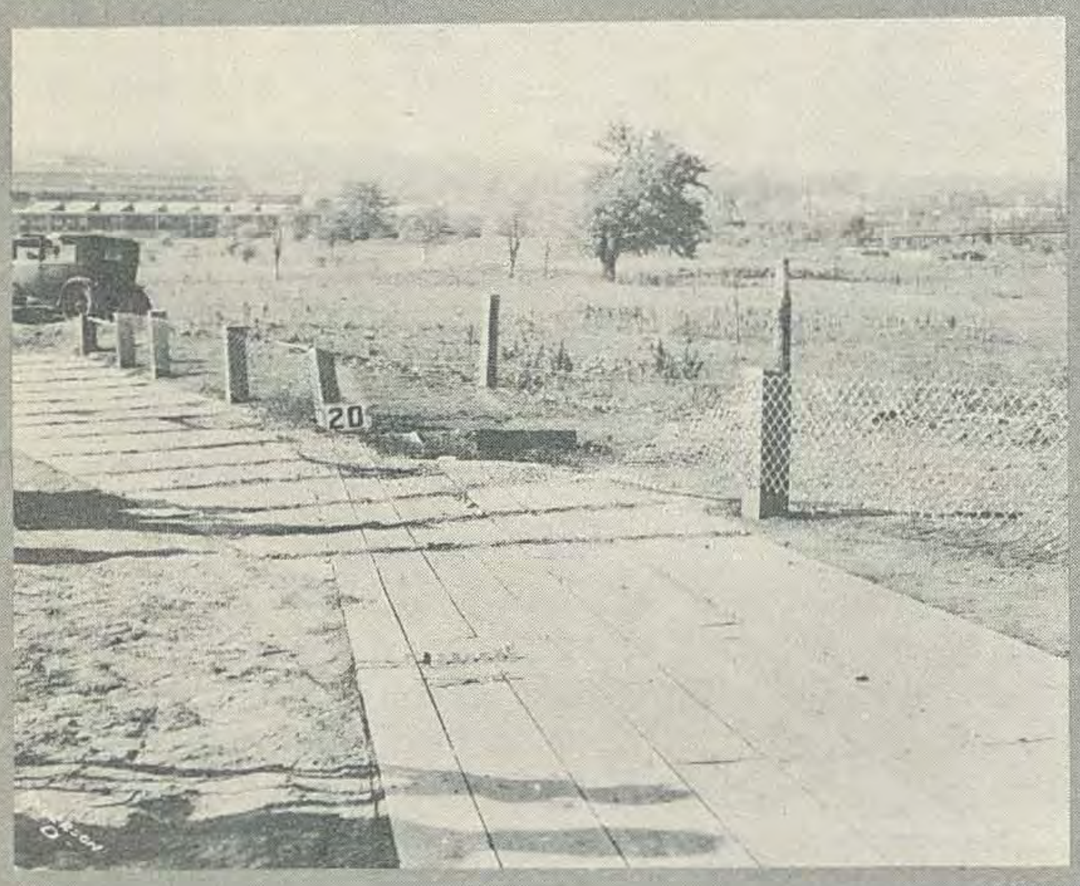
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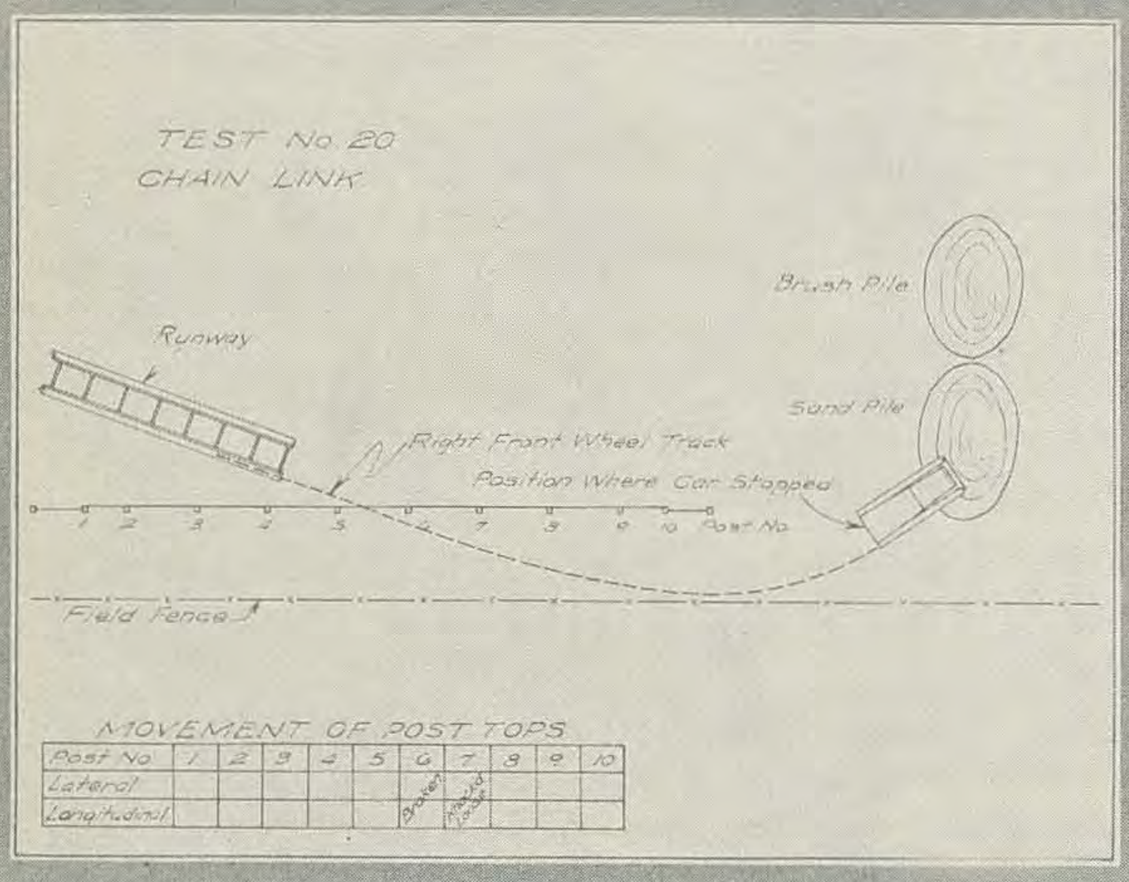

TEST No. 20
CHAIN LINK
Brush Pile
Runway
Sand Pile
Right Front Wheel Track
Position Where Car Stopped
1 2 3 4 5 6 7 8 9 10 Post No.
Field Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8 9 10
Lateral
Longitudinal
Broken
Bent Back

20

TEST NO. 20

Description of Rail - The rail used for this test was Chain Link. It is fabricated from No. 6 gauge wire formed into meshes 2.22" square and the design of the fence is such that there are no longitudinal tension members. The fence was 24" wide and was mounted on 6" x 8" pine posts which were set four feet in the ground, ten feet center to center. The fence was placed with its center 18" above the ground and was stapled directly to the posts. The end posts were anchored to a dead man. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 4" at the top of the rail and 3-1/2" at the bottom of the rail.

