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Title Performance of Various Wet Film Thicknesses (WFT) of Waterborne Paint	**Type of Report** Draft
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Supplementary Notes

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Ron Stoski, Technology Development Technologist, Alberta Transportation
Don Stefanyk, Project Engineer, AMEC

Abstract

The durability of traffic paint is dependent on the materials used in the formulation of the paint and the rate at which the paint dries. The rate of drying is dependent on the application thickness. The rate of deterioration is influenced by film thickness and resistance to mechanical and chemical weathering, the amount of traffic, environmental conditions and presence of abrasive materials.

The waterborne paint lines on the highway 16 test deck were evaluated for general appearance and luminous directional reflectance (glass bead loss). Retro-reflectivity readings were also undertaken on each test stripe using the Mirolux 30 Field Retro-reflectometer.

The study of the Performance of Various Wet Film Thicknesses of Waterborne painted roadway lines was undertaken to quantify the effect various wet film thickness rates have on durability and retro-reflectivity.

Key Words Traffic paint Glass Bead Retro-reflectivity Waterborne Wet Film Thickness	**Distribution** Unlimited **Project Co-ordinator** Roger Skirrow, Director, Geotechnical and Material Services

ALBERTA TRANSPORTATION

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STUDY of PERFORMANCE of VARIOUS WET FILM THICKNESSES of WATERBORNE TRAFFIC PAINT

1.0 INTRODUCTION

A large potential for reducing VOC emissions was identified for traffic paint applications involving the replacement of solvent based paints (alkyd) with waterborne paints (latex). Waterborne traffic paints accounted for approximately 16% of all traffic coating applications in 2002 in Canada.

When traffic paints are applied to the pavement, volatile organic compounds (VOC) are released into the atmosphere contributing to air pollution. The use of waterborne traffic paints will reduce the release of VOC’s by a margin 3 to 1 (see Table 1).

The conversion from solvent-borne to waterborne paint lines began in 2001. While solvent-borne traffic paints are typically formulated at 450g/l of VOC, waterborne traffic paints contain less than 150g/l of VOC (see table 1).

The Canadian Council of Ministers of the Environment have set maximum VOC limits for industrial maintenance coating product type for traffic markings which came into effective January 1, 2005. Table 1 illustrates the maximum VOC limits.

Table 1

Product Type	Maximum VOC Content (g/l as used)
Solvent-borne coatings	450
Water-borne coatings	150

Seasonal considerations restrict the extent to which waterborne coatings may be used. Water based paints cannot be applied successfully below 10^{o}C or during periods of high humidity. However, paint manufacturers are presently developing waterborne paints that may be applied at colder temperatures and during periods of high humidity.

Alberta Transportation applied various waterborne wet film thicknesses (WFT) to the test deck in the 2004 season. Three WFT's (12, 13 & 15 mils) were applied in May 2004 on an asphalt concrete pavement surface of the Alberta Transportation line paint test deck (Highway 16 east, near Elk Island Park entrance) Appendix 'B'. The different WFT's were applied on the test deck in order to determine the most durable application rates.

The three WFT's were evaluated monthly for 6 months. The evaluation consisted of general appearance, luminous directional reflectance (glass bead loss) and retro-reflective readings taken on each test line using the Mirolux 30 field retro-reflectometer.

2.0 OBJECTIVES

The objectives of the study are:

- determine the effect that the rate of application has on durability and retro-reflectivity.
- determine the optimum film thickness that provides the best bead retention.
- determine what effect thinner film thicknesses have on the performance of traffic paint lines.

3.0 BACKGROUND

Waterborne paints have performed well on Alberta highways and the departments test deck since 2001. Several waterborne paint formulations have been approved for use based on the test deck performance. Alberta Transportation has increased the use of waterborne traffic paint yearly since 2001.

Historically, highway traffic paint durability is dependent on the film thickness and resistance to mechanical and chemical weathering. Typically the thinner the paint, the quicker it becomes hard and brittle. It will then chip, flake, abrade and deteriorate so that nothing remains on the road surface,

4.0 FILM THICKNESS and BEAD RETENTION

A thinner paint application rate will allow rapid loss of the large and intermediate size beads due to less of the glass bead being embedded into the paint film. This should result in initial high retro-reflectance readings followed by rapid deterioration due to bead loss.

An increase in paint application rate may result in lower initial retro-reflectance due to the beads sinking into the paint. Retro-reflectance readings will improve and would deteriorate at a slower rate as more beads are exposed over time.

Ideally, glass beads should be embedded so that 60% of the glass bead is covered in the paint, with 40% exposed. This would result in the maximum amount of light reflected back to the driver (the thinner line may not hold beads very well).

5.0 GLASS BEADS

The sole function of glass spheres (beads) in highway marking is to maximize the reflectivity of the markings, thus improving the driving environment and increasing highway safety. The beads actually cause the light beam to be focused and then returned to the driver's eyes by a process known as retro-reflection.

6.0 RETRO-REFLECTIVITY

Retro-reflectivity is the scientific term that describes the ability of a surface to return light back to its source.

Nighttime visibility is greatly enhanced by the application of glass beads to the paint surface. The glass beads that protrude above the surface of the traffic markings reflect light from headlight beams back to the driver. The returned light is referred to as retro-reflectivity. The retention of retro-reflectivity is a key determinant of traffic marking performance and ability to hold glass beads.

7.0 ROAD PERFORMANCE EVALUATION

The evaluation of the various wet film thicknesses of waterborne paint was based on the Road Service Test (Paint Stripe Evaluation – ASTM D713) (Appendix A) performed on asphalt concrete pavement. General appearance and bead loss are the primary factors in the rating system. The Road Service Test is regarded as the most thorough method of assessing paint stripe durability.

A total of 6 (3 white and 3 yellow) waterborne paint stripes (100mm wide) were applied to a bituminous surface on the Department's test track by AMEC on May 18, 2004. Transverse paint lines of 12mm, 13mm & 15mm wet film thickness were put down side-by-side on the highway 16 test deck in May 2004. Compared with the normal longitudinal traffic paint lines, the transverse lines get crossed by vehicles much more frequently which provides for accelerated wearing data.

