TP 13128E

Study of Adding Reflective Materials to Crossing Signs and Posts

Prepared by
Transportation Development Centre
Safety and Security
Transport Canada

Beauchemin - Beaton - Lapointe Inc.
CONSULTING ENGINEERS

2045, Sanley Street, Montréal, Québec, H3A 2V4

Member of Cartier Group Ltd., Certified ISO 9001

November 1997 (revised edition July 1999) CDT 9103

TP 13128E

Study of Adding Reflective Materials to Crossing Signs and Posts

by
Wasi Hanafi

Beauchemin - Beaton - Lapointe Inc.
CONSULTING ENGINEERS

2045, Sanley Street, Montréal, Québec, H3A 2V4

Member of Cartier Group Ltd., Certified ISO 9001

November 1997 (revised edition July 1999) CDT 9103

This report reflects the views of the author and not necessarily those of the Transportation Development Centre.

Since some of the accepted measures are imperial, a combination of both metric and imperial units is used in this report.

The revised edition contains new values in Table 5 on page 16.

Ce document est également disponible en français : «*Étude sur l'application de matériau rétroréfléchissant sur les dispositifs de signalisation des passages à niveau*», TP 13128F.

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 13128E	2. Project No. 9142	3. Recipient's Catalogue No.
4. Title and Subtitle Study of Adding Reflective Materials to Crossing Signs and Posts		5. Publication Date November 1997
		6. Performing Organization Document No.
7. Author(s) Wasi Hanafi		8. Transport Canada File No. ZCD1465-615
9. Performing Organization Name and Address Beauchemin-Beaton-Lapointe Inc. 2045 Stanley Street Montreal, Quebec H3A 2V4		10. PWGSC File No. XSD93-00060-671
		11. PWGSC or Transport Canada Contract No. T8200-33512
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 800 René Lévesque Blvd. West 6th Floor Montreal, Quebec H3B 1X9		13. Type of Publication and Period Covered Final
		14. Project Officer J.-L. René

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

More than half of all accidents in Canada occur at non-automated crossings. There is an urgent need for low-cost and cost-effective warning devices at these crossings. In response, several American states have installed high-performance retroreflective strips on crossing posts and signs. The system has proven effective in improving safety at passive crossings, and the U.S. Federal Highway Administration (FHWA) recommends the use of retroreflective material on crossing signs and posts at passive crossings throughout the U.S.

The use of retroreflective material in Canada should be equally effective and could significantly reduce nighttime accidents, resulting in substantial potential saving in accidents. The system would be low-cost and cost-effective.

Research will be necessary to identify the most effective configuration for adoption as a Canadian standard. Pending further research, the use of a four-inch wide strip on the front and the back of the crossing sign on the full length of each blade and on the front and the back of the sign post on the full length of each post is recommended. The retroreflective material should be a high-performance, prismatic-type sheeting or its equivalent.

17. Key Words Passive crossing, non-automated crossing, Canadian standard, crossing sign, crossbuck, reflectorization, retroreflective material, prismatic-type reflective material	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages viii, 42, apps	23. Price —

Transports Canada / Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 13128E	2. N° de l'étude 9142	3. N° de catalogue du destinataire
4. Titre et sous-titre Study of Adding Reflective Materials to Crossing Signs and Posts		5. Date de la publication Novembre 1997 6. N° de document de l'organisme exécutant
7. Auteur(s) Wasi Hanafi		8. N° de dossier - Transports Canada ZCD1465-615
9. Nom et adresse de l'organisme exécutant Beauchemin-Beaton-Lapointe Inc. 2045, rue Stanley Montréal, Québec H3A 2V4		10. N° de dossier - TPSGC XSD93-00060-671 11. N° de contrat - TPSGC ou Transports Canada T8200-33512
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 800, boul. René-Lévesque Ouest 6e étage Montréal (Québec) H3B 1X9		13. Genre de publication et période visée Final 14. Agent de projet J.-L. René

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

16. Résumé

Au Canada, plus de la moitié des accidents rail-route se produisent à des passages à niveau non protégés par des systèmes automatiques. Le besoin de dispositifs d'avertissement efficaces et peu coûteux à ces passages à niveau est donc pressant. Devant le même problème, plusieurs États américains ont eu recours à des matériaux rétroréfléchissants haute performance, appliqués sur le dispositif de signalisation même et sur le poteau auquel il est fixé. Cette solution s'est avérée efficace, et la U.S. Federal Highway Administration (FHWA) recommande qu'elle soit adoptée par tous les États.

Cette mesure serait avantageuse au Canada également. Elle permettrait de réduire considérablement le nombre d'accidents survenant la nuit à ces passages à niveau, de même que les coûts qui leur sont associés. Et ce, pour un investissement peu élevé et rapidement recouvré.

Il faudra faire une étude pour déterminer quelle configuration adopter comme norme canadienne. D'ici à ce que cette étude soit achevée, il est recommandé d'utiliser une bande de matériau rétroréfléchissant de quatre pouces de largeur, appliquée à l'avant et à l'arrière de chacune des deux pièces de la croix et sur leur pleine longueur, ainsi qu'à l'avant et à l'arrière du poteau et sur toute sa longueur. On choisira un matériau de type prismatique et à haute performance, ou l'équivalent.

17. Mots clés Passages à niveau non protégés, passages à niveau non protégés par un sytème automatique, norme canadienne, dispositif de signalisation de passage à niveau, croix d'avertissement, réflectorisation, matériau rétroréfléchissant, matériau réfléchissant de type prismatique	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication) Non classifiée	20. Classification de sécurité (de cette page) Non classifiée	21. Déclassification (date) —	22. Nombre de pages viii, 42, ann.	23. Prix —

CDT/TDC 79-005
Rev. 96

Canada

SUMMARY

More than half of all accidents in Canada occur at non-automated crossings. There is an urgent need for low-cost and cost-effective warning devices at these crossings. For this purpose, several jurisdictions in the United States have installed high-performance retroreflective material to the front and the back of the crossing post and sign at non-automated crossings.

The purpose of this study is to learn from the American experience and to generate input for development of a standard for a uniform application across Canada.

Eight different configurations are in use in the US. The most common configuration adds two-inch wide white retroreflective strip to the front and the back of the posts on the full length of each post and uses double-sided retroreflective crossing signs. The double-sided crossing sign uses retroreflective material on both sides of the sign blades on the full length and width of each blade. Table 2 summarizes the configurations in use in the United States.

Addition of high-performance retroreflective material on the front and the back of the crossing post and sign improves nighttime safety at passive crossings. The bright crossing posts and signs at night alert drivers to the presence of the passive crossing as they approach the crossing with increased awareness of the likely hazard. The retroreflective material on the back of the post and the sign, under appropriate conditions, helps the motorists detect the train in the crossing due, either to disappearance from view of the left sign and post or, the flicker effect produced by passage of the train across the crossing.

A new grade-crossing standard has been adopted by the Federal Highway Administration (FHWA) in the US. It recommends the use of retroreflective material on crossing signs and posts at passive crossings. The FHWA recommends the use of white reflective strips, not less than two-inches wide, on the front and the back of the post on the full length of each post and on the back of the crossing sign blades on the full length of each blade. As a result of the FHWA recommendation, the use of retroreflective material on the crossing post and sign at passive crossings, is likely to become a universal practice in the US

Use of retroreflective material on the crossing signs and posts should be beneficial in Canada as well. If the system is fully implemented, it could reduce the nighttime accidents at passive crossings by as much as 60%, resulting in a possible saving of as much as five million dollars annually in cost of accidents and fatalities. At this rate of saving, the investment in adding the retroreflective material to the passive crossings across Canada could be recovered in two years. The monetary benefits from savings in accidents exceed the cost by a wide margin. Use of high-performance retroreflective material on the crossing sign and post should therefore be adopted as a standard practice.

Several options are possible for adding retroreflective material to the posts and the sign at the passive crossings. These are:

- 5 cm wide strip on the front and back of each post and 5 cm wide strip on the back of each blade of the crossbuck;
- 5 cm wide strip on the front and back of each post and 10 cm wide strip on the back of each blade of the crossbuck; and,

- 10 cm wide strip on the front and back of each post and 10 cm wide strip on the back of each blade of the crossbuck.

The costs of these options vary, as shown in Table 3. Their effectiveness might vary also. Further research will be necessary to identify the optimum and/or the most effective option. If further research is not practical, the configuration using the *10 cm wide strip on the post and the crossbuck blades should be adopted.*

Research is also recommended to select the most suitable type of retroreflective material for adoption as a Canadian Standard appropriate to the location of the crossing and the approach road geometry. The materials, nevertheless, should be of the high-performance prismatic type.

A Canadian Standard should specify high-performance retroreflective material on both the crossing post and crossbuck. For integrity of the system therefore, it will be necessary to replace the existing crossbucks, which have a high-intensity material on the front face, by a new sign. The existing crossbucks are old and are not very bright under low headlight beam conditions. However, if it is desired to retain the existing signs, as an intermediate step in implementation of the full Canadian Standard, the implication of this process for safety and the long-term financial benefits should be studied.

Two states, Ohio and Idaho, attach shields to the posts in addition to the retroreflective strips. The shields have coloured retroreflective stripes arranged diagonally on the front and on the back. The value of the shield in addition to the retroreflective strips on the posts, in improving nighttime safety, is not clear.

A research is in progress in the State of Ohio on the benefits of the shield for the nighttime and the daytime safety. The results of the research, when available, should be carefully studied and if the benefits of the shield are established by the research, the use of the shield should be considered in Canada.

TABLE OF CONTENTS

List of appendices

List of tables

List of exhibits

1 INTRODUCTION

There are nearly 16,200 non-automated or passive public crossings in Canada. From 1993 to 1995, 432 accidents occurred at these crossings, resulting in 84 injuries and 73 deaths. Of these, 144 accidents occurred during the nighttime only, resulting in 31 injuries and 15 deaths. A disproportionately large number of accidents at nighttime occurred as a result of road vehicles striking the trains.

A major problem at passive crossings at night is the motorist's difficulty to detect the train at the crossing to stop in time to avoid collision.

Further, at nighttime, there is nothing to help the motorist distinguish a passive crossing from a crossing equipped with flashing lights from a distance sufficient to allow him to safely stop before colliding with the train.

Studies show that the current crossing sign alone, while plainly visible to motorists, does not have sufficient impact on the approaching motorists to reflect the true danger presented by the crossing. Drivers expect flashing red lights. If they don't see them, they tend to proceed without concern. The situation is much worse at night.

The front-only reflectorized crossing sign may not be sufficiently conspicuous for a motorist approaching the crossing at a high speed to estimate the correct distance from the crossing.

The usual methods of resolving the problems are installation of overhead lights or adding automatic warning system at the crossing. Both of these methods are expensive.

A possible low-cost and potentially cost-effective means of resolving some of these problems is to add high-performance retroreflective material to the back and the front of both crossing signs and posts and several jurisdictions in the United States have done so.

The Saskatchewan Association of Rural Municipalities (SARM) has submitted a proposal to Transport Canada requesting funding for the installation of retroreflective material at all non-automated crossings in the province and for evaluation of the safety benefits through a before and after study and motorist surveys.

If it is decided to add reflective material at all non-automated crossings, it would be advisable to amend the crossing standards to ensure that uniform safety standards are applied across Canada. Transport Canada has therefore commissioned this study to learn from the American experience and to generate input for the development of a Canadian standard.

The purpose of this study is to:

- review completed and ongoing studies of the addition of retroreflective material to the back of the standard crossing sign and crossing sign post;

- describe and discuss the practice of the American jurisdictions including the basis on which such practices were implemented and any reports, evaluations, or other conclusions reached on its effectiveness; and,

- based upon the evaluation of these studies, tests, and current practices in other jurisdictions, recommend to Transport Canada an approach for the implementation of reflectorization, additional evaluations or studies to determine whether or not adding additional retroreflective material will effectively offer guarantees of higher safety at crossings and reduce crossing accidents in Canada.

The conclusions and the recommendations contained in this report are based on review of research literature, telephone interviews and consultations with American researchers and state officials, analysis of Canadian accident data, and evaluation of benefit-cost ratios of several configuration options.

2 AMERICAN REFLECTORIZATION RESEARCH AND PRACTICE

The adding of retroreflective material to crossing sign posts is a recent practice. Only three states, Texas, Minnesota, and Ohio, have completed some form of reflectorization program, and six states, Idaho, Kansas, Nebraska, North Dakota, Virginia and Washington, are in early stages of implementation.

Two major research studies at Kansas State University (KSU) and in Virginia, and one pilot project in Idaho examined the safety benefits of reflectorization.

Ohio has implemented two versions of reflectorization configurations and is evaluating their benefits. The results of the evaluation will be available in early 1998.

A list of the projects studied and their status is provided in Table 1. Descriptions are provided in **APPENDIX A**.

TABLE 1
RESEARCH AND IMPLEMENTATION PROJECTS STUDIED

STATE	DESCRIPTION	STATUS
Kansas	Research study	Completed 1993
Virginia	Research study	Completed 1995
Idaho	Pilot project	Completed 1994
Washington	Pilot project	Begun 1997
Idaho	Implementation project	Begun 1996, 10% complete
Kansas	Implementation project	Begun 1993, 25% complete
Minnesota	Implementation project	Began 1990, complete
Nebraska	Implementation project	Begun 1993, 35% complete
North Dakota	Implementation project	Begun 1995, 10% complete
Ohio	Implementation and evaluation project	Installation completed, evaluation in progress
Texas	Implementation	Completed early 1990s
Virginia	Implementation	Begun 1997, implementation in progress

2.1 Reflectorization Configurations in Use

Eight different configurations are in use in the US. The differences between these configurations are almost entirely in the manner the post is reflectorized. The main variations are in the width of the retroreflective strips, the length of the retroreflective strips, and the grade of the retroreflective material used. All the states reflectorize the front and the back of the posts. Minnesota is the only state which reflectorizes the back of the post only and Ohio reflectorizes the sides of the posts in addition to the back and the front.