Description of the Car - The car used for the test was a Cadillac sedan, which weighed 5,100 pounds. The speed of the car was 32.1 miles per hour. This car had been used previously for tests No. 15 and No. 16.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6 and ran over the rail, breaking off post No. 6 and knocking post No.7 loose. Post No.7 was knocked loose by the left front wheel. The car did not turn until after it had run over the rail when it turned to the left and ran into the sandpile at the end of the test section.

Damage to Rail - The portion of the fence between posts No. 5 and No.7 (20 feet) was stretched to 25 feet. The rail was also torn in two halfway from the bottom at post No. 6. Post No. 6 was broken off at the ground and post No. 7 was loosened.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace 20 feet of the fence and one post and to retamp one post.

Damage to Car - The left front fender was bent and the bumper was bent and broken, having been torn loose on the left side.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - Where the impact force is large enough to stretch the fence materially, as it was in this test, the fence does not turn the car.

Results - This rail did not prevent the car from leaving the roadway.

TEST NO. 21

Description of Rail - The rail used for this test was "Pittsburgh Safety Highway Guard" (Pittsburgh Steel Company). The fence is composed of twenty-four No. 8 gauge longitudinal wires with No. 10 gauge vertical spacer wires, spaced 2" center to center. These wires are fabricated into a woven band 14" wide which was mounted directly on 6" x 8" pine posts, set four feet in the ground, sixteen feet center to center. The faces of the posts were rounded to a 6" radius above the ground line. The band was fastened to the intermediate posts by means of a light clamp, bolted to the post with two 1/2" bolts, and was fastened to the end posts by means of four conical sleeves and tapered pins, each of which held six of the longitudinal wires. These four sleeves were bolted to the end posts and the end posts were anchored to a dead man. The center of the rail was placed 19" above the ground. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 1-3/8".

Description of Car - The car used for the test was a four-passenger Cadillac coupe, which weighed 5,100 pounds. The speed of the car was 34.6 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, the bumper hitting the rail eight feet back of post No. 5 and at three feet back of post No. 5 the bumper or wheel hub rammed into the rail, breaking eighteen spacer wires. The rear of the car was thrown in against the rail and as it impacted the rail the car tipped approximately ten degrees from the vertical. The car hit post No. 5 hard, breaking it off, and as post No. 5 leaned back the right front wheel climbed up and over the rail. The car then turned parallel to and the right rear wheel climbed over the rail. Riding astraddle of the rail, the car hit post No.6, breaking if off, and was finally stopped abruptly by post No.7, coming to rest with the front axle supported on the rail against post No.7.

Damage to Rail - Eighteen spacer wires were broken just back of post No.5 and the bottom longitudinal wire was torn loose from the spacers for five feet back from post No. 6. Posts No. 5 and No. 6 were broken, posts No. 4 and No. 7 were loosened in the ground, and posts No. 1, No. 2 and No. 3 were moved slightly. Post No. 5 was shoved along the rail, so that six spacer wires were forced together and post No. 6 was shoved along the rail so that nine spacer wires were forced together.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace thirty-three spacer wires and two posts and to retamp two posts.

Damage to Car - The left front fender and the right rear fender were bent. The bumper was bent and broken, being torn off on the right side. The right rear tire was cut and punctured. A 2" strip was torn off the right running board. The steering wheel was broken by a bag of sand thrown forward from the floor in the rear of the car and the windshield directly in front of the steering wheel was cracked.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

Results - This rail twisted about its longitudinal axis, after one post was struck and broken, allowing the car to mount the rail. The car was turned but was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impacts of the car with the rail caused no appreciable damage to either the car or the rail.

TEST NO. 21

Description of Rail - The rail used for this test was "Pittsburgh Safety Highway Guard" (Pittsburgh Steel Company). The fence is composed of twenty-four No. 8 gauge longitudinal wires with No. 10 gauge vertical spacer wires, spaced 2" center to center. These wires are fabricated into a woven band 14" wide which was mounted directly on 6" x 8" pine posts, set four feet in the ground, sixteen feet center to center. The faces of the posts were rounded to a 6" radius above the ground line. The band was fastened to the intermediate posts by means of a light clamp, bolted to the post with two 1/2" bolts, and was fastened to the end posts by means of four conical sleeves and tapered pins, each of which held six of the longitudinal wires. These four sleeves were bolted to the end posts and the end posts were anchored to a dead man. The center of the rail was placed 19" above the ground. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 1-3/8".

Description of Car - The car used for the test was a four-passenger Cadillac coupe, which weighed 5,100 pounds. The speed of the car was 34.6 miles per hour. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, the bumper hitting the rail eight feet back of post No. 5 and at three feet back of post No. 5 the bumper or wheel hub rammed into the rail, breaking eighteen spacer wires. The rear of the car was thrown in against the rail and as it impacted the rail the car tipped approximately ten degrees from the vertical. The car hit post No. 5 hard, breaking it off, and as post No. 5 leaned back the right front wheel climbed up and over the rail. The car then turned parallel to and the right rear wheel climbed over the rail. Riding astraddle of the rail, the car hit post No.6, breaking if off, and was finally stopped abruptly by post No.7, coming to rest with the front axle supported on the rail against post No.7.

Damage to Rail - Eighteen spacer wires were broken just back of post No.5 and the bottom longitudinal wire was torn loose from the spacers for five feet back from post No. 6. Posts No. 5 and No. 6 were broken, posts No. 4 and No. 7 were loosened in the ground, and posts No. 1, No. 2 and No. 3 were moved slightly. Post No. 5 was shoved along the rail, so that six spacer wires were forced together and post No. 6 was shoved along the rail so that nine spacer wires were forced together.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace thirty-three spacer wires and two posts and to retamp two posts.

