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Paint and Bead Durability Study

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16. Abstract

This study was undertaken to evaluate paint and bead durability in four areas: water emulsion paint performance, glass bead performance, application thickness of paint effectiveness, and cementitious pavement marking materials.

A series of airport pavement markings were placed at the William J. Hughes Technical Center and Atlantic City International Airport, Atlantic City, New Jersey, for evaluation. Results from the testing showed that HD-21A Rohm and Haas water emulsion paint had the superior performance since it held the beads in place better; Type III (1.9 Index of Refraction (IOR)) airport beads had the best retro-reflectivity, initially and over time. All four new beads had higher retro-reflectivity than the 1.5 IOR highway bead but not as high as the 1.9 IOR Airport bead. The four new beads that were used in this study were 1.5 IOR Visibead A (L-511), 1.5 IOR Visibead B (L-511 Millennium), 1.5 IOR Megalux A (Airport and Highway High Quality and High Performance Drop-On), and 1.5 IOR Megalux B (Airport "Beacon" High Quality and High Performance).

The Lumimark cementitious pavement marking material was not evaluated because the concrete mixture was out of date, causing the concrete to flake. Even though it was not evaluated, immediately after installing this product, the beads sank into the cementitious material, causing very low retro-reflective readings. Therefore, the process still needs some refinement.

The PermaStripe cementitious pavement marking material, which is being evaluated by the U.S. Air Force and U.S. Army Corps of Engineers at Tyndall Air Force Base, is still under investigation and, therefore, is not ready for commercial application. At present, the PermaStripe product is hand applied with a squeegee. A paint hand-sprayer had been modified but is in the prototype stage. PermaStripe also needs to address the issue of very low retro-reflectivity readings.

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EXECUTIVE SUMMARY

The Federal Aviation Administration Office of Aviation Research, Airport Technology Research and Development Branch, AAR-410, has evaluated paint and bead durability in four areas: water emulsion paint performance, glass bead performance, application thickness of paint effectiveness, and cementitious pavement marking materials. A series of airport pavement markings were placed at the William J. Hughes Technical Center and Atlantic City International Airport, Atlantic City, New Jersey, for evaluation. Results from the testing showed that HD-21A Rohm and Haas water emulsion paint had the superior performance since it held the beads in place better.

Type III (1.9 Index of Refraction (IOR)) airport beads had the best retro-reflectivity, initially and over time. All four new beads had higher retro-reflectivity than the 1.5 IOR highway bead but not as high as the 1.9 IOR Airport bead. The four beads that were used in this study were 1.5 IOR Visibead A (L-511), 1.5 IOR Visibead B (L-511 Millennium), 1.5 IOR Megalux A (Airport and Highway High Quality and High Performance Drop-On), and 1.5 IOR Megalux B (Airport "Beacon" High Quality and High Performance).

The Lumimark cementitious pavement marking material evaluation was discontinued because the concrete mixture's shelf life was out of date, causing the concrete to flake. Immediately after installing this product, the beads sank into the cementitious material, causing very low retro-reflective readings. Therefore, the process still needs some refinement.

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INTRODUCTION

The Airport Technology Research and Development (R&D) Branch, AAR-410, in response to a request from the Office of Engineering and Specification Division, AAS-200 (the division was reorganized from AAS-200 to AAS-100 as the Airport Engineering Division) undertook this project to examine paint and bead durability in four areas: water emulsion paint performance, glass bead performance, application thickness effectiveness of paint, and suitability of cementitious pavement marking materials.

Airport pavement markings are a critical component of ground visual aids for pilots, and it is especially important that they be well maintained. In order to accomplish this, airports expend considerable resources to maintain the effectiveness of the marking systems. Current practices in marking airport pavements have evolved over the years and are historically related to the application of roadway markings by highway departments.

The Federal Highway Administration has numerous documents concerning standard practices in highway pavement markings. While this has offered benefits in the transfer of technology and application techniques, airport pavements present some unique requirements for marking materials. Among these are adhesion, climate, abrasion, and resistance to jet fuel, as well as braking/friction characteristics. These additional criteria require special testing to ensure suitability.

BACKGROUND

BEADS.

Various types of glass beads that are used for airport markings are broken down by their index of refraction (IOR). The IOR is a scale index of the rate at which a material refracts light towards the source. The IOR correlates with the quality of the focal properties of the material used to refract the light. The characteristics that change the IOR are the size, density, and roundness of the beaded material.

Two types of beads are detailed in the Federal Specification TT-B-1325C, i.e., type I (1.5 IOR) and type III (1.9 IOR). Currently, type I beads are used for roadway markings as well as airport markings, and type III beads are used exclusively for airport markings. Four alternative types of beads were evaluated to provide better retro-reflectivity than type I beads. These four new beads are 1.5 IOR Visibead A (L-511), 1.5 IOR Visibead B (L-511 Millennium), 1.5 IOR Megalux A (Airport and Highway High Quality and High Performance Drop-On), and 1.5 IOR Megalux B (Airport "Beacon" High Quality and High Performance) propose to provide higher retro-reflectivity than type I beads at a lower cost. The existing type I (1.5 IOR) highway bead and type III (1.9 IOR) airport bead will also be tested as a comparison to the new beads. While using type III beads at airports provides maximum retro-reflectivity, the cost is higher.

PAINT.

In recent years, environmental restrictions on paints have increased significantly. Some states have limited the use of the original five Government Services Administration (GSA)-specified

paints. Only waterborne paint, which meets Federal Specification TT-P-1952D, has been relatively unaffected. The primary concern is air pollution, which is caused by the contaminants with the greatest impact on airport markings, and those with volatile organic compounds (VOCs). The South Coast Air Quality Management District (Los Angeles) has placed limits on the amount of volatile emissions that can be released per day. This has impacted the use of solvent-borne paints, and as a result, waterborne paints are now used. The use of waterborne traffic paint is now standard practice in most of Southern California. Other states have raised concerns about the disposal of solvent-borne paint shipping containers (55-gallon drums), which are classified as hazardous materials.

The Clean Air Act of 1970 established pollution limitations, including carbon monoxide, which is a contributor to the amount of VOCs in the ambient atmosphere. Because solvent type paints exceed the VOC requirements, more and more airports are using waterborne paints, which have a short usable life span in an airport environment. This creates a greater need for alternative materials. New and better waterborne paints, new types of beads, and new techniques for pavement markings were evaluated in this study.

RELATED DOCUMENTS.

Related documents dealing with this evaluation project are:

- FAA Advisory Circular AC 150/5370-10A, "Standards for Specifying Construction of Airports," February 17, 1989.
- FAA Advisory Circular AC 150/5320-12C, "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces," March 18, 1997.
- Specification TT-P-1952D, "Paint, Traffic and Airfield Marking, Water Emulsion Base," January 7, 1994.
- Specification TT-B-1325C, "Beads (Glass Spheres) Retroreflective," June 1, 1993.
- Statement of Work (SOW) between the United States Air Force Civil Engineering Services Center (AFCESA) and the U.S. Army Corps of Engineers concerning Polymer Composite Pavement Marking Materials, June 7, 2000.
- DOT/FAA/CT-94/120, "Evaluation of Retro-Reflective Beads in Airport Pavement Markings," December 1994.
- DOT/FAA/CT-94/119, "Evaluation of Alternative Pavement Marking Materials," January 1995.
- DOT/FAA/AR-TN96/74, "Follow-On Friction Testing of Retro-Reflective Glass Beads," July 1996.

- FAA Advisory Circular AC 150/5340-1H, "Standards for Airport Markings," December 1, 2000.

- ICAO Annex 14, Volume I, "Aerodrome Design and Operation," August 9, 2000.

- ASTM-E-2177-01, "Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Marking in a Standard Condition of Wetness," December 2001.

OBJECTIVE.

The objectives of this evaluation were to discover:

- Which water emulsion paint holds the beads the best.
- Which beads have the highest retro-reflectivity.
- If the four new 1.5 IOR beads are acceptable.
- Which application thickness the beads adhere to best.
- If a coupling agent improves bead retention.
- How visible the beads are when placed on black paint.
- If cementitous pavement marking material is a suitable material.

EVALUATION

METHOD.

The approach taken during the course of this project was to evaluate potential materials for operational and environmental suitability. The candidate materials that were selected met these requirements and were installed on an airport environment.

WATER EMULSION DISCOLORATION AND DURABILITY EVALUATION. Inspection and data collection visits to the airport sites reporting discoloration, due to either oil bleeding from the asphalt or to acid rain conditions, were conducted to document the existing conditions with photographs, graphs, and samples. Discoloration was determined by using a spectrophotometer and then graphing it on an International Commission on Illumination (CIE) standard illuminant D_{65} chromaticity chart. Chromaticity is the aspect of color that includes consideration of its dominant wavelength and purity. A CIE standard illuminant D_{65} chromaticity chart is found in International Civil Aviation Organization (ICAO) Annex 14, Volume I—Aerodrome Design and Operations, pages 131 and 132. These charts are duplicated in appendix A, figures A-1 and A-2, of this report.

Water emulsion paints, from three manufacturers, were evaluated by applying test markings at various high-traffic locations at the William J. Hughes Technical Center and Atlantic City International Airport. Identical sets of test markings were applied to old hot-mix asphalt (HMA), newer hot-mix asphalt, and Portland cement concrete (PCC) surfaces to determine the effect of each type of surface material on the paint's appearance and durability. Yellow, white, and black paint were tested. Q-panels (a 7- by 18-inch metal sheet to be used as a paint sample) were made

at the same time of application to compare wear and aging over time. The differences between the appearance of the Q-Panel and pavement markings are due to time. The Q-panels were made at the time of application, June 2001, and the pavement markings are shown in July 2002 (see figures 1, 2, and 3).

FIGURE 1. YELLOW PAINT WITH Q-PANELS

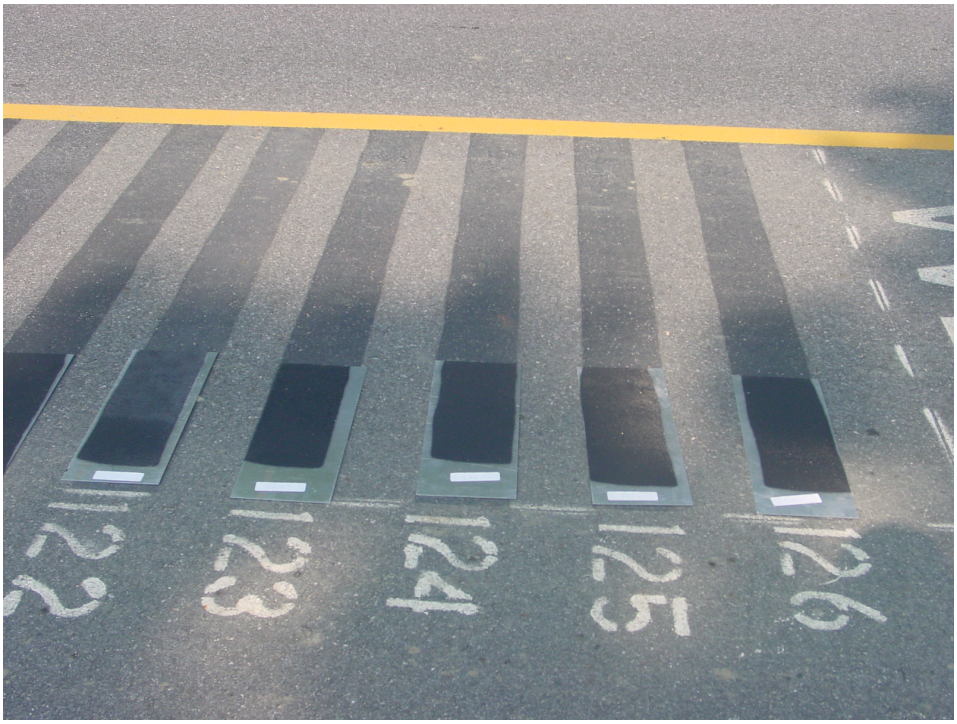


FIGURE 2. BLACK PAINT WITH Q-PANELS

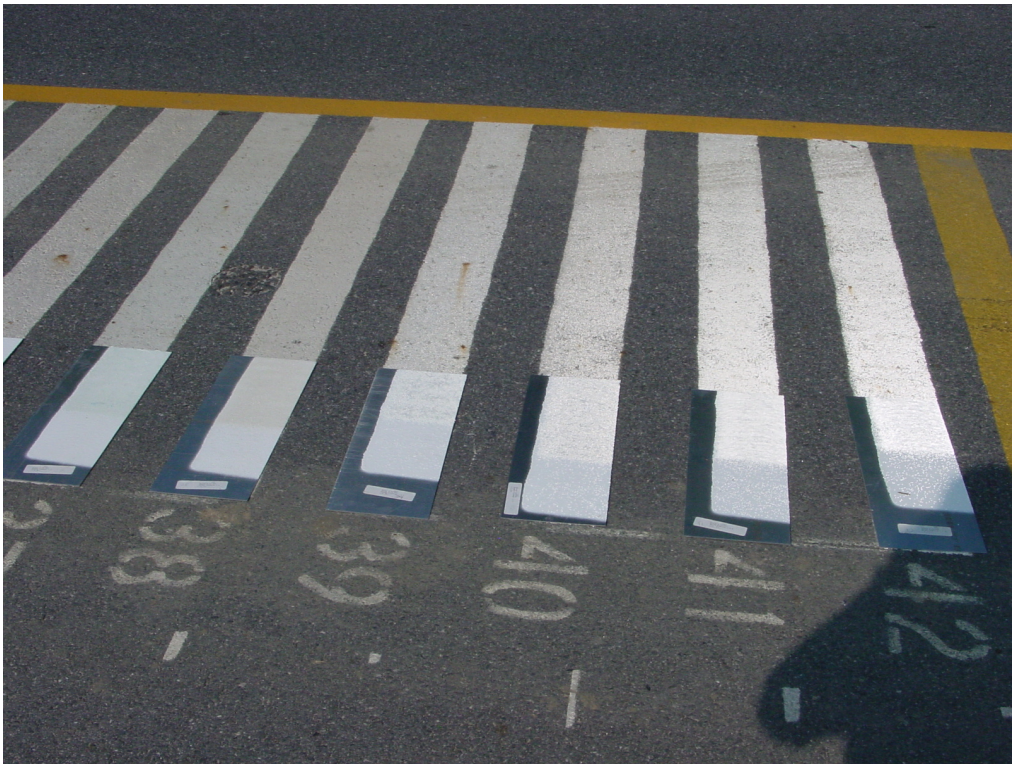


FIGURE 3. WHITE PAINT WITH Q-PANELS

Table 1 shows a matrix of the three brands of paint, six types of beads, and three colors (yellow, white, and black). Three sets of test markings were painted on the three pavement types. (See appendix A, figures A-15 through A-17, for Rohm and Haas's formulation for HD-21A resin, white paint, and yellow paint.) The matrix of 126 lines, (99 through 105 not used), consist of the three brands of paint with three colors applied at the standard application thickness of 0.33 mm (15-mil wet film thickness) and at the refresh or temporary thickness of 0.17 mm (7.5-mil wet film thickness). Since Rohm and Haas did not provide a black paint, white paint at a thickness of 0.44 mm (20-mil wet film thickness) was used to replace the lines that should have been black in the matrix.

The test stripes were located toward the center of the taxiway to expose each stripe to an equal amount of landing gear wear. The test stripes were 6 feet long by 6 inches wide and laid out with the following bead configuration or layout: nonbeaded (no beads), Highway 1.5 IOR (existing), Airport 1.9 IOR (existing), Visibead A 1.5 IOR (new), Visibead B 1.5 IOR (new), Megalux A 1.5 IOR (new), and Megalux B 1.5 IOR (new). (See appendix A, figures A-5 through A-8, for an explanation of each bead type).

TABLE 1. TEST LAYOUT FOR OLD HOT-MIX ASPHALT PAVEMENT, NEW HOT-MIX ASPHALT PAVEMENT, AND PORTLAND CEMENT CONCRETE PAVEMENT

Line No.	Sherwin-Williams	Line No.	Rohm and Haas	Line No.	TMT
1	Yellow Nonbeaded, 15 mil	22	Yellow Nonbeaded, 15 mil	43	Yellow Nonbeaded, 15 mil
2	Yellow Beaded Hwy 1.5 IOR, 15 mil	23	Yellow Beaded Hwy 1.5 IOR, 15 mil	44	Yellow Beaded Hwy 1.5 IOR, 15 mil
3	Yellow Beaded Airport 1.9 IOR, 15 mil	24	Yellow Beaded Airport 1.9 IOR, 15 mil	45	Yellow Beaded Airport 1.9 IOR, 15 mil
4	Yellow Beaded Visibead A 1.5 IOR, 15 mil	25	Yellow Beaded Visibead A 1.5 IOR, 15 mil	46	Yellow Beaded Visibead A 1.5 IOR, 15 mil
5	Yellow Beaded Visibead B 1.5 IOR, 15 mil	26	Yellow Beaded Visibead B 1.5 IOR, 15 mil	47	Yellow Beaded Visibead B 1.5 IOR, 15 mil
6	Yellow Beaded Megalux B 1.5 IOR, 15 mil	27	Yellow Beaded Megalux B 1.5 IOR, 15 mil	48	Yellow Beaded Megalux B 1.5 IOR, 15 mil
7	Yellow Beaded Megalux A 1.5 IOR, 15 mil	28	Yellow Beaded Megalux A 1.5 IOR, 15 mil	49	Yellow Beaded Megalux A 1.5 IOR, 15 mil
8	White Nonbeaded, 15 mil	29	White Nonbeaded, 15 mil	50	White Nonbeaded, 15 mil
9	White Beaded Hwy 1.5 IOR, 15 mil	30	White Beaded Hwy 1.5 IOR, 15 mil	51	White Beaded Hwy 1.5 IOR, 15 mil
10	White Beaded Airport 1.9 IOR, 15 mil	31	White Beaded Airport 1.9 IOR, 15 mil	52	White Beaded Airport 1.9 IOR, 15 mil
11	White Beaded Visibead A 1.5 IOR, 15 mil	32	White Beaded Visibead A 1.5 IOR, 15 mil	53	White Beaded Visibead A 1.5 IOR, 15 mil
12	White Beaded Visibead B 1.5 IOR, 15 mil	33	White Beaded Visibead B 1.5 IOR, 15 mil	54	White Beaded Visibead B 1.5 IOR, 15 mil
13	White Beaded Megalux B 1.5 IOR, 15 mil	34	White Beaded Megalux B 1.5 IOR, 15 mil	55	White Beaded Megalux B 1.5 IOR, 15 mil
14	White Beaded Megalux A 1.5 IOR, 15 mil	35	White Beaded Megalux A 1.5 IOR, 15 mil	56	White Beaded Megalux 1.5 A IOR, 15 mil
15	Black Nonbeaded, 15 mil	36	White Nonbeaded, 20 mil	57	Black Nonbeaded, 15 mil
16	Black Beaded Highway 1.5 IOR, 15 mil	37	White Beaded Highway 1.5 IOR, 20 mil	58	Black Beaded Highway 1.5 IOR, 15 mil
17	Black Beaded Airport 1.9 IOR, 15 mil	38	White Beaded Airport 1.9 IOR, 20 mil	59	Black Beaded Airport 1.9 IOR, 15 mil
18	Black Beaded Visibead A 1.5 IOR, 15 mil	39	White Beaded Visibead A 1.5 IOR, 20 mil	60	Black Beaded Visibead A 1.5 IOR, 15 mil
19	Black Beaded Visibead B 1.5 IOR, 15 mil	40	White Beaded Visibead B 1.5 IOR, 20 mil	61	Black Beaded Visibead B 1.5 IOR, 15 mil
20	Black Beaded Megalux B 1.5 IOR, 15 mil	41	White Beaded Megalux B 1.5 IOR, 20 mil	62	Black Beaded Megalux B 1.5 IOR, 15 mil
21	Black Beaded Megalux A 1.5 IOR, 15 mil	42	White Beaded Megalux A 1.5 IOR, 20 mil	63	Black Beaded Megalux A 1.5 IOR, 15 mil

TABLE 1. TEST LAYOUT FOR OLD HOT-MIX ASPHALT PAVEMENT, NEW HOT-MIX ASPHALT PAVEMENT, AND PORTLAND CEMENT CONCRETE PAVEMENT
(Continued)

Line No.	Sherwin-Williams	Line No.	Rohm and Haas	Line No.	TMT
64	Yellow Nonbeaded, 7.5 mil	85	Yellow Nonbeaded, 7.5 mil	106	Yellow Nonbeaded, 15 mil
65	Yellow Beaded Hwy 1.5 IOR, 7.5 mil	86	Yellow Beaded Hwy 1.5 IOR, 7.5 mil	107	Yellow Beaded Hwy 1.5 IOR, 7.5 mil
66	Yellow Beaded Airport 1.9 IOR, 7.5 mil	87	Yellow Beaded Airport 1.9 IOR, 7.5 mil	108	Yellow Beaded Airport 1.9 IOR, 7.5 mil
67	Yellow Beaded Visibead A 1.5 IOR, 7.5 mil	88	Yellow Beaded Visibead A 1.5 IOR, 7.5 mil	109	Yellow Beaded Visibead A 1.5 IOR, 7.5 mil
68	Yellow Beaded Visibead B 1.5 IOR, 7.5 mil	89	Yellow Beaded Visibead B 1.5 IOR, 7.5 mil	110	Yellow Beaded Visibead B 1.5 IOR, 7.5 mil
69	Yellow Beaded Megalux B 1.5 IOR, 7.5 mil	90	Yellow Beaded Megalux B 1.5 IOR, 7.5 mil	111	Yellow Beaded Megalux B 1.5 IOR, 7.5 mil
70	Yellow Beaded Megalux A 1.5 IOR, 7.5 mil	91	Yellow Beaded Megalux A 1.5 IOR, 7.5 mil	112	Yellow Beaded Megalux A 1.5 IOR, 7.5 mil
71	White Nonbeaded, 7.5 mil	92	White Nonbeaded, 7.5 mil	113	White Nonbeaded, 7.5 mil
72	White Beaded Hwy 1.5 IOR, 7.5 mil	93	White Beaded Hwy 1.5 IOR, 7.5 mil	114	White Beaded Hwy 1.5 IOR, 7.5 mil
73	White Beaded Airport 1.9 IOR, 7.5 mil	94	White Beaded Airport 1.9 IOR, 7.5 mil	115	White Beaded Airport 1.9 IOR, 7.5 mil
74	White Beaded Visibead A 1.5 IOR, 7.5 mil	95	White Beaded Visibead A 1.5 IOR, 7.5 mil	116	White Beaded Visibead A 1.5 IOR, 7.5 mil
75	White Beaded Visibead B 1.5 IOR, 7.5 mil	96	White Beaded Visibead B 1.5 IOR, 7.5 mil	117	White Beaded Visibead B 1.5 IOR, 7.5 mil
76	White Beaded Megalux B 1.5 IOR, 7.5 mil	97	White Beaded Megalux B 1.5 IOR, 7.5 mil	118	White Beaded Megalux B 1.5 IOR, 7.5 mil
77	White Beaded Megalux A 1.5 IOR, 7.5 mil	98	White Beaded Megalux A 1.5 IOR, 7.5 mil	119	White Beaded Megalux A 7.5 IOR, 15 mil
78	Black Nonbeaded, 7.5 mil	99	Not Used	120	Black Nonbeaded, 7.5 mil
79	Black Beaded Highway 1.5 IOR, 7.5 mil	100	Not Used	121	Black Beaded Highway 1.5 IOR, 7.5 mil
80	Black Beaded Airport 1.9 IOR, 7.5 mil	101	Not Used	122	Black Beaded Airport 1.9 IOR, 7.5 mil
81	Black Beaded Visibead A 1.5 IOR, 7.5 mil	102	Not Used	123	Black Beaded Visibead A 1.5 IOR, 7.5 mil
82	Black Beaded Visibead B 1.5 IOR, 7.5 mil	103	Not Used	124	Black Beaded Visibead B 1.5 IOR, 7.5 mil
83	Black Beaded Megalux B 1.5 IOR, 7.5 mil	104	Not Used	125	Black Beaded Megalux B 1.5 IOR, 7.5 mil
84	Black Beaded Megalux A 1.5 IOR, 7.5 mil	105	Not Used	126	Black Beaded Megalux A 1.5 IOR, 7.5 mil

Table 2 shows the brand and part numbers of the waterborne paints that were applied.

