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FINAL REPORT

IDENTIFICATION OF HUMP HIGHWAY/RAIL CROSSINGS IN KANSAS

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16. Abstract

Hump crossings or high-profile crossings are a highway/rail intersection (HRI) at which the road surface profile across the rail tracks may pose a risk to a low-clearance vehicle becoming stuck on the tracks. They may also pose a threat to heavy vehicles that are required to stop at the crossings due to the steep grades.

States are required to identify high-profile crossings, sign them appropriately, and keep their information in an electronic database. In 1997, FHWA adopted a new advance symbol sign for crossings. However, there is no standard procedure from FHWA on how to identify such crossings. KDOT maintains an electronic database of about 7,000 public grade crossings. In 2000, they added the value of the grade to the crossing.

The objective was to develop an effective process to identify and rank crossings where there may be a problem with the approach grade profiles. This identification includes some physical characteristics of the highway/rail crossing and a centerline and edge-of-road profile of the approaches. It identifies characteristics of "critical" vehicles that are susceptible to being hung-up on these Kansas crossings. Also, it develops "critical" profiles for one or more critical vehicles.

Developing a methodology for hump crossing identification included establishing a project advisory committee, evaluating the existing HANGUP computer program, conducting a survey of Kansas counties and other states, developing a physical vehicle model, and creating a protocol for identification of hump crossings with hang-up potential in the field.

The study is limited to hump crossing information and does not cover countermeasures.

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Final Report

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A Report on Research Sponsored By

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

KANSAS STATE UNIVERSITY
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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

NOTICE

DISCLAIMER

ABSTRACT

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ACKNOWLEDGMENTS

The authors wish to acknowledge the input of an actively involved advisory committee that attended several meetings and offered advice and encouragement throughout the project (see Appendix A). Special thanks go to Mickey Thull who was primarily responsible for acquiring materials and building the physical model described in Chapter 4. The extreme patience of Al Cathcart, Coordinating Engineer and K-TRAN: KSU-99-1 Project Monitor, Bureau of Design, Kansas Department of Transportation, was especially appreciated.

The authors appreciate the time and effort of those persons from Kansas counties and other states who answered mail survey questions and participated in follow up phone calls.

The funds for this study were provided by the Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program. The views, conclusions and recommendations expressed in this report are the authors and not necessarily those of KDOT.

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Introduction

1.1 Background

Hump crossings or high-profile crossings are a highway/rail intersection (HRI) at which the road surface profile across the rail tracks may pose a risk to a low-clearance vehicle becoming stuck on the tracks. There are several vehicle types that, due to low clearances or long overhangs, may become high centered or "hung-up" on highway/rail crossings. Some school busses are susceptible to being hung-up on crossings due to their rear overhang. Trucks hauling hazardous materials are also a critical vehicle type for these hump crossings due to the potential catastrophic consequences. Various types of farm vehicles also may be susceptible to getting hung-up.

High profile crossings with highway approaches on steep grades may pose difficulty to heavy vehicles that may be required to stop at the crossings. Because of low acceleration capabilities and high gross weights, heavy vehicles may experience difficulties in stopping and starting from a stop on steep grades.

Theoretically, improvement strategies for hump crossings could vary from the elimination of at-grade crossings (e.g. consolidation, grade separation), reconstructing highway approaches to lessen the grades, or warning critical vehicles to avoid hump crossings with signing or routing. Costs of these strategies could vary from the cost of a grade separation to minor grading and surfacing. The benefits could be great because the calculated costs for HRI crashes involving heavy vehicles can be exorbitant. This is especially true when school busses or hazardous materials may be involved or derailment occurs.

The hang-up problem may also be attributed to potholes or unevenness of road surface due to poor road surface maintenance. This situation is a maintenance problem and beyond the scope of this study.

Safety problems at high-profile crossings are one of the five safety problem areas identified by the Grade Crossing Task Force (USDOT 1996). The task force was formed after the accident in Fox River Grove, Illinois, on October 25, 1995 in which a school bus carrying 35 high school students was struck by a commuter train, resulting into seven fatalities and 24 injuries. The task force recommended several measures to deal with high-profile crossings including a recommendation that the states identify such crossings.

1.2 Problem Statement

Among the short-term recommendations by the Grade Crossing Task Force states are: (USDOT 1996)

State and local highway agencies, working with railroads, should identify problem crossings, i.e., crossings with a history of, or evidence of vehicle hang-ups by reviewing accident data and consulting with highway engineers, local railroad officials, truckers, and public officials. Once identified:

a. Standard advance warning signs and crossing identification signs should be conspicuously installed;

b. As states identify high-profile crossings, the Federal Railroad Administration (FRA) should retain the information in the U.S. DOT/AAR National Highway-Rail Crossing Inventory; and

c. States and/or the FRA should enable state special permit offices to electronically access rail crossing databases and develop maps that identify problematic rail crossings to delineate routes for special permit vehicles.

In summary, states are required to identify high-profile crossings, sign them appropriately, and keep their information in an electronic database. In 1997, the Federal Highway Administration (FHWA) adopted a new advance symbol sign (W10-5) for crossings that might create a hang-up of long wheelbase vehicles or trailers with low ground-clearance. However, there is no standard procedure from FHWA on how to identify such crossings. As most of the hump crossings remained unsigned, drivers of low ground-clearance vehicles are left with the decision of judging whether they can traverse such crossings safely.

The Task Force recommended that identification of hump crossings be done by looking at the accident/incident history of the crossings. However, the limitations to this approach lies in the way accidents are reported. The field "position" (in the database) that indicates the position of the highway user during the crash/incident is reported as either of the four categories:

1 = stalled on crossing;

2 = stopped on crossing;

3 = moving over the crossing; or

4 = trapped.

None of the four categories can be explicitly used to identify a hang-up situation.

Use of a crossing database would seem to be an objective way to identify hump crossings. The Kansas Department of Transportation (KDOT) maintains an electronic database of about 7000 public grade crossings. However, the variables that define the approach highway grade in the KDOT's inventory database (Prior to 2000)* are not sufficient for "hump" crossing identification purpose.

The data fields in the KDOT database that represent the grade of the highway approach are coded as "Highway Grade on Approach Side of Crossing" and "Highway Grade on Depart Side of Crossing." These fields can take one of the following values:

- 1 for flat grade;
- 2 for grades between 0 and 3 percent;
- 3 for grades between 4 and 6 percent; or
- 4 for grades greater than 6 percent.

The highway grade is described as the maximum approach/depart grade, over a horizontal distance of not less than 10 feet within a distance of 300 feet of the center of the main track. (KDOT 1995 pp. 24-25)

The problem with using KDOT's pre-2000 inventory variables for classification of hump crossings was three-fold:

1. With categorical data, it is difficult to differentiate grades that are significantly different, i.e., a grade of 9 percent is recorded the same way as for the grade of 6.5 percent;
2. The exact location of the recorded grade is not known. With the range of up to 300 feet from the center of the track for which the grade is reported, a reported grade could be far away from the crossing such that it has no influence on vehicle trajectory at the crossing; and
3. The reported grades do not reveal whether there is a change in slope from the approaching side to the departing side. For example, a slope of +5 percent on the approach side and a slope of -5 percent on the departing slope will be recorded the same way as the slope of

---

*During 2000, the Kansas Department of Transportation (KDOT) upgraded the state inventory and developed procedure to make a preliminary identification of hump crossing candidates. This will be discussed in a following section.

+5 pecent on the approach side and a slope of +5 percent on the departing side. While the former might cause a hang-up problem, the later will probably not.

While KDOT staff may know of select crossings where there have been problems of vehicles hanging up on highway/rail crossings, there was no current data or methodology to identify crossings where improvements are needed to avoid future problems of this nature.

1.3 Study Objectives

The objective of this study was to develop an effective process to identify and rank crossings where there may be a problem with the approach grade profiles. This identification includes some physical characteristics of the highway/rail crossing and a centerline and edge-of-road profile of the approaches. This research should also identify the characteristics of "critical" vehicles that are currently using Kansas roads, i.e., those most susceptible to being hung-up at highway/rail grade crossings in Kansas. It would also develop "critical" profiles for one or more critical vehicles. The study was limited to hump crossing identification and did not cover countermeasures.

1.4 Study Methodology

The study methodology included:

1) establishing a project advisory committee;
2) conducting a literature review of existing information on hump crossings;
3) obtaining computer software that analyses hump crossings;
4) conducting surveys of other states and Kansas counties;
5) developing a physical model to simulate vehicles on grade crossing in the field;
6) measuring dimensions of critical vehicles; and
7) developing protocol for field identification of hump crossings.

Chapter 2

Literature Review

A literature review was conducted to synthesize documented literature on hump crossing identification. Very little published literature was uncovered.

2.1 Hump Crossing and Low-Clearance Vehicle

A hump crossing is defined as a crossing where a low, ground-clearance vehicle is likely to become lodged (hung-up) when traversing over the crossing. The two main factors that will determine the potential for a vehicle hanging-up at the crossing are: 1) vertical profile of the highway over the crossing, and 2) the combination of the vehicle ground-clearance and the length between front and back axles (wheel base) or length of vehicle overhangs.

It is apparent that for any highway profile across an HRI (except one of level grade), theoretically, there exists a combination of wheel base and ground-clearance that may cause a hang-up situation. Therefore the quantitative definition of a hump crossing in terms of the vertical profile is not possible without also defining a low, ground-clearance vehicle. Likewise, the definition of a low ground-clearance vehicle is not possible without defining a vertical profile. Because of this interdependence between hump crossings and low ground-clearance vehicles, both terms are always defined in subjective terms.

The majority of the grade-crossing communities concur that vehicles commonly called "low-boys" are the low ground-clearance vehicles that are most likely to hang-up at crossings. Eck and Kang (1991) identified four categories of low ground-clearance vehicles for West Virginia highways. These categories are: 1) low-boy, equipment trailers, 2) double drop, van trailers, 3) auto transporters, and 4) car/truck with trailer. Little standardization within the vehicle manufacturing industry regarding minimum ground clearance suggests that the categorization of low ground-clearance vehicles by Eck and Kang is not definitive. The Task Force (USDOT 1996) reported that several states refer to low ground-clearance of less than 12.7 mm (0.5-in) per foot of the distance between any two adjacent axles or, in any event, less than 22.9 cm (9-in) measured above the level surface of roadway. Walter and O'Neil (1998) mentioned that in a study of 114 low-bed trailers entering in the state of Oregon in 1988, ground clearances as low as 5.1 cm (2-in) were observed.

2.2 Identification of Hump Crossings

There are two approaches to identifying hump crossings: 1) before any hang-up incident/accident has happened on the crossing (pre-incident), or 2) after the hang-up incident/accident has been reported.

2.2.1 Pre-Incident/Accident

In this case either the entire procedure is done in the field at the crossing, or the procedure is done in the office with a computer simulation model. For the field procedure, a team of experts would visit the crossing in the field and assess, subjectively, the potential for hang-up. In fact, motor vehicle drivers use this method to determine their potential of getting hung-up whenever they go over a crossing. More objectively, the field procedure may involve pushing a prototype or driving an actual vehicle over the crossing to determine the potential for hang-up. A prototype may be a physical model with adjustable ground clearance. Virginia uses a template that was designed using low-boy ground clearance measurements. In Howard County, Maryland, a low-bed trailer with ground clearance of 12.7 mm (0.5-in) less than the trailer used to design the crossing was used to check the hang-up potential at a recently modified crossing (Walter and O'Neil 1998). When using an actual vehicle, assurance from the railroad company that there will be no train at the crossing at the time of testing is necessary. Eck and Kang (1991) developed a computer model called HANGUP which can be used in the office to assess the hang-up problem. The computer model needs input of the highway approach elevations relative to center of track(s). The computer model HANGUP will be discussed in more detail later in the report.

2.2.2 Post-Incident/Accident

In this case, the crossing is identified as a hump crossing after such an incident has occurred. Police reports can be used, or gouge marks on the pavement at the crossing can be identified. Gouge marks may be the best physical indication. However, the gouge marks method is limited only to paved roads.

2.3 Design and Maintenance Practice

The Task Force (USDOT 1996), identified crossing design and maintenance, among other factors, as contributing factors to the hump crossing problem. The first guideline regarding the highway profile at HRI is found in the Manual for Railway Engineering authored by the American Railway Engineering Association (AREA). The same guide is found in the American Association of State Highway and Transportation Officials (AASHTO) since the 1990 version (AASHTO 1990). The guideline specifies that the surface of the highway be not more than 3 inches (76 mm) higher nor 6 inches (152 mm) lower than the top of nearest rail at a point 30 feet (9.1 in) from the rail, unless track superelevation dictates otherwise. Although there are very general guidelines, some states have adopted the guidelines as it is, and some have adapted it with minor variations.

According to the Task Force, most states consider the AREA and AASHTO guidelines appropriate for design of new projects but not applicable to maintenance projects on existing crossings. With lack of crossing maintenance guidelines, some crossings become humped after successive track raising during maintenance. Dips in the approach roadways, particularly from poor maintenance on non-paved roads, can also cause hang-ups.

2.4 Hump Crossing Treatments

Practical treatments for a hump crossing includes elimination of the at-grade crossing (grade separation or consolidation), reconstructing highway approaches to less severe grades, and vertical alignment or signing to warn potential hang-up vehicles. Among the three treatments, signing is considered the alternative with the least cost. Different states such as North Carolina, Florida, New York, etc. have adopted the advance warning signs for hump crossings. It was not until January 1997 that FHWA through its National Committee on Uniform Traffic Control Devices (NCUTCD) adopted a new symbolic advance sign, designated as W10-5, as a standard warning sign for substandard vertical curves over railroad crossings. The symbol on the sign is the same as used by New York State Department of Transportation. The sign depicted in Figure 1 has a yellow background color with a black symbol and border.

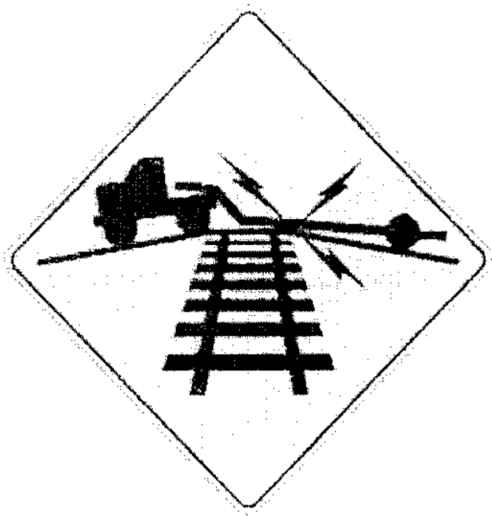

Figure 1: Low Ground Clearance Highway Rail Grade Crossing Sign (W10-5) (MUTCD 2000, p. 8B-11, Section 8B.14)

In essence, the sign has messages similar to those in the Florida and North Carolina signs showing a low-boy trailer lodged at a crossing. The Millennium MUTCD states the following (MUTCD, 2000, p 8B-11, Section 8B.14):

> One deficiency is noted with these signs. The driver may not be given an alternative route which does not contain a hump crossing. Also, it may be difficult, if not impossible, for a driver to turn around or back up from the location that the sign at the crossing is visible to the driver. Advance warning should be located where alternate routes are available. State and local highway jurisdictions have the option of using or not using the sign.
>
> **Guidance:**
>
> If the highway profile conditions are sufficiently abrupt to create a hang-up situation for long wheelbase vehicles or for trailers with low-ground clearance, the Low Ground

Clearance Highway-Rail Grade Crossing (W10-5) sign should be installed in advance of the highway-rail grade crossing.

Standard:

New warning signs such as this that might not be readily recognizable by the public shall be accompanied by an educational plaque, LOW GROUND CLEARANCE which is to remain in place for at least 3 years after its initial installation (see Chapter 2A).

Guidance:

Auxiliary signs such as AHEAD, NEXT CROSSING, or USE NEXT CROSSING (with appropriate arrows) should be placed at the nearest intersecting highway where a vehicle can detour or at a point on the highway wide enough to permit a U-turn.

Figure 2 shows the educational plaque that should supplement the W10-5 for at least three years after installation. It is also important that auxiliary signs be placed at locations ahead of the W10-5 where low ground clearance vehicles can alter their route.

FIGURE 2: Educational Plaque to supplement the W 10-5 low ground clearance sign

Chapter 3

Developing Methodology for Hump Crossing Identification

Developing methodology for hump crossing identification included establishing a project advisory committee, obtaining computer software (HANGUP) for analyzing hump crossings, conducting a survey of other states and counties in Kansas, developing a physical model, and developing protocol for identification of hump crossings in the field.

3.1 Establishing a Project Advisory Committee

A project advisory committee was established to work with Kansas State University (KSU) researchers to provide guidance and background concerning the department's philosophy, policy and guidelines in the area of highway/rail grade crossings. The number and composition of the advisory committee was determined in consultation with the KDOT contract monitor. Appendix A is the list of the advisory committee.

3.2 Computer Software

Only one computer software program known as HANGUP version 2.4 was found during the literature review. It is capable of simulating the movement of a vehicle over the crossing. HANGUP was developed as part of a research project "Low-Clearance Vehicles at Grade Crossings" at West Virginia University between 1990 and 1991 (Eck and Kang 1992). The software will run on IBM compatible microcomputers. It takes vehicle dimensions (wheelbase, rear and front overhang, ground clearance between axles, rear and front ground clearances) and highway approaches profile (elevations of road surfaces relative to track) as input. With the HANGUP software, one can determine the vehicle measurements that will cause a hang-up problem at a given crossing, or one can investigate different design alternatives for the highway profile that will accommodate a given vehicle.

Given a crossing, the program will suggest one of the three outputs for each combination of vehicle wheelbase and vehicle ground clearance. The three outputs are

1) "Hangup,"
2) "Safe" and
3) "More detailed study warranted."

It is understood that the "more detailed study warranted" is the borderline case between hang-up and safe. This borderline case implies that the available ground clearance is greater than zero, but less than a threshold value preset by the user. The program does not take into consideration the type and maintenance level of the intersecting road when deciding the borderline case. For example, a 2.5 cm (1-iN) clearance on a paved road might not pose a hang-up threat as an unpaved road surface might.

