PAVEMENT MARKINGS USING WATERBORNE PAINT AND VISIBEADS® IN REGION 2

Final Report

State Research Project

By

H. Martin Laylor
Research Unit
Engineering Services Section
Oregon Department of Transportation
Salem, Oregon 97310

Prepared for

Oregon Department of Transportation
Salem, Oregon 97310

December 1994

Technical Report Documentation Page

1. Report No. OR-RD-95-01	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Sub-title PAVEMENT MARKINGS USING WATERBORNE PAINT AND VISIBEADS* IN REGION 2 Final Report		5. Report Date December 1994 6. Performing Organization Code
7. Author(s) H. Martin Laylor		8. Performing Organization Report No. OR-RD-95-01
9. Performing Organization Name and Address Oregon Department of Transportation Research Unit 2950 State Street Salem, Oregon 97310		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Unit 2950 State Street Salem, Oregon 97310		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Oregon Department of Transportation staff evaluated waterborne, latex traffic paint and Visibeads* to determine if the application characteristics and durability of these pavement marking materials deserved further consideration. Findings indicate that: waterborne latex paint is an acceptable alternative to conventional paints, at least in geographical areas that have a significant amount of time that the road is dry and pavement and air temperatures are above 50° F; Visibead* application technology and bead use rate resulted in the recommendation that use of these beads should not be considered until these problems are overcome; and significant improvement in worker safety is also expected.

17. Key Words	18. Distribution Statement
PAINT, MARKING, STRIPING, WATERBORNE, LATEX, TRAFFIC PAINT	Available through the National Technical Information Service (NTIS)

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

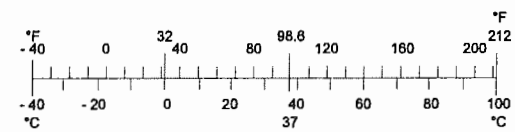
S* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO S UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM S UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* S is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

Special thanks to Oregon Department of Transportation personnel who contributed to this project. Particularly noteworthy are the efforts of Mike Dunning, Jim Nash, Hector Morales, Wayne Cobine, Keith Martin, Scott Nodes, and the Region 2 paint crew. Also, Mirolux, for permitting inclusion of their material in an appendix.

DISCLAIMER

PAVEMENT MARKINGS USING WATERBORNE PAINT AND VISIBEADS® IN REGION 2

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 OBJECTIVES 2
1.2 SCOPE 2

2.0 DATA COLLECTION PROGRAM 5

2.1 DATA NEEDS 5
2.2 SITES 5
2.3 MATERIALS 6
2.3.1 Conventional Pavement Marking Materials - Paint 6
2.3.2 Conventional Pavement Marking Materials - Beads 6
2.3.3 Waterborne Pavement Marking Materials - Paint 6
2.3.4 Waterborne Pavement Marking Materials - Beads 7
2.3.5 Cost Of Materials 7
2.4 APPLICATIONS DATA 8
2.5 MIROLUX® SITE DATA 9
2.6 DRY-NIGHT VISIBILITY DATA 9
2.7 ENVIRONMENTAL IMPACT 9

3.0 ANALYSIS AND EVALUATION 13

3.1 CASCADE RANGE SITES 13
3.2 CASCADE FOOTHILLS SITES 14
3.3 COASTAL PLANE SITE 15
3.4 VALLEY FLOOR SITES 15
3.5 COAST RANGE SITE 16

4.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS . . . 17

4.1 SUMMARY 17
4.2 FINDINGS 18
4.3 CONCLUSIONS 19
4.3.1 Paint 19
4.3.2 Visibeads® 20
4.4 RECOMMENDATIONS 20

APPENDICES

Appendix A: EPA MEMO TO THE REGULATORY NEGOTIATION COMMITTEE MEMBERS
Appendix B: DRAFT FIELD SAMPLING PLAN AND MIROLUX® INFORMATION
Appendix C: MIROLUX® SITE DATA
Appendix D: LABORATORY TEST RESULTS
Appendix E: SPECIFICATIONS FOR WATERBORNE PAVEMENT MARKING PAINTS

LIST OF TABLES

Table 1.1 HIGHWAYS INCLUDED IN THE PROJECT 2

Table 2.1 SITE MATRIX 5

Table 2.2 OREGON'S BEAD GRADATION REQUIREMENTS 6

Table 2.3 COST OF MATERIALS 7

Table 2.4 SUMMARY STATISTICS - RETROREFLECTANCE 10

Table 2.5 NIGHT RATING OF LINES 5/9/94 11

LIST OF FIGURES

Figure 1.1 LOCATION AND VICINITY MAPS 3

Figure 3.1 CASCADE RANGE - Retroreflectance in Millicandellas Versus Age 13

Figure 3.2 CASCADE FOOTHILLS - Retroreflectance in Millicandellas Versus Age . 14

Figure 3.3 VALLEY FLOOR - Retroreflectance in Millicandellas Versus Age 16

Figure 3.4 COAST RANGE - Retroreflectance in Millicandellas Versus Age 16

1.0 INTRODUCTION

Recently, the Oregon Department of Transportation (ODOT), Environmental Protection Agency (EPA), Department of Environmental Quality (DEQ), Oregon Occupational Safety and Health Division (OR - OSHA), and others have become concerned with the Volatile Organic Compound (VOC) emissions from conventional traffic paints. The EPA is in the process of attempting to set VOC standards that would require the use of low VOC traffic paints by 1996 (see EPA "Regulatory Negotiation Committee" memo, Appendix A). Some states, like California, are already using waterborne paints in many areas to comply with local VOC emission standards. Due to the VOC emission requirements, ODOT may be required to change its policies for traffic paint used for pavement markings in the near future.

Further, conventional solventborne yellow traffic paints normally contain lead chromate ($PbCrO_4$, medium chrome yellow) as the primary yellow pigment. This same pigment was used in the early formulations of yellow waterborne traffic paints. Recently, lead free stable organic yellow pigments have been developed that are compatible with the new waterborne formulations. This means that, for a moderate increase in the cost per gallon, stable, lead free, yellow paints are now available.

Thus, there is a need to evaluate and/or modify the materials, methods, and procedures required to apply these paints to provide durable, long-lasting, and safe pavement markings.

Historically, waterborne latex paint for pavement markings have had problems. Some of these were: poor durability, slow drying, uneven films, incompatibility with the available application equipment, and operator inexperience.

Advances in new pavement marking equipment and paint formulations have been reported to address the problems and permit handling of waterborne paints with little trouble. In order to evaluate the new equipment and materials, ODOT Region 2 staff bought Dura-Line™ 2000 (manufactured by Morton International), waterborne, lead-free, traffic paint and placed approximately 760 linear miles of longitudinal lines to cover five distinct geographic locations.

Concurrently, Potter Industries reported that "Visibeads®," were very compatible with waterborne striping paints. Visibeads® are a large diameter glass bead that has been reported to give improved wet-night visibility. To evaluate this claim, Visibeads® were included in the project.

1.1 OBJECTIVES

The objectives of this research are to apply and evaluate pavement markings using waterborne, latex traffic paint, regular highway beads, and Visibeads®. Also addressed are the costs, environmental concerns, and operational issues regarding the use of these materials. The focus will be on product durability, costs, environmental safety, ease of application, application procedures, and weather constraints.

1.2 SCOPE

Pavement markings (centerlines, lane lines, pavement edge lines) were applied to the following highways in Region 2:

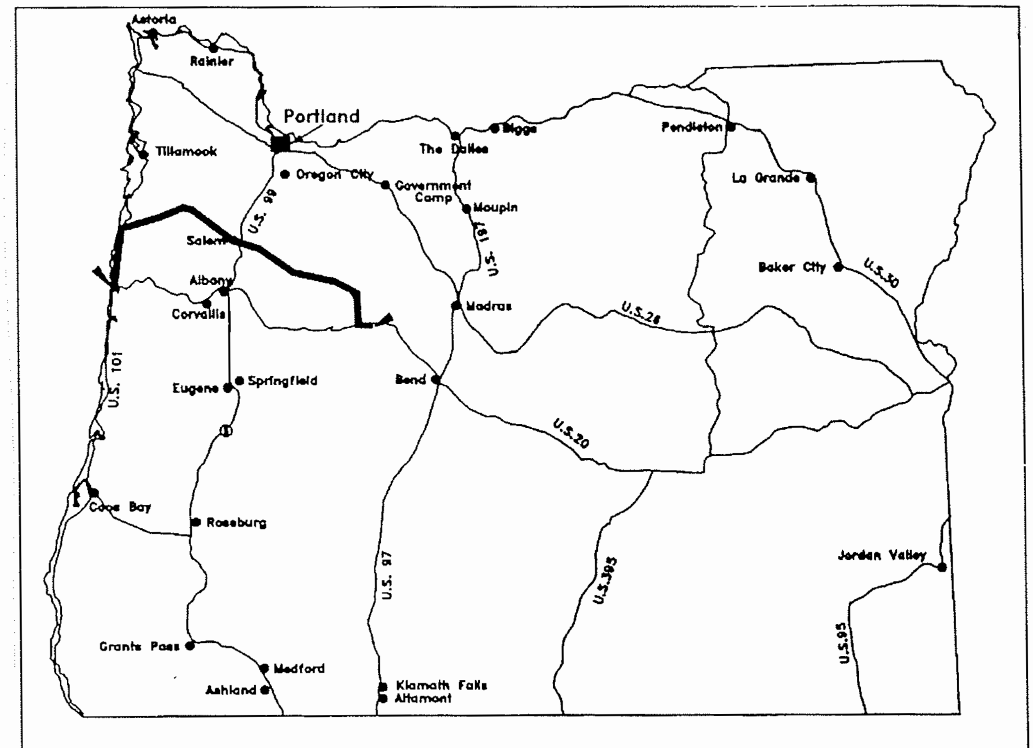
- U.S. Route 20 (State Highway No. 16) from the ODOT Region 4 boundary to North Santiam Highway (State Route 22) Junction;
- State Route 22 (State Highway Nos. 162, 72, 30) from the U.S. Route 20 Junction to Valley Junction;
- State Route 18 (State Highway No. 39) from Valley Junction to Otis Junction; and,
- U.S. Route 101 (State Highway No. 9) from Otis Junction to Agate Beach.

This represents an estimated 760 linear miles of longitudinal lines where application characteristics were evaluated. In this area, eleven quarter-mile study sites, representative of various pavement, traffic, and climate conditions, were selected for performance studies. Details of the painted areas are in Table 1.1 and Figure 1.1, below.

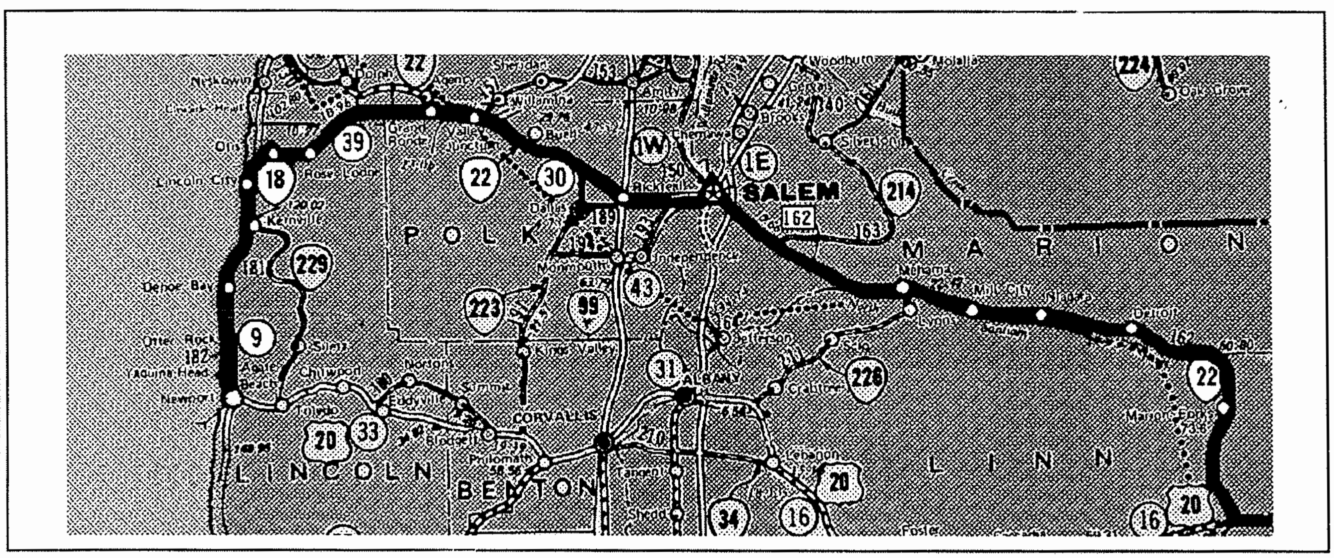
Table 1.1 Highways Included in the Project

HWY	HIGHWAY NAME	BMP[1]	EMP[2]	LENGTH
16	Santiam	74.81	89.20	14.39
162	North Santiam	1.21	81.74	80.53
72	Salem	4.93	8.52	3.59
30	Willamina - Salem	0.00	26.13	25.92
39	Salmon River	23.06 xO.22	27.17 23.06	4.11 23.13
9	Oregon Coast	104.96	138.77	28.58
[1-2] Begin and End Mile Points			TOTAL CENTERLINE MILAGE	180.23

Figure 1.1
LOCATION AND VICINITY MAPS



VICINITY MAP



2.0 DATA COLLECTION PROGRAM

2.1 DATA NEEDS

Part of this project included obtaining, and using a Mirolux® portable retrorefelectometer to quantify longitudinal line retroreflectance. Statistics available from the manufacturer were inadequate to identify a sampling frequency which would include site variability. Consequently, a short study to find adequate data sampling procedures was done. The Mirolux® operating information, and sampling plan are in Appendix B. The important findings were:

- The retroreflectance of longitudinal lines is dependent on the direction of painting. Generally, longitudinal lines appear brighter when viewed in the direction of painting.
- On the single broken line site, it was found that a minimum of three measurements on each of seven single broken lines were needed.
- On new, continuous lines, it was found that a minimum of thirteen measurements were needed per 1/4 mile test site. As the sites aged, 20 readings were taken because the variability over the site increased with time.