Two states, Ohio and Idaho, also attach shields to the posts. The shields are reflectorized on both the front and the back using coloured, diagonal, retroreflective stripes.

Table 2 summarizes the configurations in use.

TABLE 2

SUMMARY OF REFLECTORIZATION CONFIGURATIONS IN USE

No.	State	Description	Grade of Retroreflective material	Number of States
Post Reflectorization				
1	Idaho Washington	Retroreflective strip: 2" wide, 9' long, back and front; Shield: 27" wide, 38" long with word "YIELD" on each post.	Diamond L.D.P.	2
2	Kansas	Retroreflective strip: 4" wide, 5' long, back and front.	Diamond L.D.P.	1
3	Minnesota	Retroreflective strip: 2" wide, 4' long, back side only.	Diamond L.D.P.	1
4	Nebraska	Retroreflective strip: 2" wide, 4' long, back and front.	High Intensity	1
5	North Dakota	retroreflective strip: 2" wide, 4' long, back and front.	Diamond L.D.P.	1
6	Ohio	Retroreflective strip: 3" wide, 9' long, back and front; 2" wide, 8' long on the sides; Shield: 27" wide, 38" long on each post. Stop sign on each post.	Diamond L.D.P.	1
7	Texas	Retroreflective strip: 3" band wrapped around the post at headlight level.	Diamond L.D.P.	1
8	Virginia	Retroreflective strip: 2" wide, 9' long, back and front.	Diamond V.I.P.	1
Crossbuck Reflectorization				
1	Texas, Minnesota, North Dakota, Ohio, Idaho, Washington, Kansas.	Back and front (double sided)	Diamond L.D.P.	9

The patterns used by Idaho, Kansas, Ohio, Texas and Virginia are shown on the Exhibits.

The State of Virginia uses the pattern recommended by the Virginia research, and the configuration used by the State of Kansas is influenced by the KSU research. The configuration recommended by the KSU research is shown on Exhibits 6.1 to 6.3. Illustrations using only the right-hand side delineators are shown.

Most jurisdictions use the Diamond Grade Long Distance Performance™ (LDP) retroreflective sheeting. Exceptions are the state of Virginia, which uses Diamond Grade Visual Impact Performance™ (V.I.P) sheeting recommended by the Virginia research and, possibly Nebraska, which is reported to have used the High Intensity™ grade sheeting.

2.2 **Review of Reflectorization Research and Implementation Projects**

Reflectorization of posts and crossbucks using high-performance retroreflective sheeting is now widely considered an effective means of improving safety at non-automated crossings in the US. The consensus is based upon findings of research studies, voluntary feedback from the travelling public, and subjective judgement of state transportation officials.

There is very little statistical evidence of before and after effects of reflectorization, based upon either analysis of human behaviour or analysis of accidents, to show that the reflectorization in fact improves safety. Findings of the Ohio study will be important in this respect.

2.2.1 ***Research Projects***

The KSU and Virginia studies will provide the major research on reflectorization of the posts and the crossbucks.

According to the Virginia study, reflectorizing the back and the front of the crossbuck and the back and the front of the post increases:

- the visibility of the crossing;
- the uniformity in which passive crossings are marked;
- the driver's depth perception of the crossing; and,
- the driver's ability to detect a train in the crossing.

Exhibit 5 shows the system recommended by the Virginia study.

The KSU study supports these conclusions. Based on their research and several years of experience, the KSU researchers conclude that "reflectorization is very important;" and, recommend that "*as a minimum, high-performance retroreflective material should be used on both sides of the crossbuck and the full length of both posts*".

Exhibits 6.1, 6.2, and 6.3 show the delineation system tested by the KSU study. The research did not separate the impact of reflectorized posts and the crossbuck only from that of the full delineation system. Nevertheless, on the basis of subjective analysis, the study finds that:

- high-performance retroreflective tape on both sides of the crossbuck post without the roadside delineators has a very high impact on the approaching driver;

- the post is brightly visible even before the crossbucks are recognizable;

- on a level roadway at night in a dark, rural area the reflectorized posts have high visual impact at about 600 m (2000 ft) or more;

- reflectorizing both sides of the post creates a "goal post" effect which gives the driver better orientation and a better estimate of the distance from the crossing.

The roadside delineators have been blacked out in the illustration at the bottom of Exhibit 6.2 to show the effect of reflectorized post and crossbuck without the roadside delineators.

Both the Kansas and Virginia studies recommend reflectorization of the full length of the front and the back of the posts and the front and the back of the crossbuck. The Virginia study finds that the visibility of the entire crossing suffers when the back of the far side post is reflectorized but the front of the near side post is not. This phenomenon is shown on the Exhibit 7.

The two studies arrive at nearly the same conclusion but used somewhat different approaches. The main differences between the Virginia and Kansas studies are:

- Virginia uses 5 cm wide retroreflective strips compared to 10 cm wide strips used by Kansas;

- Kansas uses the Diamond Grade L.D.P.™ retroreflective sheeting while Virginia uses the Diamond Grade V.I.P™ sheeting on its recommended configuration;

- Virginia bases its research on photographs and videos taken from a distance of nearly 60 m whereas Kansas tests the visibility of the crossings over distances of up to 245 m;

- Kansas tests statistical significance of its conclusions while Virginia uses subjective analysis based upon the opinions of nineteen subjects. (That all the subjects unanimously selected the configuration recommended by the Virginia study is significant.)

The Virginia study evaluates the reflectorization systems from an approach distance of 60 m and finds the Diamond Grade™ V.I.P. material to be the most effective in this range. The study does not discuss the effectiveness of the system over distances more than 60 m.

The Kansas study, on the other hand, shows that the 5 cm wide Diamond Grade™ retroreflective strip is very bright at a distances of 200 m and more. The KSU demonstration photographs are shown in Exhibits 6.1, 6.2, and 6.3.

These findings of the Kansas and Virginia studies point to the possible need for selecting a different material for each site depending upon the geometry of the site and the operating requirements.

The KSU research has also studied the Ohio Shield and recommends that the shield be field tested at a few locations. Professor Russell of KSU, quoting Abrams' findings (1992), adds the following perceived benefits:

- during daylight, the Buckeye Crossbuck with its red striped Joyce shield (Conrail Shield) affords additional driver warning due to its unique configuration, colour, and design;

- subjective responses during daytime showed a discernible recognition of the Buckeye Crossbuck at a distance of 300 m;

- subjective responses during darkness by vehicle drivers to the Buckeye Crossbuck system consistently demonstrated a discernible, distinct and unique "goal post" early warning system at 460 m for high beams and 300 m for low beam.

- the use of Buckeye Crossbuck at passive railroad crossings is a significant improvement over the current existing crossbucks as an early warning system for approaching drivers during both day and night.

Evaluation of the Buckeye Crossbuck is in progress in Ohio and the findings will be published in early 1998. Early indications are that posts with the shield are favoured by road users over the standard reflectorized post and crossbuck by a wide margin.

2.2.2 ***Implementation Projects***

None of the jurisdictions have made any assessment of effectiveness of the reflectorization based upon either analysis of accidents or other statistical measurements. However, the transportation officials of all the states where reflectorization program has been implemented consider reflectorization to be an effective means to improve safety. Their opinion is based on subjective judgement and feedback from the travelling public.

Reflectorization of the post began in the early 1990s. Most states reflectorize the back and the front of the posts. The exceptions are Minnesota, which reflectorizes only the back side of the posts, and Ohio, which reflectorizes the sides as well as the front and the back.

Variations also exist in the width, length, and type of retroreflective material applied to the post. Table 2 shows the reflectorization configurations used by the various states.

Minnesota reflectorizes only the back side of the crossbuck and the post. The stated purpose is to create a strobe effect when a vehicle approaches a crossing while a train is travelling through the crossing at night. Minnesota officials are satisfied that the reflectorization produces the strobe effect at non-skewed crossings and helps detection of the train in the crossing.

Minnesota DOT officials, however, appreciate the potential benefits of reflectorizing both the front and the back of the post.

Ohio has reflectorized half the crossings with 7.5 cm wide retroreflective sheet on the full length of the front and the back of the post and 5 cm wide and 244 cm long strips on the sides of the post. In addition, Ohio has added Buckeye shields to the remaining half of the crossings. The shield is reflectorized both on the front and the back using coloured, diagonal, retroreflective stripes. The shield is mounted nearly 1 m below the crossbuck or nearly 70 cm above the road level. The configurations used by Idaho and Ohio are shown on Exhibit 3.

Ohio expects the Buckeye Crossbuck to produce the following safety benefits:

- convey a message to motorists that the crossing has no flashing signals and gates;
- increase motorists recognition of the grade crossing;

- reflect the oncoming train headlight in the direction of the motorist to warn of the approaching train;

- red and white colour scheme and three panel shield adds target value for increased daytime recognition.

Idaho is the second state that has adopted the use of the shield. The original plan was to attach the reflectorized shield to non reflectorized posts. The system field tested had the posts non reflectorized. However, apparently influenced by the Virginia study, Idaho is reflectorizing the post and the back of the crossbuck also using the Virginia configuration.

The Idaho Shield differs from the Ohio Shield. It does not have the word "YIELD". The word "YIELD" has been omitted since the Idaho law requires stop signs at all crossings unless it can be proven that it is safer not to install them.

The Idaho test concludes that the shield improves the stopping behaviour of the motorists by 43% and looking behaviour by 62% (compared to non-reflectorized posts).

Contrary to the Ohio belief, some researchers doubt that the shield would reflect any significant amount of headlight from the oncoming train towards the motorist. Results of the Ohio study should clarify the situation. However, increased conspicuousness, during both day and night, could be a major benefit of the shield. Kansas research has concluded that "use of Buckeye Crossbuck at passive railroad crossings could be a significant improvement over the current existing crossbucks as an early warning system for approaching drivers during both daytime and nighttime".

2.3 **US Federal Highway Administration (FHWA) Standard**

Federal highway standards and guidelines in the US are issued through the Manual of Uniform Traffic Control Devices (MUTCD). Changes have recently been proposed to the MUTCD standards for passive crossings. The new standards require that the back of the crossbucks and the front and back of the posts should be reflectorized. Changes have been proposed to the Section 8B-2 of the MUCTD which require that:

- at all roadway-rail intersections, a strip of retroreflective material no less than 5 cm in width shall be used on the back of each blade of each crossbuck sign for the length of the blade;

- a strip of high grade retroreflective white material, no less than 5 cm in width, shall be used at passive roadway-rail intersections on the full length of the front and back of each support from the crossbuck (R15-1) sign or number of track (R15-2) sign to near ground level.

The standards proposed by the FHWA serve as important guidelines, and eventually lead to adoption of similar or higher standards by other states. More and more states would therefore be expected to adopt reflectorization at passive crossings.

2.4 **Discussion of American Configurations**

2.4.1 ***Types of Configurations***

The reflectorization patterns in use in the US can be divided into two broad configurations.

a) The Basic Configuration

The basic configuration adds retroreflective material to the front and the back of the sign post and to the back of the crossbuck. Most states use 5 cm wide strips on the post. Many reflectorize only part of the length of the post. The trend, however, is towards reflectorizing the full length of the post, from the crossbuck to the ground level.

This configuration has been recommended by the two main American studies on reflectorization, the KSU study and the Virginia study. It is also recommended by the new MUTCD standard for grade crossing. *It should be expected to become the industry standard in the US.*

b) Retroreflective Post and Crossbuck with Shield

The second configuration attaches to each post a shield, reflectorized both on the front and on the back using coloured retroreflective bands. The posts and the crossbucks are reflectorized according to the basic configuration.

This configuration is considered effective in Ohio and Idaho where it has been adopted. The shield adds a large retroreflective surface area to the post at a location where the automobile headlight illumination is very bright. The merits of the shield for nighttime visibility are obvious. But the added benefits of the shield, over and above those of the basic configuration and, consequently, the justification for the additional expenditure, remain to be demonstrated.

The shield has not been recommended either by the KSU or by the Virginia study. The potential daytime benefits of the shield mentioned by the KSU study, however, could be of value in improving daytime safety at the crossings. The KSU study recommends field testing of the shield.

American researchers, state officials, and the FHWA (MUTCD) consider the 5 cm wide retroreflective strip sufficient if high-performance retroreflective material (Diamond Grade™ or equivalent) is used. The incremental cost of adding width to the strip is small and the researchers agree that wider strips would produce greater impact.

2.4.2 ***Types of Retroreflective Materials***

Three types of materials, the High Intensity™, the Diamond Grade Long Distance Performance (LDP)™, and the Diamond Grade Visual Impact Performance™ (V.I.P.) are in use in the US. Most jurisdictions favour the Diamond Grade LDP™ sheeting. Virginia, however, uses the Diamond Grade VIP™ material.