HANGUP version 2.4 is limited to two-dimensional analysis. It cannot be accurate at a crossing where the cross section of the intersecting road is not level, such as where the railroad is on curve and usually superelevated. Also, on an unsurfaced road, i.e., gravel, earth, etc., no single vertical section will give the true condition of the crossing. Version 3.0, which is intended to simulate in three-dimensional form, was released by West Virginia University (Eck and Kang, 1992) during the draft of this report. The authors were sent copies of HANGUP version 3.0 and spent several weeks attempting to get it to run but were unsuccessful.

3.3 Physical Model

A physical model that can be used in the field to check for a hang-up potential was developed during this study. It consists of the triangular beam resting on two axles (an old aluminum television (TV) antenna worked very well for this purpose). The wheel base, ground clearance, and the shape of the beam between the axles are adjustable. It can be adjusted to any reasonable wheelbase and clearance and rolled over the crossing to find out whether a vehicle with that given wheel base will hang-up or pass safely, similar to the computer program. The added advantage over the computer program is that the value of the available clearance can be immediately known to the operator by an actual field test. The prototype model can be broken down into three, 3-meter (10-ft) sections for hauling or storing.

3.4 County Survey

Seventy-nine out of the total 105 counties in the state returned the questionnaire. Of the 79, 60 counties returned the questionnaire in the first phase. The other 19 counties returned the questionnaire after the second phase. The questionnaire consisted of (from the 60 counties who responded in the first phase) a cover letter to all 105 counties. The cover letter either thanked the respondents for returning the questionnaire and asked for further comments based on the summary responses (for those who returned in the first phase), or reminded the addressee the importance of the study and that the response is still needed. Four of the 60 counties could not be identified because the information which could have been used to identify them was not provided on the questionnaire responses. Three counties out of the 79 who returned the questionnaire did not answer questions one through eight because either there was no technical personnel to do that or there are no railroad crossings in the county.

After analyzing the responses, the issues which were of interest to the researchers or those that needed more detail were followed up. The follow-up was made through telephone, e-mail, fax, and/or field visit. Results of the survey follow:

<u>3.4.1</u> ***<u>Question One</u>* - In the last year or two, do you know of any location where a vehicle was hung-up on a highway-rail grade crossing?**

Ten counties (13 percent) responding to this question had experienced the hang-up problem in the last year or two, while 87 percent had not. Figure 3 shows the distribution of the counties with regards to the hang-up experience.

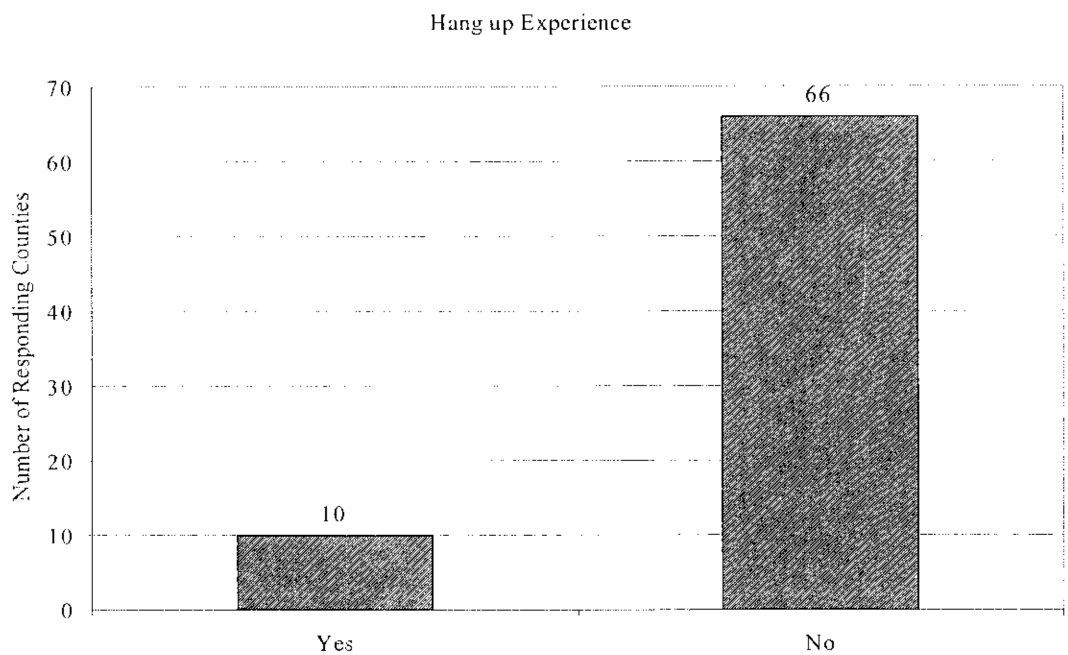

FIGURE 3: Counties With Hang up Experience

<u>3.4.2</u> *<u>Question Two:</u>* ***- If yes, could you estimate the number of such incidents?***

The ten counties who experienced hang-up indicated a total of 48 such incidences. A follow-up was made to get more information (type of vehicle, road profile) on the indicated hang-up incidence. On a follow-up with county engineers, there was only one crossing in Saline County which was available for obtaining both road profile and hang-up vehicle data. For the rest, either the engineer could not recall the information to pin-point the location and/or type of the vehicle that hung-up, or the road approaches were reconstructed and no profile data for the conditions before the incident was available. Table 1 shows the profile data for the crossing in Saline County. (For the vehicle data, refer to "cattle trailer" in section 5.7).

A computer simulation of this Saline grade crossing was run with a computer program HANGUP. The program is explained in Chapter 5 and the results of the computer simulation of the Saline County crossing shown in Table 1 are summarized in section 5.9.1.

TABLE 1: Profile Data for the Saline County Crossing

Distance From Outer Rail (ft)	North Bound Approach Elevation Relative to Top of Rail (ft)	South Bound Approach Elevation Relative to Top of Rail (ft)
0	0	0
4	0.005	-0.053
8	0.094	-0.196
12	0.012	-0.319
16	-0.285	-0.402
20	-0.555	-0.467
24	-0.800	-0.548
28	-1.167	-0.626
32	-1.471	-0.670
36	-1.810	-0.724
40	-2.118	NA*
44	-2.435	NA
48	-2.718	NA
52	-2.942	NA
56	-3.177	NA

*NA = not available

<u>3.4.3</u> <u>Question Three:</u> - If no, do you have crossings you think could cause a problem?

This question was intended for those respondents who had no hang-up experience. However, five counties or 50 percent of those who reported having had hang-up experience (Question 1) responded to this question. One county (ELK) provided the comment "No more than usual, crossings are rough in (the) county." Another county (GRANT) apart from the giving the "Yes/No" response, provided the comment "not on hang-ups, just rough Xings."

Thirty-four out of 66 counties (52 percent) who did not experience hang-up in the last year or two indicated that they have crossings that may cause a hang-up problem. Figure 4 shows the distribution of counties that have not experienced hang-up problem but believes that they have crossings that have potential to cause the problem.

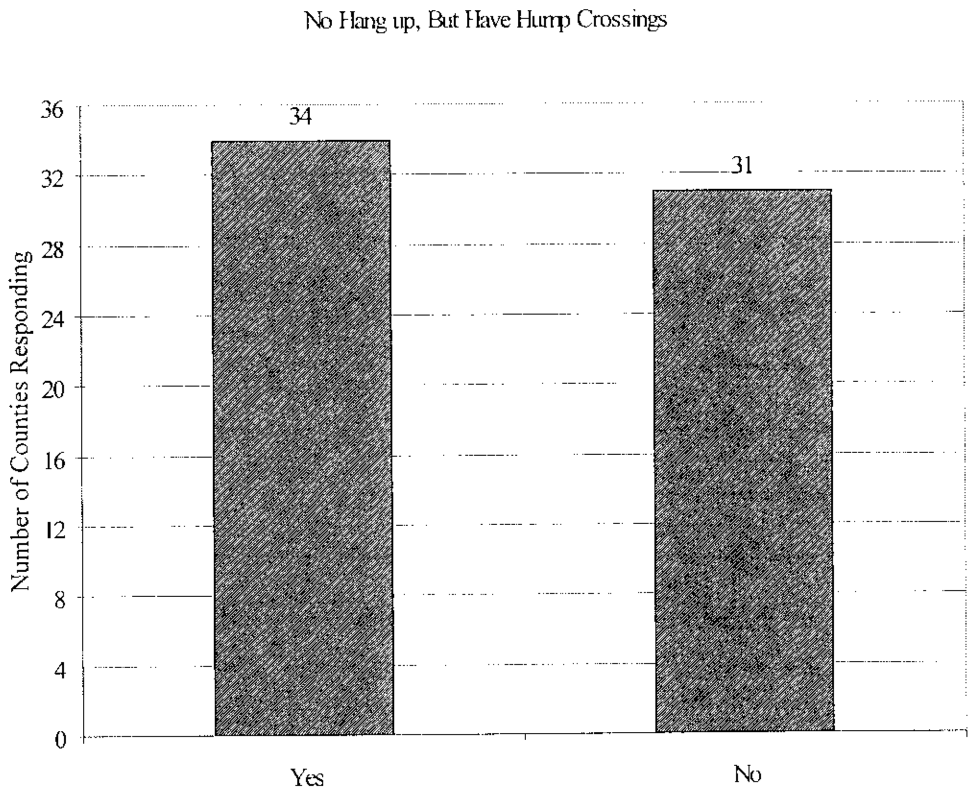

FIGURE 4: Counties With Hump Crossings But No Hang-Up Experience

3.4.4 Question Four: - What type of vehicle(s) using county roads are likely to experience hang-up problems in your county?

Types of vehicles that are likely to hang up on county roads includes: pot belly, belly dumps, low-boy, grader, semi-tractor, cattle truck, low clearance cars, tractor trailer, farm equipments, etc. The following list of vehicles includes types of vehicles indicated by the questionnaire respondents.

- Pot belly semi stock trailers (CLARK)
- We try to shoulder roads up to meet the tracks (WALLACE)
- Low-boy trailers (ELLIS)
- Low-boy trailers (BROWN)
- Low-boy, belly dumps, normal traffic (MORRIS)
- No problems (HASKELL)
- Motor graders (SEDGWICK)
- Semi trucks and trailers (SEWARD)
- Low-boy trailers and combined trailers (FORD)
- Light vehicles could be launched--truck trailers combination could become high centered (KINGMAN)
- None (RILEY)
- Low-boy trailers (RUSH)
- Low clearance cars and cattle trailers (MONTGOMERY)
- Cattle trucks and hay trucks (SALINE)
- Heavy equipment being transported on low-boy trailers (WASHINGTON)
- Tractor/trailer, farm equipment (REPUBLIC)
- Field entrances (MCPHERSON)
- Low-boy trailers (JEWEL)
- None (FRANKLIN)
- Semi (SHAWNEE)
- Farm equipment, farm trucks and semi-tractors with trailers (LYON)
- Low-boy trailers (JACKSON)
- Semi-trailers-more farmers are using semi trailers (ANDERSON)
- Low-boy and pot-bellied cattle trucks (JEFFERSON)
- Semis (THOMAS)
- Semi-trailers, low-boys, road graders, extra long loads (NEOSHO)
- Semi-tractor-trailer combs (DECATUR)
- Bull pots & Grain trailer (WOODSON)
- Farm equipment (CHEYENNE)
- Low profile cars (PRATT)
- Low-boy trailers or bottom dump material trailers (GREENWOOD)
- Low-boy trailers (JOHNSON)
- Semi-tractor/trailer rigs w/low clearance (BUTLER)
- Gravel trucks with belly dumps (HAMILTON)

- Any vehicle that is longer than 15' between axles and 18" clearance (WILSON)
- Cattle trailers (pots), Low-boy trailers (OSAGE)
- Farm machinery (TREGO)
- Farm implements (GOVE)
- Low-boy trailers (KEARNY)
- Tractor-Trailer Rigs (LANE)
- Low-boy trailers and agricultural trailers (MARSHAL)
- Cattle trailers and farm equipments of different types being pulled by tractors (PAWNEE)
- Farm equipment (CLAY)
- Pickups pulling trailers (horse/cattle or equipment) (LINN)
- Cars or small passenger vehicles (SHERMAN)
- Low-boy semis, belly dump grain trailers (HARVEY)
- None (GRANT)
- Low-boys, pot belly stock trailers (CHASE)
- Low-boy types (CHASE)
- Trailer trucks - low-boy trailers, bottom dump grain trucks and some low cars (CHEROKEE)
- Low-boy trailers (FINNEY)
- Low-boy trailers, belly dumps (ALLEN)
- Low equipment trailers - wide farm equipment (COFFEY)
- Low lay down trailers (ELLSWORTH)
- Cattle trailers - low boy trailers (SCOTT)
- Tractor trailer (BARBER)
- Semi-trailer (BARTON)
- None (LINCOLN)
- Possum-belly cattle trailers/low-boy trailers/some horse trailers (PHILLIPS)
- Cattle trucks (COMANCHE)

It is obvious from the response to this question that there is no one typical truck or set of dimensions that can be used at all crossings.

3.4.5 Question Five: - ***What mitigation measures are used for the hang-up problem?***

Fifty-nine counties responded to this question. Three counties (5 percent) treat hump crossings by closing the road over the crossing. The same percentage restrict certain vehicles from using the hump crossings. Ten counties (17 percent) use signing to warn motorists of a potential hang-up at the hump crossing. Twenty-one counties (36 percent) mitigate hump crossings by reconstructing highway approaches, while 28 (47 percent) do nothing on hump crossings. Figure 5 shows the distribution of counties with regard to hump crossing treatment methods. Eight counties (14 percent) indicated that they use more than one hump crossing treatment.

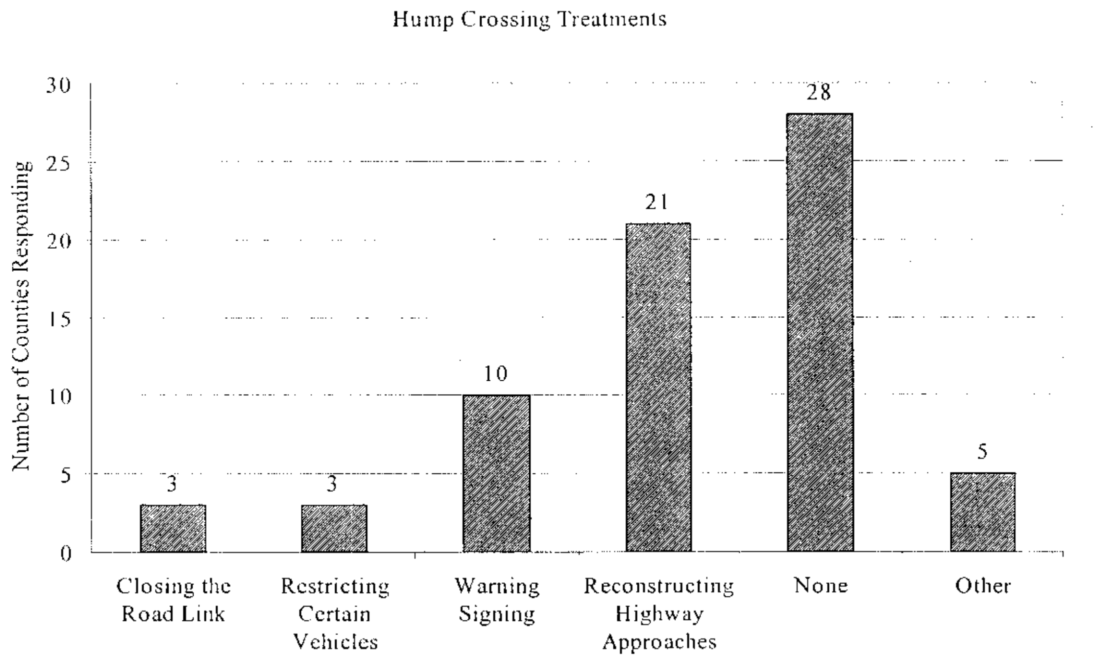

FIGURE 5: Hump Crossing Treatments

3.4.5.1 "Other" Category

Five counties indicated they use "other" measures for dealing with the hang-up problem. However, in-depth analysis of the mentioned other methods suggest that either there is no new method other than those suggested in the questionnaire or what was provided as "other" was just a comment.

The responses for the "other" category is shown below:

- The railroad company chief council is advised by the county counsel that the county engineer has determined a danger exists and that railroad shall bring the crossing in conformance with provisions of the Kansas statutes. (MONTGOMERY)

- Fix crossings (JEWEL)
- Waiting on the results of this study to determine the best approach to the problem (LYON)
- Build up road on both sides of rail. (WOODSON)
- Railroad is going to abandon its line. (COMANCHE)

3.4.5.2 Comments

Seven counties used the space intended to provide the method for "other" method to provide comments. This probably indicated that there should have been a space for comments regarding the method of mitigating hang-up problem. The seven comments are given below:

- This crossing was updated this year by the railroad - (not enough asphalt was used) (SEWARD)
- We are in the process of closing three crossings and the railroad is improving one. (ANDERSON)
- Most of ours can be seen at a distance - people avoid them most times (WILSON)
- None [mitigating methods] have been used to this point although reconstructing some approaches has been discussed (MARSHAL)
- We have problems getting the railroad to do their part (COFFEY)
- Roads to crossing points are not improved (dirt) and it is very rare to have semi on road. (BARTON)
- The railroad is going to abandon its line (COMANCHE)

3.4.6 Question Six: - Have railroad companies been involved in solving the hang-up problem?

Forty-nine counties out of 59 (83 percent) indicated dissatisfaction by the railroad companies participation in solving hump crossing problems. Figure 6 shows this distribution.

