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Secretary:

**Submission to House of Representatives Standing Committee on Transport and Regional Services**

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# Train Illumination Enquiry

**From: Dr. Edward Humphries, Technical and Regulatory Affairs Manager, 3M Traffic Safety Systems Division, 3M Australia, PO BOX 99, Pymble, NSW, 2073.**

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**After Jan 30th direct correspondence to Mr. Andrew King**

## Introduction

3M is a global, diversified technology company with operations in over 60 countries worldwide. 3M's products span numerous market areas from office and medical through to mining and oil and gas production. 3M Traffic Safety Systems division is the worlds leading manufacturer and supplier of retroreflective materials for road safety applications. Although most commonly used in signage, these materials find application in vehicle marking, road marking and other applications.

A number of fundamental advances these materials have occurred since the previous enquiry into train illumination and railway level crossing accidents and these advances could help improve train and railway crossing visibility with little or no increase in cost relative to current treatments.

## Specific Areas Addressed

### 1. Reflective Markings on Rolling Stock

A major recommendation of the previous enquiry was that all rolling stock be fitted with retroreflective markings or paint. Retroreflective materials, or as they are more colloquially called, reflective materials, function by reflecting an incident beam of light back in the direction of its source. This is in contrast to a mirror reflector, which reflects the incident light at an equal but opposite angle. Appendix 1 contains a short explanation of some of the criteria used to categorise reflective material performance.

Retoreflective materials are classified based on various performance measures described in the Australian/New Zealand Standard 1906.1:2006 *Retroreflective Materials and Devices for Road Traffic Control Purposes, Part 1: Retroreflective Sheeting* . The sections relevant to this enquiry are those dealing with retroreflective performance and daytime colour. The retroreflective properties of these materials are defined by several performance "classes" according to the AS/NZS1906 standards. These classes and brief descriptions are listed below.

- Class 2 (AS/NZS1906.1): The first retroreflective material widely used for signage. These material has a short (7 years) service life and provides low levels of reflectivity.
- Class 1 (AS/NZS 1906.1): This class of material features on the vast majority of signage on Australian roads and is now the minimum

specified performance level for all regulatory signage in Australia. This material provides a high level of reflective perfomance

- Class 1A (AS/NZS1906.2): This class of material is designed for use on roadside guidepost delineators. It replaces all "cats-eye" style round reflectors in this application with a rectangular piece of reflective film. This material is designed to retroreflect light a tight cone shape, that is, these materials will appear very bright when viewed at essentially 90° angles (head on), however once the position of the reflective material to the driver changes significantly from head on the reflective material ceases to function. This phenomenon can be easily seen during night time driving on our roads and is designed to draw the driver's attention towards the road ahead.
- Class 1W (AS/NZS1906.1): This is the highest performance class and was introduced in the 2006 review of AS/NZS1906.1. These materials are designed to reflect light at much wider angles than the other classes. The most common roadway application of this material is on disadvantaged signage such as overhead signs or signs mounted on the right hand side of the road. However Queensland Main Roads has instituted a blanket specification for Class 1W materials to be used on all regulatory signage.

At present, the Australian Railway Association (ARA) national standard document references AS/NZS 1906.1:1993 to characterise the type of reflective material deemed acceptable, and the material specified is Class 1A. This material is specifically designed for long distance, head-on viewing and is the material recommended in the Australian Trucking Association Voluntary Code of Practice for Truck Conspicuity Markings (although that CoP refers to a European ECE regulation when the specifying reflective material).

Class 1A materials are generally suitable for enhancing night time visibility of trucks on the roadway, as both the viewer (the driver) and the truck are positioned on the roadway and the construction of most roads does not allow for wide angle visibility during intersection approaches. Furthermore, markings on the rear of trucks will almost exclusively be viewed from behind, i.e., in a head-on configuration. In the case of a train approaching and then passing through a level crossing, Class 1A materials currently in use will be most effective as reflectors during the period where the train is directly in front of the vehicle – at which point the train is already passing through the roadway. Class 1A conspicuity markings may provide the driver with little opportunity for advance warning of the train during the approach to the road/rail intersection. Furthermore, the performance requirements of Class 1A material (per AS/NZS1906.2:2007) demand very little in terms of observation angle performance, resulting in substantially reduced reflectivity levels when observed from high observation angle vehicles, such as trucks.