Virginia's decision to use the Diamond Grade VIP™ type sheeting is based upon the following considerations:

- the distance of 60 m from crossing is critical for motorists' decision making and safety manoeuvres. The crossing should therefore be highly conspicuous from the last 60 m on the approach to the crossing;

- at distances of more than 60 m, the V.I.P.™ is brighter than the high intensity sheeting and nearly as bright as the Diamond Grade LDP™;

- at distances of less than 60 m, the V.I.P.™ is as bright as it is from further away whereas the Diamond Grade LDP™ becomes darker the closer one moves to the sign, and is less effective than the VIP grade material.

None of the jurisdictions, with the possible exception of Nebraska, uses the high intensity grade material.

2.4.3 ***Assessment of Effectiveness***

Sufficient objective data does not exist to quantitatively evaluate the effectiveness in reducing accidents of any of the configurations used in the US.

Nevertheless, state officials believe that reflectorization improves crossing safety and KSU and the Virginia studies support these findings. The specific benefits identified by these studies have been discussed in section 2.2.

The KSU and Virginia studies recommend the use of high-performance (prismatic) retroreflective material on the back and the front of the posts and the crossbucks. The KSU research, however, suggests that:

- roadside delineators should be used at grade crossings where road speeds are very high or other conditions call for higher visual impact; and,

- installation of the Conrail Shield may be considered at a few experimental grade crossings and the results should be monitored.

Idaho DOT has tested the shield installed on unreflectorized post and concludes that the shield alone improves the safety behaviour of the drivers approaching the crossing. The IDOT test does not establish if these benefits are over and above those produced by reflectorizing the posts and the back of the crossbucks. The Ohio study, based upon the analysis of accident data, observation of driver behaviour (approach speed, point of brake application), and survey, to gain insight into driver behaviour, is expected to compare the benefits of adding retroreflective material to the front and back of the posts and the back of the crossbucks and the added benefits of attaching the shield under both daytime and nighttime conditions.

2.5 Conclusions from American Reflectorization Research and Implementation Experience

Adding high-performance retroreflective material to the back and the front of the post on the full length of the post and to the front and the back of the crossbuck blades on the full length of each blade at passive crossings produces positive safety benefits and could be a major factor in reducing the frequency of accidents at the crossings at night.

The practice of adding retroreflective material to the crossing sign post was started by Minnesota. The purpose of the Minnesota initiative was to help motorists detect the train in the crossing by producing a "strobe effect" as the train travelled through the crossing. For this purpose, the Minnesota DOT added retroreflective material to the back side of the posts only.

While this effect has been confirmed in Minnesota and elsewhere, research and field tests have identified other, perhaps more important characteristics of reflectorization when high-performance retroreflective material is added to both the front and the back of the posts and the crossbucks:

- the reflectorized posts have a very high visual impact at night, especially in dark rural areas from a distance of as much as 600 m;

- retroreflective posts create a "goal post" effect at night which helps the driver more accurately estimate the distance from the crossing.

These characteristics are expected to result in the following benefits:

- drivers approach the crossing at a higher level of alertness, at a slower speed and consequently, better prepared to stop if necessary;

- drivers expect to see two bright posts – a "goal post". The absence of the left post from the view, or the intermittent appearance and disappearance of the left post as the train travels past the crossing, alerts the drivers to the presence of the train.

Researchers recommend that high-performance retroreflective strips must be applied to:

- the full length of the crossbuck blades both on the front and on the back; and,

- the full length of the sign post both on the front and on the back.

Many states in the US already have reflectorization programs under way on the basis of these recommendations and other states are considering reflectorization programs.

The US FHWA has adopted these recommendations and is changing the MUTCD grade crossing standards. The adoption of these standards by the FHWA should lead to adoption of similar or higher standards by all states.

3 CONFIGURATION OPTIONS FOR A CANADIAN STANDARD

3.1 Potentially Effective Configurations

The basic configuration found to be effective in improving safety in the US and adopted as a standard by the FHWA uses the following basic configuration:

- strip of high grade retroreflective material on the full length of each blade of the crossing sign (crossbuck) both on the front and on the back, and;

- strip of high grade retroreflective material on the full length of each post both on the front and on the back.

Some US jurisdictions have added a shield, reflectorized on both sides, in addition to the retroreflective strips. The added benefit of the shield at night, relative to the added cost, is not evident at the present time. A research project is in progress in Ohio which should identify the benefits of the shield, if any, over and above those of the basic configuration. The results should be available early in 1998. Until then, we will not consider the use of the shield as a necessary element of the system.

3.2 Configuration Options for Canada

On the basis of the American experience, we propose the use of the basic configuration without the shield. However, before a Canadian standard can be adopted, the following questions must be answered:

- What should be the width of retroreflective strips on the post and the back of the crossbuck?

- What grade of retroreflective material should be used?

These issues are discussed below.

3.2.1 *Width of the Retroreflective Strip*

To select the width of the strip, we have identified the following three configurations for further analysis:

- Configuration # 10 x 10:
  This configuration uses a 10 cm wide strip on the front and the back of the post and a 10 cm wide strip on the back of the crossbuck blades;

- Configuration # 5 x 10:
  This configuration uses a 5 cm wide strip on the front and the back of the post and a 10 cm wide strip on the back of the crossbuck blades; and,

- Configuration # 5 x 5:
  This configuration uses a 5 cm wide strip on the front and the back of the post and a 5 cm wide strip on the back of the crossbuck blades.

The width of the white retroreflective strips on the front face of the crossbuck blades is 10 cm for all three configurations described above.

3.2.2 ***Type of Retroreflective Material***

Two types of prismatic retroreflective materials may be used. 3M sheeting such as the Diamond Grade LDP™ and VIP™ are currently used. The Diamond Grade LDP™ is the most widely used material in the US. However, the Virginia research recommends the use of Diamond Grade VIP™ due to its advantage over other materials within 60 m of the crossing. Further study is necessary to develop criteria and/or a methodology for selection of the best material.

The costs of the two materials are the same.

4 BENEFITS AND COSTS OF POTENTIAL CONFIGURATIONS

4.1 Cost Estimate

Costs have been estimated for the three configurations identified above using Diamond Grade™ retroreflective material.

The cost estimate is shown in Table 3. The estimate is based on the use of new crossbucks with Diamond Grade™ retroreflective material both on the front and the back. The existing crossbucks do not use the prismatic type retroreflective material and any material appreciably inferior to the Diamond Grade™ material is not recommended for a Canadian standard. Furthermore, the existing crossbucks are nearly 10 years old and near the end of their useful life. They may not appear bright under low headlight-beam conditions and may even appear dark and ineffective compared to the bright strips on the posts.

Cost has also been estimated for adding shield to the posts should the Ohio study establish the benefits of the shield for nighttime and/or daytime safety over and above those produced by the retroreflective posts. The cost of adding shield is shown in Table 4.

TABLE 3
COST OF THE CONFIGURATIONS EXAMINED, USING NEW CROSSBUCKS

Description	**Cost per crossing ($)**			**Total Investment (million $)**
	Material	***Labour***	***Total***	
10 cm strips on posts and 10 cm strips on the back of crossbucks	404	153	557	9.0
5 cm strips on the post and 10 cm strips on the back of the crossbucks	333	153	485	7.8
5 cm strips on posts and 5 cm strips on the back of the crossbucks	311	153	464	7.5

TABLE 4
COST OF ADDING SHIELD AT A LATER DATE

Description	**Cost per crossing ($)**			**Total Investment (million $)**
	Material	***Labour***	***Total***	
Add shield at a later date	519	43	561	9.1

4.2 Estimate of Avoidable Accidents

4.2.1 *Base Year Accident Data*

Table 5 shows 10-year accident data from 1986 to 1995 and 3-year accident data from 1993 to 1995. Appreciable changes have occurred in accident trends in recent years and it is felt that the 10-year accident trend is no longer meaningful. *Our analysis is therefore based upon the 3-year accident data.*

TABLE 5
ACCIDENT DATA AT PASSIVE CROSSINGS

DESCRIPTION	10-YEAR AVERAGE 1986 – 1995	3-YEAR AVERAGE 1993 – 1995	CHANGE %
Daytime Accidents			
Accidents per year	122.4	96	-22%
Train struck vehicle	80.2	72.3	-10%
Proportion of train struck vehicles	65.5%	75%	+10%
Vehicle struck train	42.2	23.7	-44%
Proportion of vehicle struck train	34.5%	25%	-10%
Number of injuries	52.1	17.6	-66%
Number of fatalities	18	19.3	+7%
Nighttime Accidents			
Accidents per year	55.6	48	-14%
Train struck vehicle	32.2	20.3	-37%
Proportion of train struck vehicle	42%	42%	0%
Vehicle struck train	32.4	27.7	-15%
Proportion of vehicle struck train	58%	58%	0%
Number of injuries	22.7	10.3	-54%
Number of fatalities	4.2	5	+19%

4.2.2 *Potentially Avoidable Accidents*

The primary benefit of reflectorization results from increased visibility, differentiation from the automated crossing and improved driver orientation and judgement of distance from the crossing due to the goal post effects. Drivers approach the crossing at a higher level of awareness and are better prepared to stop. Furthermore, when a train is occupying the crossing, the absence of the left post of the goal post and/or the intermittent appearance of the post – strobe effect – alerts the driver to the presence of the train in the crossing. Together, these effects should reduce the number of the two major types of crossing accidents, those caused by the trains striking vehicles and those caused by the vehicles striking trains.

4.2.2.1 *Accidents Involving Trains Striking Vehicles*

The number of nighttime accidents with the train striking the vehicle is 28% of similar daytime accidents (see Table 5). Considering the volume of nighttime traffic, this number seems disproportionately high.

To estimate the impact of reflectorization and, consequently, the possible reduction in the number of such accidents, we assume the average hourly nighttime traffic volume to be 20% of the daytime traffic. If the reflectorization is *fully* effective it may be possible to reduce the number of nighttime accidents involving the train striking the vehicle to as low as 14.5 per year.

4.2.2.2 *Accidents Involving Vehicles Striking Trains*

From Table 5 we see that the frequency of vehicles striking trains at night is 58% compared to 25% daytime frequency. If the reflectorization is *fully* effective, the nighttime frequency of such accidents should be nearly the same as the daytime frequency. The number of the accidents involving vehicles striking trains should thus decline to about 4.8 per year.

Reflectorization can thus potentially reduce the total number of nighttime accidents by as much as 29 per year as derived from Table 6.

TABLE 6
ESTIMATE OF THE NUMBER OF ACCIDENTS AVOIDABLE IF FULL BENEFIT OF REFLECTORIZATION IS ACHIEVED

DESCRIPTION	BEFORE	AFTER	CHANGE
Accidents per year	48	19.33	-59.73%
Train struck vehicle	20.3	14.5	-28.57%
Proportion of train struck vehicle	42%	75%	33%
Vehicle struck train	27.7	4.83	-82.56%
Proportion of vehicle struck train	58%	25%	33%

4.2.3 ***Potential Savings from Accidents Avoided***

The potential annual savings from avoidable accidents may be as high as $4.8 million as shown in Table 7.

The total annual cost of nighttime accidents, which result in 10.3 injuries and 5 fatalities is estimated at $8 million, or nearly $166,600 per accident. The cost is estimated on the basis of the data obtained from Transport Canada, Rail Safety Division for injuries and fatalities. The cost of property damage is based upon a 1972 report to the US Congress by the Federal Railroad Administration identified in a BBL study in 1978 for TDC to define requirements for railway level crossings protection acceptable for train operations up to 150 MPH.

TABLE 7
ESTIMATE OF ACCIDENT COSTS AND SAVINGS

	UNIT COST	EVENTS	TOTAL COST
Property loss	8,000	48	384,000
Injury	11,000	10.3	113,300
Fatality	1,500,000	5	7,500,000
Total	-	-	7,997,300
Cost per accident	-	-	166,610
Potentially avoidable accidents per year	-	29	-
Potential savings/year from avoided accidents	-	-	4,831,690

4.2.4 ***Break-Even Number of Accidents***

The number of accidents which must be avoided each year to justify the investment in each of the three configurations is shown in Table 8. The break-even number for each configuration is very low and should be easily achievable.

TABLE 8
NUMBER OF ACCIDENTS TO AVOID TO JUSTIFY INVESTMENT IN REFLECTORIZATION

CONFIGURATION	INVESTMENT REQUIRED (MILLION $)	NUMBER OF ACCIDENTS TO AVOID EACH YEAR TO JUSTIFY INVESTMENT
10 cm retroreflective strips on the post and 10 cm retroreflective strip on the back of the crossbuck	9	5.4
5 cm retroreflective strip on the post and 10 cm retroreflective strip on the back of the crossbuck	7.8	4.7
5 cm retroreflective strip on the post and 5 cm retroreflective strip on the back of the crossbuck	7.5	4.5

4.3 **Benefit-Cost Analysis**

4.3.1 ***Option Used for Benefit-Cost Analysis***

It is assumed that only the configuration using 10 cm wide Diamond Grade™ retroreflective strips on the front and the back of the post and 10 cm wide Diamond Grade™ retroreflective strips on the front and the back of the crossbuck blades will have the necessary impact to produce the full monetary benefits estimated in Table 7. The benefit-cost ratio is therefore calculated for this option only.

4.3.2 ***Estimate of Benefit-Cost Ratio***

Manufacturers guarantee the prismatic grade retroreflective sheeting for a period of 7 years. Based upon the experience with the material to date, the guarantee period is expected to be increased to 10 years. The following data is therefore used for estimation of benefit-cost ratio:

• Assumed service life of reflectorization-years	10
• Accidents avoidable in 10 years	287
• Benefit of safety improvement - million $	48
• Cost of the configuration selected - million $	9

The benefit-cost ratio for the selected option is thus estimated at 5.3 over a life of 10 years.

