ENGINEERING ASPECTS

OF

RAIL-HIGHWAY GRADE CROSSING SAFETY EVALUATION

by

Neilon J. Rowan

and

Ned E. Walton

RESEARCH REPORT NUMBER 111-3(F)

RAIL-HIGHWAY GRADE CROSSING SAFETY EVALUATION

RESEARCH STUDY NUMBER 2-8-67-111

Sponsored by the
Texas Highway Department
in Cooperation with the
U. S. Department of Transportation
Federal Highway Administration

August, 1970

Texas Transportation Institute
Texas A&M University
College Station, Texas

ENGINEERING ASPECTS

OF

RAIL-HIGHWAY GRADE CROSSING SAFETY EVALUATION

by

Neilon J. Rowan

and

Ned E. Walton

RESEARCH REPORT NUMBER 111-3(F)

RAIL-HIGHWAY GRADE CROSSING SAFETY EVALUATION

RESEARCH STUDY NUMBER 2-8-67-111

Sponsored by the
Texas Highway Department
in Cooperation with the
U. S. Department of Transportation
Federal Highway Administration

August, 1970

Texas Transportation Institute
Texas A&M University
College Station, Texas

ABSTRACT

The diagnostic study team concept was used at thirty-six rail-highway grade crossing sites in Texas as a part of an overall study on rail-highway grade crossing safety. The objective of the diagnostic study phase was to determine the type of protection that would provide acceptable efficiency under the conditions encountered on the various classifications of grade crossings. As a result of the investigations at the thirty-six crossings, recommendations were made for improving the safety conditions and included the development of new advance warning signs and sign location criteria. These signs were evaluated at nine crossing sites in a follow-up study. In addition, recommendations have been made for implementation of engineering and environmental studies to improve safety at specific grade crossings.

SUMMARY

This report describes an approach to the improvement of safety conditions at rail-highway grade crossings. It is based on comprehensive field studies conducted at selected grade crossing locations in Texas as a part of an overall study on grade crossing safety evaluation. The study was sponsored by the Texas Highway Department in cooperation with the Federal Highway Administration.

The responsibility for rail-highway grade crossing safety has been divided between two agencies: the railroad company, within the bounds of the railroad right-of-way; and either the state, county or local government, on the approaches to the crossing. Since grade crossing safety must extend through the entire bounds of the crossing, it is imperative that safety be coordinated by the two responsible agencies. This coordinated effort will insure maximum effectiveness of the crossing's advance warning and protective device system.

The subject study involved a diagnostic study team concept as a safety evaluation tool and coordination and implementation tool. The objective of the study was to determine the type of protection that would provide acceptable efficiency under the conditions encountered on the various classifications of grade crossings.

Thirty-six sample crossings were selected for study by the diagnostic team to identify crossing characteristics which contribute to safe and unsafe conditions. Results of the team studies were summarized and presented, and the following general observation was made concerning the use of the diagnostic team technique in the evaluation of safety conditions at rail-highway grade crossings.

1. The diagnostic study team approach provides a highly reliable method for identifying, isolating and measuring factors which contribute to unsafe conditions that exist at rail-highway grade crossings.
2. The diagnostic study team provides a basis for determining not only which crossings should be protected but more importantly what type of protection should be employed in order to achieve acceptable levels of safety among all crossings.
3. The diagnostic study team provides recommendations for improving and upgrading existing protective equipment, roadway and railway with minimum expense to responsible agencies.
4. The diagnostic study team provides recommendations for on-the-spot safety measures such as the relocation of signals and signs, alignment of flashing lights, replacement of broken or worn signs or signal apparatus, upgrading pavement markings, relocation of public or railroad property, and other measures to reduce accident potential at specific crossings.
5. The diagnostic study team provides an interdisciplinary approach to the solution of a common problem by utilizing technology common to each of the professions represented in its membership.

6. The diagnostic study team develops a line of communication between the various groups and individuals who are responsible for the safe operation of rail-highway grade crossings.

As a means of implementing the findings of the diagnostic studies in the research program, a special committee of twenty members was selected from the various team members that had served in the diagnostic studies of the 36 crossings. This committee considered the research findings relating to the design, operation and maintenance of devices, and procedures used in grade crossing protection, and made recommendations for improvement. These recommendations pertained mainly to special treatments to be implemented in the interest of improving certain crossings included in the thirty-six sites studied previously. The recommendations were as follows:

1. All signs and devices pertaining to advance warning and crossing control should be placed on both sides of the approaching roadways so that maximum effectiveness may be achieved. It was pointed out that vehicles following larger vehicles and vehicles in the act of passing were not afforded an appropriate opportunity to view advance signs and control devices unless they are placed on both sides of the approach.
2. Advance warning signs should be larger and unique in color, color combinations, and shape in order to attract the driver's attention. It was recommended that advance warning signs be a minimum of 42 inches and preferably 48 inches in vertical and horizontal dimensions.

3. Two advance warning signs should be placed on each approach. The first advance warning sign should be located at a distance where the driver could make a comfortable stop before reaching the crossing. This sign should be located at the stopping sight distance, including adequate allowances for perception and reaction time. To explain these signs further, the first advance warning sign should incorporate the familiar railroad crossbuck superimposed over a circular sign. This would achieve a double exposure of uniqueness to railroad grade crossing protection devices.
4. The second advance warning sign should be located at a point comparable to the braking distance at the design speed of the facility or the speed limit, whichever is higher. The message included in this sign should inform the driver as to the type of crossing protection device and/or the sight conditions at the crossing. The second advance warning sign should indicate the type of protection at the crossing. For crossings protected with signals, the sign would indicate a signal head with the red lenses and the general outline of the framework of the signal. For nonprotected crossings, the second advance warning sign should convey a dynamic message such as "look for trains" with arrows pointing in each direction that would be suggestive of the dynamic requirements of the driver to actually look for a train.

5. Where the signal used for crossing protection is not visible to the driver at the first advance warning sign, it is desirable to use a double flashing amber light in conjuction with the advance warning sign and interconnected with the signal so that it would operate only when the signal is activated.
6. In situations where visibility of trains is restricted, it is recommended that a combination of signs be used to warn the driver of the existing conditions. The first and uppermost sign of the "tree" should be a red rectangular sign with white letters indicating "danger." The second sign of the combination should be diamond in shape and include the message "limited view of trains." The third sign should also be a diamond sign conveying an advisory speed.
7. A section of rough textured pavement should be placed an appropriate distance in advance of the first sign to alert the driver and induce a more positive recognition of the sign. This pavement surface should not constitute what is now being used as a rumble strip, but it should provide sufficient contrast in texture to alert the driver. This rough texture would also be a desirable place to use pavement markings to signify the railroad grade crossing.
8. The conventional crossbucks used at nonprotected crossings should be made larger, 1' x 6', and constructed of white reflectorized sheeting as a background for black letters.

These crossbucks should be well maintained and, further, they should be placed on each side of both approaches to the crossing.

9. Spot illumination should be provided at nonprotected rail-highway grade crossings where provision of such illumination is feasible. At crossings where spot illumination is not feasible, some type of delineation device should be used to inform the driver of the presence of a train on a crossing. It was suggested that some unique delineation system be placed on the opposite side of the track so that it would be visible under the train and would indicate motion by the intermittent passage of the train wheels.

As a result of the recommendations, nine sites were selected for follow-up studies. The sites were improved in keeping with the recommendations and economical constraints and included installation of new sign designs based on the committee actions. The follow-up studies indicated a significant improvement in the safety of the crossings as a result of the new sign designs.

A procedure was developed to assist the designer in evaluating and designing grade crossing protection and control. The procedure consists of the following elements:

1. Engineering investigation and data collection
2. Environmental investigation and data collection
3. Considerations for initial warning designs
4. Considerations for final warning designs
5. Considerations for crossing protection designs
6. Techniques for evaluating designs

IMPLEMENTATION

The results of the subject study have immediate application to the rail-highway grade crossing safety problem. A later section of the report contains suggestions for implementation. It has been prepared as a guide for the engineer with the responsibility for rail-highway grade crossing protection. It is not intended to replace existing standards for crossing control; rather it is intended to supplement these standards by providing direction to analysis of crossing conditions and requirements. Further, recommendations are made for improvements to grade crossings in areas not normally covered by standards.

TABLE OF CONTENTS

INTRODUCTION

The Problem

In its simplest form a rail-highway grade crossing is nothing more than an intersection which handles two conflicting streams of traffic. The character of the traffic, that is, vehicles in one stream and trains in another, and both with entirely different operating characteristics, constitutes the real basis of the problem. The driver of an automobile enjoys the freedom of mobility, the right to move at will and the ability to maneuver independently. With this goes the responsibility of judgment to avoid conflict with the train which is restricted to the rails and is incapable of anything more than planned and deliberate maneuvers. There is no question that drivers respect trains - the problem seems to be that they rarely expect them. For example, on a roadway carrying 10,000 vehicles per day, there is a low probability that any one vehicle will encounter a train. Thus, the driver is led into drawing a dangerously false conclusion that he will not encounter a train. This normally results in the driver's failing to take the necessary precautions in approaching a rail-highway crossing.

Most drivers respond satisfactorily to signals which warn of a potential train conflict. Compliance is not always achieved, but at least the driver is apprised of the situation and is afforded the opportunity to make a decision regarding a possible conflict. It appears that the major problem would occur at crossings which do not have signals, described in common terminology as "nonprotected crossings."

At such crossings, the responsibility to determine the prevailing safety conditions lies completely with the driver. In such a situation, the driver is totally dependent upon the advance warning system and the devices that mark the crossing to warn him and draw his attention to the possibility of a train conflict.

There are a number of contributing factors that influence the effectiveness of the system of traffic control which is to provide for safe and orderly operation at the crossing. This is mainly an interjurisdictional problem. The railroad is responsible for the installation, maintenance, and upkeep of equipment located within the railroad right-of-way, while the governmental agency, either local municipal government, state government, or county government, is responsible for devices placed on the approach to warn and advise the driver of conditions at the crossing. Because of the interjurisdictional differences, the devices are not designed and maintained as a complete system of traffic control, but as two separate entities that are functionally interdependent but otherwise unrelated. Most problems exist because of a lack of attention in every phase - the design, the operation, and the maintenance of facilities to achieve grade crossing safety protection. The collective attention of all agencies involved will contribute the greatest immediate benefits to improvements in grade crossing safety.

Research Objectives

In 1967, the Texas Transportation Institute entered into a research study agreement with the Texas Highway Department, in cooperation

with the Federal Highway Administration, to study safety conditions at public rail-highway grade crossings in Texas. The objectives of the research study were specified as follows:

1. To compile a history of the nature and extent of accidents at Texas rail-highway grade crossings over the past few years and to analyze this history.
2. To determine the type of protection that would provide acceptable efficiency under the conditions encountered on the various classifications of grade crossings.
3. To determine the overall cost of providing the recommended levels of protection at rail-highway grade crossings that are found to be ineffectively protected.
4. To develop a system whereby crossings may be assigned priorities for improvements.

In order to accomplish certain of these objectives, it was decided in the spring of 1968 that a diagnostic study team approach would be employed to study a sample of crossings for the purpose of identifying crossing characteristics which contribute to accidents. This report presents the results of the investigation, while a companion report covers Objectives 1, 3, and 4.

Diagnostic Study Team Concept

The diagnostic study team approach provides an excellent means of focusing the attention of all concerned agencies on the problem. Such an approach brings together the representatives of the various agencies involved and immediately establishes lines of communication so that ultimately

a functional system of crossing protection may be provided. The "diagnostic study team" is a somewhat sophisticated term used to describe a very simple procedure of utilizing experienced individuals from various agencies and disciplines, bringing their attention to bear on a common problem. To date, the most successful diagnostic team studies have involved professional people from the railroads, the highways, and the cities, representing the disciplines of administration, design, operation, maintenance, and research.

The diagnostic study team concept is a convenient medium for direct implementation of research findings. To be most effective in the evaluation, the diagnostic team is composed of practicing engineers and other specialists who deal with one facet or another of the grade crossing problem. As a result, they are the people who can, in turn, put the collective findings of this team to work in the most expeditious manner.

The diagnostic study team research concept deals mainly with the practical aspects of the problem. This is not to imply that more conventional research techniques are not worthwhile or appropriate. Such research is very worthwhile and will eventually lead to improved practices for grade crossing protection. Considering the existing state of the conditions, however, the greatest benefits will be realized by focusing attention on the inadequacies of crossing protection and bringing the protection methods up to the level of the known technology.

CONDUCT OF THE DIAGNOSTIC STUDIES AT THIRTY-SIX LOCATIONS

Team Composition

The primary factors for consideration in the assignment of the diagnostic team members are first, that the team is interdisciplinary in nature, and second, that it is representative of all groups having responsibility for the safe operation of rail-highway grade crossings.