Changing the reflective material specification for Rolling Stock markings to Class 1W (AS/NZS 1906.1:2006) can help improve this situation as Class 1W materials are specifically designed to deliver improved retro reflectively at wide entrance angles while maintaining high levels of reflectivity at narrow entrance angles ("head on" geometries). This is one of the benefits of Class 1W materials that have led to widespread usage of this material class for vehicle marking in the mining industry. Class 1W performance also significantly improves the night time conspicuity of the material when viewed from vehicles with larger separation between the driver's eye and the vehicles headlight (observation angle), for instance, in the case of heavy articulated trucks. It is important to note that when viewed at larger observation angles, Class 1A material can be all but invisible. The importance of wide angle reflectivity was specifically noted in the committee's previous report.

As Class 1W materials are the highest performance class in AS/NZS1906.1, a material that meets the minimums for Class 1W is often considered erroneously considered the equal of a material which far exceeds the Class 1W requirements. Unfortunately, the Australian Standards setting environment can result in a "lowest common denominator" outcome where the best performing materials are deemed equivalent to materials that in reality are far inferior in order to placate the various commercial interests present. With this in mind, consideration should be given for using materials that are well in excess of the Australian Standard defined minimum performance level.

The most recent development in reflective materials is called micro full cube technology. These are broadly considered as Class 1W materials in Australia but in fact greatly exceed the requirements of the class. Micro full cube materials reflect up to 60% of incident light, in contrast to most Class 1 and Class 1W materials which reflect only 30-35% of incident light. This extra available reflected light is distributed more evenly to all viewing angles, such that high wide angle performance is not sacrificed for high narrow angle performance. High performance is possible throughout all viewing positions.

It is noted that night time accidents represent a relatively smaller percentage of level crossing incidents involving road users and trains than other times. This is similar to most crash statistics in absolute terms. However that analysis neglects to correct the data for the reduced traffic volumes seen at night.

The proposed change will be essentially cost neutral and delivers an incremental benefit from the previous enquiry's recommendation on this subject. Class 1W materials were not officially recognised by an Australian Standard in 2004, however this is no longer the case. Further, as outlined in Appendix 1, there have been significant advances in the technology of reflective materials in the intervening years.

## 2. Colour of Rolling Stock Conspicuity Markings

The ARA/RISSB Standard for Train Conspicuity markings allows for the use of red, white or yellow Class 1A reflective markings. This type of marking will provide a measure of night time visibility for the train, however the reflective properties do not function during daylight hours and the standard colours of red, yellow or white do not provide any enhancement of the daytime visibility of the train.

Independent of the aforementioned proposed change to the material *class*, it is proposed that the specified colour of train conspicuity markings be changed to fluorescent yellow.

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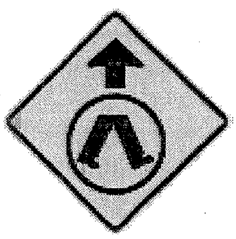
Fluorescent materials are manufactured using pigments and dyes that are able to absorb a portion of the sun's (invisible) UV radiation and convert this radiation to visible light which is then emitted. This process is behind the exceptional visual impact that fluorescent colours possess during daylight hours. Put simply, there is more light being emitted from the surface of a fluorescent coloured material during the day than there is from a non-fluorescent coloured material.

Furthermore, fluorescent materials are particularly visible during the hours of dawn, dusk, overcast periods and areas of reduced ambient sunlight such as in shaded areas. During these conditions and times non-fluorescent colours appear dull and inconspicuous.

Fluorescent materials are increasingly being used on Australian roads in signage applications. The most widespread use is fluorescent yellow-green (sometimes referred to as lime-yellow) for pedestrian corridor signage such as the crossing ahead or "mother and child" signs below.




Fluorescent yellow-green is gaining an association with pedestrian activity in the drivers mind and for this reason it is not recommended for use in the railway zone. Similarly, fluorescent orange is most widely used for certain roadworks signs but also in school zones in some Australian states. Fluorescent yellow as a colour is still available for general roadway use and it is proposed here as a colour to improve the daytime visibility of train. Furthermore, this can be achieved by using a combined performance fluorescent and retroreflective material for conspicuity markings.