TABLE 2. WATERBORNE PAINT FOR TESTING

Manufacturer	Part Number
Rohm and Haas	HD-21A White
Rohm and Haas	HD-21A Yellow
Rohm and Haas	No Black
Sherwin-Williams	White TM2152
Sherwin-Williams	Yellow TMT2153
Sherwin-Williams	Black TMT2154
TMT	White WW2712A9
TMT	Yellow WY2713A9
TMT	Black WB2677A7

Chromaticity readings were taken at the beginning and end of the test and are presented in appendix A, figures A-3 and A-4.

Glass Bead Evaluation. Four new beads were tested: the 1.5 IOR Visibead A (L-511), the 1.5 IOR Visibead B (L-511 Millennium), the 1.5 IOR Megalux A (Airport and Highway High Quality and High Performance Drop-On), and the 1.5 IOR Megalux B (Airport "Beacon" High Quality and High Performance), as well as the two existing beads, the 1.5 IOR Highway Bead and the 1.9 IOR Airport bead. The beads were applied with a coupling agent for white, yellow, and black waterborne paint. A Q-panel was taken of each paint line. The paint lines were placed in three locations at the Atlantic City International Airport, on taxiway Hotel, Delta, and on a new airport asphalt test area. (Refer to table 1 for the detailed listing of the new paint lines.) Data were collected every month and analyzed, then graphs were made to represent how the beads were deteriorating.

The beads were visually analyzed for any effects from snow removal equipment. Retro-reflective readings were also taken to see the effects on the retro-reflectivity of the paint markings. A 2-liter, ASTM-E-2177 water test was performed on the lines to determine whether the new Visibead and Megalux beads reflect better than the highway and airport beads in wet-weather conditions.

Black paint with beads was applied to simulate accidental application of beads. It was evaluated by painting black markings with and without beads to determine the effects. Figure 4 shows black paint with beads.

FIGURE 4. BLACK PAINT WITH BEADS

All beads mentioned in table 1 were again applied at the temporary paint line thickness of 7.5 mil to see how well the beads adhered. Temporary paint lines are 50% of the specified coverage and are used when it is necessary to open new asphalt pavement to traffic sooner than it has had time to cure. Asphalt usually takes at least 30 days to cure.

Friction tests were performed on seven paint markings along the centerline of runway 4/22 at the Atlantic City International Airport (ACY) in July 2001. The purpose of the friction tests were to determine the effects of paint and beads on the frictional characteristics of the base pavement. The runway centerline stripes (3 by 120 feet) installed on runway 4/22 involved replacing the existing runway centerline stripes with test materials. Due to ACY's limitation on the amount of painting and the time allotted, Sherwin-Williams paint was the only brand of paint used on the runway marking phase of the study. Table 3 lists the test markings on runway 4/22.

TABLE 3. TEST MARKINGS AT RUNWAY 4/22

Stripe No.	Bead Type
1	White Nonbeaded
2	White Beaded Highway 1.5
3	White Beaded Airport 1.9
4	White Beaded Visibead 1.5 A
5	White Beaded Visibead 1.5 B
6	White Beaded Megalux 1.5 A
7	White Beaded Megalux 1.5 B

Application Thickness of Paint Evaluation. Federal Standard TT-P-1952D type II waterborne paint from three manufacturers was evaluated. Three sets of paint markings were applied at the standard thickness of 0.33 mm (15-mil wet film thickness), three sets of paint markings were applied at the refresh or temporary thickness of 0.17 mm (7.5-mil wet film thickness), and seven lines at a thickness of 0.44 mm (20-mil wet film thickness). (See table 1 for a detailed listing of the paint lines.)

Retro-reflectometer readings were taken every month. They were evaluated and graphed to determine how the beads held up at a thickness of 7.5 mil, 15 mil, and 20 mil. (See figures A-12 through A-14 in appendix A.)

Lumimark's Cementitious Pavement Marking Material Evaluation. Lumimark's cementitious pavement marking material was installed at the William J. Hughes Technical Center as a taxiway hold line and as an aircraft-parking (T) marking. Initial retro-reflectivity readings were very low. The test was discontinued at the request of Lumimark because the cement mixture's shelf life was out of date.

PROJECT PARTICIPANTS.

EVALUATION SUBJECTS. The project team was comprised of engineers and pilots. Individuals from the AAR-411 organization, along with contract support personnel, supervised installation of the paint markings and coordinated the effort required at ACY.

EQUIPMENT REQUIREMENTS. The following equipment was used for testing:

- Retro-Reflectometer, Flint Trading, Inc., 30-meter geometry, LTL 2000 built by Delta Lights and Optics of Denmark (Standard traceable to Denmark)
- Spectrophotometer, Color-guide 45°/0º, BYK-Gardner USA, 20 mm, 6805-SVC, built by BYK-Gardner of Germany
- Saab Friction Tester ASTM 1551 Tire at 30 psi with water on
- Skidabrader Outflow Meter

- Dyna Z16 Pull-Off Tester (used to find out the tensile strength of the bond between the pavement and paint, also used to determine if the bond fails cohesively or adhesively see page 13 for explanation)

- Digital Camera

- Wet Film Thickness Gauge

PROCEDURES.

The project team took readings with a retro-reflectometer and spectrophotometer every month at the three test marking locations. At the newer hot-mix asphalt test site (pavement placed 1999) located adjacent to building 296 along Pangborn Road, six readings were taken on each line at the beginning, middle, and end of the line and then in the opposite direction at the beginning, middle, and end of the line. Prior to September 11, 2001, the readings at taxiways Hotel and Delta were handled in the same manner. Post September 11, 2001, one reading per line was allowed due to heightened security at the airport. Figures 5, 6, and 7 show the lines at the newer hot-mix asphalt test site, taxiway Hotel, and taxiway Delta.

FIGURE 5. LINES AT NEWER HOT-MIX ASPHALT TEST SITE
(Pavement Placed 1999)

FIGURE 6. LINES AT TAXIWAY HOTEL ON PORTLAND CEMENT CONCRETE

FIGURE 7. LINES AT TAXIWAY DELTA ON OLD HOT-MIX ASPHALT

Spectrophotometer readings were taken of the lines and Q-panels shortly after being painted. Figures A-3 and A-4 in appendix A show the initial readings presented on a CIE standard illumination D_{65} chart. The 1931 D_{65} chart defines the chromaticity limits of colors to be used for aeronautical ground markings. The specifications are in accordance with the International Civil Aviation Organization Annex 14 Volume I, August 9, 2000. The chromaticities are expressed in terms of the standard observer and coordinate system.

The Skidabrader Outflow meter tests have been performed on all of the lines at the newer hot-mix asphalt test site (see appendix A, figure A-10). The Outflow meter tests were taken for each line to see how fast the water sheets off the paint lines with beads. A 2-liter water test (ASTM-E-2177) was performed on the lines to determine whether the new Visibead and Megalux beads reflect better than the highway and airport beads in wet-weather conditions. The two graphs show that the greater the slope of the line, the faster the retro-reflectivity recovers. Since ASTM-E-2177 was not approved until February 2002, the test was not performed until July 2002. Also, Dyna-meter test plugs were performed before the end of testing. This test determined whether there is an internal failure, which is cohesive, or an external failure, which is adhesive. With a cohesive failure, the paint fails; with an adhesive failure, the asphalt or concrete fails. The Dyna-meter provides a tensile strength reading at failure when a test plug is pulled from the asphalt. The test was performed to determine if the paint is stronger than the asphalt (see appendix A, figure A-11).

The readings were taken at runway 4/22 on seven lines, each having a different type of bead. A Saab friction test vehicle was used to obtain friction readings. Tables 4 and 5 show the test markings at runway 4/22.

DATA COLLECTION.

Water Emulsion Type Paint Performance. Using a color-guide spectrophotometer, color readings were obtained from the Q-panels and the actual paint markings. The paint markings were evaluated at the beginning and end of the test with the spectrophotometer. The readings were graphed at the beginning and end points on a CIE Standard Illuminant D_{65} chart to see how much the data point had shifted over time (see appendix A, figures A-3 and A-4).

It was observed over time how the coverage of the paint changed.

A Dyna-Meter Z16 Pull-Off Tester was used to determine the tensile strength of the bond between the paint and the asphalt or concrete (see appendix A, figure A-11).

A Saab friction test was performed at the beginning and end to obtain the friction readings of the pavement, paint, and paint with beads.

Application Thickness of Paint Evaluation. Retro-reflectivity readings were obtained of each paint marking over time to show a permanent marking versus temporary or refresh markings and how well the beads adhered to the paint. The paint markings were evaluated every month for 1 year with a retro-reflectometer. Taking retro-reflective readings of paint markings is a way of measuring which application thickness is most appropriate for the beads to adhere

properly. (See appendix A, figure A-12, for the newer hot-mix asphalt test site; figure A-13 for taxiway Hotel; and figure A-14 for taxiway Delta.) At initial application, the thickness of the paint was checked with a wet-film thickness gauge.

Glass Bead Evaluation. Retro-reflective readings of each type of bead were taken each month. The paint markings continued to be evaluated over a 1-year period with a retro-reflectometer. The Skidabrader Outflow meter was used to determine how quickly water dissipated from the paint marking (see appendix A, figure A-10). A 2-liter, ASTM-E-2177 water test was performed on the paint markings to determine wet-weather recovery of the beads (see appendix A, figure A-9).

Cementitious Pavement Marking Material Evaluation. The cement mixture's shelf life was out of date for Lumimark; therefore, the test was discontinued. The PermaStripe installed at Tyndall Air Force Base was reapplied and is currently under test.

RESULTS

The initial evaluation of the test materials was started in July 2001, a month after installation, at each test location, i.e., newer hot-mix asphalt test site, taxiway Hotel, and taxiway Delta at ACY. Monthly examinations of the test markings were performed through June 2002.

The paint applied at 15 mil (see figure 8) has higher retro-reflectivity than the 7.5 mil by approximately 100 mcd/m^2/lx (Lines 30, 31, 32, 33, 34, and 35). It was found that paint at 15-mil wet film thickness provides the highest retro-reflectivity for each type of bead.

The retro-reflective readings, shown in figure 9, indicate that it is worthwhile to place beads on temporary or refresh markings (7.5 mil). This graph shows that an unbeaded surface (Line 92) has a retro-reflectivity of approximately 50 mcd/m^2/lx. When beads are placed on the line, the retro-reflectivity is anywhere from 200-700 mcd/m^2/lx initially (Lines 93, 94, 95, 96, 97, and 98) and 150-400 mcd/m^2/lx after 12 months. The coupling agent placed on the beads helped the beads adhere to the paint.

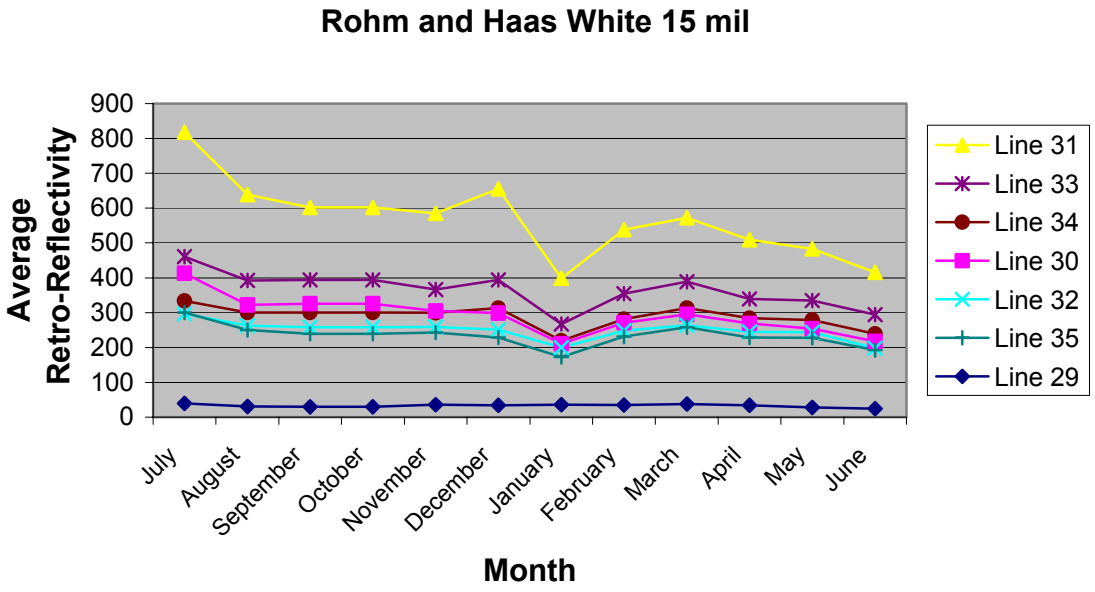


FIGURE 8. APPLICATION OF 15-mil WET FILM THICKNESS

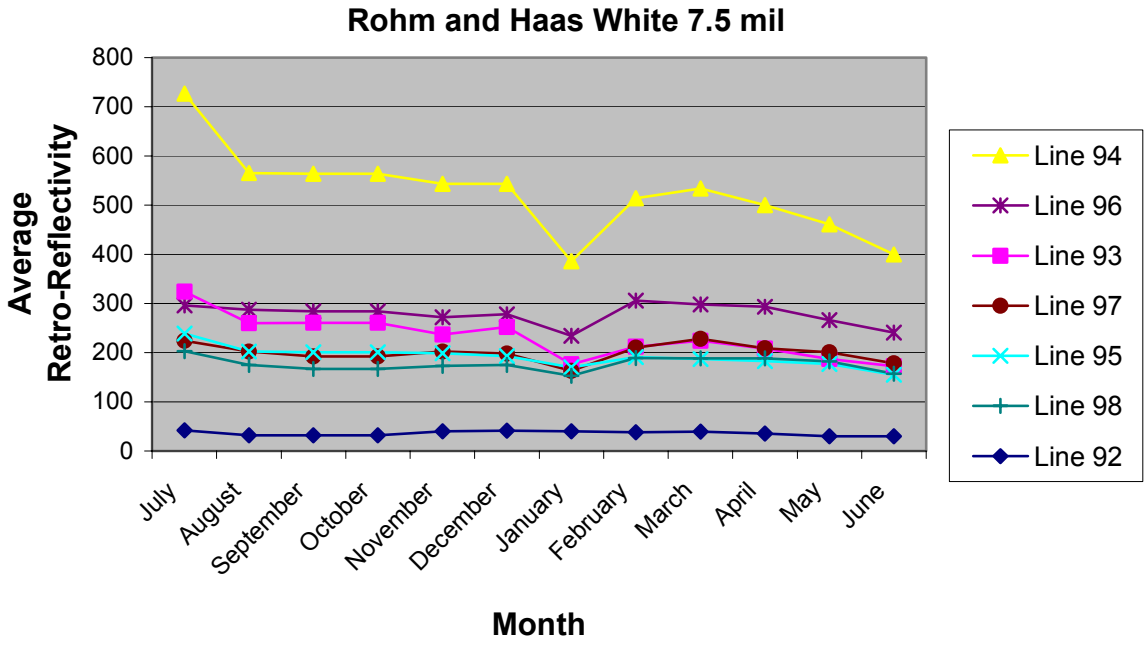


FIGURE 9. APPLICATION OF 7.5-mil WET FILM THICKNESS

All the retro-reflectivity charts for the newer hot-mix asphalt test site (pavement placed 1999) are in figure 12 of appendix A. All the graphs for taxiway Hotel are in figure A-13 of appendix A. The paint test lines at taxiway Hotel are on Portland cement concrete. All of the graphs for

taxiway Delta are in figure A-14 of appendix A. The paint test lines at taxiway Delta are on old hot-mix asphalt.

At the beginning of the test (July 16, 2001), a Saab friction tester determined that the average mu (μ) reading for an unpainted surface was 0.80 μ; for unbeaded paint, it was 0.57 μ; and for beaded paint, it was 0.38 to 0.56 μ (see table 4). At the end of the test (November 25, 2002), a Saab friction tester determined that the average mu (μ) reading for an unpainted surface was 0.76 μ; for unbeaded paint, it was 0.43 μ; and for beaded paint, it was 0.42 to 0.47 μ (see table 5). In other words, the beads make the paint have less friction. For both tables 4 and 5, lines 1-7 were painted as part of the test. The test lines were painted with Sherwin-Williams paint because that was what was in the equipment at the time of application. Due to the airport only allowing seven paint lines, Sherwin-Williams was the only paint used. Line 8 was an existing line that had been painted about a year prior to this test. Since this was a runway centerline marking, it was painted white. Line 1 had no beads, line 2 had highway 1.5 IOR beads, line 3 had airport 1.9 IOR beads, line 4 had Visibead A 1.5 IOR, line 5 had Visibead B 1.5 IOR, line 6 had Megalux A 1.5 IOR, and line 7 had Megalux B 1.5 IOR.

TABLE 4. FRICTION READINGS FOR JULY 16, 2001

Section		Run 1	Run 2	Run 3	Run 4	Average
Unpainted		0.80	0.80	0.80	0.80	0.80
Unbeaded	(1)	0.57	N/A	0.57	N/A	0.57
Highway 1.5	(2)	0.48	0.53	0.44	0.49	0.49
Airport 1.9	(3)	0.56	0.45	0.40	0.45	0.47
Visibead A	(4)	0.53	0.42	0.53	0.39	0.47
Visibead B	(5)	0.44	0.43	0.37	0.39	0.41
Megalux A	(6)	0.38	0.35	0.37	0.33	0.36
Megalux B	(7)	0.49	0.33	0.38	0.34	0.39
N/A Existing	(8)	0.22	0.17	0.20	0.18	0.19

TABLE 5. FRICTION READINGS FOR NOVEMBER 25, 2002

Section		Run 1	Run 2	Run 3	Run 4	Average
Unpainted		0.74	0.74	0.78	0.78	0.76
Unbeaded	(1)	0.42	0.41	0.45	0.42	0.43
Highway 1.5	(2)	0.44	0.44	0.47	0.48	0.46
Airport 1.9	(3)	0.38	0.41	0.43	0.46	0.42
Visibead A	(4)	0.47	0.48	0.47	0.47	0.47
Visibead B	(5)	0.43	0.40	0.47	0.47	0.47
Megalux A	(6)	0.40	0.45	0.46	0.47	0.45
Megalux B	(7)	0.43	0.40	0.44	0.41	0.42
N/A Existing	(8)	0.23	0.21	0.23	0.23	0.23

A thorough review of the graphs provided in appendix A shows that the Rohm and Haas paint was the most successful at holding the beads. For example, compare the Rohm and Haas yellow 15 mil (figure A-12) with the Sherwin-Williams yellow 15 mil (figure A-12) for the airport bead. The Rohm and Haas yellow retro-reflectivity starts at 445 mcd/m²/lx and finishes at 261 mcd/m²/lx in 12 months, and the Sherwin-Williams yellow retro-reflectivity starts at 614 mcd/m²/lx and finishes at 89 mcd/m²/lx in 12 months. The Sherwin-Williams paint starts with higher retro-reflectivity, but does not retain the beads as well. Compare the Rohm and Haas yellow 15 mil (figure A-12) with TMT yellow 15 mil (figure A-12) for the airport bead. The Rohm and Haas yellow retro-reflectivity starts at 445 mcd/m²/lx and finishes at 261 mcd/m²/lx in 12 months, and the TMT yellow retro-reflectivity starts at 487 and finishes at 174 mcd/m²/lx in 12 months. The TMT yellow starts out with higher retro-reflectivity, but does not retain the beads as well. All three paint manufacturers used the same HD-21A resin (the formulation is shown in appendix A, (figure A-15). The Rohm and Haas yellow and white paint formulas are found in figures A-16 and A-17 in appendix A. In general, all the paints lasted longer on asphalt than concrete. On the concrete where patches had been made, the paint was gone within 3 months. The white paint had started to turn yellow on the asphalt 3 months after installation.