4.4 **Conclusions from Benefit-Cost Analysis**

Adding high-performance retroreflective material to the front and the back of the post and the crossbuck can potentially reduce the nighttime accidents at passive crossings by as much as 60%. Over the guaranteed life (10 years) of the retroreflective material, the monetary benefits from accident reduction could be as high as $48 million, for an estimated investment in the range of $9 million. The lifetime benefit-cost ratio over the guaranteed life of 10 years using the most expensive configuration is estimated at 5.3. In other words, the investment could be recovered in less than two years.

Further research will be necessary to identify the most cost-effective option. We do not believe that such a determination can be made on the basis of accident analysis alone. The research would have to rely on the study of human factors and the driver behaviour and response to each configuration.

5 RECOMMENDED CONFIGURATION

We have examined three configurations, identified in Section 3, for the selection of a Canadian configuration. However, the benefit-cost ratio has been estimated for the most expensive configuration only, assumed to be the most effective in reducing the number of accidents during the nighttime. However, this assumption needs to be tested. Further research will be necessary to determine the most effective configuration for selection of the Canadian standard.

If further research is not practical, we would recommend the use of the basic configuration, which uses a 10 cm wide white, prismatic, retroreflective strip on the front and back of the post on the full length of each post and a 4-inch wide white, prismatic, retroreflective strip on the front and the back of the crossbuck blades on the full length of each blade.

This option, despite its high cost, has a high benefit-cost ratio and is likely to recover the investment in less than two years.

Research is also recommended to identify the most appropriate type of retroreflective material (Diamond Grade LDP™ or Diamond Grade VIP™ or equivalent) for various site conditions and approach geometry at crossings.

6 IMPLEMENTATION STRATEGY

For the Canadian standard, we recommend the use of high-performance, prismatic-type retroreflective material, to be used on the posts and the crossbucks. Appendix C shows the vast superiority of the Diamond Grade™ material over the High Intensity™ material used on existing crossbucks. The existing crossbucks do not meet the reflectivity requirement. In addition, they are ten years old, near the end of their useful life and not very bright under low headlight beam conditions. Ideally, they should be replaced when the strips are added to the posts.

However, during the Project Review Committee meetings, strong opinions were expressed in favour of retaining the existing crossbuck and field attaching retroreflective strips to the back of the crossbuck blades.

This should be an intermediate step to implementation of a Canadian standard. The cost of this stage of implementation is shown in Table 9.

TABLE 9
COST OF IMPLEMENTATION USING OLD CROSSBUCKS

Description	**Cost per crossing ($)**			**Total Investment (million $)**
	Material	***Labour***	***Total***	
10 cm strips on posts and 10 cm strips on the back of crossbuck	235	169	404	6.5
5 cm strips on post and 10 cm strips on the back of crossbuck	163	169	333	5.4
5 cm strips on posts and 5 cm strips on the back of crossbuck	117	169	287	4.6

A comparison of Table 3 and 9 will show the short-term cost saving from adopting this strategy. However, before any decision on implementation strategy is made, a thorough study should be made to assess the safety implications as well as the long-term financial implications of the strategy.

7 CONCLUSIONS

a) Reflectorization has been found to be effective in enhancing safety during the nighttime at non-automated (passive) highway-rail grade crossings in the US. Consequently, the new grade crossing standard recommended by the FHWA requires the use of retroreflective material on both the posts and the crossbucks at all passive crossings. As a result of the FHWA initiative, reflectorization at passive crossings become a universal practice throughout the US.

b) Reflectorization will also be beneficial for Canada. By suitable reflectorization, the number of nighttime accidents at passive crossings in Canada can potentially be reduced by as much as 60%, possibly saving as much as $5 million in cost of accidents. The reflectorization would be cost-effective and the investment can be recovered in less than two years.

c) For reflectorization to be fully effective:

   - the retroreflective strips must be applied to the front and the back of the posts and the front and the back of each blade of the crossbuck;

   - the retroreflective material must be applied to the full length of the post and to the full length of each blade of the crossbuck;

   - the retroreflective material must be a high-performance, prismatic-type sheeting.

d) The width of the strip on the post and the back of the crossbuck must not be less than 5 cm. Wider strips should be more effective. The cost of using the wider strip would also be higher; however, it is not clear if the wider strips would also be more cost- effective.

e) Research is needed to identify most effective width of the retroreflective strip. If research is not practical, it would be prudent to use a wider strip on both the post and the back of the crossbuck.

f) The benefits of reflectorization are limited to nighttime only. It may be possible to improve daytime safety at passive crossings by installing the so-called "Shield" on the post. The Ohio study currently under way is expected to identify the benefits of the shield. Should the Ohio study prove the daytime benefits of the shield, over and above those of the retroreflective strips, the use of the shield at passive crossings in Canada should be considered.

8 RECOMMENDATIONS

a) Reflectorization of the front and the back of the post and the crossbuck should be adopted as a standard practice at passive crossings.

b) A suitable configuration for a Canadian standard can be selected from the following three options:

- 5 cm wide strips on the front and the back of the posts and 5 cm wide strips on the back of the crossbuck;

- 5 cm wide strips on the back and the front of the posts and 10 cm wide strips on the back of the crossbuck;

- 10 cm wide strips on the back and the front of the posts and 10 cm wide strips on the back of the crossbuck.

(These options assume that the crossbucks will be equipped with 10 cm wide high-performance white retroreflective material on the front face.)

Research should be undertaken to identify the most effective and/or optimum width. However, if research is not practical, a *10 cm wide white retroreflective strip on the front and back of the post, and a 10 cm wide white retroreflective strip on the front and the back of the crossbuck blades should be used*.

c) Regardless of the width selected, the retroreflective strip should be applied on the full length of the post and on each blade of the crossbuck.

d) The retroreflective material must be high-performance, prismatic sheeting, such as Diamond Grade™ or equivalent.

e) Research should be conducted to select the most appropriate type of retroreflective material, the location of the crossing and the approach road geometry.

f) For integrity of the system and for full implementation of a Canadian Standard, the existing crossbuck should be replaced by new crossbuck equipped with high-performance retroreflective material on both faces of the blades. However, should it be desired to retain the existing crossing sign with high-intensity retroreflective material on the front face, this should be only an intermediate step to full implementation of the Canadian standard. A careful assessment should be made of safety and long-term financial implications of the process.

g) The findings of the Ohio research should be studied when they become available. If the Ohio research confirms that the shield improves safety during the daytime or enhances the effectiveness of the retroreflective strips at the nighttime, the use of the shield at passive crossings should be considered.

h) An education program should be initiated to inform motorists of the implications of adding retroreflective material to the front and the back of the post and the signs at passive crossings. Motorists should know what to look for when approaching a reflectorized crossing, how to interpret and react to disappearance from view of the left post and how to interpret the flicker or strobe effect.

i) Decision-makers should visit passive crossings in Idaho, Kansas, Ohio, and Virginia where retroreflective material has been installed.