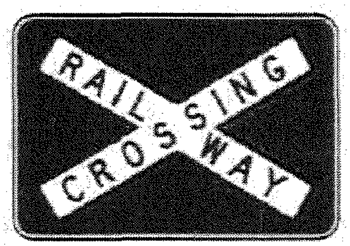
Once again, this change would be cost neutral to the industry as the cost difference in changing from a non-fluorescent coloured reflective film to a combined performance fluorescent/retroreflective material is negligible.

References 2-5 contain more detailed information regarding the performance and visibility benefits offered by fluorescent materials.

## 3. Road Signage at Railway Crossings

Presently, road safety treatments at level crossings are covered by AS 1742.7:2007 Manual of Uniform Traffic Control Devices, Part 7: Railway Crossings. This standard designates sign designs and use, road marking treatments and flashing symbol design among other things. State road authorities contribute to the development of this standard through their peak body organisation, Austroads. It is then a matter for each road authority to implement areas of the standard appropriate to their state and road safety goals. Generally speaking the agreed content of an Australian Standard will become the state road practice but this is not always the case.

Past updates of AS1742.7 have recommended the use of a new "railway crossing" sign design as a replacement of the white regulatory x-shaped crossbuck sign (pictured). The newer sign design is referred to as a "Confederate Flag" and consists of the white crossbuck element on a field of red.


The specific recommendation was that the confederate flag be used on all new installations and replacements of existing damaged crossbuck signage. While this usually does occur for State Road Authority controlled level crossings, crossings that are in local council areas or remote areas are only maintained when the sign is completely removed, eg, hit by a vehicle. Therefore despite the visibility benefit offered by the increase in sign surface area presented to the driver and the improved visual contrast provided by the white on red design, this style of signage is seldom seen on the remote passively controlled crossings where it would be of most benefit.

An additional improvement of level crossing recognition could be achieved through the use of fluorescent yellow for all railway crossing lead in warning signage. Lead in signage is defined as the required signage on the roadway that gives the driver advanced warning of the hazard, in contrast to the confederate flag or crossbuck signs which are installed to mark the exact position of the hazard. These signs are currently manufactured from standard yellow reflective materials. Utilising fluorescent yellow in this application could dovetail well with proposal number 2 for the use of fluorescent yellow conspicuity markings on rolling stock, creating a fluorescent yellow "railway crossing corridor". At present, the fluorescent yellow colour is available for general signage use with road authority permission in all states but is not widely used.

A number of studies have demonstrated that fluorescent signage has improved recognition and detection properties in comparison to standard coloured signage.[2-5]

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The previously published data on railway crossing incidents are clear on the fact that the majority of incidents are occurring at level crossings during fine, daytime conditions.[1] Therefore, particularly in the case of passively controlled crossings, any improvement in the visual impact of the controlling signage will be beneficial in improving driver awareness of the level crossing.

The Australian Transport Council's 2003 report entitled "National Railway Level Crossing Safety Strategy" raises the interesting fact that most crashes occur in locations where the driver has a 'local understanding of the railway level crossing'. Previous studies have demonstrated that drivers who are familiar with a particular fluorescent sign make an increased number of eye fixations on the fluorescent sign in subsequent passes through the zone containing the signage.[2] This learning effect could be leveraged to help remind inattentive, familiar drivers of the presence of a railway level crossing.

More broadly, increasing the size of signage can play a major role in improved visibility and recognition of a sign. This principle could by applied to many level crossings where there are no engineering issues preventing the use of larger than the minimum required sign.

Although research has supported the assertion that most railway crossing accidents occur during daylight hours, night time visibility of road markings and signage should not be considered unimportant. It comes as no surprise that daylight periods are prevalent in the statistics, as this is the period of time during which most vehicles are using the roads and hence more opportunities exist for road/rail collisions to occur.

As with the previous recommendations, the cost difference both in changing from crossbuck to confederate flag and yellow to fluorescent yellow would be relatively small as the major contributors to signage cost are labour and installation rather than the materials used.