2.2 SITES

Table 2.1 Site Matrix

PAVEMENT TYPE[1]	TRAFFIC VOLUME[2] HIGH > 15000 MED 5000 - 15000 LOW < 5000	CLIMATOLOGICAL AREA			
		CASCADE FOOTHILLS	VALLEY FLOOR	CASCADE RANGE	COASTAL PLANE
ASPHALT CONCRETE: DENSE GRADED	HIGH		HWY 30 MP 19		HWY 9 MP 116
	MED	RTE 22 MP 17 E RTE 22 MP 18 E	RTE 22 MP 5 HWY 30 MP 20		
	LOW			RTE 22 MP 65 E	
ASPHALT CONCRETE: OPEN GRADED	HIGH				
	MED	RTE 22 MP 18 W RTE 22 MP 17 W	RTE 22 MP 5		
	LOW			RTE 22 MP 78 E	

[1] No significant amounts of PCC pavement exist in the study area

[2] Average Annual Daily Traffic

2.3 MATERIALS

2.3.1 CONVENTIONAL PAVEMENT MARKING MATERIALS - PAINT

ODOT staff purchases conventional traffic paint on a performance specification similar to the specification for waterborne paints (Appendix E). The white and yellow paints used in 1993 were manufactured by Morton International and have a VOC of approximately 450 grams per liter (g/l), weigh approximately 12.0 pounds per gallon and have a volume solids of 55%. The yellow paint contains 0.6 pounds per gallon lead chromate. The white paint is pigmented with titanium dioxide (TiO_2) and contains no lead compounds.

2.3.2 CONVENTIONAL PAVEMENT MARKING MATERIALS - BEADS

The specifications for beads require that they shall be transparent, clean spherically shaped, colorless glass with the following graduation requirements:

Table 2.2 Oregon's Bead Gradation Requirements

US Standard Sieve Number	Percent Passing by Weight
US 30	95 - 100%
US 40	70 - 85%
US 50	25 - 40%
US 80	0 - 5%

The spheres shall have a minimum index of refraction of 1.50, a specific gravity between 2.40 and 2.55 and are coated with a silane coupling agent coating.

2.3.3 WATERBORNE PAVEMENT MARKING MATERIALS - PAINT

The ODOT staff purchased Dura-Line™ 2000 from Morton International as an "off-the-shelf" item. These paints have a VOC of approximately 135 g/l, weigh approximately 14.5 pounds per gallon, and have a volume solids of 65%. The yellow paint pigments are organic and the paint is lead-free. The white paint is pigmented with titanium dioxide and contains no lead compounds.

2.3.4 WATERBORNE PAVEMENT MARKING MATERIALS - BEADS

The beads requested for the project were to be a blend of 50% conventional beads and 50% "off-the -shelf" Visibeads®. The beads were to be coated with a silane coupling agent compatible with the waterborne formulation. The beads supplied by Potter's Industries for the project were 100% off-the-shelf Visibeads®.

2.3.5 COST OF MATERIALS

The cost comparisons in Table 2.3 are for materials only and do not reflect such things as the cost of environmental impact and for the disposal of solvents as hazardous materials.

Table 2.3 Cost of Materials

MILES OF PAVEMENT MARKING		ESTIMATED GALLONS		COST OF STANDARD PAINT*		COST OF WATERBORNE PAINT	
WHITE	YELLOW	WHITE	YELLOW	WHITE	YELLOW	WHITE	YELLOW
400	360	7,000	6,500	$44,700	$40,600	$59,500	$56,300
TOTAL	760		13,500		$85,300		$115,800
ADDED COST FOR 50/50 VISIBEADS®/STANDARD BEADS**							$29,600

*Standard paint was not used in this project - these are the expected costs if standard paint was used.

**This was the cost for the amount purchased, not the amount used.

Based on the information in Table 2.3, the cost per longitudinal line mile is:

Solventborne:	White	$112	Yellow	$113
Waterborne:	White	$149	Yellow	$156

If the costs associated with worker safety, clean-up and environmental impact were included, the total cost of solventborne paint would be higher. It was beyond the scope of this study to determine these costs.

2.4 APPLICATIONS DATA

The trial runs using the new waterborne paint were made with standard beads. During this time, the Region 2 striping crew experienced the normal difficulties associated with using new materials and painting equipment.

The first tests involved identifying the equipment settings which resulted in obtaining the desired line characteristics. These line characteristics were:

- A paint application rate of 17.5 gallons per mile. This results in the desired wet film thickness of approximately 16 mils (~10 mils dry).

- A standard bead application of 5 to 6 pounds per gallon.

Once this was accomplished, the change to Visibeads® was attempted. Potters' representatives recommended an application rate of 15 pounds per gallon, approximately three times greater than the conventional bead usage.

Immediate problems with the bead-guns were experienced. The local representative from Morton worked with the Potters' representatives to try and modify the available guns so they would handle the new mix at the rate recommended by Potters. The field application on Oregon Route 22 showed that only a small amount of the beads being dispensed stayed in the paint. The remainder of the beads were blown off the road onto the shoulder by the wind from passing vehicles.

After applying pavement markings for several miles, it was decided that the Visibeads® were too large, and at the recommended application rate, too many beads failed to stay in the line. The Visibeads® portion of the project was abandoned.

The remainder of the project went well with application rates comparable to conventional traffic paint. The findings from using waterborne paint are:

- The application rate was comparable to conventional paints.

- The paints "time to no pick-up" was comparable to the solventborne paints currently in use.

- The paint has an agreeable odor.

- No solvents that contain VOC's are required for clean-up. This eliminates the need to dispose of the spent solvents as a hazardous material.

- The number of lane-miles that could be painted per day was comparable to the number of lane-miles per day using conventional traffic paint.

- Due to differences in the rheological properties of the paints, the waterborne paint clogged filters at a much higher rate than conventional paint. This required that the filters be cleaned daily (the filters for conventional paint are cleaned approximately monthly).

2.5 MIROLUX® SITE DATA

Data was collected approximately monthly. The detailed site data is in Appendix C and the summary is in Table 2.4.

The areas that are "invalid" indicate that the data was taken when the retroreflectometer was found to be in need of internal calibration.

The comments "with" and "against" refer to the direction in which the readings were taken. "With" means in the direction of painting and "against" is the opposite direction.

2.6 DRY-NIGHT VISIBILITY DATA

Near the end of the field testing phase of the project, three people from the ODOT Operations Support Section performed a dry-night visual evaluation on nine sites. The results are tabulated in Table 2.5. The numerical ratings range from a "0" for a line that is not visible to a "5" for a line that is comparable to a new line. A rating lower than 2.5 ($\pm$ .5) indicates that the line may need to be repainted.

2.7 ENVIRONMENTAL IMPACT

In 1993, ODOT purchased approximately 390,000 gallons of conventional traffic paint[1]. This paint is reported to have a VOC of about 450 g/l. The proposed 1996 EPA regulation for traffic paints calls for a VOC of no more than 150 g/l (Appendix A). The waterborne paint[1] used on this project was 135 $\pm$5 g/l. At the current paint usage rate, there would be about a 1.1 million pound reduction in VOC solvents released into the atmosphere with the switch to waterborne paint.

Clean-up of equipment that uses solventborne paint requires the use of solvents. This means that these solvents also release VOC to the atmosphere. The spent solvents have to be contained and disposed of as a hazardous material.

[1]Morton International is the supplier of the 1993 Oregon specification solventborne paint and the Dura-Line™ 2000 used on this project.

Table 2.4 Summary Statistics - Retroreflectance

SITE	CASCADE RANGE			ELEVATION	3000'			WITH	AGAINST	WITH	AGAINST	
NO. 1	DATE	9/21/93	11/2/93	12/22/93	12/28/93	2/10/94	3/8/94	3/29/94	3/29/94	4/20/94	4/20/94	
	AGE - DAYS	5	47	77	103	147	173	194	194	216	216	
	MEAN	256	273	125	126	SNOW	152	131	102	134	118	
	STD DEV	29.4	17.5	14.0	16.5		37.1	35.8	19.7	38.8	38.0	
SITE	CASCADE RANGE			ELEVATION	2500'			WITH	AGAINST	WITH	AGAINST	
NO. 2	DATE	9/21/93	11/2/93	12/22/93	12/28/93	2/10/94	3/8/94	3/29/94	3/29/94	4/20/94	4/20/94	
	AGE - DAYS	4	46	96	102	146	172	194	194	216	216	
	MEAN	335	334	97	167	SNOW	98	94	70	75	66	
	STD DEV	33.1	21.8	10.2	14.3		13.2	31.4	14.9	22.7	14.5	
SITE	CASCADE FOOTHILLS			ELEVATION	500'	NOTE 1:		WITH	AGAINST	WITH	AGAINST	
NO. 3	DATE	9/24/93	11/2/93	1/11/94	2/12/94	3/11/94	3/23/94	4/18/94	4/18/94	6/9/94	6/9/94	
	AGE - DAYS	1	27	97	129	155	167	193	193	241	241	
	MEAN	393	147	191	156	INVALID	290	318	287	303	276	
	STD DEV	39.9	35.4	40.6	49.7		21.4	19.5	18.6	23.7	21.5	
SITE	CASCADE FOOTHILLS			ELEVATION	500'	NOTE 1:			WITH	AGAINST	WITH	AGAINST
NO. 4	DATE	9/24/93	11/2/93	12/2/93	1/11/94	2/12/94	3/11/94	3/23/94	4/18/94	4/18/94	6/9/94	6/9/94
	AGE - DAYS	1	27	57	97	129	156	168	194	194	242	242
	MEAN	332	231	176	217	242	INVALID	269	281	250	291	217
	STD DEV	50.1	19.0	17.5	39.1	23.0		24.9	20.0	21.7	22.3	21.1
SITE	CASCADE FOOTHILLS			ELEVATION	500'	NOTE 1:		WITH	AGAINST	WITH	AGAINST	
NO. 5	DATE	9/24/93	11/2/93	12/22/93	2/12/94	3/11/94	3/25/94	4/22/94	4/22/94	6/9/94	6/9/94	
	AGE - DAYS	1	27	77	129	156	170	198	198	246	246	
	MEAN	363	179	223	166	INVALID	199	188	176	180	160	
	STD DEV	29.6	26.2	40.2	37.1		33.7	24.2	37.3	27.3	27.3	
SITE	CASCADE FOOTHILLS			ELEVATION	500'	NOTE 1:		WITH	AGAINST	WITH	AGAINST	
NO. 6	DATE	9/24/93	11/2/93	12/22/93	2/12/94	3/11/94	3/25/94	4/22/94	4/22/94	6/9/94	6/9/94	
	AGE - DAYS	1	27	77	129	156	170	198	198	246	246	
	MEAN	304	186	193	141	INVALID	182	175	149	170	143	
	STD DEV	52.7	17.5	17.3	20.6		21.5	19.1	17.2	13.7	23.2	
SITE	COASTAL PLANE			ELEVATION	25'	NOTE 2:						
NO. 7	DATE	10/26/93	11/18/93	12/21/93	2/10/94	3/29/94						
	AGE - DAYS	17	40	73	124	171						
	MEAN	149	139	54	0	13						
	STD DEV	35.7	29.3	20.2		14.3						
SITE	VALLEY FLOOR			ELEVATION	300'		WITH	AGAINST	WITH	AGAINST		
NO. 8	DATE	10/26/93	11/18/93	12/21/93	2/12/94	3/4/94	3/29/94	3/29/94	4/22/94	4/22/94		
	AGE - DAYS	40	63	96	150	169	194	194	218	218		
	MEAN	278	264	251	113	224	261	227	203	171		
	STD DEV	21.7	20.6	35.3	36.3	37.6	47.2	45.8	27.6	30.5		
SITE	VALLEY FLOOR			ELEVATION	250'		WITH	AGAINST				
NO. 9	DATE	10/26/93	11/21/93	2/12/94	3/8/94	3/25/94	4/18/94	4/18/94				
	AGE - DAYS	26	52	135	159	176	200	200				
	MEAN	244	209	186	204	176	155	114				
	STD DEV	30.5	42.7	43.3	54.4	56.2	57.2	32.3				
SITE	VALLEY FLOOR			ELEVATION	200'	NOTE 3:						
NO. 10	DATE	9/29/93		1/21/94		3/4/94						
	AGE - DAYS	2		116		158						
	MEAN	277		154		171						
	STD DEV	27.9		27.2		40.8						
SITE	COAST RANGE		ELEV. 450'		NOTE 4:		WITH	AGAINST	WITH	AGAINST		
NO. 11	DATE	10/26/93	12/27/93	2/10/94	3/4/94	3/29/94	3/29/94	4/22/94	4/22/94			
	AGE - DAYS	26	88									
	MEAN	324	207	306	261	198	153	198	147			
	STD DEV	22.2	27.3	23.7	26.9	24.3	18.1	16.8	16.4			

Note 1: These sites had double coverage with Visibeads in the first pass and standard beads in the second pass.

Note 2: This site was painted in out of specification conditions. The surface was damp and cold, 7 °C (44°F). The surface temperature was below the specified minimum temperature for painting.

Note 3: This area was inadvertently repainted shortly after the last recorded readings.

Note 4: This area was inadvertently repainted. The shaded area is conventional solventborne paint with Oregon specification beads.

Table 2.5 Night Rating of Lines 5/9/94

SITE	HIGHWAY	MILEPOST	RATING	COMMENTS
1	RTE 22	65.09 EB	3	
	RTE 22	71.20 SB	3	
	RTE 22	73.00 SB	3	
	RTE 22	73.00 NB	3	
2	RTE 22	77.8 EB	2.5	
3	RTE 22	17.30 EB	5	Double striped site
4	RTE 22	18.00 EB	5	Double striped site
	RTE 22	18.00 WB	5	Double striped site
6	RTE 22	17.30 WB	5	Double striped site
8	RTE 18	21.1 WB	5	
9	RTE 22	4.60 WB	4	

Water is used for clean-up of waterborne paints. The clean-up waste water does not need to be disposed of has a hazardous material. (Problems have been reported when disposal is into a local septic system.)

The conventional yellow pavement marking materials contain approximately 0.6 pounds of lead chromate for the yellow pigment. ODOT used about 175,000 gallons of yellow paint in 1993. This represents about 100,000 pounds of lead chromate pigment in the paint.

Concurrently, chromium pigment restrictions for traffic paint are under consideration. Chromium containing pigments could be restricted as early as the year 2000.