EXHIBITS

EXHIBIT 1

IDAHO Retroreflective SHIELD

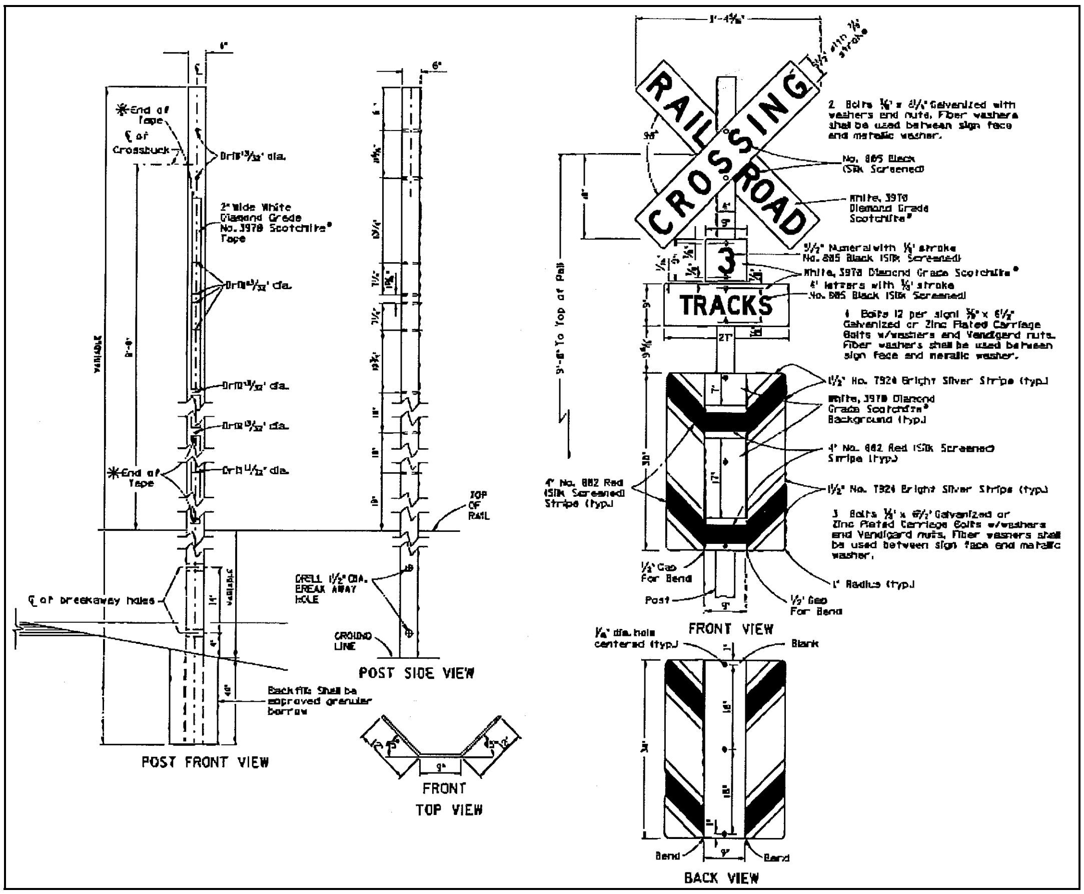


EXHIBIT 2
Kansas Reflectorized Railroad Crossing Sign and Post

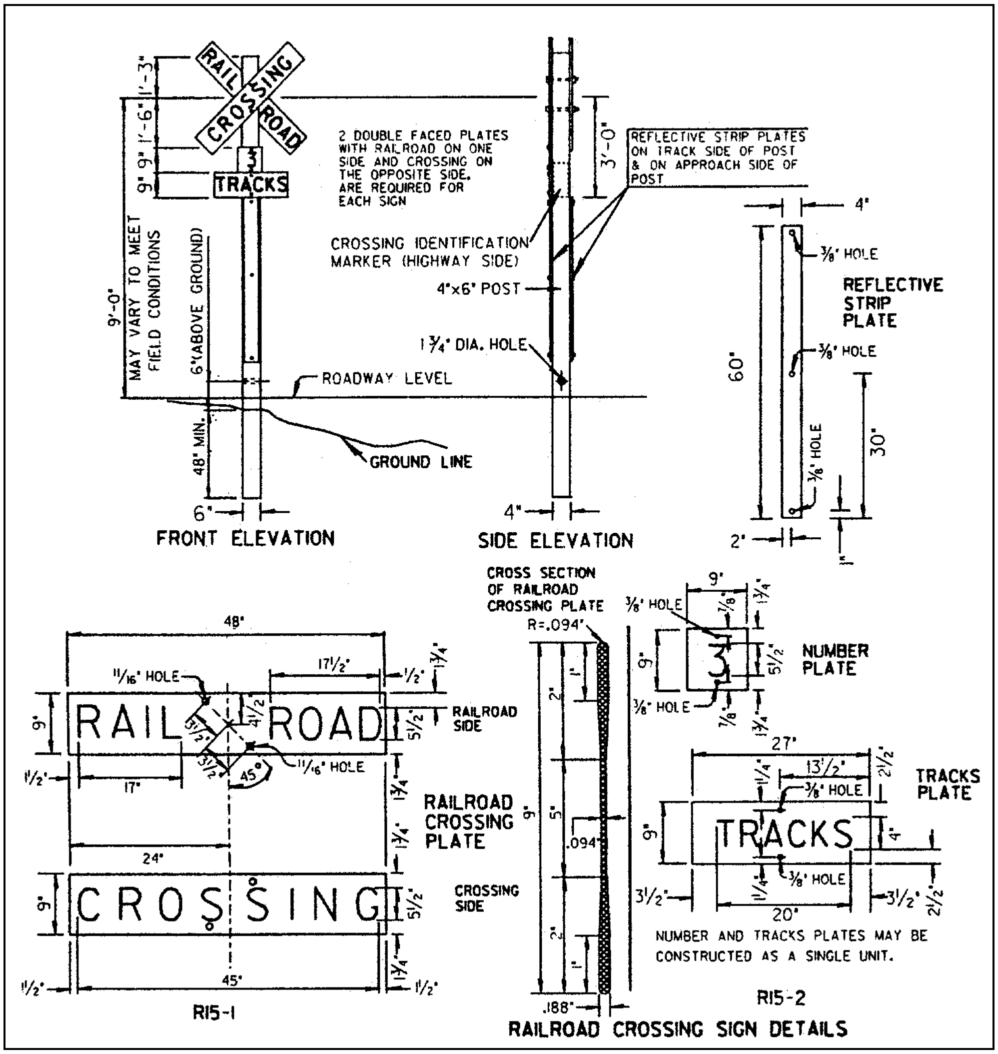


EXHIBIT 3.1

Plan of Ohio Buckeye Crossbuck

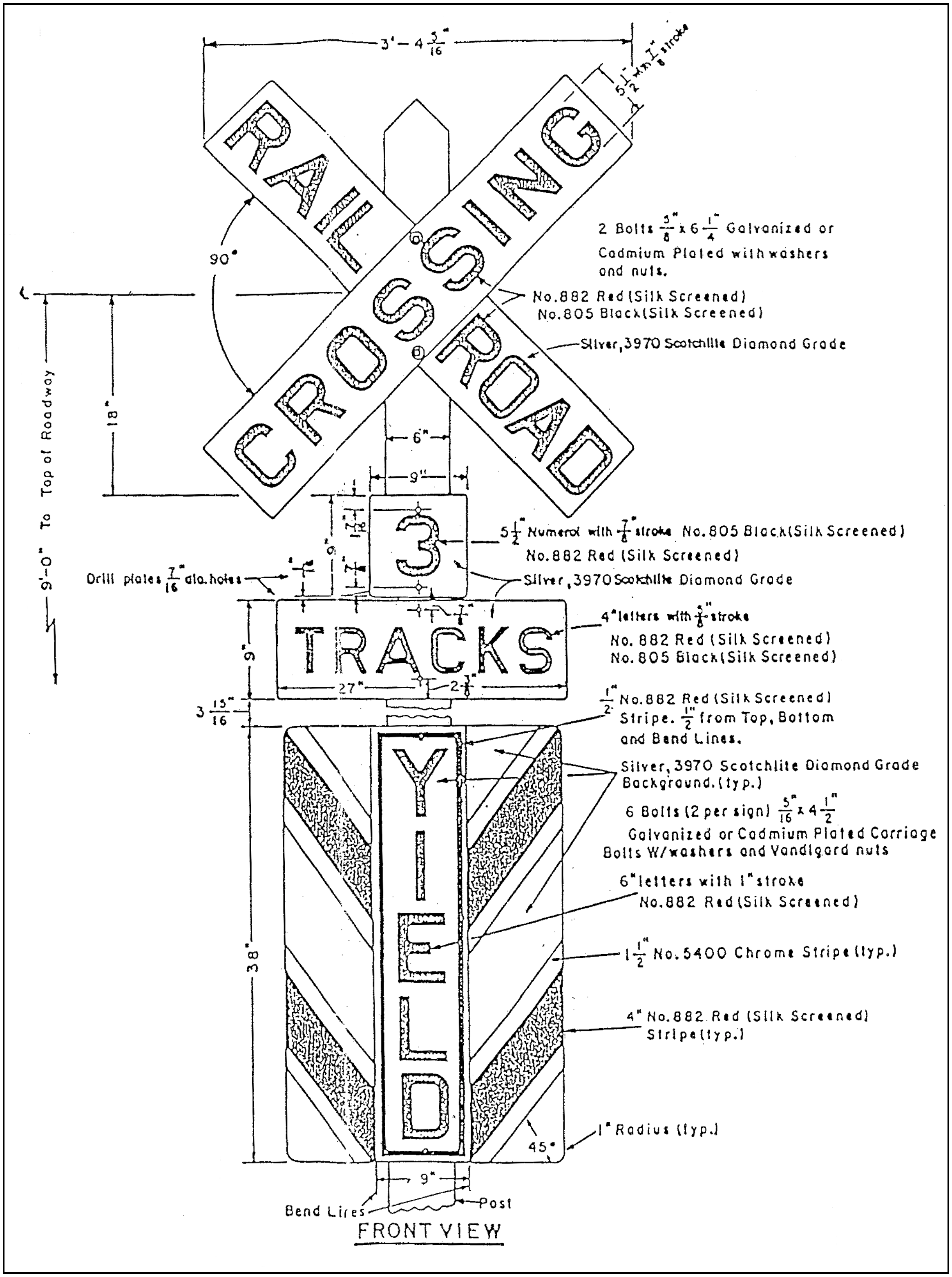


EXHIBIT 3.2
Plan of Ohio Buckeye Crossbuck, Back View

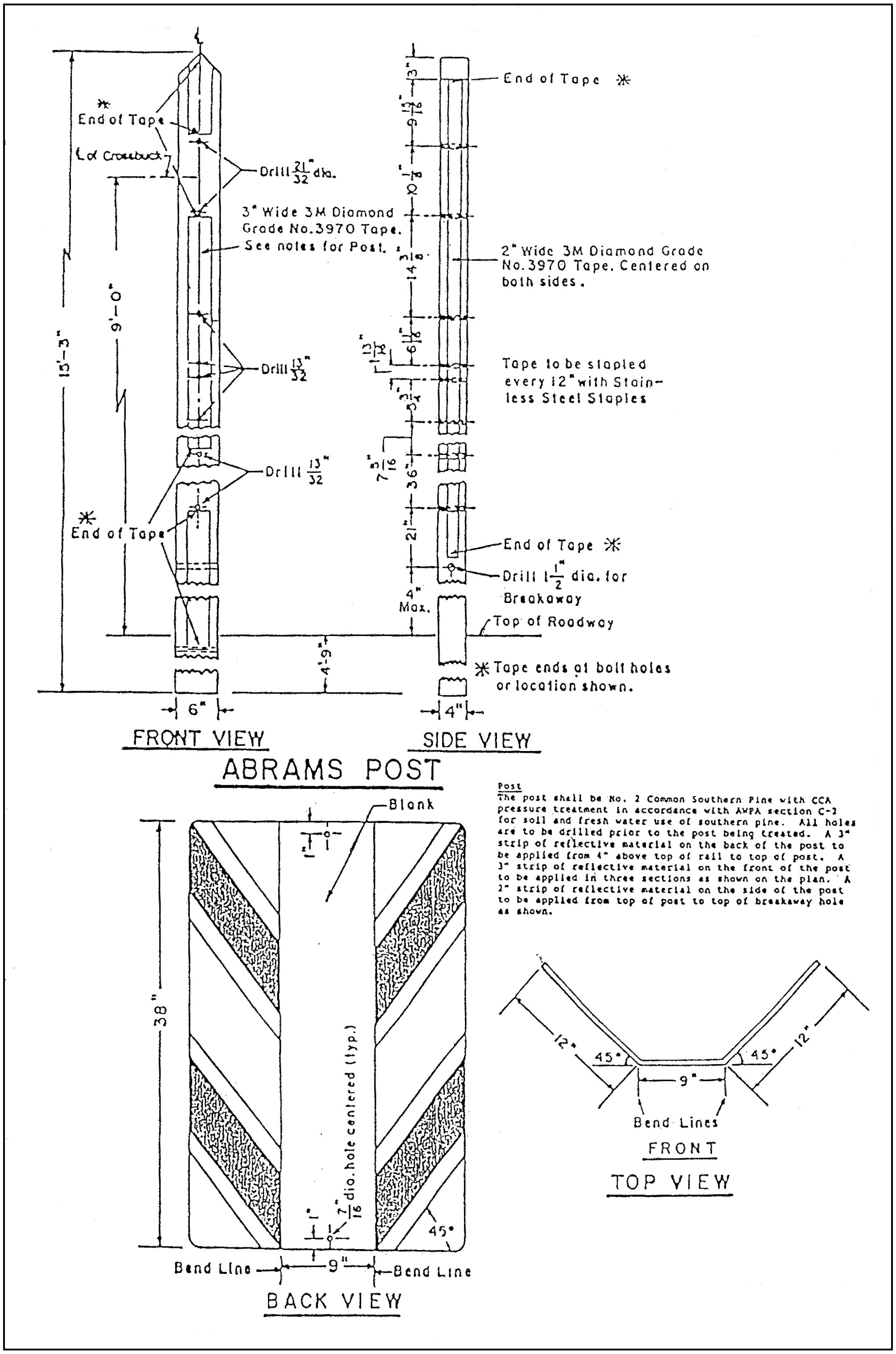


EXHIBIT 4
Plan of Texas Reflectorized Railroad Crossing Sign and Post

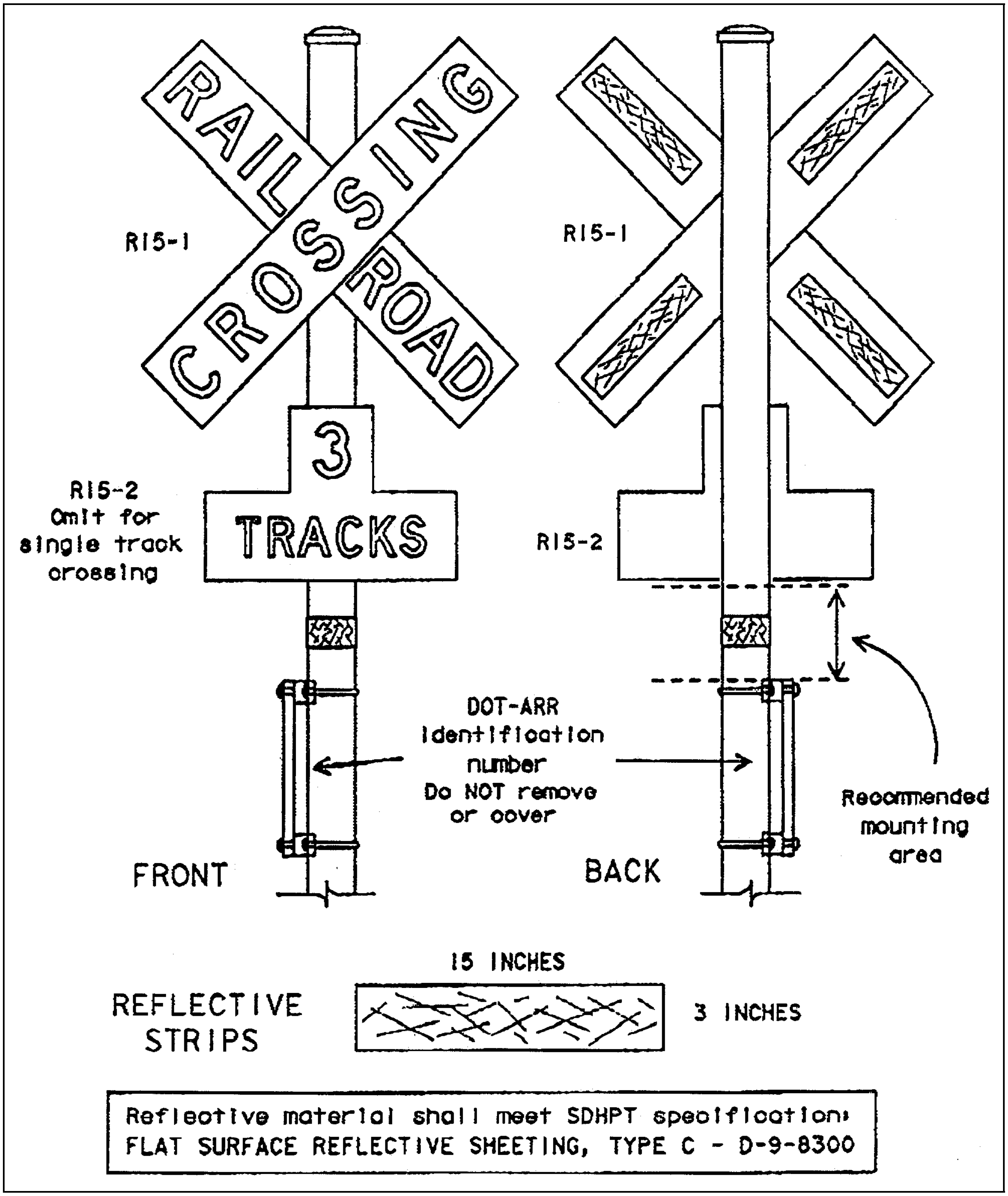
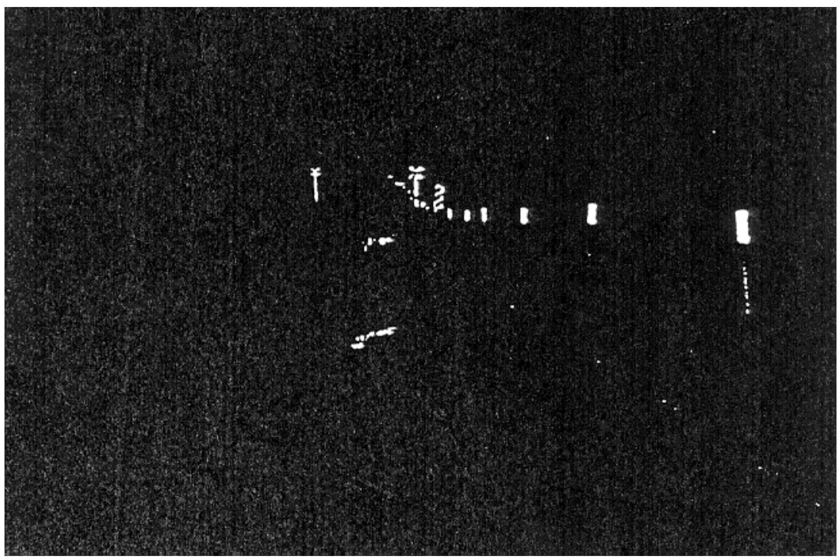


EXHIBIT 5
Virginia Reflectorized Railroad Crossing Sign and Post
Source: *Stephen C. Brich, Virginia Research Council. Investigation of Reflective Sign Materials at Passive Railroad Crossings*