## Conclusions

Signage and passive control measures, in isolation, are unlikely to result in measurable reductions in the number of railway level crossing accidents involving vehicles and rolling stock. However they play an important and pre-existing role in current level crossing safety treatments. Recent advances in the technology used to construct retroreflective materials and the availability and effectiveness of combined performance fluorescent/retroreflective materials can be leveraged to enhance the state of current signage for railway level crossing use. These changes to both rolling stock markings & approach signage can be implemented with almost no cost differential over the existing materials in use.

## References

1. House of Representatives Standing Committee on Transport & Regional Services, Train Illumination Enquiry Report 2004

2. T Schnell, P. Ohme; Transportation Research Board (TRB) Paper #01-2584, Jan **2001**.

3. H. T. Zwahlen, U. D. Vel; TRB Record 1456, **1994**

4. D. M. Burns, L. A. Pavelka; *COLOR Research and Application*, **20**(*2*), April, **1995**.

5. SINTEF Transport Engineering, TRB Paper #981435.

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# Appendix 1

**Basics of Retroreflectivity**

Retroreflective material performance is generally categorised based on how its reflectivity changes as a function of two variables. The first variable, entrance angle, is the angle subtended by a line between the headlight and the material and a theoretical line perpendicular to the face of the sign or reflective material (see fig 1 below). Signage is generally installed in positions where the entrance angle will not exceed 10° at the position in which the driver reads the sign. Road side delineators are generally positioned such that the entrance angle is much less than 4°. Rail crossings often cut roads at angles much greater than 10°, so excellent entrance angle performance is a consideration for materials used to improve rolling stock visibility.

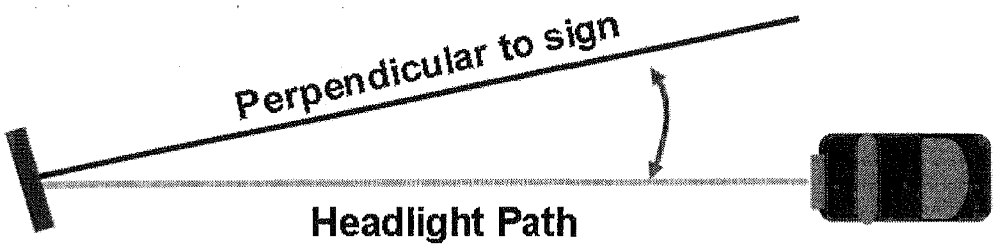



Fig 1: Entrance angle

The second variable is called observation angle. This is the angle subtended by a line from the headlight to the reflective material and a line from the material to the drivers eye (see fig 2, below) . Typically observation angle moves within of 0.1-3° during a vehicles approach to a sign, being smaller at greater distances and increasing as the vehicle approaches. For vehicles with larger separation between the driver's eye and the headlights, larger observation angles are experienced. Therefore truck drivers experience larger observation angles than car drivers. Reflective materials and signage are designed to serve the largest proportion of drivers, therefore manufacturers usually prefer to serve car drivers by delivering are larger portion of the limited available reflected light to narrow observation angles. However many of the incidents involving road and rail level crossing accidents are of a truck or other heavy vehicle colliding with a train, therefore wide observation angle performance must also be considered.

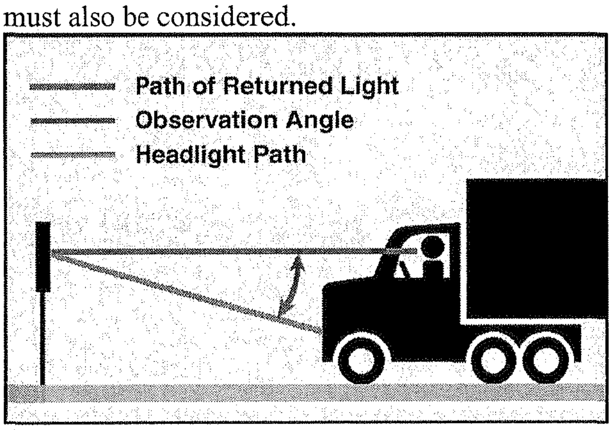



Fig 2: Observation angle

All retroreflective materials reflect light in a cone-like distribution. This is demonstrated in figure 3.