The application equipment for the paint test stripes and glass beads was provided by Amec (Appendix B).

The stripes were evaluated by a four-member panel, to determine the general appearance and luminous directional reflectance (bead loss) of each test stripe. The road stripes were evaluated as per the Road Service Test (ASTM D713) for Evaluation of Pavement Marking Materials (Appendix A).

Retro-reflectance readings were also taken along both wheel paths of each line (2 readings per line in wheel path) using the Mirolux 30 Field Retro-reflectometer.

The Road Service Test evaluations and Retro-reflective readings were undertaken monthly from June 2004 through December 2004.

8.0 EQUIPMENT DESCRIPTION

The Mirolux 30 Field Retro-reflectometer is a precision instrument designed to measure retro-reflective materials in field applications. This instrument provides accurate retro-reflectivity measurements over the range from 20 to 1200 mcd/Lux/m^2.

Retro-reflectivity is dependent on several factors:

- the number of glass beads
- depth of embedment (60% embedment of glass bead in paint is optimum)
- quality of the glass bead
- type of pigment in the paint
- ability of paint to hold the bead
- wearing properties of the paint

9.0 BENEFITS of THICKER PAINT LINES

Drivers encounter difficulties in nighttime guidance, especially during rain and fog. Increasing pavement marking thickness will increase retro-reflectivity thus increasing pavement marking visibility and preview distances. The thicker lines were found to hold a greater number of beads and provide higher retro-reflective values during the evaluation period.

The life expectancy of traffic markings or durability is related to film thickness. Once the volatiles leave the waterborne paint film, the dry film thickness ends up being only 9 mils which is similar to the dry film thickness of solvent-borne alkyd paints (based on 15mil WFT). Alkyd paints are only predicted to last 6 months, while standard waterborne paint is expected to provide a one-year lifetime. The primary reason for the longer performance of the waterborne paint is that the latex retains its elasticity much longer than alkyds.

10.0 FIELD MEASUREMENTS

Retro-reflective readings in the wheel path were taken on each waterborne paint strip. Two readings in the wheel path were taken at each paint strip and the average for each line was plotted (Charts 1, 2, 3, & 4).

Based on the results of the road evaluation, a service factor “R” for both general appearance and luminous reflectance was determined as per the following:

$$R = \frac{r_1 t_1 + r_2 t_2 + r_3 t_3 + \dots r_n t_n}{t_1 + t_2 + t_3 + \dots\dots t_n}$$

Where;	R	=	Service Factor or R Value
	r_n	=	Average rating for the panel of 4 on a particular date
	t_n	=	Time lapse between successive ratings

A weighted service factor was calculated using a 50% weighting for general appearance and 50% weighting for luminous directional reflectance. The weighted service factor for both white and yellow paint stripes are shown in Charts 5 and 6. The “R” values for general appearance and bead loss are shown in Charts 7 and 8 and Charts 9 and 10.

Note the Mirolux 30 readings are only a measure of the quantity of light reflected using a specific instrument. The bead loss ratings are subjective ratings between 1 -10, evaluating quantity of beads retained after specific intervals of wear.

11.0 DISCUSSION of RESULTS

The following process was used to evaluate the various wet film thicknesses for both white and yellow waterborne paint lines:

a) Retro-reflective readings were taken on each line using the Mirolux 30 instrument. Two readings were taken along the wheel path of each line and averaged. Retro-reflective readings were conducted on a monthly basis for 6 months.

b) Road performance evaluation consisted of a panel of 4 people (Don Stefanyk (Amec), Glenn Murphy (Amec), Ron Stoski and Joe Filice (Alberta Infrastructure & Transportation) who visited the test site from the months of July to December 2004 to evaluate each line performance. The evaluations were conducted for General Appearance and for Bead Loss of each line based on the ASTM D713 Road Service Test (Appendix A).

The evaluation of the paint lines consisted of observing and rating the wheel path sections of each line. The evaluation was conducted on days that were clear and sunny.

c) The results were documented and plotted for the various WFT's. The following charts have been generated as a result of the field study:

Traffic Paint Retro-reflection

A. Charts 1 and 2, White Waterborne Traffic Paint, 12mil, 13mil and 15mil WFT (inside wheel path).
B. Charts 3 and 4, Yellow Waterborne Traffic Paint, 12mil, 13mil and 15mil WFT (inside wheel path).

Traffic Paint Road Performance

A. Chart 5, White Waterborne Traffic Paint – Weighted "R" Values, 12mil, 13mil and 15mil WFT.
B. Chart 6, Yellow Waterborne Traffic Paint – Weighted "R" Values, 12mil, 13mil and 15mil WFT.
C. Chart 7, White Waterborne Traffic Paint – Appearance Only "R" Values, 12mil, 13mil and 15mil WFT.
D. Chart 8, Yellow Waterborne Traffic Paint – Appearance Only "R" Values, 12mil, 13mil and 15mil WFT.
E. Chart 9, White Waterborne Traffic Paint – Bead Loss Only "R" Values 12mil, 13mil and 15mil WFT.
F. Chart 10, Yellow Waterborne Traffic Paint – Bead Loss Only "R" Values 12mil, 13mil and 15mil WFT.

12.0 OBSERVATIONS

Retro-reflectivity

White Lines

The retro-reflectivity of the 15mil WFT white line remained substantially higher than the 13 and 12mil WFT white lines throughout the 209 day test period (Chart 1 & 2). The 15mil WFT white line remained above the 100 mcd/m^2/lux for approximately 160 days. The 13mil WFT white line remained above the 100 mcd/m^2/lux for just over 100 days and the 12mil WFT white line dipped below the 100 mcd/m^2/lux at 38 days.

Retro-reflectivity through the spring and summer months was greatly reduced for the 12 and 13mil wet film thicknesses of the white paint lines.

Yellow Lines

Similarly to the white lines, the 15mil WFT yellow line outperformed the 12 and 13mil WFT lines by a wide margin for most of the test period. The gap narrowed near the end of the test period (Charts 3 & 4). However, it is interesting to note that the yellow 12 and 13mil WFT lines recorded similar retro-reflective readings after 66 days (Chart 3).