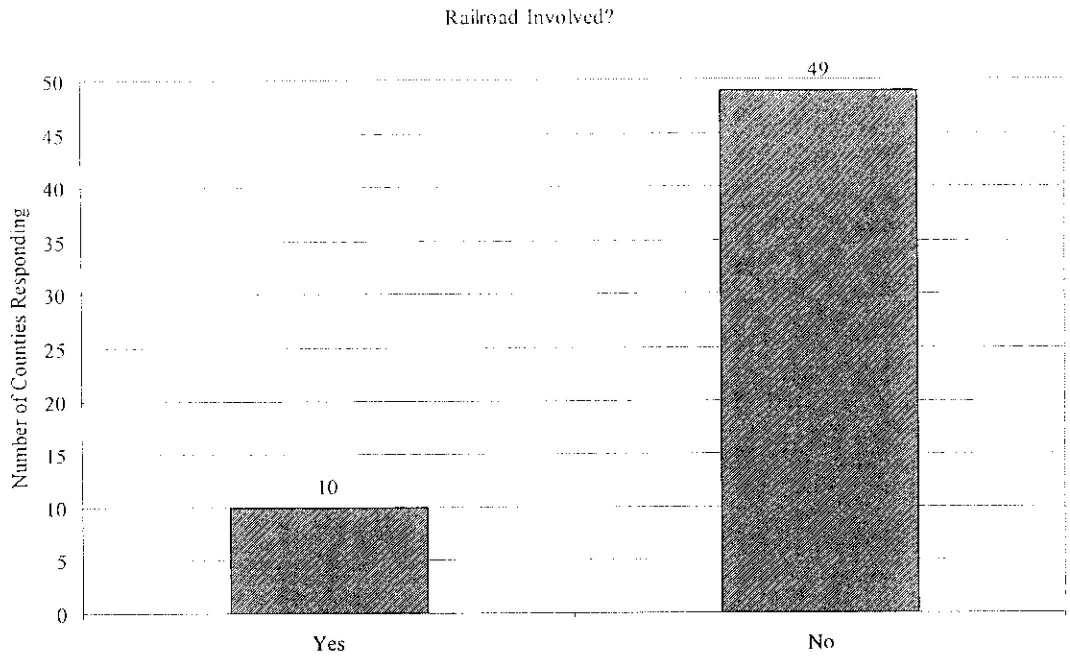

FIGURE 6: Participation of Railroad Companies

<u>3.4.7</u> <u>Question Seven:</u> - Please provide us with a contact name and identify your preferred method of communication.

During the first stage, four counties of the 60 responding (6.7 percent) did not provide any information for a contact person, therefore it was not possible to identify the responding county. During the second stage, one county out of 19 responding (5.3 percent) also did not provide information for a contact person, however, the questionnaire sent during the second stage were number coded for the purpose of identification.

<u>3.4.8</u> <u>Question Eight:</u> - Would you be willing to participate in a study of identifying hump crossings?

Thirty-four counties (57 percent) of the responding counties indicated their willingness to participate in the study. Figure 7 depicts this distribution.

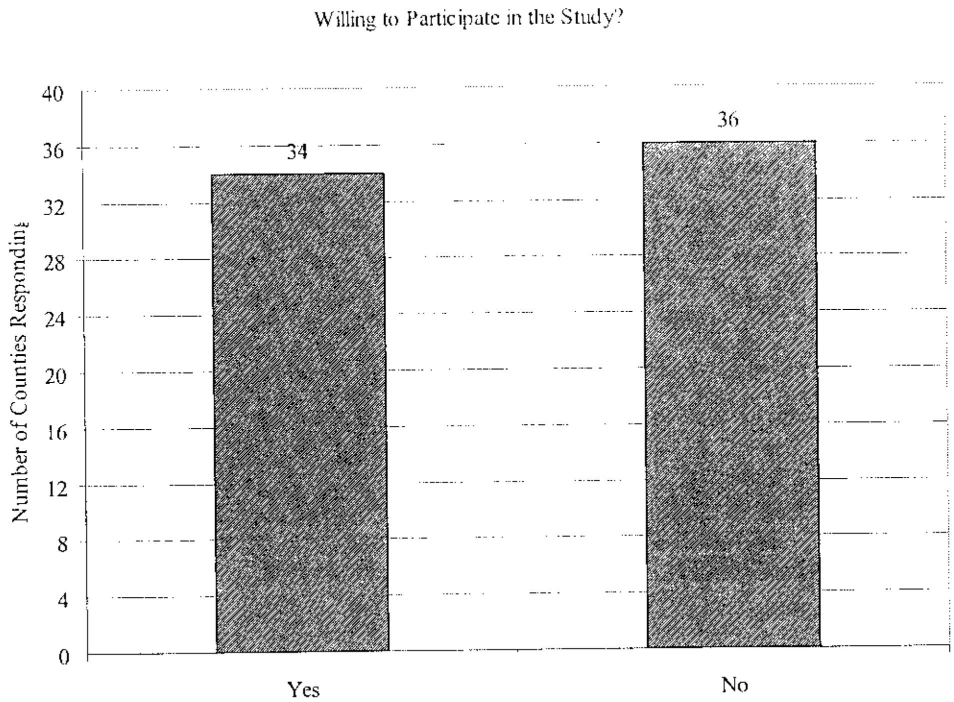

FIGURE 7: Willingness of Counties to Participate in the Study

3.4.8.1 List of Counties willing to participate in the study:

- WALLACE
- BROWN
- MORRIS
- HASKELL
- SEDGWICK
- SEWARD
- MORTON
- FORD
- RUSH
- MONTGOMERY
- SALINE
- REPUBLIC
- SHAWNEE
- LYON
- JACKSON
- ANDERSON
- NEOSHO
- DECATUR
- WOODSON
- GREENWOOD
- BUTLER
- HAMILTON
- WILSON
- TREGO
- MARSHALL
- PAWNEE
- WYANDOTTE
- HARVEY
- GRANT
- COWLEY
- CHEROKEE
- COFFEY
- BARBER
- PHILLIPS

3.4.9 Question Nine: - General comments relevant to the hump crossing/hang-up problem.

The following is the list of general comments (some minor editing was done for clarity):

- The railroad is in the process of raising the tracks through the County approximately 6 to 8 inches. We are raising the roads to meet the tracks. (WALLACE)
- We move our excavator with a low-boy and cannot cross some crossings. (BROWN)
- Humped crossings and underpasses on abandoned rail to trails routes are also involved. (MORRIS)
- There are two factors to consider, safety and public relations. (SEWARD)
- Not a great problem in our county at this time, as most of our small line railroads are ceasing operations. (KINGMAN)
- This is an important issue. (SALINE)
- We have no problem. (OSBORNE)
- No hump crossings in our county. (FRANKLIN)
- Should we have a problem we will go to the railroad for help. (JACKSON)
- This is a great undertaking. (ANDERSON)
- There is a law in the books (KSA 227, copy enclosed) that would take care of this problem if enforced. In Jefferson County alone, 11 out of 13 crossings on the UPRR do not satisfy this law. (JEFFERSON)
- Poor crossing maintenance by a short line railroad has made the problem worse in last few years. (NEOSHO)
- The county no longer has any railroads and the crossings were removed. (CHAUTAUQUA)
- Railroad company, specifically the CKRR out of Wichita is not interested in repairing their crossings.
- On our county roads, we haul dirt and/or gravel to improve rail crossings. If we did not, I do not think it would get done since rail companies are slow as molasses! (CHEYENNE)
- We just have one crossing with a problem at a double track crossing on a super--so it is not a typical hump crossing. (JOHNSON)
- Although state statutes place responsibility to construct approaches at a six percent or less grades railroads refuse to accept this responsibility and KCC refuses to enforce the statutes. (MARSHALL)
- Clay County has only one rail line in the county. (CLAY)
- Railroad crews work well with our county to try and correct any problems. (SHERMAN)
- Grant County's worst problem with railroad crossings is on pavement. Cimarron Valley railroad will not spend money on crossings. Most are low and rough, and need to be

raised. We reconstruct approaches to crossings on dirt or pavement. Perhaps this small line needs some grant aid. (GRANT)

- Although we have no recent reports of hang-ups, several crossings have potential. (CHASE)
- Cowley County is a township unit and most "hump" xings are not on county roads; but rather on township roads; so the county may not have information on all railroad crossing problems. (COWLEY)
- I have been here for four years and have yet to face this type of challenge. (FINNEY)
- The railroad has removed all tracks and crossings from Graham County. We no longer have any crossings at all. (GRAHAM)
- We have more problems with crossings being narrow and rough than with hump crossings. (COFFEY)
- Ellsworth County does not have all the roads in the county. I have only five places the railroad tracks cross county roads. (ELLSWORTH)
- The places in Barber County that could give us a problem are on township roads. (BARBER)
- Railroads are abandoning lines in Barton County so we will probably be removing crossings in the near future. (BARTON)
- Hump crossings are not a problem in Stevens County. (STEVENS)

3.5 Survey of Other States

The same questionnaire was sent electronically by e-mail system to all 50 states. Only nine states (18 percent) responded, this was viewed as a poor response by both the researchers and steering committee. Because the questionnaires were sent to the pool e-mail address of the state department of transportation, it was suspected that in most states, the questionnaire did not reach the correct person. Telephone communication was used to find the person in charge of railroad grade crossing programs in the states. After identifying them, questionnaires were resent in most cases using fax to the states from whom we did not receive responses. An additional 24 states responded to the questionnaire making a total responding states to 34 (68 percent). When analyzing the responses, respondents were contacted to solicit more information or clear ambiguities whenever detected. Hawaii did not respond to any of the questions with the following comment: "Hawaii does not have any hump crossings."

3.5.1 Question One: - Rate the hang-up problem in your state on the 1 to 5 scale.

Thirty-one gave ranks as expected. One state (Arkansas) did not respond to this question, while Nebraska did not give a rank, but commented as follows: "Nebraska does not gather enough data on humped crossings to rate the problem with any accuracy. Nebraska does have humped crossings that are a problem occasionally, but they are usually corrected by changing the roadway approaches." Pennsylvania additional comment: "A limited problem based on complaints or department staff. This issue is being reviewed at this time." Only one state (3 percent) thinks that the hang-up is a very serious problem. Three states or 10 percent do not think that hang-up is a problem at all. Figure 8 shows how states rank the hang-up problem, with the majority of 16 states (52 percent) ranked the problem to 4 on a 1 (very serious) to 5 (not a problem) scale.

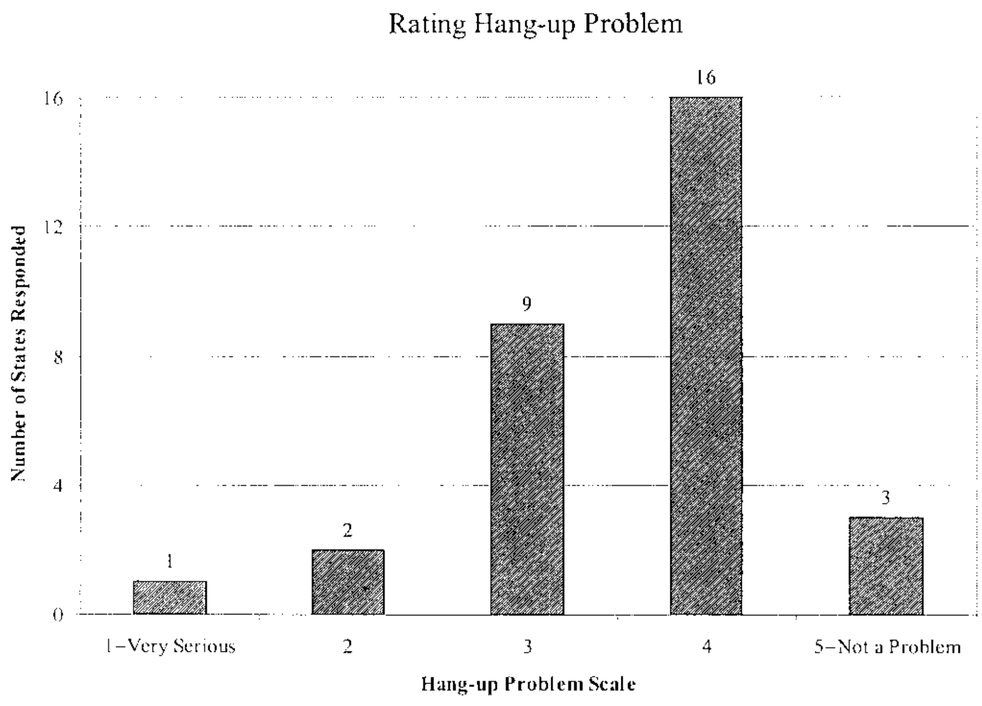

Figure 8: Distribution of States on Rating the Hang-up Problem

3.5.2 Question Two: - How do you identify a hump crossing?

One state (3 percent) uses a database to identify hump crossings. Thirteen states (39 percent) use field visits. Ten states (30 percent) use both field visits and databases. Majority of states wait until there is a hang-up incident before tagging it as hump crossing, i.e., 22 states (67 percent). Ten states would also classify the crossing as a humped crossing after an accident, while eight (24 percent) use other methods as described in the following subsection. Figure 9 shows the distribution based on methods for identifying crossing as humped.

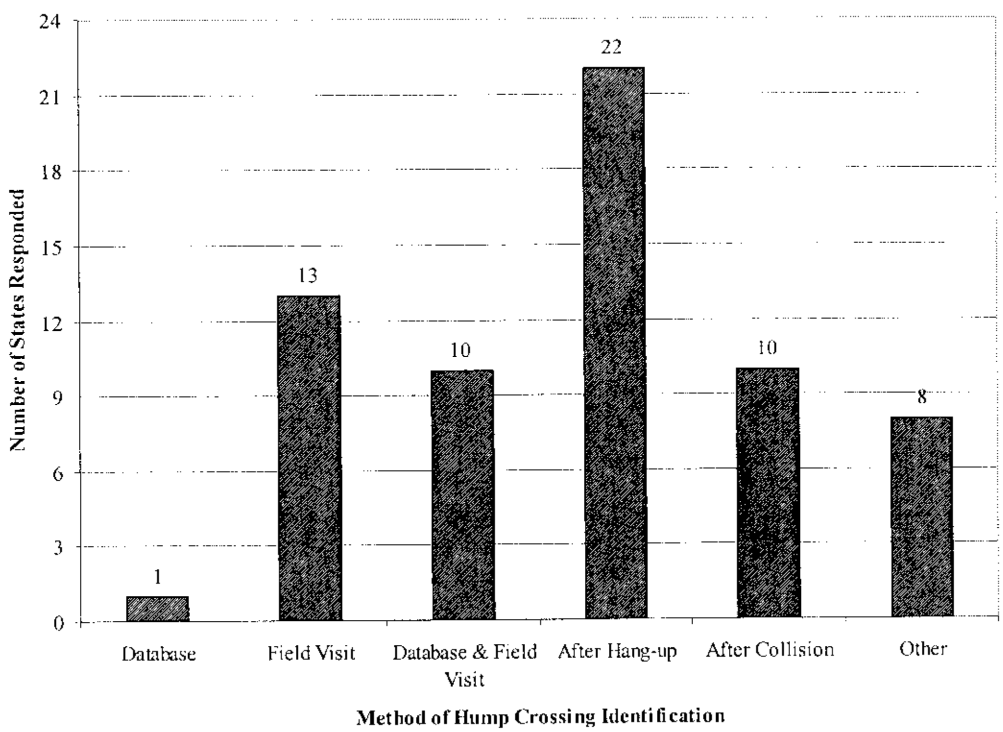

FIGURE 9: Methods Used to Identify Hump Crossings

3.5.2.1 "Other" Category

Ten states marked on the questionnaire that they use "other" methods for identifying hump crossings. New Hampshire was among the states who marked "other" but they specified a method which was already included in the choice option. Florida marked "other" but when specifying the method, just gave a comment. This reduced the "other" category to eight. The response from one other state is illegible. The "other" methods include:

- When reported by highway workers local agency, and public. (COLORADO)
- Survey. (WISCONSIN)
- When inventorying a crossing we use a template we developed to measure HUMP crossings. (VIRGINIA)
- We have percent rise and fall of the approaching roadway in our database, which may or may not be indicative of high profile crossings. We still need to include this attribute into our database. I haven't been hearing much about accidents caused by low profiles. But the potential, in some cases, is there. (MINNESOTA)
- Citizens report on high or rough crossings and by crossing diagnostic inspections. (NEBRASKA)
- Scrape marks on pavement observed during routine on-site reviews. (MICHIGAN)
- Reports received from police, railroad companies, and highway field maintenance crew. (ARKANSAS)

3.5.2.2 Comments

Four respondents used the space meant for specifying the "other" method for comments. The comments include:

- We have reviewed all crossings on the state system and we have no hump crossings. (FLORIDA)
- The Ohio Rail Development Commission (ORDC) is in the process of letting a contract for major filed data collection and creation of new fields for existing GX database. (OHIO)
- In some cases, humps developed over the years of usage due to poor design and poor maintenance. (NEW YORK)

➤ Each crossing is measured according to AASHTO Green book standards. (NEVADA)

Ohio indicated it was in the process of measuring road profiles to the accuracy of about one half inch.

3.5.3 Question Three: - Are there any variables in your database to help identify humps crossings?

Of the thirty states who responded to this question, nine (30 percent) indicated that there were variables in their database which could help identify hump crossings. Figure 10 shows this distribution.