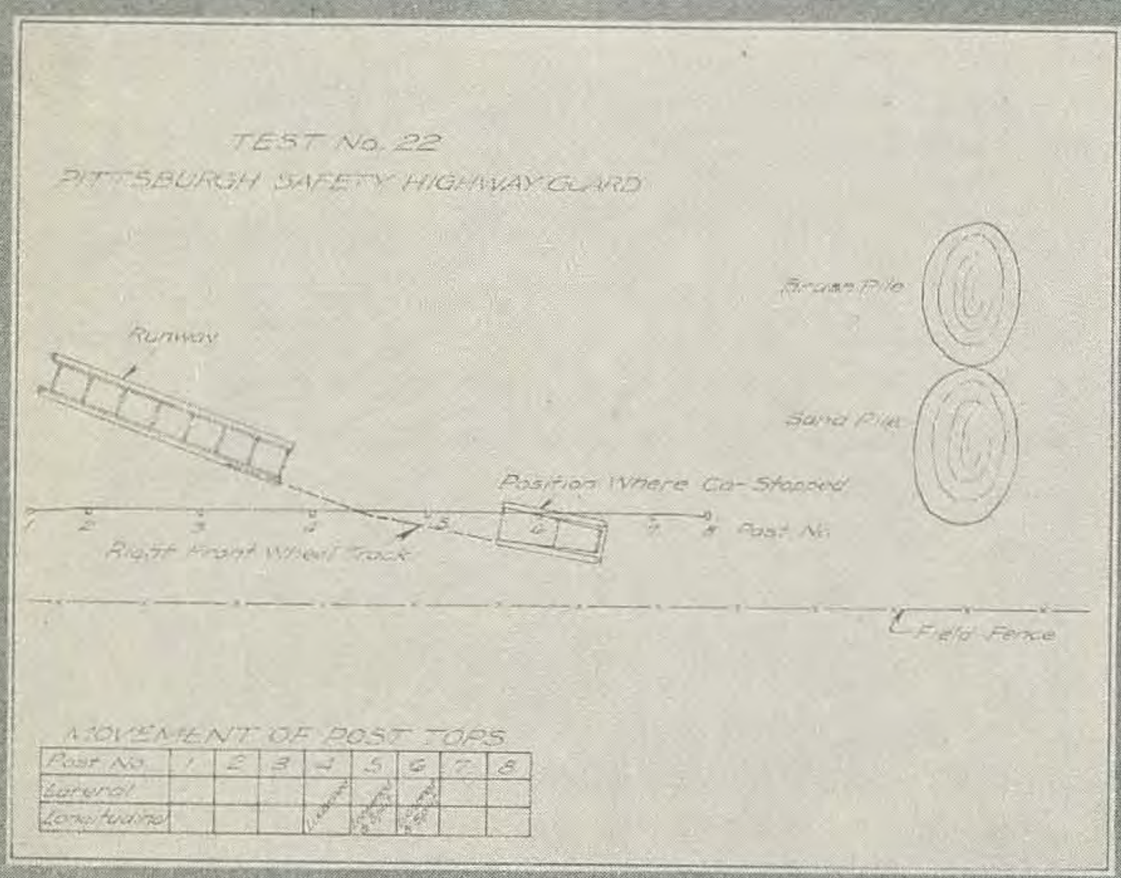
Damage to Car - The left front fender and the right rear fender were bent. The bumper was bent and broken, being torn off on the right side. The right rear tire was cut and punctured. A 2" strip was torn off the right running board. The steering wheel was broken by a bag of sand thrown forward from the floor in the rear of the car and the windshield directly in front of the steering wheel was cracked.

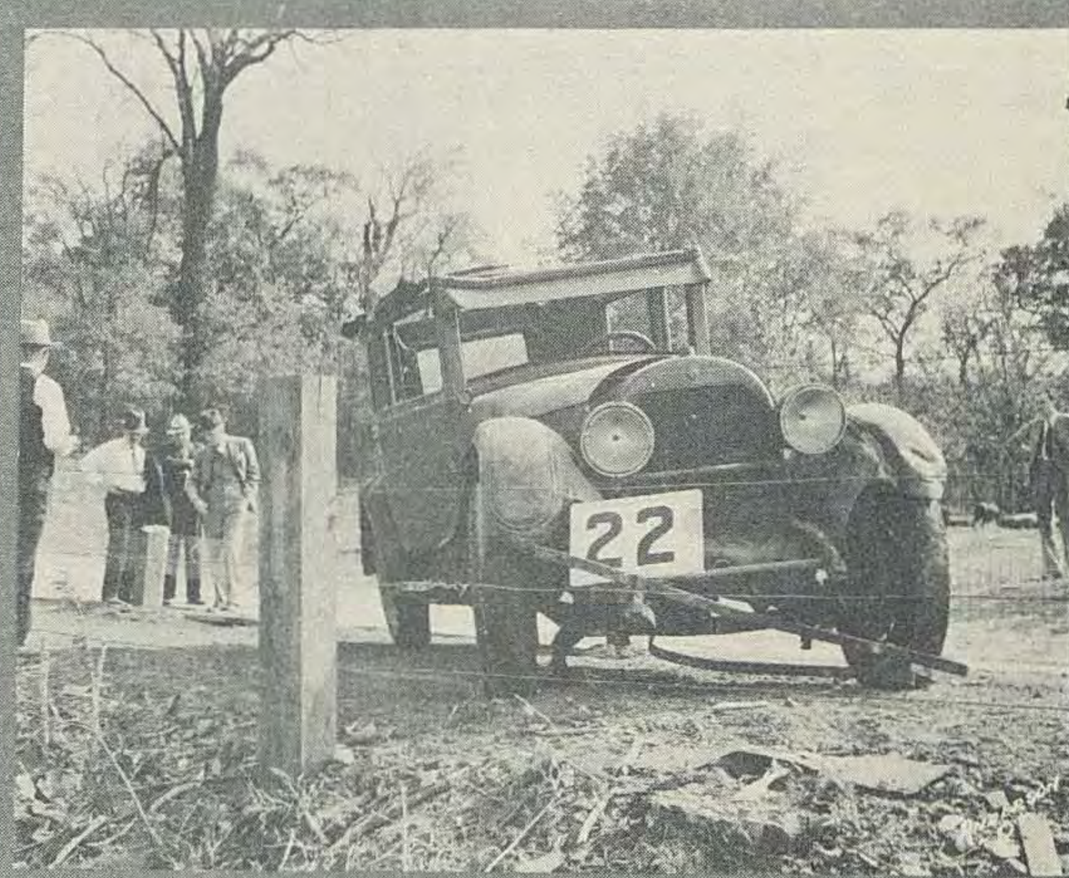
Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

Results - This rail twisted about its longitudinal axis, after one post was struck and broken, allowing the car to mount the rail. The car was turned but was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impacts of the car with the rail caused no appreciable damage to either the car or the rail.

22

22


TEST No. 22
PITTSBURGH SAFETY HIGHWAY GUARD
Brush Pile
Runway
Sand Pile
Position Where Car Stopped
Post No.
Right Front Wheel Track
Field Fence
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral
Longitudinal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TEST NO. 22

Description of Rail - The rail used in this test was "Pittsburgh Safety Highway Guard" (Pittsburgh Steel Company). The design of the rail was similar to the design of the rail used for test No. 21, except that the steel spacer wires were of a harder grade steel. Erection details were the same as those of test No. 21. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 1-1/4".