Road Performance Evaluation

The various WFT white and yellow paint lines were applied transversely to the highway 16 test deck on May 18, 2004. The paint lines were then evaluated on a monthly basis until December of 2004. The wheel path of each transverse line was evaluated for general appearance and bead loss. Scoring is based on a scale from 0 – 10 for general appearance and glass bead loss.

Based on the results of the road evaluation, a service factor “R” for both general appearance and luminous directional reflectance was determined and plotted for both the white and yellow lines. A weighted service factor was also calculated using a 50% weighting for general appearance and 50% weighting for luminous directional reflectance (glass bead loss).

The transverse test paint lines get crossed by vehicles much more frequently than the normal longitudinal lines on roadways. Therefore, the road performance evaluation of the transverse paint lines has provided accelerated test data for this study.

Appearance Only “R” Values

White Lines

The general appearance rating varied from a low of 4.93 (12mil WFT) to a high of 7.8(15mil WFT) at 209 days (Chart 7). The general appearance rating for the 15mil and 13mil WFT paint lines performed similar (7.8 to 7.16 rating) as the performance of the 12mil WFT paint line deteriorated quickly (4.93). It appears that a decrease in the application rate will negatively affect the durability of the paint lines as shown for the 12mil WFT paint line at 209 days (Chart 7).

Yellow Lines

The general appearance rating varied from a low of 6.88 (12mil WFT) to a high of 8.0 (15mil WFT) at 209 days (Chart 9). The yellow paint lines performed better than the white lines for all three wet film thicknesses. Similarly to the white lines, a decrease in the WFT application rate will affect the durability of the paint line (Chart 9).

Bead Loss Only “R” Values

White Lines

The bead loss exhibited rapid deterioration over the 209 days of service for the thinner (13mil & 12mil WFT) paint lines (Chart 8). The 15mil WFT line performed much better than the thinner lines. The 12 and 13mil WFT paint lines rating (12mil – 5.15, 13mil – 6.08) was below the 6.5 threshold used for accepting paint lines.

Yellow Lines

The bead loss deterioration rate for the yellow paint lines was similar to the white paint lines (Chart 10) with the yellow paint lines bead loss performing slightly better than the white paint lines bead loss. Similar to the white paint lines, the 15mil WFT paint line outperformed the thinner lines by a wide margin.

Weighted “R” Values

White Lines

Based on the weighted “R” values, the 15 and 13mil WFT lines were rated above the 6.5 threshold rating considered the cut-off value for accepting new paint formulations. The rating at 209 days is as follows:

15mil – 7.48
13mil – 6.62
12mil – 5.04

Therefore, the 12mil WFT line is clearly below the 6.5 threshold rating value for accepting new paint formulations. The 15mil WFT paint line performed substantially better than the 13mil WFT line. However, the 13mil WFT white paint line was rated above the 6.5 threshold rating which would indicate that 13mil WFT lines could be used (Chart 5).

Yellow Lines

The weighted “R” values for the yellow paint lines performed similarly to the white lines. With the exception of the 12mil wet film thicknesses, the yellow paint lines marginally outperformed the white paint lines after 209 days (Chart 6). The rating at 209 days is as follows:

15mil – 7.68
13mil – 6.83
12mil – 6.23

The 15 and 13mil WFT yellow paint lines were rated above the 6.5 threshold rating level. The 12mil WFT yellow paint line fell below the 6.5 threshold level.

The 13mil WFT yellow paint line was rated above the 6.5 rating threshold which would indicate that 13mil WFT lines could be used (Chart 6).

13.0 SUMMARY of OBSERVATIONS

The results of this study indicate that a decrease from the normal application rate of 15mil WFT will have an influence on the performance of the traffic paint lines.

Traffic paint line durability and rate of deterioration are functions of the time the paint line is exposed to weather, oxidization, snowplows and vehicular wear as illustrated in the weighted “R” values for both the white and yellow paint lines (Charts 5 & 6).

The road service test is conducted under actual road conditions using transverse test lines. This practice covers the determination of the relative service life of traffic marking materials. This practice is an accelerated evaluation of wear characteristics and bead retention of fluid traffic markings.

In reality, traffic lines are predominantly placed longitudinally to the roadway, therefore not subjected to the same vigorous wear of the transverse test lines. The retro-reflective readings taken in the wheel path have dropped off dramatically over time. Based on previous studies, retro-reflective readings outside the wheel path will drop off gradually over time. However, this reasoning may not be practical due to the fact that snow plows would reduce the number of beads in the longitudinal paint lines. The thinner paint lines would exhibit an even higher bead loss due to their lower bead loss resistance.

<u>Performance After One Year of Service</u>

A visual inspection was conducted on May 30, 2005 to determine the performance of the various film thicknesses after 1 year of service. It is evident that the thicker 15mil WFT lines have outperformed the thinner lines for both white and yellow paint. (see photographs Appendix ‘C’).

The 12mil WFT lines are almost completely worn off with no glass beads present. The thinner paint line (12mil WFT) did not perform very well through the winter as the bead retention is very poor. The 12mil WFT line retro-reflective properties are non existent as the glass beads have completely worn off.

14.0 CONCLUSIONS

1. The 15mil WFT traffic paint lines exhibited better durability than the thinner lines (13mil & 12mil). However, when you closely examine the weighted “R” values for both the white and yellow 13mil WFT paint lines, it is evident that the 13mil WFT “R” rating is acceptable. The weighted “R” rating for both the white and yellow 13mil WFT paint lines was rated above the 6.5 threshold value for accepting paint lines (charts 5 & 6).

2. The thinner paint lines (13 & 12mil) exhibit a more rapid bead loss than the thicker 15mil WFT white and yellow paint lines (Charts 8 & 10). Initial retro-reflectivity readings taken at 38 days for both white and yellow paint lines exhibited considerably higher readings for the 15mil WFT lines (Charts 1 & 3). The 15mil WFT paint lines provided better bead retention throughout the study period of 209 days.

3. Waterborne traffic paint lines will provide acceptable performance at thinner (14mil or 13mil) WFT applications. However, on highways with higher traffic volumes (ex. Hwy 2) the 15mil WFT application should be used to optimize paint line performance.