Eastbound, low beam, 200 ft. (61 m)

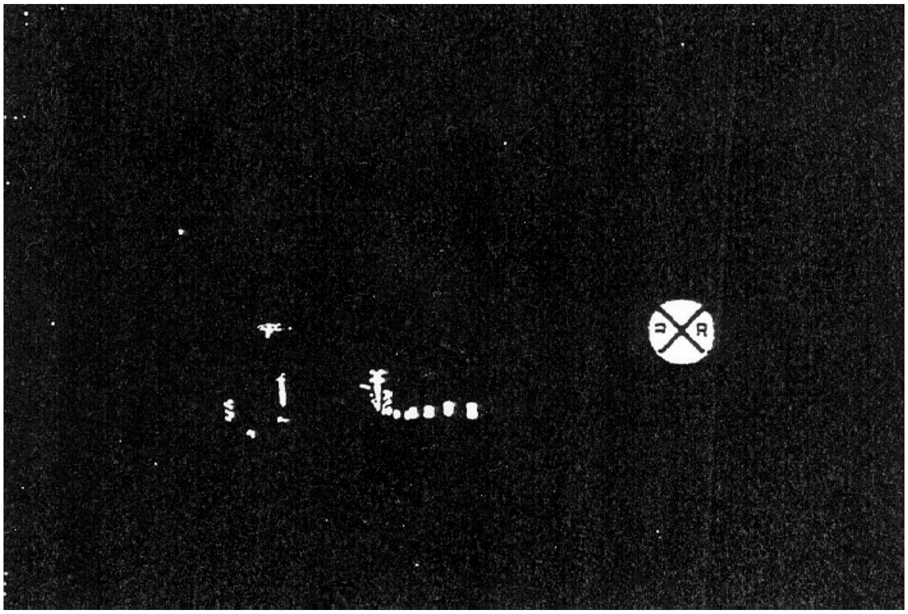
Eastbound, high beam, 200 ft. (61 m)

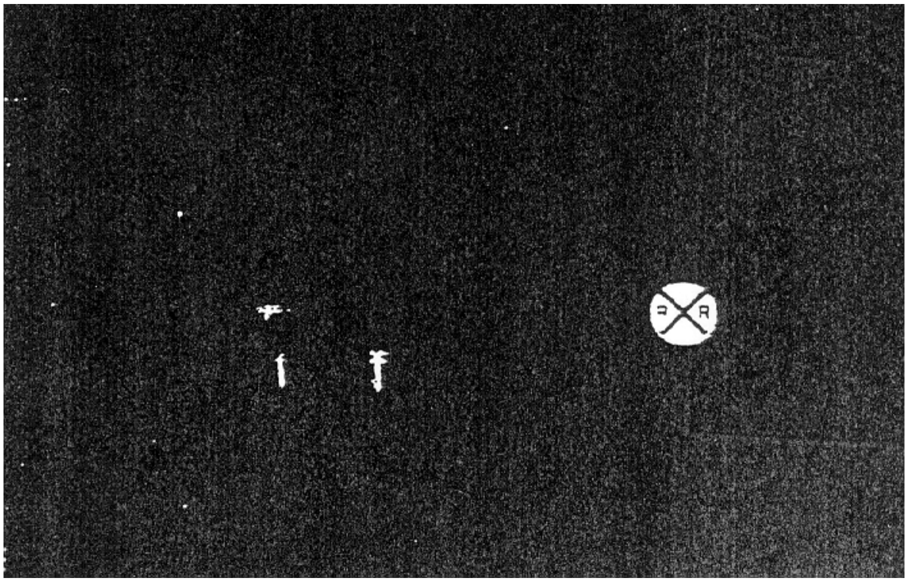
EXHIBIT 6.1
Night view of KSU Research Delineation System from 198 m (650 ft.) with Roadside Delineators at 15.3 m (50 ft.)
Source: *Eugene R. Russel, Professor, Civil Engineering, Kansas State University. Further Studies of the Use of Retroreflective Material at Highway-Rail Grade Crossing*



Nighttime picture of the delineation system at enterprise grade crossing
from 650 ft. (198 m) with southbound approach

EXHIBIT 6.2
Night View of KSU Research Delineation System from 244 m (800 ft.) with Roadside Delineators at 15.3 m (50 ft.)
Source: *Eugene R. Russel, Professor, Civil Engineering, Kansas State University. Further Studies of the Use of Retroreflective Material at Highway-Rail Grade Crossing.*





Night view of KSU research delineation system from 244 m (800 ft.) with delineators removed

EXHIBIT 6.3

Night View of KSU Research Delineation System from 244 m (800 ft.) with Roadside Delineators at 30.5 m (100 ft.)

Source: *Eugene R. Russel, Professor, Civil Engineering, Kansas State University. Further Studies of the Use of Retroreflective Material at Highway-Rail Grade Crossing.*

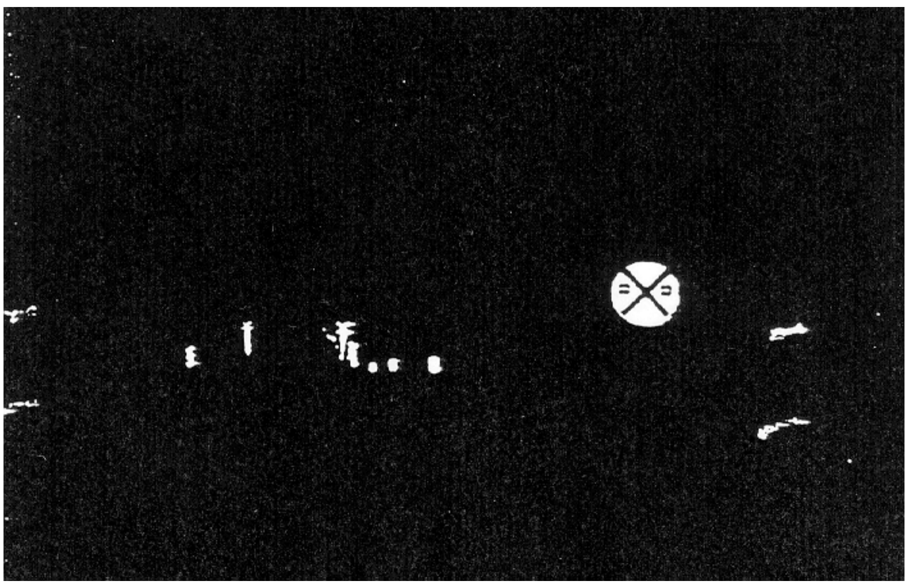


EXHIBIT 7

Photograph of Demonstration by Virginia Research Showing the Effect of Reflectorizing Only the Back Side of the Sign and Post

Source: *Stephen C. Brich, Virginia Research Council. Investigation of reflective sign materials at passive railroad crossings*

Visibility of the whole crossing is lowered when the front of the post is not reflectorized.

REFERENCES

[1] Minnesota DOT, Office of Railroad & Waterways. 1993. Minnesota Railroad-Highway Grade Crossing Safety Program Signing and Pavement Marking Program Overview.

[2] Russell, E.R. and Abrams, B.S. *Recommended Practice for the Use of Additional Retroreflective Material at Rail-highway Grade Crossing Without Active Devices*. Winnipeg, Manitoba, June 1994.

[3] Russell, E.R., Rys, M., and Abrams, B.S. *Headlight Illumination and Other Results Supporting the Use of Retroreflective Material at Grade Crossings*. Knoxville, Tennessee, October 1994.

[4] Russell, E.R. and Rys, M. *A Review of Theory Research and Practice Leading to Recommendation for Greater Use of Retroreflectorization at Highway-Rail Crossing at Grade*. Prague, Czech Republic, September 1995.

[5] Russell, E.R., Rys, M., and Liu, L. *Further Studies of the Use of Retroreflective Material at Highway-Rail Grade Crossings*. Knoxville, Tennessee, October 1996.

[6] Ohio DOT, Division of Rail Transport. 1993. Proposal for the Evaluation of the Buckeye Crossbuck at Public, Passive Railroad/Highway Grade Crossing in Ohio.

[7] Brich, S.C. Virginia Transportation Research Council. 1995. *Final Report: Investigation of Retroreflective Sign Material at Passive Railroad Crossings*.

[8] Dolan, L. Office of railroads & waterways, Minnesota Department of Transportation. April 1996. Are Minnesotans Aware of the Dangers of Railroad Crossings?

[9] Idaho reflective Shield program. Results of a pilot study between July 1994 and October 1995.

[10] Warning sign visibility at railroad grade crossing. Art 6370b. Acts 1989, 71st Leg., ch. 269, eff. August 28,1989, Texas, Texas state legislation.

[11] The Highway & Rail Safety Newsletter, February 1997; Hoy A. Richards publisher. MUTCD Proposed Changes.

[12] Subpart D: Marking and Warning Devices at Grade Crossings. 92 Illinois Administrative Code.

[13] Manual of Uniform Traffic Control Device.

[14] Telephone conversation with researchers and state transportation officials.

APPENDIX A
DESCRIPTION OF RESEARCH AND IMPLEMENTATION PROJECTS

TABLE OF CONTENTS

1 INTRODUCTION

This document describes the practice of American jurisdictions and research studies for the addition of retroreflective material to the back of the standard crossing sign and to the crossing sign post including the basis on which such practices were implemented and evaluations or other conclusions reached on its effectiveness.

The document is based upon review of literature and telephone interviews and consultations with researchers and state transportation officials.

Two research projects, three demonstration projects, and eight implementation projects in the U.S.A. were studied.

2 RESEARCH PROJECTS

2.1 Kansas Research

The Kansas research was directed by Professor Russell at Kansas State University (KSU). The research was based upon the knowledge of nighttime human vision and automobile headlight characteristics, and demonstrates that reflectorization enhances visual impact of the crossing. On the basis of a demonstration project, which tested five reflectorization systems at six passive crossings on Kansas highways, the KSU research recommends the use of configurations based upon the so called "Delineation System" as follows:

a) use double sided crossbucks;

b) use, at the least, high-performance retroreflective material on both sides of the cross-bucks and full length of both posts;

c) where road approach speeds are very high or other conditions call for high visual impact, install roadside delineators on the approaches;

d) where applicable, the delineators should be installed on both sides of the approaches beginning at the advance warning sign and spaced no more than 30 m apart.

The "Delineation System" tested by the KSU research comprises 10 cm wide high intensity retroreflective tape on both sides of both posts and roadside, retroreflective delineators on the right side of each approach spaced at 15 m, from advance warning sign to the crossbuck and extended an equal distance beyond the crossbuck post.

The Delineation System was tested at two locations and was found effective in producing long term favourable changes in two variables - deceleration rate and looking behaviour of the drivers. The changes were found to be statistically significant. There were positive changes in braking percentages and patterns (shifting outward from the tracks) also but statistical significance of this change could not be established.

The research did not separate the effect of posts and crossbucks from that of the delineators. But the researchers, on the basis of subjective analysis, concluded that high-performance retroreflective tape on both sides of the crossbucks posts, even without the roadside delineators, has a very high impact on an approaching driver. On level road in dark rural area, the reflectorized posts have high impact at 600 m. Reflectorizing both sides of the posts makes two posts, one on either side of the road, visible to an approaching motorist creating the so-called "goal post" effect. The goal post effect (*frames the crossing and*) gives the driver the best possible orientation to the grade crossing. The separation distance between the posts helps a driver estimate his/her distance from the crossing. Reflectorization of the far-side post can (*under appropriate crossing geometry*) create flicker between railcars of a moving train.

An illuminated crossbuck can be very bright but, unless the post is also reflectorized, it can appear to float in the sky. High-performance retroreflective tape on the full length of the post "ties" it to the ground (*and provides the third dimension or relief*) making it easier to orient the position of the post and the crossbuck relative to the roadway.
The other four configurations tested by the KSU research were:

- Conrail shield attached to the post centred 1.0 m above the road surface;
- a standard yield sign on a separate post at grade crossing and a standard yield ahead sign on the approach;
- a combination of the Conrail shield and delineation system; and,
- a combination of the Conrail shield, the delineation system and the yield sign.

Professor Russell of the KSU quoting Abram's findings (1992) reports the perceived benefits of the shield as follows:

- during daylight, the Buckeye Crossbuck with its red striped Joyce shield (Conrail Shield) affords additional driver warning due to its unique configuration, colour, and design;

- subjective responses during daytime buy observers showed a cognitively discernible acknowledgement of the Buckeye Crossbuck at a distance of 300 m;

- subjective responses during darkness by vehicle drivers to the Buckeye Crossbuck system consistently demonstrated a cognitively discernible, distinct and unique "goal post" early warning system at 460 m for high beams and 300 m for low beam;

- the use of Buckeye Crossbuck at passive railroad crossings is a significant improvement over the current existing crossbucks as an early warning system for approaching drivers during both daytime and nighttime.

2.2 **Virginia Study**

The Virginia study was designed after an investigation of several configuration for marking crossbucks and posts at railroad grade crossing by the use of retroreflective material. The purpose of the project was to identify an efficient and low-cost means to improve visibility and safety of passive crossings at night, and to apply it uniformly throughout the Virginia Commonwealth. The study was conducted by the Virginia Department of Transport jointly with the University of Virginia.

Five configurations were developed after review of literature and practices reported by other states and tested at five passive grade crossings in Virginia. Photographs were taken at night from an approaching vehicle at each crossing once using low beam and again using high beam. Videotapes were also produced under the two headlight beam conditions to supplement the photographs.