3.0 ANALYSIS AND EVALUATION

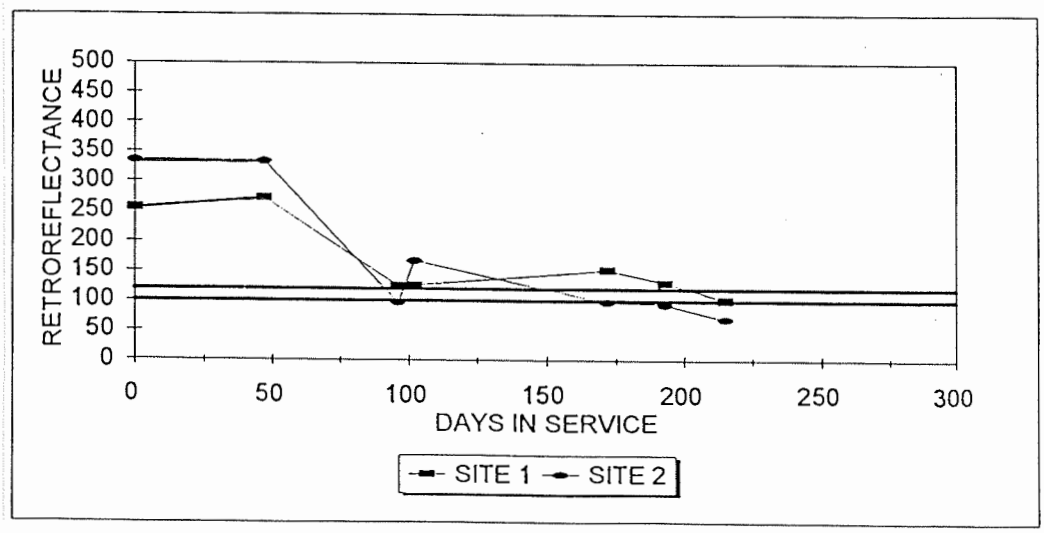
3.1 CASCADE RANGE SITES

There are two evaluation sites in the Cascade Range section. They are located on Oregon Route 22 and are above 2500 feet elevation. These sites represent the worst conditions in the test, since cinders are used very heavily for maintaining traction during the winter season. These sites, along with the adjacent highway, were marked on September 16 and 17, 1993.

Figure 3.1, below, is a graph of the retroreflectance, in millicandellas, of the lines taken over the 214 days following painting. The lines had excellent retroreflectance for the first 1 1/2 to 2 months. Between day 47 and day 77, the maintenance crew reported that they applied cinders to the area eight times. The cinders clearly had an adverse effect on the reflectance of the lines, both in terms of physical damage to the lines and cinder residue.

The two parallel lines near the bottom of the graph cover a retroreflectance band from 100 to 120 millicandellas. This represent the range at which re-marking is recommended by several leading experts in the field.

Figure 3.1
Cascade Range
Retroreflectance in Millicandellas Versus Age



The overall performance of the waterborne striping material at these sites is considered to be very good.

Following the sanding event, the lines increased in retroreflectance. This is most likely due to cleaning of the line by rain and vehicle action since the weather after that time was quite mild.

On May 9, 1994, 234 days after striping, a night evaluation of the dry lines was made by personnel from the Operations Support Section. Site 1 was rated as a "3" and site 2 was rated as a "2.5". These rating values indicate the lines are marginally acceptable.

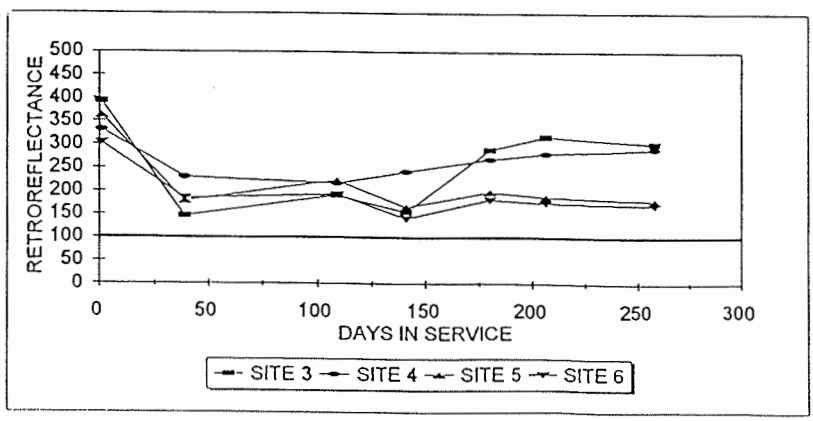
During early sanding events, the lines may appear to be substandard, however, they usually recover to acceptable levels afterwards. The improvement in the lines after the event is most likely due to rain and scrubbing by tires.

3.2 CASCADE FOOTHILLS SITES

There are four evaluation sites in the Cascade foothills section. They are located on Oregon Route 22 at an elevation of about 500 feet. The long term behavior of these sites is the most interesting of all the sites studied. These sites, along with the adjacent highway, were first marked on September 23 and 24, 1993. The weather at these sites was mild and no sanding events were noted.

Figure 3.2 is a graph of the retroreflectance, in millicandellas, of the lines taken over the 242 days following painting. The reflectance of the lines dropped in what was thought to be a normal manner in the beginning. However, as the re-marked material started to wear away, the previously covered Visibeads® began to appear and the decrease in reflectance stopped and proceeded to stay the same or increase. This phenomena was observed visually as well as from the Mirolux® data.

Figure 3.2
Cascade Foothills
Retroreflectance in Millicandellas Versus Age



As discussed previously, these sites were to represent the first applications of the Visibeads®. Problems with bead application forced the crews to discontinue using the large bead mix. From the appearance of the lines, it was thought that the large bead mix would fail prematurely. Consequently, on October 6, 1994, the lines were re-marked using the conventional bead mix.

On May 9, 1994, 215 days after striping, a night evaluation of the lines that were dry was made by personnel from the Operations Support Section. The sites were rated as a "5" which is equivalent to a new line. The rating values indicate the lines are outstanding for their age.

The overall performance of the double application of waterborne striping materials, first with Visibeads® and then with standard specification beads, is considered to be exceptional.

3.3 COASTAL PLANE SITE

There was one evaluation site in the coastal plane section. It was located on U.S. Route 101 near sea level. This site was marked on October 8, 1993, during cool, damp conditions. The pavement temperature was 39°F, 11°F below the manufacturers minimum recommended application temperature of 50° F. Premature failure of the pavement markings was evident early on, with rapid deterioration and discoloration of the lines.

The Region 2 striping crew had successfully placed conventional paints under these conditions without adverse effects.

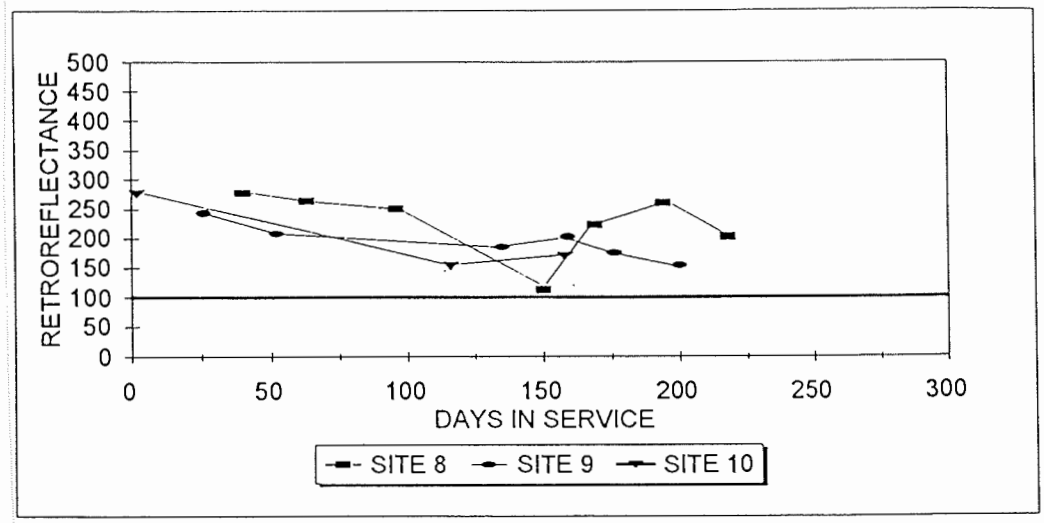
This points out how critical moisture and the low end application temperature is for waterborne paints. This will significantly effect the amount of available time to successfully apply waterborne markings on highways near the coast.

3.4 VALLEY FLOOR SITES

There are three evaluation sites in the Valley Floor section. These sites are located on Oregon Route 22 at an elevation of 200 to 300 feet. These sites, along with the adjacent highway, were marked between September 16 and 30, 1993 and had standard specification beads applied.

Figure 3.3, below, is a graph of the retroreflectance, in millicandellas, of the lines taken at various times following painting. The one large, rapid drop on site eight was taken immediately after a sanding event. Site ten has only three data points since it was re-marked prematurely.

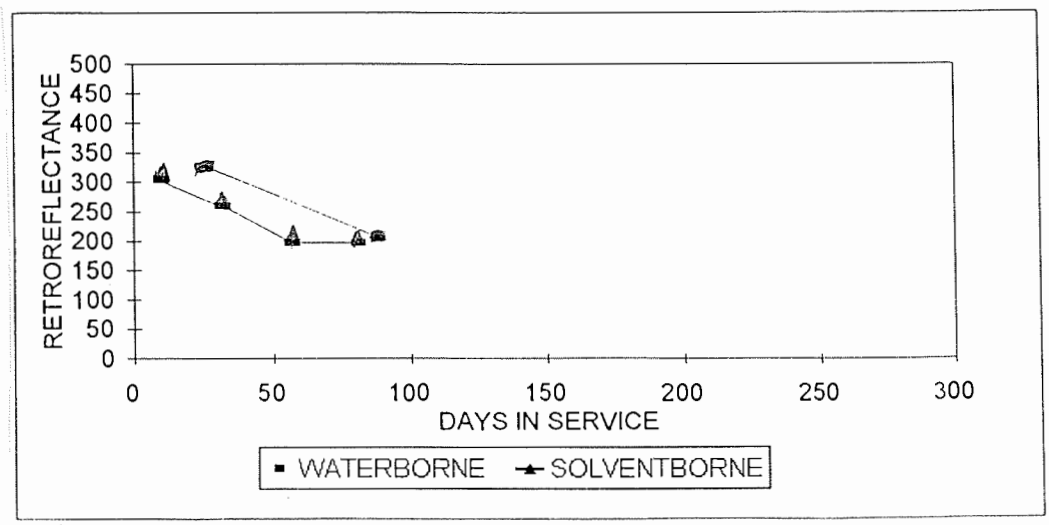
Figure 3.3
Valley Floor
Retroreflectance in Millicandellas Versus Age



3.5 COAST RANGE SITE

There was one evaluation site in the Coast Range section. This site, located on Oregon Route 22 at an elevation of approximately 500 feet, was marked shortly before October 26, 1993. According to the paint crew records, the site was re-marked the first week in February, 1994. Readings were taken for comparative purposes (Figure 3.4).

Figure 3.4
Coast Range
Retroreflectance in Millicandellas Versus Age



4.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1 SUMMARY

The Oregon Department of Transportation spends approximately $6 million a year to keep painted pavement markings on the highway for the safety of the motoring public. Approximately $2.3 million dollars is for the paint, $400,000 for beads, with the remainder going for equipment and labor. The paint that is currently being used is a solventborne paint that has a significant Volatile Organic Compound (VOC) content. In addition, lead chromate is used as the yellow pigment in the conventional yellow paint.

VOC emissions from conventional traffic paints have been perceived to cause environmental impact. In order to reduce this impact, and be ready for the time when strict restrictions may be put into effect, traffic paint suppliers and users have been developing and testing waterborne and high-solids alternative paints. Advances in new pavement marking equipment and paint formulations have solved many of the problems with waterborne paints. Handling of waterborne traffic marking paints is similar to handling conventional paints.

The magnitude of the environmental impact, by the ODOT, in Oregon can be estimated as follows. In 1993, the ODOT purchased about 210,000 gallons of white and about 175,000 gallons of yellow traffic paint. Each gallon of paint released approximately 3.75 pounds of organic solvents to the atmosphere. This means that approximately 1.4 million pounds were lost to the atmosphere from the state-wide painting operation. By going to water-base paints, the reduction in VOC would reduce solvent losses to the atmosphere by about 1.1 million pounds per year.

Even though the above numbers may seem very large, there was no known violation of any Federal or State standards or guidelines for air quality from the pavement marking operations in 1993.

Currently, the EPA and DEQ are developing regulations that include restrictions on release of solvents into the atmosphere by solventborne traffic marking paints. The expected effective date for the EPA regulations is 1996 or later. The DEQ may have local restrictions in place before the EPA does.

Historically, lead chromate ($PbCrO_4$, medium chrome yellow) has been used as the superior color stable, cost effective, yellow pigment in yellow traffic paints. The most serious limitation to the use of this pigment is that it does contain lead. This means that there are

legal restrictions on the labeling and use of trade sales paints containing them[1]. Further, there may be future legal restrictions on the use of chrome containing pigments by the year 2000.

For many years, the organic pigment industry have been trying to develop yellow organic pigments that are color stable, cost effective and compatible with waterborne paints. They were recently successful in producing such pigments and making them available to the traffic paint manufacturers. This means that the ODOT can now obtain lead and chrome free yellow traffic paint and reduce the lead chromate in the paints by approximately 100,000 pounds per year.

In order to evaluate the new pavement marking equipment and materials, ODOT Region 2 staff bought a sufficient amount of Morton International's Dura-Line™ 2000 waterborne paint to place approximately 760 linear miles of longitudinal lines. The areas where the paint was applied cover five distinct geographic locations and sites in each location were monitored for six months.

Concurrently, Visibeads® were evaluated. Visibeads® are high, wet-night, visibility beads, that are treated with a special silane and reported to be compatible with waterborne pavement marking paints.

4.2 FINDINGS

- The cost of paint for a one mile continuous, four inch wide, white longitudinal line was: $149 for the waterborne paint and $112 for conventional paint.

- The cost of paint for a one mile continuous, four inch wide, yellow longitudinal line was: $156 for the waterborne paint and $113 for conventional paint.

- Application characteristics of the waterborne paint were comparable to conventional paint.

- Application rates with the waterborne paint were comparable to conventional paints.

- The pavement marking equipment was easier to clean-up after using waterborne paint compared to conventional paint, however, some clean-up activities needed to be performed more frequently.

- Worker exposure to VOC's and lead chromate is significantly reduced when using waterborne paints. (No data was taken to measure the reduction.)

[1] "Federation Series on Coatings Technology," Unit Eight, Inorganic Color Pigments, Federation of Societies for Coatings Technology, 1982.

- Clean-up solvents were eliminated and waste paint was no longer disposed of as a hazardous waste.

- The cost of beads for a one mile continuous, 4 inch wide, longitudinal line was: $16 for Oregon specification beads and $147 for Visibeads®.

- Available bead application equipment was not suitable for Visibeads®. Potters Industries, the supplier of the beads, was unable to supply the recommended bead application guns.

4.3 CONCLUSIONS

4.3.1 PAINT

- The durability of the waterborne paint, especially nighttime effectiveness, is equal to or better than conventional solventborne paints. Consequently, specifications for waterborne pavement marking paints have been developed by ODOT.

- The time to "no-pick-up" in traffic, of this waterborne paint, meets the requirements for the conventional paints being currently used.

- Waterborne latex paints are more sensitive than conventional paints to cool and damp environmental conditions during application. This could significantly reduce the amount of available painting time each year.