In order that each of the vital factors relating to the operational and physical characteristics of the crossing may be properly identified, it is necessary that individual team members be selected on the basis of the specific expertise and experience of each. Figure 1 illustrates the basic organization of the diagnostic team described in this paper. It should be noted that the overall structure of the team is built upon three desired areas of team responsibility. These areas include local responsibility, administrative responsibility, and advisory capacity. All operational and physical characteristics of individual or groups of crossings may be classified in one of the three following areas:

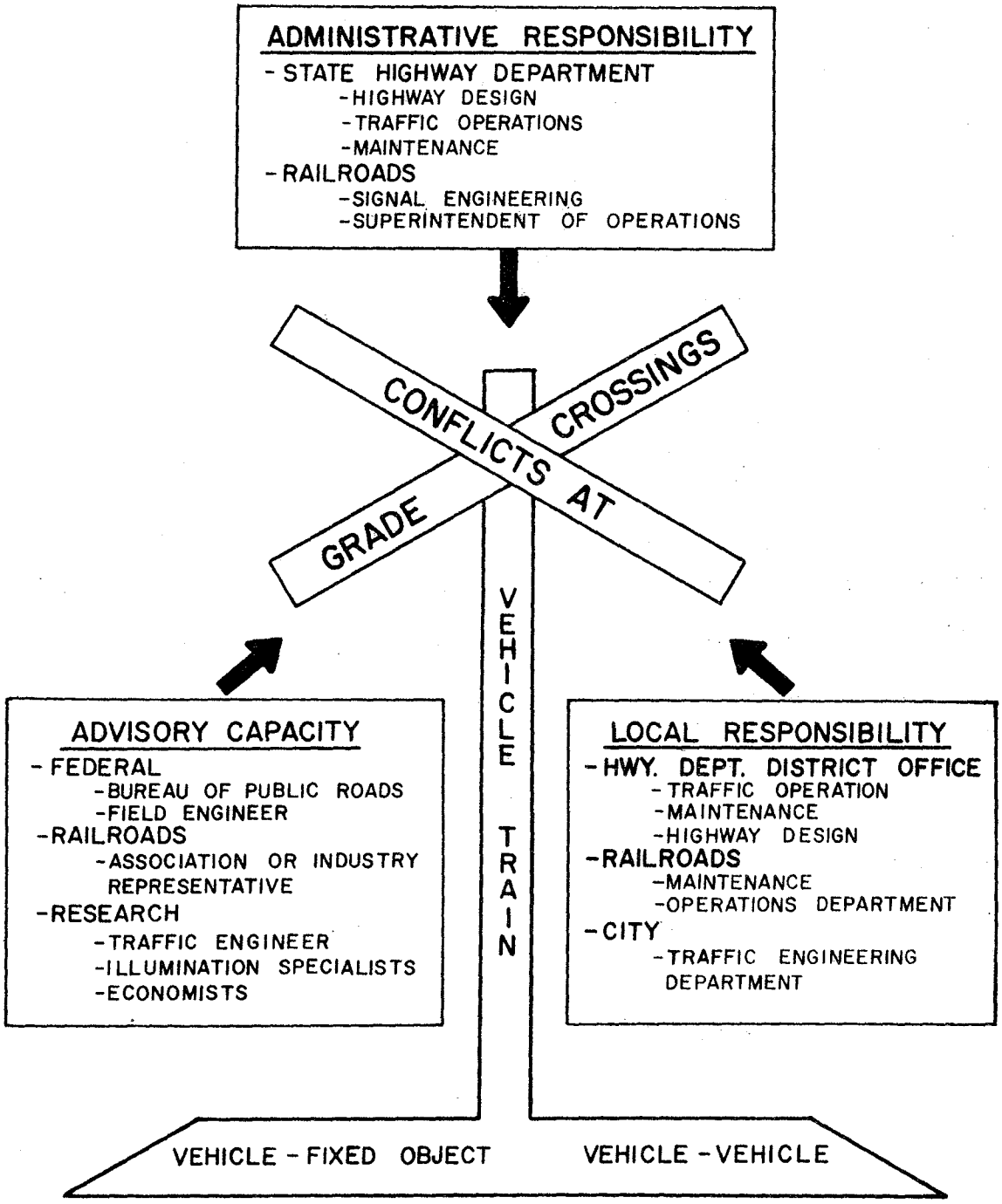
1. Traffic Operations
2. Signal and Communication
3. Administration

In general, the responsibility of team members within each of these categories may be defined as follows:

Traffic Operation. This area includes both vehicular and train traffic operation. Responsibilities of highway traffic engineers and

FIGURE I

DIAGNOSTIC TEAM STRUCTURE



railroad operating personnel chosen for team membership include, among other criteria, specific knowledge of the vehicular and train volume, peak period characteristics, operating speeds, and type of vehicle, such as information on train class and length, and automobile-truck-bus make up of vehicular traffic.

Signal and Communication. The highway maintenance and signal control engineer, along with the railroad signal and communication engineer, provides the best source for expertise in this area. Responsibilities of these team members include special knowledge of grade crossing warning and protective signal systems, train communication systems, interconnection of adjacent signalized highway intersections, warning and control devices for vehicle operation, and highway signs and pavement markings.

Administration. Since many of the problems relating to rail-highway grade crossing safety involve the apportionment of administrative and financial responsibility, it is necessary to recognize this fact in the membership of the diagnostic team. Members of the team representing this area should be carefully selected from the upper echelon of both highway department and railroad company management. The primary responsibility of these representatives is to advise the team of specific policy and administrative rules applicable to any decision to modify or upgrade crossing protection.

In addition to the basic diagnostic team structure described above, local representatives of highway maintenance, railway signal maintenance, city and county traffic engineers (when applicable), are

needed to complete the team membership. The addition of research-oriented advisory personnel to membership on the team provides a highly technical and workable combination of an eight-to ten-member diagnostic team.

When diagnostic team activities may cover a rather large geographic area, requiring considerable time and travel on the part of team members, it is suggested that the membership be rotated. This practice was employed in the Texas study not only to reduce time and travel requirements of individual members, but also to develop a rather large group of experienced people for future team membership. As a result of this approach, there are currently 65 experienced team members available in Texas for assignment to diagnostic study teams.

It is suggested that if the rotating membership method is employed, there should be established some degree of continuity among the membership. The permanent membership should have representatives from each of the areas of local responsibility, administrative responsibility, and advisory capacity.

Team Activities

The scheduling of team activities will depend primarily upon the number of crossings to be studied, the geographic location of the study crossings, and the administrative responsibilities of the highway department, railroad company and cities or counties. Since the state of Texas has an inventory of approximately 2,500 rail-highway grade crossings under the administrative responsibility of the highway

department, it was obvious that during one fiscal year all crossings could not be evaluated by the diagnostic team; therefore, it was determined that a sample of 36 crossings would be selected for study. In order that the findings of the diagnostic team would be applicable to the total inventory, classes of crossings, representative of all highway department crossing types, were established. To be representative, the crossings were classified according to the following criteria:

1. Location in either rural or urban areas
2. Accident experience within the last three years
3. Type of crossing protective devices, either actuated or non-actuated

Twelve crossings within each of the three classes were selected for study.

Another major objective of this phase of the research study was to evaluate the total concept of the diagnostic team approach to grade crossing safety evaluation; therefore, care was taken in the selection of study crossings to insure that as many highway offices and railroad companies as was feasible were involved in the study.

It was found that once the study crossings had been selected, the scheduling of diagnostic team activities was greatly simplified. The technique used in the research project was to request the responsible and interested agencies to select qualified personnel, as defined previously, for team membership. Names were submitted by the State Highway Department, Federal Highway Administration, and the railroad

companies. In addition to these, city traffic engineers were invited to participate as members of the team that studied grade crossings located within their respective cities.

The responsibility for scheduling the diagnostic team activities was given to the research project staff. Information relative to the location of each study crossing and the date and hour the team was to assemble to evaluate the crossing was prepared and made available to each diagnostic team participant. Approximately two hours were allocated to each study crossing. No more than six study crossings were to be visited during any one week, with all diagnostic work to be accomplished in a period of three months. It is interesting to note that although the schedule was prepared at least a month in advance of the first assembly of the team, and the last three crossings visited by the diagnostic team were scheduled some four months in advance, no request for changes in the schedule were made during the entire study period. Only on three occasions was a team member absent. Since there were more than 65 different people who comprised the various diagnostic teams, these facts point out the interest that can be shown in diagnostic study team participation.

Diagnostic Study Support Data

The collection of physical data to supplement and support the diagnostic study of rail-highway grade crossings may be classified by two categories, i.e., operational and environmental characteristics. Operational characteristics include factors such as these:

1. Train and vehicle speed, volume and types

2. Accident records

3. Signalization and signing

4. Adjacent roadway and railway vehicle and train operations

Environmental characteristics include, among other factors, the following:

1. Roadway geometrics

2. Location of buildings, trees and other structures near the crossing

3. Location of adjacent streets, roadways and railways

4. Topography of immediate area of the crossing

5. Population density

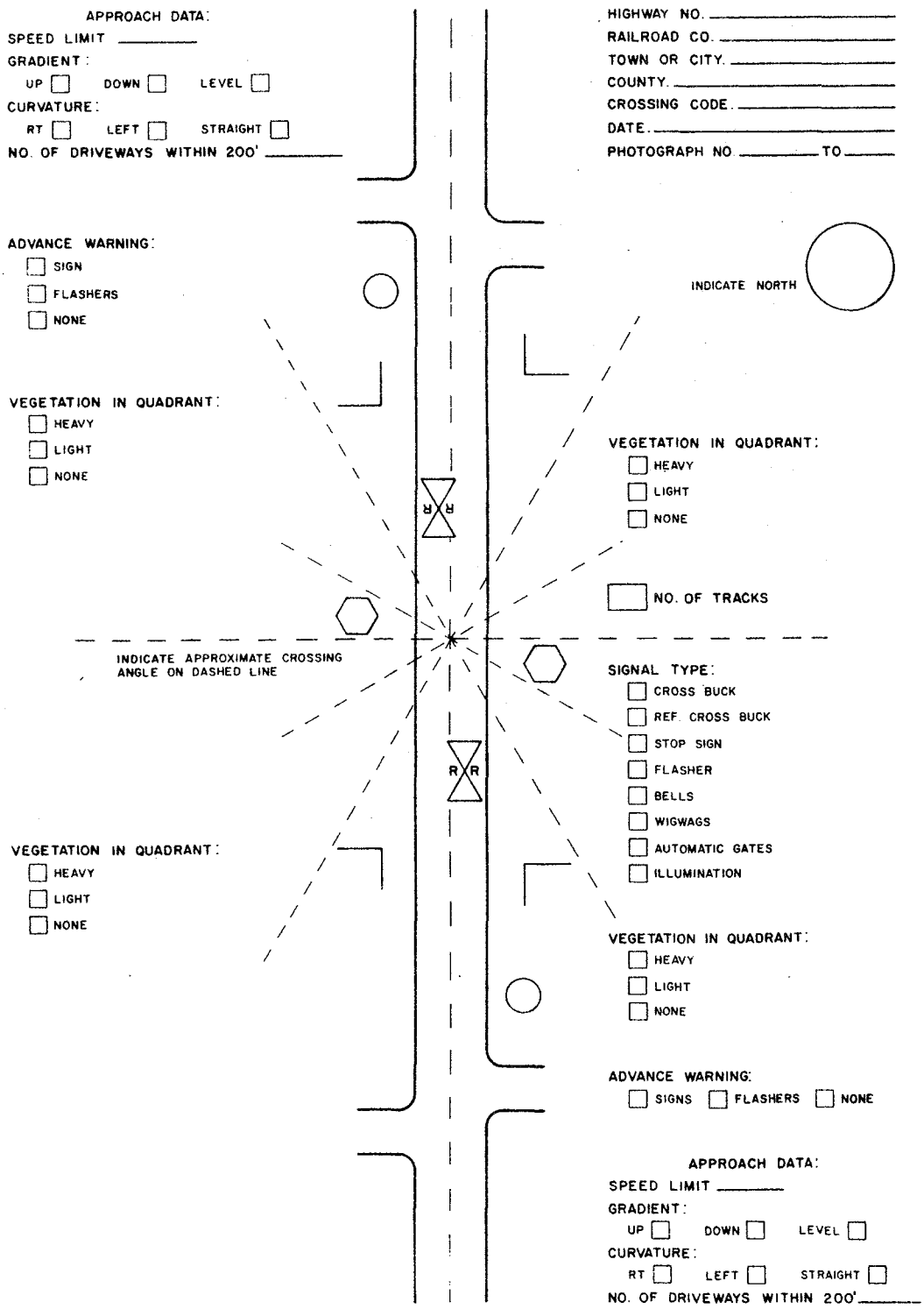
The following data collection procedures were developed for use in the collection of physical data:

1. Grade Crossing Inventory. From the Texas Highway Department inventory of rail-highway grade crossings, compiled jointly by the railroad companies of Texas and the Texas Highway Department, basic information relating to train frequency, speed, etc., was obtained. The highway department and local traffic engineers supplied data relative to vehicle average daily traffic count, distribution by time period and type of vehicles using the crossing.

2. Inventory of Physical Characteristics. Figure 2 is a reproduction of the data form that was designed to record data relating principally to environmental characteristics of the crossing.

FIGURE 2

GRADE CROSSING FACILITY INVENTORY



3. Accident Records. The Texas Railroad Commission rail accident report form, Texas Department of Public Safety accident report, and local police accident reports were the primary sources of information necessary to compile these records. A summary of the reports of all accidents occurring at each rail-highway crossing during the three previous years was available to the diagnostic team.
4. Aerial Photographs. The highway department provided several aerial views of the study crossings. These photographs were available to the diagnostic team during the crossing evaluations.

Diagnostic Study Procedure

The first task of this phase of the study was to determine the manner in which individual member's evaluations of the crossing would be recorded. Previous research at the Texas Transportation Institute employing the diagnostic study technique had revealed that the study questionnaire is a feasible method of collecting these data. The technique of using the critique was considered to acquire each member's observations of the crossing. However, this procedure was rejected because of the relatively large number of participants in the diagnostic study, the lack of adequate methods for noting or recording team member observations, and the lack of facilities near the crossing for conducting the critique.