The evaluation at New Bedford Airport showed that the number of layers of paint should be limited to approximately four layers or 60 mils, because anything greater than this thickness will start to peel up and sheet off, due to shrinkage, while the paint is drying. For example, at New Bedford Airport there were approximately eight layers of paint and the paint was coming up in sheets. Therefore, it is very important that the surface be prepared correctly to ensure proper adherence of the paint.

In a previous report, "Evaluation of Retro-Reflective Beads in Airport Pavement Markings," December 1994, the study noted that after the testing had begun the Federal Specification TT-B-1325B was updated to version C. The primary change in the specification was the elimination of the largest sieve size of type III beads. The evaluation showed that over time, a reduction occurred in retro-reflectivity of the 1.9 IOR beaded materials while the 1.5 IOR beaded materials tended to sustain performance. At the completion of the 1-year test period, all 1.5 IOR beaded materials at the Atlantic City and Pittsburgh test sites had higher retro-reflectivity than their 1.9 IOR counterparts. In the present evaluation, all beads had a coupling agent applied to them. The type III beads adhered the best because of the coupling agent. Therefore, they performed better over time.

The discoloration of the paint due to oil from the asphalt washing over the surface and acid rain was observed at New Bedford Airport in New Bedford, Massachusetts; Worcester Airport in Worcester, Massachusetts; and Lawrence Airport in Lawrence, Massachusetts (see figure 10). At all three locations, the white paint was turning yellow. The paint was also coming up in big sheets because there were at least eight layers of paint already applied at the time of repainting.

FIGURE 10. YELLOWING OF THE WHITE PAINT AT NEW BEDFORD AIRPORT, NEW BEDFORD, MASSACHUSETTS

A 2-liter, ASTM-E-2177 water test was performed on the lines to determine whether the new Visibead and Megalux beads reflect better than the highway and airport beads in wet-weather conditions. The wet retro-reflectivity readings were documented, analyzed, and graphed (see figures 11 and 12).

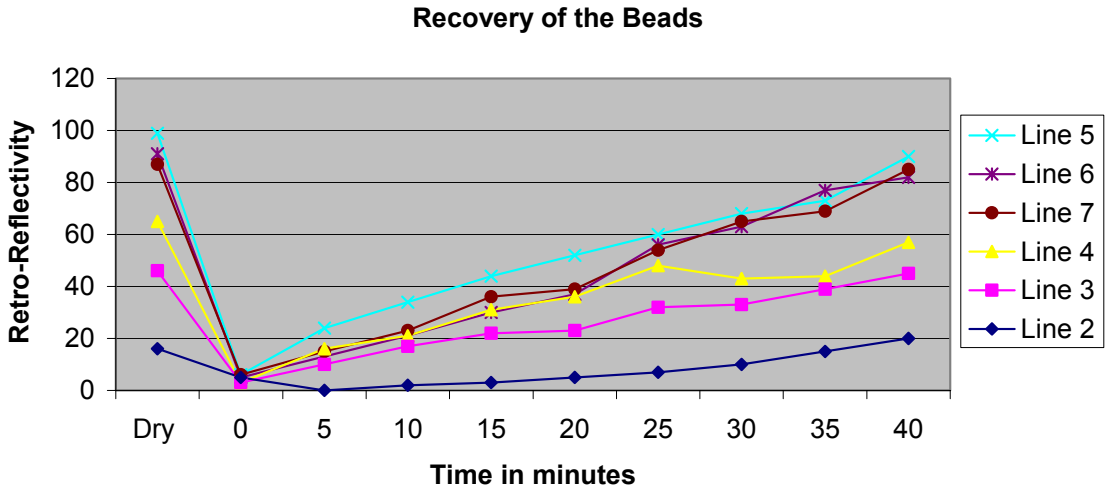


FIGURE 11. ASTM-E-2177/01 WATER TEST (Lines 2 through 7)

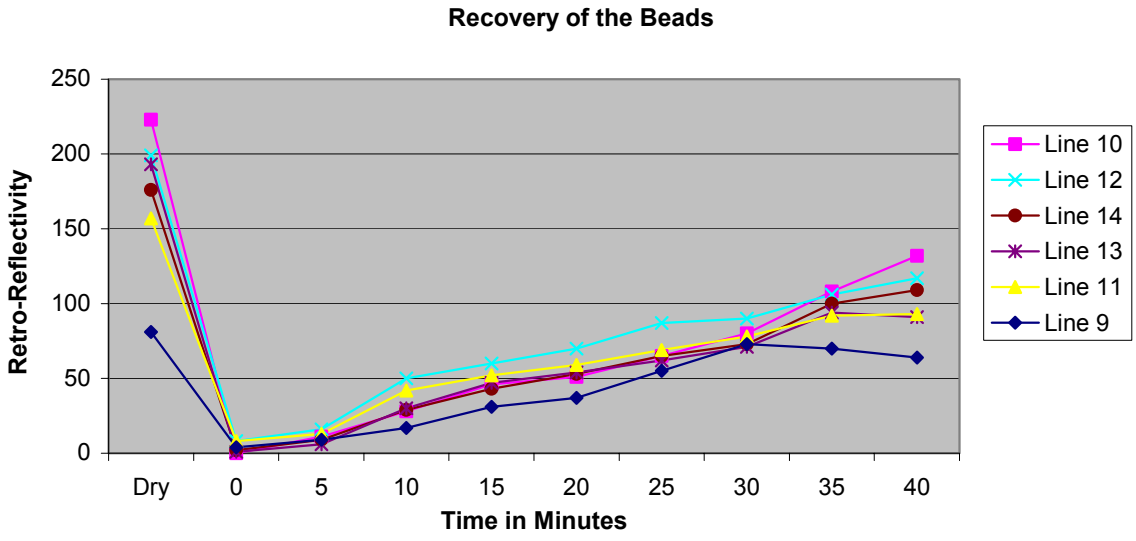


FIGURE 12. ASTM-E-2177/01 WATER TEST (Lines 9 through 14)

As the graphs show, Visibead B (line 5) sheeted the water off the fastest. It took all of the beads at least 40 minutes to recover. This test was performed July 2002, at the end of the 1-year evaluation, in accordance with the newly released ASTM test procedures (appendix A, figure A-9). Immediately after application of the 2 liters of water each line's retro-reflectivity was approximately zero.

Lumimark cementitious pavement marking material was installed at the William J. Hughes Technical Center for evaluation. A taxiway hold line was installed at the pavement test building as well as an aircraft-parking T at the FAA ramp. This product was not evaluated due to the expiration of the cement mixture's shelf life, which caused the cement mixture to flake off. Even though it was not evaluated, immediately after installation this product's retro-reflectivity was extremely low. Therefore, the process still needs some refinement. The beads sank into the cementitous material, which caused very low retro-reflectivity readings.

The U.S. Air Force and the U.S. Army Corps of Engineers evaluated PermaStripe at Tyndall Air Force Base in Panama City, Florida. In 2000, this material was put down on a taxiway and a runway, which were replaced with new material in April 2002. (This product is not ready for commercial application. PermaStripe also needs to address the issue of very low retro-reflectivity readings.) A recommendation regarding this product cannot be made at this time.

CONCLUSIONS

Based on the results of this evaluation effort, it is concluded that:

- The HD-21A Rohm and Haas water emulsion paint held the beads better.
- The Type III (1.9 IOR) Airport bead had the highest retro-reflectivity initially and over time, in direct contrast to the evaluation in 1994, because of the coupling agent being applied to all of the beads. All four new beads had higher retro-reflectivity than the 1.5 IOR Highway bead but not as high as the 1.9 IOR Airport bead. The four new beads were the (1.5 IOR) Visibead A (L-511), (1.5 IOR) Visibead B (L-511 Millennium), 1.5 IOR Megalux A (Airport and Highway High Quality and High Performance Drop-On), and 1.5 IOR Megalux B (Airport "Beacon" High Quality and High Performance).
- All four new 1.5 IOR beads are acceptable.
- At the application thickness of 0.33 mm (15-mil wet film thickness), more beads adhere to the paint, allowing better retro-reflective readings.
- The coupling agent sprayed on the beads improves bead retention on the paint initially and over time.
- The black paint appears gray when beads are accidentally applied to the paint making the marking contrast not as good. Over time, the black paint blends in with the asphalt color and texture.
- The Lumimark cementitious pavement marking material's shelf life was out of date, therefore, was not evaluated, but in general this process needs refinement. The beads are sinking into the cementitious material, which causes very low retro-reflective readings.
- The PermaStripe cementitious pavement marking material being studied by the U.S. Air Force and U.S. Army Corps of Engineers is still under investigation but is not ready for commercial application. The cementitious pavement markings were applied by hand with a squeegee at first; now they are being applied with modified paint equipment, but the thickness and bead application are not correct. When the thickness is greater than 15 mil, the beads sink into the mixture producing very low retro-reflectivity. PermaStripe also needs to address this issue.