4. The 15mil WFT for traffic paint has been the industries standard for many years. Based on the results of this study, the 15mil WFT for white and yellow traffic paint lines has proven to be the most effective thickness for holding glass beads the longest.

15.0 RECOMMENDATIONS

Selection of the most effective wet film thickness application for pavement marking systems is dependent on three main factors; retro-reflectivity (bead loss), durability (appearance) and cost (not taken into consideration in this study).

The recommended wet film thickness application rate to optimize durability and retro-reflectivity performance is 15mil's WFT, as proven in this study. The 15mil WFT traffic paint exhibited higher retro-reflectivity throughout the 209 day evaluation period.

The following table shows the number of days the various wet film thicknesses retro-reflectivity values stayed above the 100 mcd/m^2/lux for white and yellow paint:

Retro-reflectivity above 100 mcd/m^2/lux

	White			Yellow		
	15mil	13mil	12mil	15mil	13mil	12mil
Days	160	115	38	90	45	<38

The recommended application rates to optimize durability and retro-reflectivity performance are:

Minimum Application Rate: WFT – ℓ/km
15mil - 38 ℓ/km, high volume roads
13mil to 14mil 33 ℓ/km to 35.6 ℓ/km, low volume roads

Note: Traffic volume on the highway 16 test deck is approximately 11,000 AADT.

Further study is required to determine optimum application rates on various traffic volume roads.

16.0 IMPLICATIONS OF RECOMMENDATIONS

- 15mil WFT/38 ℓ/km application rate will provide the optimum performance based on the highway 16 test track. Potential for longer serviceability particularly for lower volume roads.

- 13 mil to 14mil WFT/33 ℓ/km to 35.6 ℓ/km application rate will provide suitable performance on lower volume roads based on the highway 16 test track. Additional field study is required to determine optimum application rate.

- 12 mil WFT/31 ℓ/km application rate will adversely affect the durability of the paint line, thus reducing its effectiveness as a pavement marking.