Recognizing that the diagnostic study questionnaire would require field testing and possible revisions, a draft of the questionnaire was

prepared for initial diagnostic studies. Subsequent revision of the initial questionnaire design produced a data form that has satisfactorily met the objective of its intended design.

Diagnostic Study Questionnaire

As pointed out previously, the purpose of the diagnostic team study is to determine the conditions at rail-highway grade crossings which affect safety. Therefore, the objective of the questionnaire is to provide a record of the individual team member's evaluation of these conditions at each study crossing.

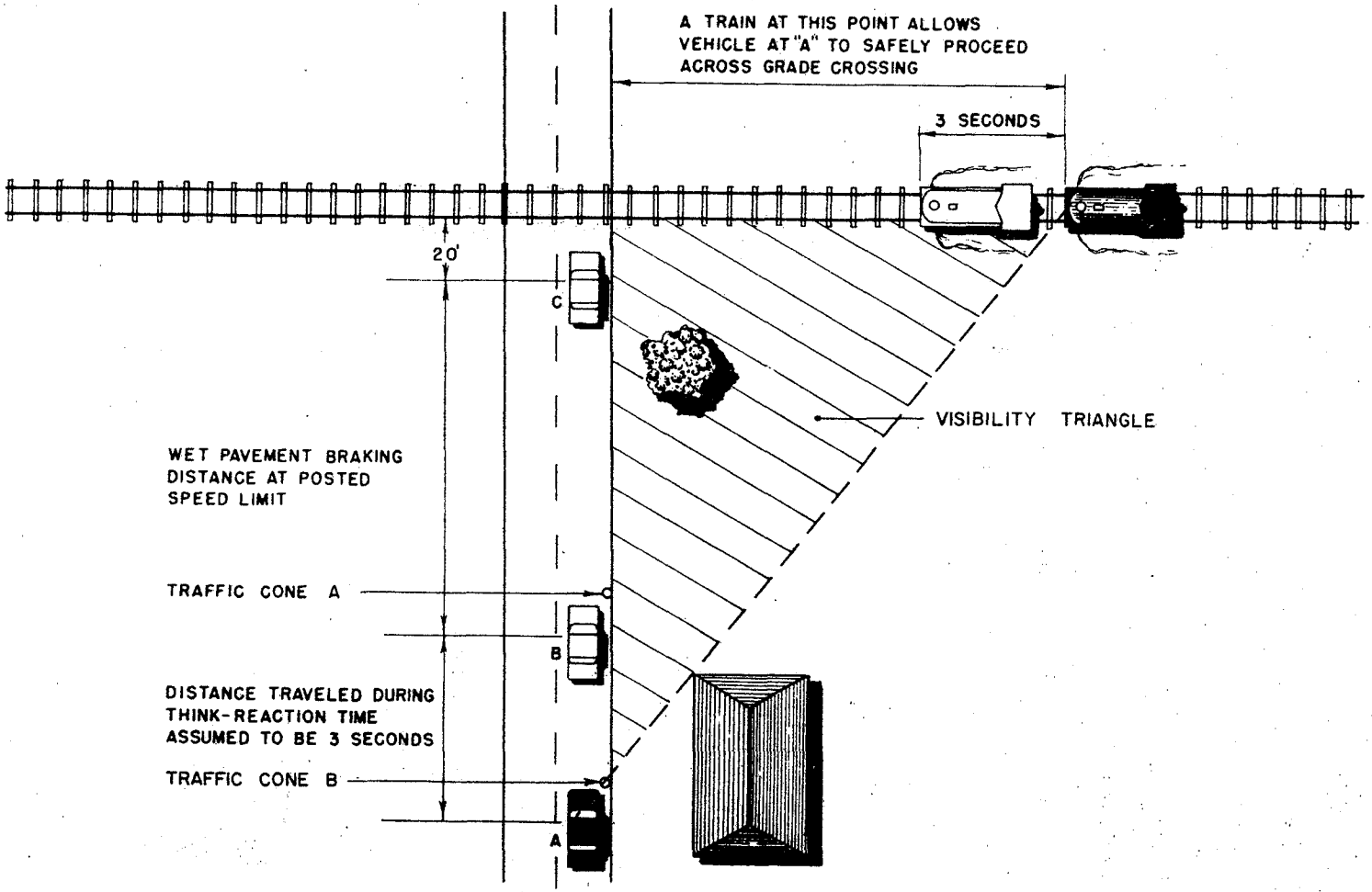
For organizational purposes the questionnaire is divided into three areas. Two sections are to be completed on each roadway approach and one on the crossing in general. Each of the areas which applies to the crossing approaches is further divided into sections in which driver requirements vary. This may be best explained by referring to Figure 3. Traffic cones are placed in the area of the approach as illustrated by the drawing. Cone B is placed at the point where the driver must begin making his decision as to whether or not he may safely proceed over the crossing. Cone A is placed where the driver must begin applying his brakes if he is to stop short of the crossing. Both measurements are based on the maximum legal or practical vehicle speed and stopping distance on wet pavements.

Referring again to the organization of the questionnaire*, each section may be summarized in the following manner:

*Due to the length of the questionnaire developed for the Texas study, it has not been included as a part of this report. Copies of the questionnaire may be obtained from the authors.

FIGURE 3

SIGHT CLEARANCE



Section I. The questions in this section are concerned with whether or not the average driver will be aware of the presence of the crossing. This sense of awareness must be established prior to reaching the first traffic cone so that the driver would be prepared to begin his decision-making process. In order to properly respond to questions in this section, the crossing should be observed in an area of the roadway approaching traffic cone B. Items in this section of the diagnostic study questionnaire are related to:

1. Driver awareness
2. Visibility
3. Effectiveness of advance warning signs and signals
4. Geometric features of the roadway
5. "Repeat driver" regard for the crossing

Section II. The questions in this section are concerned with whether or not the driver has sufficient information to make correct decisions while traversing the crossing. Observations for responding to questions in this section should be made in the area between the two traffic cones. Where protective devices are installed, for questions in this section it is assumed that the devices have been actuated. Factors considered by these questions include the following:

1. Awareness of approaching trains
2. Driver dependence on crossing signals
3. Obstruction to view of train approach
4. Roadway geometrics diverting driver attention
5. Location of standing rail cars or trains

6. Removal of sight obstruction

7. Availability of information for proper stop or go decisions on the part of the driver

Section III. The questions in this category apply to observations in the section of roadway adjacent to the crossing. Traffic using any adjacent streets or driveways should be observed briefly to determine whether traffic not passing over the crossing could affect traffic over the crossing. Questions in this section relate to these considerations:

1. Pavement markings
2. Conditions conducive to vehicle becoming stalled
3. Other traffic control devices contributing to vehicles stopping on the crossing
4. Hazards presented by vehicles required by law to stop at crossing
5. Signs and signals as fixed object hazards
6. Opportunity for evasive action by driver

General Section. In this section the diagnostic team is given the opportunity to do the following:

1. List major features of the crossing which contribute to safety
2. List features which reduce crossing safety
3. Suggest methods for improving safety at the crossing
4. Give an overall evaluation of the crossing
5. Provide comments and suggestions relative to the questionnaire

Implementation of the Study

In order to describe the manner in which the diagnostic study was implemented, a discussion of the chronological order of events leading to the complete evaluation of a study site may be useful.

EVENT A - Briefing. As the diagnostic team assembles at the study crossing, informal introductions of team members, with special emphasis upon individual professional training and job responsibilities, are encouraged. With introductions completed, a member of the project staff briefs the team as to the purpose and objectives of the study. The questionnaire is then distributed to team members. Instructions are given for completing the questionnaire. The first page of the questionnaire has space available for vehicle and train operation data. As this information is made available to the team, appropriate agency representatives are asked to verify and update this data. The next step in the briefing is to summarize accident reports and ask for the personal experiences of local team members who are familiar with circumstances surrounding the reported accidents. Aerial photographs are then reviewed to give team members a better perspective of the total environment of the crossing.

While the briefing is being conducted, a member of the project staff is locating traffic cones on both crossing approaches according to the criteria discussed previously.

EVENT B - Driving the Approaches. Team members are assigned to vehicles for the evaluation process. Normally, two vehicles are required for this event. Representatives of railroad, highway, and

administrative interests are divided equally among the vehicles. Team members then drive each approach several times in order to become familiar with all conditions that exist at or near the crossing. If the crossing is protected by a signal device, the railroad signal engineer is requested to activate these signals so that flashing light alignment, light intensity, awareness of light and audible signal, and traffic operation over the crossing may be observed. When the team members are satisfied with their familiarity with the driver's view of each approach, the signals are turned off and the evaluation is continued.

EVENT C - Completion of the Questionnaire. Positioning the vehicles according to the instruction provided by the questionnaire, individual team members answer questions within specific sections of the questionnaire. As each section is completed, the vehicle is moved to the next required location until all questions have been answered.

EVENT D - Inventory of Physical Characteristics. Concurrent with Event C, a member of the project staff is completing the physical characteristics inventory form shown in Figure 2. When this is accomplished, photographs are taken from specified locations. These data and photographs are for the purpose of reconstructing the crossing at a later date, either with a model or by a drawing.

EVENT E - Critique. After the questionnaires have been completed the team is reassembled for a short critique and discussion period. At this point the questionnaires have been collected; therefore, opinions expressed during this session do not bias individual team member questionnaire responses. The critique begins with a permanent team member's

summarizing his observations as to conditions that exist at the crossing. This generally leads to a discussion by team members of possible ways to improve the safety of the crossing. Other areas are open for discussion during this period, including better means of communication and cooperation among agencies represented by the diagnostic team members.

Results of Study

Based upon conditions observed by the diagnostic teams at each of the study crossings, 60 percent of these crossings were considered fairly safe or safe, while the remaining 40 percent were rated either unsafe or hazardous.

Table 1 lists the unsafe conditions observed and reported by the team in order of their frequency of mention. From this list it may be seen that pavement markings were mentioned in the report of unsafe conditions at 72 percent of the study crossings. Also, 60 percent of the study crossings may exhibit unsafe conditions due to the requirement that certain vehicles must stop at all crossings. Approximately 50 percent of the study crossings were observed as having obstruction of driver visibility due to heavy vegetation growth. Illumination, signing, signalization, and fixed object hazards were mentioned with approximately the same frequency, while roadway geometrics, maintenance of railroad devices, and traffic conditions on adjacent roadways were the least frequently observed unsafe conditions.

Following the listing of unsafe conditions at each study crossing, the diagnostic team was requested to make recommendations for the

TABLE 1

UNSAFE CONDITIONS OBSERVED BY DIAGNOSTIC TEAM
AT STUDY RAIL-HIGHWAY GRADE CROSSINGS

	CONDITIONS OBSERVED	PERCENTAGE OF CROSSINGS AT WHICH CONDITIONS OBSERVED
1.	Pavement markings are missing, improperly located or in need of maintenance	72
2.	Vehicles required by law to stop at all crossings would present a hazard to other vehicles by blocking traffic lanes and obstructing view of protective device	60
3.	Driver's visibility of railroad approach obstructed by growth of vegatation	52
4.	Under nighttime conditions lack of illumination presents additional hazards at grade crossing	44
5.	Traffic conditions and location of traffic control devices cause conflicts for drivers' attention	40
6.	Advanced warning signs missing, improperly located or in need of maintenance	40
7.	Absence of vacant area immediately adjacent to grade crossing or a refuge area for the driver to take evasive action	36
8.	Highway signs and fixed objects obstruct driver's view of protective and warning devices	32
9.	Fixed base protective devices or barriers present fixed object hazard to vehicles	32
10.	Legally parked vehicle would block drivers view of protective and warning devices	28
11.	Geometrics of roadway design contribute to unsafe conditions at the crossing	20
12.	Railroad protective device is not properly located or maintained	12
13.	Traffic conditions on adjacent roadway is conducive to vehicles becoming stalled or stopped on railroad tracks.	8

improvement of these conditions. Table 2 lists specific recommendations made for grade crossings included in this study. For purposes of analysis the recommendations have been grouped into three categories. Listings of the recommendations within each group are made according to their frequency of mention by the diagnostic team.

An analysis of the recommendations indicates that more than 60 percent were directed specifically to the maintenance of signals, signs and pavement markings. Although approximately 50 percent of the study crossings were protected only with crossbuck signs, less than 30 percent of the diagnostic team recommendations were concerned with or involved the installation of actuated, protective and warning devices. Recommendations for widening the existing roadway or for the addition of traffic lanes at the approach to the crossing comprised the remaining 10 percent of the team's suggestions for safety improvement.