A subjective analysis was made to determine which of the five systems was the most visible at night.

The photographs and the videotapes of the five crossings were shown to 19 individuals from the Virginia Department of Transport, the Virginia Department of Rail and Public Transportation, and the Virginia Transportation research Council. They were then asked to rate the system during one-on-one interviews.

The study found that:

a) using double sided crossbucks and reflectorizing the full length of both the front and the back of the posts increases the visibility of the crossing, the driver's depth perception of the crossing, and the driver's ability to detect a train moving across the road;

b) at non-skewed crossings, a strobe effect from vehicle headlight shining between the moving cars of the train on the crossbuck and the post on the far-side helps the motorists detect if the crossing is active;

c) at skewed crossings a limited strobe or flicker effect is produced by vehicle headlights shining between the moving undercarriage and wheels of the moving cars of the train on the bottom section of the reflectorized post on the far-side;

d) when asked to chose the best system, all the 19 respondents chose the system with double sided crossbucks and full length reflectorized posts.

The researcher acknowledges that the sample size was limited, however, the findings and conclusions are consistent with other studies.

3 DEMONSTRATION PROJECTS

Three demonstration projects - Idaho, Ohio and Washington were studied. Idaho has completed tests and is implementing the improvements throughout the state. Ohio has implemented the reflectorization using two types of configurations and is evaluating their effectiveness. State of Washington, influenced by the Idaho reflectorization program, is starting a demonstration/pilot project. Brief descriptions of these projects are provided below.

3.1 Idaho

3.1.1 *Project Description*

The Idaho Department of Transport (IDT) has begun a reflectorization program to:

a) upgrade reflectorization material on both the front and the back of the crossbucks from engineering grade to Diamond grade;

b) reflectorize the sign posts on both the front and the back; and,

c) add "Idaho Shield" to crossbuck posts.

The new system will be installed at all the 1300 passive crossings in the state. So far, 10% of the work has been completed.

3.1.2 *Configuration*

The crossbuck sign is double sided and reflectorized with 14 cm black letters. The post is reflectorized on both the front and the back with 5 cm wide retroreflective strip from 10 cm above the top of the rail to the top of the post. The retroreflective material is Diamond GradeTM.

The Idaho Shield is attached to the post below the multiple track sign facing the approach road. The shield has red, silver and white retroreflective strips of Diamond Grade™ quality both on the front and the back. The shield is installed so that the bottom of the shield is 61 cm above the top of the rail but no more than 91 cm above the ground.

Idaho Shield is a modified version of the Ohio Shield. The letters YIELD have been removed since the Idaho law requires stop signs at all passive crossings.

3.1.3 *Basis for Reflectorization Program*

The Idaho program was inspired by the Ohio Shield. Before starting the program, Idaho tested the effectiveness of a modified Ohio Shield called the Idaho Shield, at 25 locations. The following configuration was tested:

a) the Idaho Shield was attached to the crossbuck post facing the approaching traffic;

b) the original crossbuck had engineering grade reflectorization;
c) the posts were not reflectorized.

d) the retroreflective material applied to the shield was Diamond grade;

e) the shields were installed at 25 crossings with STOP sign.

The effectiveness of the shield was tested as follows:

f) the effectiveness was measured by changes in STOPPING and REACTION (looking for train) behaviours;

g) observations were taken six months after the installation in July 1994, and again, in October 1995;

h) hundred observations were taken at each of the 25 experimental crossings with STOP sign and the Idaho Shield (2500 observations in all) and the results were compared with an equal number of observations taken at "control" crossings with STOP signs only;

i) two persons at each site recorded the stopping behaviour while two recorded the reaction behaviour.

The results of the observations are tabulated below.

BEHAVIOUR	STOP SIGN ONLY	STOP SIGN AND SHIELD
July 1994 Observations		
Stopping	45%	69%
Looking	55%	88%
October 1995 Observations		
Stopping	58%	77%
Looking	73%	89%
Average of July 1994 and October 1995 Observations		
Stopping	51%	73%
Looking	55%	89%

Idaho Operations Lifesaver was instrumental in persuading the state authorities to initiate the pilot project and provided funding.

3.1.4 ***Assessment of Effectiveness***

The effectiveness of the project was established by the pilot project. The results are shown in the preceding table. Analysis of accident data has not been done to study the effectiveness of the system. The IDT feels that the accident sample is too small to yield meaningful results.

3.2 **Ohio**

3.2.1 ***Project Description***

Ohio has begun a two-year study of its new crossbuck called the Buckeye Crossbuck. For this purpose, installation of the Buckeye Crossbuck at half of the 3740 passive crossings has been completed. The remaining half the crossings are equipped with the standard double sided crossbucks, reflectorized on both front and back. All the posts, at Buckeye Crossbuck as well as at standard crossbuck, are reflectorized on all four faces. Both, the standard and the Buckeye Crossbuck, are placed randomly.

In addition to the standard crossbucks, the Buckeye Crossbucks, and the reflectorized posts, high-intensity retroreflective advanced warning signs and pavement markings are installed at all crossings.

Evaluation of effectiveness is in progress and the analysis is expected to be completed by December 1997. Report of the study is expected by early 1998.

The evaluation will be based upon analysis of accident data and human behaviour before and after the improvements. The results should be expected to:

a) quantify the superiority of one system (standard reflectorized crossbuck and post) over the other (Buckeye Crossbuck), and

b) quantify the effectiveness of both systems in improving crossing safety.

The human behaviour evaluation will study the approach speed and the point of brake application under both daytime and nighttime conditions for a minimum sample of 100 vehicles per site per evaluation.

3.2.2 ***Configuration***

Ohio is testing two configurations, the Improved Standard Crossbuck and the Buckeye Crossbuck. The Improved Standard Crossbuck is a double sided crossbuck reflectorized on both the front and the back with black lettering on white retroreflective background.

The Buckeye Crossbuck is similar to the Improved Standard Crossbuck with red lettering instead of black, on white background. It also has a Shield (called the Conrail Shield, also called Joyce Shield and often Ohio Shield) at the headlight level. The shield consist of three panels, a 23 x 97 cm middle panel and two 30 x 97 cm side panels. The two side panels are bent back at 45E to the centre panel forming an inverted trough. The side panels have diagonal red and white strips of high-performance retroreflective material both on front and back. The red stripes are 11 cm wide and are bordered by 38 mm mirror strips. The middle panel has 13 mm wide red border and "YIELD" written vertically in 11 cm reflectorized red letters on a silver background.

The retroreflective sheeting material used is Diamond Grade™.

3.2.3 ***Basis for Reflectorization Program***

The purpose of the Ohio DOT study is to evaluate the effectiveness of the new, experimental Buckeye Crossbuck in improving crossing safety. The Buckeye Crossbuck will be compared to an Improved Standard Crossbuck with reflectorized post.

The original version of the Buckeye Crossbuck was developed by Martin Joyce, a Conrail locomotive engineer and chairman of a Conrail team assembled to develop a more effective warning device for passive crossings. The purpose of the device is to "improve driver recognition and awareness of the potential dangers at crossings without active warning devices".

Following the original development work by Conrail much work has been done, according to a report by the Ohio DOT of October 1993, in refining the design. Expert opinion has been sought from people across the nation and "the new concept has been shown to various Transportation research Board (TRB) committees, and has been demonstrated to many others from various states".

3.2.4 ***Assessment of Effectiveness***

Evaluation of effectiveness is in progress and the analysis is expected to be completed by December 1997. Report of the study is expected by early 1998.

The evaluation will be based upon analysis of accident data and human behaviour before and after the improvements. The results should be expected to:

a) quantify the superiority of one system (the Improved Standard Crossbuck and post) over the other (Buckeye Crossbuck), and

b) quantify the effectiveness of both systems in improving crossing safety.

In the meantime, safety is considered to have improved since the installation of the Improved Standard Crossbucks. There are indications of improvements in accident rate. Positive feedback from public, bus and truck operators, police and locomotive engineers has also been received.

3.3 **State of Washington**

3.3.1 ***Description of the Project***

Washington state is considering reflectorization of passive crossing using the Idaho system. The state has begun a pilot project to evaluate the system.

3.3.2 ***Configuration***

Similar to Idaho reflectorization.

3.3.3 ***Basis for Reflectorization Program***

Washington state is inspired by Idaho program and encouraged and assisted by the Idaho Operations Life Saver.

3.3.4 ***Assessment of Effectiveness***

The pilot program has just begun.

4 REFLECTORIZATION PROGRAMS IMPLEMENTED BY THE VARIOUS STATES

Several states have implemented some kind of reflectorization program. Brief description and status of the reflectorization program implemented by Texas, Kansas, Ohio, Minnesota, Iowa, North Dakota, Nebraska, and Idaho, the configuration of reflectorization, the basis for reflectorization, and assessment of effectiveness are provided below.

Commonwealth of Virginia is in early stages of implementation.

4.1 Texas

4.1.1 *Description and Status*

Texas has reflectorized all passive crossings. The retroreflective strip has a guaranteed life of seven years. Future replacement will be done by the railways as part of their maintenance responsibility according to Texas law.

Texas State Department of Highway and Public Transport (SDHPT) has no other reflectorization program. Any future change or improvements will most likely be through maintenance programs.

4.1.2 *Configuration*

Texas State Department of Highway and Public Transport (SDHPT) specifies that the "reflectorized material shall be fixed to the back of crossbucks and support posts at all public railroad crossings not protected by active warning devices in a manner that retroreflects light from vehicles headlights to focus attention to the presence of non-signalized crossings." The reflectorization design calls for:

a) 38 cm retroreflective strips to the back blades of the crossbuck, and

b) one 3" high retroreflective strip wrapped around the post at a height, depending upon the approach and crossing geometry so that the band will align with the headlight/line of vision so as to have high visibility.

4.1.3 *Basis for Reflectorization Program*

Texas reflectorization is by legislation: Texas Civil Statutes, Article 6370b - Warning sign visibility at railroad crossings (1989). The Act required establishment of rules by SDHPT for installations and maintenance of reflectorized materials within six months and completion of installations within two years of the effective date of the act. The effective date of the ct is August 1989.

We have not found any research study, either on the rationale or on the benefits of reflectorization or, on the patterns or the configurations to be used.

4.1.4 *Assessment of Effectiveness*

There is apparently no assessment of effectiveness based upon accident analysis. In general the accidents are declining. However, it is difficult to relate the results, in a statistically significant way, to the reflectorization since there are other parallel programs such as public education, awareness, and enforcements etc.

4.2 Kansas

4.2.1 *Description and Status*

A reflectorization program is in progress. The program began in 1992/93. To date, about 1500 highest priority crossings have been reflectorized. Kansas has about 8000 crossings, 6000 are passive.

4.2.2 *Configuration*

Kansas reflectorizes the crossbuck and the post as follows:

a) new crossbucks and new posts are installed;

b) crossbuck are double sided;

c) both the crossbucks and the posts are reflectorized on both sides, the front and the back;

d) the retroreflective strip on the post is 100 mm (4 in.) wide and 1524 mm high and reflectorizes the length of the post from 300 mm (1 ft.) to 1.824 m above the road level;

e) the retroreflective strip is Diamond Grade™ prismatic retroreflective sheeting.

In addition to the reflectorization, Kansas crossing improvement requires:

f) advance warning signs at all passive crossings; and

g) cold plastic retroreflective pavement railroad markings and stop bars where the road surface permits.

4.2.3 *Basis for Reflectorization Program*

The Kansas program was influenced by the KSU research by Professor Russell.

4.2.4 *Assessment of Effectiveness*

Kansas has not made any assessment of effectiveness of reflectorization on the basis of accident analysis. However, on the basis of opinions expressed, field observations of conspicuousness of crossings and night photographs, the State officials believe that the reflectorization has been effective.

4.3 *Ohio*

The Ohio program is discussed in detailed Section 3.2 above.

4.4 Minnesota

4.4.1 *Description and Status*

Minnesota has completed a program for improvement of passive grade crossings. The improvements included the following "state-of-the-art enhancements":

a) installation/replacement of crossbucks assembly crossbuck signs, retroreflective strips, wood post, necessary stop signs and number of track signs and drilling and treatment of breakaway holes);

b) application of retroreflective strip to the back of the crossbuck post;

c) installation of brightly reflectorized 36" advance warning signs;

d) installing retroreflective plastic pavement marking tape where quality of surface permits. Retroreflective epoxy paint is used at other locations.

Together, these improvements are expected to enhance visibility and awareness of the crossings.

Minnesota DOT has completed a study/opinion survey to assess the Minnesotans' perceptions and their awareness of the dangers of the railroad crossings. The Minnesotans feel that additional safety improvements should be done at railroad crossings such as installation of red flashing warning lights and gates at the crossings, installation of flashing lights at crossing stop signs and advance warning signs and, installation of bright street lights at dark crossings.

4.4.2 *Configuration*

The reflectorization configuration is the following:

a) the crossbucks are reflectorized both on the front and on the back. The post is reflectorized by 2"x 4" retroreflective strip installed vertically on the back of the post only;

b) the back of the crossbuck assembly, the crossbuck and the post, is reflectorized to create a strobe effect when a vehicle approaches a crossing while a train is travelling through the crossing at night.

4.4.3 *Basis for Reflectorization Program*

The Minnesota DOT's improvement program to "enhance the visibility and awareness of the railroad-highway grade crossings" was the result of public demand for stronger state program to enhance safety at railroad crossings. The demand was a recurring theme at 14 safety forums held by the Minnesota DOT in 1988 and 1989 throughout the state. These forums pointed out the need to improve visibility of the railroad-highway grade crossings to the driving public.