- Latex based paints seem to hold dirt more than conventional paints. This makes them appear, after a relatively short period of time, to perform poorer than conventional paints. This dirt retention does not effect night-time visibility. It does affect daytime appearance but the functionality of the line is not significantly impaired.

- Sanding has an adverse impact on waterborne and solventborne line quality. However, it appears that lines "bounce back" to some degree after the sanding event (due to subsequent washing by rain and scrubbing by vehicles).

- It appears that a "double application" technique, with Visibeads®, could be developed for high wear areas that would maintain line quality for an extended period of time.

- Even though the first costs for waterborne paints is higher than solventborne paints, the actual costs would be much closer together when worker safety,

environmental damage and clean-up of conventional paints are taken into account.

- The reflectivity at night, as the motorists see the line, is dependent on the direction of painting. This could have an impact on how the centerline of two lane roads should be treated.

4.3.2 VISIBEADS

- The recommended application rate of 15 pounds per gallon for Visibeads® is unrealistic and needs to be revised because of the high cost and lack of adequate wet film thickness of the paint.

- Modification of available guns for application of these beads was relatively unsuccessful. Use of Visibeads® will not be practical for highway applications until satisfactory techniques and equipment for bead distribution are developed.

4.4 RECOMMENDATIONS

- ODOT should convert to waterborne paint in selected geographic areas.

- Waterborne paints should be used for all manual applications of legends as soon as practical.

- An "Expert Task Group" (ETG) should be assembled to identify problems and deliver solutions to converting to waterborne paints. This group should make sure that the latest practices are being made available to the crews on a uniform basis.

- The ETG should identify research which would be aimed at making painting easier and more efficient as well as providing the public with optimum line quality.

- The ETG should address the bi-directional reflectivity on two-lane, two-way, centerline applications.

- The ETG should address the development of a double-coverage technique with Visibeads® in high wear areas.

- Cities and counties should be encouraged to change to waterborne paints to reduce VOC's and environmental long term damage.

Appendix A

EPA Memo to the Regulatory Negotiation Committee Members

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

June 3, 1994

OFFICE OF AIR QUALITY PLANNING AND STANDARDS

Dear AIM Coatings Regulatory Negotiation Committee Members:

As you all know we have all worked hard for over two years to try to reach a consensus position on the AIM Reg/Neg. At our last meeting it was obvious that the discussion draft EPA had put together was not going to form the basis for agreement and that we still had major differences between the various caucus positions. As I committed at that meeting, I have spent considerable time reviewing our status and looking for ways to bridge the differences.

After discussing the situation with a number of people, I decided to ask representatives from each caucus to meet with me to review the status and to determine if there was any potential for a consensus position. After much discussion we have been able to put together a framework of a potential rule which representatives feel has a reasonable chance of receiving support. This framework will be distributed to each of you on June 3, 1994, to determine if you can or cannot support it. Unfortunately, several versions of the framework seem to be floating around, each of which have errors in them. The only framework that you should focus on is the one that I will be sending to you this week. While I certainly want you to exercise your freedom in accepting or rejecting the framework, I believe it is very important that we are working from the same framework.

I have asked the representatives from each caucus who attended the meeting to report back to me with the positions of their caucuses. If this framework appears to prevent a foundation for agreement among Committee members, EPA will proceed to develop another complete draft for review and formal decision making by Committee members.

I believe that after two years of negotiations this framework represents a great deal of give and take and forms the best chance for an agreement. However, I want to emphasize that each Committee member is totally free to make their own decision to support or not support this framework. My recommendation to the Agency regarding the future of the Reg/Neg will be determined by my assessment of the views of the Committee members.

Appendix II

Table of Standards for 1996, 2000, and 2004
(VOC Content of Coating-g/l)

	1996	2000	2004
Dry Fog Coatings	400	400	250
Flat Coatings N.O.S			
Exterior			
Solventborne	250	200	150
Waterborne	200	200	150
Interior	200	150	100
*High Performance Coatings			
Floor coatings	400	350	300
Rust Preventative Coatings	400	300	300
Concrete Protective Ctgs	400	350	300
Industrial Maintenance (I/M) Ctgs	350	350	300
Lacquers - Clear	680	650	600
Opaque	650	650	600
Metallic Pigmented Coatings	500	450	400
Non-Flat Coatings N.O.S			
Exterior			
Solventborne	250	250	150
Waterborne	250	250	150
Interior			
Solventborne	350	250	200
Waterborne	250	200	150
Primers and Undercoaters N.O.S			
Waterborne	150	150	150
Solventborne	350	250	250
Quick Dry Coatings			
Quick Dry Enamels	450	350	300
Primers, Slrs, & --	450	350	300
Roof Coatings	250	200	200
Sealers - Incl Specialty Slrs	400	350	350
Shellacs - Clear	650	600	600
Opaque	550	500	500
Stains - Opaque			
Solventborne	350	250	200
Waterborne	200	200	150

Table of Standards for 1996, 2000, and 2004
(VOC Content of Coating-g/l)
(continued)

	1996	2000	2004
Semi Transparent Stains	550	400	350
Low Solids	120	120	120
Traffic Marking Paints	150**	150**	100**
Varnishes	450	350	300
Waterproofing Sealers			
Clear	600	500	450
Opaque	400	400	400
Wood Preservatives			
Below Ground	550	550	550
Clear L Semi-Transp.	550	550	350
Opaque			
Solventborne	350	250	200
Waterborne	200	200	150
Low solids (not less water)	120	120	120
Estimated % VOC Reduction	20%	30%	40%

*This category is still being worked on. It is desired to allow products other than the three listed to be in the category, but language needs to be incorporated to ensure that only needed high performance products are in the category.

**A provision should be incorporated into the rule which would allow for the use of higher VOC traffic marking paints in seasonal conditions.

Appendix B

Draft Field Sampling Plan and Mirolux®

Instructions for Determination of

Reflectance of Pavement Marking Paint with Beads

Using the Mirolux® Reflectometer

Draft Field Sampling Plan For Determination of Reflectance of Pavement Marking Paint with Beads Using The Mirolux® Retroreflectometer

INTRODUCTION

Part of a current project to evaluate waterborne pavement marking materials included using the Mirolux® retroreflectometer to quantify longitudinal line brightness. The preliminary data that was obtained indicated there was either a problem with the instrument or there was a problem with how the test sites were being sampled. To resolve the problem, a site was selected and sampled at a rate that significantly exceeded minimum sampling requirements for data collection. The results of the measurements are discussed below.

GENERAL FINDING

The mean of the individual measurements is dependent on the direction of painting. Ten broken longitudinal lines in a preliminary test section were examined. The hypothesis tested was: the same mean reflectance will be obtained regardless of the direction of testing. This hypothesis cannot be accepted. The mean of the reflectance over the test site was greater when the meter was pointed in the direction of painting when compared to the mean of the reflectance when the meter was pointed opposite the direction of painting.

GENERAL RECOMMENDATION

When the long dimension of the instrument is aligned with the long direction of the line being measured, the display end of the retroreflectometer should be pointed in the direction of painting. This will eliminate directional inconsistencies.

SAMPLING BROKEN LONGITUDINAL LINES

Identify an area that represents uniform painting practices and normal vehicle impact (avoid curves, driveways, intersections, etc.). Randomly select a minimum of seven broken lines and determine the reflectance at three points on each line.

Note: Variability can be reduced by avoiding measurements on the "head" or "tail" (approximately the first and last 12 inches of the line) of the line.

SAMPLING CONTINUOUS LONGITUDINAL LINES

Identify an area that represents uniform painting practices and normal vehicle impact (avoid curves, driveways, intersections, etc.). For a new line, randomly select a minimum of 13 test points in the area to be evaluated and determine the reflectance. As the line ages, the variability over the site increases. To compensate for the higher variability, increase the number of test points to 20 or more.

GENERAL GUIDELINES

For evaluation of pavement markings using the Mirolux®, Figures B.1 and B.2 can be used to get an estimate of the number of points that need to be taken for the desired confidence and range of readings. The 90% or 95% confidence interval is the 90% or 95% probability that the mean lies within the selected (+/-) range.

For example, suppose you took 15 *readings,* (x_i, i=1, 15) *with an average* ($\bar{x}$) *of* 110. *Calculate the standard deviation from the formula:*

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \bar{x})^2}{N-1}}$$

Suppose the standard deviation of the 15 readings was 25. You want to be 95% confident that the true mean is within +/- 10 of the measured mean (110 +/- 10). Go to figure B.2 to get the estimate of N, which is about 24. Nine more readings are needed. Note that the additional readings may slightly change the average. Now you can be 95% confident that the true mean is within +/- 10 of the new average.

Note: Many hand calculators come equipped with the average (mean) and standard deviation functions. Be sure to check if the calculator uses N or N - 1 in the standard deviation calculation.

Figure B.1

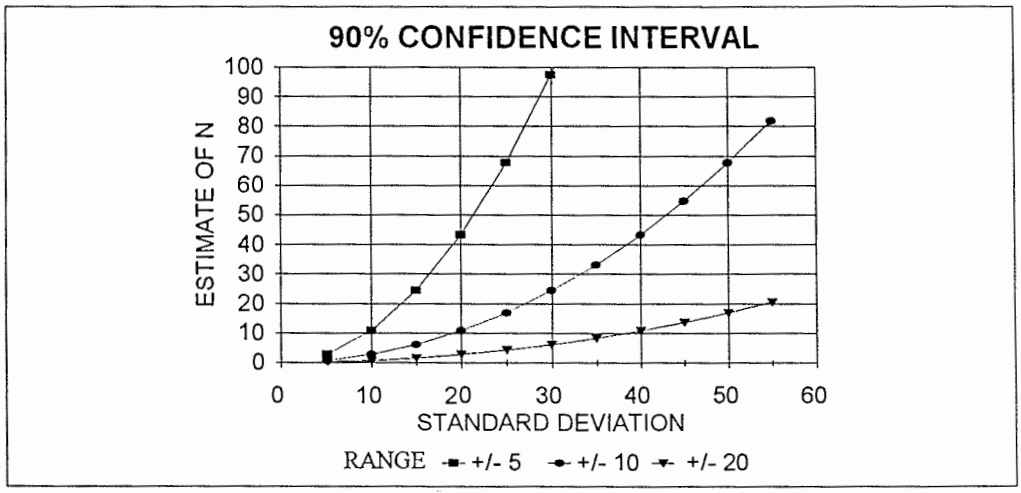
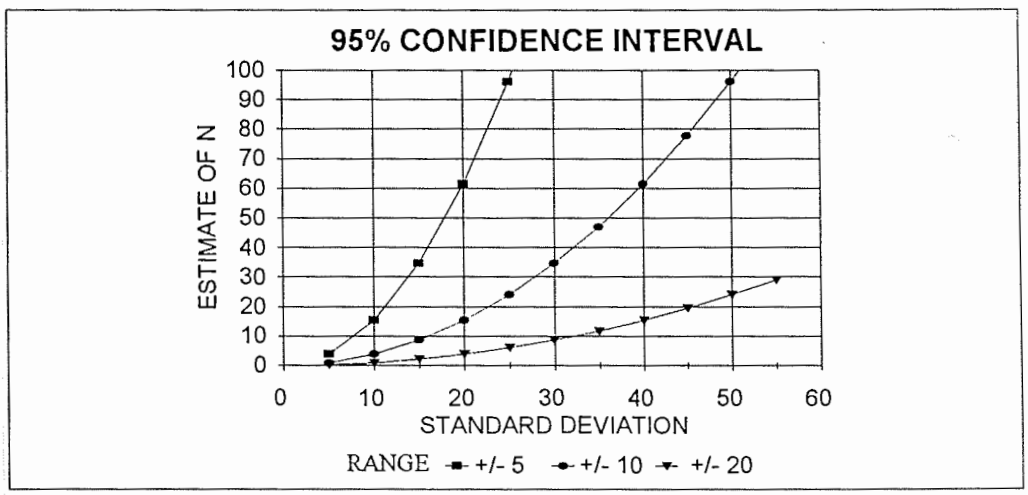


Figure B.2



MIROLUX 12

Instruction Manual

MIRO-BRAN ASSEMBLERS, INC.
ELECTRO-MECHANICAL ASSEMBLIES
107 East 27th Street, Paterson, New Jersey 07514
Telephone (201) 278-6166

MIROLUX 12

Receipt of Instrument

The Mirolux 12 is a delicate scientific instrument which must be unpacked carefully making sure that no defects occurred during transportation. If any defects did occur they should be reported immediately to Miro-Bran Assemblers Inc.

The shipping container should contain the following items:

- Mirolux 12
- Extra battery pack
- A.C. adapter
- Black-White test plate

Mirolux 12 Retroreflectometer

- Reliable performance evaluation of horizontal road markings
- Direct measurement in millicandelas/M^2/LX
- Measurement on dry surfaces in daylight or dark
- Portable, self-contained construction
- Digital readout
- Rechargeable power supply
- Battery charger and accessories for calibration and performance check
- Internal & external calibration plates for ease and reliability
- Light weight and low cost

Putting Unit Into Service

1. Place on flat, dry, clean surface in vicinity of road marking test area.
2. Turn on power switch and light switch (Fig.2).
3. Check battery by pushing in test button (Fig.1). Should read between 115 (11.5v) and 125 (12.5v). Press button again and turn off light switch.
4. Allow 3 - 5 minutes for warm-up.
5. Unlock zero adjust knob (Fig.1) and adjust to zero on digital display.
6. After 3 minutes, digital display should remain at zero - if necessary, readjust (Step 5).
7. With digital display at zero, turn light switch to on position (Fig.1).
8. To assure proper placement of calibration plate, pull calibration control knob (Fig.2) two (2) times and leave in the in position.
9. Unlock calibration knob and adjust to given value (Fig.1).
10. Unit is now ready to take reading.
11. Place unit on calibration test panel (white side). Pull calibration control knob two (2) times and let unit settle. Reading should be within range marked on reverse side of panel. Be sure Mirolux 12 is placed directly on the test panel (Fig.3).
12. Carefully place unit on area to be tested, ensuring unit is stable. Place the unit lengthwise on the stripe to be measured. Mark the exact place of the instrument on the road (Fig.3).
13. Pull calibration control knob out and allow unit to settle.
14. When display stabilizes, record reading.

Note: Periodically check battery level and internal calibration. If battery level is below 11.5v (115), it needs to be recharged (see section on battery).

Measuring Procedure

Three (3) readings on the same line within ten [10] feet of each other should be +-10% of the average of the readings. If not, two (2) more readings should be taken.

Battery

Located in side door panel (Fig.2)

To Remove Battery - Open door, pull battery plug from unit, unscrew two (2) black knobs, remove plate and slide battery out using tabs. Do not pull on wires.

To Install Battery - follow instructions above to remove old battery. Slide battery pack onto two (2) mounting posts, install plate with two (2) black knobs to retain battery, replace plug and close door.