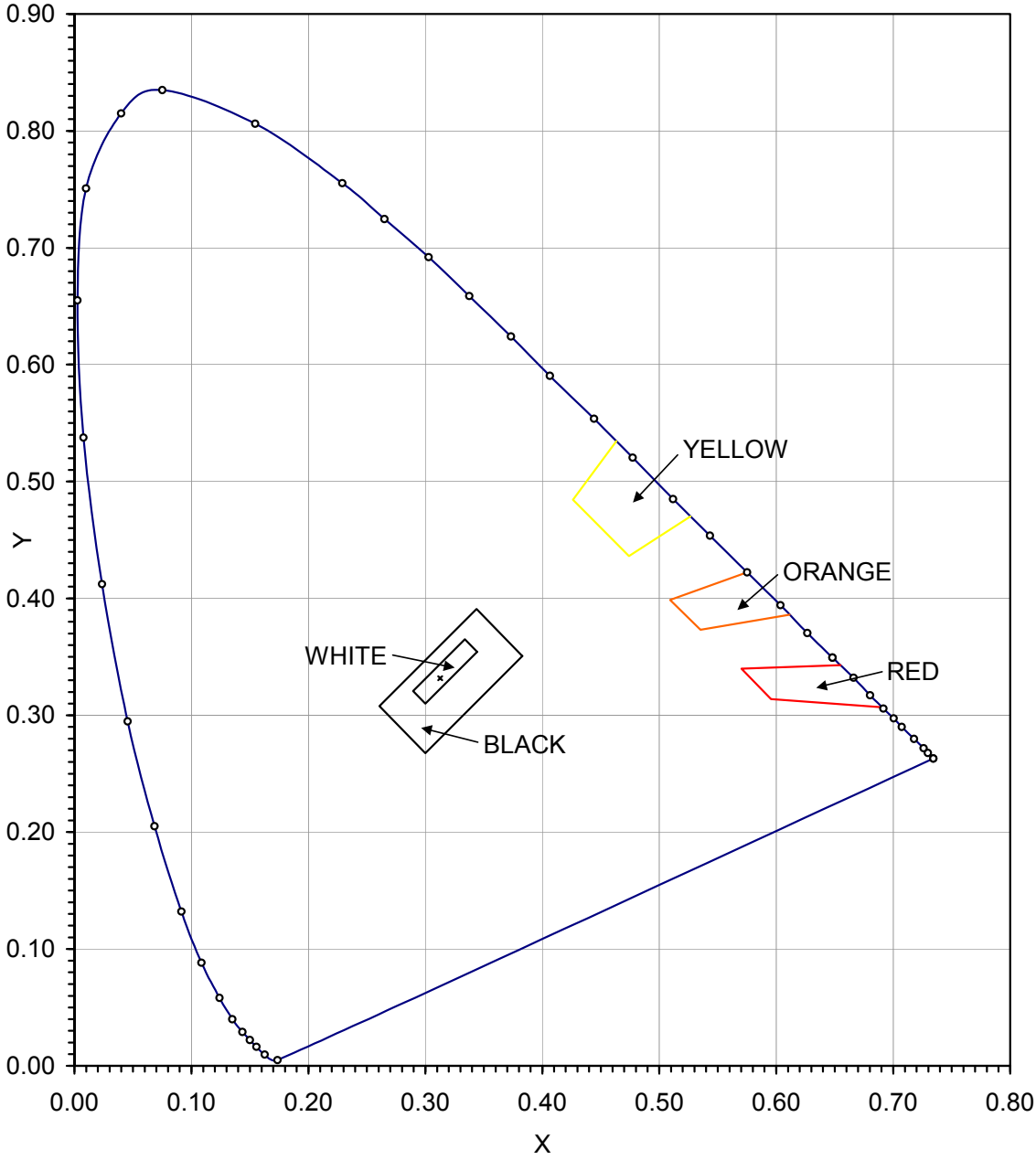


FIGURE A-1. ORDINARY COLORS FOR SURFACE MARKINGS

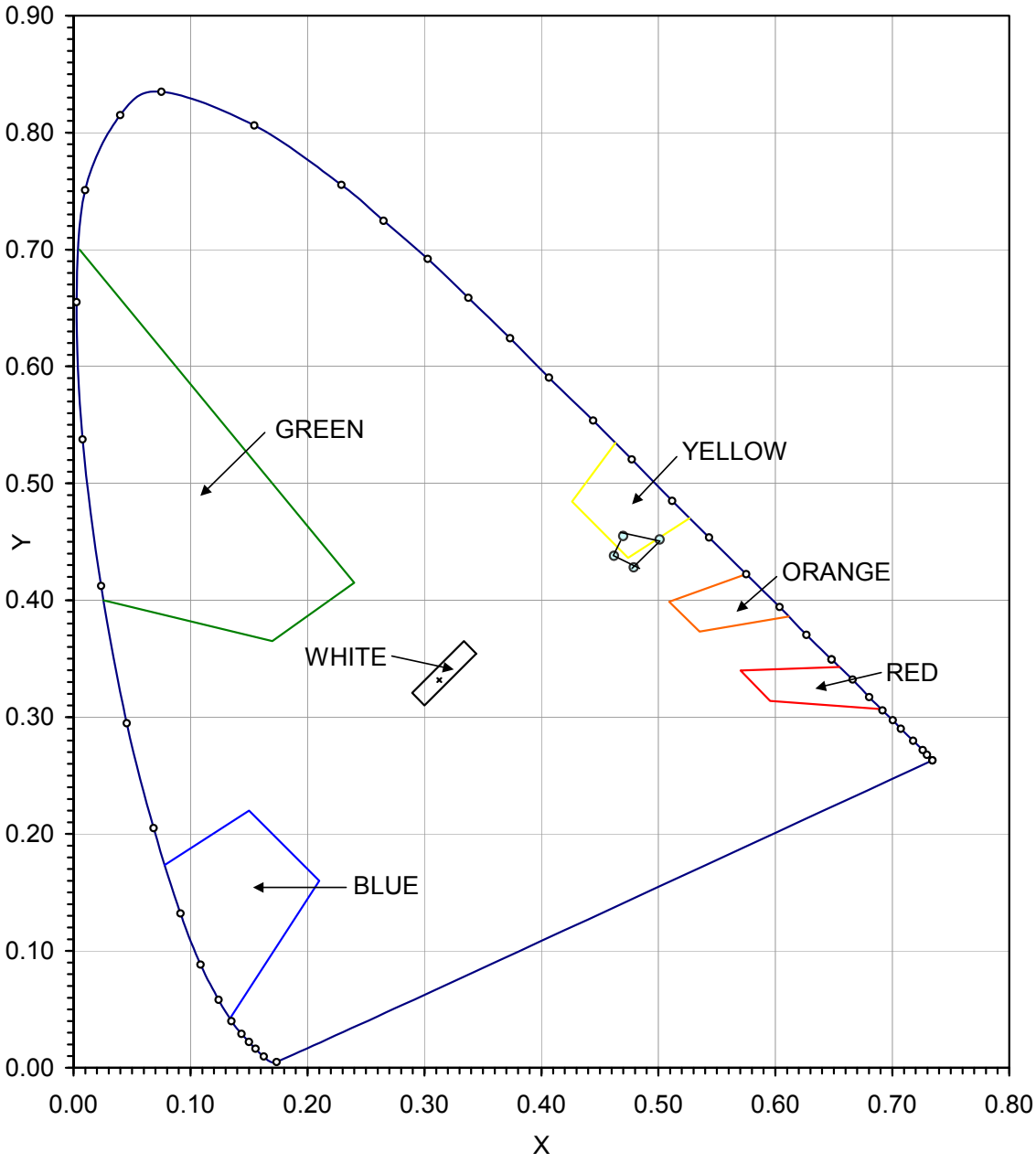


FIGURE A-2. COLORS OF RETRO-REFLECTIVE MATERIALS FOR MARKINGS, SIGNS, AND PANELS

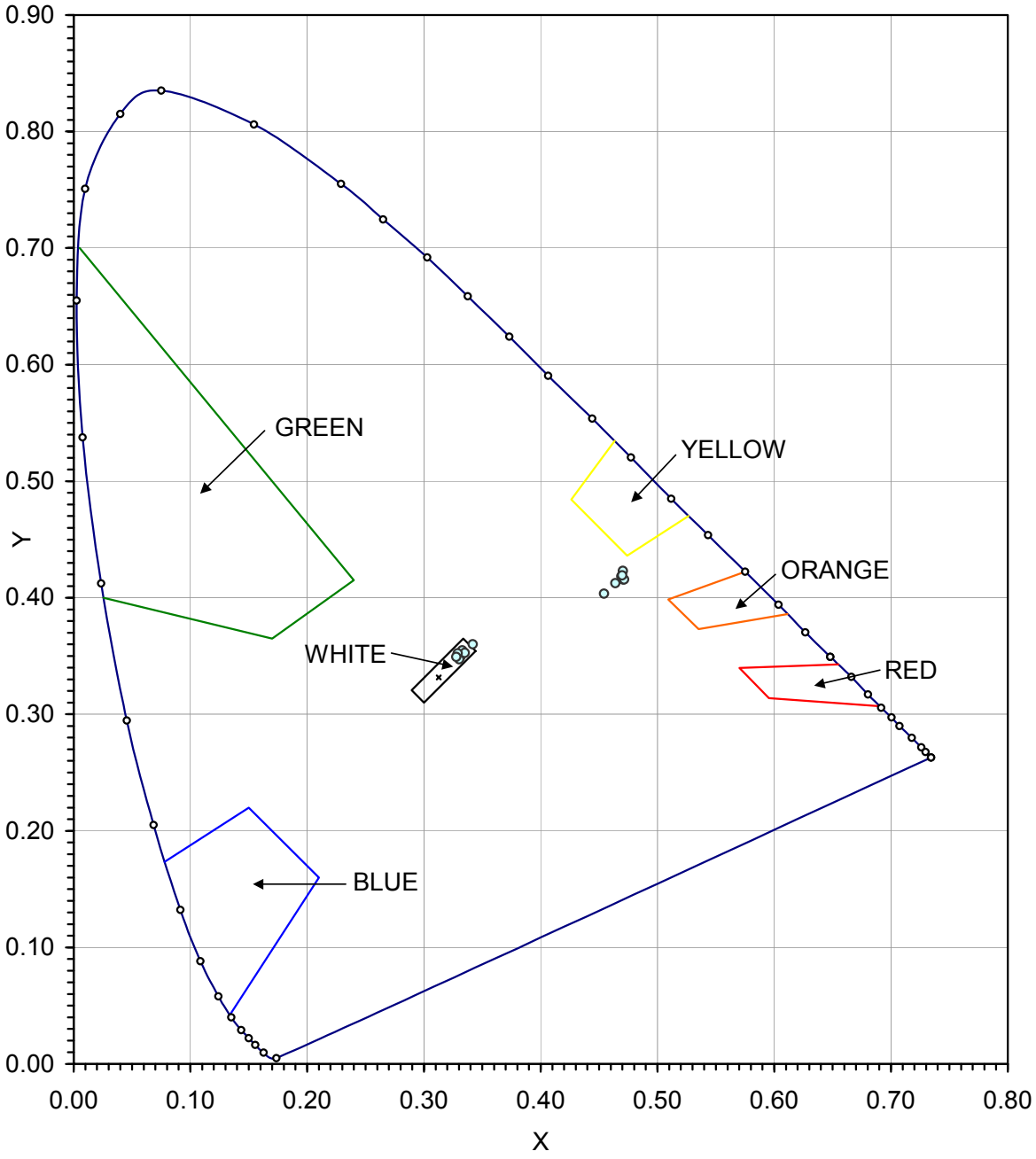


FIGURE A-3. COLOR GUIDE READINGS FOR NEW HOT-MIX ASPHALT TEST SITE JULY 2001

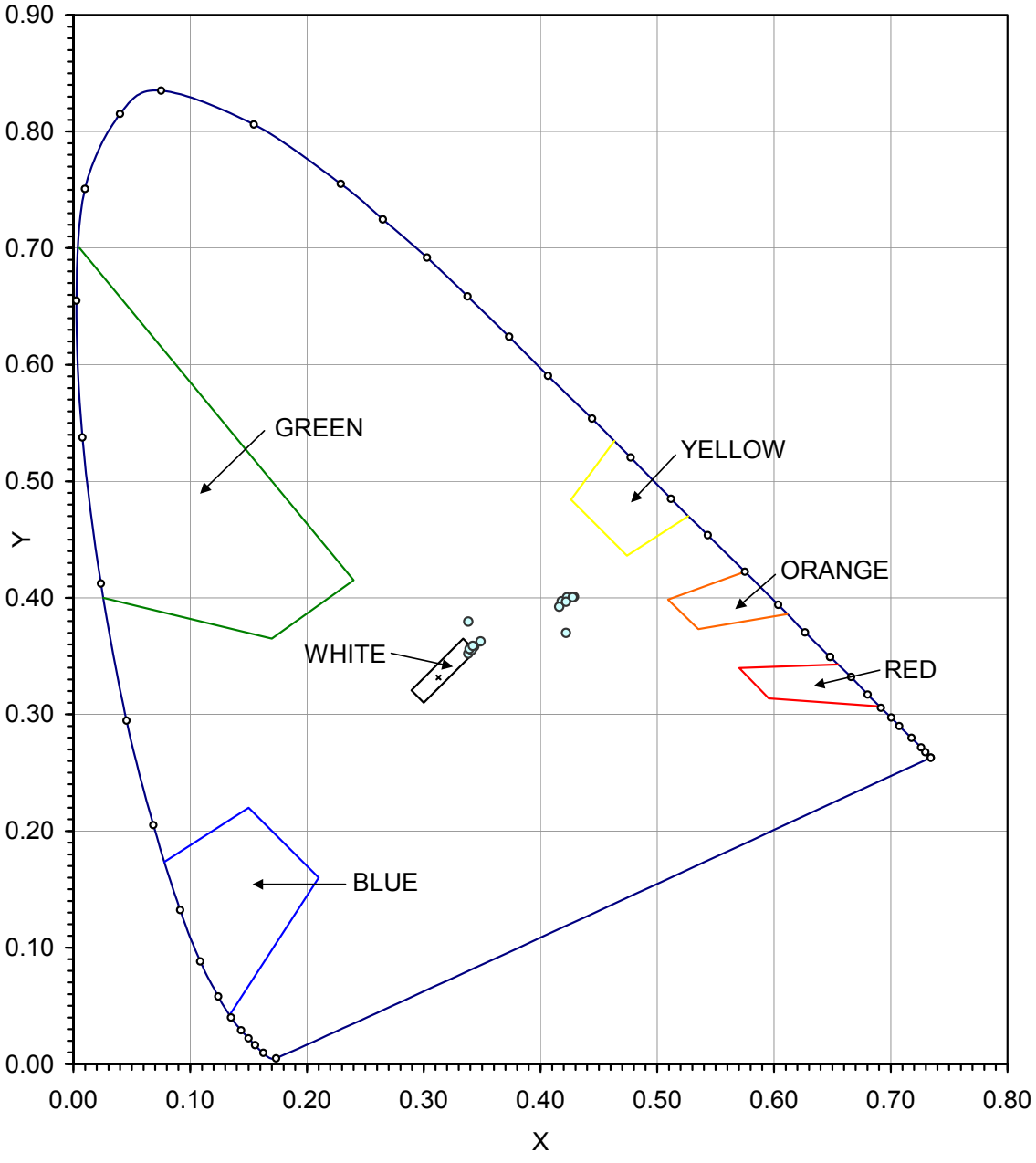


FIGURE A-4. COLOR GUIDE READINGS FOR NEW HOT-MIX ASPHALT TEST SITE (PLACED IN 1999) JUNE 2002

swarco
REFLEX
P.O. BOX 1558
MEXIA, TX 76667• 1558
254 - 562-9879
FAX 254 • 562-7601

(Type A)
AIRPORT AND HIGHWAY
HIGH QUALITY AND HIGH PERFORMANCE
DROP-ON MEGALUX GLASS BEADS

Megalux Glass Spheres for Airport and Highway Markings:
The particulars of our "Megalux"/Airport highway glass beads are as follows:

GRADATION		
U.S. Mesh	Microns	% Retained
12	1700	0
14	1400	0-5
16	1180	0-15
18	1000	30-70
25	710	20-50
PAN		0-15

Hardness. The megalux beads shall exhibit an average hardness of C70.5 when measured using the Rockwell C scale method and with a minimum sampling of 100 glass beads.

Crushing Strength. The megalux beads shall exhibit an average crushing strength of not less than 60,000 psi when measured the L/D two (2) method and with a minimum sampling of 100 glass beads.

Color/ Clarity. Beads shall be colorless / clear and free of carbon residues.

Roundness. Minimum 90% true spheres by visual inspection.

Index of refraction. Minimum 1.50.

Air Inclusions. Maximum 5 %.

Resistance to acid. When tested as specified in 4.3.6, the beads shall not develop any surface haze or dulling per TT-P Federal Spec. 1325C.

Resistance to calcium chloride. When tested as specified in 4.3.7, the beads shall not develop any surface haze or dulling per TT-P Federal Spec. 1325C.

Resistance to sodium sulfide. When tested as specified in 4.3.8, the sodium sulfide solution shall not darken the beads.

Water resistance. When tested as specified in 4.3.9, the water shall not produce dulling or hazing of the beads, and not more than 4.5 ml of 0.1 N hydrochloric acid shall be used for the titration per TT-P Federal Spec. 1325C.

Coatings. Per customer request and specification - Moisture Resistance, Adherence Coating, Dual Coating, and Flotation.

FIGURE A-5. AIRPORT AND HIGHWAY HIGH QUALITY AND HIGH PERFORMANCE DROP-ON MEGALUX GLASS BEADS

swarco
REFLEX
P.O. BOX 1558
MEXIA, TX 76667-1558
254 - 562-9879
FAX 254 • 562-7601

(Type B)
Airport "Beacon"
High Quality And High Performance
Megalux Glass Beads

Megalux "Beacon" Glass Spheres for Airport Markings:

	GRADATION	
U.S. Mesh	Microns	% Retained
12	1700	0
16	1180	0-5
20	850	30-60
30	600	30-60
PAN	-600	0-5

- Hardness The Megalux beads shall exhibit an average hardness of C70.5 when measured using the Rockwell C scale method and with a minimum sampling of 100 glass beads.
- Crushing Strength The Megalux beads shall exhibit an average crushing strength of not less than 60, 000 psi when measured the L/D^2 method and with a minimum sampling of 100 glass beads.
- Color/Clarity Beads shall be colorless / clear and free of carbon residue.
- Roundness Minimum 90% true spheres by visual inspection.
- Index of Refraction Minimum 1.51, by oil immersion method.
- Air Inclusions Maximum 1%, by visual count.
- Resistance To Acid When tested as specified in 4.3.6, the beads shall not develop any surface haze or dulling per TT-P Federal Spec. 1325C.
- Resistance To Calcium Chloride When tested as specified in 4.3.7, the beads shall not develop any surface haze or dulling per TT-P Federal Spec. 1325C.
- Resistance To Sodium Sulfide When tested as specified in 4.3.8, the sodium sulfide solution shall not darken the beads per TT-P Federal Spec. 1325C.
- Water Resistance When tested as specified in 4.3.9, the water shall not produce dulling or hazing of the beads, and not more that 4.5 ml of 0.1 hydrochloric acid shall be used for the titration per TT-P Federal Spec. 1325C.
- Coatings Per customer request and specification - Moisture Resistance, Adherence Coating, Dual Coating, or Flotation.

FIGURE A-6. AIRPORT "BEACON" HIGH QUALITY AND HIGH PERFORMANCE MEGALUX GLASS BEADS

Potters Industries Inc.
an affiliate of The PQ Corporation

Corporate Technical Center
600 Industrial Road
P.O. Box 6626
Carlstadt, NJ 07072, U.S.A.

R&D: (201) 507-4207
Telefax: (201) 939-6452

(Type A)
L-511 VISIBEAD® SAFETY MARKING SPHERE

PRODUCT DESCRIPTION:

Glass Beads - CAS # 65997-17-3 meet requirements of Federal Specification FP-96 Soda Lime Glass

USES:

Glass beads for application on (and in) a variety of striping materials to provide improved retroreflective performance and measurable wet retroreflective performance when properly applied to the marking material.

APPLICATION:

The product shall be distributed upon the marked areas immediately after application of the paint. A dispenser shall be furnished which is properly designed for attachment to the marking machine and suitable for dispensing glass beads. The beads are dropped by gravity on to the wet material. The bead nozzle is located immediately behind the paint nozzle so that the beads are dropped almost simultaneously with the paint application.

APPLICATION CONDITIONS:

Surface area must be prepared to the binder's specifications before glass can be applied.

APPLICATION RATES:

Beads must be applied at the following rate 121b of glass bead/gallon paint.

PHYSICAL PROPERTIES:

Gradation Specifications
Percent by Mass Passing Designated Sieve
(ASTM D 1214) & P114 103

Sieve Size U.S. Mesh	Microns	%Passing
#12	1700	100
#14	1400	95-100
#16	1180	80-95
#18	1000	10-40
#20	850	0-5
#25	710	0-2
Pan		

Roundness	80% visually per test FLHT520-93 and ASTM 1214-89
Index of Refraction	1.50 -1.52 per PI I #109
Specific Gravity	2.30-2.50gm/L

FIGURE A-7. L-511 VISIBEAD

Potters Industries Inc.
an affiliate of The PQ Corporation

Corporate Technical Center
600 Industrial Road
P.O. Box 6626
Carlstadt, NJ 07072, U.S.A.

R&D: (201) 507-4207
Telefax: (201) 939-6452

HIGH PERFORMANCE AIRPORT GLASS SPHERES
(L-511 Millennium) (Type B)

PRODUCT DESCRIPTION:

Glass Beads-CAS # 65997-17-3 meet requirements of Federal Specification FP-96 Soda Lime Glass.

USES:

Glass beads for application on (and in) a variety of striping materials to provide improved retroreflective performance and measurable wet retroreflective performance when properly applied to the marking material.

APPLICATION:

The product shall be distributed upon the marked areas immediately after application of the paint. A dispenser shall be furnished which is properly designed for attachment to the marking machine and suitable for dispensing glass beads. The beads are dropped by gravity on to the wet material. The bead nozzle is located immediately behind the paint nozzle so that the beads are dropped almost simultaneously with the paint application.

APPLICATION CONDITIONS:

Surface area must be prepared to the binder's specifications before glass can be applied.

APPLICATION RATES:

Beads must be applied at the following rate 121b of glass beads/gallon paint.

PHYSICAL PROPERTIES:

Gradation Specification
Percent by Mass Passing Designated Sieve
(ASTM D 1214) & PII#103

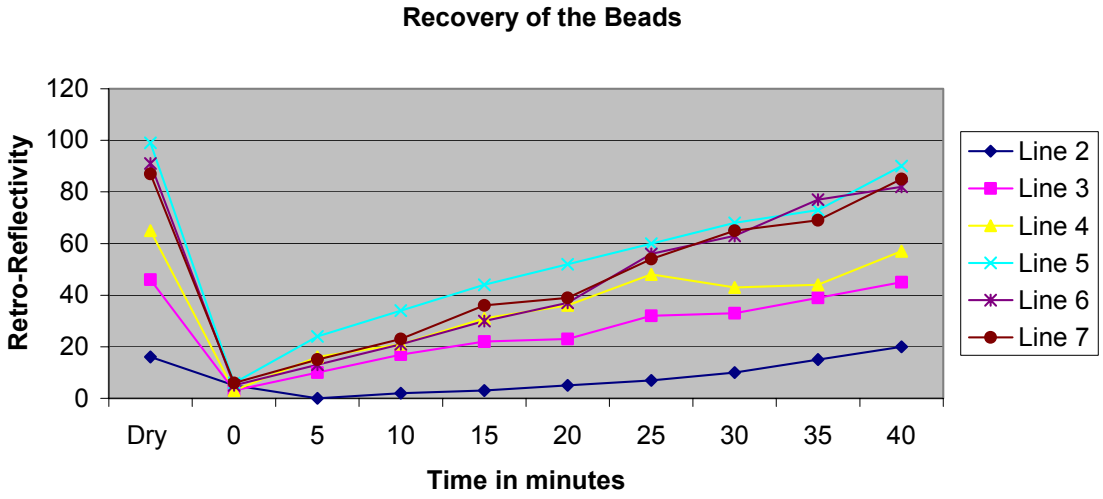
Sieve Size U.S. Mesh	Microns	% Passing
#14	1400	0-5
#16	1180	5-20
#18	1000	10-40
#20	850	0-5
Pan		

Roundness	90% visually per test FLHT520-93 and ASTM1214-89
Index of Refraction	Greater than 1.58 per PII#109
Specific Gravity	2.30-2.50gm/L
Air Inclusions	Less than 1% per P11 #114A

FIGURE A-8. L-511 MILLENNIUM—HIGH PERFORMANCE AIRPORT GLASS BEADS

Water Test-Recovery of the Beads over a 40 minute Period

	Dry	0	5	10	15	20	25	30	35	40
Line 2	16	5	0	2	3	5	7	10	15	20
Line 3	46	3	10	17	22	23	32	33	39	45
Line 4	65	3	16	21	31	36	48	43	44	57
Line 5	99	6	24	34	44	52	60	68	73	90
Line 6	91	5	13	21	30	37	56	63	77	82
Line 7	87	6	15	23	36	39	54	65	69	85



	Dry	0	5	10	15	20	25	30	35	40
Line 9	81	4	9	17	31	37	55	73	70	64
Line 10	223	0	11	28	46	51	65	80	108	132
Line 11	157	8	13	42	52	59	69	78	92	93
Line 12	199	8	16	50	60	70	87	90	106	117
Line 13	193	1	6	30	47	54	62	71	94	91
Line 14	176	2	9	29	43	53	65	73	100	109

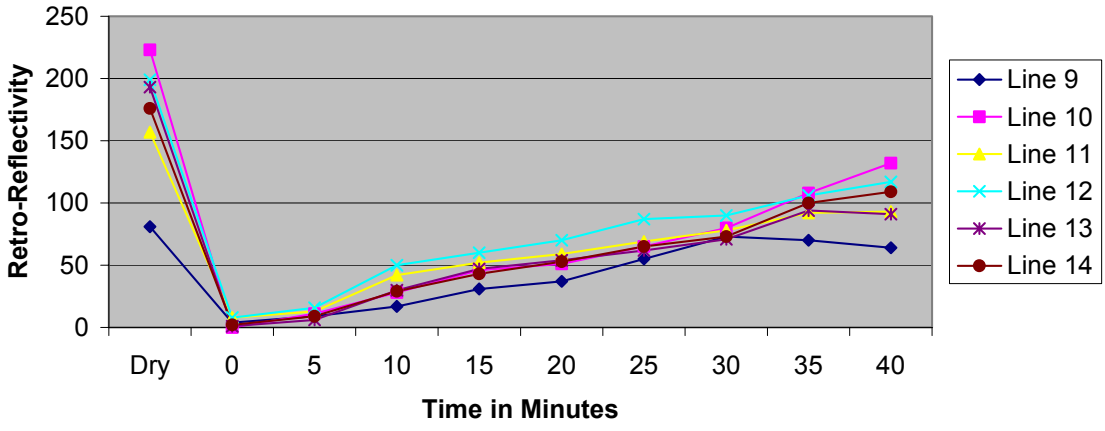


FIGURE A-9. ASTM E-2177 WATER TEST

Average Water Flow Meter at Hot-Mix Asphalt Test Site

Non-Beaded	27
Highway	28
Airport	17
Visibead A	7
Visibead B	8
Megalux B	10
Megalux A	9

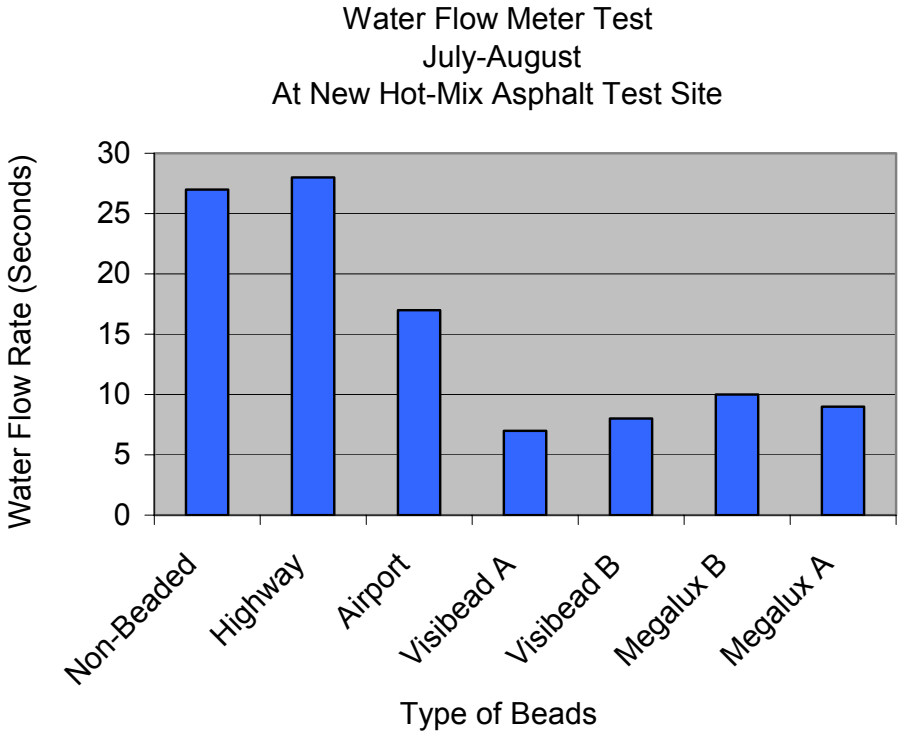
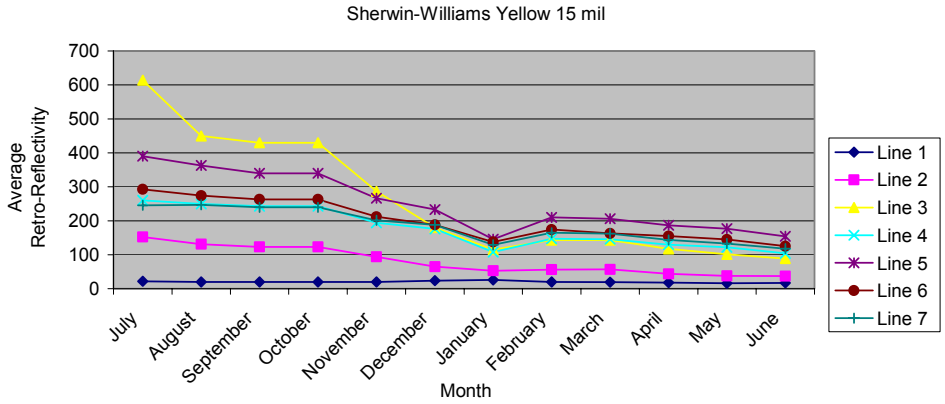


FIGURE A-10. AVERAGE WATER FLOW METER TEST

Pull Test Results		
Line Number	Tensile Strength	Cohesive/Adhesive
	N/mm^2-mm-0.50mm	
8	0.78	adhesive
22	0.47	adhesive
29	0.27	adhesive
1	0.51	adhesive
43	0.62	adhesive
50	0.73	adhesive

FIGURE A-11. PULL TEST RESULTS

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	22	152	614	260	390	293	246
August	20	131	450	250	363	274	247
September	20	123	430	243	340	263	240
October	20	123	430	243	340	263	240
November	20	94	287	194	266	212	201
December	24	65	180	176	233	188	188
January	26	53	115	108	146	138	129
February	20	56	143	147	210	174	165
March	19	57	143	146	206	163	162
April	18	44	117	130	187	155	144
May	16	38	101	122	177	145	133
June	17	37	89	104	154	125	118



	Line 8	Line 9	Line 10	Line 11	Line 12	Line 13	Line 14
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	35	365	687	203	297	222	178
August	30	256	559	187	293	177	158
September	33	246	566	194	285	179	166
October	33	246	566	194	285	179	166
November	29	230	522	181	242	185	167
December	31	197	512	207	268	201	175
January	34	126	295	166	193	159	160
February	29	160	372	200	243	227	216
March	32	155	375	213	228	265	252
April	28	146	360	208	236	254	242
May	25	131	325	200	238	239	237
June	25	111	264	182	212	215	210

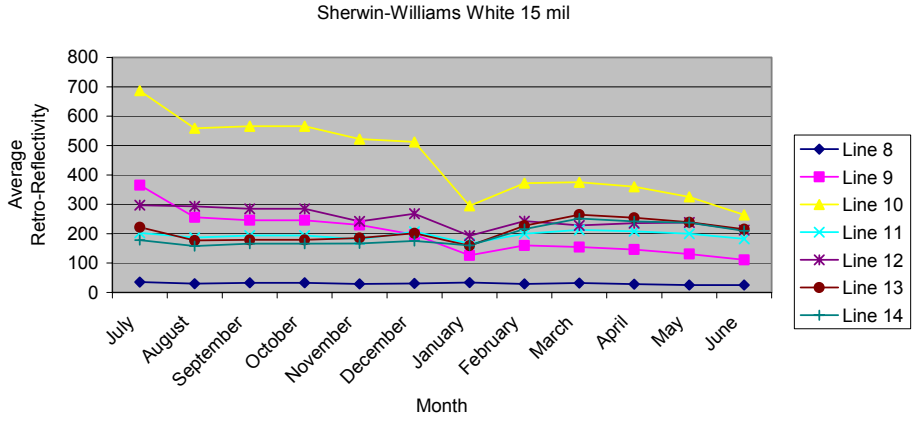
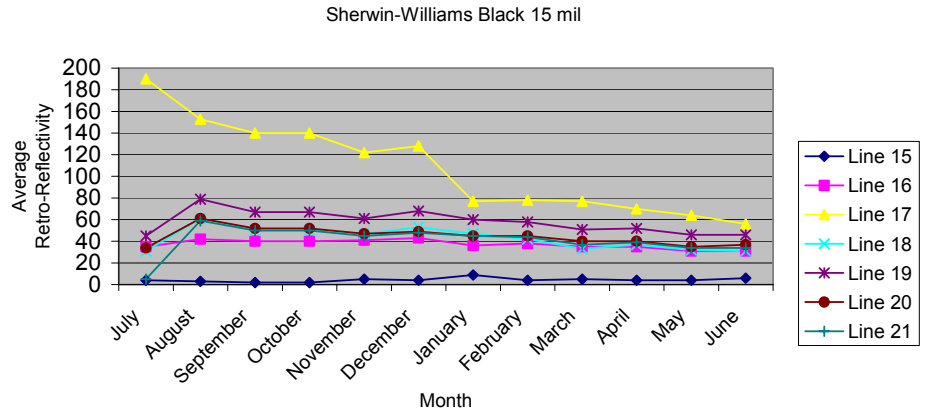