Summary

The results of the thirty-six studies suggest that the *diagnostic team* study technique, applied to the evaluation of rail-highway grade crossing safety, contributed to a safety program in the following manner:

1. The diagnostic team approach provides a highly reliable method for identifying, isolating and measuring factors which contribute to unsafe conditions existing at rail-highway grade crossings.
2. The diagnostic team provides a basis for determining not only which crossings should be protected, but, more

TABLE 2

DIAGNOSTIC TEAM RECOMMENDATIONS FOR THE IMPROVEMENT OF SAFETY AT STUDY RAIL-HIGHWAY GRADE CROSSINGS

I. Maintenance and Relocation of Protective Devices, Signs and Pavement Markings.

*1. The addition of vehicle stop lines on approach to crossing
*2. Addition or relocation of advanced warning signs to conform with vehicle approach speed
3. The removal of vegatation to provide adequate sight distance on the approach to the crossing
4. Provision of a safety zone in the area immediately adjacent to the crossing to provide the driver with an opportunity to take evasive action
5. Location of the protective device away from edge of roadway or replacement with break-away design
6. Elimination of parking on all approaches to the crossing to insure driver visibility at the crossing
7. Continual maintenance of protective devices
8. Removal of fixed objects to provide an unobstructed view of the crossing
9. Relocation of traffic sign obstructing view of protective and warning devices

II. Installation of Actuated Protective and Warning Devices

1. Addition or relocation of advanced warning signs to conform with vehicle approach speed
2. Installation of illumination to increase nighttime safety at the crossing
3. Installation of flashing lights at crossings protected only with crossbucks
4. Installation of larger diameter advance warning sign
5. Installation of actuated advance warning sign
6. Installation of cantilever-type actuated signals
7. Interconnection of traffic signal with actuated flashing device
8. Installation of control signs at cross streets intersecting crossing approach

III. Widening of existing Roadway or Addition of Traffic Lanes to Crossing Approach

1. Addition of traffic lanes at the crossing approach for vehicles required by law to stop at all crossings
2. Widening of roadway in area adjacent to the crossing
3. Realignment of roadway approach to crossing

*Proper maintenance of pavement markings on a continuing basis was also included in these recommendations.

importantly, the best type of protection which should be employed in order to achieve acceptable levels of safety among all crossings.

3. The diagnostic study team provides recommendations for improving and upgrading existing protective equipment, for both roadway and railway, with minimum expense to responsible agencies.
4. The diagnostic study team develops recommendations for on-the-spot safety measures, such as the relocation of signals and signs, alignment of flashing lights, replacement of broken or worn signs or signal apparatus, upgrading pavement markings, relocation of public or railroad property, and other measures to reduce accident potential at specific crossings.
5. The diagnostic study team provides an interdisciplinary approach to the solution of a common problem by utilizing technology acquired by each of the professions represented in its membership.
6. The diagnostic study team develops a line of communication between groups and individuals who are responsible for the safe operation of rail-highway grade crossings.

GRADE CROSSING COMMITTEE ACTION

This section of the report summarizes the actions and recommendations of a special committee appointed to support and assist the subject research project. This committee, consisting of twenty members from the Texas Highway Department, Federal Highway Administration, Texas Transportation Institute and the Railroads, was selected from various members of the diagnostic teams that studied thirty-six rail-highway grade crossings during the summer of 1968, in connection with the subject project. The purpose for the appointment of this committee was to discuss matters relating to the project, the various diagnostic studies, and to recommend methods of improving the various elements of grade crossing safety protection.

Committee Discussion

The committee discussed a number of items relating to rail-highway grade crossing safety. These items are summarized as follows:

1. Revised standards for stopping sight distance were presented by a representative of the Texas Highway Department. The committee indicated its desire to have the revised stopping sight distance values used in the placement of advance warning signs for rail-highway grade crossings.
2. A considerable amount of discussion concerned the inadequacy of existing rail-highway grade crossing protection. In general, it was felt that existing signs are

not effective, poorly placed, and not adequately maintained. There was a general consensus of opinion that standard practices and known technology are not being exercised to their fullest extent in the treatment of rail-highway grade crossing protection. It was felt that this problem is influenced greatly by the interjurisdictional problems at rail-highway grade crossings.

3. Rail-highway grade crossing protection methodology has not been changed to compensate for changes in the conditions relating to trains, the crossing and the automobile. Even though we have evolved to air conditioned automobiles well insulated to eliminate road noise, we still depend on bells and whistles for warning the driver. Sight has become the most important factor in detecting a potential vehicle-train conflict. It was recognized that sight of the train cannot always be provided at rail-highway grade crossings and this should be taken into consideration in designing crossing protection.

4. It was pointed out that all grade crossings have the same advance warning treatment regardless of the type of protection provided and conditions relative to this protection. Discussion pointed toward the need for the advance signing to indicate the type of crossing protection and the conditions of visibility that might be expected by the driver prior to his arrival at the crossing.

5. The responsibility for maintenance of crossing protection devices was discussed at considerable length. It seemed to be a general consensus of opinion that the various agencies responsible for grade crossing protection should jointly seek a more logical arrangement for better maintenance procedures.
6. Rumble strips were suggested as advance warning devices. However, the committee was informed that Texas Highway Department Policy discourages the use of rumble strips across traffic lanes.
7. The general conditions and effectiveness of crossbucks at nonprotected rail-highway grade crossings was discussed. The committee was of the opinion that present crossbucks are ineffective and should be designed, placed and maintained to achieve maximum effectiveness.
8. The possible use of illumination at nonprotected crossings was discussed. Spot illumination can be used effectively to indicate the occurrence of a rail-highway grade crossing and the presence of a train on the crossing.
9. It was suggested that a flashing beacon, such as that used on emergency vehicles, be used on the locomotive. This flashing red light demands a considerable amount of respect and there is no question that the locomotive deserves the same respect as an emergency vehicle such as an ambulance or fire truck. It is believed that it would improve the

visibility of trains tremendously. Further, it would not be necessary to operate this beacon continously. It could be operated in urban areas and in advance of the crossings.

Committee Recommendations

Based on the extensive discussion of conditions relating to the design, operation and maintenance of devices, and procedures used in grade crossing protection, a number of recommendations were made by the committee. These recommendations pertain mainly to special treatments to be implemented in the interest of improving certain crossings included in the 36 sites studied in the summer of 1968. It was pointed out that these recommendations definitely would not be in conformance with the Uniform Manual of Traffic Control Devices, and further that additional effectiveness could not be achieved by compliance with the manual. Since these recommendations were to be implemented in a limited experimental nature on projects that are sanctioned for research, no problems were anticipated because of their failure to comply with the established standards. The recommendations of the committee are as follows:

1. All signs and devices pertaining to advance warning and crossing control should be placed on both sides of the approaching roadways so that maximum effectiveness may be achieved. It was pointed out that vehicles following larger vehicles and vehicles in the act of passing were not afforded an appropriate opportunity to view advance signs

and control devices unless they are placed on both sides of the approach.

2. Advance warning signs should be larger and unique in color, color combinations, and shape in order to attract the driver's attention. It was recommended that advance warning signs be a minimum of 42 inches and preferably 48 inches in vertical and horizontal dimensions.
3. Two advance warning signs should be placed on each approach. The first advance warning sign should be located at a distance where the driver could make a comfortable stop before reaching the crossing. This sign should be located at the stopping sight distance, including adequate allowances for perception and reaction time. To explain these signs further, the first advance warning sign should incorporate the familiar railroad crossbuck superimposed over a circular sign. This would achieve a double exposure of uniqueness to railroad grade crossing protection devices.
4. The second advance warning sign should be located at a point comparable to the braking distance at the design speed of the facility. The message included in this sign should inform the driver as to the type of crossing protection device and/or the sight conditions at the crossing. The second advance warning sign should indicate the type of protection at the crossing. For crossings protected

with signals, the sign would indicate a signal head with the red lenses and the general outline of the framework of the signal. For nonprotected crossings, the second advance warning sign should convey a dynamic message such as "look for trains" with arrows pointing in each direction that would be suggestive of the dynamic requirements of the driver to actually look for a train.

5. Where the signal used for crossing protection is not visible to the driver at the first advance warning sign, it is desirable to use a double flashing amber light in conjunction with the advance warning sign and interconnected with the signal so that it would operate only when the signal is activated.
6. In situations where visibility of trains is restricted, it is recommended that a combination of signs be used to warn the driver of the existing conditions. The first and uppermost sign of the "tree" should be a red rectangular sign with white letters indicating danger. The second sign of the combination should be diamond in shape and include the message "limited view of trains." The third sign should be a square sign conveying an advisory speed.
7. A section of rough textured pavement should be placed an appropriate distance in advance of the first sign to alert the driver to facilitate more positive recognition of the sign. This pavement surface should not constitute what

is now being used as a rumble strip, but it should provide sufficient contrast in texture to alert the driver. This rough texture would also be a desirable place to use pavement markings to also signify the railroad grade crossing.

8. The conventional crossbucks used at nonprotected crossings should be made larger, 1' x 6', and constructed of white reflectorized sheeting as a background for black letters. These crossbucks should be well maintained and, further, they should be placed on each side of both approaches to the crossing.

9. Spot illumination should be provided at non-protected rail-highway grade crossings where provision of such illumination is feasible. At crossings where spot illumination is not feasible, some type of delineation device should be used to inform the driver of the presence of a train on a crossing. It was suggested that some unique delineation system be placed on the opposite side of the track so that it would be visible under the train and would indicate motion by the intermittent passage of the train wheels.

In addition to the above, it was recommended by the committee that the impact behavior of railroad crossing protection devices be investigated. Crash tests were conducted in support of this recommendation and are discussed in Appendix B.

Response to Committee Recommendations

In compliance with the request of the rail-highway grade crossing committee, drawings of proposed rail-highway grade crossing sign layouts were furnished to the Texas Highway Department. New signing concepts were designed based on the type of crossing protective device and the sight conditions on the approach to the rail-highway grade crossing. Signing layouts were designed for the following four types of rail-highway grade crossings:

1. Protected crossing with obstructed view (Figure 1A, Appendix A)
2. Protected crossing with unobstructed view (Figure 1A, Appendix A)
3. Nonprotected crossing with obstructed view (Figure 2A, Appendix A)
4. Nonprotected crossing with unobstructed view (Figure 2A, Appendix A)

Proposed signs (with slight modifications after follow-up studies) are also illustrated in Appendix A, Figure 3A and 4A that conform to the committee recommendations.

It was the desire of the rail-highway grade crossing committee that the proposed signs be considered by the Texas Highway Department's Rail-Highway Grade Crossing Diagnostic Team for placement at several grade crossings within the State of Texas. The committee was of the opinion that the proposed grade crossing signs could be installed and evaluated at one or more rail-highway grade crossings.

Technical memoranda, presenting the findings and recommendations for each of the crossings were prepared and submitted to the Texas

Highway Department. These memoranda were forwarded to applicable district offices for consideration, along with information pertaining to the proposed new approach warning signs. Several districts were asked to consider updating the crossings to current standards and/or installing the proposed new signs for an evaluation of their effectiveness. As a result of this action, nine sites were selected for follow-up studies.

FOLLOW-UP STUDIES

Follow-up or "after" studies were planned to evaluate the effectiveness of the new sign design and installation criteria recommended by the special advisory committee. Of nine study sites selected, eight were to receive the new approach warning signs, while one was to be brought up to current standards. Four of the crossings to receive the new signs were from the original thirty-six crossings studied, while four were not from the original thirty-six.

Studies numbered 1A to 4A were conducted at the four study sites not in the original thirty-six crossings. Studies 5A, 6A, 8A, and 9A, were restudies at previously studied locations, modified by the addition of the proposed signs. Study 7A was a restudy of a previously studied site modified by updating to current standards. Table 3 presents a description of the follow-up study sites. Table 4 presents a summary of the advance warning and protection devices at each crossing. Figure 4 shows several photographs of typical installations.

Results

The questionnaire from the follow-up studies were analyzed to determine those factors contributing most to safe and unsafe conditions at the study sites. Table 5 is a summary of these factors with each assigned a ranking of importance for the various study crossings. It

TABLE 3

DESCRIPTION OF STUDY SITES FOR FOLLOW-UP STUDIES

Site No.	Location		Railroad	No. Trains Per Day	Train Speed (mph)	Highway ADT	Highway Speed Limit (mph)	Restricted Sight Distance	Protected Crossing	Restricted Crossing Speed (mph)
	City	Highway								
1A	Corsicana	US 287	Fort Worth and Denver, Burlington & Rock Island.	8	59	1470	70	NA	Yes	
2A	Shiro	SH 30	Burlington and Rock Island	7	50	1260	35	NA	Yes	
3A	Benchley	OSR	Southern Pacific	6	50	380	60(North) 30(South)	Yes	No	15
4A	Clay	FM 50	Atchison-Topeka and Santa Fe	6	40	430	70	Yes	No	40
5A	Wichita Falls	FM 2650	Forth Worth & Denver	3	35	380	60	No	No	
6A	Seymour	US 183-283	Forth Worth & Denver	3	35	570	50(North) 60(South)	NA	Yes	
7A	Crockett	FM 2110	Missouri-Pacific	8	40	608	35	No	No	
8A	Trinity	SH 94	Missouri-Pacific	7	45	1220	30	NA	Yes	
9A	Dayton	FM 1960	Missouri-Pacific	8	79	2000	70	No	Yes	

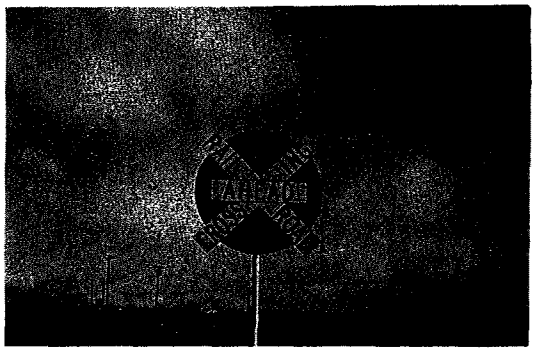
TABLE 4

SUMMARY OF ADVANCED WARNING AND CROSSING PROTECTION DEVICES AT THE NINE FOLLOW-UP STUDY SITES

Device Present	Site No. 1A	2A	3A	4A	5A	6A	7A	8A	9A
Actuated Crossing Signal	Yes	Yes				Yes		Yes	Yes
Actuated Advance Warning Sign (New)									Yes
Advance Warning Sign (New)	Yes	Yes	Yes	Yes	Yes	Yes			
Advance Pavement Marking (Standard)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Final Warning Sign (New)	Yes	Yes	Yes	Yes	Yes	Yes			Yes
Advance Warning Sign (Standard)							Yes	Yes	
Stop Lines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