Note: When battery reads below 11.5 v (115) - remove and recharge.

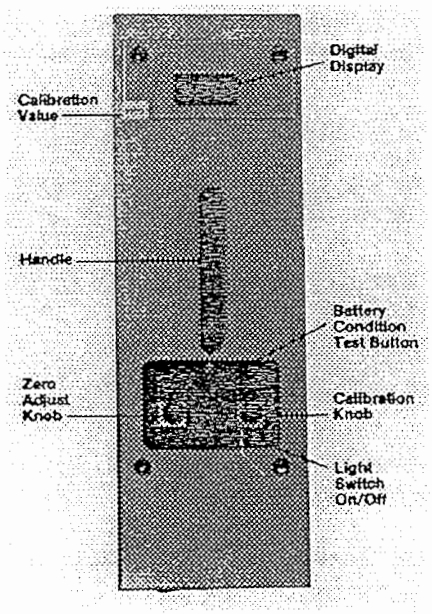


Fig 1

Recharging Battery

Every two to three weeks, the battery should be dissipated, in the unit, by turning the power supply and light on until voltage reading is below 10.0v (100). This can be done overnight. Allow approximately ten (10) hours. This procedure will ensure that the NICAD battery memory is not established and full capacity can be maintained.

To charge batteries in the Mirolux 12, turn off the instrument. Insert the AC adaptor into a wall plug and insert the prong into the plug at the bottom of the left end. The batteries will now charge. The extra set of batteries can be recharged by again inserting the AC adaptor into a wall plug and inserting the prong into the socket where the wires of the battery come together (Fig 2 recharging socket in off position).

Note: For each hour the batteries are used they should be charged for two hours. The batteries cannot be overcharged.

Operating Tips

- For best results, store and operate your Mirolux 12 between 32°F and 100°F. Avoid excessive temperatures, including the trunk of a car.
- When removing battery, be careful not to pull on the wires. Be sure plug is fully inserted.
- Place unit squarely on surface to be tested. Clear the area of debris (stones, gravel, etc.) first.

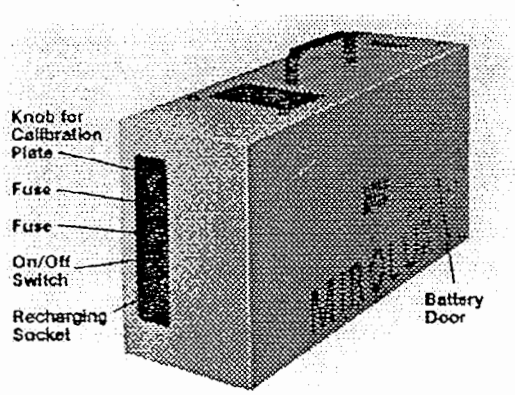
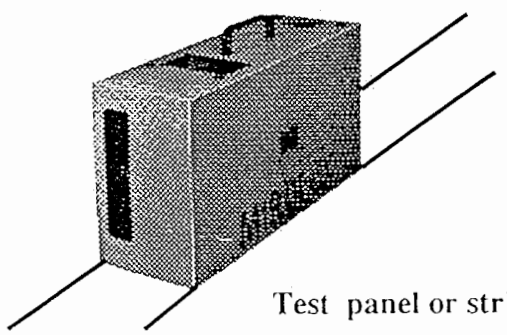


Fig 2

Fig 3



Test panel or stripe

MIROLUX 12

- Calibration control knob should be in out position only when taking readings.
- Avoid moisture and dampness.
- Keep digital display out of direct sunlight.
- Once calibrated and warmed-up, leave light on. Turn off only when finished taking readings.
- Store calibration test panel carefully in carrying case.

Maintenance

The instrument does not require special maintenance. The optics are protected against dirt and dust. It is recommended that the only cleaning be done using oil free compressed air of maximum 1.5 to 2 bar for gently cleaning the crevices.

CAUTION: The optics housing may under no circumstances be opened because the measuring geometry would be changed and this would negate any guarantee for correct functioning. The measuring geometry can be adjusted only in the factory.

LAMP: The lamp is the heart of the optical system. The lamp must be exactly fixed in the socket to guarantee the correct light beam. If the filament of the lamp is not in the exact position the angularity will be off. The lamp glass may not be touched. If the lamp has been touched by mistake it has to be cleaned thoroughly with alcohol.

Specifications for Mirolux 12

Mirolux 12 is a portable retroreflectometer which is useful for testing highway traffic markings for luminous reflectorance using directions of illumination and observation similar to those occurring during night traffic.

Readout	3 Digit Digital Display
Light Source	12v 12w Halogen Lamp
Standard Calibration	Built-in
Controls For	On/Off, Lamp On/Off, Zero Adjustment, Calibration Adjustment, Battery Check
Power Requirements	12v dc
Dimensions	18 in. long, 6 in. wide, 9 in high, (455 x 152 x 229 mm)
Weight	14lbs. (61/2 kg) (w/carrying case 35 lbs)

Accessories

Extra Battery Charger
Extra Battery Pack
Test Panel
Foam Rubber Replacement Kit

It is advisable to have 2 battery packs and chargers to allow for extended use.

Potters Industries Inc.
an affiliate of The PQ Corporation
20 Waterview Boulevard, Parsippany, NJ 07054, U.S.A.
Tel. (201) 299-2900 Telexfax: (201) 299-1101 Telex: 219054

CALIBRATION OF MIROLUX 12
(RE-CALIBRATION)

1. Tools required:

   a. Digital meter,
   b. small screwdriver,
   c. small jumper (12" wire with 2 alligator clips),
   d. 1/2" wrench,
   e. clean black/white test panel, and
   f. diagram of boards showing adjustment points.

2. To calibrate machine - remove cover:

   a. Remove battery first,
   b. remove 4 screws on top and remove cover, and
   c. place battery pack into machine and plug in.

3. There are 6 adjustment POT's on the 2 boards (4 if the machine is serial no. 257 or lower with blue cover) plus 1 POT on front support to adjust voltage to lamp.

4. Turn on main power. Leave light off. The first adjustment is POT #4 for the digital display. Attach the minus side of the digital meter to the ground or minus volt (to #5 or #6) and the plus + side to test point #1 on display board. This reading should be 1.00 $\pm$ .02 volts. If not, adjust the POT #4 with small screwdriver until this reading is on the digital meter; not the display board. Remove meter.

5. The second adjustment is the zero control. Turn the zero dial to read 500 on the dial (not the display). This is the mid range of the zero control. With a small jumper, clip one end on the - volts lead and the other end onto the wire end of R5 (refer to diagram). Adjust POT #1 with the screwdriver to get 000 $\pm$ 002 on the digital display. Wait until it is stable. Remove the jumper from both connections. The reading may change; that is normal. Adjust POT #2 to get 000 $\pm$ 002 on the digital display.

6. Get the range numbers from the back of the test panel. Record these numbers. Place the machine on the white side of the test panel. The span between the two numbers is 20. An example is 390 - 410. The adjustment will be made to the middle reading (400). Open the calibration flap and turn on the light. Adjust the calibration control until this number (example - 400) is obtained on the digital display. If this can be done and the dial reading on the calibration control is 500 - 900, the machine is close to final adjustment.

7. If the reading is below 500, look at the light source to see if the lenses are dirty. This will make the light look dull. If the light is dull, the 2 lenses can be cleaned with long cotton swabs and alcohol. DO NOT remove the lamp assembly from the machine. Use 1 swab to clean with alcohol and 1 to dry the lenses. (A pencil with a cotton ball taped to it can also be used.)

8. After cleaning the lenses, check and see if the reading is higher. If you can now get the readings described in Step #6, turn the machine 180° and place it on the black side of the panel. The reading should be 000 ± .005. If not, adjust POT #3 to get 000. After this reading is stable, turn the machine 180° and place it on the white side of the panel. Check reading and readjust to 400 (example). After the reading is stable and the dial reading is still 500 - 900, the calibration is near completion. Push the flap control to closed position and record reading after it is stable. Open and close the flap control several times to see if the numbers remain close to the reading established with the flap open and closed. If they do, record the number with the flap closed and use this number for the internal calibration number.

9. If the calibration cannot be accomplished, there are several alternate steps required:

    a. Turn off the lamp switch. Check battery voltage. This should be checked with the digital meter to #3 + volts to #4 - volts. Turn on the lamp switch and make sure the voltage does not go below 11.8 volts.

    b. If it does, replace the battery with a fully charged battery. Once the battery voltage is good (12 volts and better), proceed to check the lamp voltage - terminal #6 - volts and terminal #2 + volts. This reading should be 9.8 volts to 10 volts. This adjustment is on the right hand support . Unlock the lock nut with 1/2" wrench and adjust the slotted shaft to get the reading. If the calibration dial is below 500, increase the voltage to 10.2 and see if this brings the reading into range. If the calibration dial is 900 or better, decrease the voltage to 9.6 and see if that brings the reading into the range, If it does, the calibration is now complete.

10. Turn off all switches and remove battery. Install cover and 4 screws. Install battery and clamp. Turn on main power and zero machine after it is stable. Turn on light switch and set calibration number established in step #8. Place machine on white test panel and take reading. This should be 400 (example) or close to it + 010. Check this several times on the white and do the same on the black side.

11. If the machine can not be set up to read the test panel within the accepted range, check the following:

    a. The test panel is in good shape, clean and on a flat surface.

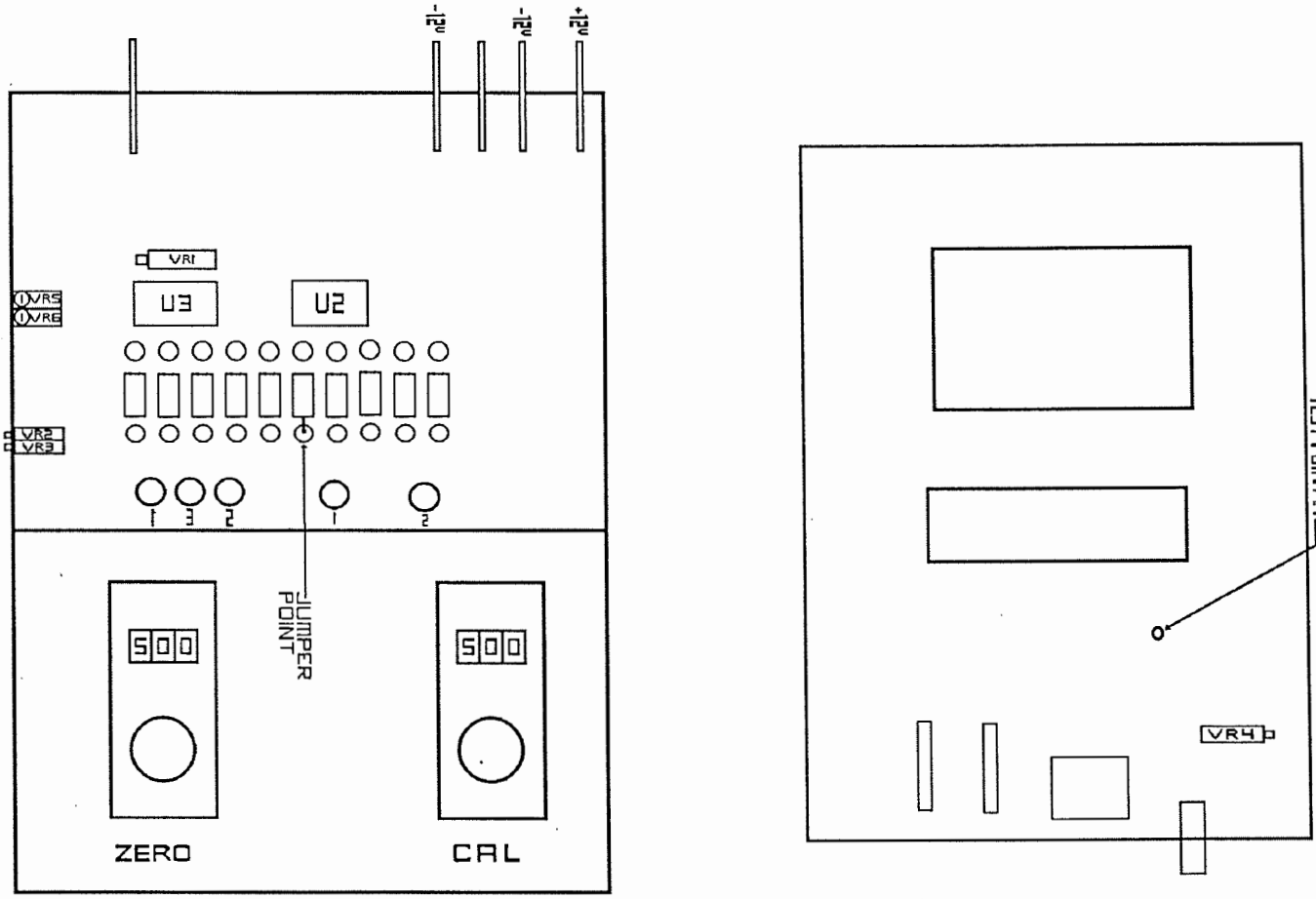
b. Battery supply is fully charged and does not drain down fast. Some batteries, after years of use, will not retain a voltage with the lamp switch on. A new battery is required.

c. Rubber seal on bottom of machine is in good shape. Do not replace the foam with any other type of foam rubber; this could throw the reading off. A replacement kit is available.

d. If machine can not be adjusted, call Miro-Bran Assemblers for instructions -

Nicholas Mirowsky at 201-278-6166.