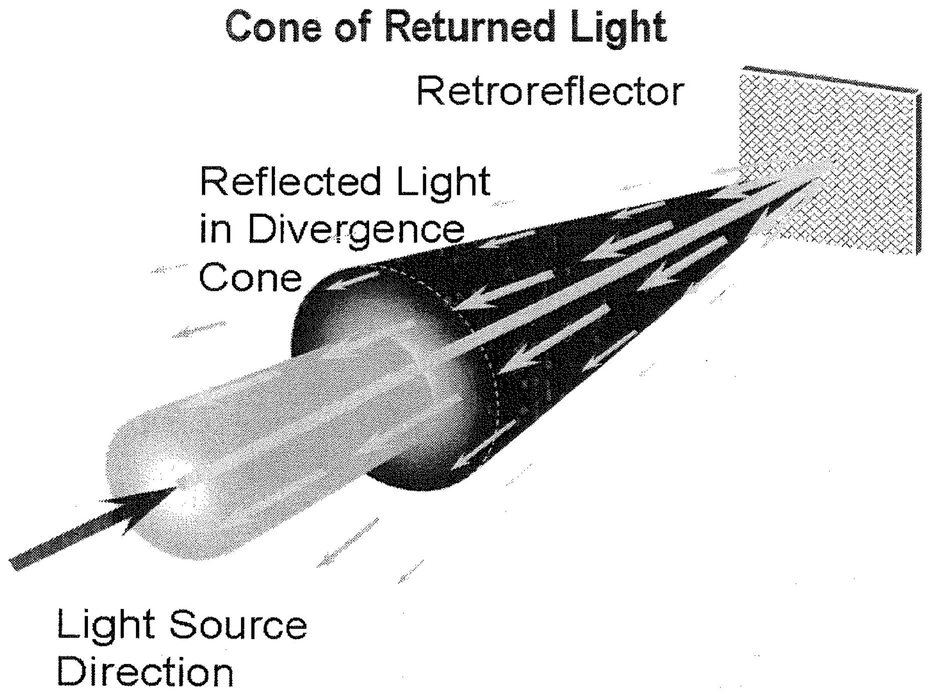



Fig 3: Cone of retroreflection

The cone of retroreflection, or divergence cone, is a way of visualising observation angle. The reflected light is brightest in the centre of the cone and fades as the observer moves further towards the edge of the cone. This is a simplification of the process, as there is no "edge" of the cone as such. Rather, the intensity of reflected light fades gradually to zero.

Retoreflective materials are designed to have either a narrow cone of reflectivity or a relatively wider cone. Class 1A materials have quite a narrow cone, while Class 1W materials have a much wider cone. Practically speaking, this simply means that the reflectivity remains brighter for a larger region inside the cone. This is why trucks can benefit from the use of Class 1W materials, as the wider cone of retroreflection allows more light to reach the truck driver's eye.

The methods for construction retroreflective sheetings have also evolved substantially in the past 7 years. Previously, retroreflective materials were predominantly based on the use of glass bead lens are the active reflective component. Today, most high brightness reflective materials are composed of structures called microprismatic reflective elements,. These are microscopic hollow prisms are embedded into a resin matrix (fig 4). The reflective properties of the material are a function of the geometric configuration of these prisms.