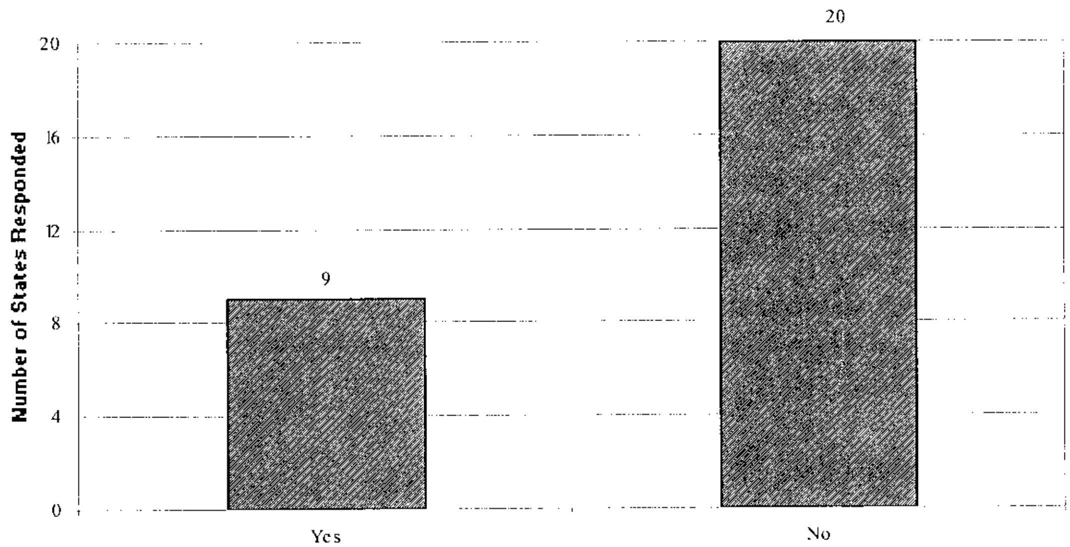

FIGURE 10: Distribution of States With Variables in Database for Hump Crossing Identification

3.5.4 Question Four: - How current is your database?

- Average 1½ yrs old. (SOUTH DAKOTA)
- N/A, MODOT does not maintain the database.
- Current. (ARIZONA)
- Varies to site and area but reasonably current. (LOUISIANA)
- Revised on a yearly basis. (OKLAHOMA)
- 1989. (VERMONT)
- Somewhat current. (ALASKA)
- Within 2 years for every public crossing. (OREGON)
- 5-20 yrs old. (MASSACHUSETTS)
- Every new crossing is measured & checked after overlay. (NEVADA)
- Ranges from current to fifteen years. Changes are being made in conjunction with FRA data changes. (PENNSYLVANIA)
- 115 updated every year. (WYOMING)
- Continually updated. (UTAH)
- We are continuously updating, latest date 1995. (VIRGINIA)
- 1992 to 1994. (MINNESOTA)
- Current. (NEW YORK)
- We just use GX (and you know how accurate that is). (MARYLAND)
- Brand new in 1999. (OHIO)
- Varies. (WEST VIRGINIA)
- Jan 1 1999. (IDAHO)
- Warning devices--Current, Approach grades--not up-to-date. (CALIFORNIA)
- We re-visit database every 3 years to up-to-date. (FLORIDA)
- N/A (ILLINOIS)
- Fairly current. (IOWA)
- Updated 100% every 3 years. (MAINE)
- Current. (MICHIGAN)
- 1-5 years. (ARKANSAS)

3.5.5 Question Five: - What mitigation measures are used for the hang-up problem?

Figure 11 shows the number of states and methods used to mitigate hang up crossings. Most states, (i.e., 26 out of 34 responding states) either use the method of road approach reconstruction alone or with other methods to solve hump crossing problems.

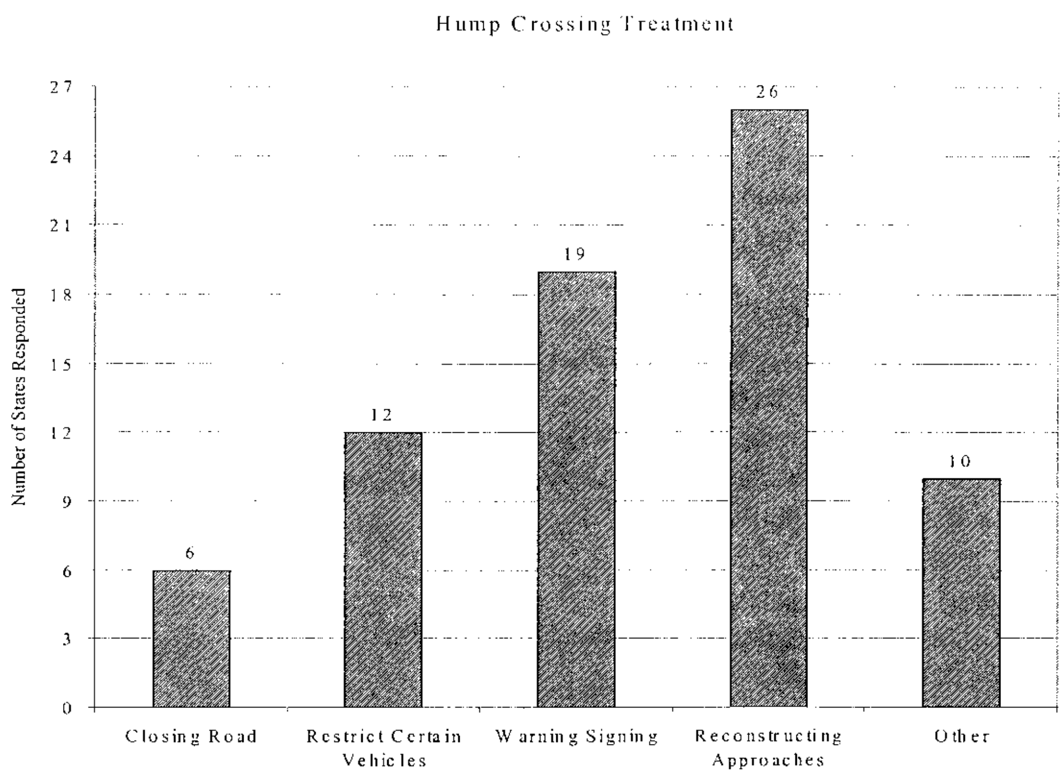

Figure 11: Distribution of Hump Crossing Treatments

3.5.5.1 Other Category:

- Close crossing; redirect to better site. (LOUISIANA)
- Reconstructing highway. (COLORADO)
- N/A (NORTH DAKOTA)
- N/A (VERMONT)
- Posted signs at all crossings giving emergency number to call. (ALASKA)
- Adjust railroad alignment/vertical profile. (OREGON)
- Normally "feathering" approaches to reduce humping. (PENNSYLVANIA)
- Reconstruct some crossings funding through the Safety Improvement Program. (VIRGINIA)
- Signs plus an advisory detour route. (MINNESOTA)
- We are using section 130 Federal Funds to reconstruct highway approaches on the city/county system. (FLORIDA)

3.5.6 Question Six: - How do you identify the type of vehicles likely to hang-up at a given crossing?

Although a considerable number of states consider the low-boy as most prone to be hung up at a hump crossing, it is obvious from the response to this question that there is no one unique scientific method that is used across the states in identifying vehicles that are likely to hang-up at hump crossings. The following is the list of responses on this question:

- Nature of types of trucks that use the crossings most of the problem has been with bottom dump grain semi trailers. (SOUTH DAKOTA)
- Complaints of vehicles dragging over RR tracks, report of a vehicle that got hung-up, etc. (MISSOURI)
- Low-boy carriers would be the most common vehicle to high center on a crossing. (ARIZONA)
- They tend to be low-boy type. No formal method in place to identify. (COLORADO)
- Have not done. (VERMONT)
- Low-boy trailers. (ALASKA)
- We look at vertical clearance of the vehicle. (OREGON)
- By typical/generic truck manufacturers' literature. (MASSACHUSETTS)
- Types are not identified. AASHTO green book evaluated types to set standards. (NEVADA)
- We do not. (WISCONSIN)
- Presently based on MUTCD low-bed, furniture van clearance. Working with Pennsylvania Motor Truck Association, American Trucking Association and FRA for better identification. (PENNSYLVANIA)
- Length of vehicle (axles). (UTAH)
- Using a template that was designed using low-boy vehicle clearance measurements. (VIRGINIA)
- Visual inspection of the profile of the roadway. (MINNESOTA)
- Not identified. (NEBRASKA)
- Low clearance vehicles. (NEW YORK)
- We currently do not make this type of identification. (OHIO)
- See what occurs in traffic stream. (WEST VIRGINIA)
- Police officers report. (IDAHO)
- Based upon the approach grade data; usually low-ground-clearance vehicles. (CALIFORNIA)

- Florida statute 316.170 on moving heavy equipment at railroad grade crossings. (FLORIDA)
- NA (ILLINOIS)
- At this point we haven't identified specific vehicles, however, there are vehicles that are prone to these hang-ups such as farm implements, low-boys and low hanging semis. (IOWA)
- Assume low-boy vehicles use crossing. (MAINE)
- We have not instituted any at risk vehicle studies by individual crossing sites. (MICHIGAN)
- Meet at the site to determine the vehicles that use the crossing. (ARKANSAS)

***3.5.7 Question Seven:* - Are the railroad companies involved in solving the hang-up problem?**

Twenty states out of 31 (67 percent) indicated their satisfaction by the railroad companies participation in solving hump crossing problems. Figure 12 shows this distribution. This is opposite to the feeling of county engineers in Kansas, of whom most are not satisfied with the cooperation from the railroad companies.

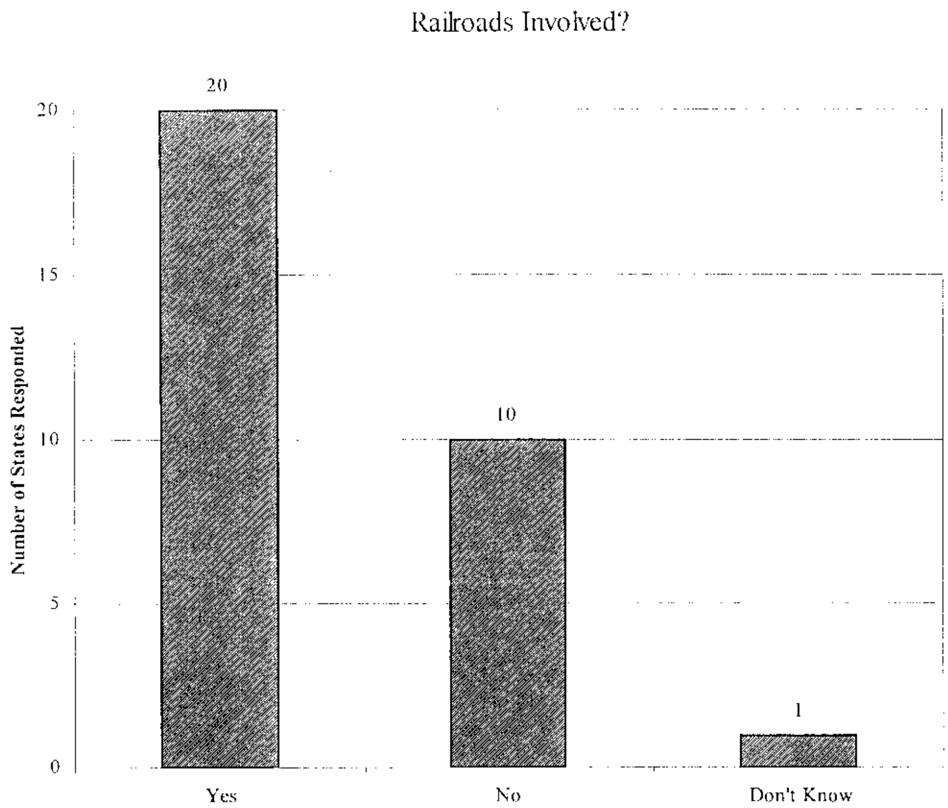

FIGURE 12: Distribution of States on the Participation of Railroad Companies

<u>3.5.8 Question Eight:</u> - Do the highway design manuals used in your state consider the hang-up problem?

Seventeen out of 30 or 57 percent of states responding to this question consider hump crossings in their highway design manuals. Figure 13 shows the distribution of states on the consideration of hump crossings in highway design manuals. Further analysis of the responses in this question and follow-ups, revealed that most of the states that consider hump crossings in highway design manuals, also adopt the AREA/AASHTO guidelines as it is or with some modifications.

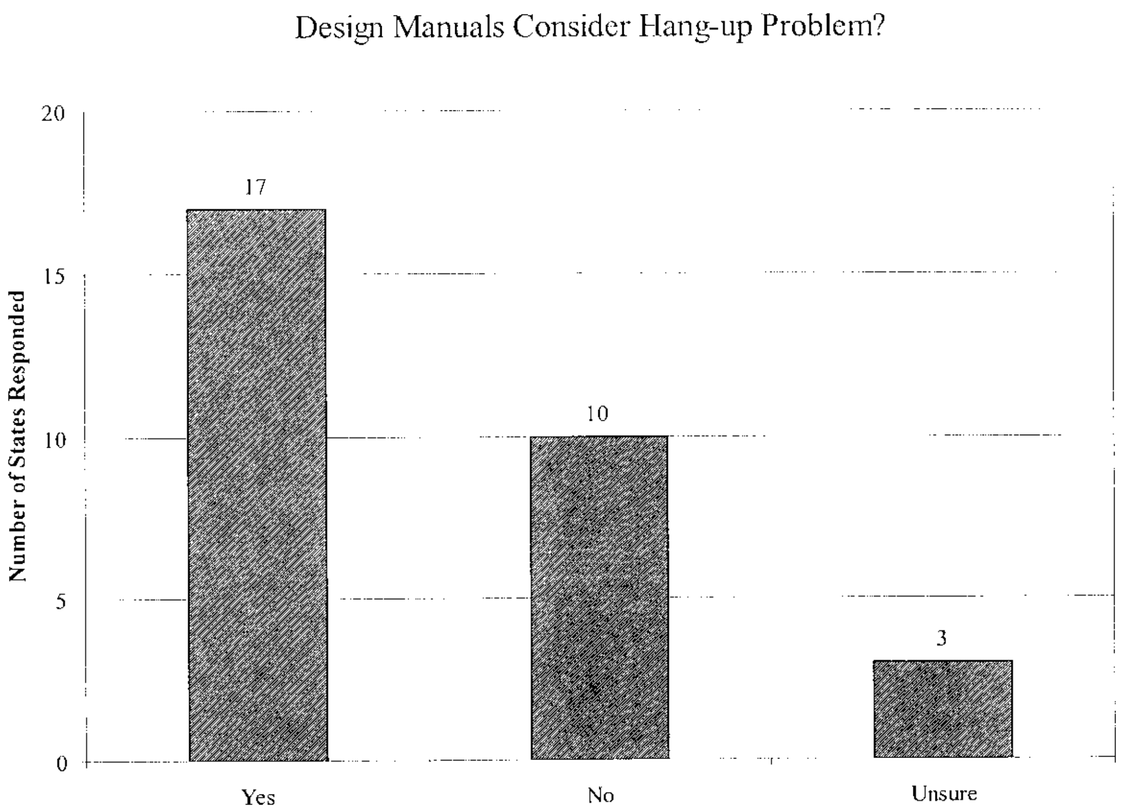

FIGURE 13: Distribution of States on the Hump Crossing Consideration at Design Stage

3.5.8.1 Comments:

- On state routes. (MISSOURI)
- Our design manuals being redone; not sure status of new. (LOUISIANA)
- Other than that provided in the Green book (AASHTO Design Policy). (COLORADO)
- Our state is quite flat. No known incidents. (NORTH DAKOTA)
- Utilize Green book. (OKLAHOMA)
- Don't know, RR requires 100 ft level at crossing approach. (ALASKA)
- Not specifically to crossings, but more of a general highway concern. (OREGON)
- Railroad Safety Section reviews standards with designer before project. (NEVADA)
- Not formally, but hang-up problems are individually addressed during project field reviews. (PENNSYLVANIA)
- We use the AASHTO Green book and state standards. (WYOMING)

- In the MMUTCD, Minnesota Manual of Uniform Traffic Control Devices on page 813-8, there is a sign W 10-5, which indicates (by showing a low-boy making contact with the crossing surface) a low ground clearance crossing. This was recently added to the manual (1- 97). We need to add this sign to our inventory database in order to track these signs. We also need to pass this on to the county engineers around the state. (MINNESOTA)
- Profiles of railroad crossings are considered in depth. (NEBRASKA)
- Unsure. (OHIO)
- Fifty foot approach not to exceed 27 percent grade. (IDAHO)
- Current design manual does not specifically address Railroad crossings. Currently use AREMA standards. (MAINE)
- On state-funded projects, crossing approaches designed to AASHTO standards (6 inch change vertically in 30 feet). (MICHIGAN)

3.5.9 Question Ten: - Would you like a copy of the results of this?

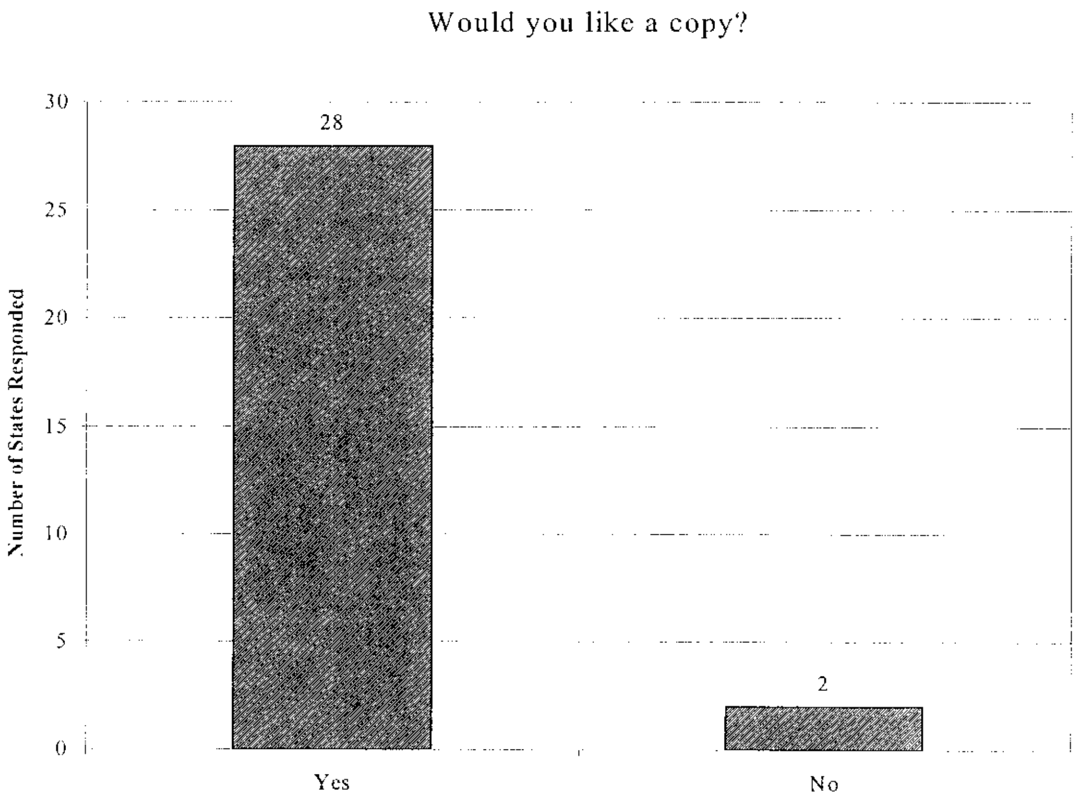

FIGURE 14: Distribution of States on the Desire to Get a Copy

Overwhelming majority of states, i.e., 28 out of 30 or 93 percent were interested to have a copy of the questionnaire responses. This might be the indication of the interest of most states in this area of hump crossing identification. Figure 14 shows this distribution.