Figure B.3
Component Layout for the Mirolux Reflectometer



Appendix C

MIROLUX® SITE DATA

WATER BASE STRIPING – EVALUATION – CASCADE RANGE

SITE INFORMATION

SITE	1
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	< 5,000
BEGIN MP	65.09 E.B.
DATE APPLIED	9/16/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	72
AIR TEMP	67
WIND	N\A
REL HUMIDITY	45%
PRECIPATION	NONE
CLOUD COVER	NONE

N\A – NOT AVAILABLE

MIROLUX DATA

9/21/93	11/2/93	12/22/93	12/28/93	2/10/94	3/8/94	3/29/94	3/29/94	4/20/94	4/20/94
				NO TEST		WITH	AGAINST	WITH	AGAINST
269	246	117	122		146	106	133	87	67
201	287	152	117		160	109	107	114	102
254	280	113	126		128	149	134	99	80
269	273	139	103		141	96	143	119	102
287	267	138	93		143	98	111	93	110
	274	117	102		78	107	105	121	124
	274	122	110		141	94	81	67	97
	266	115	144		200	74	92	107	64
	235	105	157		199	131	76	118	105
	272	107	148		116	126	60	95	77
	282	139	126		145	73	90	132	55
	307	121	150		149	165	115	184	137
	289	136	144		135	198	109	159	145
			122		120	119	111	188	114
			138		193	185	91	217	141
			126		153	147	84	162	174
			123		182	181	94	187	153
			125		220	157	105	147	183
			121		199	166	102	155	181
			119		85	129	96	125	147
MEAN	256	273	125	126		152	131	102	134	118
STD DEV	29.4	17.5	14.0	16.5		37.1	35.8	19.7	38.8	38.0
COEF VAR	11.5	6.4	11.2	13.1		24.5	27.5	19.3	29.0	32.2

PAINTING LOG DATA

SEPTEMBER 16, 1993
WHITE – TANK NOS. 428 & 456
2 BAGS REGULAR BEADS
61 MILES – SHOULDER LINE

NOTES:

NOV.2 – TEST INCLUDES PATCH SECTION – CLEAR, WARM, LINE CLEAN DRY.
DEC. 2 – FOG, STANDING WATER, LINE WAS HAND DRIED
MAINTENANCE REPORTED APROX (8) APPLICATIONS OF CINDERS
BETWEEN LAST TEST DATE (11 – 2) AND THIS TEST DATE (12 – 2)
DEC 28 – OVERCAST, LINE DRY, FIRST PART OF LINE COVERED WITH CINDERS
ONLY TESTED CLEAN PORTION OF LINE, SIGNS OF SNOW PLOW
SCRAPES.
FEB 10 – NO TESTING SITE COVERED WITH SNOW AND RED CINDERS
MAR. 8 – LINE CLEAN, NO CINDERS ON LINE, SOME SNOW PLOW SCRAPES
MAR 29 – THE PAINT HAS YELLOWED AND IS WEARING DOWN. THE SOLVENT LINE IS
IS VISIBLE IN SOME SPOTS.
APR 20 – MAINTENANCE BROOMED THE SITE EARLIER – SOLVENT LINE
IS SHOWING THROUGH IN SOME PLACES

WATER BASE STRIPING PAINT – EVALUATION – CASCADE RANGE

SITE INFORMATION

SITE	2
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	OPEN A/C
TRAFFIC	< 5,000
BEGIN MP	77.80 E.B.
DATE APPLIED	9/17/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	88
AIR TEMP	64
WIND	N\A
REL HUMIDITY	40%
PRECIPATION	NONE
CLOUD COVER	NONE

N/A – NOT AVAILABLE

MIROLUX DATA

	9/21/93	11/2/93	12/22/93	12/28/93	2/10/94	3/9/94	3/29/94	3/29/94	4/20/94	4/20/94
					NO TEST		WITH	AGAINST	WITH	AGAINST
	303	351	95	167		72	40	74	49	48
	338	325	107	153		90	50	78	32	32
	306	328	97	177		88	53	71	48	55
	335	313	87	142		109	61	78	71	53
	395	321	115	162		77	55	89	68	66
		295	96	165		101	61	71	60	68
		312	109	156		98	68	104	46	50
		337	105	191		101	106	90	67	58
		357	94	164		113	82	83	61	63
		322	110	182		110	97	81	77	54
		351	115	179		106	114	67	53	81
		378	82	151		97	104	69	81	69
		350	93	162		81	128	63	80	94
			93	139		117	133	68	104	75
			84	172		103	96	61	104	65
			93	168		85	124	54	95	78
			94	172		106	130	46	108	85
			82	192		115	135	48	99	82
			97	183		105	102	52	76	76
			84	160		78	132	52	112	65
MEAN	335	334	97	167		98	94	70	75	66
STD DEV	33.1	21.8	10.2	14.3		13.2	31.4	14.9	22.7	14.5
COEF VAR	9.9	6.5	10.6	8.6		13.5	33.6	21.4	30.5	22.0

PAINTING LOG DATA –

SEPTEMBER 17, 1993
YELLOW – TANK NO.490
1 BAG REGULAR BEADS
20 MILES – CENTER LINE AND
CONTINOUS LEFT TURN

NOTES:

NOV 2 – CLEAR, WARM, LINE CLEAN AND DRY.
DEC 22 – 8 APPLICATIONS OF CINDERS SINCE LAST TEST.
CLEAR, SUNNY, DRY, RED CINDERS HAND SWEPT FROM LINE
FIVE SKIP LINES WERE TESTED FROM THE W.B. LANES FOR REF.
READINGS WERE (100, 106, 105, 107, 104).
DEC 28 – OVERCAST, DRY, LINE CLEAN, SNOW PLOW SCRAPES ON LINE.
FEB 10 – NO TEST, SITE COVERED WITH SNOW AND RED CINDERS
MAR 9 – LINE CLEAR OF CINDERS, SHOWING WEAR ON ABOUT 30% OF THE LINE,
PROBLEMS WITH "0".
MAR 29 – THE PAINT IS WEARING THROUGH TO THE AC. TRACES OF OLD LINE VISIBLE
APR 20 – TOPS OF AGGREGATE NO LONGER COVERED WITH PAINT
BEADS STILL VISIBLE IN THE CREVICES

WATER BASE STRIPING PAINT – EVALUATION – CASCADE FOOTHILLS

SITE INFORMATION

SITE	3
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	5–15 K
BEGIN MP	17.3 EB
DATE APPLIED	9/23/93
BEAD TYPE	BOTH
PAVEMENT TEMP	88
AIR TEMP	70
WIND	14
REL HUMIDITY	44%
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

9/24/93	11/2/93	1/11/94	2/12/94	3/11/94	3/23/94	4/18/94	4/18/94	6/9/94	6/9/94
VISIBEADS	REGULAR	REGULAR		VISIBEADS	RECALIB	WITH	AGAINST	WITH	AGAINST
409	198	189	185	350	338	312	254	319	297
314	172	177	172	418	294	368	254	314	292
407	140	184	158	446	295	320	296	322	309
409	134	167	118	394	286	334	271	299	281
425	125	179	133	475	307	332	271	343	316
	133	144	127	433	318	307	267	310	282
	144	138	131	424	319	302	293	329	271
	117	150	143	416	293	344	298	310	288
	104	166	101	412	275	344	268	287	303
	96	175	117	448	293	310	281	352	229
	124	123	99	371	301	329	287	263	269
	112	149	96	386	293	330	277	313	255
	102	206	110	340	274	304	297	291	289
	159	236	133	341	250	313	280	292	274
	135	247	141	360	278	316	314	305	260
	166	236	201	408	275	286	316	273	262
	218	241	214	283	265	320	294	274	254
	165	260	254	350	251	287	316	310	245
	189	222	242	347	286	306	306	289	269
	210	240	246	336	300	303	297	264	283
MEAN	393	147	191	156	INVALID	290	318	287	303	276
STD DEV	39.9	35.4	40.6	49.7		21.4	19.5	18.6	23.7	21.5
COEF VAR	10.2	24.0	21.2	31.9		7.4	6.1	6.5	7.8	7.8

PRODUCTION LOG DATA –

SEPTEMBER 24, 1993
WHITE – TANK NO. N12
3 BAGS VISIBEADS
27 MILES – SHOULDER LINE
– CENTER LINE

OCTOBER 6, 1993
WHITE – RETRACE
42 MILES
550 GALLONS
4500 POUNDS REGULAR BEADS

NOTES:

REGULAR BEADS OVER VISIBEADS – (RESTRIPPED).
NOV 2 – OVERCAST, LINE DRY, COOL – READINGS WERE DRIFTING.
JAN 1 – LINE IS VERY CLEAN DUE TO RECENT RAIN, BUT HAS YELLOWED.
LINE DRY, EDGE OF PAVEMENT WET., CLOUDY
THE RESTRIPE IS WEARING, VISIBEADS ARE STARTING TO SHOW.
FEB 12 – LINE IS SHADED BY TREES AND IS IN A FROST ZONE – NO SANDING.
MAR 11 – THE VISIBEADS ARE NOW SHOWING THROUGH.
CALIBRATION AND "0" ING PROBLEMS.
MAR 23 – THESE TESTS WERE RUN USING NEW CALIBRATION VALUE OF 520.
APR 18 – VISIBEADS ARE EAISLY SEEN

WATER BASE STRIPING PAINT – EVALUATION – CASCADE FOOTHILLS

SITE INFORMATION

SITE	4
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	5 – 15 K
BEGIN MP	18.0 E.B.
DATE APPLIED	9/23/93
BEAD TYPE	BOTH
PAVEMENT TEMP	88
AIR TEMP	70
WIND	14
REL HUMIDITY	44%
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

9/24/93	11/2/93	12/2/93	1/11/94	2/12/94	3/11/94	3/23/94	4/18/94	4/18/94	6/9/94	6/9/94
VISIBEADS	REGULAR			VISIBEADS	VISIBEADS	RECALIB	WITH	AGAINST	WITH	AGAINST
369	252	166	269	241	391	314	294	229	323	275
278	259	184	278	285	396	304	309	247	324	275
364	243	204	240	249	412	282	280	246	288	245
264	218	191	251	258	369	269	317	243	316	208
383	221	196	272	256	376	253	300	250	271	208
	194	185	234	260	368	238	241	244	253	208
	204	149	261	258	389	220	247	276	252	208
	227	148	261	280	389	276	276	239	296	208
	249	172	243	241	407	289	282	241	295	208
	221	182	231	237	418	248	245	253	307	208
	240	173	189	230	398	278	289	237	300	208
	221	184	179	242	350	263	271	212	304	208
	250	150	171	215	363	245	293	254	292	208
			172	204	363	223	292	228	263	208
			188	190	385	263	279	217	321	208
			182	215	385	291	305	263	297	208
			191	255	393	267	281	297	274	208
			165	234	411	295	279	270	260	208
			177	255	393	282	270	281	299	208
			185	237	429	286	267	282	275	208
MEAN	332	231	176	217	242	INVALID	269	281	250	291	217
STD DEV	50.1	19.0	17.5	39.1	23.0		24.9	20.0	21.7	22.3	21.1
COEF VAR	15.1	8.3	9.9	18.0	9.5		9.2	7.1	8.7	7.7	9.7

PAINTING LOG DATA –

SEPTEMBER 24, 1993
WHITE – TANK NO. N12
3 BAGS VISIBEADS
27 MILES – SHOLDER LINE
AND CENTER LINE

NOTES:

REGULAR BEADS OVER VISIBEADS – (RESTRIPPED)
NOV 2 – OVERCAST, COOL, LINE DRY.
DEC 2 – OVERCAST, STARTED TO DRIZZEL, DRIED LINE WITH TOWEL, PHOTOS
JAN 11 – LINE DRY, EDGE OF PAVMENT WET, CLOUDY, RECENT RAIN HAS CLEANED THE LINE, NO SANDING TO DATE.
FEB 12 – TOP LINE IS FLAKING OFF, UNDERLYING VISI BEADS MAY BE CAUSING THIS
MAR 11 – VISIBEADS ARE NOW SHOWING. SUNNY, DRY. BEADS BRIGHT IN SUN, PHOTOS. YELLOW INSIDE FOG LINE TESTED (306, 324, 348, 327, 330). CALB. PROBLEMS.
MAR 23 – THEST TESTS WERE RUN USING NEW CALIBRATION NUMBER 520.
APR 18 – IT APPEARS THAT THERE ARE FEWER VISIBEADS THAN TEST SITE NO.3.

WATER BASE STRIPING PAINT – EVALUATION – CASCADE FOOTHILLS

SITE INFORMATION

SITE	5
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	OPEN A/C
TRAFFIC	5–15K
BEGIN MP	18.0 W.B.
DATE APPLIED	9/23/93
BEAD TYPE	BOTH
PAVEMENT TEMP	102
AIR TEMP	78
WIND	8
REL HUMIDITY	35%
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

9/24/93	11/2/93	12/22/93	2/12/94	3/11/94	3/25/94	4/22/94	4/22/94	6\9\94	6\9\94
VISIBEADS	REGULAR			VISIBEADS	RECALIB	WITH	AGAINST	WITH	AGAINST
379	189	234	146	316	252	188	185	177	180
348	248	243	210	323	231	152	160	224	193
316	201	273	188	369	250	236	197	240	185
366	191	281	168	330	177	173	179	177	138
404	213	213	137	287	176	214	131	179	146
	178	182	165	304	182	186	143	193	112
	150	203	145	286	226	188	144	165	151
	169	298	175	306	214	164	220	144	190
	200	222	160	289	206	174	150	213	198
	156	231	146	273	170	168	128	222	196
	156	199	286	344	216	178	165	188	184
	144	155	215	264	253	174	150	169	155
	156	225	182	284	237	173	206	167	138
	171	299	135	298	166	174	204	155	116
	190	239	124	299	162	217	256	136	192
	168	197	140	295	201	185	207	161	135
	173	198	124	288	202	240	244	145	126
	209	219	140	290	153	164	118	188	144
	174	177	163	287	161	183	163	168	163
	139	165	169	302	149	222	178	190	159
MEAN	363	179	223	166	invalid	199	188	176	180	160
STD DEV	29.6	26.2	40.2	37.1		33.7	24.2	37.3	27.3	27.3
STD DEV	8.2	14.6	18.0	22.4		16.9	12.9	21.2	15.2	17.1

PAINTING LOG DATA

SEPTEMBER 24, 1993
WHITE – TANK NO. N12
3 BAGS VISIBEADS
27 MILES – SHOULDER LINE
AND CENTER LINE

OCTOBER 6, 1994
WHITE – RETRACE
42 MILES
550 GALLONS
4500 POUNDS REGULAR
BEADS

NOTES:

REGULAR BEADS OVER VISIBEADS
NOV 2 – PARTLY SUNNY,
DEC 22 – FOGGY, LINE DRY, DID NOT USE SUN SHIELD. NO SANDING TO DATE.
FEB 12 – BLACK TIRE MARK DOWN MOST OF TEST LENGTH. MOISTURE NEAR LINE. VISIBEADS STARTING TO SHOW. NO FLAKING.
MAR 11 – BLACK MARK GONE. VISIBEADS SHOWING, LINE DRY AND CLEAN, SUNNY. CALIBRATION AND "0" ING PROBLEMS.
MAR 25 – VISIBEADS ARE EVIDENT THIS TEST RUN WITH NEW CALIBRATION VALUE.
APR 22 – VISIBEADS CLEARLY EVIDENT

WATER BASE STRIPING PAINT – EVALUATION – CASCADE FOOTHILLS

SITE INFORMATION

SITE	6
HIGHWAY	162
LINE TESTED	FOG LINE
PAVEMENT TYPE	OPEN A/C
TRAFFIC	5 – 15K
BEGIN MP	17.5 W.B.
DATE APPLIED	9/24/93
BEAD TYPE	BOTH
PAVEMENT TEMP	102
AIR TEMP	78
WIND	8
REL HUMIDITY	35%
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