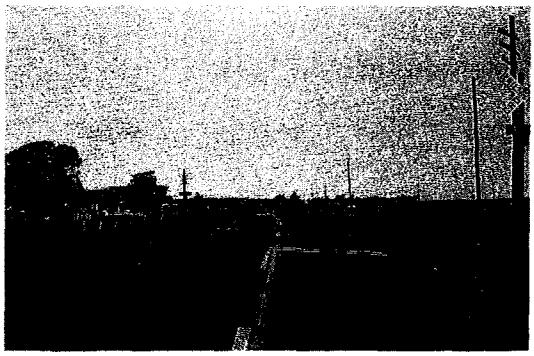
SITE 3A

SITE 3A



SITE 6A

SITE 5A



SITE 7A

SITE 7A

FIGURE 4
SIGNS USED AT SOME OF THE FOLLOW-UP STUDY SITES

TABLE 5

RANKING OF FACTORS*
CONTRIBUTING MOST TO SAFE AND UNSAFE CONDITIONS
AT THE NINE FOLLOW-UP STUDY SITES

Factors Contributing Most to Safe Conditions	Site No. 1A	2A	3A	4A	5A	6A	7A	8A	9A
Advance Warning Signs	1	2	1	1	1	2	2	2	2
Actuated Crossing Signals	2	1				1		1	1
Adequate Visibility Distance	3			3	3	4	4	3	4
Pavement Markings	4	5	3	2	2	3	5		
No Passing Stripes	5	8							
Satisfactory Speed Zoning		3	2				3	4	
Geometry		4			4		1		3
Train Speed & Volume		6			5				
Vehicle Volume		7	4						

*Ranking based on 1 being most important or highest ranking factor

TABLE 5 (CONTINUED)

RANKING OF FACTORS*
CONTRIBUTING MOST TO SAFE AND UNSAFE CONDITIONS
AT THE NINE FOLLOW-UP STUDY SITES

Factors Contributing Most to Unsafe Conditions	Site No. 1A	2A	3A	4A	5A	6A	7A	8A	9A
Inadequate Visibility Distance	1	1	1	1	2	2	2	2	
Geometry	2	3	2	6		1	1	3	2
Unsatisfactory Speed Zoning	3	5		2	4	3			3
Unsatisfactory Signs & Markings	4						3	1	
Local Traffic Characteristics		2							
Fixed Object Hazard		4			5	4		4	1
Lack of Fixed Illumination			3	5					
Train Speed & Volume				3	3				
Lack of Actuated Crossing Signals				4	1		4		

is interesting to note that the new advance warning signs were regarded very highly as a factor contributing most to safety and inadequate visibility distance as a factor contributing most to unsafe conditions. Other factors frequently mentioned as safety factors were actuated crossing signals, adequate visibility distance, pavement markings, speed zoning, and geometry. Other factors frequently mentioned as unsafe factors were geometry, unsatisfactory speed zoning, and fixed object hazards associated with the crossing protection devices.

The questionnaires were also analyzed to determine the effectiveness of the advance warning signs for all sites (1A to 9A), and a summary of this analysis is presented in Table 6. It should be noted that the study team felt that the conventional system of advance warning signs was ineffective, while the new advance warning signs were generally felt to be very effective, but could be improved further with modifications in sign layout. It was the general consensus of the study teams that much greater effectiveness could be achieved using a contrasting border on all signs, to give them greater contrast with the visual background. Also, it was felt that the initial warning sign should be placed on a square or rectangular black background to increase its contrast and target value. In addition, it was suggested that the "AHEAD" portion of the initial warning sign should be taken out of the center of the crossbuck and placed across the bottom of the sign as shown in Figure 3A, Appendix A.

It is significant to note that Site 9A, FM 1960 and Missouri-Pacific, located between Dayton and Huffman was rated at maximum effectiveness by the study team. A schematic diagram of the site is shown in Figure 5. Photographs of the site are shown in Figure 6. The letter designations for signs used in the treatment are referenced to Appendix A. The main characteristic of the crossing treatment that contributed to this maximum effectiveness rating was obviously the use of amber flashing signals used in conjunction with the advance warning signs. These flashers were interconnected with the signals to flash when the crossing signals were activated. Along with good sign placement and the absence of clutter along the roadway, the flashers did an outstanding job of attracting the driver's attention to the approach warning system.

The flashers were installed at Site 9A mainly because geometric conditions reduced the visibility distance of the crossing signals. Also, the site was located in a high-speed rural area where maximum advance warning is a genuine asset.

In summary, the proposed advance warning signs provided much greater protection than current standards, and the treatment at Site 9A was judged by the team as an achievement of optimum effectiveness in rail-highway grade crossing protection.

TABLE 6

EFFECTIVENESS OF ADVANCE WARNING SIGNS
AT THE NINE FOLLOW-UP STUDY SITES

Site No.	Effectiveness
1A	Effective but could be improved further
2A	Effective but could be improved further
3A	Effective but could be improved further
4A	Effective but could be improved further
5A	Effective but could be improved further
6A	Effective but could be improved further
7A	Ineffective. In line of sight only
8A	Effective but could be improved further
9A	Maximum effectiveness achieved

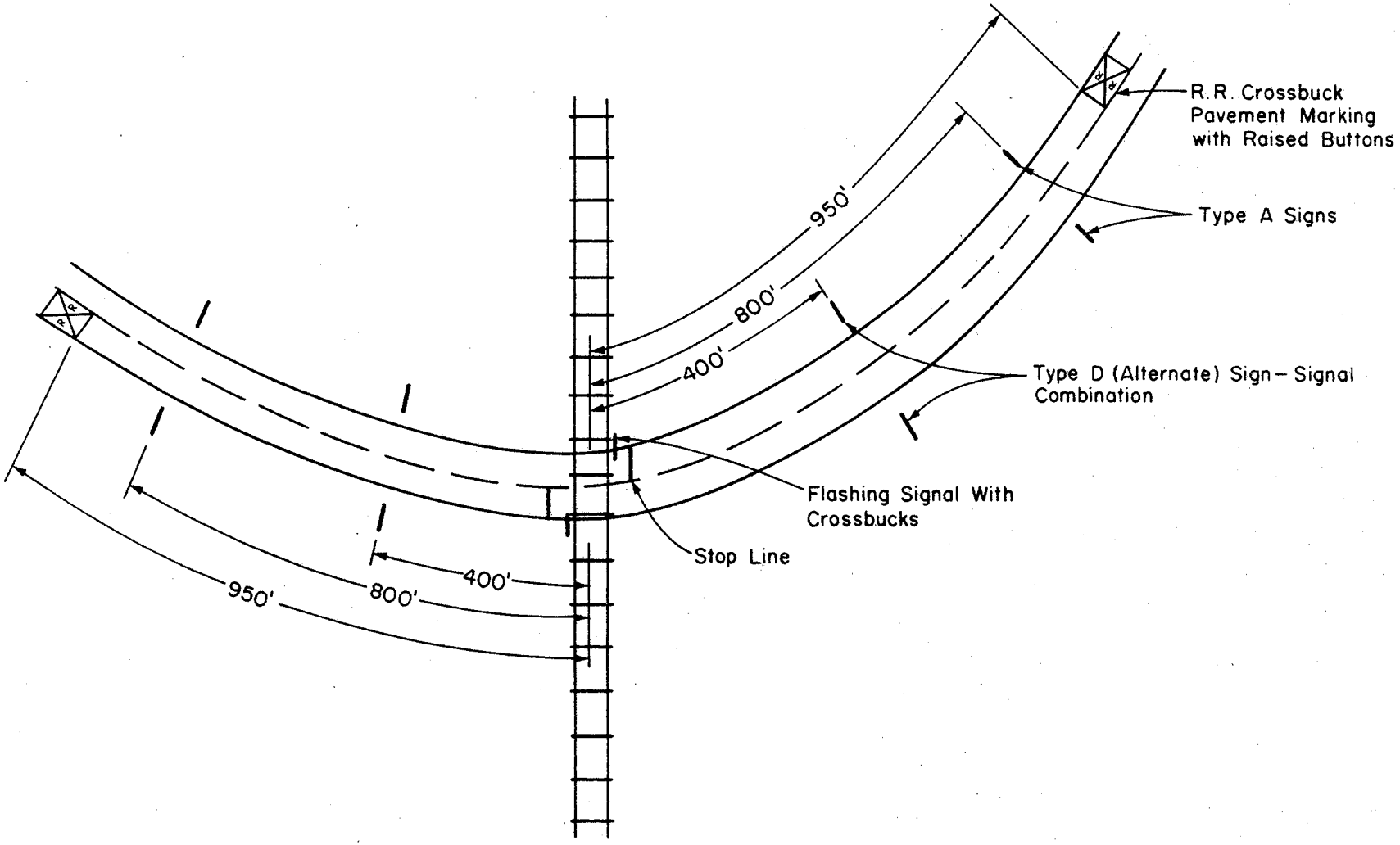
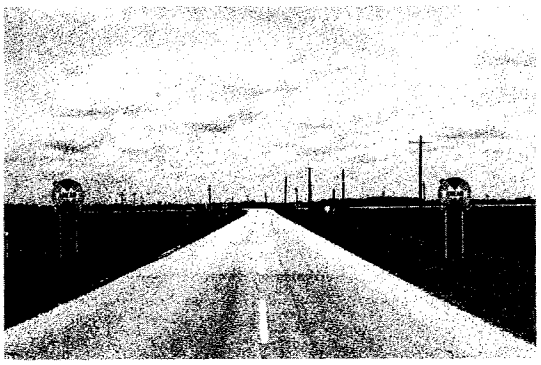
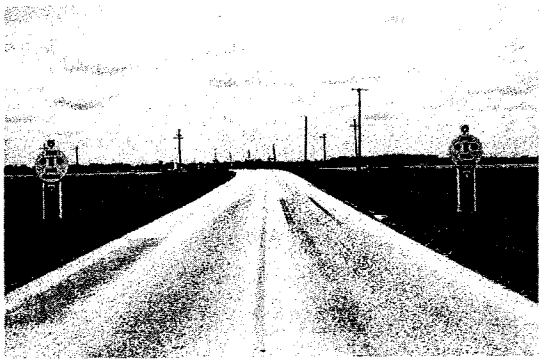


FIGURE 5
SCHEMATIC LAYOUT
STUDY SITE 9A
FM 1960 - MISSOURI PACIFIC
DAYTON

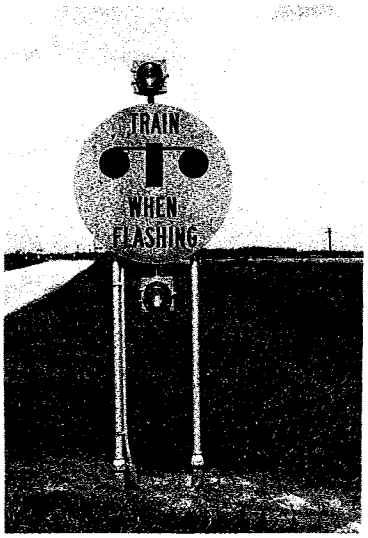


INITIAL VIEW OF ADVANCE WARNING SIGNS



SECOND VIEW OF ADVANCE WARNING SIGNS

VIEW OF CROSSING



CLOSE-UP OF SECOND ADVANCE WARNING SIGN

STUDY SITE 9A
FIGURE 6

IMPLEMENTATION

Introduction

This section of the report is prepared to serve as a guide for the engineer with the responsibility for rail highway grade crossing protection. It is not intended to replace existing standards for crossing control; rather it is intended to supplement these standards by providing direction to the analysis of crossing conditions and requirements. Further, recommendations are made for improvements to grade crossings in areas not normally covered by standards.

The Rail Highway Grade Crossing Problem

Fundamentally, the rail highway grade crossing is a simple intersection of two traffic streams. The characteristic that one stream is automobiles and the other is trains is the first complicating factor. While there may be several thousand vehicles using the highway, ten to twelve trains per day is a rather high volume for most crossings. Thus, the major problem with rail highway grade crossings stems from the fact that because of the infrequent encounter of many drivers with trains at a particular crossing, the driver grows to expect the absence rather than the presence of trains. For this reason, the approach warning system and the crossing protection system must change the driver's expectancy and alert him to actions that may be required of him to assure a safe crossing.

Car-Train Relationship. The fact that the automobile is easily maneuverable whereas maneuvers made by the train must be planned and

deliberate, places the automobile always in the position of yielding to the train traffic. Drivers normally do not question this responsibility placed on them. On the other hand, they develop dangerous expectancy patterns because they seldom encounter a train at a rail highway grade crossing.