Description of Car - The car used for the test was a Cadillac sedan which weighed 5,100 pounds. The speed of the car was 31.7 miles per hour. This car had been used previously for tests No. 15, No. 16 and No. 20.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, six feet ahead of post No. 4. The right front wheel immediately climbed up on the rail and post No. 5 was hit, loosened in the ground and shoved along on the rail. The front end of the car, with no deflection, continued on over the rail and as the right rear wheel followed on over the rail, the car tipped to the left, approximately fifteen degrees from the vertical. The car was stopped abruptly by the left rear wheel catching on the rail at post No. 6 and came to rest with the left rear wheel remaining suspended in the air.

Damage to Rail - One spacer wire was broken at the point of impact and post No. 5 was shoved ahead on the rail, so that six spacer wires were forced together and broken. Posts No. 4, No. 5 and No. 6 were loosened and posts No. 5 and No. 6 were both split on one corner below the ground.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace seven spacer wires and two posts and to retamp one post.

Damage to Car - The bumper was bent, broken, and torn off on the left. The right front fender was bent and torn loose from the running board. Both running boards were bent. The engine pan was torn loose in the front and the front axle was shoved back 4" on the right.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

Results - This rail twisted about its longitudinal axis allowing the car to climb the rail. The car was not turned and was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impact of the car with the rail caused an appreciable damage to the car but did not seriously damage the rail.

TEST NO. 22

Description of Rail - The rail used in this test was "Pittsburgh Safety Highway Guard" (Pittsburgh Steel Company). The design of the rail was similar to the design of the rail used for test No. 21, except that the steel spacer wires were of a harder grade steel. Erection details were the same as those of test No. 21. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of 1-1/4".

Description of Car - The car used for the test was a Cadillac sedan which weighed 5,100 pounds. The speed of the car was 31.7 miles per hour. This car had been used previously for tests No. 15, No. 16 and No. 20.

Behavior of Car and Rail - The car struck the rail between posts No. 4 and No. 5, six feet ahead of post No. 4. The right front wheel immediately climbed up on the rail and post No. 5 was hit, loosened in the ground and shoved along on the rail. The front end of the car, with no deflection, continued on over the rail and as the right rear wheel followed on over the rail, the car tipped to the left, approximately fifteen degrees from the vertical. The car was stopped abruptly by the left rear wheel catching on the rail at post No. 6 and came to rest with the left rear wheel remaining suspended in the air.

Damage to Rail - One spacer wire was broken at the point of impact and post No. 5 was shoved ahead on the rail, so that six spacer wires were forced together and broken. Posts No. 4, No. 5 and No. 6 were loosened and posts No. 5 and No. 6 were both split on one corner below the ground.

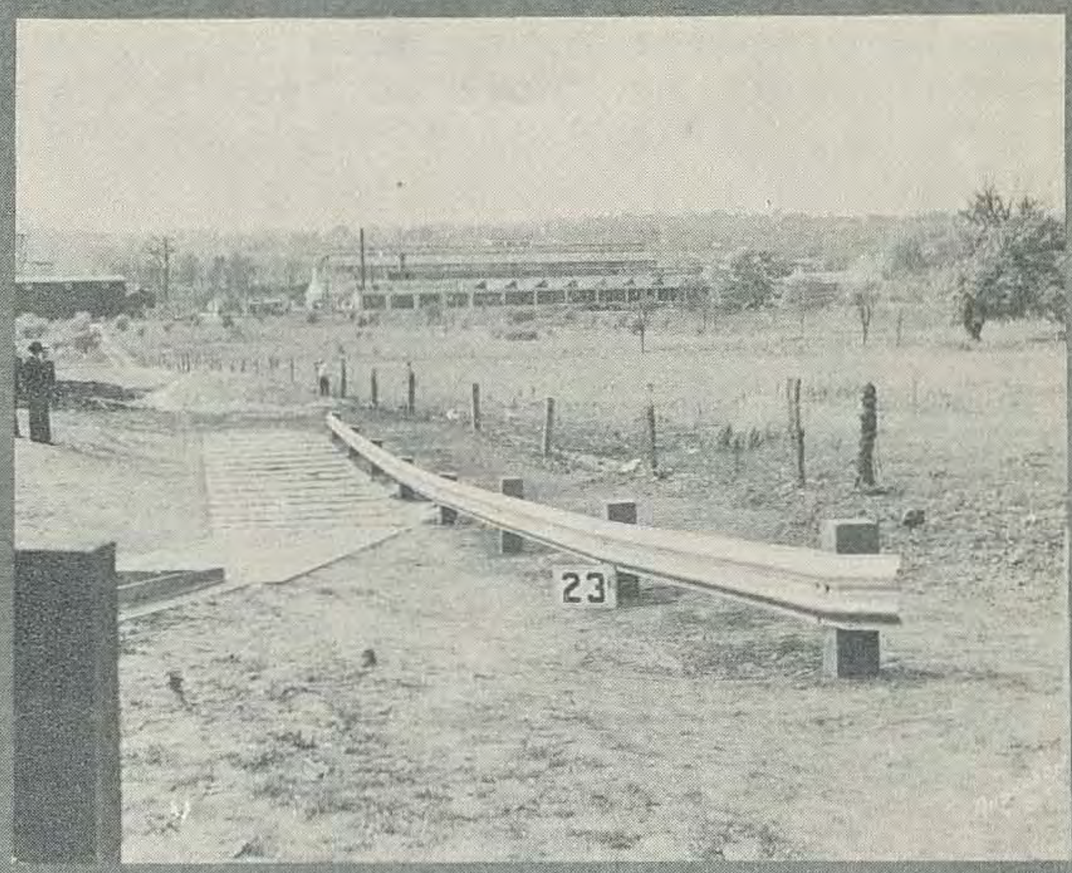
Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace seven spacer wires and two posts and to retamp one post.

Damage to Car - The bumper was bent, broken, and torn off on the left. The right front fender was bent and torn loose from the running board. Both running boards were bent. The engine pan was torn loose in the front and the front axle was shoved back 4" on the right.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

Results - This rail twisted about its longitudinal axis allowing the car to climb the rail. The car was not turned and was stopped in such a short distance and so abruptly that there was considerable probability of injury to occupants. The impact of the car with the rail caused an appreciable damage to the car but did not seriously damage the rail.