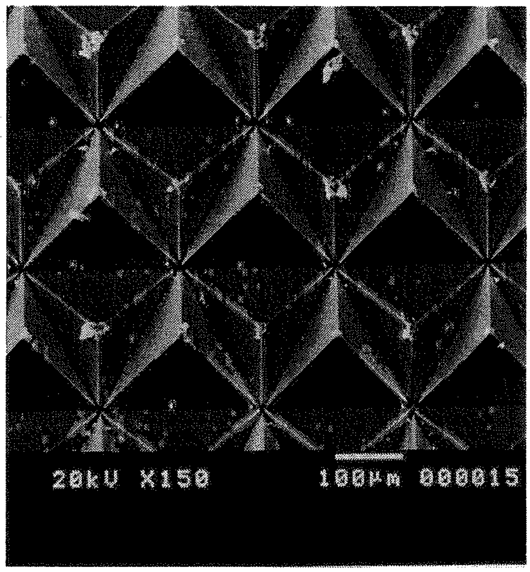
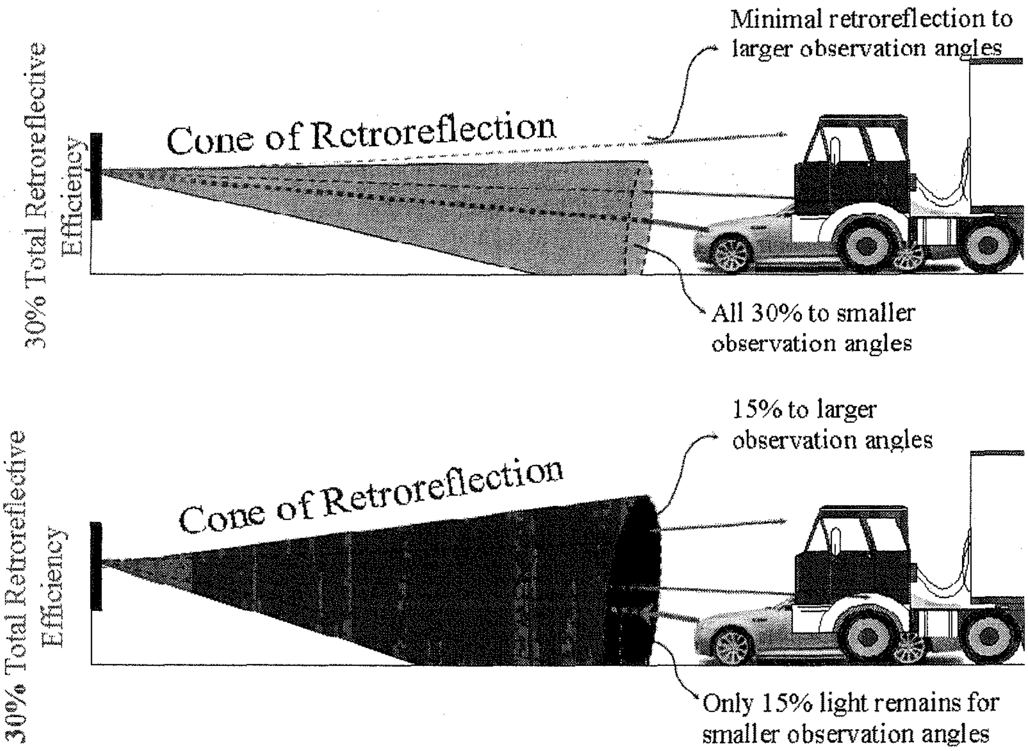



Fig 4: Rear view of microprismatic elements

The man-made nature of these prism structures leads to the conclusion that an almost infinite spectrum of reflective performance can be achieved. However, there is a limitation in this technology. Most microprismatic materials reflect only around 35% of incident light. This means that manufacturers must trade off reflective performance in one area to enhance it in another, ie, sacrifice long distance head-on performance for wide angle performance. For this reason, Class 1A materials are brighter than Class 1W materials when measured at narrow angles. At wide angles, the opposite is true.