9/24/93	11/2/93	12/22/93	2/12/94	3/11/94	3/25/94	4/22/94	4/22/94	6/9/94	6/9/94
VISIBEADS	REGULAR			VISIBEADS	RECALIB	WITH	AGAINST	WITH	AGAINST
323	171	221	148	302	180	149	135	155	137
236	199	223	153	308	164	181	154	160	207
262	203	221	173	312	205	178	157	181	151
313	201	182	152	277	215	196	155	206	177
388	204	206	125	340	188	221	173	195	134
	220	210	135	296	208	199	159	167	123
	186	194	166	260	193	180	141	176	132
	184	164	162	260	186	163	175	188	137
	176	164	155	280	198	176	177	164	149
	156	184	121	274	182	165	182	160	184
	179	192	144	278	230	155	135	167	135
	166	195	143	297	167	154	138	155	151
	174	187	136	299	169	136	132	172	129
		185	115	282	142	166	148	165	141
		166	112	275	146	183	145	156	156
		193	105	276	177	175	126	156	139
		195	110	302	167	186	153	163	123
		178	154	294	171	170	130	158	116
		196	175	308	170	197	122	169	108
		202	136	292	172	170	140	177	130
MEAN	304	186	193	141	invalid	182	175	149	170	143
STD DEV	52.7	17.5	17.3	20.6		21.5	19.1	17.2	13.7	23.2
COEF VAR	17.3	9.4	9.0	14.6		11.9	10.9	11.6	8.1	16.2

PAINTING LOG DATA –

SEPTEMBER 24, 1993
WHITE – TANK NO. N12
3 BAGS VISIBEDS
27 MILES – SHOULDER LINE
AND CENTER LINE

OCTOBER 6, 1993
WHITE – RETRACE
42 MILES
550 GALLONS
4500 POUNDS REGULAR
BEADS

NOTES:

REGULAR BEADS OVER VISIBEADS OVER RELATIVELY NEW LINE (~ 1 MONTH)
NOV 2 – LINE DRY AND CLEAN
DEC 22 – PAVEMENT AND LINE DRY – HEAVY FOG ALL DAY
DID NOT USE SUN SHIELD – NO SANDING TO DATE
FEB 12 – AVOIDED TESTING MOIST AREA AT START OF SITE.
TESTED YELLOW INSIDE FOG LINE ACROSS FROM TEST (140, 145, 140).
MAR 11 – VISIBEADS ARE SHOWING, PHOTOS, SUNNY, LINE DRY.
CALIBRATION AND ZERO – ING PROBLEMS. DATA IS INVALID
MAR 25 – VISIBEADS ARE SHOWING, USING NEW CALIBRATION
APR 22 – VISIBEADS ARE SHOWING.

WATER BASE STRIPING PAINT – EVALUATION – COASTAL PLANE

SITE INFORMATION

SITE	7
HIGHWAY	101
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	>15K
BEGIN MP	116 S.B.
DATE APPLIED	10/8/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	39
AIR TEMP	55
WIND	6
REL HUMIDITY	82%
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

10/26/93 S.B.	11/18/93 S.B.	12/21/93 S.B.	2/10/94 S.B.	12/21/93 S.B	12/21/93 N.B.
86	101	10	8	20	51
98	81	20	5	3	67
109	113	15	2	0	138
68	80	22	0	–4	109
119	108	46	0	–4	134
144	149	52	–10	–4	143
154	151	44	–7	–3	75
183	157	62	–6	0	72
201	182	76	0	2	41
179	156	71	2	10	53
186	176	66	5	11	98
134	130	72		34	132
162	153	64		29	
158	142	71		51	
155	136	71		22	
169	163	65		15	
197	181	63		17	
149	145	66		22	
164	157	59		15	
166	124	57		17	

MEAN	149	139	54	0	13	89				
STD DEV	35.7	29.3	20.2		14.3	35.5				
COEF VAR	24.0	21.1	37.7		113.0	39.8				

PAINTING LOG DATA –

OCTOBER 8, 1993
WHITE – TANK NO. N/A
3 BAGS REGULAR BEADS
58 MILES – SHOLDER LINE

NOTES:

OCT 8 – THE LINE WAS PLACED UNDER "NOT RECOMMENDED" CONDITIONS
THE PAVEMENT TEMPERATURE WAS 39 DEGREES, 11 DEGREES BELOW
THE RECOMMENDED MINIMUM.
OCT 26 – LINE LOOKS POOR, FADDED WHITE, SPOTS MISSING.
NOV 18 – BEADS ARE GONE. LINE DRY AT 3:00 P.M.
DEC 21 – LINE LOOKS POOR. BUT LINE IS STILL VISIBLE. BATTRY LOW 11.9.
FEB 10 – ITS ESTIMATED 75% OF THE LINE IS GONE, LINE HAS NARROWED TO 2 IN.
THE LINE BARELY PROVIDES A VISIBLE DAY GUIDE TO THE EYE.
WHITE LINE ACROSS THE WAY HAD READINGS OF (113, 100, 83).
MAR 29 – LINE NOT RESTRIPED, VERY FAINT. NORTH READINGS ARE MOSTLY SOLVENT.

WATER BASE STRIPING PAINT – EVALUATION – VALLEY FLOOR

SITE INFORMATION

SITE	8
HIGHWAY	39
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	5 – 15K
BEGIN MP	21.1 W.B.
DATE APPLIED	9/16/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	NA
AIR TEMP	NA
WIND	NA
REL HUMIDITY	NA
PRECIPATION	NA
CLOUD COVER	NA

NA – NOT AVAILABLE

MIROLUX DATA

10/26/93	11/18/93	12/21/93	2/12/94	3/4/94	3/29/94	3/29/94	4/22/94	4/22/94
			DIRT	FILM	WITH	AGAINS	WITH	AGAINST
231	248	184	60	188	240	268	161	120
239	213	219	64	142	218	252	188	142
249	285	257	98	214	246	274	180	153
273	278	259	114	199	242	263	174	181
266	279	253	83	220	236	178	199	180
292	270	298	71	220	226	276	180	149
280	271	292	90	219	259	290	222	136
265	285	296	109	254	134	247	196	138
284	265	279	107	310	261	241	133	168
298	265	300	93	232	263	273	237	123
293	252	285	125	241	278	150	215	198
304	262	268	83	264	196	223	222	198
290	270	250	76	235	320	261	251	230
299	259	212	132	280	306	250	230	183
294	211	262	138	260	249	199	218	179
292	275	230	156	205	328	173	213	155
244	289	246	178	197	292	120	193	195
279	284	179	180	167	323	209	219	184
296	259	220	155	213	325	209	210	227
300	256	229	153	211	271	193	227	189
MEAN	278	264	251	113	224	261	227	203	171
STD DEV	21.7	20.6	35.3	36.3	37.6	47.2	45.8	27.6	30.5
COEF VAR	7.8	7.8	14.1	32.1	16.8	18.1	20.1	13.6	17.8

PAINTING LOG DATA –

SEPTEMBER 16, 1993
WHITE – TANK NO. 428 & 456
2 BAGS REGULAR BEADS
SHOULDER LINE

NOTES:

OCT 26 – FIRST TEST STARTS BY TRAIN, LINE LOOKED DULL BUT TESTED GOOD.
NOV 18 – LINE DRY, RAINED IN THE MORNING, CLEARING AND COOL,
LINE HAS DIRT FILM FROM NEARBY MILL, RESTURAUNT, ETC.
DEC 21 – CLEAR, SUNNY,NO SANDING TO DATE
FEB 12 – THIS IS A COMMERCIAL ZONE WITH AND INTERSECTION NEARBY.
DURING THIS TESTING THE LINE WAS UNDER A HEAVY FILM OF DIRT.
THIS LINE SHOULD BE RETESTED AFTER A WASHING.
THERE ARE SIGNS OF RECENT SANDING.
MAR 4 – RECENT RAIN HAS CLEANED LINE SOME, BUT FILM STILL PRESENT.
READINGS WERE HIGHER THAN ANTISAPATED WITH THE FILM.
READINGS AT END OF SITE WHERE LINE WAS CLEANER WERE SAME VALUE
MAR 29 – LATEX IS WORN AT SPOTS, SOLVENT LINE IS SHOWING THROUGH IN SPOTS

WATER BASE STRIPING PAINT – EVALUATION – VALLEY FLOOR

SITE INFORMATION

SITE	9
HIGHWAY	30
LINE TESTED	FOG LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	5–15K
BEGIN MP	4.6 W.B.
DATE APPLIED	9/30/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	NA
AIR TEMP	NA
WIND	NA
REL HUMIDITY	NA
PRECIPATION	NA
CLOUD COVER	NA

MIROLUX DATA

10/26/93	11/21/93	2/12/94	3/8/94	3/25/94	4/18/94	4/18/94			
					WITH	AGAINST			
270	239	206	278	255	222	134			
267	276	230	278	266	226	164			
285	275	160	248	243	232	131			
226	283	212	279	181	185	115			
234	255	213	218	191	243	142			
187	235	188	180	205	193	154			
229	215	205	164	214	210	147			
216	234	136	90	224	162	142			
204	144	152	149	210	152	135			
213	155	125	115	159	173	118			
235	170	101	121	172	196	119			
260	171	106	196	169	144	112			
247	168	216	217	90	141	126			
268	180	199	273	115	115	112			
229	143	208	220	94	124	104			
305	187	206	245	69	68	65			
284	200	187	217	97	76	80			
216	208	220	199	160	73	74			
234	210	277	211	177	88	62			
277	222	170	186	223	72	45			

MEAN	244	209	186	204	176	155	114			
STD DEV	30.5	42.7	43.3	54.4	56.2	57.2	32.3			
COEF VAR	12.5	20.5	23.3	26.6	32.0	37.0	28.3			

PAINTING LOG DATA –

SEPTEMBER 30, 1993
WHITE – TANK NO.
4 BAGS REGULAR BEADS
SHOULDER LINE AND
CENTER LINE

NOTES:

OCT 26 – THIS IS THE FIRST SET OF READINGS. NO APPLICATION DATA WAS TAKEN.
NOV 21 – CLEAR DRY SUNNY (BATTERY MAY HAVE BEEN LOW) NO SANDING.
FEB 12 – AREA FOG, SANDING MATERIAL PRESENT ALONG SHOLDER. LOCAL FINE–
DIRT TRAPPED IN PVMT. CREVICES, LINE STARTING TO WEAR THIN.
MAR 8 – STARTING TO WEAR AWAY AT TESTS (90, 149, 115, 121).
CALIBRATION WAS DRIFTING RECALIBRATION O.K. LINE CLEAN.
MAR 25 – LINE DRY AND CLEAN
APR 18 – PAVEMENT – TWO DIFFERENT TYPES OF MIX???

WATER BASE STRIPING PAINT – EVALUATION – VALLEY FLOOR

SITE INFORMATION

SITE	10
HIGHWAY	30
LINE TESTED	SKIP LINE
PAVEMENT TYPE	DENSE A/C
TRAFFIC	>15000
BEGIN MP	19.00 W.B.
DATE APPLIED	9/27/93
BEAD TYPE	REGULAR
PAVEMENT TEMP	NA
AIR TEMP	NA
WIND	NA
REL HUMIDITY	NA
PRECIPATION	NONE
CLOUD COVER	NONE

MIROLUX DATA

9/29/93		1/21/94		3/4/94					
292	253	118	130	172	121				
258	246	98	142	82	200				
252	244	115	161	125	223				
335	292	148	139	200	131				
279	332	148	147	159	180				
270	304	102	206	104	198				
303	283	160	171	231	141				
313	251	144	149	223	172				
277	315	146	174	147	177				
262	288	192	152	194	141				
254	333	179	168	241	162				
261	248	157	180	101	177				
250	265	155	166	224	150				
235		195		162					
274		209		187					
284		129		192					
265		135		224					

MEAN		277		154		171				
STD DEV		27.9		27.2		40.8				
COEF VAR		10.1		17.7		23.8				

PAINTING LOG DATA:

SEPTEMBER 27, 1994
WHITE – SKIP LINE
1 BAG REGULAR BEADS
27 MILES SKIP LINE
250 GALLONS PAINT

NOTES:

THREE READINGS WERE TAKEN FROM EACH SKIP
ALL STRIPES WERE APPLIED OVER AC CRACK SEALENT

9/23/93 – LINE DRY, WEATHER CLEAR, HOT SUNNY.
1/21/94 – LINE DRY, WEATHER OVERCAST WITH PATCHY FOG.
THE SKIP LINE WAS PLACED OVER CRACKED PAVEMENT THAT HAD BEEN SEALED.
DIRT TENDS TO COLLECT. THE LINE IS STARTING TO SHOW WEAR.
3/04/94 – LINE CLEAN AND DRY FROM YESTERDAYS RAIN. MOSTLY SUNNY.
EQUIPMENT DRIFTING DURING CALIBRATION.
SKIP LINE IS REPRESENTATIVE OF REST OF LINE IN THE AREA.
LINE INADVERTENLY RETRACED WITH SOLVENTBORNE PAINT

WATER BASE STRIPING PAINT – EVALUATION – COAST RANGE

SITE INFORMATION

SITE	11
HIGHWAY	18
LINE TESTED	FOG LINE
PAVEMENT TYPE	OPEN GRADE A/C
TRAFFIC	5K – 15K
BEGIN MP	6.9 WB
DATE APPLIED	
BEAD TYPE	REGULAR
PAVEMENT TEMP	
AIR TEMP	
WIND	
REL HUMIDITY	
PRECIPATION	
CLOUD COVER	

MIROLUX DATA

10/26/93	12/27/93	2/10/94	3/4/94	3/29/94	3/29/94	4/22/94	4/22/94		
LATEX	LATEX	SOLVENT	SOLVENT	WITH	AGAINST	WITH	AGAINST		
364	183	295	280	211	163	176	131		
316	141	280	272	202	152	195	133		
349	176	304	262	206	168	193	128		
344	177	290	268	201	179	194	161		
335	194	321	235	186	160	229	126		
314	209	290	207	181	165	186	142		
350	218	265	228	187	156	196	158		
323	221	320	218	170	172	195	161		
319	214	319	237	163	148	209	142		
295	223	285	269	165	146	207	143		
325	204	269	268	169	184	197	145		
315	202	298	254	195	158	219	149		
311	209	326	260	210	129	214	163		
333	210	295	288	190	138	214	139		
370	191	337	307	249	121	204	160		
304	199	295	237	238	114	177	174		
281	232	348	272	245	153	230	176		
302	217	307	267	191	158	172	116		
311	261	340	312	192	163	180	157		
316	265	342	282	217	132	180	127		
MEAN	324	207	306	261	198	153	193	147		
STD DEV	22.2	27.3	23.7	26.9	24.3	18.1	16.8	16.4		
COEF VAR	6.9	13.2	7.8	10.3	12.3	11.8	8.5	11.2		

NOTE:

OCT 26 – LINE IN NEW CONDITION.
DEC 21 – RECENT GRAY SANDING MATERIAL WELL TO SIDE OF LINE. LINE CLEAN. LINE LOOKS GOOD WITH A THICK PAINT COATING AND NO GAPS.
FEB 10 – THIS LINE HAS RECENTLY BEEN RESTRIPED WITH SOLVENT BASED PAINT.