3.5.10 Question Eleven: - General Comments:

The following is the list of general comments as given by responding states some edited for better comprehension:

- You should fax this questionnaire to the Missouri Department of Economic Development/Division of Motor Carrier & Railroad Safety. They are the regulatory authority in Missouri they maintain the database. (MISSOURI)
- It is the responsibility of the driver to determine if his vehicle will clear the tracks. (ARIZONA)
- Many Louisiana roads near railroads go back many years. Rail crossing often pose a poor profile. I think trucks can only be allowed to cross railroads. (LOUISIANA)
- You may wish to contact BNSF or CP railroads for additional comments. (NORTH DAKOTA)
- Rather than having a state-by-state effort, states should work with the FRA to create a national plan/procedure to address "Hump Crossings." (PENNSYLVANIA)
- This is a new field. There is no database information available. But we need to get and identify these crossings. The county engineers could help us greatly in this endeavor. I will talk more about this issue. (MINNESOTA)
- Ohio is also starting a pilot program to improve high profile crossings. We are starting with 25 locations in 1999. (OHIO)
- Refer to state law and permit general provisions. (ILLINOIS)
- This is still an emerging area of study for us. (MICHIGAN)
- We realize a need for better data at hump crossings. (ARKANSAS)
- Hawaii does not have any hump crossings. (HAWAII)

Chapter 4

Physical Model

Among different definitions of the word "model" as given in the dictionary, the following is appropriate for the context of this study: *A model is a simplified version of something complex, used for example, to analyze and solve problems or make predictions*. The model can take two forms: i.e., a set of mathematical functions and procedures or a physical representation of the real thing. When the computer is used as a tool, it is referred to as a computer model. This chapter deals with a physical model developed as a tool to find grade crossings with hang-up potential. The next chapter will discuss a computer model that can be used for the same purpose.

4.1 Demand for the Physical Model

There are several reasons for incorporating a physical model in this study as briefly described in the following subsections.

4.1.1 Nature of the Problem

The nature of the hump crossing problem can be associated with the risk of loss of human life and loss of property and associated legal liability. In such circumstances the problem should be carefully analyzed. The physical model is considered one of the tools that can be used for analyzing hump crossings.

Good decision making in engineering depends on both education and field experience. Engineering decisions made in the office about a phenomenon in the field will be based on approximated and limited field information. One factor directly related to identification of a hump crossing is how current the information is in the database. On average, KDOT updates crossing data once every ten years. If the evaluation of the crossing is done in the office alone, there is a probability that the information on the crossing in the database does not reflect the current field conditions, and therefore the decision might be inappropriate. Limitation of the current (at the time of this study) KDOT grade crossing database for the purpose of hump crossing identification was explained earlier in Section 1.2. Field visits will offer the opportunity to apply professional judgement.

4.1.2 Uses of the Model

The physical model could be used to supplement the computer model to increase the reliability of the decision making process for hump crossing identification, or by itself to check if a specific vehicle is "safe" crossing a specific grade crossing.

4.1.3 Detailed Study

The current version (2.4) of the computer program (HANGUP) will suggest one of three outputs for each combination of wheelbase and clearance: 1) "Hangup," 2) "Safe" and 3) "More detailed study warranted." It is understood that the "more detailed study warranted" is the borderline case between "hangup" and "safe." The physical model could be a very useful tool in checking out this grey area.

4.1.4 Represent a Variable Vehicle

Verification for a potential hang-up in the real world would require driving a real vehicle over the crossing. Such practice could be expensive for the following reasons: 1) the requirement to coordinate with the railway company to ensure that there will be no trains during the exercise; 2) in case the vehicle hangs-up, special equipment may be needed to remove it; 3) a vehicle needs to be in its maximum loaded state; and 4) where more than one vehicle is needed, it would turn out to be a difficult or lengthy exercise. A single well-designed physical model can easily solve all these problems.

4.2 Development and Features: Overview

The model was developed by the research team with advice from the steering committee. The development of the model was based on the following desirable characteristics:

- Compatibility with the HANGUP computer model;
- Easy to assemble, dismantle, and transport; and
- Compatibility with a range of vehicles.

The model represents a vehicle profile in two dimensions (vehicle length or wheel base and vehicle ground clearance). It consists of a triangular beam resting on two wheels at each end. The model has the flexibility of varying the wheel base and the ground clearance. Also the frame has a bottom chord that can be pulled upward at the center to create a bow-like shape observed on some low-boy trailers as explained in section 3.6.

4.3 Details of the Model

The physical model was built from an old, aluminum television (TV) antenna tower, and motorcycle wheels. Wheels of any type or dimension could be substituted to match the dimensions of a specific vehicle's wheels.

The model can be adjusted for various wheel bases up to 30 feet and clearances from close to zero to several inches. The model developed was considered a prototype to subjectively test the concept and was not intended to be a working, final model, i.e., several refinements could be

The figures below show the basic concept. Figure 15 shows an end view of the 30-foot model. Figure 16 shows measurements being taken from the prototype model at an abandoned grade crossing in Andover, Kansas.

FIGURE 15: An End View of the Prototype Model

FIGURE 16: Taking Clearance Measurements from the Prototype Model

Figure 17 shows a close up of the model's frame where two sections are connected together. Although bolts and nuts are used here, some system of “quick release” connectors could be substituted. Figure 18 shows the model's three 10-foot sections. These sections and the wheels are relatively quick and easy to assemble and disassemble. If a 40-foot model was desired, another 10-foot section could be easily added. There was not much sag in the 30-foot model; however, the cable and adjustment system could be used to control sag.

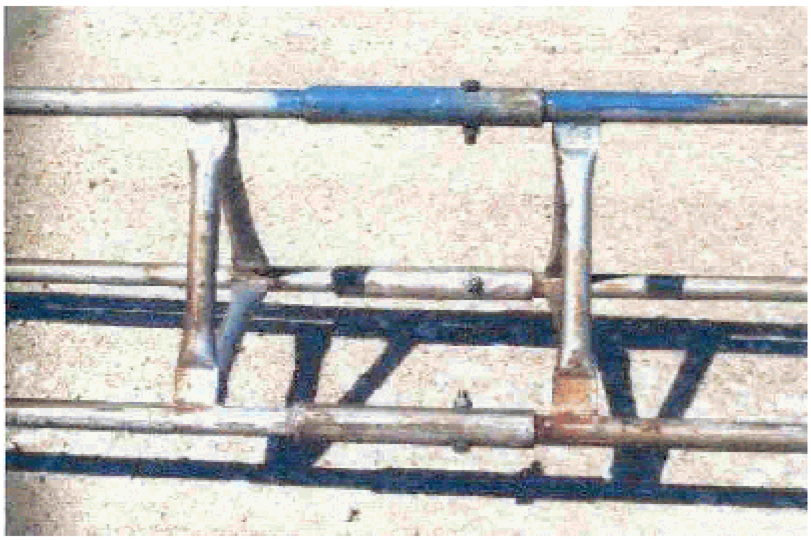

FIGURE 17: A Close Up of the Frame of the Model

FIGURE 18: The Easily Disassembled, Wheels and Three, 10-foot Sections of the Model

Figure 19 shows the disassembled model in the bed of a pickup for transport.

It was concluded that the model could be valuable if a trucker developed it and adjusted it to the dimensions of his vehicle, e.g., a loaded low-boy. It could be carried on the vehicle (either assembled or disassembled) and pushed across any grade crossing where the driver felt that there was a possibility that his vehicle would hang-up. It could also be valuable for checking suspect grade crossings by a crew inspecting grade crossings, i.e., for field checks.

Figure 19: The Model in the Bed of a Pickup for Transport

4.4 Physical Model and Real Vehicle

In this procedure, a physical model or a real vehicle rolls over the crossing and the hang-up potential is assessed. In this case study, both the model and a real vehicle were used at a gravel road grade road crossing on 159th Street in Andover, Kansas, a suburb of Wichita, Kansas. The aim of using both the vehicle and the physical model was to compare the performance of the model. The vehicle (a low-boy) passed over the crossing and ground clearances were recorded. The model was also rolled over the crossing and ground clearances were recorded. It was the intention to compare the two sets of measurements.

4.4.1 Ground Clearances From the Low-Boy Trailer

A low-boy trailer mentioned in Section 3.6 was used. The crossing was non-operational at the time of measurements. This ensured that no train would be using that line during measurements. Ground profile measurements were taken on the southbound approach. The starting point was such that the front wheel of the power unit was aligned with the south rail. The clearances were measured at 2 foot intervals along the bed of the trailer, then the vehicle moved 2 feet before taking the next set of measurements. Measurements were taken on both left and right edges of the trailer.

4.4.2 Ground Clearances From the Physical Model

(Details of the physical model are presented in Chapter 4)

The physical model was pushed over the crossing (159th St. in Andover). These clearances should have been comparable with those obtained from the low-boy trailer's left or inner edge. However, the readings were taken on different days and, unfortunately, the road was regraveled and graded after the low-boy readings were taken. Thus, only an approximate numerical comparison could be made and the readings are not presented in this report. Subjectively, it was concluded that the results based on the model were comparable to those based on the low-boy and were quicker and easier to obtain. If the model parameters are made the same as the trailer, readings should be identical.

Chapter 5

Computer Program HANGUP

This chapter addresses the computer program HANGUP which can be used in the analysis of a railroad grade crossing with respect to the hang-up potential of low ground clearance vehicles. As it was indicated before in Section 2.2.1, HANGUP was the only computer program the authors found documented in the literature. The current version of the program, HANGUP version3.0, a 3-D version, has been developed and the authors obtained a copy. However, numerous attempts over several weeks were unsuccessful in getting the program to run. Attempts to get the developer (West Virginia University) to fix the problem also met with no success. Therefore, the older 2-D version, HANGUP 2.4 was used in this project and will be the only one discussed here.

5.1 Program History

HANGUP is a menu-driven computer program capable of simulating the movement of a vehicle over the crossing in a two-dimensional scenario. HANGUP was developed by Eck and Kang as part of a research project "Low-Clearance Vehicles at Grade Crossings" at West Virginia University between 1990 and 1991 (Eck and Kang 1992). The software will run on IBM-PC compatible microcomputers. Version 2.4 is a two dimensional version that essentially looks at one vertical slice through the grade crossing. Version 3.0 would be similar to version 2.4, except that it would simulate three-dimension scenarios, i.e., a plane surfaces.

5.2 Program Input

Input for the program HANGUP consists of the profile data along a longitudinal line over the grade crossing and the dimensions of the vehicle to be simulated. The profile data includes the location of a series of elevations along a line on the roadway approaches. Usually, either the centerline or wheel track(s), or both, may be chosen. It is suggested that points be no more than 5 feet apart and extend outward 60 feet from the track. Dimensions of the vehicle necessary for the simulation are the wheelbase, the rear and front overhang, the level ground clearance between axles, and the rear and front ground clearances.

5.3 Program Logic

The program computation assumes the bottom of the vehicle is a beam with a span equal to the wheelbase. The vehicle is advanced one step (1-ft) forward, until the whole roadway section (60-ft each side of the track) is covered. For each step, the program calculates the elevation of the beam at one-foot intervals and compares the beam elevation and profile elevation at those particular points. If there are any points where the beam is below profile, the points are displayed on the screen and stored in an array of variables for the report.

5.4 Program Output

The program output is both tabular and graphic and displayed on the screen and/or in computer files. The following is the list of the major output:

1. The profile, shown graphically on the computer monitor. (This is shown in Figure 20.)
2. The profile with potential hang-up points shown on the profile. (This is shown in Figure 21.)

3. A matrix of potential hang up points for a combination of wheel bases from 10-feet to 40-feet and ground clearances from 1 inch to 10 inches. In the matrix, "1's" represent hang-up potential, "0's" represent a safe condition and "*" indicates more study is warranted. (This matrix is shown as Table 2.)

Figure 20 shows a sample profile as it would appear on the monitor.

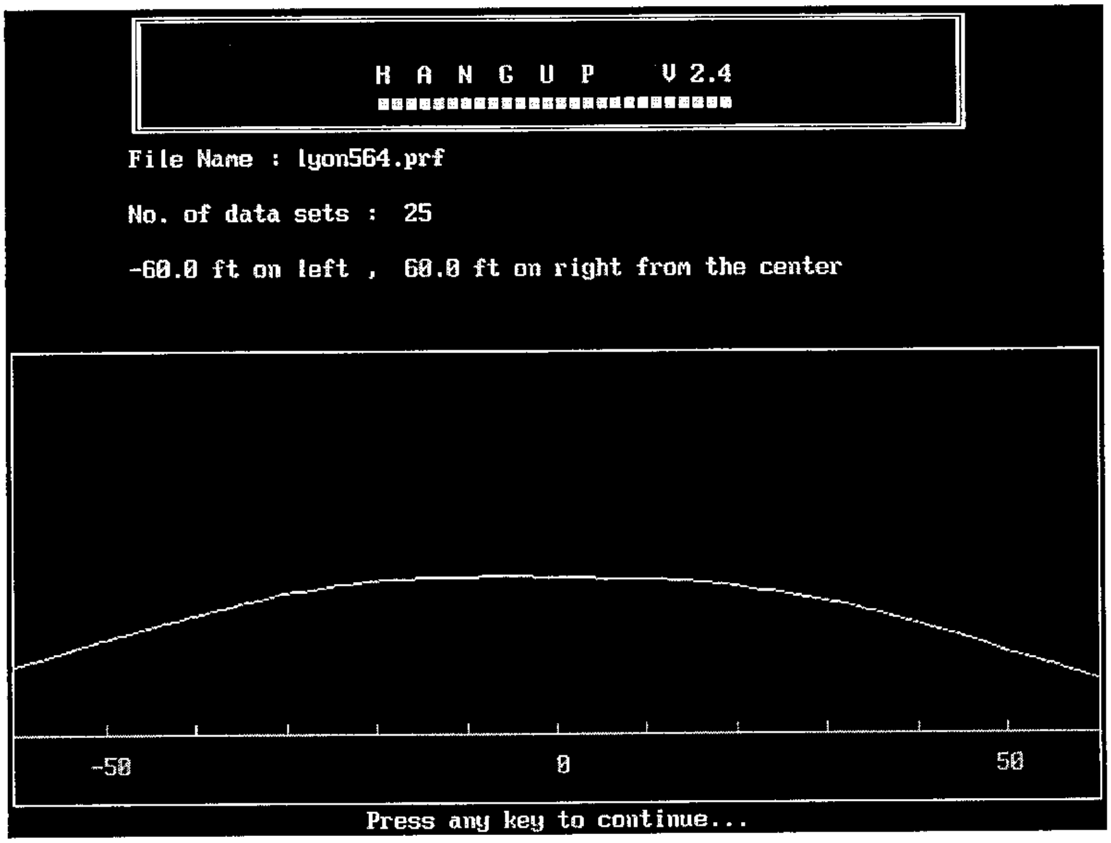

FIGURE 20: Highway Profile as Depicted on the Monitor

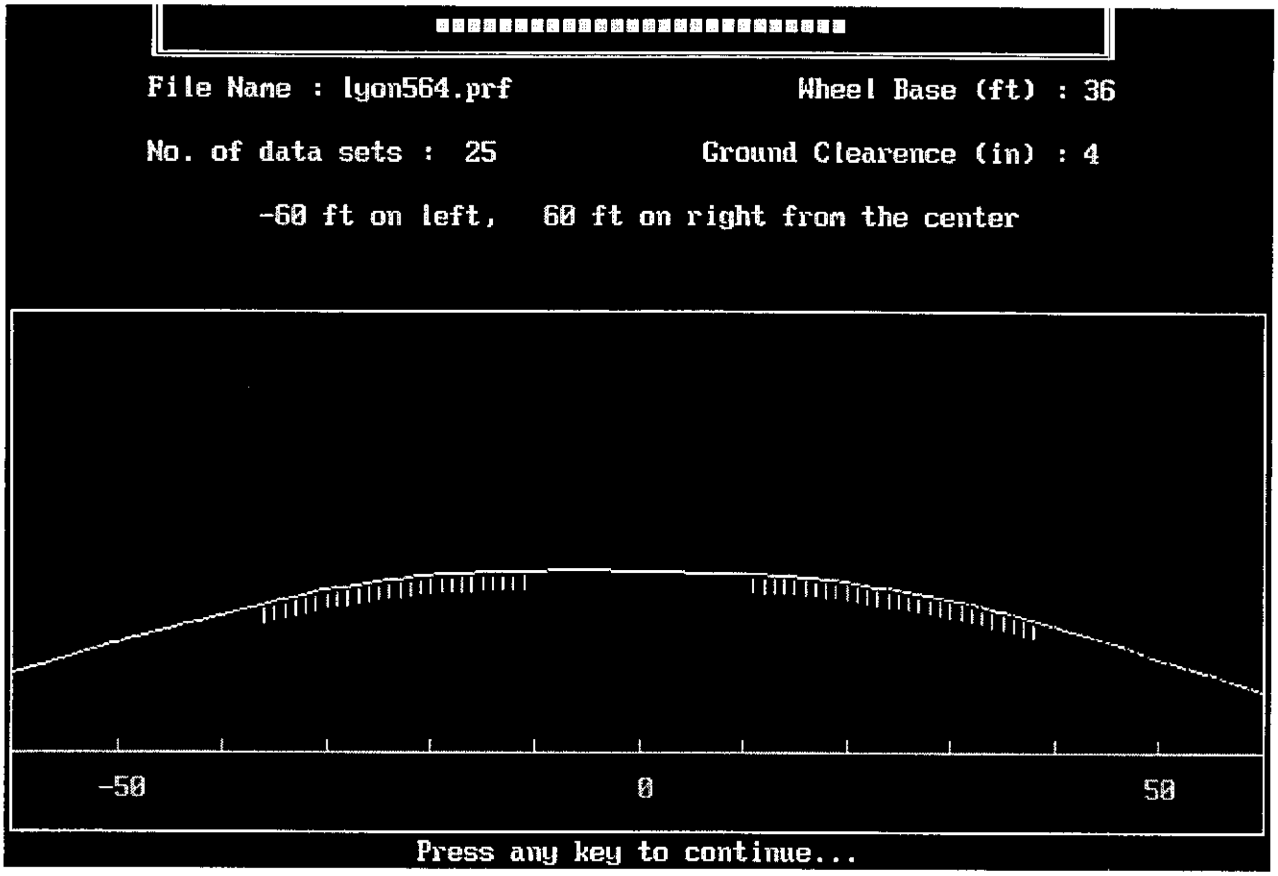

FIGURE 21: Profile With Hang up Positions

TABLE 2: Tabular Output of HANGUP

H A N G U P

File Name : lyon564.prf Date : 10-10-2000

Ground Clearance (in)