4.4.4 *Assessment of Effectiveness*

It is understood that no assessment of effectiveness of the "reflectorization" has been made on the basis of accident analysis. It is difficult to isolate and quantify the effect of reflectorization on safety improvement from other safety improvement initiatives.

However, Minnesota DOT has recently completed a study/opinion survey to assess the Minnesotans' perceptions and their awareness of the dangers of the railroad crossings. The survey was conducted to find out what future efforts should be made for crossing safety improvements. The survey found that people notice crossings but do not expect trains. They were also aware that work had been done at the crossings. It may be concluded that the crossings are now more visible. However, the contribution of reflectorization in enhanced visibility is difficult to assess.

4.5 Iowa

4.5.1 *Description and Status*

State of Iowa has replaced all passive signs at grade crossings with new signs with high intensity retroreflective sheeting as part of a project to identify crossings, update crossing inventory and identify and replace deficient signs and sign posts. The project was completed in 1987.

One of the objectives of the project was to improve safety at highway-railroad grade crossings.

4.5.2 *Configuration*

Only crossbucks are reflectorized. Both the front and the back are reflectorized. The front of the crossbuck blades have silver high intensity retroreflective sheeting with black 5" lettering. The back of each blade has 5" strip of Scotchlite No. 3870, High Intensity sheeting on the full length.

The sign posts are not reflectorized.

4.5.3 *Basis for Reflectorization Program*

Crossbucks were replaced and reflectorized as part of a project by the Iowa Department of Transport (DOT) to install crossing warning signs consistent with the industry standards.

In 1982, Iowa's grade crossing warning, identification and sign systems were outdated, inconsistent, and inadequate and, the railroad companies were unable to install new signs or devote staff to update crossing information. A project was therefore undertaken by the Iowa Department of Transport Rail and Water Division to provide correct identification of railroad-highway crossings, update crossing inventory and install crossing warning signs consistent with industry standards.

About 10,000 crossbucks were replaced and reflectorized under this project.

4.5.4 *Assessment of Effectiveness*

Apparently there is no analysis of accident data to evaluate effectiveness of the reflectorization. Many factors contribute to safety improvements and it is difficult to isolate the impact of reflectorization.

However the DOT believes that the project has contributed to safety improvement. The reflectorized crossbucks are visible from both approaches and the flickering effect from the far-side crossbuck during the passage of a train is evident.

The DOT officials like the reflectorization of the posts by Minnesota DOT and may adopt the system.

4.6 North Dakota

4.6.1 *Description and Status of Reflectorization*

North Dakota has initiated a four year program to replace and reflectorize crossbucks and posts at all passive crossings. Under this program the state provides crossbuck blades and reflective strips for the posts. The railroads supply the posts and install the system.

The project is in the second year and nearly 400 of a total of 4700 crossings have so far been completed.

4.6.2 *Configuration*

Crossbucks are double sided, the front and the back reflectorized. The posts are also reflectorized by 2"x 4' retroreflective strips attached to both the front and the back.

4.6.3 *Basis for Reflectorization Program*

The present program was requested by the railroads and authorized by the state legislature. No study or test was done to establish the safety benefits of the reflectorization.

4.6.4 *Assessment of Effectiveness*

No assessment of the effectiveness of the reflectorization has been done so far.

4.7 Nebraska

4.7.1 *Description and Status of Reflectorization*

State of Nebraska has an on-going program to reflectorize the crossbucks and the posts at passive grade crossings. Nebraska has 3800 grade crossings, about 75% are passive.

The reflectorization program was started about three years ago. So far, work has been completed on 1000 crossings on the two Class I railroads and on 500 crossings on short lines.

4.7.2 *Configuration*

The crossbucks are reflectorized on both front and back. The posts are reflectorized on both the front and the back by 2"x 4' retroreflective strips. The retroreflective strips white, single colour, high-intensity type.

4.7.3 *Basis for Reflectorization Program*

Nebraska reflectorization program is inspired by the Minnesota program. No independent study was carried out.

4.7.4 *Assessment of Effectiveness*

No accident analysis has been done for assessment of the effectiveness of the reflectorization. However positive feedback has been received from the residents, motorists and highway officials.

4.8 Virginia

4.8.1 *Description and Status of Reflectorization*

Virginia is proceeding to upgrade signs at all passive crossings. The project will install new crossbucks with the front and the back reflectorized and install retroreflective strips on the front and the back of the crossbuck posts. The state will supply the crossbucks and the retroreflective strips for the posts and the railroads will install them.

Contract for supply of material has been awarded. The installation is expected to be completed within 1997.

4.8.2 *Configuration*

The crossbucks and the posts are reflectorized both on the front and on the back. The post is reflectorized by 2" wide tape applied to the full length of the post. The retroreflective material is V.I.P., type.

4.8.3 *Basis for Reflectorization Program*

The project was designed on the basis of a research study carried out jointly by the Virginia Department of Transport and the University of Virginia described in Section 2.2 above.

4.8.4 *Assessment of Effectiveness*

The project is in early stages of implementation.

4.9 Idaho

Idaho program is described in detail in Section 3.1.

4.10 **North Carolina**

We understand that the state of North Carolina is considering a program to reflectorize passive grade crossings. They are studying the reflectorization programs and research undertaken by other states.

APPENDIX B
ACCIDENT DATA

APPENDIX B

Nighttime					Daytime		
Year	***Type***	***Number of Accidents***	***Fatalities***	***Injuries***	***Accidents***	***Fatalities***	***Injuries***
1986	Train Struck	38	0	9	96		
	Train Struck by	46	3	35	59		
1986 totals		**84**	**3**	**44**	**156**	**15**	**71**
1987	Train Struck	30	2	9	84		
	Train Struck by	41	0	29	44		
1987 totals		**71**	**2**	**38**	**131**	**12**	**66**
1988	Train Struck	24	1	6	77		
	Train Struck by	30	5	13	61		
1988 totals		**54**	**6**	**19**	**140**	**14**	**72**
1989	Train Struck	13	0	2	85		
	Train Struck by	39	0	23	53		
1989 totals		**52**	**0**	**25**	**137**	**21**	**53**
1990	Train Struck	29	4	5	83		
	Train Struck by	31	2	24	47		
1990 totals		**60**	**6**	**29**	**132**	**19**	**51**
1991	Train Struck	16	1	3	88		
	Train Struck by	34	1	21	55		
1991 totals		**50**	**2**	**24**	**145**	**21**	**85**
1992	Train Struck	21	4	5	72		
	Train Struck by	20	4	12	32		
1992 totals		**41**	**8**	**17**	**10**	**20**	**70**
1993	Train Struck	18	3	2	80		
	Train Struck by	24	3	8	29		
1993 totals		**42**	**6**	**10**	**109**	**24**	**23**
1994	Train Struck	20	1	1	72		
	Train Struck by	30	0	8	23		
1994 totals		**50**	**1**	**9**	**95**	**21**	**13**
1995	Train Struck	23	2	3	65		
	Train Struck by	29	6	9	19		
1995 totals		**52**	**8**	**12**	**84**	**13**	**17**
	Train Struck	232	18	45			
	Train Struck by	324	24	182			
TOTAL		**556**	**42**	**227**			
Average	*10 years*	*55.6*	*4.2*	*22.7*	*123.3*	*18*	*52.1*
Average	*last 3 years*	*48*	*5*	*10.3*	*96*	*19.3*	*17.7*

APPENDIX C

RETROREFLECTIVE MATERIAL –
REFLECTIVITY TABLE

APPENDIX C

RETROREFLECTIVE MATERIAL REFLECTIVITY					
Observation Angle	***Incidence Angle***	***Material Type***			
		High Intensity	*Diamond Grade LDP™*		*Diamond Grade V.I.P.™*
			New Material	*After Seven Years*	
.2	-4	250	800	400	430
.2	+30	150	400		235
.2	+45		145		150
.2	+60		35		
.5	-4	95	200		250
.5	+30	65	100		170
.5	+45		75		35
.5	+60		30		

APPENDIX D
COSTS TABLES

APPENDIX D

COST TABLE 1 – TOTAL COST PER CROSSING
USING NEW CROSSBUCK

IDENTIFICATION	MATERIAL COST	LABOUR COST	TOTAL COST
4-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$404	$153	$557
2-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$333	$153	$485
2-inch wide strip on post and 2-inch wide strip on the back of crossbuck	$311	$153	$464
Add shield later	$519	$43	$561

COST TABLE 2 – MATERIAL COST PER CROSSING

IDENTIFICATION	POST RETROREFLECTIVE STRIPS	CROSSBUCK	SHIELD	TOTAL
4-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$144	$261		$404
2-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$72	$261		$333
2-inch wide strip on post and 2-inch wide strip on the back of crossbuck	$72	$239		$311
Add shield later			$519	$519

COST TABLE 3 – LABOUR COST PER CROSSING USING NEW CROSSBUCK

IDENTIFICATION	TOTAL LABOUR COST
4-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$153
2-inch wide strip on post and 4-inch wide strip on the back of crossbuck	$153
2-inch wide strip on post and 2-inch wide strip on the back of crossbuck	$153
Add shield later	$43

COST TABLE 4 – MATERIAL COST FOR ADDING RETROREFLECTIVE SHEET TO POST

System ID	**Post**				**Unit Price per sq.ft.**				**Amount**	
	Dimensions		***Quantity – sq.ft.***		***Sheeting***	***Substrate***	***Hardware & Cont.***	***Total***		
	Wide (")	*Long (')*	*One Side*	*Both Sides*					*Per Post*	*Per Xing*
4-inch wide strip on post	4	9	3.00	6.00	$8.15	$3.25	5%	$12	$72	$144
2-inch wide strip on post	2	9	1.50	3.00	$8.15	$3.25	5%	$12	$36	$72

COST TABLE 5A – MATERIAL COST OF NEW CROSSBUCK USING 4-INCH WIDE STRIP ON THE BACK

Description	**Cost Per Crossbuck**							**Cost Per Crossing**
	Dimensions		***Quantity – sq.ft.***		***Unit Price***	***Hardware & Cont.***	***Amount***	
	Wide (")	*Long (')*	*One Blade*	*Both Blade*				
Current Price	8	4	2.67	5.33	$9	15%	$55	
Prismatic Sheet on the Front	8	4	2.67	5.33	$8.15	0%	$43	
Prismatic Sheet on the Back	4	4	1.33	2.67	$8.15	0%	$22	
Labour to Add Sheet to the Back					$10		$10	
Total Cost							**$130**	**$261**

COST TABLE 5B – MATERIAL COST OF NEW CROSSBUCK USING 2-INCH WIDE STRIP ON THE BACK

Description	**Cost per Crossbuck**							**Cost Per Crossing**
	Dimensions		***Quantity – sq.ft.***		***Unit Price***	***Hardware & Cont.***	***Amount***	
	Wide (")	*Long (')*	*One Blade*	*Both Blade*				
Current Price	8	4	2.67	5.33	$9	15%	$55	
Prismatic Sheet on the Front	8	4	2.67	5.33	$8.15	0%	$43	
Prismatic Sheet on the Back	2	4	0.67	1.33	$8.15	0%	$11	
Labour to Add Sheet to the Back					$10		$10	
Coût total							**$120**	**$239**

COST TABLE 6 – MATERIAL COST FOR SHIELD

Description	**Shield**				**Unit Price per sq.ft.**				**Amount**	
	Dimensions		***Quantity – sq.ft.***		***Sheeting***	***Substrate***	***Hardware & Cont.***	***Total***		
	Wide (")	*Long (')*	*One Side*	*Both Sides*					*Per Post*	*Per Xing*
Shield	34.46	38	9.09	18.19	$8.15	$4.25	15%	$14	$259	$519

COST TABLE 7 – LABOUR COST PER CROSSING USING NEW CROSSBUCK

DESCRIPTION	INSTALLATION COST	TRAVEL COST	TOTAL COST PER CROSSING
2-inch or 4-inch wide strip on post and 2 or 4-inch wide strip on crossbuck	$152	$1	$153
Shield Only	$42	$1	$43

COST TABLE 8 – LABOUR COST FOR INSTALLATION

DESCRIPTION	LABOUR TIME IN MINUTES							Labour Cost per Crossing		
	Per Post				***Per Crossing***					
	Install Strip	*Install Crossbuck*	*Install Shield*	*Total*	*Installation*	*Travel* (1)	*Total*	*Hours*	*Rate*(2)	*Amount*(3)
2" or 4" wide strip on post and 2" or 4" wide strip on crossbuck	15	25		40	80	11	91	1.52	$80	$152
Shield Only			7	7	14	11	25	0.42	$80	$42

(1) See Cost Table 10 for estimate of travel time.
(2) Two-person crew at $40 per person-hour
(3) Using output efficiency of 80%: see Cost Table 10

COST TABLE 9 – TRAVEL BETWEEN CROSSINGS

Description	**Travel Expense**		
	Distance [(1)]	***Rate***	***Amount ($)***
All configurations	3	$0.35	$0.97

(1) See Cost Table 10 for travel distance.

COST TABLE 10 – GENERAL INPUT DATA

Number of Crossings in Canada	23,482
Total Track km in Canada	65,000
Average Crossing Spacing – km	2.77
Average Crew Travel Speed Between Crossings – km/h	15
Average Travel Time Between Crossings – Minutes	11.07
Output Efficiency – %	80%