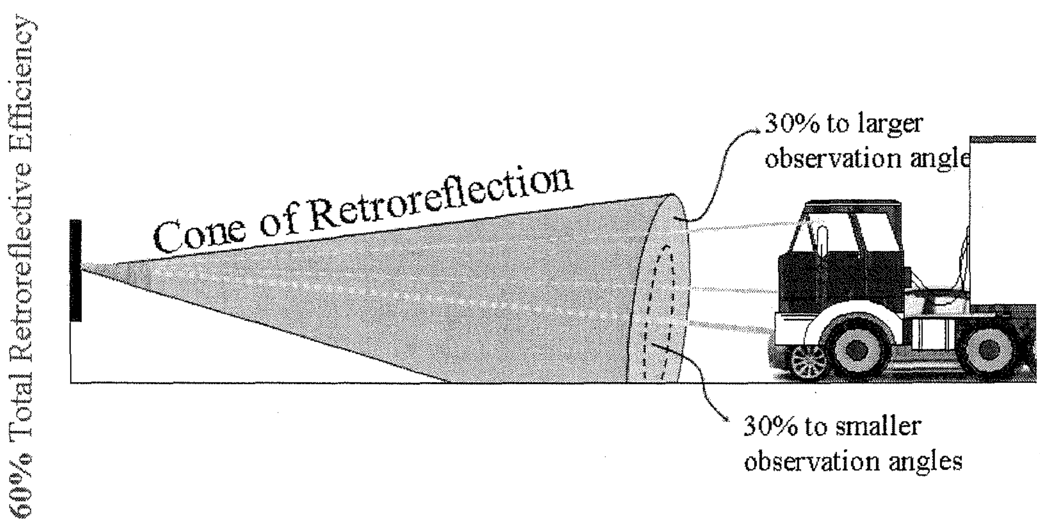
The body test of this submission discussed a reflective material technology called "micro full cube" prismatic sheeting. This material is currently the most efficient reflective material available, meaning that it returns more of the incident light back to the driver than any other reflective materials. One such example of this material is 3M's Diamond Grade Cubed $DG^3$ material. Formally a Class 1W material in Australia (and approved as such by all Australian State Road Authorities), the extra reflected light that this material generates allows specifiers to provide high reflectivity levels to the drivers of both cars and trucks. One way to think of the difference between this and materials that reflect less light is shown the series of images below.

In the first case (fig 5), we have a car and truck viewing a traditional prismatic retroreflector which returns around 30% of the incident light. Such a material can therefore either attempt to serve the majority driver (the car) by directing all 30% to the narrow observation angle or deliver a compromise position by sending 15% to the narrow region and the remaining 15% to the truck drivers in the wider region (fig 5).



<u>Fig 5:</u> Alternative ways of distributing light within the cone

Using a higher efficiency reflective material such as the micro full cube DG[3] material, the increased amount of reflected light can be directed to the truck without the need to compromise by removing light availability for the car driver. This example is seen in figure 6.



<u>Fig 6:</u> Even distribution of light with brighter reflective sheeting

The potential benefits of using a reflective material with these properties for conspicuity markings on rolling stock should be apparent, and those same benefits would apply to extending this to the signage around the level crossing environment.

Government of South Australia
Department for Transport, Energy and Infrastructure

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The Secretary
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Dear Sir/Madam,

*SUBMISSION INTO UPDATE OF 2004 REPORT ON TRAIN ILLUMINATION*

I write as chair of the South Australian State Level Crossing Strategy Advisory Committee. The Committee wishes to make a submission to the update of the 2004 Standing Committee report titled: *Train Illumination: inquiry into some measures proposed to improve train visibility and reduce level crossing accidents*.

The South Australian Government, through the Department for Transport, Energy and Infrastructure (DTEI), has implemented a number of processes and programs to improve level crossing safety in South Australia, including:

- establishing a State Level Crossing Strategy Advisory Committee and a Level Crossing Unit within DTEI
- surveying and assessing all level crossings on public roads in South Australia using the Australian Level Crossing Assessment Model (ALCAM)
- implementing a level crossing improvement program targeting traffic queuing at level crossings in metropolitan Adelaide, with around $13m spent to June 2008, and
- producing the successful 'Don't Play with Trains' television and radio education campaign on the dangers at level crossings.

South Australia has had a State Level Crossing Strategy Advisory Committee for many years and in January 2007 the Committee was reformed with a strategic focus to provide advice on the best mix of infrastructure, regulation and policy strategies to improve level crossing safety. The Committee has representation from DTEI, Australian Rail Track Corporation, Great Southern Rail, Local Government Association, Pacific National, Genesee and Wyoming, Australian Rail, Tram & Bus Industry Union, Royal Automobile Association, South Australia Police, Council of Historic Railways and TransAdelaide. The committee has provided advice to the government based on the "Three E's" of level crossing safety – Education, Engineering and Enforcement.

Using this framework, DTEI has led the implementation of a number of initiatives during 2007 and 2008.

<u>Education</u>

- Continued to promote level crossing safety through the 'Don't Play with Trains' television and radio campaign and with a new education campaign proposed in 2009, produced by the National Level Crossing Behavioural Coordination Group (BCG).
- Continued to promote safe and appropriate behaviour on trains and near railway lines through the school based SafeTrack education program delivered by TransAdelaide.
- Promoted level crossing safety through existing community road safety groups and local Councils.
- Coordinated activities for the Australasian Railway Association Rail Safety Awareness week in conjunction with TransAdelaide, DTEI and South Australia Police.