23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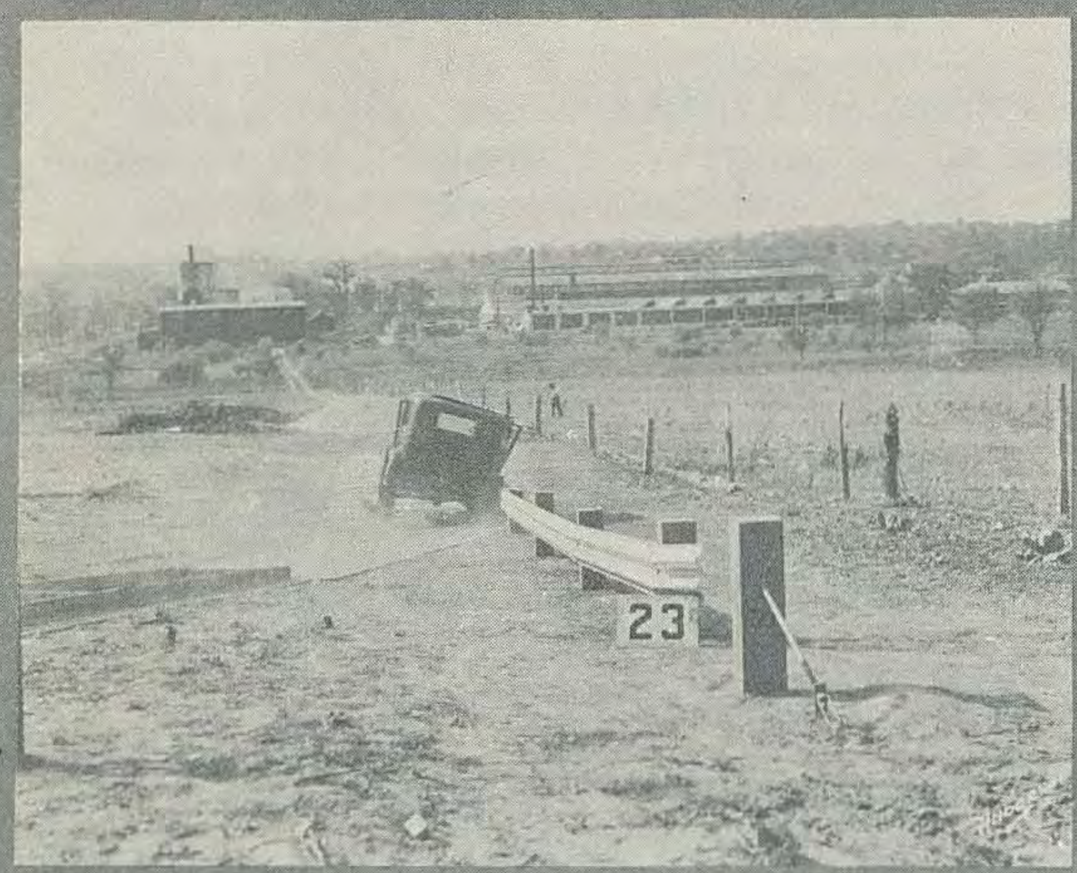
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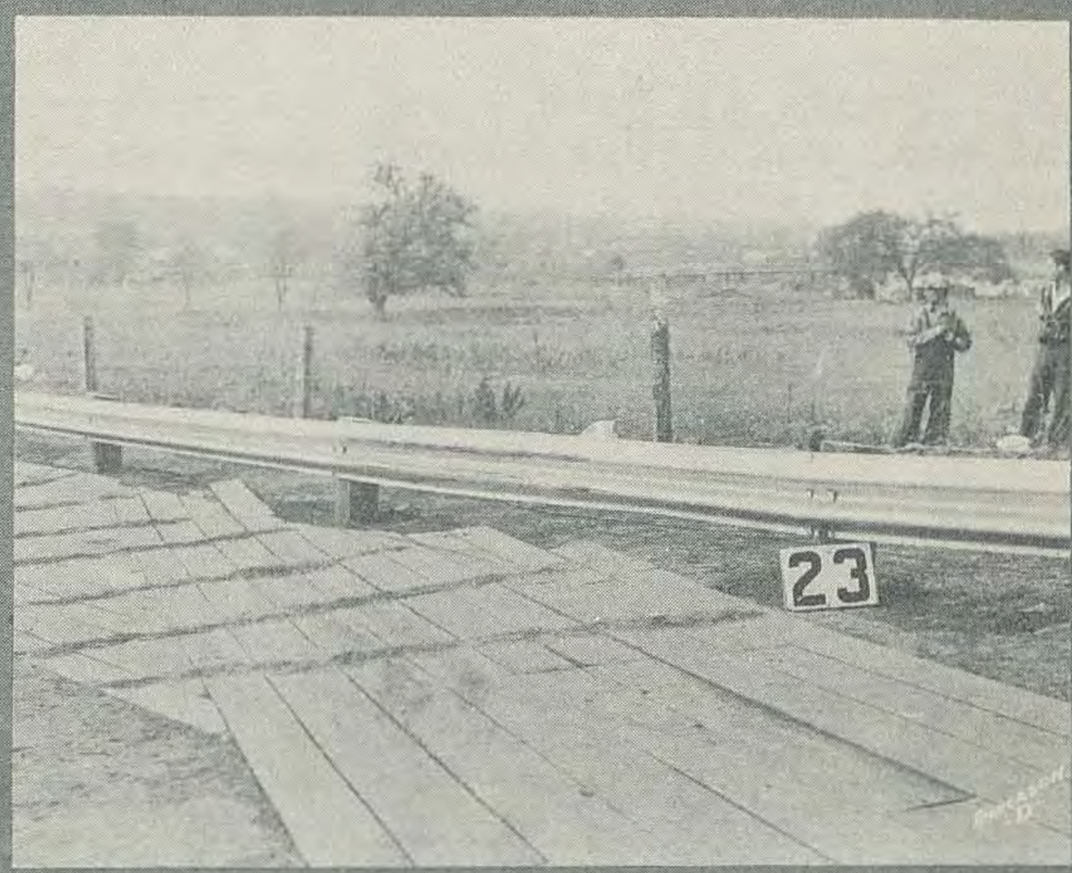
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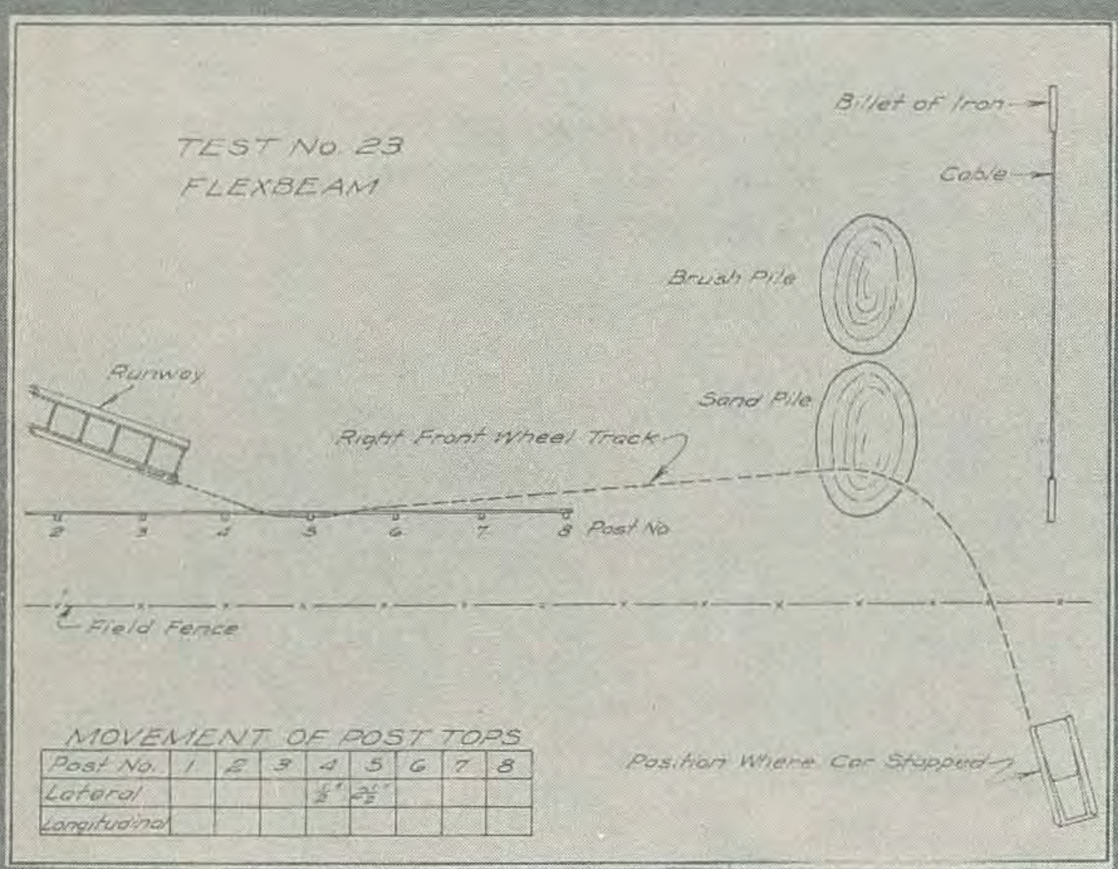