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE

	Line 15	Line 16	Line 17	Line 18	Line 19	Line 20	Line 21
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	4	35	190	31	45	34	5
August	3	42	153	61	79	61	59
September	2	40	140	50	67	52	50
October	2	40	140	50	67	52	50
November	5	41	122	47	61	47	45
December	4	43	128	53	68	49	48
January	9	36	77	47	60	45	45
February	4	38	78	42	58	45	44
March	5	35	77	33	51	40	37
April	4	35	70	37	52	40	39
May	4	31	64	32	46	35	34
June	6	31	56	31	46	37	34



	Line 64	Line 65	Line 66	Line 67	Line 68	Line 69	Line 70
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	25	60	628	98	145	135	79
August	21	48	427	67	73	92	48
September	19	44	379	52	65	70	41
October	19	44	379	52	65	70	41
November	20	42	254	41	45	56	36
December	21	40	225	39	47	48	36
January	22	31	94	30	33	35	29
February	18	26	95	26	32	32	26
March	19	25	66	24	29	30	23
April	16	22	71	22	26	27	23
May	14	19	61	18	22	24	19
June	16	20	50	19	23	24	19

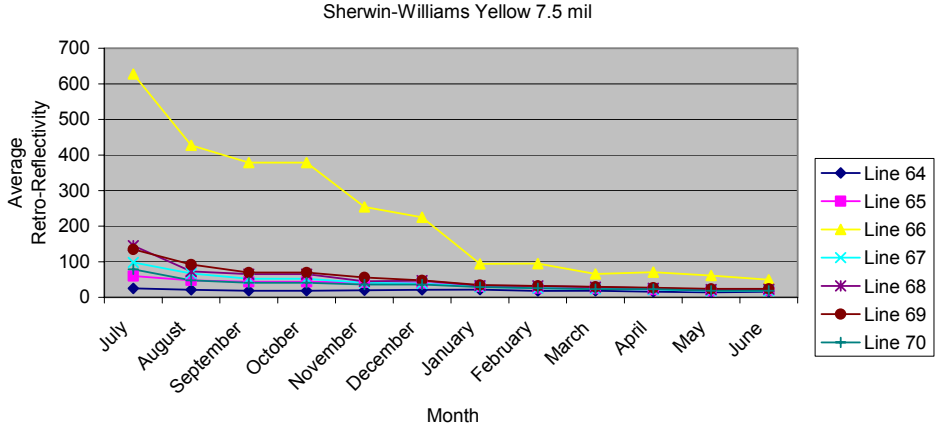
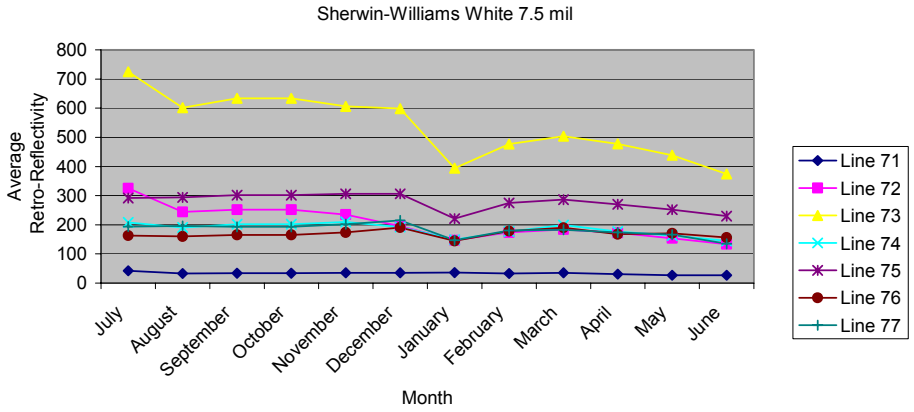


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 71	Line 72	Line 73	Line 74	Line 75	Line 76	Line 77
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	42	325	725	208	292	163	194
August	33	244	602	191	294	160	196
September	34	252	634	202	302	165	193
October	34	252	634	202	302	165	193
November	35	235	606	210	306	174	202
December	35	195	599	192	306	191	215
January	36	147	394	149	221	145	147
February	33	174	477	177	275	178	181
March	35	184	504	199	286	190	183
April	31	172	478	177	270	168	174
May	27	154	439	163	252	171	166
June	27	133	374	145	230	156	135



	Line 78	Line 79	Line 80	Line 81	Line 82	Line 83	Line 84
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	5	37	174	42	52	35	35
August	9	55	167	64	87	71	64
September	2	46	143	53	78	57	53
October	2	46	143	53	78	57	53
November	6	44	123	57	73	55	49
December	3	40	115	53	73	51	36
January	8	41	102	49	72	53	44
February	5	43	107	45	67	49	37
March	5	40	98	36	51	38	30
April	5	37	91	38	56	41	34
May	4	33	88	32	48	34	28
June	6	34	79	37	52	40	32

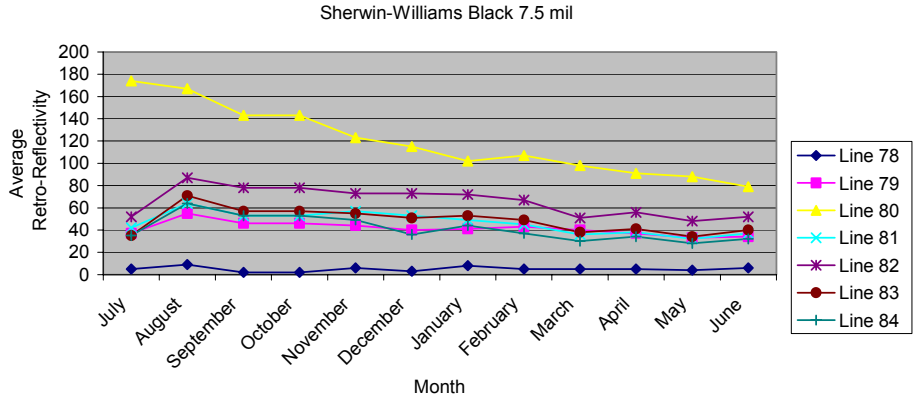
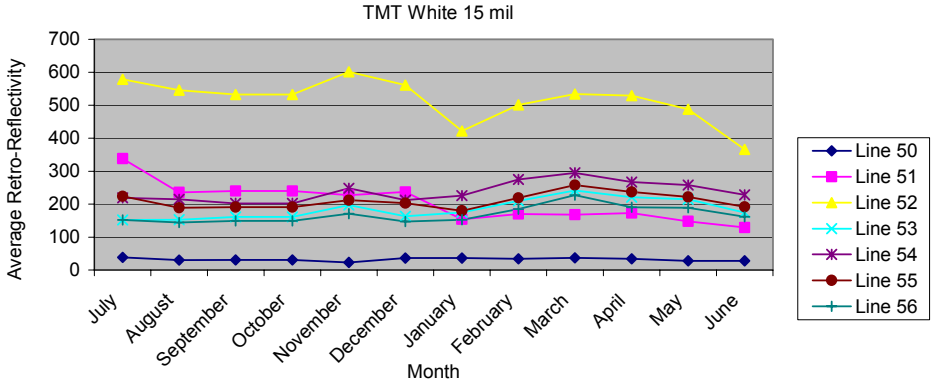


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 50	Line 51	Line 52	Line 53	Line 54	Line 55	Line 56
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	38	338	579	152	219	224	152
August	30	236	546	153	215	189	144
September	31	240	533	161	202	191	149
October	31	240	533	161	202	191	149
November	23	227	602	197	248	212	171
December	36	237	561	163	212	203	147
January	36	154	422	175	226	180	153
February	34	170	501	210	275	219	185
March	37	168	534	241	295	258	227
April	34	173	529	221	267	237	190
May	28	148	488	215	258	222	189
June	28	129	366	174	228	192	162



	Line 57	Line 58	Line 59	Line 60	Line 61	Line 62	Line 63
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	6	27	105	29	38	26	35
August	4	29	84	38	49	31	56
September	5	34	93	34	44	28	46
October	5	34	93	34	44	28	46
November	5	31	94	36	47	31	49
December	4	29	72	36	46	33	57
January	9	31	64	38	50	33	48
February	5	31	65	37	51	32	48
March	4	35	69	36	52	34	43
April	3	31	58	33	47	30	43
May	3	29	51	30	42	27	39
June	6	27	45	28	40	26	36

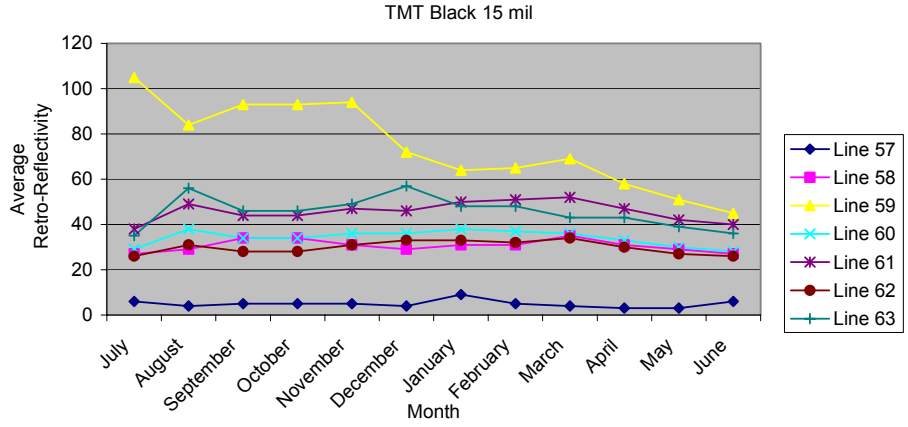
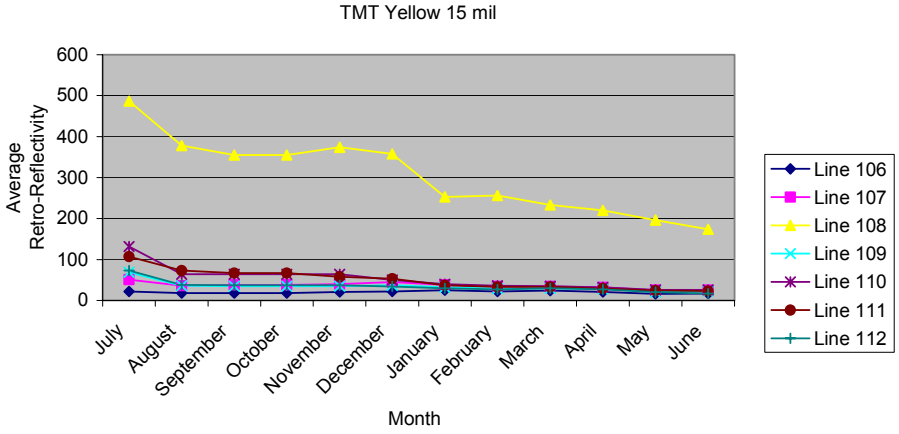


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 106	Line 107	Line 108	Line 109	Line 110	Line 111	Line 112
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	22	51	487	69	132	107	73
August	18	36	378	36	64	73	38
September	18	38	355	35	64	67	37
October	18	38	355	35	64	67	37
November	21	40	374	35	64	58	37
December	22	45	358	37	50	53	34
January	25	38	253	32	40	37	30
February	22	34	256	29	36	33	27
March	24	34	233	30	35	33	30
April	21	32	220	28	32	29	27
May	16	25	196	21	26	24	20
June	17	25	174	23	26	23	17



	Line 113	Line 114	Line 115	Line 116	Line 117	Line 118	Line 119
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	38	263	601	243	332	194	199
August	36	207	533	204	284	191	193
September	32	209	533	200	311	194	199
October	32	209	533	200	311	194	199
November	25	215	646	183	320	216	187
December	38	198	577	173	301	216	197
January	38	144	426	84	169	182	110
February	36	159	507	82	174	196	108
March	38	172	526	87	181	192	114
April	36	164	503	82	165	194	100
May	29	139	467	68	147	182	88
June	28	127	403	63	128	157	76

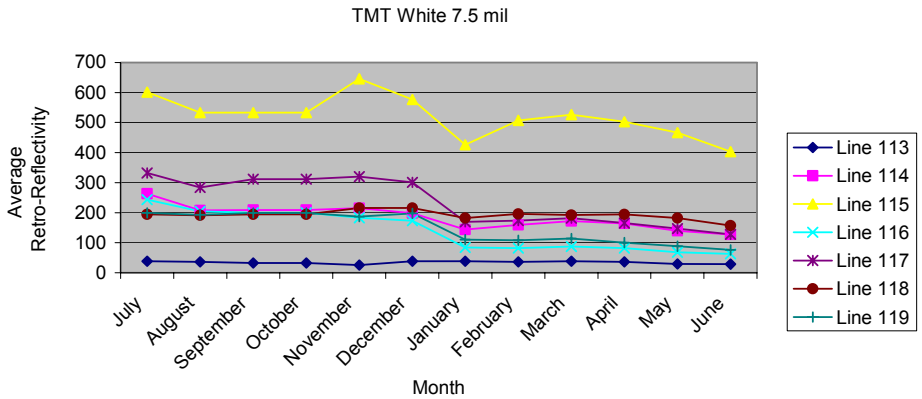
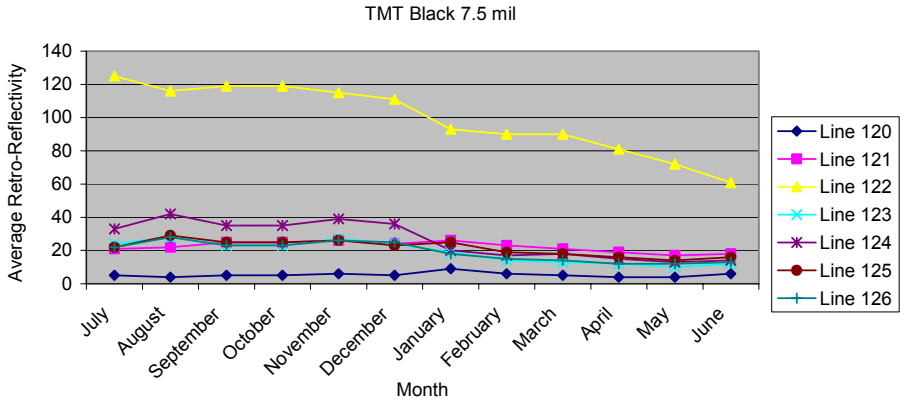


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 120	Line 121	Line 122	Line 123	Line 124	Line 125	Line 126
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	5	21	125	24	33	22	22
August	4	22	116	28	42	29	28
September	5	25	119	23	35	25	23
October	5	25	119	23	35	25	23
November	6	26	115	27	39	26	26
December	5	24	111	24	36	23	25
January	9	26	93	19	20	25	18
February	6	23	90	14	17	19	15
March	5	21	90	13	18	18	14
April	4	19	81	12	15	16	12
May	4	17	72	10	13	14	12
June	6	18	61	12	14	16	13



	Line 22	Line 23	Line 24	Line 25	Line 26	Line 27	Line 28
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	30	221	445	257	363	297	278
August	27	197	401	251	342	281	261
September	29	207	416	248	349	272	261
October	29	207	416	248	349	272	261
November	17	205	437	254	369	287	267
December	27	208	365	239	333	274	256
January	29	164	306	197	284	219	216
February	27	189	351	223	331	257	250
March	28	199	365	233	349	272	263
April	25	192	341	221	323	252	251
May	22	174	311	213	306	242	233
June	21	155	261	181	260	203	201

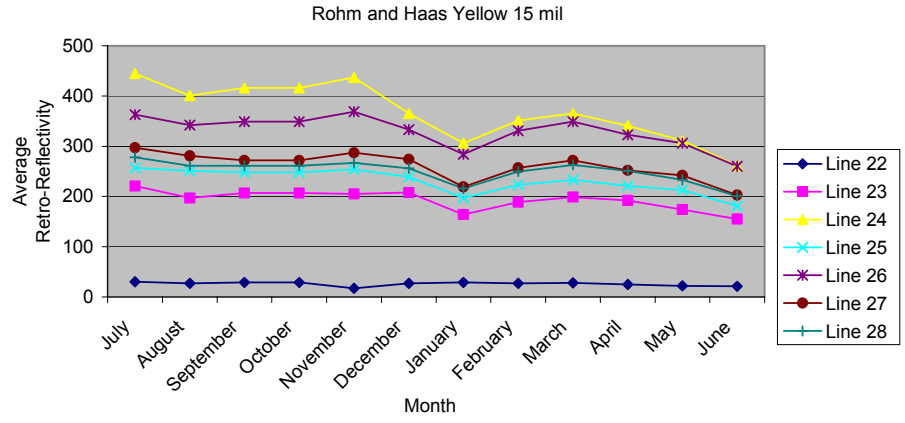
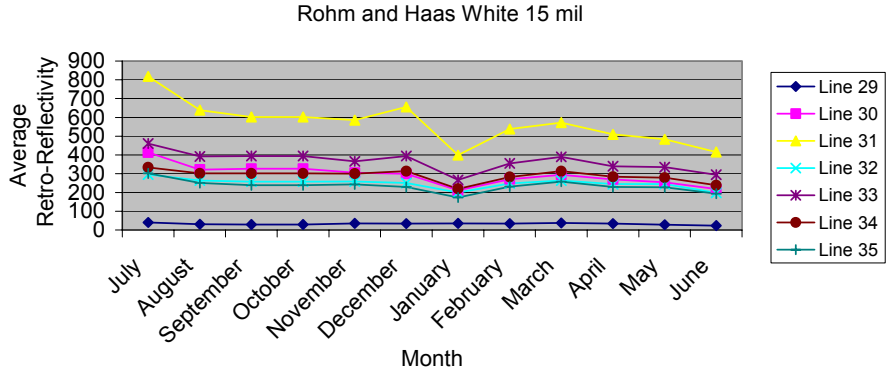


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 29	Line 30	Line 31	Line 32	Line 33	Line 34	Line 35
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	40	413	818	296	461	334	301
August	31	322	639	263	392	301	250
September	30	326	602	258	394	301	239
October	30	326	602	258	394	301	239
November	36	305	585	259	366	300	243
December	34	299	655	251	394	313	229
January	36	211	399	200	267	220	173
February	35	271	538	248	355	282	231
March	38	295	572	264	389	313	258
April	34	269	509	245	339	284	229
May	28	254	483	244	335	279	228
June	24	218	416	198	294	239	193



	Line 36	Line 37	Line 38	Line 39	Line 40	Line 41	Line 42
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	37	375	635	288	385	351	280
August	28	276	532	224	309	242	193
September	29	290	567	248	343	251	219
October	29	290	567	248	343	251	219
November	34	268	534	214	280	242	201
December	34	271	548	228	291	261	231
January	35	201	381	164	236	200	172
February	35	251	495	204	292	259	218
March	37	274	545	217	322	285	235
April	33	257	510	207	300	269	213
May	28	232	445	198	275	253	210
June	28	201	380	162	228	211	176

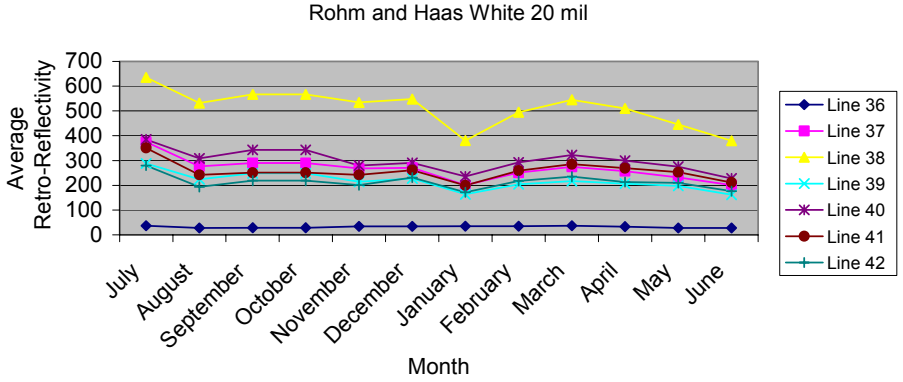
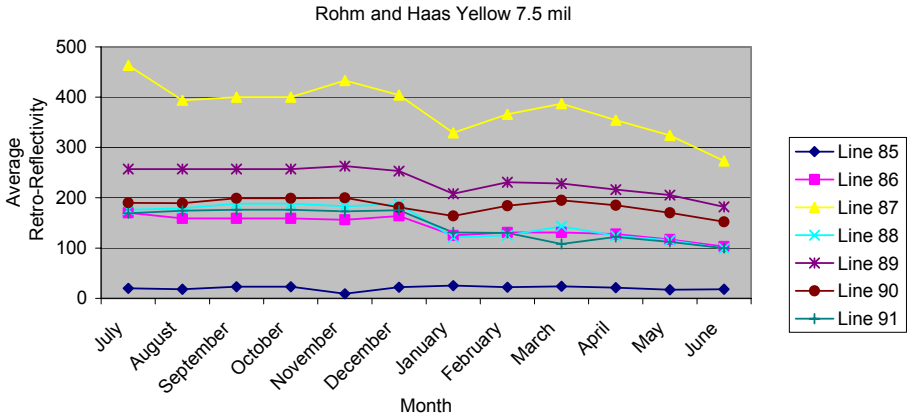