Needs of the Driver. Recognizing that the negative expectancy pattern exists, the driver needs very positive advance warning on the approach to a crossing. Since we must change his expectancy, it is necessary to institute redundancy in approach warning. Unique signs should be placed on both sides of the road, and it is desirable that these be supplemented with pavement markings. When the driver has reached a certain point in his approach to the crossing, he should be given specific information concerning his responsibility at the crossing. If it is an unprotected crossing and the burden is placed on the driver for the detection of an approaching train, he should be told. If there is limited sight distance and the safe approach speed is less than the normal highway speed, he should be informed accordingly. Further, if the crossing is protected by gates or signals, the driver should be advised so that he can develop his expectancies accordingly.

Quite frequently, geometric conditions of the highway or the abutting property influence the traffic operation at the crossing. These conditions should be considered very carefully and the driver advised accordingly. For example, horizontal and vertical alignment of the highway often restricts the view of the crossing itself from the point where the driver must make a decision regarding the safety

of the crossing. Also, physical features on abutting property may restrict the view of trains on unprotected crossings. All of these factors should be taken into consideration in the design of the approach warning system.

The subsequent sections of this phase of the report deal with an engineering study to summarize the traffic operational characteristics of the crossing and an environmental study to ascertain the conditions of the environment that may influence the requirements of the approach warning system and the crossing control. Further, recommendations will be made for the design of the approach warning and the crossing protection system, and methods suggested for checking the sufficiency of the design.

Engineering Study

The Engineering Study should consist of a survey of the physical features of the crossing, its approaches and its general environment, a study of accident history and analysis of accident potential.

A. Study of Physical Features

1. Roadway Conditions

a. Obtain design plans of roadway if available.

b. Up-date plan from field observations, make note of all driveways, intersections and other geometric conditions that may exist.

c. Make photographs or color slides at selected intervals along each approach, toward the crossing and along the track approaches.

d. Check pavement surface condition.

e. Check availability of escape routes for vehicles to avoid a collision with a train on the crossing.

2. Track and Train Conditions

a. Determine the number of main tracks, sidings and other auxiliary trackage.

b. Obtain data on train frequency and train speed.

c. Determine geometry of track approaches that may have an influence on visibility of an approaching train.

3. Traffic Conditions

a. Obtain traffic volume data for both approaches.

b. Obtain traffic speed data similar to that obtained for speed zoning. Where there is a condition of natural deceleration in the traffic stream, speed measurements should be made in the approach zone where the driver should be first looking for a train on the track approaches. The speed data should be analyzed to determine the 85-percentile speed for later sight distance computations.

c. Determine turning movements near the crossing, and particularly within the approach warning system

d. Determine percentage of truck traffic required by law to stop at crossings. This information will be helpful in making a decision as to whether added lanes should be provided.

4. Crossing Control

   a. Observe the sufficiency of crossing protection systems while a train is occupying the crossing. Notation should be made of the general appearance, alignment, maintenance and repair for communication with the railroad company.

   b. A check should be made for fixed object hazards placed unduly close to the traffic lanes, such as pipes or rail sections placed in the ground to protect the signal standard.

   c. Location and sufficiency of stoplines should be checked.

5. Approach Warning System

   a. The sign location and message content should be recorded for all signs on both approach roadways.

   b. Advance warning pavement markings should be checked for condition and location.

6. Sight Distance Evaluation

   a. Train speed and the 85-percentile speed of traffic on each approach should be used to establish a sight triangle that will provide stopping distance on wet pavements for vehicles on each approach.

   b. If the sight distance is not sufficient, action to eliminate the problem, or a determination of the safe approach speed should be made.

c. Determine the maximum distance on each approach that a driver will be able to see the crossing and/or the control devices under day and night conditions.

B. Accident History

1. City and State Agency Reports. Accident reports should be obtained from the appropriate records file for at least the last three years.

2. Railroad Accident Reports. Accident reports should be obtained from the appropriate railroad agency files.

3. All accident data should be analyzed to determine if possible causative factors can be isolated for consideration in the approach warning and control treatment.

Environmental Study*

A. Driver Expectancy

1. Level of Expectancy. This section is intended to determine if the driver is conditioned to expect a potential vehicular conflict in the approach to the crossing.

a. Check to determine if the driver has been traveling in rural, suburban, or urban conditions prior to the crossing approach.

---

*This environmental study is considered to be the minimum requirements for evaluation of the environmental conditions. A more detailed evaluation can be achieved using a diagnostic team approach as described in a previous section of this report.

b. Determine the number and locations of intersections or other potential conflict areas on each of the approaches to the crossing.

B. Competition for Driver Attention

1. Determine if geometric conditions on the approaches to the crossing are such that they demand the attention of the driver during the period in which he must be making a decision regarding the crossing.
2. Observe entering traffic conditions at or near the crossing and determine if it has a significant effect on driver attention to the crossing.
3. Determine intersection activity and controls for their effects on driver attention to the crossing.

C. Other Environmental Effects

1. All formal information systems including signs, markings, delineations and other appurtenances should be checked as to their possible effect on crossing safety.
2. Other informational systems including advertising signs, and lighting should be observed with special emphasis on their effects on driver awareness of the crossing.
3. Activity of abutting development near the crossing and crossing approaches should be observed and conditions listed that could affect driver performance at the crossing.

4. All other traffic activity, geometric conditions, natural conditions (such as late evening sun), and environmental development should be surveyed.

Design of Crossing Warning and Protection System

A. Initial Warning

1. Driver Attention. From the engineering and environmental studies, determine the initial warning necessary to demand the driver's attention. Initial warning can include advance warning messages, pavement markings, raised pavement markings for auditory and tactile stimulation and advance flashers.

2. Crossing Location. The initial warning system design should assist the driver in locating the actual crossing. Determination can be made from the engineering and environmental studies of the steps necessary to advise the driver of the crossing location. In some cases, geometric and environmental conditions may be such as to prevent actual visual location of the crossing by the driver. In such cases, the driver should be so advised by the initial warning.

3. Operating Conditions. A determination should be made from the engineering and environmental studies of the operating conditions the driver should expect. If modifications in operating conditions, such as speed change, must be made by

the driver, the initial warning should advise the driver of the changes required.

B. Final Warning

1. Decision Information. The final warning of the grade crossing should provide the driver with all the information necessary to make a stop or go decision. The engineering and environmental studies will provide the necessary input for determining what information must be provided for the stop or go decision. For example, if geometric, visibility, traffic or environmental conditions are such at a crossing that the driver cannot be made aware of an approaching train, the final warning system should advise the driver of this situation.

2. Final Action. The final warning system should be designed to advise the driver of the conditions prevailing at the crossing.

C. Crossing Control (In Cooperation with RR Co.)

1. Location of Controls. The determination of crossing control necessary for safe operation at the grade crossing can be made from the data collected in the engineering and environmental studies. Once the determination is made, careful consideration should then be given to establishing the location of the controls that will provide maximum attention qualities and minimum impact hazard potential.

2. Adjustment of Controls. The crossing control design should carefully specify the adjustment of the control faces to provide maximum attention and visibility conditions.

D. Design Check

1. Designer Analysis. The designer of the crossing warning and protection system should carefully evaluate the design from the driver's viewpoint, using slides and drawings. Adjustments should be made if necessary to provide maximum driver expectancy and information.

2. Team Analysis. As a final check of the design, the designer should select a group of people (not other designers) to review the design. This team should confirm that the design means to them what the designer intended it to mean. Adjustments should be made if necessary to provide this confirmation. Slides of warning devices and controls to be used in the design and slides of the crossing and its approaches can be very effective in this task.

APPENDIX A

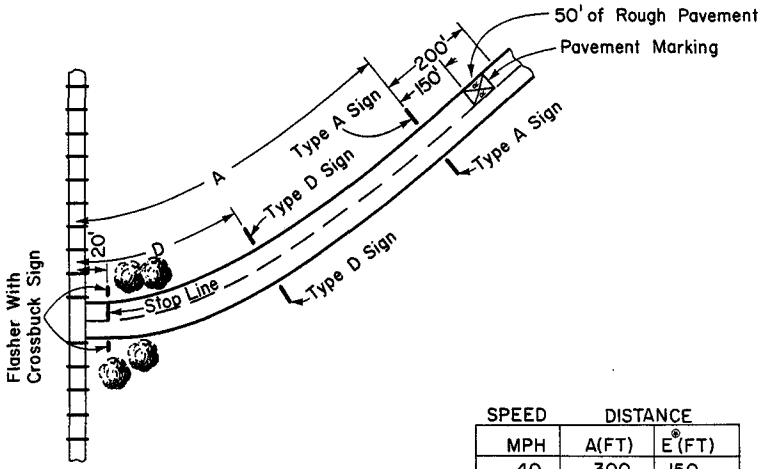
APPENDIX A

This appendix contains the proposed standards for application and new sign designs for rail-highway grade crossing protection, which were developed in committee action and based on the results of diagnostic studies of existing rail-highway grade crossings.

Threre are four proposed standards for application, as shown in Figure 1A, which are applicable for the following control and visibility conditions.

1. Protected crossings with obstructed view
2. Protected crossings with unobstructed view
3. Non-protected crossings with obstructed view
4. Non-protected crossing with unobstructed view

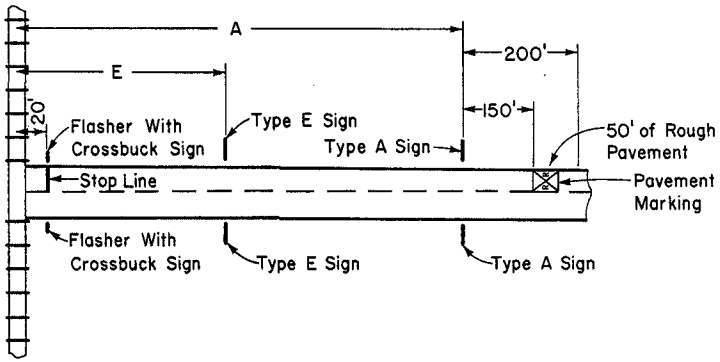
There are eight proposed new sign designs which are illustrated in Figure 2A. These signs are applied as indicated in the standards of application (Figure 1A).



PROTECTED CROSSING
OBSTRUCTED VIEW

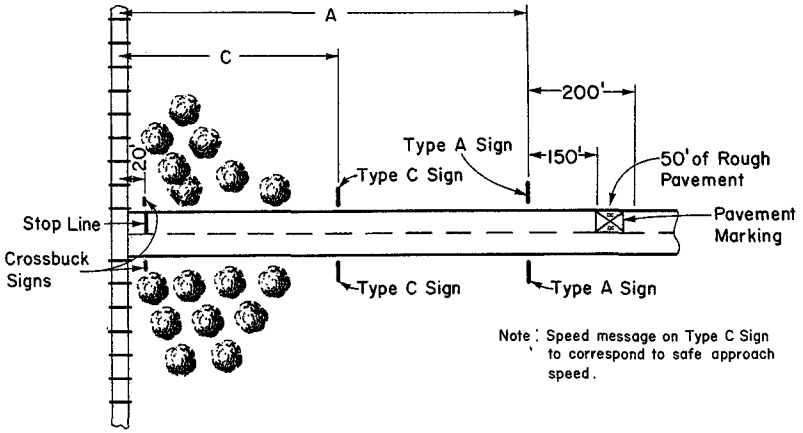
SPEED	DISTANCE	
MPH	A(FT)	E®(FT)
40	300	150
50	450	225
60	600	300
70	800	400
80	950	525

®Based on braking distance from AASHO Geometric Design of Rural Highways.



PROTECTED CROSSING
UNOBSTRUCTED VIEW

FIGURE IA (1)
STANDARDS FOR APPLICATION
ADVANCE WARNING SIGNS FOR
PROTECTED CROSSINGS

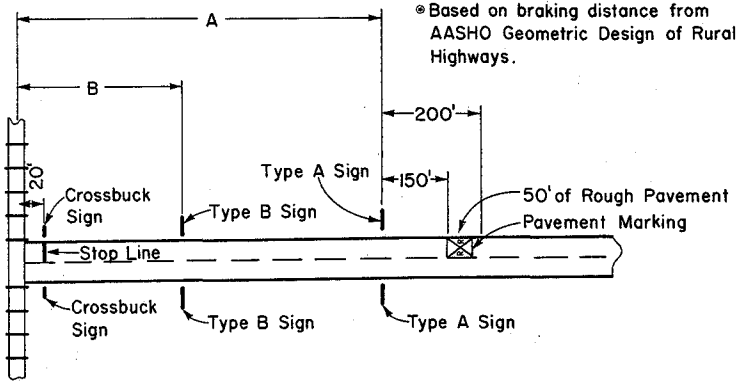


Note: Speed message on Type C Sign to correspond to safe approach speed.

NON-PROTECTED CROSSING
OBSTRUCTED VIEW

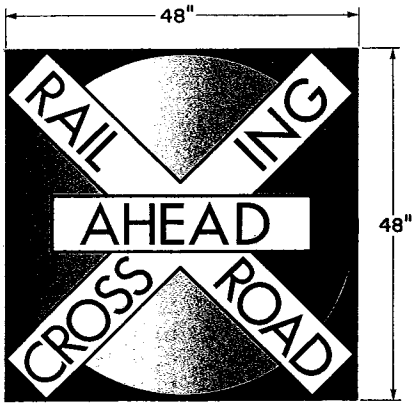
SPEED	DISTANCE	
MPH	A (FT)	B®(FT)
40	300	150
50	450	225
60	600	300
70	800	400
80	950	525

®Based on braking distance from AASHO Geometric Design of Rural Highways.