TEST No. 23
FLEXBEAM
Billet of Iron
Cable
Brush Pile
Sand Pile
Runway
Right Front Wheel Track
2 3 4 5 6 7 8 Post No.
Field Fence
Position Where Car Stopped
MOVEMENT OF POST TOPS
Post No. 1 2 3 4 5 6 7 8
Lateral
Longitudinal

23

TEST NO. 23

Description of Rail - The rail used for the test was "Flex-Beam" (Sheffield Steel Corporation). It consisted of a plate 18" x .139" corrugated 3" deep. The projected width of the corrugated plate was 12-1/2". The rail panels were mounted on 6" x 8" pine posts which were set four feet in the ground, twelve feet center to center, and were fastened to the posts by a 1" bolt. Adjoining panels were connected by a single lap splice which was made with three 3/4" bolts, in addition to the 1" post bolt. The center of the rail was placed 17" above the ground. No anchors were used on the end posts.

Description of Car - The car used for the test was a Model A Ford sedan, which weighed 2,350 pounds. The speed of the car was 31.8 miles per hour. This car did not have a front bumper. This was the first test in which this car was used.

Behavior of Car and Rail - The car struck the rail between posts No.4 and No.5, 4-1/2 feet ahead of post No. 4 and the front of the car was deflected. The rear of the car was thrown into the rail and as it impacted the rail, the car tipped approximately twenty-five degrees from the vertical. The car ran along the rail for fifteen feet, then parted contact and rolled free at an angle of approximately ten degrees with the rail, running over the sandpile and finally stopping about thirty feet to the right and sixty feet beyond the end of the test section.

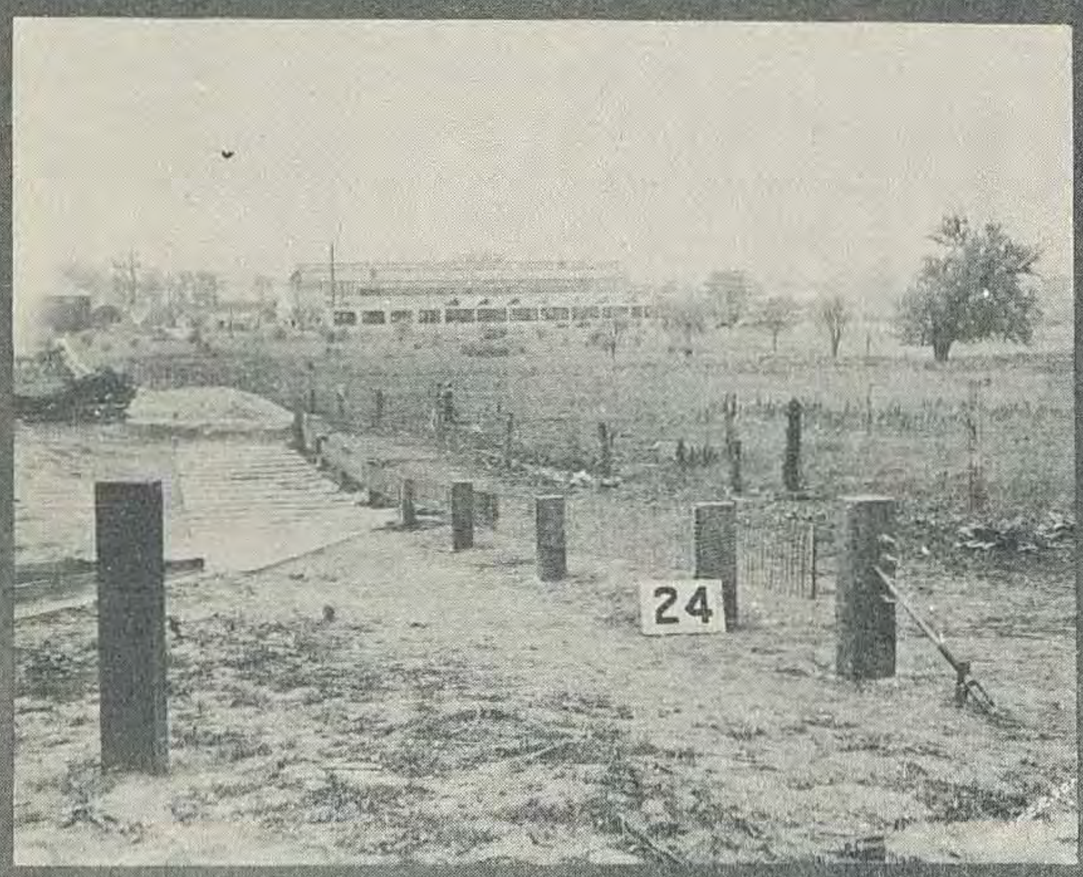
Damage to Car - The right rear fender was crumpled and the right headlight was bent and the lens broken. The right front tube was cut on the rim of the wheel. The top support, in which the wood had rotted, was broken on the left side.