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 85	Line 86	Line 87	Line 88	Line 89	Line 90	Line 91
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	20	170	463	176	257	190	169
August	18	159	394	179	257	189	174
September	23	159	400	188	257	199	176
October	23	159	400	188	257	199	176
November	9	156	433	183	263	200	173
December	22	164	404	187	253	181	175
January	25	125	329	121	208	164	131
February	22	131	366	125	231	184	130
March	24	131	387	143	228	195	108
April	21	128	354	124	216	185	122
May	17	117	324	115	205	170	112
June	18	103	273	99	182	152	100



	Line 92	Line 93	Line 94	Line 95	Line 96	Line 97	Line 98
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	42	324	727	239	296	224	203
August	32	260	565	202	287	202	175
September	32	261	564	201	284	192	167
October	32	261	564	201	284	192	167
November	40	237	543	199	272	202	173
December	41	252	543	193	278	198	175
January	40	176	386	170	234	163	153
February	38	212	514	191	306	210	189
March	39	224	534	187	298	228	188
April	35	208	500	183	293	209	188
May	30	187	461	177	266	201	182
June	30	172	400	155	241	178	157

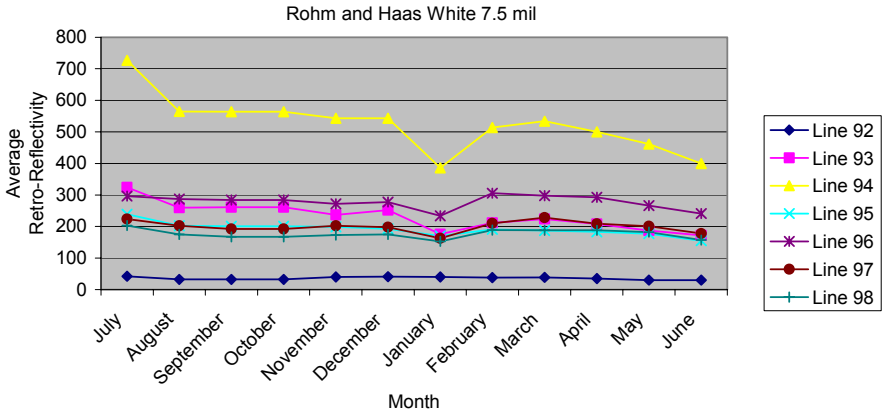


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 43	Line 44	Line 45	Line 46	Line 47	Line 48	Line 49
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	21	144	385	90	117	89	93
August	17	98	326	94	146	96	93
September	17	109	339	93	140	98	99
October	17	109	339	93	140	98	99
November	20	107	337	110	162	118	113
December	21	112	366	103	158	120	110
January	24	79	289	83	149	106	91
February	22	87	332	87	163	115	100
March	24	85	329	88	159	116	102
April	21	87	322	83	153	110	96
May	16	71	280	72	141	98	79
June	17	66	250	68	131	92	84

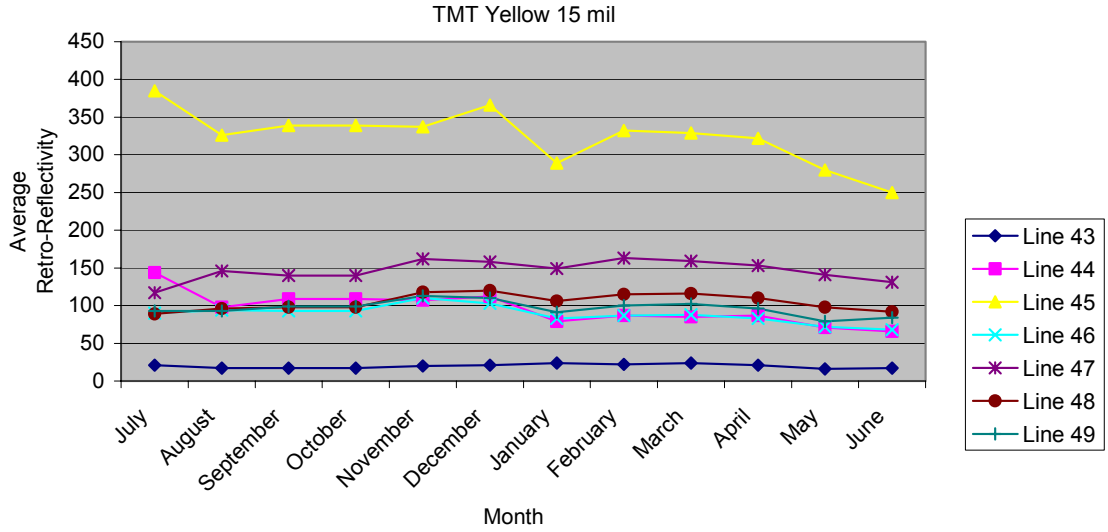
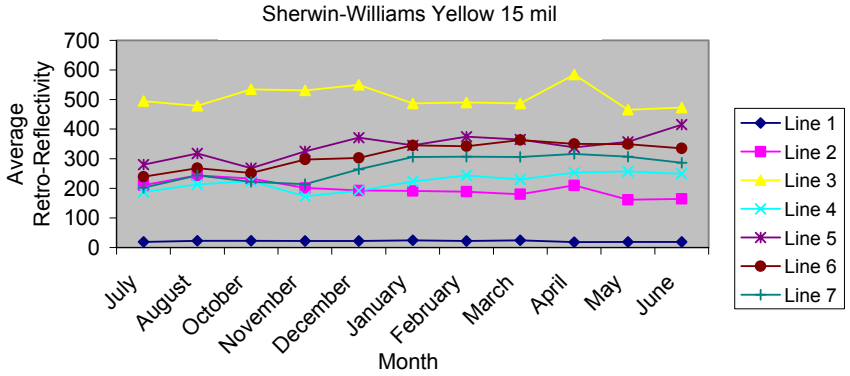


FIGURE A-12. RETRO-REFLECTIVE COMPARISON CHART AT NEWER HOT-MIX ASPHALT TEST SITE (Continued)

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	19	211	495	187	280	239	202
August	23	244	479	213	318	268	244
October	23	233	535	224	268	252	222
November	22	201	531	173	325	297	214
December	22	193	550	192	371	303	264
January	24	191	487	223	345	345	306
February	22	189	490	244	374	342	307
March	24	180	487	230	365	363	306
April	18	210	584	253	338	350	316
May	19	161	466	257	357	349	307
June	19	164	473	249	415	335	286



	Line 8	Line 9	Line 10	Line 11	Line 12	Line 13	Line 14
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	80	350	568	359	273	279	262
August	36	373	653	380	282	314	267
October	37	425	701	301	380	432	312
November	38	402	659	282	387	343	298
December	39	359	712	300	391	402	319
January	36	379	735	335	382	489	405
February	36	360	700	386	434	547	424
March	37	375	700	387	417	553	434
April	33	390	839	398	473	544	426
May	34	341	671	429	442	541	441
June	35	338	800	486	403	552	461

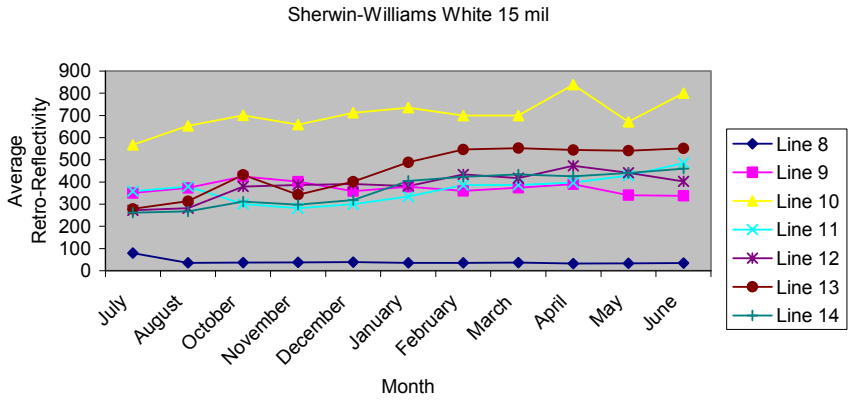
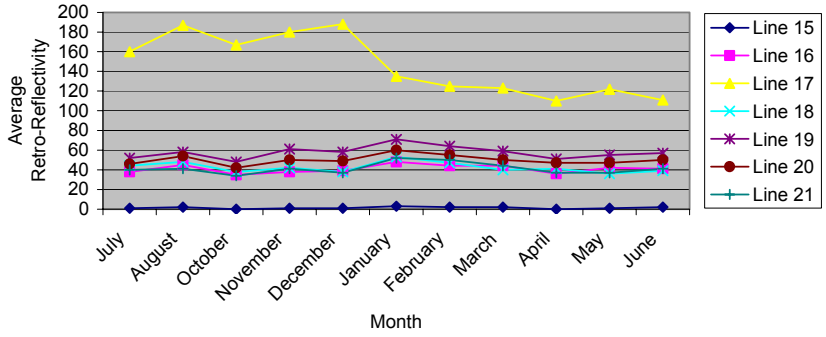


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART
(September readings are not included due to September 11th)

	Line 15	Line 16	Line 17	Line 18	Line 19	Line 20	Line 21
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	1	38	160	44	52	46	40
August	2	45	187	48	58	54	41
October	0	35	167	38	48	42	34
November	1	38	180	42	61	50	41
December	1	39	188	38	58	49	37
January	3	48	135	53	71	60	52
February	2	44	125	47	64	55	50
March	2	44	123	40	59	50	44
April	0	36	110	41	51	47	37
May	1	42	122	36	55	47	37
June	2	41	111	39	57	50	41

Sherwin-Williams Black 15 mil



	Line 64	Line 65	Line 66	Line 67	Line 68	Line 69	Line 70
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	25	66	518	46	77	134	92
August	28	75	517	45	81	135	75
October	27	78	566	33	62	119	48
November	26	70	439	38	51	128	37
December	28	71	444	34	48	110	36
January	27	73	374	31	34	83	31
February	26	68	331	31	32	69	26
March	28	70	362	32	33	55	26
April	24	57	459	24	34	67	26
May	24	64	346	26	28	54	26
June	23	54	351	25	28	48	26

Sherwin-Williams Yellow 7.5 mil

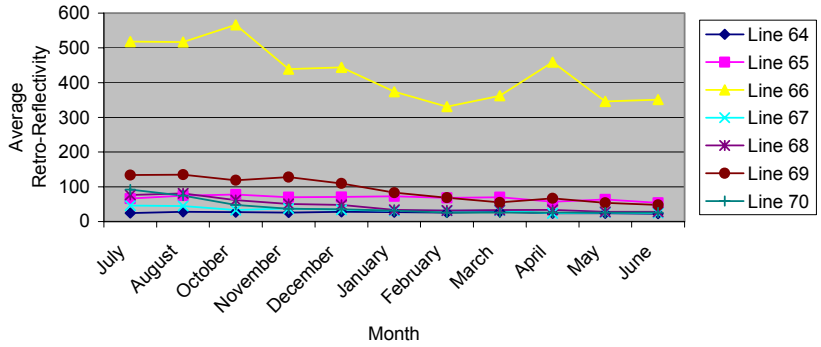
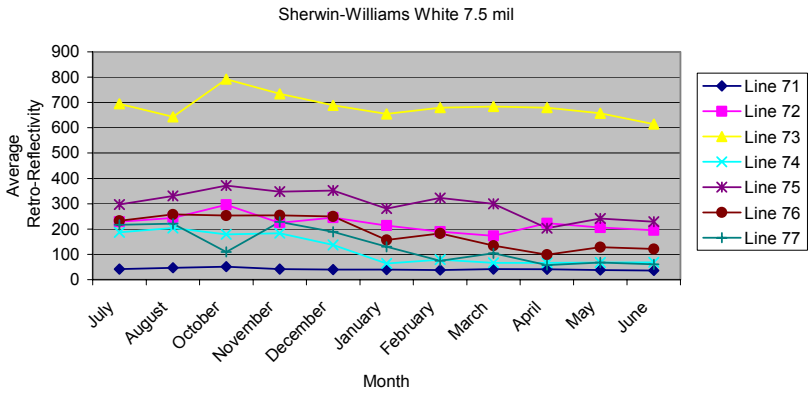


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 71	Line 72	Line 73	Line 74	Line 75	Line 76	Line 77
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	42	229	695	187	297	233	217
August	47	244	643	204	331	258	221
October	52	296	792	179	372	253	110
November	42	225	734	184	348	254	228
December	40	245	689	137	352	250	189
January	40	214	655	64	281	157	130
February	38	190	680	79	323	183	75
March	42	173	684	67	300	135	104
April	41	223	680	67	203	99	58
May	38	206	657	68	242	128	68
June	37	195	615	69	229	121	61



	Line 78	Line 79	Line 80	Line 81	Line 82	Line 83	Line 84
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	3	22	165	23	37	27	24
August	3	27	167	26	40	31	25
October	2	21	169	21	43	30	35
November	2	16	182	17	50	34	30
December	2	15	146	18	54	29	29
January	4	18	106	18	51	38	26
February	4	18	110	11	41	32	30
March	4	18	107	8	33	27	21
April	2	17	117	12	36	31	25
May	5	16	97	7	34	24	21
June	4	16	98	8	41	32	19

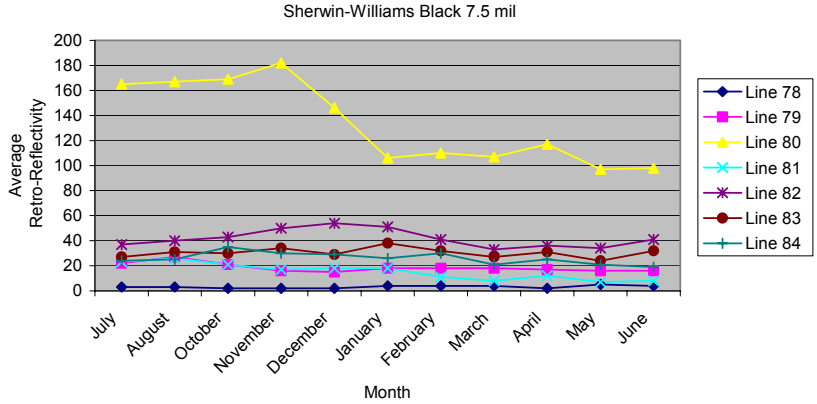
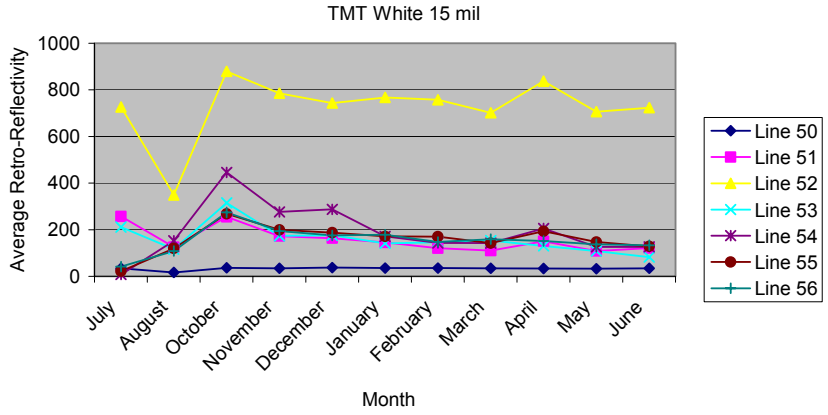


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 50	Line 51	Line 52	Line 53	Line 54	Line 55	Line 56
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	35	257	727	212	8	22	42
August	17	126	349	117	153	120	109
October	37	255	879	315	446	268	274
November	35	173	785	174	276	200	195
December	38	164	744	177	287	188	176
January	36	146	767	142	172	172	179
February	36	121	757	147	144	171	148
March	35	111	702	154	143	143	160
April	34	151	837	131	206	194	152
May	33	109	707	109	127	148	138
June	35	122	724	83	127	129	134



	Line 57	Line 58	Line 59	Line 60	Line 61	Line 62	Line 63
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	2	25	202	26	36	28	29
August	1	12	87	13	18	15	14
October	1	30	148	29	35	31	28
November	0	30	160	32	34	31	28
December	1	24	183	24	33	32	28
January	3	28	106	27	26	39	35
February	2	27	132	20	22	39	32
March	2	24	124	15	25	29	26
April	2	22	100	22	23	30	26
May	2	23	107	14	18	27	22
June	2	20	87	14	17	26	22

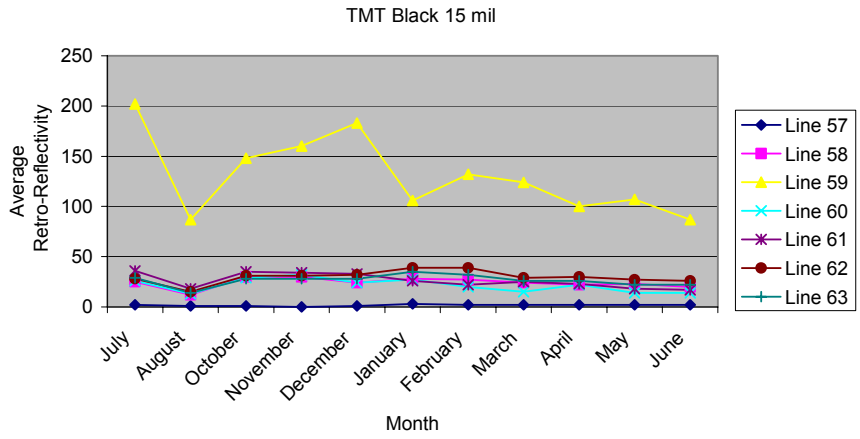
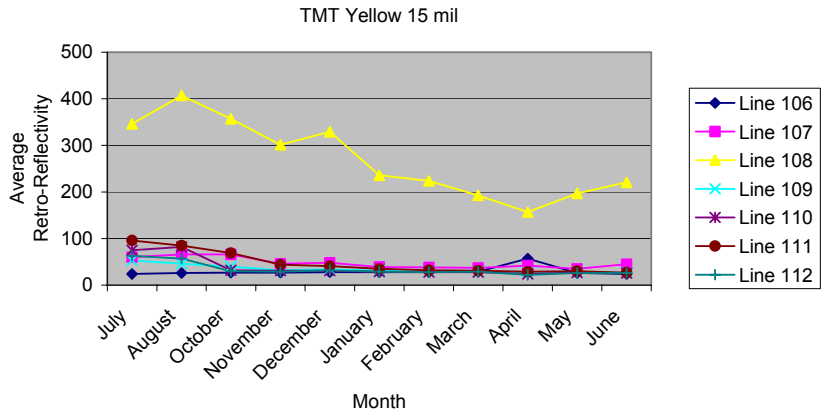


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 106	Line 107	Line 108	Line 109	Line 110	Line 111	Line 112
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	24	60	346	53	75	96	63
August	26	66	407	46	82	85	57
October	27	66	357	40	32	69	30
November	27	46	301	32	31	44	29
December	28	48	329	34	31	41	32
January	28	39	236	31	29	35	29
February	28	38	224	29	28	32	28
March	29	37	193	29	28	31	29
April	57	42	157	27	24	29	22
May	26	35	197	28	27	30	26
June	24	45	221	27	26	27	26



	Line 113	Line 114	Line 115	Line 116	Line 117	Line 118	Line 119
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	13	70	318	99	160	176	176
August	19	70	267	66	136	94	79
October	44	168	623	77	123	240	100
November	42	118	666	56	145	163	111
December	44	109	465	59	131	171	96
January	41	81	570	44	60	73	51
February	42	80	431	40	51	69	46
March	42	80	413	42	54	68	52
April	41	111	681	50	65	92	45
May	37	72	416	36	45	61	42
June	35	74	442	37	44	62	41

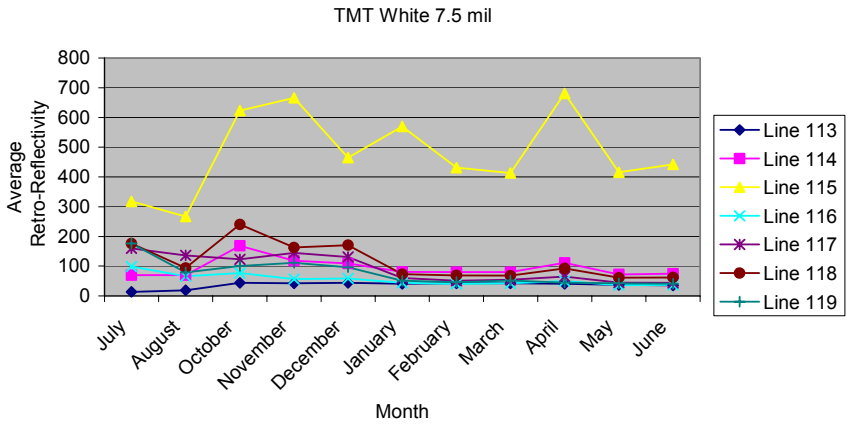
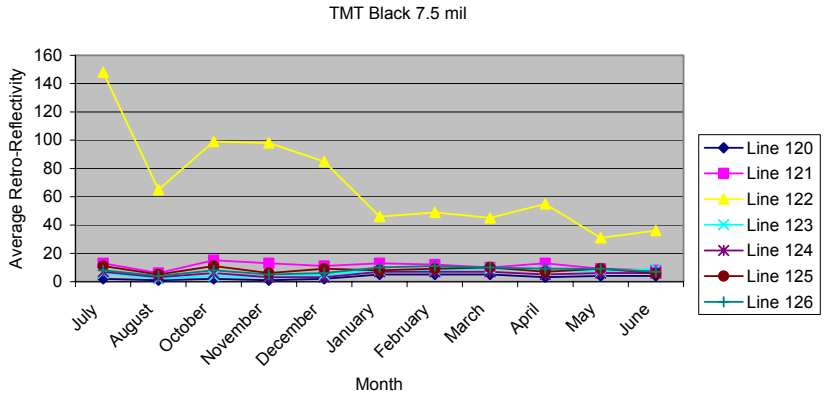