Chart 1

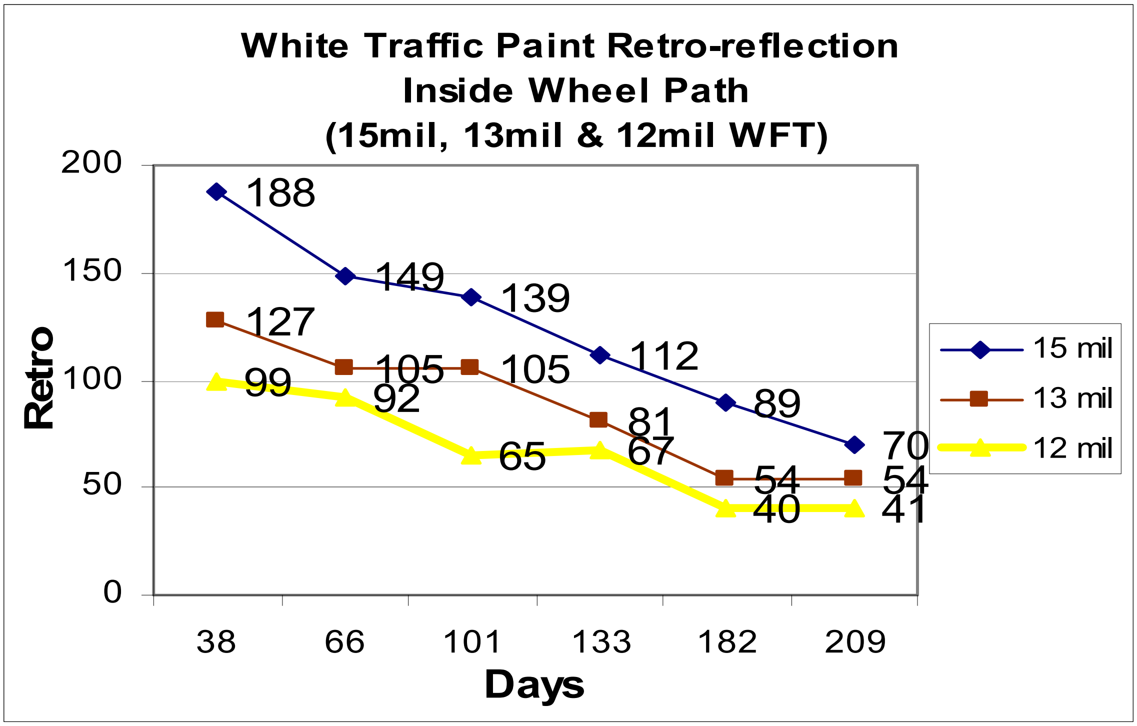


Chart 2

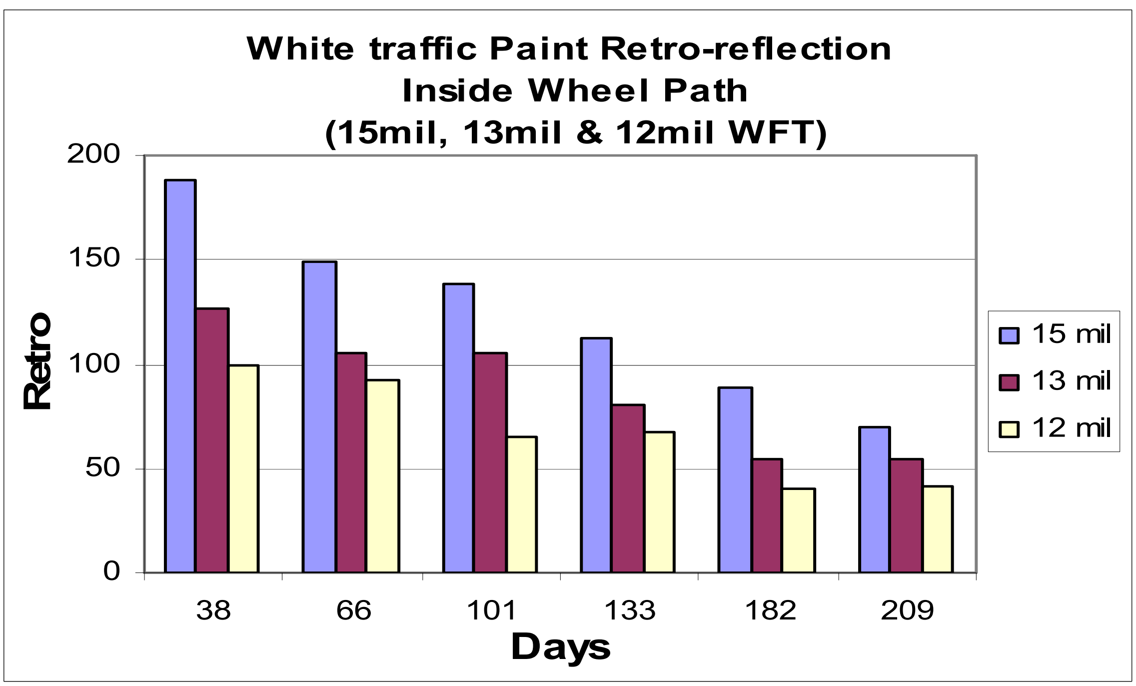


Chart 3

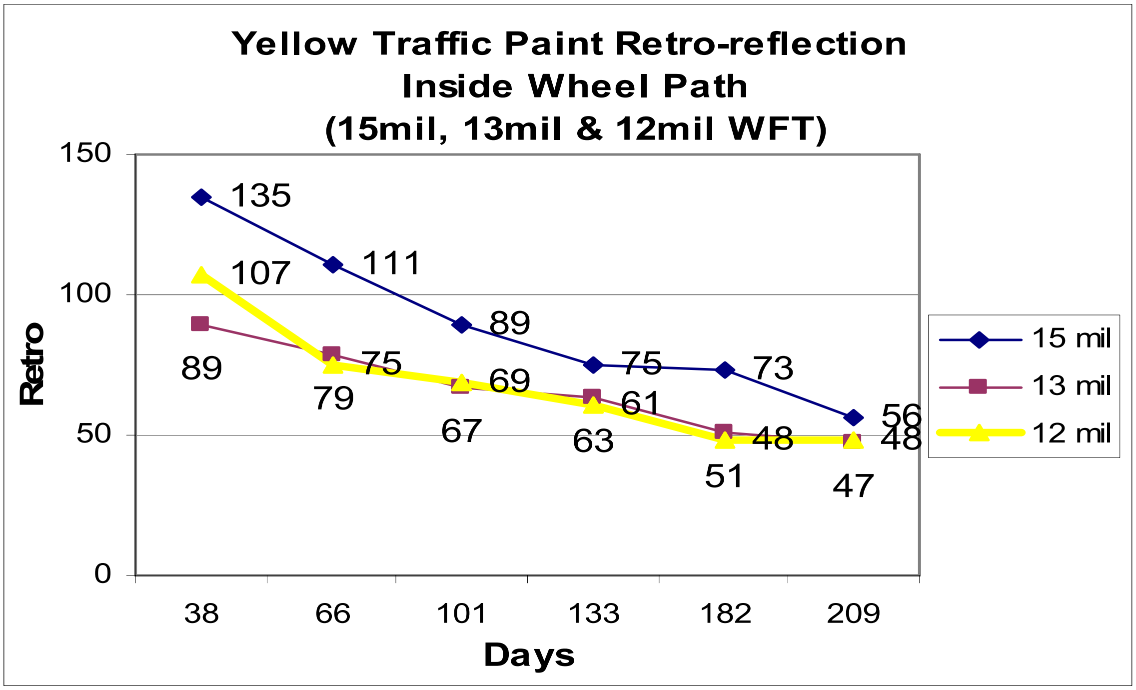


Chart 4

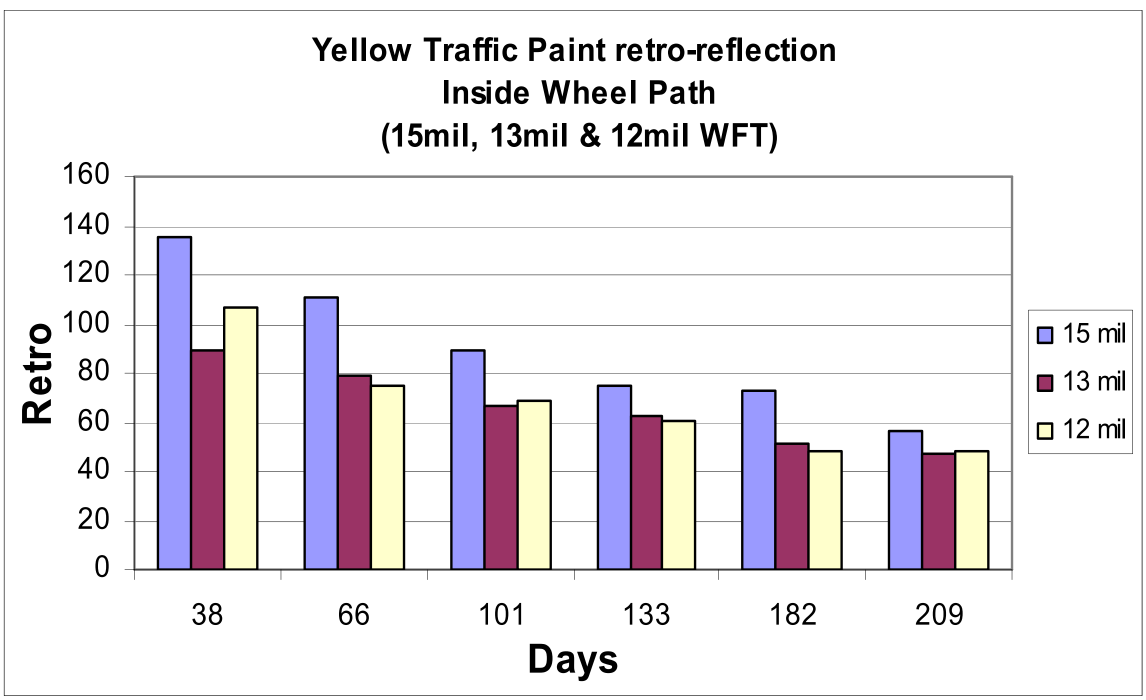


Chart 5

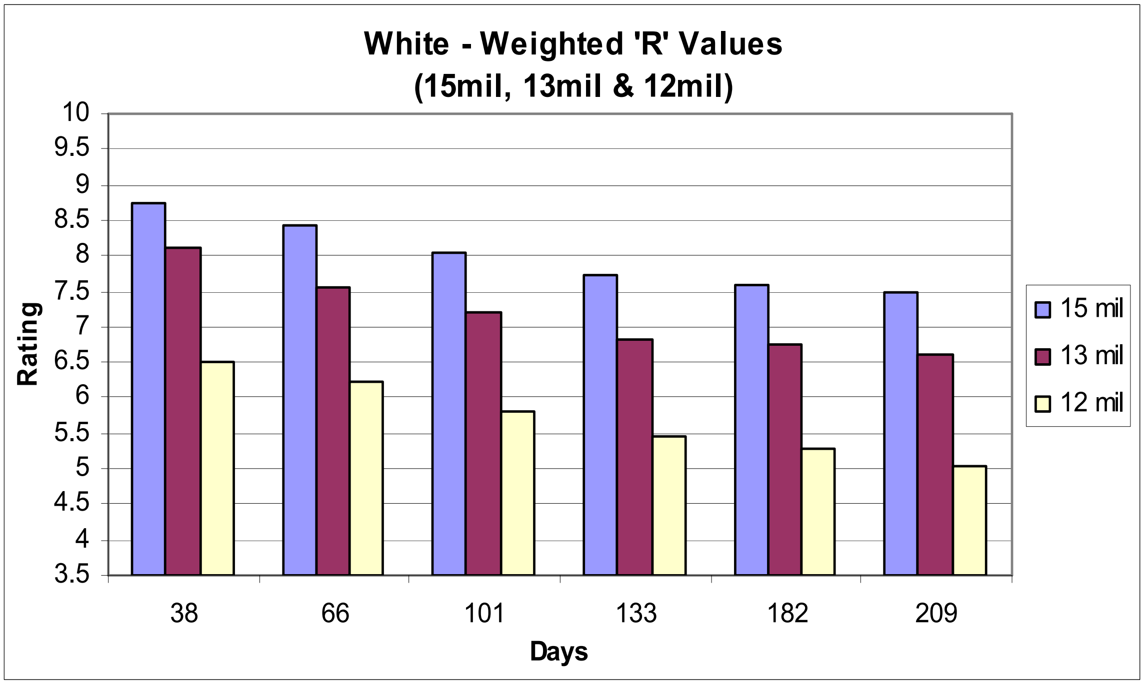


Chart 6

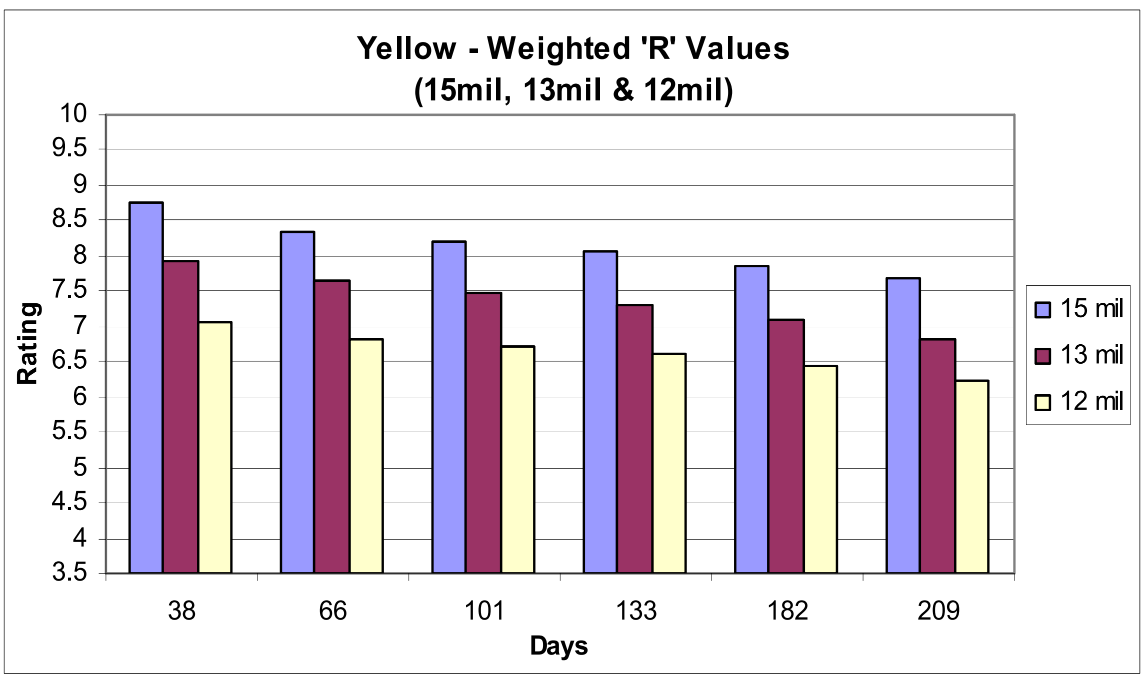


Chart 7

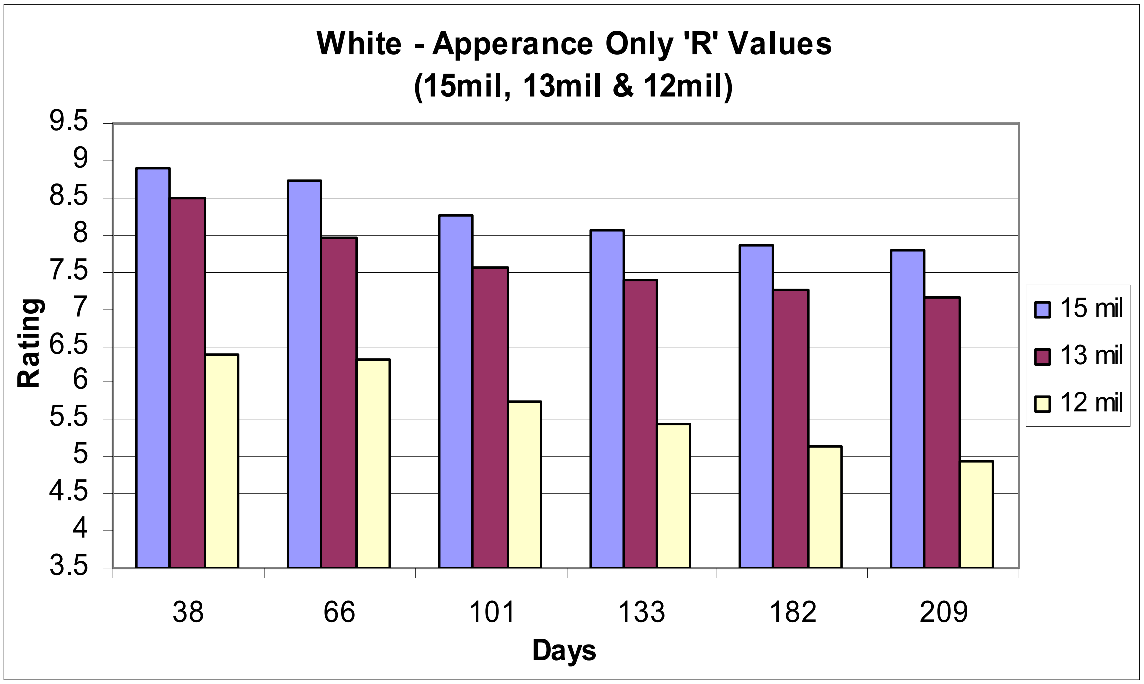


Chart 8

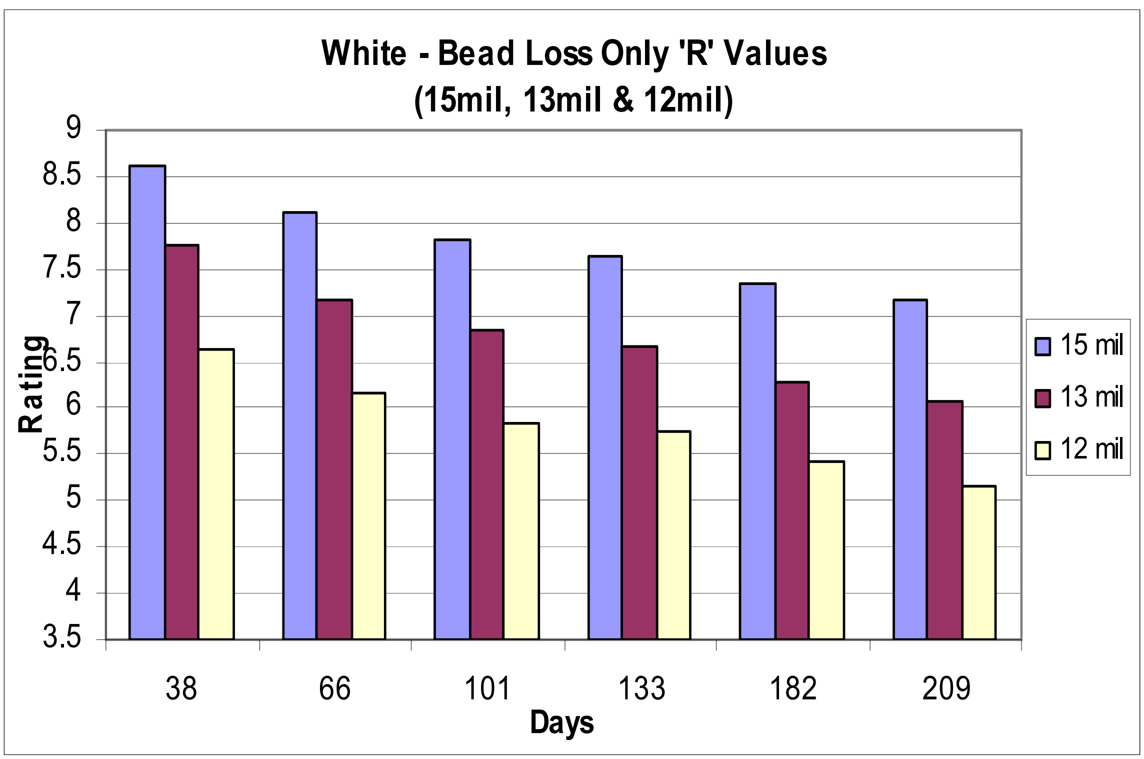


Chart 9

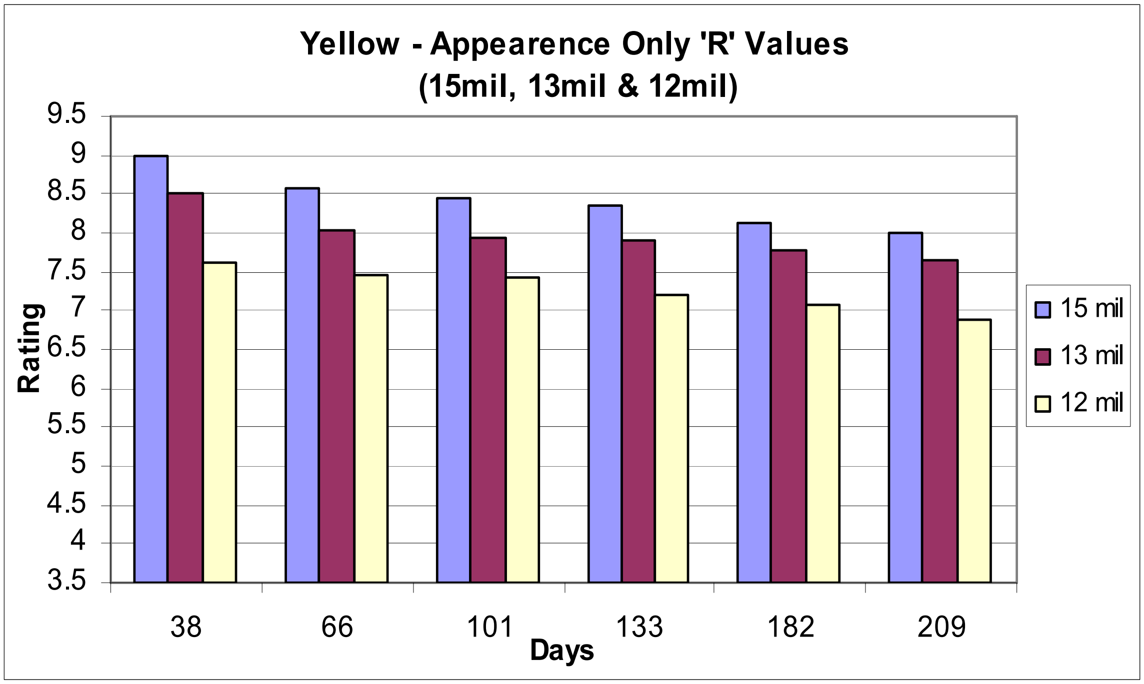
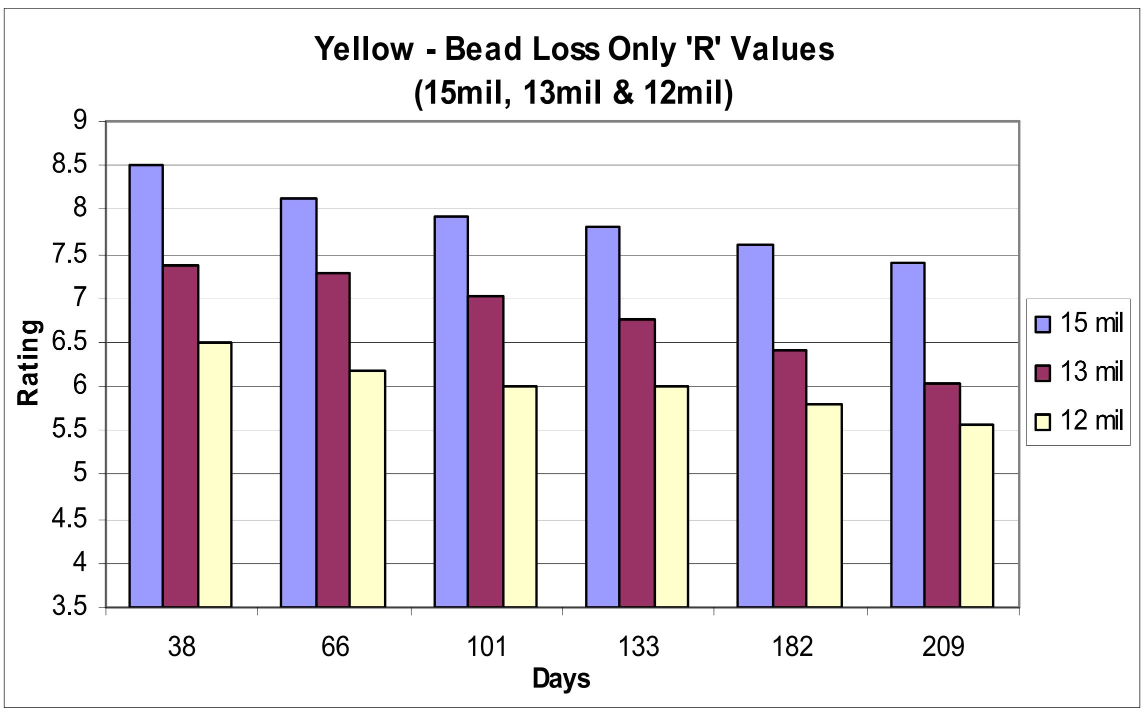


Chart 10



Appendix 'A'

Road Service Test (Paint Strip Evaluation – ASTM D713)