<u>Enforcement</u>

- Undertaking planning work to commence the installation of red light/speed cameras at high incident level crossings controlled by flashing lights.
- Increased penalties for offences at level crossings to match the penalties for similar offences committed at road intersections.
- South Australia Police has conducted targeted level crossing enforcement campaigns based on near miss incident data.

<u>Engineering</u>

- From 2008-09 a Level Crossing Safety Program will fund road infrastructure improvements at level crossings with poor visibility to approaching trains, insufficient room for vehicles to clear the tracks and those used by B-Double trucks. The focus is on improving safety where roads cross high speed main rail lines carrying both passenger and freight trains, which are predominantly in regional South Australia.
- From 2008-09 a new Level Crossing Black Spot program has been established, in partnership with local government, to jointly fund small scale improvements to level crossings on local roads only. The funding is for projects such as improved warning signs, line of site vegetation clearance, addition of lighting, traffic calming measures and closure of a crossing.

The committee will continue to formulate additional initiatives based on the "Three E's" of level crossing safety.

The Committee has the following response to the recommendations in the 2004 report into train illumination.

Recommendation 1

*The Committee recommends that the Australian Government take steps, through the Transport Ministers Council, to require that all locomotives and rolling stock in the Australian rail industry are fitted with standard reflective strips or reflective paint and that all locomotives are fitted with rotating beacons lights.*

Response

We understand that reflective strips or reflective paint has been installed on rolling stock. Also, a trial was conducted in Western Australia to determine the effectiveness of rotating beacons on locomotives but it was never adopted and the industry, through the Rail Industry Safety and Standards Board, has adopted their own standard for lighting and rolling stock visibility.

Recommendation 2

*The committee recommends that the Australian Government seek the national adoption of a level crossing risk scoring system based on the Queensland model and adapted for local conditions.*

Response

The Australian Level Crossing Assessment Model (ALCAM) is used in South Australia to assess the risk at individual level crossings. There is a national project underway within Austroads to assess the future use of ALCAM or similar risk assessment models.

Recommendation 3

*The Committee recommends that the Australian Government initiate, through the Transport Ministers Council, a program to install, as a minimum, rumble strips at high accident risk level crossings.*

Response

The Committee does not currently recommend the use of rumble strips on the approach to high risk level crossings as an effective measure to alert road vehicles of an approaching level crossing. If the level crossing is deemed to be high risk it would be more appropriate to increase the protection at the crossing to match this risk. It is not yet apparent what impact rumble strips will have on addressing the causal factors contributing to the high risk rating of a crossing. There have been studies, in particular in Western Australia, that question the effectiveness of rumble strips and the Committee will continue to monitor the effectiveness of rumble strips installed in Victoria before considering whether they should be adopted in South Australia.

Recommendation 4

*The Committee recommends that the Australian Government through the Transport Ministers Council, support continued research into the efficacy of train activated rumble strips with a view to the installation of these strips at the most dangerous level crossings.*

Response

The Committee does not consider this would be cost effective. The biggest costs in providing active protection are the train detection and control systems. Therefore, if costs are to be incurred then the provision of warning lights and boom gates is considered to be a more effective treatment.

Recommendation 5

*The Committee recommends that the Department of Transport and Regional Services, with state transport departments, formally look at the Canadian based level crossing education program, 'Operation Lifesaver', for the possible adoption into Australian state road safety programs.*

Response

South Australia has adopted the education campaign developed by the National Level Crossing Behavioural Coordination Group, as this is based on sound research into the current behaviour at level crossings. This program is considered more relevant to Australian conditions. The Committee understands that all Australian jurisdictions have agreed to use this campaign. It is possible that Operation Lifesaver may be discussed by the newly formed national level crossing group.

This submission has been authorised by Mr Jim Hallion, Chief Executive, Department for Transport, Energy and Infrastructure.

Yours faithfully,

Phil Allan
**Executive Director, Safety & Regulation Division**
Chair, State Level Crossing Strategy Advisory Committee

21 January 2009