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 120	Line 121	Line 122	Line 123	Line 124	Line 125	Line 126
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	2	13	148	6	7	11	8
August	1	6	65	2	3	5	4
October	2	15	99	4	6	11	8
November	1	13	98	3	3	6	5
December	2	11	85	5	3	9	6
January	5	13	46	8	7	8	10
February	5	12	49	8	7	9	11
March	5	10	45	9	7	10	10
April	3	13	55	8	5	7	9
May	4	9	31	7	6	9	9
June	4	8	36	9	6	6	7



	Line 22	Line 23	Line 24	Line 25	Line 26	Line 27	Line 28
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	259	137	478	139	256	201	175
August	12	64	215	63	138	106	82
October	27	132	525	161	303	210	184
November	22	111	451	111	272	208	165
December	26	125	529	84	233	201	156
January	23	110	439	125	270	120	186
February	26	105	459	80	235	163	143
March	27	115	438	80	212	153	129
April	27	116	502	140	320	236	229
May	23	126	459	88	210	169	109
June	22	128	445	86	252	137	145

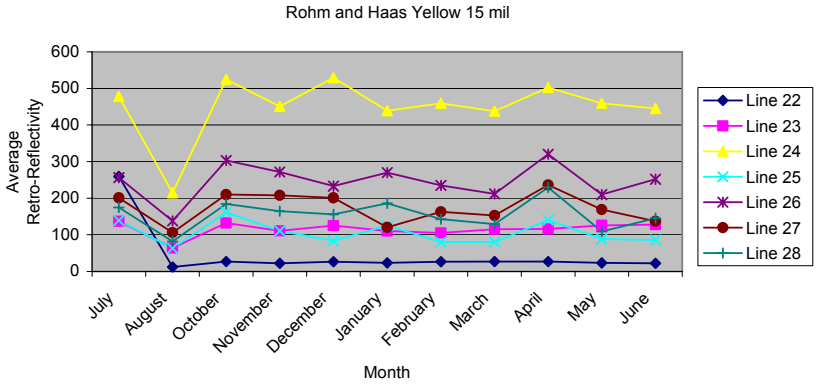
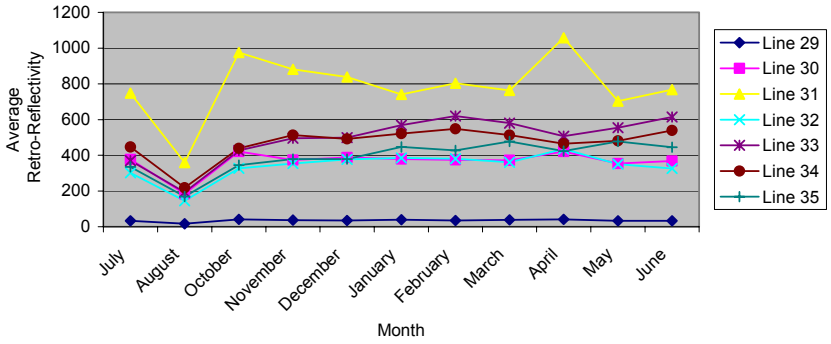


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 29	Line 30	Line 31	Line 32	Line 33	Line 34	Line 35
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	33	377	748	301	370	447	335
August	17	185	359	145	194	218	169
October	41	421	975	327	427	439	345
November	37	373	882	354	496	513	378
December	35	388	838	377	499	492	378
January	40	379	741	385	569	521	447
February	35	375	804	381	620	548	428
March	39	372	763	361	580	514	478
April	41	421	1057	435	507	464	424
May	34	354	703	350	555	481	478
June	34	368	767	326	615	539	445

Rohm and Haas White 15 mil



	Line 36	Line 37	Line 38	Line 39	Line 40	Line 41	Line 42
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	25	396	771	527	695	504	538
August	13	183	350	242	314	234	242
October	24	408	848	474	658	440	464
November	33	392	862	522	791	538	643
December	30	435	974	664	856	649	656
January	33	386	863	533	748	524	617
February	31	416	911	583	794	621	680
March	36	410	961	635	967	713	653
April	26	420	918	492	712	481	491
May	28	404	930	715	904	709	666
June	31	398	890	581	870	631	661

Rohm and Haas White 20 mil

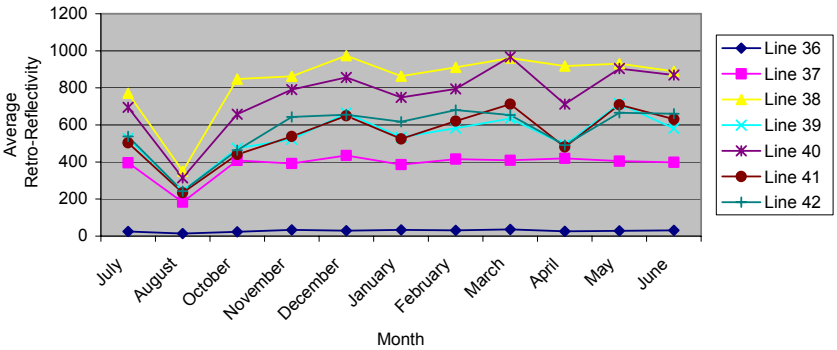
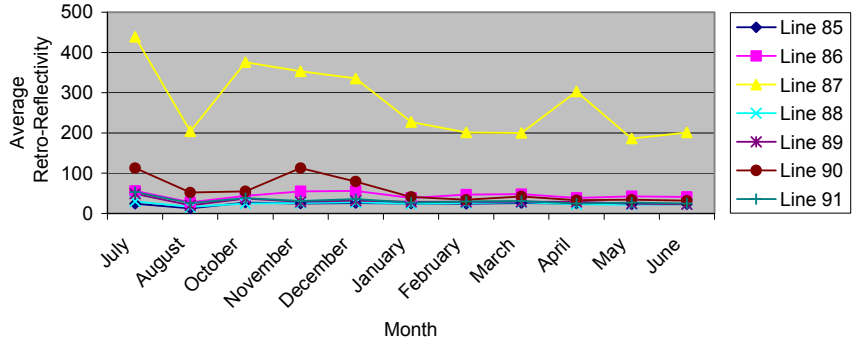


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 85	Line 86	Line 87	Line 88	Line 89	Line 90	Line 91
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	24	56	439	30	49	113	53
August	13	28	204	16	20	52	26
October	27	44	376	25	37	55	38
November	25	55	353	26	29	113	31
December	26	56	335	28	32	79	36
January	25	39	227	24	29	41	27
February	24	47	201	26	29	34	30
March	26	48	200	28	29	42	31
April	25	39	303	23	29	33	25
May	23	43	186	22	24	34	27
June	23	41	201	23	23	32	25

Rohm and Haas Yellow 7.5 mil



	Line 92	Line 93	Line 94	Line 95	Line 96	Line 97	Line 98
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	46	146	816	189	344	239	169
August	23	119	382	79	148	113	78
October	50	143	702	104	200	205	89
November	46	117	800	91	273	288	79
December	44	117	845	143	153	218	67
January	44	86	671	120	146	222	64
February	42	104	702	139	97	191	66
March	44	86	574	124	91	185	48
April	43	112	596	87	124	177	51
May	40	76	537	123	65	144	47
June	38	86	623	95	81	142	56

Rohm and Haas White 7.5 mil

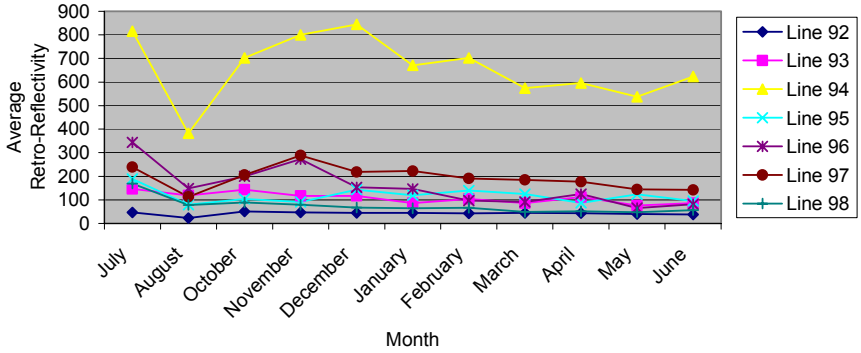


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 43	Line 44	Line 45	Line 46	Line 47	Line 48	Line 49
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	21	140	367	76	112	99	84
August	24	157	402	83	131	110	89
October	24	146	435	99	153	116	104
November	26	122	381	91	182	116	108
December	25	130	355	70	162	112	99
January	29	107	310	50	92	77	64
February	28	97	356	52	97	77	44
March	29	94	342	46	75	66	38
April	25	89	272	31	74	71	57
May	26	96	346	46	69	52	36
June	25	86	288	40	59	45	46

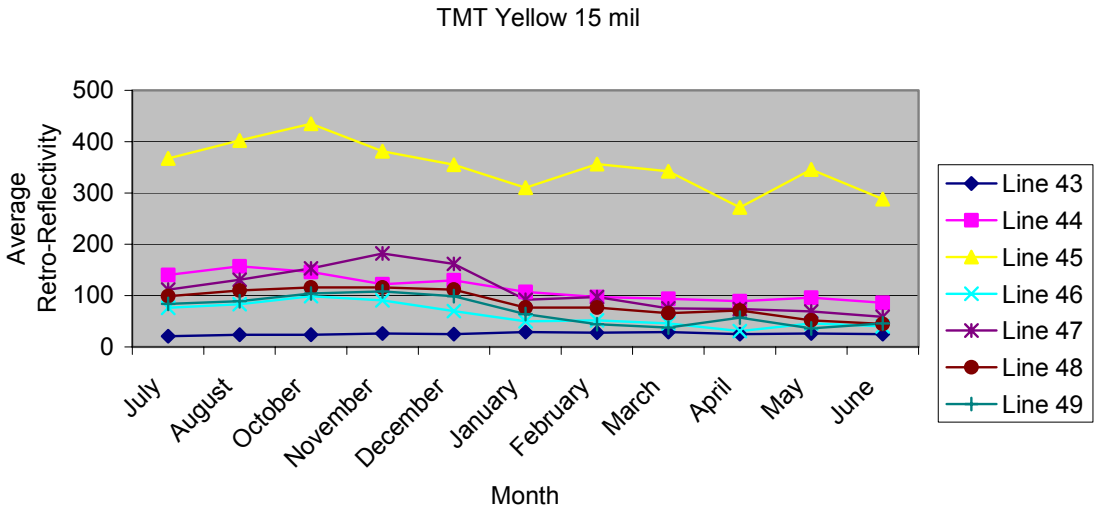
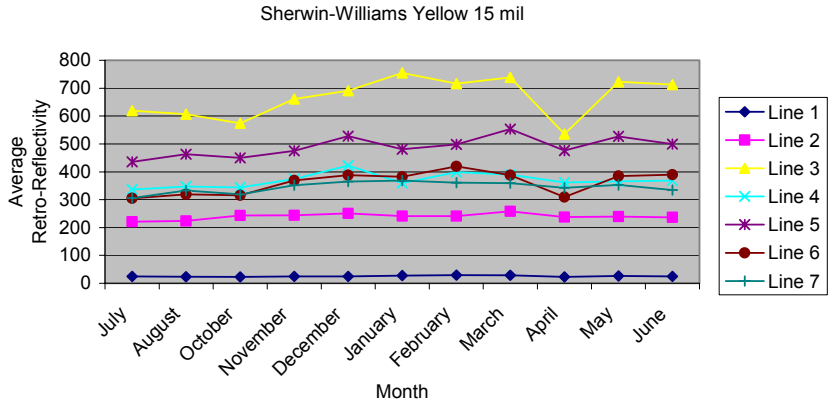


FIGURE A-13. TAXIWAY HOTEL RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	25	221	619	336	436	305	306
August	24	224	607	347	463	319	333
October	23	243	574	344	450	316	319
November	25	244	661	374	475	369	352
December	25	251	691	423	528	388	365
January	28	241	755	359	481	382	368
February	30	241	716	399	498	419	361
March	29	258	738	390	553	388	359
April	23	238	535	362	476	309	343
May	26	239	723	366	527	385	353
June	25	237	713	368	499	390	335



	Line 8	Line 9	Line 10	Line 11	Line 12	Line 13	Line 14
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	50	388	1047	462	460	517	470
August	46	393	1058	490	608	518	488
October	41	409	1001	564	661	530	509
November	42	367	1150	524	657	583	587
December	44	399	1308	534	739	627	582
January	47	356	1071	584	683	500	536
February	48	370	1205	605	691	609	604
March	47	373	802	610	729	576	585
April	41	383	973	548	639	547	583
May	44	359	1230	606	681	483	580
June	42	345	1189	530	602	466	536

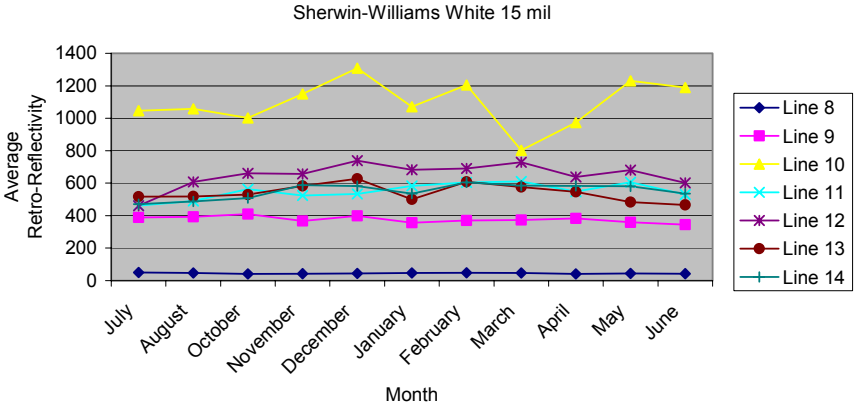
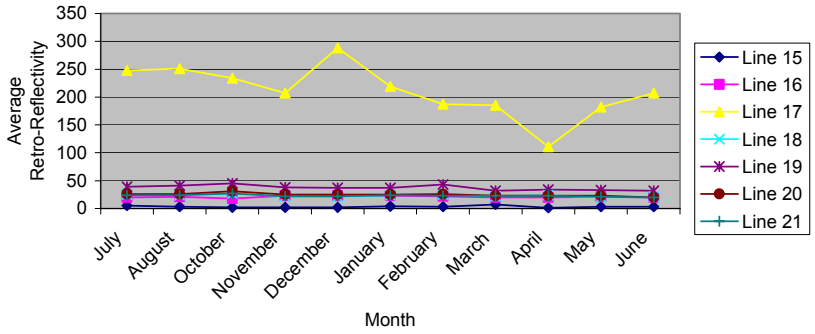


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART
(September readings are not included due to September 11th)

	Line 15	Line 16	Line 17	Line 18	Line 19	Line 20	Line 21
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	5	20	248	25	39	26	24
August	3	21	251	24	41	26	24
October	2	18	234	27	45	31	27
November	2	23	207	22	38	25	22
December	2	23	288	21	37	25	22
January	4	23	219	24	37	25	24
February	3	22	187	25	43	26	23
March	7	20	185	22	32	23	23
April	1	20	111	24	34	23	23
May	3	21	182	20	33	23	21
June	3	20	207	21	32	20	20

Sherwin-Williams Black 15 mil



	Line 64	Line 65	Line 66	Line 67	Line 68	Line 69	Line 70
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	31	160	729	257	337	243	214
August	31	169	769	269	354	236	225
October	32	176	855	316	391	311	242
November	27	157	779	286	346	253	183
December	31	176	784	295	339	272	204
January	32	151	762	252	307	210	163
February	33	145	649	242	262	212	167
March	37	132	705	234	283	207	160
April	30	167	727	338	473	298	273
May	31	171	612	226	264	207	161
June	28	154	695	243	292	194	151

Sherwin-Williams Yellow 7.5 mil

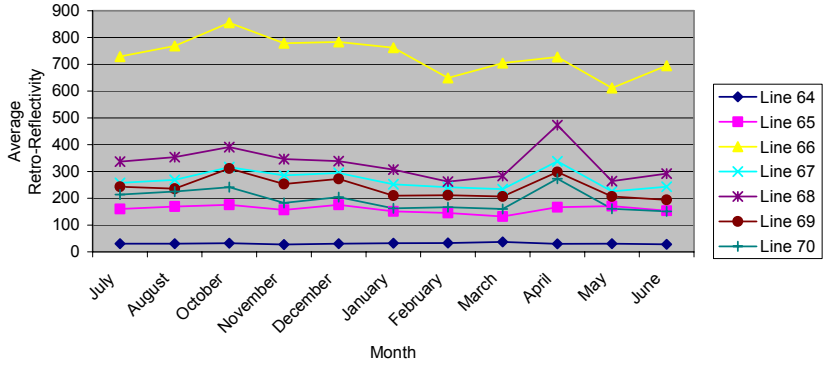
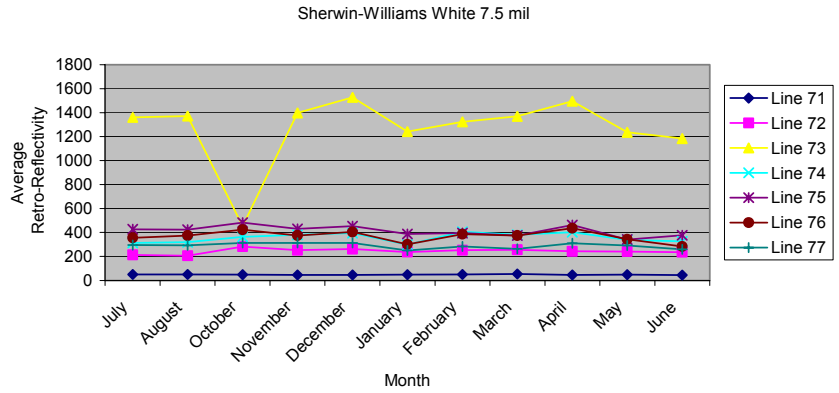


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 71	Line 72	Line 73	Line 74	Line 75	Line 76	Line 77
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	51	214	1360	314	427	357	295
August	50	206	1372	320	424	374	293
October	49	282	452	364	483	424	314
November	46	252	1397	380	431	374	313
December	47	262	1528	395	452	405	314
January	48	237	1241	299	387	300	250
February	51	252	1323	406	396	386	284
March	53	257	1369	381	375	374	263
April	46	243	1495	403	462	436	310
May	49	241	1235	337	341	344	291
June	45	235	1183	326	377	284	259



	Line 78	Line 79	Line 80	Line 81	Line 82	Line 83	Line 84
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	3	10	231	18	15	12	10
August	2	10	235	14	12	12	10
October	2	9	219	14	10	11	9
November	2	9	187	10	8	9	5
December	2	8	186	11	13	9	7
January	6	10	98	13	8	10	9
February	4	11	74	8	7	8	7
March	3	9	105	8	7	7	6
April	1	7	85	9	8	8	6
May	3	9	85	8	6	8	5
June	5	8	75	9	5	6	5

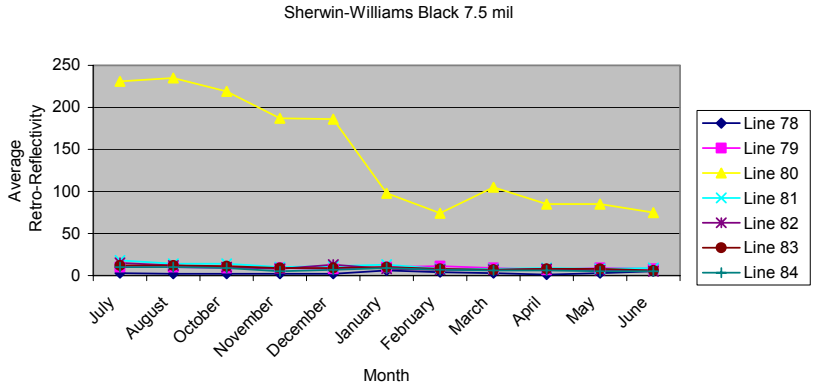
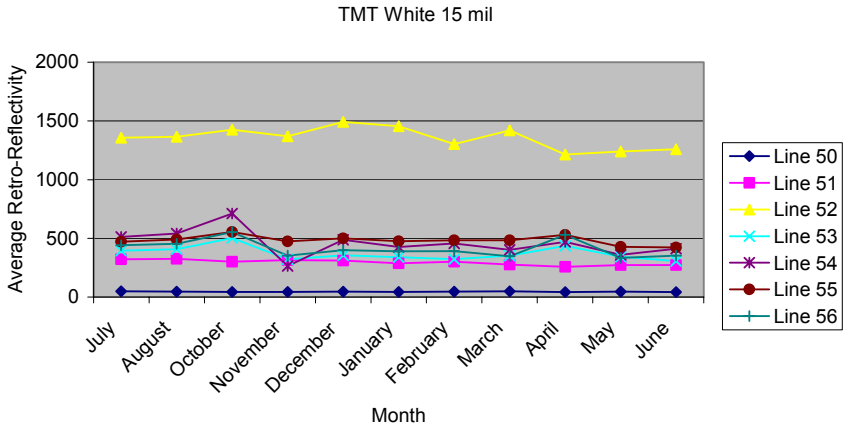