Appendix D

LABORATORY TEST RESULTS

OREGON DEPARTMENT OF TRANSPORTATION

LABORATORY RECORD

Latex Traffic Paint

LABORATORY NO. 9404731			
PROJECT: 1993-94 Latex Stripping Paint Test		DATA SHEET NO.: NONE	
HIGHWAY: 22	COUNTY: Marion/Polk	EXP.ACCT.SUBJOB: C09545804-071-262	
CONTRACTOR	FA PROJECT NO.: STATE	QUANTITY REPRESENTED	BID ITEM NO.
PROJECT MANAGER: Jim Nash	AGY.-ORG.UNIT: 73-7820	DATE RECIEVED: 11-30-93	DATE REPORTED: 6-15-94
SUBMITTED BY: Jim Nash	AGY.-ORG.UNIT: 73-7820	TEST NO.: 580X / VAR.: V	LAB CHARGE: 590
SOURCE OF MATERIAL: Morton International	TO BE USED: road delineation		
SAMPLED AT: plant	SAMPLED BY: manufacturer	DATE SAMPLED	

TEST	RESULT	SPECIFICATION
Color: white		
Viscosity @ 25 C, KU	97	105 max.
Fineness of grind, Hegman units	4	3 min
Dry to pick up @ 12 mils, minutes	<4	4 min. max.
Static heat stability	8 KU	10 KU increase max
Bleeding	no bleeding	No bleeding at #8
Directional reflectance, percent	93	88 min
Contrast ratio, percent	99	98 min
Water resistance	passed	8 cycles min.
Falling Sad Taber Abraser		0.5 max
Stability Test	7 KU	10 KU increase max.
pH	10.2	8 min.
Freeze Thaw	passed	5 cycles, min
Pendulum Hardnes		90 min.

DISTRIBUTION:

x Jim Nash - Operations
x Dick Parker - Research
x Mike Dunning - Operations
x Files

Wayne R. Blair
ENGINEER OF MATERIALS

OREGON DEPARTMENT OF TRANSPORTATION

LABORATORY RECORD

Latex Traffic Paint

		LABORATORY NO. 9404732	
PROJECT: 1993-94 Latex Stripping Paint Test		DATA SHEET NO.: NONE	
HIGHWAY: 22	COUNTY: Marion/Polk	EXP.ACCT.SUBJOB: C09545804-071-262	
CONTRACTOR	FA PROJECT NO.: STATE	QUANTITY REPRESENTED	BID ITEM NO.
PROJECT MANAGER: Jim Nash	AGY.-ORG.UNIT: 73-7820	DATE RECIEVED: 11-30-93	DATE REPORTED: 6-15-94
SUBMITTED BY: Jim Nash	AGY.-ORG.UNIT: 73-7820	TEST NO.: 580X / VAR.: V	LAB CHARGE: 590
SOURCE OF MATERIAL: Morton International	TO BE USED: road delineation		
SAMPLED AT: plant	SAMPLED BY: manufacturer	DATE SAMPLED	

TEST	RESULT	SPECIFICATION
Color: yellow		
Viscosity @ 25 C, KU	102	105 max.
Fineness of grind, Hegman units	4	3 min
Dry to pick up @ 12 mils, minutes	<4	4 min. max.
Static heat stability	7 KU	10 KU increase max
Bleeding	no bleeding	No bleeding at #8
Directional reflectance, percent	61	52 min
Contrast ratio, percent	98	96 min
Water resistance	passed	8 cycles min.
Falling Sad Taber Abraser		0.5 max
Stability Test	8 KU	10 KU increase max.
pH	9.1	8 min.
Freeze Thaw	passed	5 cycles, min
Pendulum Hardnes		90 min.

RECEIVED
RESEARCH UNIT
JUN 16 1994

RUE ___ OSC ___

TTC ___ TSC ___

FYI TAA FILE Return To: _____

DISTRIBUTION:

x Jim Nash - Operations
x ~~Dick Parker - Research~~
x Mike Dunning - Operations
x Files

Wayne Kobie
ENGINEER OF MATERIALS

Appendix E

SPECIFICATIONS FOR WATERBORNE PAVEMENT MARKING PAINTS

STATE OF OREGON
DEPARTMENT OF TRANSPORTATION
SALEM, OREGON
REVISED SEPTEMBER 1994
STANDARD SPECIFICATION FOR
WATER-BORNE TRAFFIC PAINT

1. SCOPE

This specification describes ready-mixed one-component water-borne traffic line bead binder paint to be applied to either asphaltic or Portland cement concrete pavements.

2. APPLICABLE SPECIFICATIONS

The following specifications, test methods, and standards in effect on the opening date of the Invitation for Bid form a part of this specification where referenced.

ASTM D562, ASTM D1210, ASTM D711, ASTM D1640, ASTM D2486, ASTM D2805, ASTM G53, ASTM D821, ASTM D2243, ASTM E70, ASTM D93, ASTM D3960, ASTM D969, ASTM D868, ASTM D4366, ASTM E97, ASTM D1729, ASTM D3723, ASTM D2621, ASTM D2697, ASTM D2486 and FTMS 4053.

3. GENERAL REQUIREMENTS

3.1 Silence of Specification. The apparent silence of this specification and supplemental specifications as to any detail, or the apparent omission from it of a detailed description concerning any point, shall be regarded as meaning that only the best commercial practice is to prevail and the only materials and workmanship of first quality are to be used.

3.2 Cause for Rejection. Any exception to this specification may be cause for rejection.

3.3 Approved Equal. As applied to these specifications means that the approval of the Operations Support Section Manager, or his designee, is required. This approval will not be given prior to the bid opening. Cost differences, alternates, and options should be defined on the bid submitted. This specification is intended to specify paint that will meet service requirements for highway construction and maintenance.

3.4 Composition. The composition of the paint shall be determined by the manufacturer. It will be the manufacturer's responsibility to produce a pigmented 100% water-borne paint containing all the necessary co-solvents, dispersant, wetting agents, preservatives and all other additives, so that the paint shall retain its viscosity, stability, and all of the properties as specified herein.

3.5 Certification. The manufacturer will submit within 10 days of bid acceptance, a statement certifying that they meet all of the specifications listed herein. The State will test the products when and where it deems appropriate. Failure to meet specifications at any time constitutes reason for rejection of the bid.

4. CHARACTERISTICS

4.1 Test Requirements

Viscosity at 77°F	100 KU max.	ASTM D562
Fineness of Grind, Hegman	3 min.	ASTM D1210
Laboratory dry to no pick-up time @ 12 mils wet film thickness (no beads) @ 50% humidity	10 minutes max.	ASTM D711
No-track time actual 77°F and 85% max relative humidity @ 15 mils wet film thickness	90 seconds max	
Flash Point, °F min	140 min.	ASTM D93
Pigment content, % by weight	62% max.	ASTM D3723
Nonvolatile vehicle, % by weight	41% min.	FTMS 4053
Total solids by volume	60% min.	ASTM D2697
Bleeding	#8 - no bleeding	ASTM D969/ASTM D868

Directional Reflectance		
White	88% min.	ASTM D2805
Non-lead Yellow	52% min.	ASTM D2805
Contrast Ratio		
White	98% min.	ASTM D2805
Non-lead Yellow	96% min.	ASTM D2805
Freeze Thaw	5 cycles	ASTM D2243
Volatile Organic Compound (VOC)	less than 150 g per liter	ASTM D3960
pH	8 min.	ASTM E70

The binder shall be 100% acrylic when tested in accordance with ASTM D2621.

4.2 Color. Paint draw-downs shall be prepared in accordance with ASTM E97. The reflectance of the white paint shall be evaluated in accordance with ASTM E97, and the color of the yellow paint shall be evaluated in accordance with ASTM D1729.

4.3 Scrub Resistance. The paint shall pass a minimum of 300 cycles when tested in accordance with ASTM D2486.

4.4 No-Tracking Time. The paint shall dry to a no-tracking condition in no more than 90 seconds when applied at 15 mils wet film thickness at dry pavement temperature of 50°-100°F and maximum 80% relative humidity, with 6 pounds of type B glass beads per gallon of paint, or 12 pounds of type C glass beads per gallon of paint. "No-Tracking" shall be the time required for the line to withstand the running of a standard automobile over the line at a speed of approximately 40 mph simulating a passing procedure, without tracking of the reflectorized line when viewed from a distance of 50 ft.

4.5 Static Heat Stability. Put 450 mL of paint in a 473 mL (1 pint) lined container, close the container, seal it with tape, and put in an oven maintained at 135°F $\pm$ 1°F for 7 days. Equilibrate the paint at standard conditions and mix thoroughly with gentle stirring. Examine paint for livering and hard settling and determine viscosity. The paint shall show no increase in viscosity greater than 10 KU over the viscosity at 77°F nor any coagulation, lumps, or coarse particles.

4.6 Road Service Test. One or more transverse lines of a length, width, and film thickness as designated by the State will be applied at ambient temperature on highway surfaces at locations to be selected by the State for the test. The glass beads will be furnished by the State. Only those samples meeting all the requirements in this section will be used in the Road Service Test. The State shall be the sole judge of methods, rates of application and test evaluation.

5. Samples and Testing Fees

5.1 Pre-bid Samples. All prospective suppliers will be required to submit four (4) one-quart and four (4) one-pint cans of paint to the State for each material offered. Removable labels will identify the type and color. After laboratory and road tests have been completed, a final evaluation of the paint samples will be made. Manufacturers who have submitted acceptable samples will then be requested to submit bid prices. Bid price should not be submitted with samples.

5.2 Testing Fees for Pre-bid Samples. There will be a testing charge assessed to all bidders for expenses incurred during laboratory and field testing of the paint samples. Bidders may submit more than one formulation for testing provided separate bid documents and testing fees are submitted. Checks should be made payable to the Department of General Services.

5.3 Leftover Paint Samples. After contract award, unsuccessful bidders will be notified they have 45 days to pick up leftover paint samples from the Highway Materials Laboratory. Samples not picked up will be returned COD to the bidder by the State.

5.4 Delivery Samples. The successful bidder will be required to supply to the Oregon State Highway Materials Laboratory, two one-pint can samples from each batch to be delivered to the State, prior to delivery. Acceptance and authorization for delivery of the batch will be contingent on the sample having passed successfully the laboratory tests. These tests will periodically will include instrumental analysis to ensure product uniformity throughout the contract. All samples shall be taken by an authorized inspector or agent of the State. In lieu of an agent or inspector taking samples at the plant, samples of each batch may, at the request of the State, be submitted by the manufacturer, together with certified affidavits that the sample is representative of the manufactured batch. The State reserves the right to conduct random checks and tests of shipments of traffic line paint. Leftover of delivery samples will be returned to the vendor after testing has been completed.

6. INITIAL ORDER

The low bidder agrees to sell to the State, within ten (10) days following bid opening, 250 gallons as an initial paint order at the quoted price for application testing with State-owned airless equipment. Bid award will be contingent upon compatibility of this initial order with the State-owned equipment, and compliance with the dry to no pick-up requirements detailed in Section 4. The Oregon Department of Transportation Materials Laboratory (or other laboratory as designated by the Oregon Department of Transportation) will analyze the initial order sample (including infrared spectroscopy and chromatography).

The successful bidder shall furnish a certificate which certifies that the paint being delivered is of the same formulation as the samples submitted.

7. 250-GALLON BULK CONTAINER

Vendor-furnished, at no cost to the State, returnable stainless steel containers, equal to those utilized by the State of Washington, Department of Transportation, in 1986, and meeting the following requirements:

Specifications for the containers shall be submitted to the Oregon Department of Transportation, Support Services Branch, for approval prior to filling.

The apparent low bidder may also be required to furnish and deliver, at no cost to the State, one representative 250-gallon container, for inspection and approval, prior to final bid award.

The containers shall be new or reconditioned, pressure-tested stainless steel containers, and shall conform to Federal DOT Specification 57 from CFR49, Par. 178.251, and all other appropriate rules and regulations, in the combination requested by the State of Oregon at the time of ordering.

All containers shall:

(a) Be of approximately 250 U.S. gallon capacity. One U.S. gallon is defined as 3.785 liters.

(b) Have a 46" nominal outside tank diameter.

(c) Have forklift skids (four-way) with outside dimensions of 46" $\pm$ 2" (square).

(d) Have two-way lifting lugs.

(e) Have covers and valves that can easily be resealed after partial use of contents.

(f) Have either a hinged or a bolted hatch that is at least 18" in diameter. Containers with bolt-down hatch shall have an additional screw top opening of six-inch minimum diameter.

(g) Have a two-inch ball valve fitted with a male quick-disconnect.

(h) Have a valve guard of sufficient size to protect the valve and disconnect with three inches of clearance on all sides of the valve.

(i) Have a security feature that shall protect the valve from being opened by accident or by vandals.

(j) Be equipped with stainless steel fittings, piping, etc. compatible with latex-based paint.

Bidders shall submit with their bid, a shop drawing of the 250-gallon containers they propose to use.

Each bulk container shall be labeled or stenciled, in black, on the drum head, and in a prominent location on the bulk container to show the following (abbreviations my be used):

(a) Specification/formula number

(b) Color

(c) Name of manufacturer

(d) Date of manufacturer, month and year

(e) Batch number

(f) Tare weight of empty container

The label or stencil shall be applied on a background color the same as the paint in the container.

All materials that contain solvents, cleaning agents, chemicals, or other hazardous materials shall be labeled in accordance with OAR 437, 22-015(2) with the name(s) of the hazardous ingredient(s), the hazards of the material(s) and the appropriate precautions.

All materials shall be accompanied by a MSDS corresponding the particular formulation of the material being delivered. A copy of the MSDS shall also be provided to the Highway Materials Laboratory at the beginning of the contract.

8. CONTAINER RETURNS

Submission of a bid in response to this Invitation shall constitute the vendor's guarantee to accept the return of all empty, undamaged 250-gallon containers at the point of delivery.

Delivery of paint shall not be contingent upon the return of empty tanks.

9. MEASUREMENT AND PAYMENT

The net weight of paint delivered will be determined by weighing each batch delivered and deducting the tare weight of the containers. The number of gallons to be paid for shall be determined by dividing the total net weight by the weight per gallon of the test sample corresponding to the batch(es) delivered. The weight per gallon for each batch will be determined by the Oregon Department of Transportation Materials Laboratory.

10. METHOD OF AWARD

Award shall be made to the lowest responsible and responsive bidder for the total of the items selected for award. The State reserves the right to withdraw any item from award consideration. Award shall be made to one bidder and one bidder only.