ROAD SERVICE TESTS
ASTM D713

FACTOR RATED	DESCRIPTION
a) General Appearance – 50% Rated out of 10.	Includes: -Abrasion -Bleeding -Chipping -Colour -Cracking -Dirt Retention -Hiding Power -Wrinkling -Other Failure Types As viewed from 2 – 4m, comparing worn and unworn areas, as well as comparing the stripe to panel at the same time, with the same paint thickness and subsequently stored in a cool, dry location.
b) Luminous Directional Reflectance -50% Rated out of 10.	Includes: -Bead Loss -Paint Reflectance As measured either visually, in sunlight or in an artificial light beam at night, or by a directional reflectance meter.

Total = 100%

RATING OF SUBJECTIVE TESTS

c) Changes or Undesirable Feat.	***% Lost**	**Desirable Feat.**	***% Retained**	**Rating**
None	0	Perfect	100	10
Slight Trace	1	Excellent	99	9
Trace	2 – 4	Very Good	96 – 98	8
Slight	5 – 7	Good	93 – 95	7
Slight to Moderate	8 – 12	Fairly Good	88 – 92	6
Moderate	13 – 18	Fair	82 – 87	5
Moderate to Marked	19 – 25	Fairly Poor	75 – 81	4
Marked	26 – 34	Poor	66 – 74	3
Very Marked	35 – 47	Bad	53 – 65	2
Severe	48 – 68	Very Bad	32 – 52	1
Complete Failure	68 – 100	None	0 - 31	0

*** AS ESTIMATED BY RATING PANEL**

Appendix 'B'

Highway 16 Test deck and Equipment

Equipment

Test Deck

White paint, line #9 – 15mil, line #10 – 13mil and line #11 – 12mil

Yellow paint, line #9 – 15mil, line #10 – 12mil and line #11 – 13mil

Appendix ‘C’

Performance after one year of service

Test Deck after one year of wear

White paint, line #9 – 15mil, line #10 – 13mil and line #11 – 12mil
The 12mil line (#11) is almost completely worn. The 13mil line (#10) is performing well.

Yellow paint, line #9 – 15mil, line #10 – 12mil and line #11 – 13mil
The 12mil line (#10) is almost transparent. The 13mil line (#11) is performing better.