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 50	Line 51	Line 52	Line 53	Line 54	Line 55	Line 56
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	50	322	1356	395	513	473	443
August	47	325	1365	409	540	491	454
October	44	302	1425	503	711	554	553
November	45	316	1368	322	265	475	354
December	47	311	1491	356	488	501	400
January	44	287	1456	340	426	477	389
February	47	301	1303	323	457	484	392
March	50	278	1419	353	403	485	347
April	42	257	1215	437	471	531	531
May	47	274	1241	344	360	428	333
June	43	274	1259	308	413	422	353



	Line 57	Line 58	Line 59	Line 60	Line 61	Line 62	Line 63
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	3	21	405	18	17	24	32
August	3	21	397	18	18	23	30
October	3	20	344	15	17	21	24
November	2	21	390	14	16	22	26
December	2	23	344	18	17	21	30
January	5	20	153	11	16	14	16
February	4	20	159	11	15	14	21
March	3	19	109	9	12	13	15
April	1	15	154	12	14	19	16
May	2	17	110	6	9	11	10
June	2	15	105	8	9	10	12

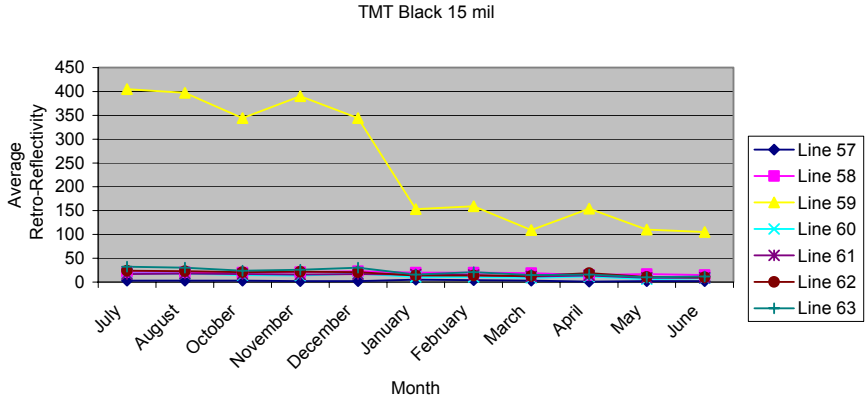
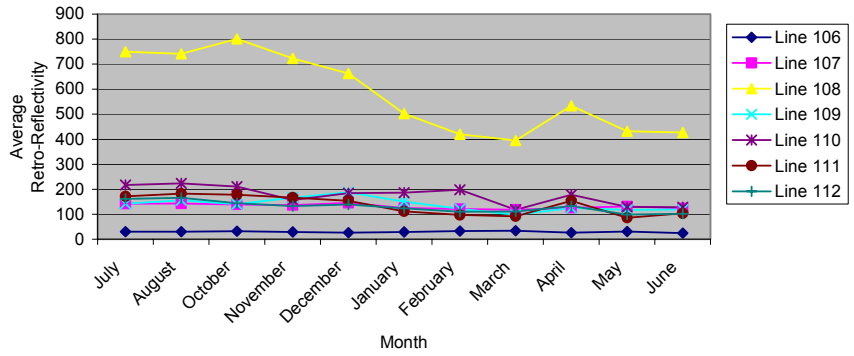


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 106	Line 107	Line 108	Line 109	Line 110	Line 111	Line 112
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	30	142	750	142	217	171	161
August	30	143	741	156	224	182	166
October	32	139	801	140	211	178	144
November	29	137	723	167	157	167	133
December	27	146	663	188	184	154	139
January	29	125	502	150	186	112	124
February	33	121	420	122	198	97	110
March	34	118	395	98	118	92	111
April	27	126	533	125	178	154	133
May	31	131	432	117	129	86	99
June	25	124	427	119	128	104	102

TMT Yellow 15 mil



	Line 113	Line 114	Line 115	Line 116	Line 117	Line 118	Line 119
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	52	147	1164	165	144	156	148
August	49	153	1167	168	177	185	176
October	46	176	1211	174	211	162	180
November	50	131	1354	116	185	163	182
December	49	189	1262	151	178	193	154
January	49	166	1047	124	150	160	163
February	48	176	934	102	140	158	186
March	51	133	1079	102	161	102	164
April	50	101	974	109	135	147	128
May	47	109	846	80	127	129	146
June	46	141	884	85	98	109	128

TMT White 7.5 mil

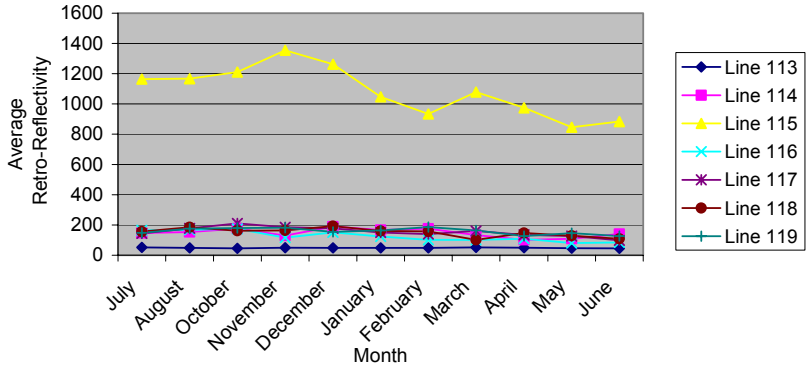
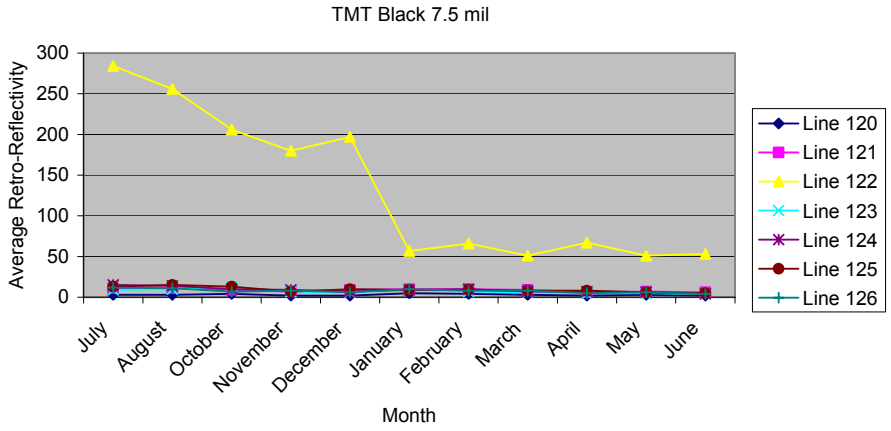


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 120	Line 121	Line 122	Line 123	Line 124	Line 125	Line 126
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	3	11	284	9	15	13	12
August	3	11	256	10	14	15	11
October	4	9	206	13	10	13	7
November	2	7	180	7	9	7	8
December	2	9	197	6	7	10	6
January	5	10	57	9	9	9	10
February	4	10	66	7	10	9	8
March	3	9	51	6	7	8	8
April	2	6	67	5	7	8	5
May	3	7	51	5	6	6	6
June	2	6	53	4	4	5	4



	Line 22	Line 23	Line 24	Line 25	Line 26	Line 27	Line 28
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	34	194	795	255	345	297	237
August	33	196	779	260	367	299	262
October	32	201	818	301	427	339	248
November	34	183	890	248	353	318	231
December	34	200	938	239	349	332	233
January	32	183	754	203	310	272	241
February	34	185	804	208	366	292	260
March	37	189	735	238	334	292	230
April	35	220	786	326	459	329	343
May	33	183	803	214	324	281	247
June	32	164	767	181	318	260	240

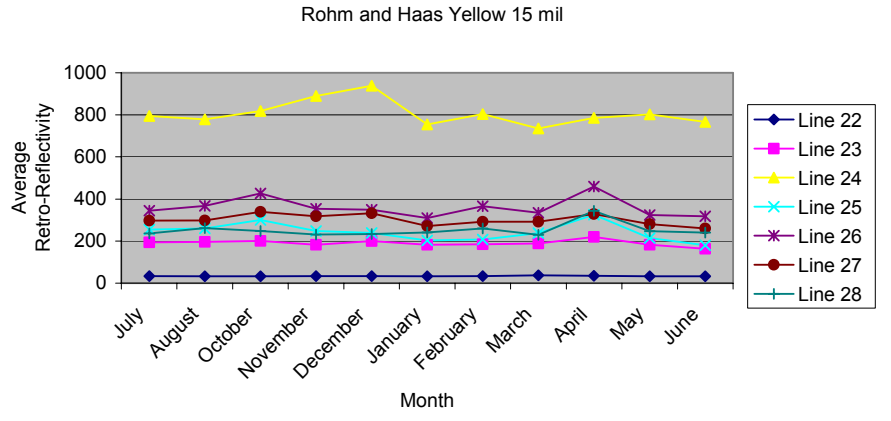
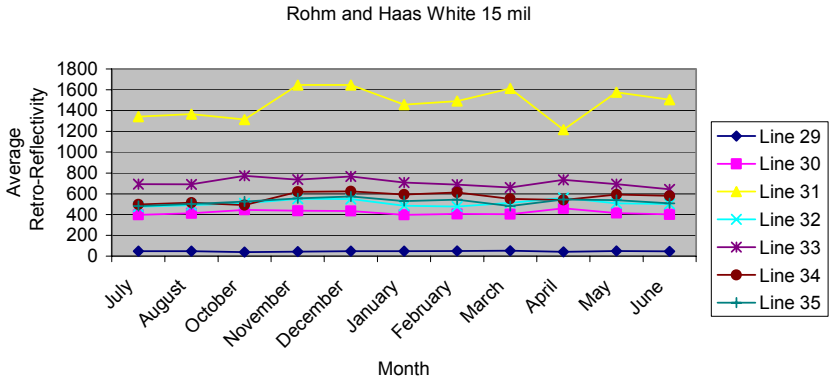


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 29	Line 30	Line 31	Line 32	Line 33	Line 34	Line 35
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	48	398	1342	475	692	498	481
August	48	412	1366	490	690	515	501
October	39	445	1314	509	773	491	526
November	44	436	1646	552	736	619	556
December	47	435	1646	549	767	623	573
January	48	398	1457	485	707	592	529
February	49	407	1491	478	689	612	543
March	53	403	1614	512	659	552	482
April	42	460	1215	561	733	541	545
May	51	414	1576	507	692	593	538
June	45	401	1505	501	643	580	508



	Line 36	Line 37	Line 38	Line 39	Line 40	Line 41	Line 42
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	149	451	1293	566	723	541	536
August	146	455	1358	579	744	557	548
October	88	483	1302	619	734	501	560
November	103	465	1560	616	831	622	547
December	84	473	1571	648	796	666	559
January	33	452	1492	613	756	599	532
February	89	432	1572	595	749	657	583
March	73	450	1722	609	787	596	565
April	102	466	1172	612	782	494	534
May	94	445	1662	593	753	579	518
June	81	429	1411	560	756	556	504

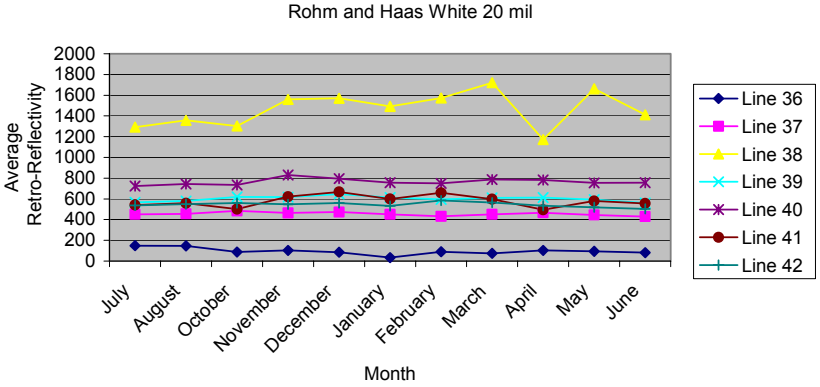
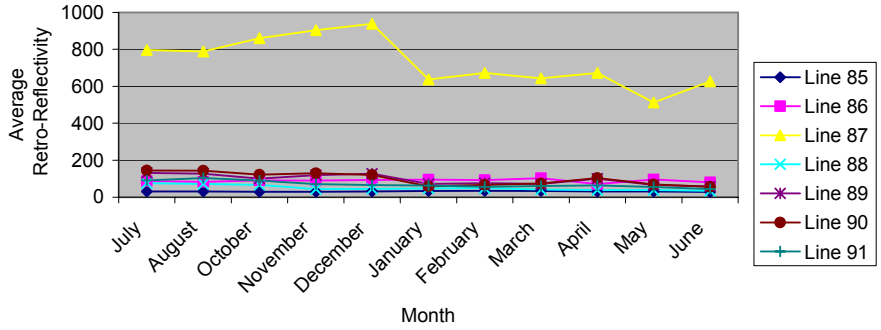


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 85	Line 86	Line 87	Line 88	Line 89	Line 90	Line 91
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	31	87	797	75	132	144	91
August	31	83	789	72	127	143	103
October	30	91	860	66	100	122	89
November	30	90	904	44	119	129	70
December	31	93	939	45	127	120	65
January	33	95	637	47	71	59	63
February	34	92	673	49	76	67	56
March	33	102	643	41	72	74	60
April	31	70	672	39	100	103	64
May	31	96	513	38	66	69	55
June	28	81	627	35	57	56	43

Rohm and Haas Yellow 7.5 mil



	Line 92	Line 93	Line 94	Line 95	Line 96	Line 97	Line 98
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	52	207	1546	240	373	302	196
August	53	219	1565	233	367	312	208
October	52	199	1649	250	325	350	249
November	48	194	1639	224	265	298	188
December	53	202	1623	251	274	310	189
January	49	152	1330	187	214	227	174
February	55	199	1475	135	307	259	189
March	61	157	1176	165	249	209	129
April	51	185	1541	165	237	268	161
May	54	168	1425	122	259	221	157
June	49	179	1215	158	200	197	137

Rohm and Haas White 7.5 mil

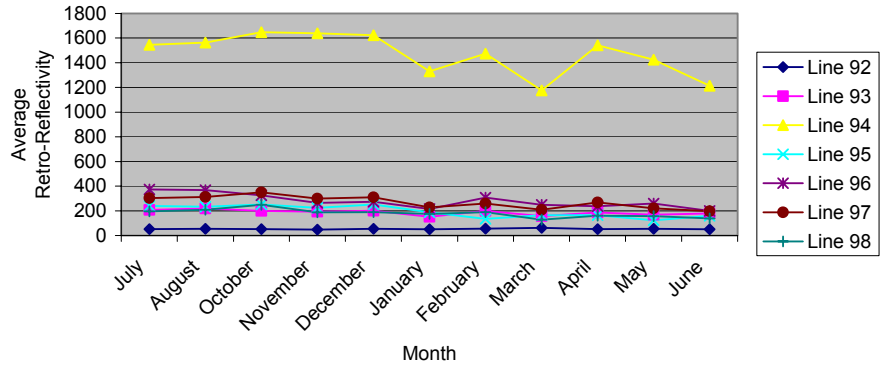


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

	Line 43	Line 44	Line 45	Line 46	Line 47	Line 48	Line 49
	Non-Beaded	Highway	Airport	Visibead A	Visibead B	Megalux B	Megalux A
July	27	178	718	253	387	282	267
August	26	214	722	267	404	299	286
October	24	231	748	290	394	298	270
November	25	229	711	280	493	305	295
December	25	235	756	291	512	336	342
January	27	228	739	324	461	335	322
February	28	212	690	357	435	360	345
March	30	230	729	324	419	373	318
April	22	230	748	338	462	325	333
May	25	228	743	328	424	358	308
June	24	212	633	270	475	328	285

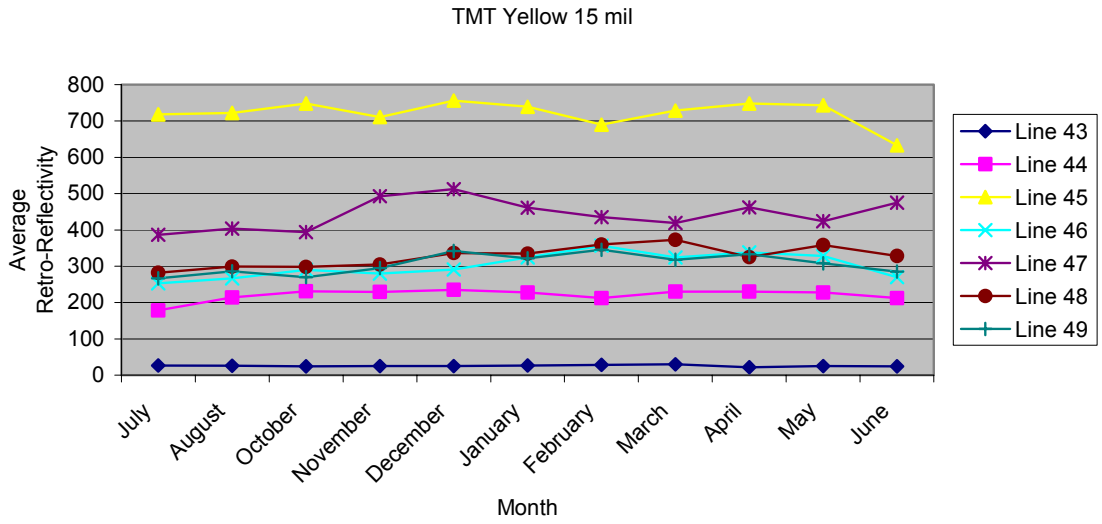


FIGURE A-14. TAXIWAY DELTA RETRO-REFLECTIVE COMPARISON CHART (September readings are not included due to September 11th) (Continued)

Typical Physical Properties These properties are typical but should not be considered specifications

Type		100% Acrylic Emulsion Polymer
Solids, weight %		49.2 % weight solids
Density, lbs/gal		
	as supplied	8.85
	dry polymer	9.43
pH		10.4

Formulating Formulations with Rhoplex Fastrack HD-21 emulsion are similar to those containing traditional Rhoplex Fastrack emulsions, such as Rhoplex Fastrack 2706, and polymer filming temperature is similar as well. Ten percent TexanoITM is recommended for film formation down to 40°F A suggested starting point formulation in order of addition is below:

Material	**Pounds**	**Gallons**
Rhoplex Fastrack HD-21P(49.2%)1	467.9	52.87
Tamol® 901	7.1	0.67
SurfynoITM CT-1 36	2.8	0.32
DreWTM L-493 Defoamer	2.0	0.28
Ti-Pure® R-900 Ti02	100.0	2.92
OmyacarbTM 5 CaC03	760.3	33.68

Mix the above with a good vortex until smooth, then add the following at slower speed:

Methanol	30.0	4.50
TexanoITM	23.0	2.90
DreWTM L-493	3.5	0.49
Water / Thickener2	11.4	1.37
Totals:	1408.0	100.00
PVC, %	60.0	
Volume Solids, %	61.0	
Viscosity,		
Initial KU	= 85	
Equilibrated KU	= 90	
pH, initial	= 10.0	

Preservatives containing formaldehyde or amine functionality should not be used due to a negative interaction with the polymer. Kathon® LX 1.5% microbicide should prove to be an acceptable alternative.

1 Stir to get a uniform sample prior to formulating. 2Adjust initial viscosity to about 85 KU. This will result in an equilibrated KU in the low 90s for spraying thick films. A 2% NatrosoITm 250HR HEC thickener is often used, but one can also use small amounts of more efficient non-ionic associative thickeners, such as Rohm and Haas's Acrysol® RM-825 or Acrysol RM-12W (thickeners reduced to 10% with water) to allow for more free water in the formulation.

FIGURE A-15. HD-21A RESIN FORMULA

STANDARD HD-21 A YELLOW

Material Name	Pounds	Gallons	Level
Grind			
Fastrack HD-21A	466.17	52.69	
Tamol 901	6.95	0.69	0.26%, Disp
Surfynol CT-136	2.78	0.32	
Drewplus L-493	2.98	0.39	
Ti-Pure R-900	19.86	0.59	0.98% PVC
Omyacarb 5	744.70	33.01	54.47%, PVC
Hansa Yellow	31.77	2.76	4.55% PVC
LetDown			
Methanol	30.00	4.53	
Texanol	22.84	2.88	10.00% Coal
Drewplus L-493	2.48	0.32	
Water	3.77	0.45	
Natrosol 250 HR(2%)	11.38	1.36	
Totals =>	1345.70	100.00	60.00% PVC

Levels without Additives	Volume Solids:	61.10%	Solvent:	3.92%
	Density:	13.4565	VOC :	91
	Weight Solids:	76.54%	Dispersant :	0.26%
	Cost / L:	4.0868	Coalescent:	10.00%
Levels with Additives	VS:	62.14%	WS:	77.25%
Other Measurements	pH:		KU	
	Gloss:		ICI	

Recommendations

FIGURE A-16. HD-21A YELLOW PAINT FORMULA

STANDARD HD-21 A WHITE

Material Name	Pounds	Gallons	Level
Grind			
Fastrack HD-21A	467.90	52.88	
Tamol 901	7.10	0.71	0.25%, Disp
Surfynol CT-136	2.80	0.32	
Drewplus L-493	2.00	0.26	
Ti-Pure R-900	100.00	3.00	4.90%, PVC
Omyacarb 5	760.30	33.70	55.22% PVC
LetDown			
Methanol	30.00	4.53	
Texanol	23.00	2.90	10.03% Coal
Drewplus L-493	3.50	0.46	
Water	5.70	0.68	
Natrosol 250 HR(2%)	5.70	0.68	
Totals =>	1408.00	100.12	60.13% PVC

Levels without Additives	Volume Solids:		Solvent	
	Density:	14.0631	VOC	
	Weight SoMds:		Dispersant:	0.25%
	Cost / L:	4.8540	Coalescent:	10.03%
Levels with Additives	VS:		WS	
Other Measurements	pH:		KU	
	Gloss:		ICI:	

Recommendations

FIGURE A-17. HD-21A WHITE PAINT FORMULA