NON-PROTECTED CROSSING
UNOBSTRUCTED VIEW

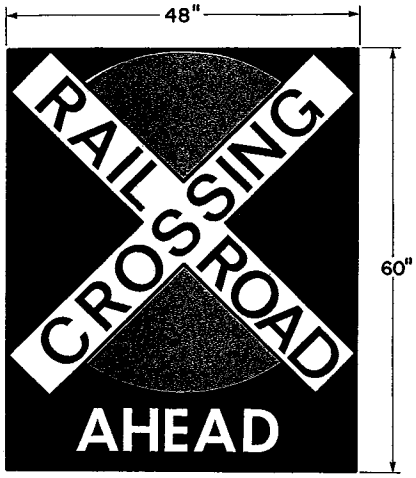
FIGURE IA (2)
STANDARDS FOR APPLICATION
ADVANCE WARNING SIGNS FOR
NON-PROTECTED CROSSINGS



CROSSBUCK 8"x 60" 6"SERIES 'C' LETTERS

(1)

TYPE A SIGN



CROSSBUCK 8"x 60" 6" SERIES 'D' LETTERS

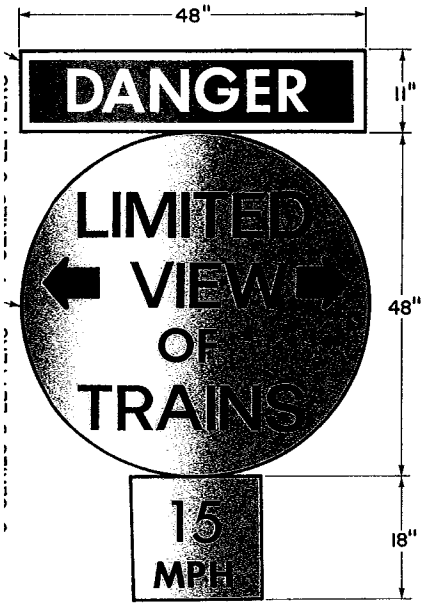
(2)

TYPE A (ALTERNATE) SIGN

7" SERIES 'C' LETTERS

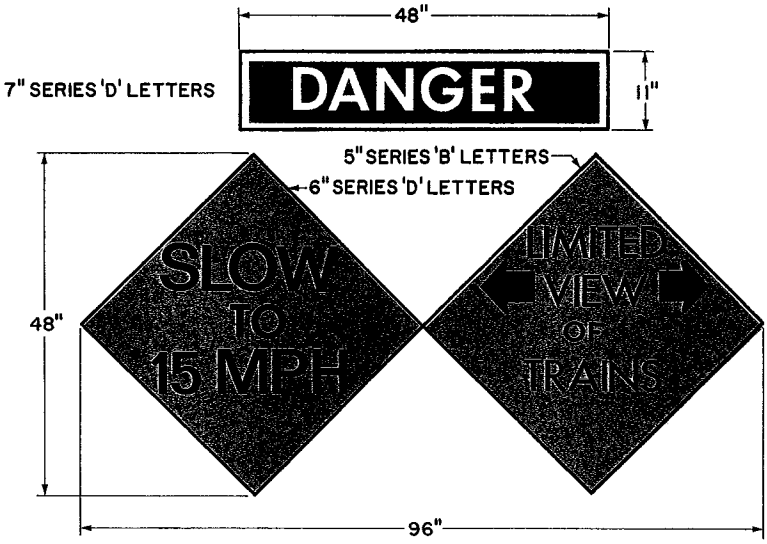
(3)

TYPE B SIGN



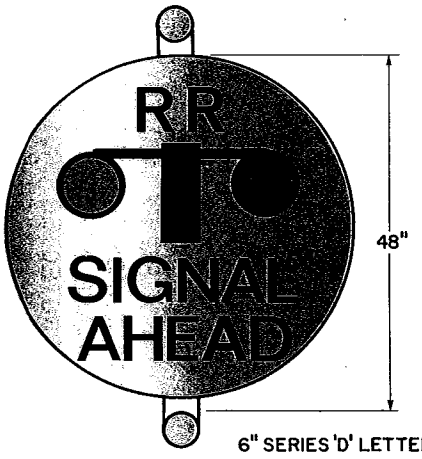
(4)

TYPE C SIGN



(5)

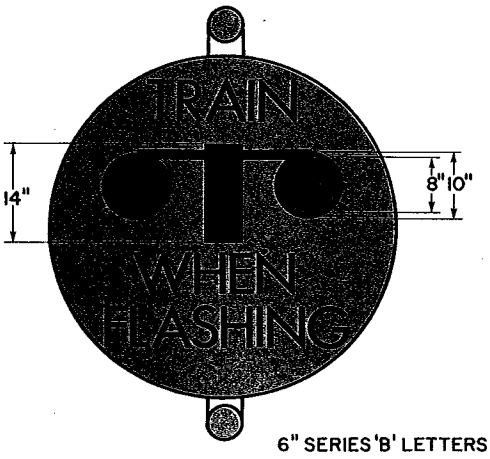
TYPE C (ALTERNATE) SIGN



6" SERIES 'D' LETTERS

(6)

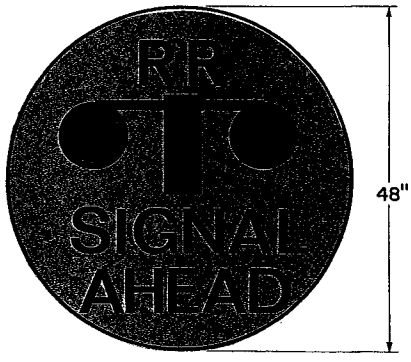
TYPE D SIGN



6" SERIES 'B' LETTERS

(7)

TYPE D (ALTERNATE) SIGN



6" SERIES 'D' LETTERS

(8)

TYPE E SIGN

FIG. 2A

PROPOSED NEW ADVANCE WARNING SIGNS

FIGURE 2A (SUPPLEMENT)

PROPOSED NEW ADVANCE WARNING SIGNS DESCRIBED
FOR APPLICATION, SEE FIGURE 1A

Type A Sign - The first of the series of advance warning signs to be used in the approaches to all protected and unprotected crossings. The sign is designed to have a unique color combination with the familiar round disc and the white crossbuck (Figure 2A(1) and 2A(2)).

Type B Sign - The second of the series of advance warning signs, to be used on non-protected crossings with unobstructed views. The sign features a dynamic message to the driver on the familiar yellow disc (Figure 2A(3)).

Type C Sign - The second of the series of advance warning signs, to be used on non-protected crossings with obstructed views. The sign incorporates a dynamic message related to the existing conditions (Figure 2A(4)). An alternate combination is provided in Figure 2A(5).

Type D Sign - The second of the series of advance warning signs, to be used on protected crossings with obstructed views. The sign features a symbolic as well as word message, and flashing amber signals interconnected with the crossing signals (Figure 2A(6). An alternate with different word message is provided in Figure 2A(7).

Type E Sign - The second of the series of advance warning signs, to be used on protected crossings with unobstructed views. It is similar to Type D but does not include flashing signals.

APPENDIX B

IMPACT BEHAVIOR OF FOUR RAILROAD GRADE CROSSING SIGNAL SUPPORTS

The successful development of the breakaway sign support introduced a whole new concept in the design of highway service structures. The breakaway concepts were applied to luminaire supports and as a result the design standards have been revised nationally. Similarly, preliminary exploratory efforts have been made in regard to the impact behavior of railroad grade crossing signal supports.

In practically every exploratory effort, the first concern is in regard to the impact behavior of the particular design now in use. For example, some of the first full-scale crash tests were on fixed base sign supports and flange mounted luminaire supports. From these, the various breakaway safety features evolved.

In planning the studies of rail highway crossing signal supports, it was found that four basic types of signal supports were currently being used. These could further be categorized into two basic groups: 1) Those that consist of a single post mounted next to the edge of the roadway and 2) The cantilever type support that can be placed a greater distance from the edge of the roadway and still provide multiple signal displays including one placed immediately over the roadway. Within these two categories there are variations in the materials used for different designs. Two in each category were selected to represent the general population of signal supports. These are described as follows:

Single Supports

1. A four inch aluminum post with a cast aluminum two piece flange-type base.
2. A four inch steel post with a two piece cast iron flange-type base.

Cantilever Supports

3. An aluminum shaft and mast arm with a cast aluminum base similar to that used under luminaire supports.
4. A steel shaft and mast arm with a steel flange-type base.

As a part of the project "Rail Highway Grade Crossing Safety Evaluation", four full scale crash tests were conducted to determine the relative impact behavior of each of the four designs described above.

Test Procedure

The procedures used in conducting crash tests of the railroad signal supports were conventional methods used in earlier testing of sign supports and luminaire supports. The test vehicle was towed into the collision and crash data were collected using Photographic and electronic instrumentation.

Results

The results of the four crash tests are summarized in Tables 1-4. Illustration of differences in impact behavior of Tests 3 and 4 are shown in Figures 1-9.

From the results of the impact tests the following conclusions are drawn:

1. Average deceleration is less severe for the single pipe and cantilever structure when equipped with frangible bases (1.6 g's vs. 2.7 g's and 2.0 g's vs. 6.4 g's.)
2. Maximum deceleration is less for the cantilever structure mounted on a frangible base (5.2 g's vs. 16.9 g's.)
3. Maximum seatbelt force is less for the cantilever structure mounted on a frangible base (100 lbs. vs. 1000 lbs.)
4. Change in velocity is less for the single pipe and cantilever structure when equipped with frangible bases (8 ft/sec vs. 11 ft/sec and 11 ft/sec vs. 32 ft/sec)
5. Vehicle damage is less for the frangible base combinations (8 inches vs. 13 inches and 15 inches vs. 36 inches)

TABLE 1

SUMMARY OF TEST 111-1

Signal Installation	All aluminum construction with a frangible base on concrete foundation.
Vehicle	1961 Ford 4-Door Sedan, weight 3800 lbs.
Vehicle Velocity	Nominally 44 mph
Maximum Seatbelt Force	Not Available
Maximum Deceleration	Not Available
Average Deceleration During Contact Period	1.6 g's
Change in Velocity	8 ft/sec
Signal Reaction	The concrete base of the signal installation was destroyed upon impact and the signal pole fell backward. The signal portion of the device struck the roof of the vehicle and the upper end of it struck the trunk. The vehicle damage was not extensive and deceleration levels were low.
Vehicle Damage	Front bumper and bumper arms, grill and hood. The total deformation of the vehicle was 8 inches.

TABLE 2

SUMMARY OF TEST 111-2

Signal Installation	Standard steel pipe railroad crossing signal installation with no break-away base on concrete foundation.
Vehicle	1962 Ford 4-Door Sedan, weight 3800 lbs.
Vehicle Velocity	Nominally 45 mph
Maximum Seatbelt Force	Not Available
Maximum Deceleration	Not Available
Average Deceleration During Contact Period	2.7 g's
Change in Velocity	11 ft/sec
Signal Reaction	The concrete base was destroyed on impact and the signal pole began to fall backward onto the vehicle. The signal light housing made contact with the roof of the vehicle. As the car was moving away from the installation, the upper end of the pole struck the trunk.
Vehicle Damage	Front bumper and bumper arms, grill and hood, radiator and fan. Total deformation of the vehicle was 1 ft. 1 inch.

TABLE 3

SUMMARY OF TEST 111-3

Signal Installation	All aluminum construction with a frangible aluminum base (Figure 1.)
Vehicle	1960 Ford 4-Door Sedan, weight 3770 lbs., color white. (Figure 2.)
Vehicle Velocity	Nominally 45 mph
Maximum Seatbelt Force	100 lbs.
Maximum Deceleration	5.2 g's
Average Deceleration During Contact Period	2.0 g's
Change in Velocity (Accelerometer Data)	11 ft/sec
Signal Reaction	The frangible base of the signal installation broke away as was desired and the support rotated up, allowing the vehicle to pass underneath untouched after the initial contact. The vehicle damage was relatively small and the decelerations experienced by the vehicle were minor.
Vehicle Damage	Front bumper and bumper arms, gravel shield, grill, hood lock support and hood, radiator and radiator fan. The total deformation of the vehicle was 1 ft. 3 inches.

TABLE 4

SUMMARY OF TEST 111-4

Signal Installation	Steel pipe Railroad Grade Crossing Signal Installation without any breakaway devices at the base. Cast steel base is attached to the foundation by four 1 in. diameter anchor bolts. (Figure 5.)
Vehicle	1960 Ford 4-Door, weight 4000 lbs., color black. (Figure 6.)
Vehicle Velocity	Nominally 45 mph.
Maximum Seatbelt Force	1000 lbs.
Maximum Deceleration	16.9 g's
Average Deceleration During Contact Period	6.4 g's
Change in Velocity (Accelerometer Data)	32 ft/sec
Signal Reaction	The steel Railroad Grade Crossing Signal broke away under the impact of the vehicle by a clean shearing action on the four foundation anchor bolts which occurred just above the leveling nut. After shearing the anchor bolts, the steel signal fell on the car as it was moving some 40 feet beyond the impact point to its final resting place. This is shown in Figures 7 and 8.
Vehicle Damage	Damage to the vehicle included the following: front bumper, bumper arms, hood, radiator, motor, frame, front windshield and top of vehicle. Total vehicle deformation was 3 ft. 0 inches. The vehicle is estimated as a total loss and deceleration levels were relatively severe.