Wheel Base	1	2	3	4	5	6	7	8	9	10
10 (ft)	*	0	0	0	0	0	0	0	0	0
11 (ft)	*	0	0	0	0	0	0	0	0	0
12 (ft)	*	*	0	0	0	0	0	0	0	0
13 (ft)	*	*	0	0	0	0	0	0	0	0
14 (ft)	*	*	0	0	0	0	0	0	0	0
15 (ft)	*	*	0	0	0	0	0	0	0	0
16 (ft)	*	*	0	0	0	0	0	0	0	0
17 (ft)	*	*	0	0	0	0	0	0	0	0
18 (ft)	1	*	*	0	0	0	0	0	0	0
19 (ft)	1	*	*	0	0	0	0	0	0	0
20 (ft)	1	*	*	0	0	0	0	0	0	0
21 (ft)	1	*	*	0	0	0	0	0	0	0
22 (ft)	1	*	*	0	0	0	0	0	0	0
23 (ft)	1	*	*	0	0	0	0	0	0	0
24 (ft)	1	1	*	*	0	0	0	0	0	0
25 (ft)	1	1	*	*	0	0	0	0	0	0
26 (ft)	1	1	*	*	0	0	0	0	0	0
27 (ft)	1	1	*	*	0	0	0	0	0	0
28 (ft)	1	1	1	*	*	0	0	0	0	0
29 (ft)	1	1	1	*	*	0	0	0	0	0
30 (ft)	1	1	1	*	*	0	0	0	0	0
31 (ft)	1	1	1	*	*	0	0	0	0	0
32 (ft)	1	1	1	*	*	0	0	0	0	0
33 (ft)	1	1	1	1	*	*	0	0	0	0
34 (ft)	1	1	1	1	*	*	0	0	0	0
35 (ft)	1	1	1	1	*	*	0	0	0	0
36 (ft)	1	1	1	1	1	*	*	0	0	0
37 (ft)	1	1	1	1	1	*	*	0	0	0
38 (ft)	1	1	1	1	1	*	*	0	0	0
39 (ft)	1	1	1	1	1	*	*	0	0	0
40 (ft)	1	1	1	1	1	1	*	*	0	0

1 -> "Hangup", 0 -> "Safe"

* -> "More Detailed Study Warranted"

Hangup Potential for Combination of Wheelbase and Clearance

5.5 Simulation

Simulation of the passage of a vehicle over the railroad crossing is a two stage process: entering profile data and vehicle measurements, and running the program.

5.5.1 Profile Data Collection

Profile data can be obtained from the plan/profile drawings from the highway agency responsible for the grade crossing. If the plan/profile information is not available, as is usually the case, the user can collect the data in the field using conventional surveying methods. A common way of collecting profile information is to set the middle of the two rails as the center point, i.e., zero X-coordinate. Specify the elevations (Y-coordinate) of the roadway surface relative to the elevation of the top rail at even increments, for example 5 feet, along the center line of the highway on both approaches until reaching a relatively flat section of the highway. But in any event, this distance does not need to go beyond 60 feet on either side. Vehicle dimensions could be obtained from manufacturers' specifications, or actual measurement of a specific vehicle.

5.5.2 Running the Program

With the HANGUP software, one can determine the vehicle measurements that will cause a hang-up problem at a given crossing or one can investigate whether a given vehicle will be hung-up at a given crossing. Once the profile data is created and specified, the user is able to simulate one vehicle of given dimensions ("Manual Mode") and obtain output as shown in Figure 21 and/or simulate many vehicles of different combinations of wheelbase and clearance ("Automatic Mode") and obtain output as shown in Table 2. These are among the main menu choices. The "Manual Mode" menu allows the operator to input vehicle dimensions in an interactive fashion. The "Automatic Mode" simulates a total number of 310 vehicle wheelbase and clearance combinations, i.e., 31 levels of wheel base (10 to 40-ft an interval of 1-ft) and 10 levels of clearance (1 to 10-ft at an interval of 1-ft).

5.6 Program Limitations

The program has the following major limitations:

1) The version available to the authors (v.2.4) can only simulate a two-dimensional scenario.

2) It does not take into consideration vehicle dynamic factors such as vehicle approach speed, deflection of vehicle bed due to loading, and vehicle suspension system response.

3) Because it is limited to two-dimensional analysis, it will not be accurate at a crossing where the cross section of the intersecting road is not level, such as where the railroad is on curve and usually superelevated. On an unsurfaced road, i.e., gravel, earth, etc., no single vertical section will give the true condition of the crossing. (However, several sections can be run if several lines of elevation data were available, which would eliminate this limitation, albeit it could be time consuming.)

4) Under the "Automatic Mode" option, given a crossing, the program will suggest one of the three outputs for each combination of wheelbase and clearance. The three outputs are 1) "Hangup," 2) "Safe" and 3) "more detailed study warranted" as depicted in Table 2. It is understood that the "more detailed study warranted" is a borderline case between "hangup" and "safe." This borderline case implies that the available ground clearance is greater than zero, but less than a preset threshold value. The program does not take into consideration the type and maintenance level of the intersecting road when deciding the borderline case. For example, a 1-inch clearance on a paved road might not pose a hang-up threat as it might on an unpaved road surface.

5) An analyst should be able to provide the highway profile that will accommodate a given vehicle. This has to be done by trial and error.

6) Under the "Automatic Mode," vehicles that could be simulated cannot have clearance of more than 10 inches or wheelbase of more than 40 feet.

7) Under the "Manual Mode," when specifying vehicle measurements, the program accepts only integer values. Rounding off the value for the wheelbase might not make a big difference on the results, but it might for the clearance. One-half inch in the clearance could change the case "safe" to "hangup."

8) The "Print Outputs" option on the main menu is misleading when the program is run under "Manual Mode." The print output has the same format as that for "Automatic Mode," i.e., similar to Table 2. Table 3 summarizes the observed results of the "Print Output" option under the "Manual Mode" simulation. The output can be misleading for two reasons: 1) Getting results for more than one wheel base, clearance combination is irrelevant, because the user specified only one combination (vehicle); and 2) For the case of a vehicle being out of range, where all vehicles within the range are shown to trace the crossing safety, a wrong decision could be made on an out of range vehicle.

TABLE 3: Behavior of Print Output Results under Manual Mode Simulation

Vehicle Dimensions	Case	Results
Within the range of "Automatic Mode" simulation: 10 ft ≤ Wheel base ≤ 40 ft. 1 in. ≤ Clearance ≤ 10 in.	Hang-up as reflected on the computer monitor and "Automatic Mode" simulation	Same print out as that under "Automatic Mode"
	Detailed study warranted as depicted under "Automatic Mode" simulation	Same print out as that under "Automatic Mode"
	No hang-up as reflected on the computer monitor and "Automatic Mode" simulation	No hang-up for all vehicles within the range
Out of range of "Automatic Mode" simulation: 40 ft ≤ Wheel base ≤ 10 ft. 10 in. ≤ Clearance ≤ 1 in.	Hang-up as reflected on the computer monitor	No hang-up for all vehicles within the range
	No hang-up as reflected on the monitor	No hang-up for all vehicles within the range

5.7 Field Studies

Typical critical vehicle measurements were determined from the literature and measurements. Data on the vertical profile of several grade crossings in Lyon County was obtained. The following sections describe how this data was used in developing case studies to determine if these crossings would hang-up a typical vehicle.

5.7.1 Critical Vehicles

School buses, low-boy trailers and cattle trailers were identified and proposed as possible critical vehicles using Kansas highways. Typical measurements for these vehicles are shown in Table 4.

TABLE 4: Measurements of Critical Vehicles

Vehicle Type	Wheel Base (ft)	Ground Clearance (in.)
School Bus	21	22
Cattle Trailer	37	12.5
Low-Boy Trailer	33	11.17 - 13.91[a]

[a]The bottom surface of the trailer bed when empty has a bow-like shape curving downward from the center.

The field protocol involved collecting profile data on 16 grade crossings in Lyon County that had steep approach grades, as determined from the KDOT database.

5.7.2 Application of Hangup to Several Lyon County Crossing

The field work required is a measurement of the profile of the highway approaches and a measurement of a critical vehicle. These measurements become the input for the computer program HANGUP. Details of the computer program HANGUP are presented in Chapter 5. The field profile measurement was necessary because the program required more precise measurements than those that could be derived from the state grade crossing database that existed during this study. The deficiency of this database for hump crossing identification was mentioned earlier in Section 1.2.

In this case study, sixteen crossings in Lyon County were selected on the basis of steep highway approach grades as indicated in the crossing database. The assumption was that steep approaches are an indication of potential hump crossings. The elevations of these highway approaches were measured in relation to the elevation of the top of the rail by the conventional rod and level method. The elevations were measured at intervals of five feet on both roadway approach center lines. Appendix B shows profile data of the highway approaches for these crossings.

Passes by the three critical vehicles whose dimensions are specified in Table 4 above were simulated using the computer program HANGUP v.2.4. This exercise resulted into 48 runs, i.e., three vehicles times sixteen crossings. Table 5 summarizes the results of these runs. The field data and plots showing the positions of hang-up points for the hang-up cases are presented in Appendix B. Based on the results of these simulations, many crossings initially thought to be a potential hang-up threat were not. This case demonstrates that a method of screening crossings based on database entries can be misleading. Crossings chosen as potential hang-up candidates using the database should be verified using computer simulations.

TABLE 5: Summary of Simulation Results of the 16 Grade Crossings Using HANGUP 2.4

Lyon County Crossing Identification Number	Result of Simulation		
	Low-boy Trailer	School Bus	Cattle Trailer
567	Safe	Safe	Safe
566	Hangup[a]	Safe	Hangup[a]
565	Hangup[a]	Safe	Hangup[a]
564	Safe	Safe	Safe
561	Hangup[a]	Safe	Hangup[a]
562	Safe	Safe	Safe
563	Safe	Safe	Safe
503	Safe	Safe	Safe
030	Safe	Safe	Safe
558	Safe	Safe	Safe
036	Safe	Safe	Safe
037	Safe	Safe	Safe
551	Safe	Safe	Safe
553	Safe	Safe	Safe
555	Safe	Safe	Safe
557	Safe	Safe	Safe

[a]See Appendix B for plots generated by HANGUP for these "Hangup" cases.

Most of the crossings above have steep slopes and lead an observer to predict that they might cause a hang-up problem to most low ground clearance vehicles. However, the computer simulation results show that looks can be deceiving. This could be due to the fact that these crossings have double tracks. Double tracks results in a wider crossing which lessens an abrupt change of slope between the two roadway approaches, and hence lessens the hang-up potential, i.e., given two crossings with similar steep slopes, one with a single track and another with double tracks, the single track is more likely to cause hang-up than the double track crossing.

5.7.3 Real Vehicle and Computer Simulation

A crossing in Saline County where it was reported that a cattle trailer was hung-up was used for this case study. Two simulations were carried out. The first simulation was done with vehicle dimensions similar to the vehicle that hung-up on the same crossing. The result was that the simulated vehicle traversed the crossing safety. The second run was done with a range of vehicle dimensions automatically provided in the program HANGUP. ("Automatic Mode" as explained in Section 5.5.2.) Results similar to the first run were observed, i.e., a vehicle with a wheelbase of 37 feet and clearance of 12.5 inches would pass over the crossing safely. With the same wheelbase, a vehicle with a 9 inch clearance would warrant a more detailed study.

The fact that a vehicle with specified wheelbase and clearance hung-up in the real world, but not in the computer simulation was interesting. At this point, we can only speculate the cause of the difference between the two conditions. However, measurements of the crossing were not made at the same time as the hang-up occurred. On most low volume road crossings, conditions and grades can change. Other possibilities are: 1) the hung-up vehicle was loaded but its dimensions were taken when empty; 2) a deficiency in the program that doesn't account for the approach speed or suspension system response; and/or 3) the under-representation of the roadway profile by a two-dimensional computer model (HANGUP v.2.4).

5.8 Updated State Inventory

As this study was being conducted, KDOT let a contract to update the state inventory. Burns & McDonnell got the contract and eventually surveyed all public grade crossings in the state. At each crossing, 60 data items were surveyed and entered into a now data base. Signs and other key features were recorded and the crossings were located with sub-meter accuracy by coordinates, using GPS technology.

As part of the survey they identified a subset of 250 potential hang-up crossings. First, they looked for scratch or gouge marks that might have been caused by a low clearance vehicle scraping bottom. In addition, all crossings with a 9.4 percent or greater approach or departure grade were put in a potential hang-up data set. The 9.4 percent cut off was arbitrarily chosen as a reasonable value. It was noted that only about one-half of the crossings with greater than 9.4 percent slopes had scratches or gouge marks.

On the subset of 250 potential hang-up crossings, profiles were generated for 30.5 meters (100-ft) from the tracks on each approach. Using a rod and level, elevations were taken every 1.5 meters (5-ft) for the first 9 meters (30-ft), every 3 meters (10-ft) thereafter. This was done along three lines; the center line and each edge of pavement or traveled way. This data base is available in an electronic format that can provide input into the computer program HANGUP.

5.9 Recent Kansas Law

In the 2001 session, the Kansas legislature passed a statute that essentially mandated use of the AASHTO's "Green Book" (A Policy on Geometric Design of Highways and Streets.) The text of the statute can be found in Appendix C. Below is a summary of the section from the "Green Book" relating to the vertical alignment of the crossing.

5.9.1 Vertical Alignment

Some of the main points are:

- It is desirable that the intersection (HRI) be as level as possible.
- Vertical curves should be of sufficient length to insure an adequate view of the crossing.
- Acceptable geometrics necessary to prevent "hang-up" of low clearance vehicles would provide the crossing surface at the same plane as the top of the rails for a distance of 2 feet outside of the rails.
- The surface of the highway should be not more than 3 inches higher or lower from the nearest rail at a point 30 feet from the rail (unless superelevation dictates).

Chapter 6

Conclusions and Recommendations

6.1 Conclusion

The following conclusions are based on the results obtained in this study:

- Field visits on crossings where vehicles had hang-up indicate that most of them had highway approaches with profiles that did not appear, subjectively, to be particularly steep. Conversely, some crossings that appeared to be hang-up candidates, due to steep approach grades, were "safe" when analyzed by the computer program HANGUP. This suggests that a driver could easily hang-up where he commits a human error thinking that he can pass over the crossing safely. In most cases, the driver may correctly judge (well in advance) the hang-up potential on a crossing with obvious very steep approaches, and avoid it.
- Hump crossing identification can be made by the computer model (HANGUP) and verified by a field visit. The field visit should assess the road's maintenance level.
- In order to easily use the computer model HANGUP the profile elevations should be retrievable from the crossing database. The state should consider following the method of precisely measuring elevations on the approaches to questionable crossings.
- The physical model could be used as a tool to determine if a vehicle with specific wheelbase and clearance values would be at risk.

6.2 Recommendations

- It is highly recommended that in the future, HANGUP version 3.0 should be used (if available and operational) instead of version 2.4.
- The dimensions of the critical vehicles should be taken when loaded, therefore those given in this report should be used with caution since they were taken when empty.