Damage to Rail - The impact of the car bent panel 4-5, causing a permanent set of 2", four and one-half feet back from post No. 5. Post No. 5 was loosened in the ground and post No. 4 was moved slightly.

Repairs to Rail - In order to have put this rail back in a serviceable condition, post No. 5 would had to have been retamped. The rail would have remained effective without the replacement of any rail panel; however, in order to have restored this rail to its original condition, one rail panel would had to have been replaced in addition to the retamping of one post.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

Results - This rail deflected the car with small probability of injury to occupants and the impact of the car with the rail caused very little damage to either the car or the rail.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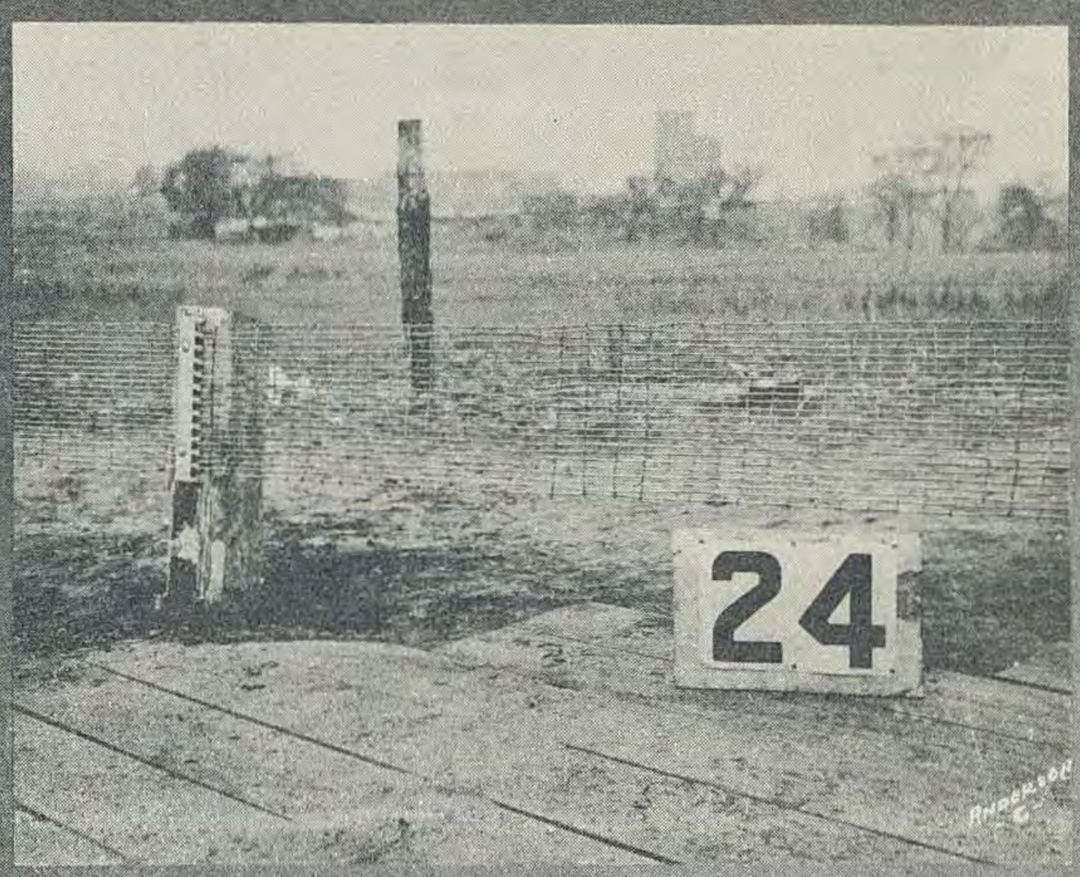
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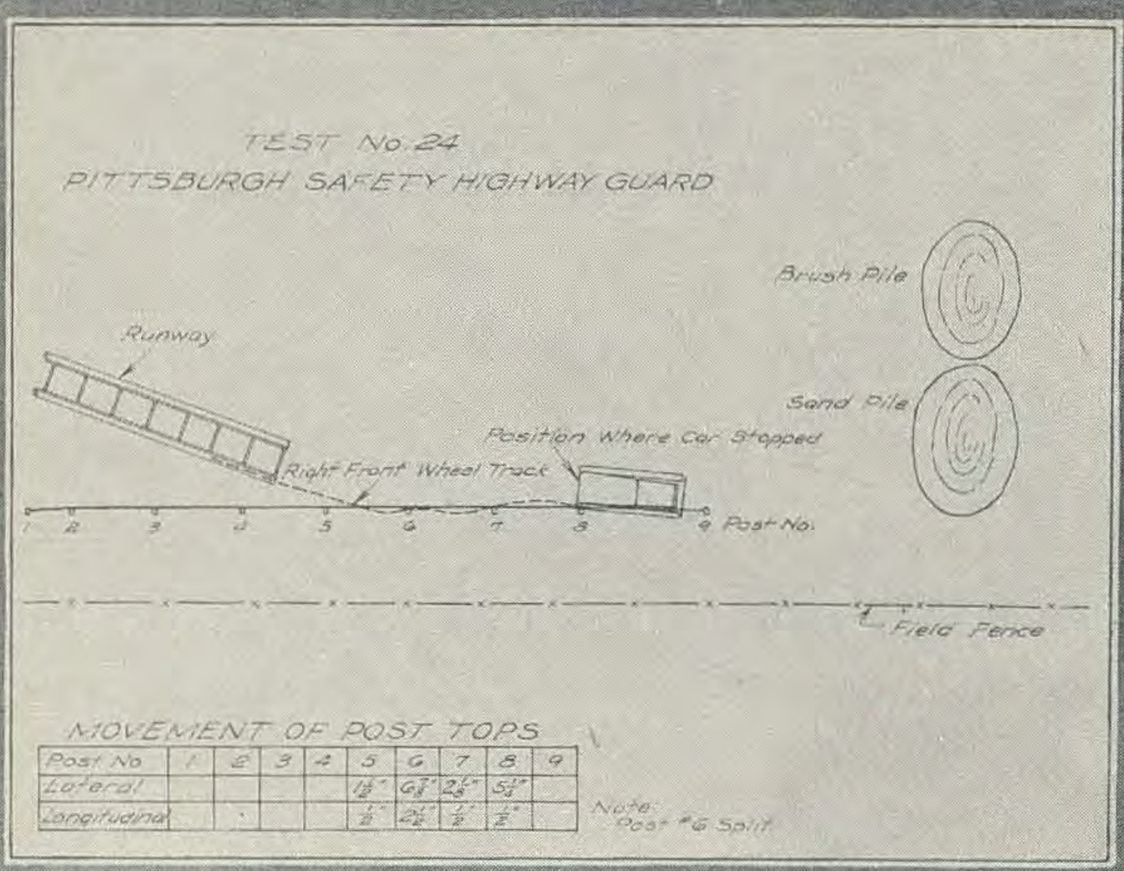
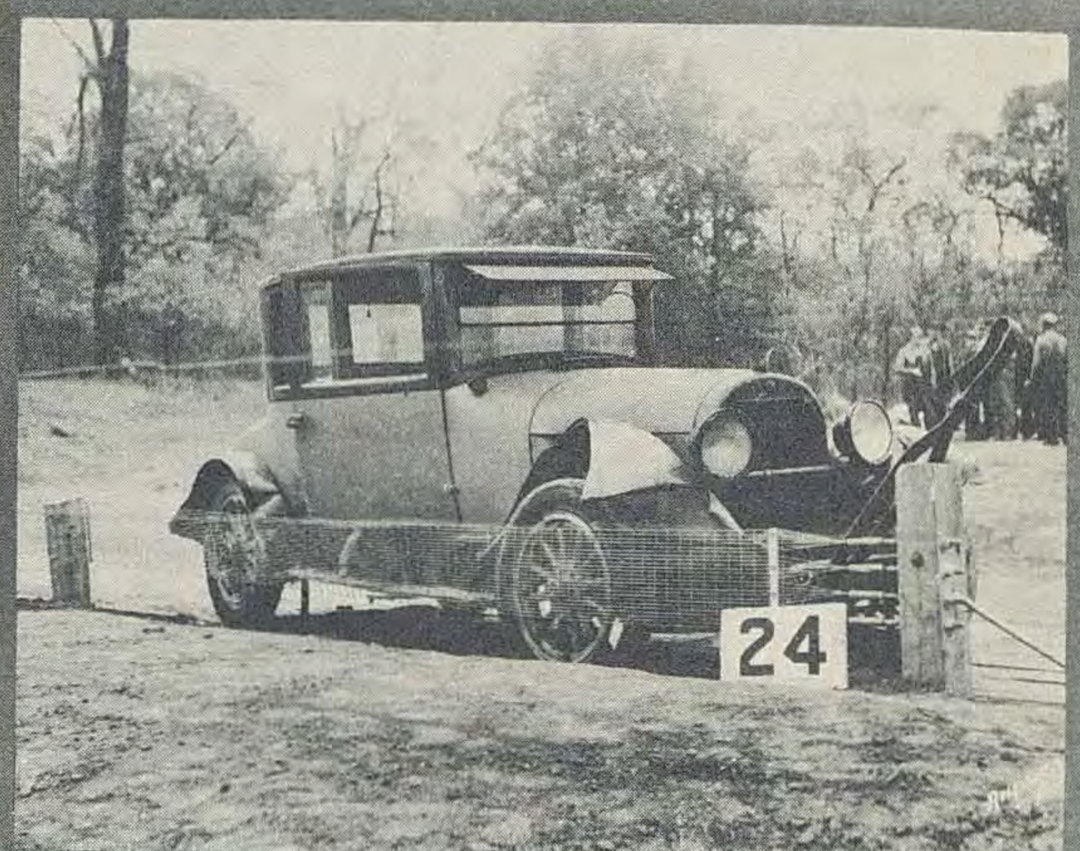