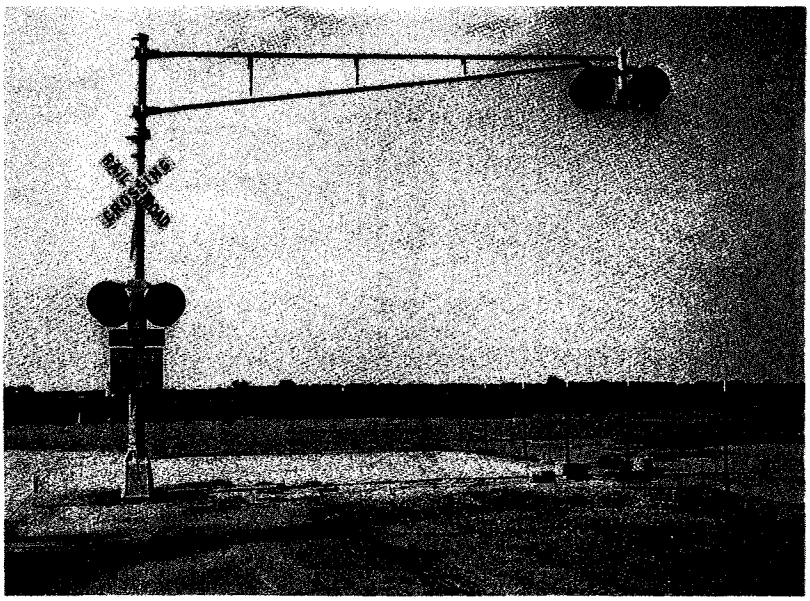


Figure 1, Signal Installation Before Test 1111-3
(Aluminim With Frangible Base)

Figure 2, Test Vehicle Before Test 1111-3

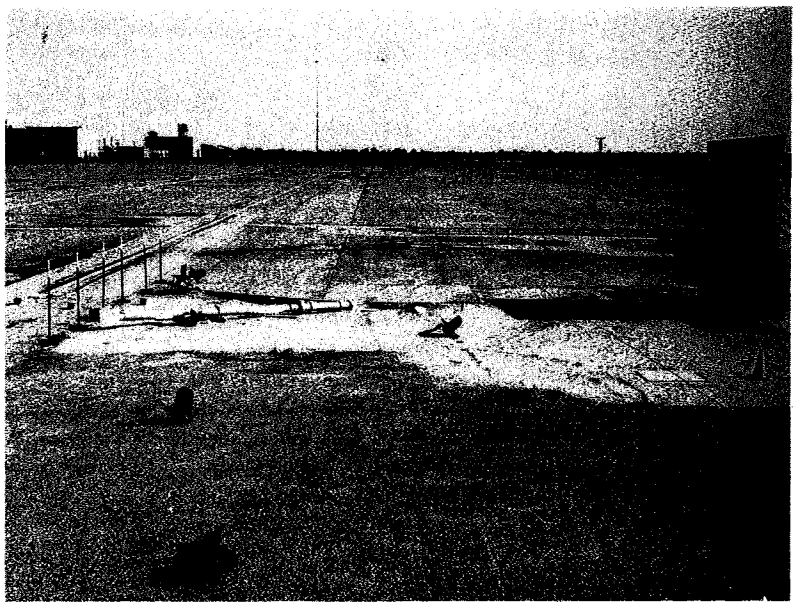


Figure 3, Signal Installation After Test 1111-3

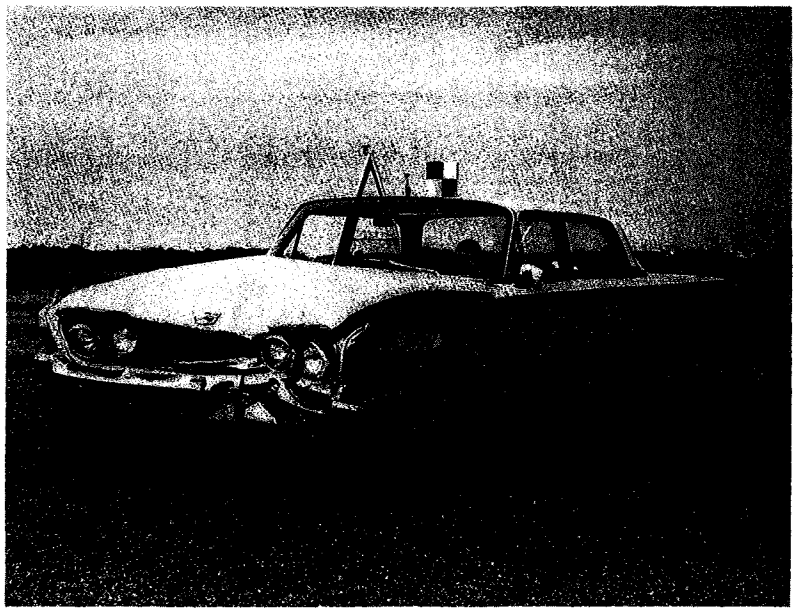


Figure 4, Test Vehicle After Test 1111-3

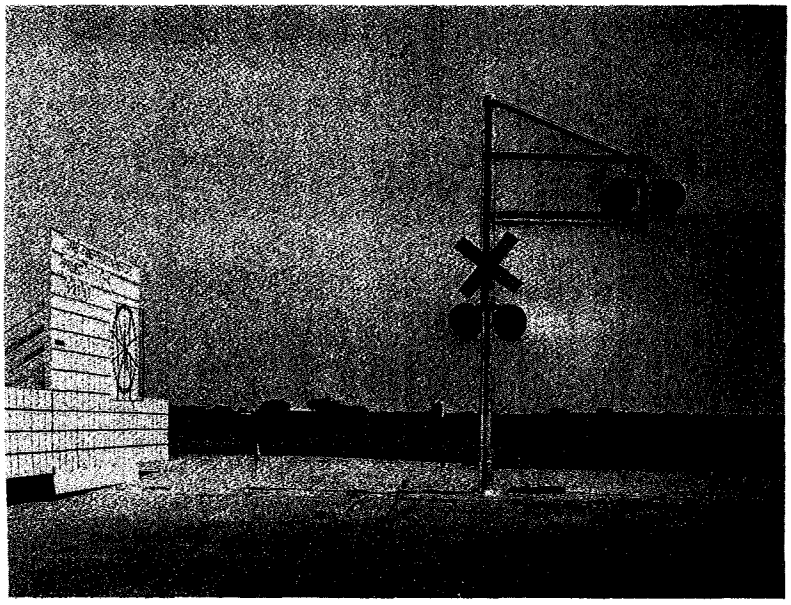


Figure 5, Signal Installation Before Test 1111-4
(Steel With 1" Anchor Bolts)

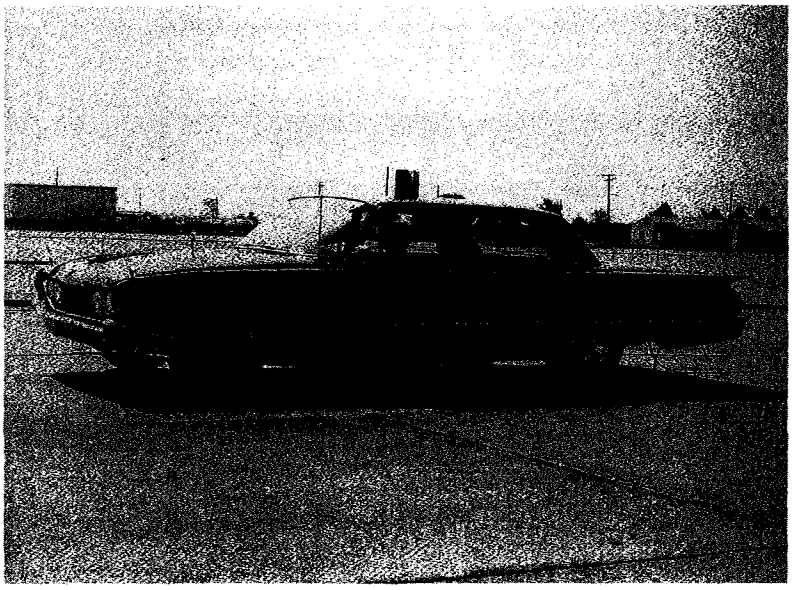


Figure 6, Test Vehicle Before Test 1111-4

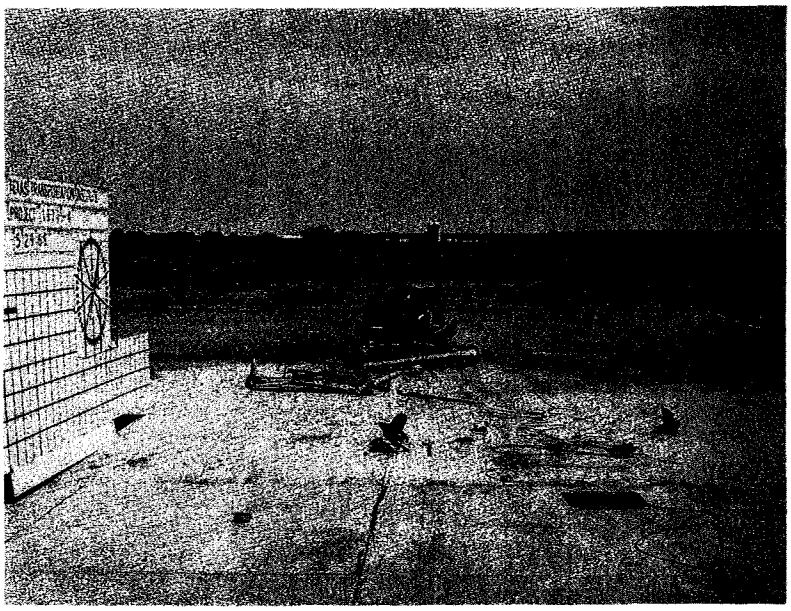


Figure 7, Signal Installation After Test 1111-4

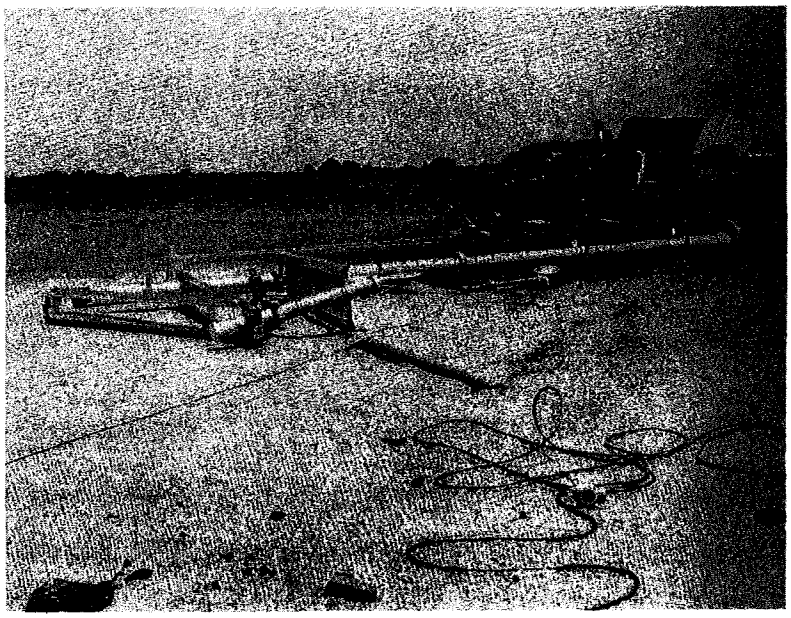


Figure 8, Test Vehicle After Test 1111-4

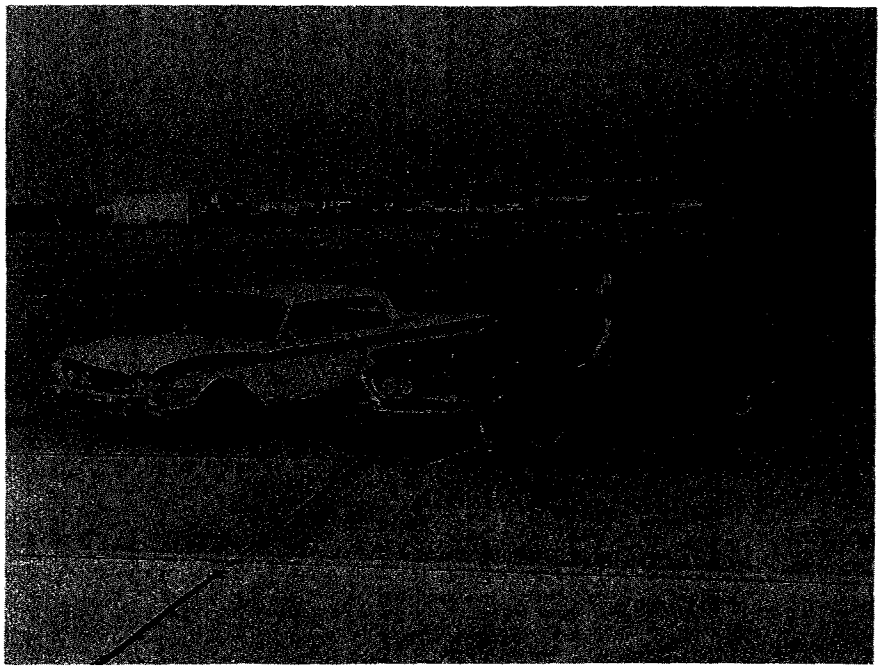


Figure 9, Comparison of Vehicle Damage