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Appendix A:
List of Advisory Committee Members

Advisory Committee Members

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George Sugars, Reno County

Mickey Thull, City of Wichita

Michael Welch, Shawnee County

Chip Woods, Lyon County

Appendix B:
High Profile Crossings in Lyon County

Distance From Center	Lyon 030	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	0.055	0.115
10	0.075	0.19
15	0.05	0.19
20	0.045	0.16
25	-0.115	-0.06
30	-0.48	-0.52
35	-0.645	-0.975
40	-0.805	-1.335
45	-1.025	-1.64
50	-1.15	-1.89
55	-1.165	-2.075
60	-1.175	-2.23

All measurements are in feet

Distance From Center	Lyon 036	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.155	-0.02
10	-0.17	-0.09
15	-0.165	-0.105
20	-0.415	-0.215
25	-0.89	-0.3
30	-1.395	-0.355
35	-1.765	-0.46
40	-2.04	-0.68
45	-2.235	-1
50	-2.42	-1.335
55	-2.57	-1.725
60	-2.69	-2.145

All measurements are in feet

Distance From Center	Lyon 037	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.05	-0.235
10	0.11	-0.2
15	0.09	-0.13
20	0.01	-0.235
25	-0.11	-0.465
30	-0.315	-0.64
35	-0.58	-0.775
40	-0.915	-0.935
45	-1.24	-1.1
50	-1.57	-1.38
55	-1.895	-1.725
60	-2.225	-2.13

All measurements are in feet

Distance From Center	Lyon 503	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.275	0.145
10	-0.355	0.055
15	-0.315	-0.155
20	-0.235	-0.32
25	-0.155	-0.585
30	-0.115	-0.83
35	0.035	-1.07
40	0.145	-1.32
45	0.245	-1.56
50	0.355	-1.79
55	0.46	-2.015
60	-0.355	-2.245

All measurements are in feet

Distance From Center	Lyon 551	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.01	-0.055
10	-0.145	0.01
15	-0.48	-0.155
20	-0.925	-0.52
25	-1.44	-1.005
30	-2.01	-1.575
35	-2.515	-2.105
40	-2.99	-2.57
45	-3.45	-2.935
50	-3.94	-3.33
55	-4.445	-3.575
60	-4.96	-3.81

All measurements are in feet

Distance From Center	Lyon 553	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	0.025	-0.065
10	0.185	-0.06
15	0.025	-0.13
20	-0.12	-0.175
25	-0.395	-0.5
30	-0.735	-0.835
35	-1.04	-1.19
40	-1.375	-1.495
45	-1.725	-1.96
50	-2.115	-2.34
55	-2.44	-2.615
60	-2.865	-2.915

All measurements are in feet

Distance From Center	Lyon 555	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.03	-0.06
10	-0.05	-0.08
15	-0.205	-0.185
20	-0.445	-0.325
25	-0.74	-0.55
30	-1.075	-0.815
35	-1.505	-1.1
40	-1.95	-1.425
45	-2.375	-1.775
50	-2.755	-2.105
55	-3.105	-2.435
60	-3.445	-2.79

All measurements are in feet

Distance From Center	Lyon 557	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.015	0
10	-0.05	-0.115
15	-0.265	-0.18
20	-0.61	-0.28
25	-0.9	-0.71
30	-1.095	-1.325
35	-1.275	-1.89
40	-1.425	-2.475
45	-1.56	-2.955
50	-1.82	-3.4
55	-1.965	-3.745
60	-2.115	-4.11

All measurements are in feet

Distance From Center	Lyon 558	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.12	0.16
10	-0.36	0.155
15	-0.465	0.375
20	-0.625	0.475
25	-0.755	0.33
30	-0.845	0.2
35	-1.05	-0.1
40	-1.32	-0.445
45	-1.595	-0.94
50	-1.935	-1.535
55	-2.265	-1.935
60	-2.64	-2.545

All measurements are in feet

Distance From Center	Lyon 561	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	0.085	-0.005
10	0.12	-0.05
15	-0.425	-0.185
20	-0.99	-0.22
25	-1.56	-0.41
30	-2.235	-0.62
35	-2.86	-0.9
40	-3.365	-1.24
45	-4.185	-1.71
50	-4.445	-2.155
55	-4.575	-2.55
60	-4.855	-3

All measurements are in feet

Distance From Center	Lyon 562	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	0.09	-0.125
10	0.165	-0.125
15	-0.08	-0.2
20	-0.455	-0.275
25	-0.95	-0.36
30	-1.515	-0.525
35	-1.965	-0.705
40	-2.415	-0.915
45	-2.86	-1.165
50	-3.245	-1.45
55	-3.615	-1.765
60	-3.885	-2.09

All measurements are in feet

Distance From Center	Lyon 563	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.195	0.087
10	-0.130	0.080
15	-0.305	-0.045
20	-0.475	-0.190
25	-0.790	-0.320
30	-1.265	-0.513
35	-1.855	-0.692
40	-2.575	-0.903
45	-3.265	-1.191
50	-3.945	-1.600
55	-4.560	-2.063
60	-5.150	-2.580

All measurements are in feet

Distance From Center	Lyon 564	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.035	0.062
10	-0.073	0.020
15	-0.127	-0.020
20	-0.304	-0.103
25	-0.600	-0.316
30	-0.873	-0.593
35	-1.275	-0.973
40	-1.735	-1.403
45	-2.220	-1.843
50	-2.790	-2.298
55	-3.290	-2.789
60	-3.833	-3.278

All measurements are in feet

Distance From Center	Lyon 565	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.117	-0.030
10	-0.140	-0.010
15	-0.235	-0.033
20	-0.447	-0.240
25	-1.085	-0.682
30	-1.860	-1.342
35	-2.760	-1.985
40	-3.580	-2.743
45	-4.383	-3.470
50	-5.125	-4.220
55	-5.715	-4.838
60	-6.293	-5.429

All measurements are in feet

Distance From Center	Lyon 566	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	0.048	-0.032
10	0.083	-0.067
15	-0.232	-0.202
20	-0.834	-0.612
25	-1.464	-1.380
30	-2.302	-2.195
35	-3.162	-2.949
40	-4.087	-3.822
45	-4.967	-4.511
50	-5.865	-5.229
55	-6.697	-5.922
60	-7.412	-6.587

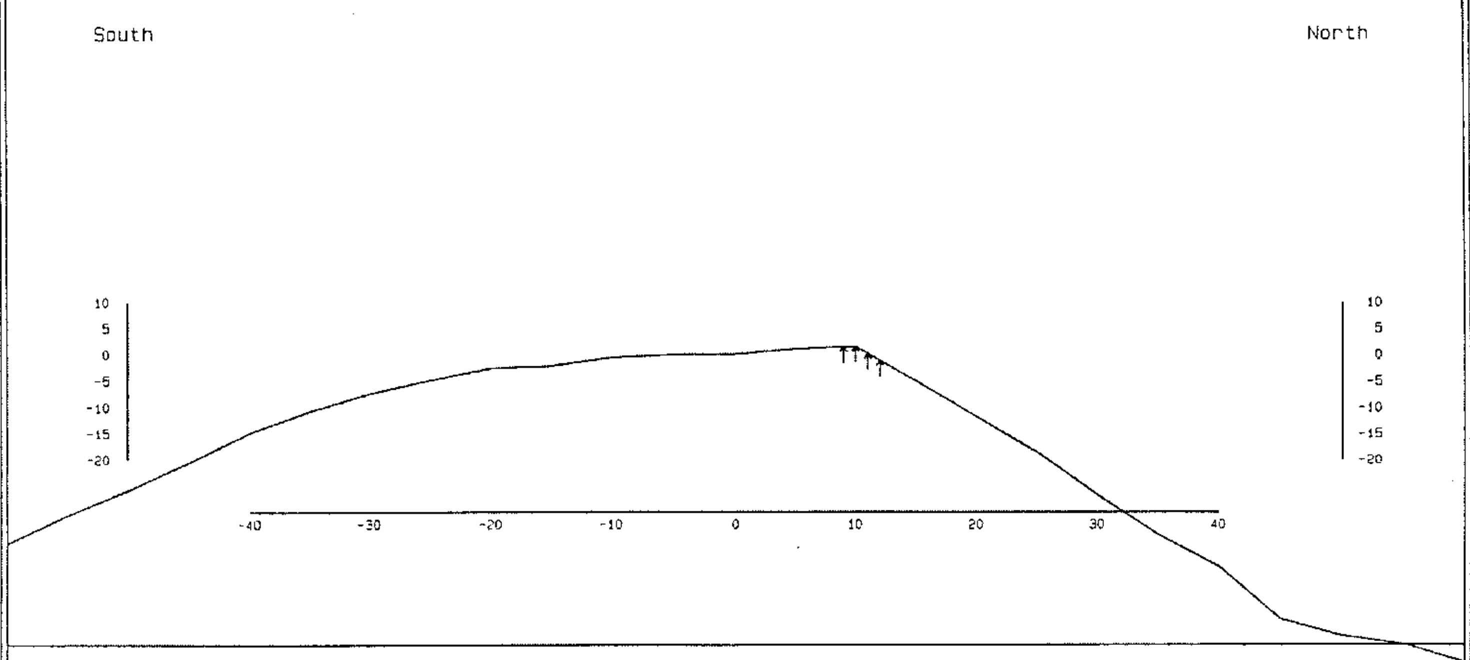
All measurements are in feet

Distance From Center	Lyon 567	
	North Bound Approach Elevation	South Bound Approach Elevation
0	0	0
5	-0.058	0.065
10	-0.180	0.090
15	-0.104	0.080
20	-0.216	0.024
25	-0.758	-0.083
30	-1.246	-0.350
35	-1.684	-0.666
40	-2.195	-1.100
45	-2.666	-1.588
50	-3.124	-2.196
55	-3.550	-2.775
60	-3.913	-3.297

All measurements are in feet

File Name : lyon561.prf
Wheel Base : 33 (ft)
Low Clearance : 11 (in)

Relative Elevation from Center to 30 ft
To Left : -7.45 (in)
To Right : -26.82 (in)

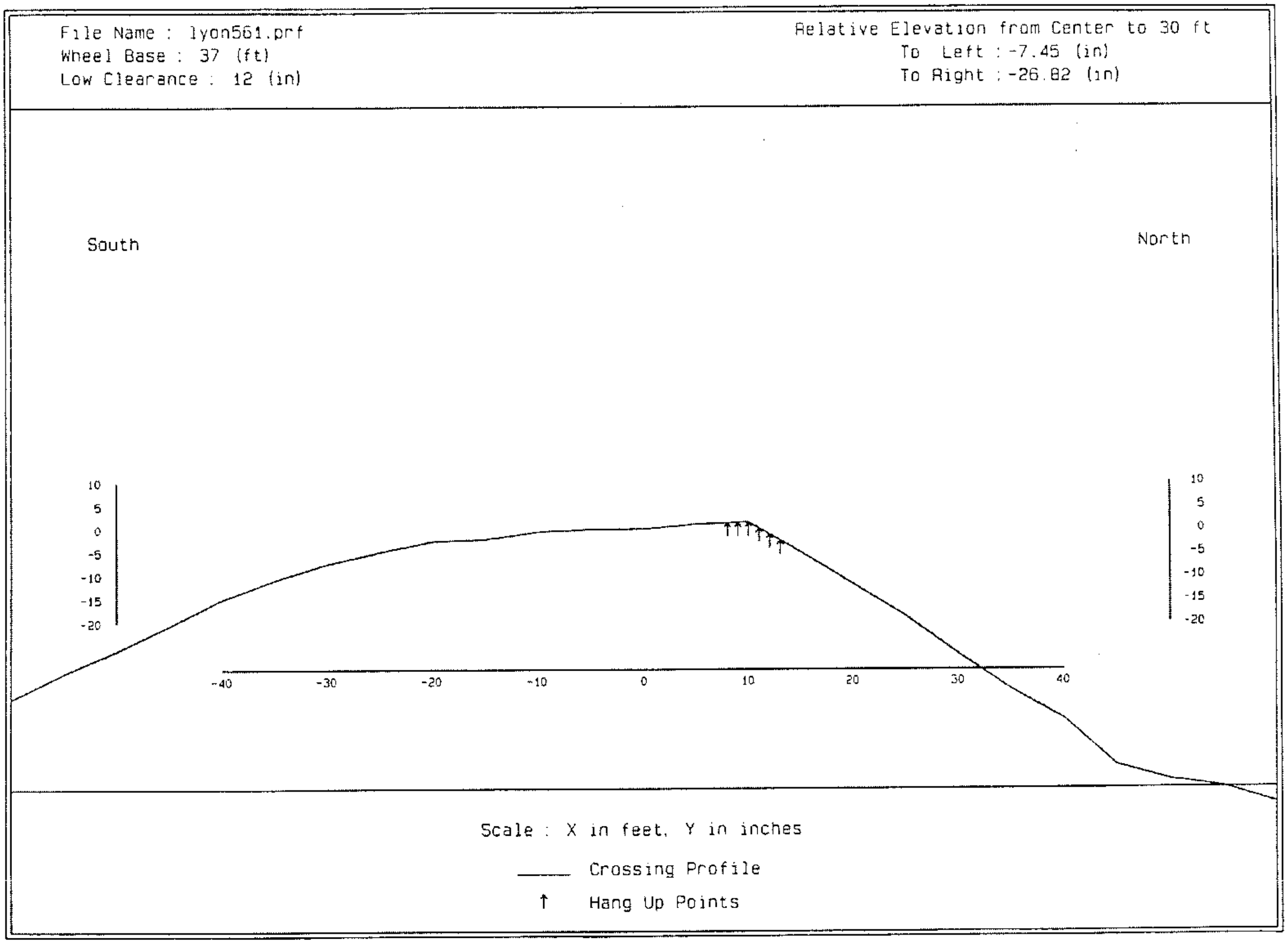


Scale : X in feet, Y in inches

_____ Crossing Profile

↑ Hang Up Points

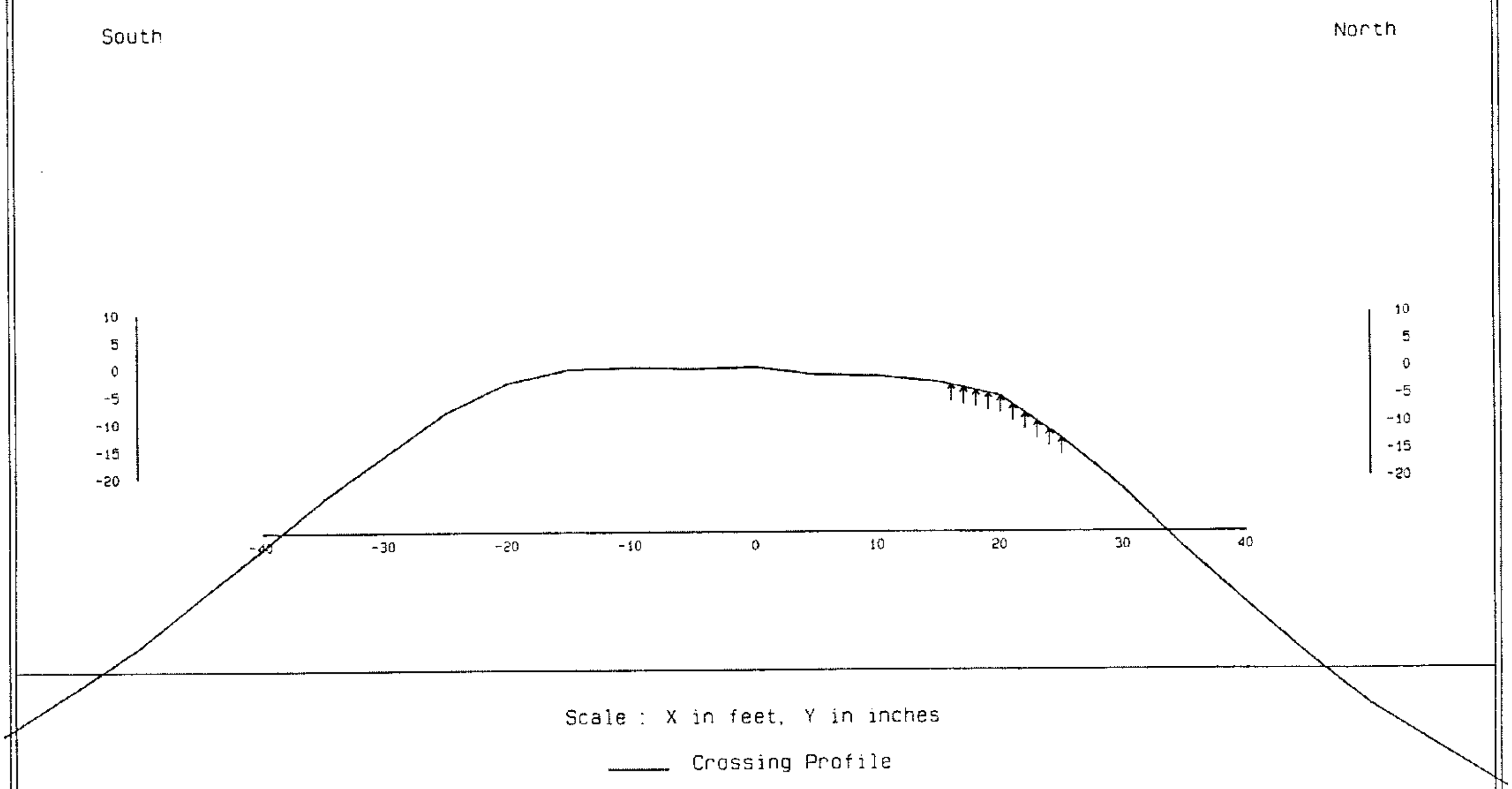
HANGUP Ver 2.4



HANGUP Ver 2.4

File Name : lyon565.prf
Wheel Base : 33 (ft)
Low Clearance : 11 (in)

Relative Elevation from Center to 30 ft
To Left : -16.11 (in)
To Right : -22.32 (in)