TEST No. 24
PITTSBURGH SAFETY HIGHWAY GUARD
Brush Pile
Runway
Sand Pile
Position Where Car Stopped
Right Front Wheel Track
1 2 3 4 5 6 7 8 9 Post No.
Field Fence
MOVEMENT OF POST TOPS
Post No 1 2 3 4 5 6 7 8 9
Lateral 1 1/2" 6 3/8" 2 1/8" 5 1/4"
Longitudinal 1/8" 2 1/4" 1/2" 1/2"
Note: Post #6 Split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TEST NO. 24

Description of Rail - The rail used in this test was "Pittsburgh Safety Highway Guard" (Pittsburgh Steel Company). The design and erection details of this rail were the same as for test No. 22 except that the post spacing was reduced to twelve feet. The rail used in test No. 22 was turned end for end and after the broken spacers had been repaired, was re-used for this test. The tension of the rail was such that a normal load of 100 pounds midspan of the posts caused a deflection of one inch.

Description of Car - The car used for the test was a four-passenger Cadillac coupe which weighed 5,100 pounds. The speed of the car was 29.9 miles per hour. This car had been used previously for test No. 21.

Behavior of Car and Rail - The car struck the rail between posts No.5 and No.6, six feet ahead of post No.5. At a point three and one-half feet back of post No.6, the car rammed into the rail, breaking two spacer wires and forcing four spacer wires together. The front end of the car was turned. The rear end of the car was thrown into the rail and rebounded from it but as it impacted the rail, the car tipped approximately fifteen degrees from the vertical. The car hit post No. 6 hard, splitting it and then rolled along to post No. 7 which it also hit. At post No. 7, the car was deflected out slightly (at six feet ahead of post No. 7, the right tire track was ten inches out from the rail), then turned in and hit post No. 8 fairly hard, loosening it in the ground. The car finally came to rest against the rail with its front wheel fourteen feet ahead of post No. 8 and five inches back of the original rail line.

Damage to Rail - Six spacer wires, two of which were broken, were deformed at the point of impact and at post No. 6 four spacer wires were deformed, one of which was broken. The clamp at post No. 6 was bent out of shape and at post No. 7, the lower clamp-bolt was pulled out about two inches and bent. Posts No.5, No.6, No.7 and No.8 were loosened in the ground. Post No.6 was split on one corner below the ground line.

Repairs for Rail - In order to have put this rail back in a serviceable condition, it would have been necessary to replace ten spacer wires, one post-clamp, three clamp-bolts and one post, and to retamp three posts.

Damage to Car - The collision of the car with the rail tore off the bumper, crumpled the right front fender, bent the right rear fender and bent the right headlight. The front axle was twisted and was shoved back about six inches on the right and about one inch on the left and the right front spring clamp was twisted. The frame was bent on the right front, the radiator was leaking badly, one-half of the right running board was split off and the right rear hub cap torn. The right front tire was chewed for twelve inches and was punctured.

Erection Notes - The rail was easily erected and no trouble was caused by the vertical curve.

General Remarks - In considering the damage to the car, some allowance should be made for the fact that this car had been used for a previous test. The shoving back of the front axle, by the impact of the car with the rail, may account for the fact that the car remained in contact with the rail until it stopped. The twelve foot spacing of the posts did not allow the rail to twist about its longitudinal axis nearly as much as did the sixteen foot spacing in tests No. 21 and 22.

Results - This rail turned the car but the car was not kept away from the posts and stopped against the rail with some probability of injury to occupants. The impacts of the car with the rail caused an appreciable damage to the car but did not seriously damage the rail.