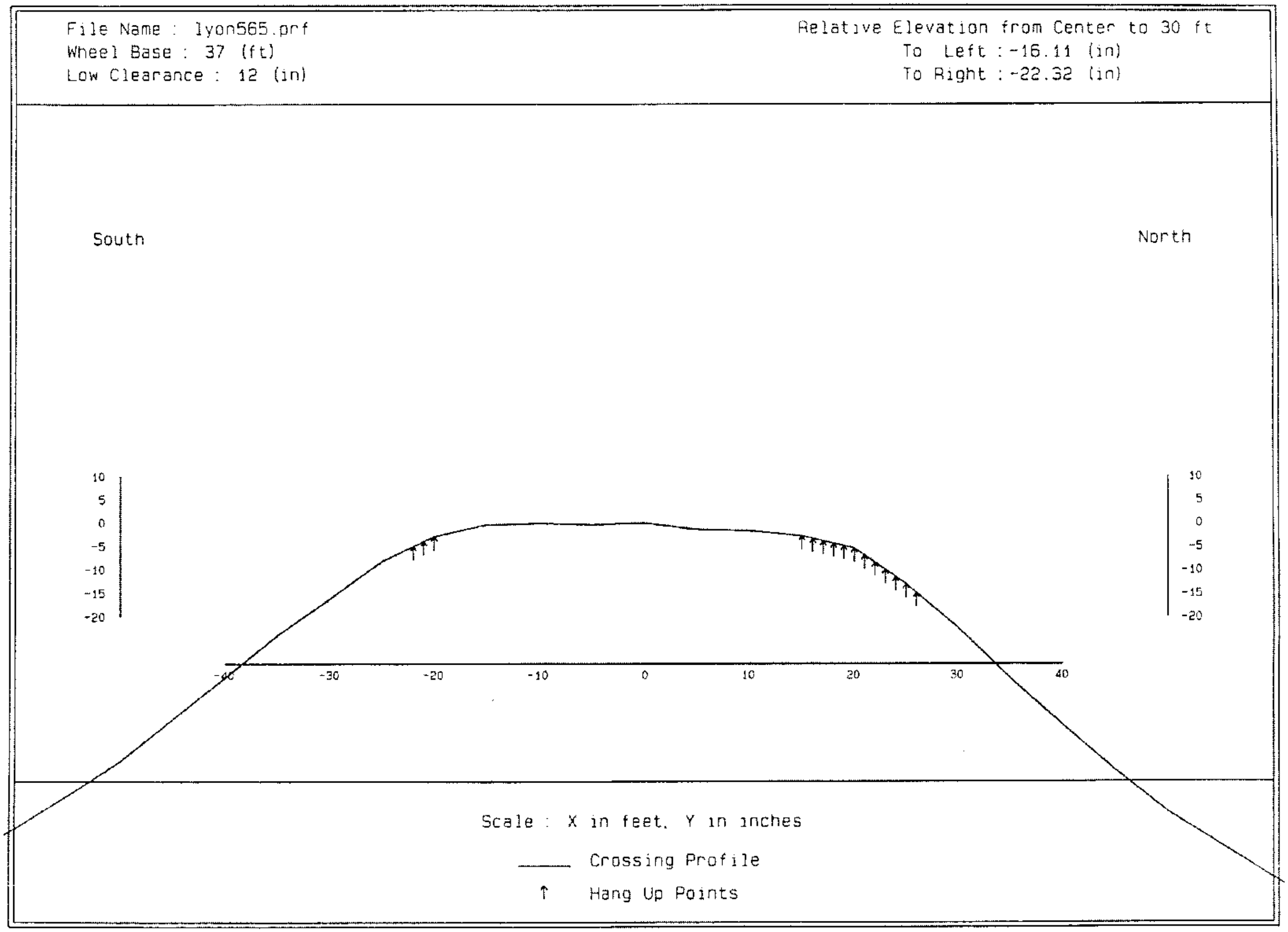


Scale : X in feet, Y in inches

—— Crossing Profile

↑ Hang Up Points

HANGUP Ver 2.4



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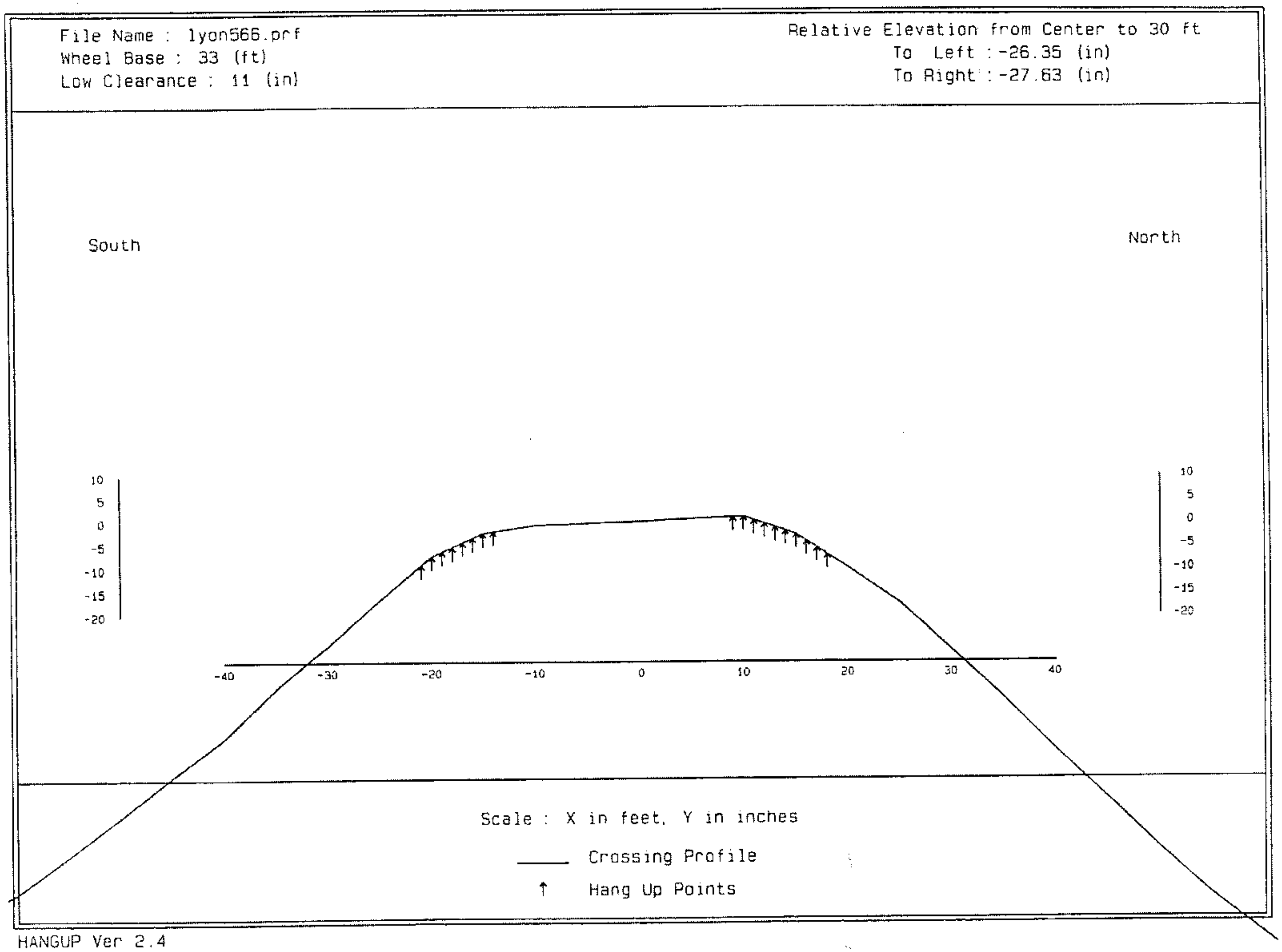
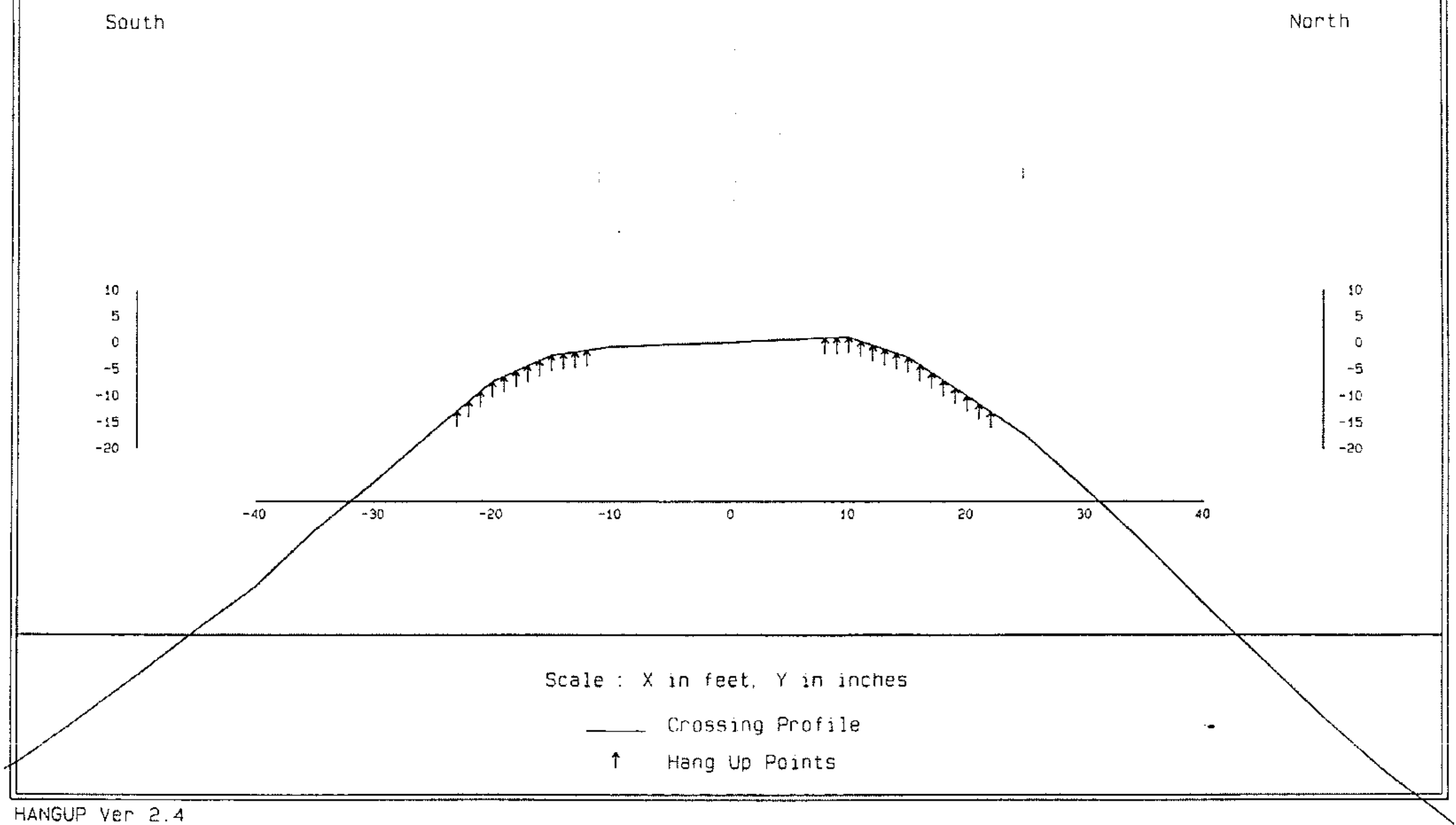

File Name : lyon566.prf
Wheel Base : 33 (ft)
Low Clearance : 11 (in)
Relative Elevation from Center to 30 ft
To Left : -26.35 (in)
To Right : -27.63 (in)
South
North
Scale : X in feet, Y in inches
Crossing Profile
Hang Up Points
HANGUP Ver 2.4

File Name : lyon566.prf
Wheel Base : 37 (ft)
Low Clearance : 12 (in)

Relative Elevation from Center to 30 ft
To Left : -26.35 (in)
To Right : -27.63 (in)



HANGUP Ver 2.4

Appendix C:
Kansas House Bill No. 2045: An Act Relating to Railroad Grade Crossings on County and Township Highways

Railroad-Highway Grade Crossings

A railroad-highway crossing, like any highway-highway intersection, involves either a separation of grades or a crossing at-grade. The geometrics of a highway and structure that involves the overcrossing or undercrossing of a railroad are substantially the same as those for a highway grade separation without ramps.

The horizontal and vertical geometrics of a highway approaching a railroad grade crossing should be constructed in a manner that does divert driver attention to roadway conditions.

Horizontal Alignment

If practical, the highway should intersect the tracks at a right angle with no nearby intersections or driveways. This layout enhances the driver's view of the crossing and tracks, reduces conflicting vehicular movements from crossroads and driveways, and is preferred for bicyclists. To the extent practical, crossings should not be located on either highway or railroad curves. Roadway curvature inhibits a driver's view of a crossing ahead, and a driver's attention may be directed toward negotiating the curve rather than looking for a train. Railroad curvature may inhibit a driver's view down the tracks from both a stopped position at the crossing and on the approach to the crossings. Those crossings that are located on both highway and railroad curves present maintenance problems and poor rideability for highway traffic due to conflicting superelevations.

Where highways that are parallel with main tracks intersect highways that cross the main tracks, there should be sufficient distance between the tracks and the highway intersections to enable highway traffic in all directions to move expeditiously. Where physically restricted areas make it impossible to obtain adequate storage distance between the main track and a highway intersection the following should be considered:

- Interconnection of the highway traffic signals with the grade crossing signals to enable vehicles to clear the grade crossing when a train approaches.
- Placement of a "Do Not Stop on Track" sign on the roadway approach to the grade crossing.

Vertical Alignment

It is desirable from the standpoint of sight distance, rideability, braking, and acceleration distances that the intersection of highway and railroad be made as level as practical. Vertical curves should be of sufficient length to ensure an adequate view of the crossing.

In some instances, the roadway vertical alignment may not meet acceptable geometrics for a given design speed because of restrictive topography or limitations of right-of-way. To prevent drivers of low-clearance vehicles from becoming caught on the tracks, the crossing surface should be at the same plane as the top of the rails for a distance of 0.6 m (2 ft) outside the rails. The surface of the highway should also not be more than 75 mm [3 in] higher or lower than the top of nearest rail at a point 9 m [30 ft] from the rail unless track superelevation makes a different level appropriate, as shown in Exhibit 9-102. Vertical curves should be used to traverse from the highway grade to a level plane at the elevation of the rails, Raj)s that are superelevated, or a roadway approach section that is not level, will necessitate a site specific analysis for rail clearances.

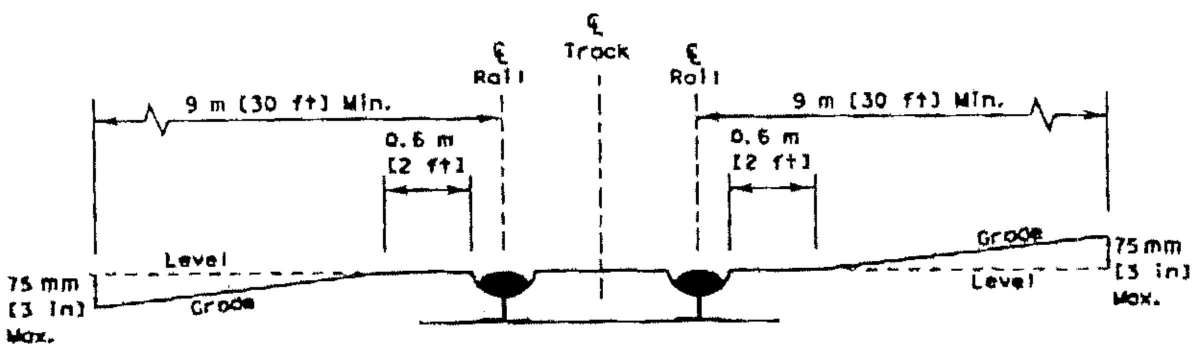


Exhibit 9-102. Railroad-Highway Grade Crossing

General

The geometric design of railroad-highway grade crossings should be made jointly when determining the warning devices to be used. When only passive warning devices such as signs and pavement markings are used, the highway drivers are warned of the crossing location but must determine whether or not there are train movements for which they should stop. On the other hand, when active warning devices such as flashing light signals or automatic gates are used, the driver is given a positive indication of the presence or the approach of a train at the crossings. A large number of significant variables should be considered in determining the type of warning device to be installed at a railroad grade crossing. For certain low-volume highway crossings where adequate sight distance is not available, additional signing may be needed.

Traffic control devices for railroad-highway grade crossings consist primarily of signs, pavement markings, flashing light signals, and automatic gates. Criteria for design, placement, installment, and operation of these devices are covered in the MUTCD (9), as well as the use of various passive warning devices. Some of the considerations for evaluating the need for active warning devices at a grade crossing include the type of highway, volume of vehicular traffic, volume of railroad traffic, maximum speed of the railroad trains, permissible speed of vehicular traffic, volume of pedestrian traffic, crash history, sight distance, and geometrics of the crossing. The potential for complete elimination of grade crossings without active traffic control devices (e.g., closing lightly used crossings and installing active devices at other more heavily used crossings) should be given prime consideration.

HOUSE BILL No. 2045

AN ACT relating to railroads; concerning railroad crossings; amending K.S.A. 66-227 and 66-229 and repealing the existing sections.

Be it enacted by the Legislature of the State of Kansas:

Section 1. K.S.A. 66-227 is hereby amended to read as follows: 66-227. It is hereby made the duty of every person or corporation owning or operating any railroad crossed by a public highway, *county highway or township road* to make, and keep in good repair, good and sufficient crossings for such *highway*, road *or street* over their tracks, including all the grading, bridges, ditches~~,~~ and culverts *within their right-of-way* that may be necessary to make a safe crossing ~~as hereinafter provided. Said crossings shall not be less than twenty-four feet in width on county roads or twenty feet in width on township roads, and shall be on the same grade as the track for thirty feet on each side of the center of said track, unless the board of county commissioners shall find the same to be unnecessary, and the approaches thereto shall not exceed a six percent grade and shall be solidly constructed of the same material throughout, except that next to the rail any suitable material may be used that will prevent the settling against the rails of any material used in said crossing, with no openings or filled spaces therein, except such as is necessary for the rails; and, for railroad crossings, such material shall be wood, gravel, crushed rock, concrete, burned clay or slag at the discretion of said company and of a permanent thickness equal to the height of the railroad rails~~. *The vertical profile or alignment of the centerline of the highway, road or street through the crossing shall comply with the American association of state highway and transportation officials (AASHTO) design manual titled, "a policy on geometric design of highways and streets" as published and in effect on January 1, 2001.*

~~That~~ When the highway crossing the track is improved by the construction of a hard-surfaced road, the railroad company shall pave the space between the rails and for a distance of two feet on each side thereof with a pavement of the same or a better type for the full width of the pavement on the highway. On other crossings where the highway has not been improved, the planking or other material used between and for a distance of one foot outside of the rails shall be of ~~sufficient length to provide for a 16-foot~~ *a length to equal the* roadway *width* measured perpendicular to the axis of the highway~~: *Provided further,* That~~. Nothing in this act shall be construed to repeal any provision of law relating to railroad crossings on streets in cities of the first and second class.

Sec. 2. K.S.A. 66-229 is hereby amended to read as follows: 66-229. *Upon complaint,* it is hereby made the duty of every county engineer and road ~~overseer~~ *supervisor* in this state to see that this act is complied with in ~~his~~ *such person's* jurisdiction~~,~~ and to report to the county attorney of ~~his~~ *such person's* county every failure on the part of any person or corporation to comply with this act~~, and~~. It is hereby made the duty of the county attorney of each county in the state to enforce this act.

Sec. 3. K.S.A. 66-227 and 66-229 are hereby repealed.

Sec. 4. This act shall take effect and be in force from and after its publication in the statute book.

I hereby certify that the above BILL originated in the HOUSE, and passed that body

____

____
Speaker of the House.

____
Chief Clerk of the House.

Passed the SENATE ______________________________

____
President of the Senate.

____
Secretary of the Senate.

APPROVED ____

____
Governor.