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Polyurea Paint Marking Material Study

October 2006

DOT/FAA/AR-TN06/46

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.: DOT/FAA/AR-TN06/46

2. Government Accession No.:

3. Recipient's Catalog No.:

4. Title and Subtitle: POLYUREA PAINT MARKING MATERIAL STUDY

5. Report Date: October 2006

6. PERFORMING ORGANIZATION CODE: ATO-P

7. Author(s): Holly M. Cyrus and Renee Frierson*

8. Performing Organization Report No.:

9. Performing Organization Name and Address

Federal Aviation Administration
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10. Work Unit No. (TRAIS):

11. Contract or Grant No.:

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Federal Aviation Administration
Office of Aviation Research and Development
Washington, DC 20591

13. Type of Report and Period Covered: Technical Note

14. Sponsoring Agency Code: AAS-100

15. Supplementary Notes

Messrs. Paul Jones, James Patterson, and Donald Gallagher of the FAA William J. Hughes Technical Center assisted in the evaluation of the pavement markings. A special thanks to Traci Stadtmueller, a summer intern, who setup all of the graphs and took countless hours of data.

16. Abstract

Pavement markings must endure the harsh airport environment. Standard waterborne, epoxy, methacrylate, and solvent base markings require frequent repainting causing the life-cycle cost to increase significantly. An elastomer material used on highways, called polyurea, has been identified as a potential alternative to existing standard pavement marking materials.

This research effort was undertaken (1) to determine the effectiveness of the polyurea marking material for use on airport surfaces, (2) to determine if retro-reflective beads are compatible with the polyurea marking material, (3) to determine if grading or sieving the beads during application results in a better retro-reflectivity, and (4) to determine how well polyurea marking material bonds to the pavement if a seal coat is applied first.

Three manufacturers' products were applied at two locations: the Federal Aviation Administration William J. Hughes Technical Center and Newark Liberty International Airport. Both asphalt and concrete test surfaces were chosen. The polyurea marking material was applied at a thickness of 20 mil on each test surface. The Four types of beads applied to the polyurea marking material during the evaluation were Type I - 1.5 Index of Refraction (IOR), Type III - 1.9 IOR, Ceramic - 1.8 IOR, and Plus 9 - 1.9 IOR. During the 1-year test period, retro-reflectivity, chromaticity, pull-off strength, friction, and water recovery tests were conducted.

The results showed that:

- Polyurea is not effective in a high-traffic area on both asphalt and concrete surfaces when using Type III beads based on retro-reflectivity. Polyurea tested on concrete with Type I beads was still effective after 6 months, based on retro-reflectivity.
- Ceramic beads are not compatible with polyurea marking material in a high-traffic area. Plus 9 beads were found to be compatible with polyurea marking material when installed in a low-traffic area.
- Sieving the beads does not improve the retro-reflectivity.
- Polyurea marking material does not bond well to pavements if a seal coat is applied first.

It is recommended that additional tests be conducted to determine if polyurea marking material using Plus 9 beads is effective in high-traffic areas.

17. Key Words: Retro-reflectivity, Chromaticity, Polyurea, Friction test, Baseline test, Pull-Off strength test, Glass beads

18. Distribution Statement: This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	39	

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	ix
INTRODUCTION	1
Purpose	1
Objectives	1
Background	1
Discussion	2
Related Documents	5
EVALUATION APPROACH	6
Method	7
Baseline Test	7
Chromaticity Test	7
Retro-Reflectivity Test	7
Two-Liter Water Recovery Test	7
Outflow Water Meter Test	7
Pull-Off Strength Test	7
Friction Test	7
Data Collection	8
Baseline Test	8
Chromaticity Test	8
Retro-Reflectivity Test	8
Two-Liter Water Recovery Test	8
Outflow Water Meter Test	8
Pull-Off Strength Test	8
Friction Test	9
TEST RESULTS	9
Baseline Test	9
Chromaticity Test	9
Retro-Reflectivity Test	9
Two-Liter Water Recovery Test	12
Outflow Water Meter Test	12
Pull-Off Strength Test	12
Friction Test	13

CONCLUSIONS 13

RECOMMENDATIONS 14

APPENDIX A—DATA COLLECTED

LIST OF FIGURES

Figure		Page
1	Four White Centerline Stripes on Hot-Mix Asphalt at the FAA William J. Hughes Technical Center	3
2	Newark Liberty International Airport Runway 4R Centerline	4
3	Newark Liberty International Airport Taxiway With Polyurea Material, Right Side of Centerline Seal Coated and Left Side of Centerline Not Seal Coated	5

LIST OF TABLES

Table		Page
1	Test Conducted at the FAA William J. Hughes Technical Center	3
2	Test Conducted at Newark Liberty International Airport	4
3	Chromaticity Test Results	10
4	Retro-Reflectivity Test Results for Ceramic and Plus 9 Bead	10
5	Retro-Reflectivity Test Results for Type I Bead	11
6	Retro-Reflectivity Test Results for Type III Bead	11
7	Retro-Reflectivity Test Results for Plus 9 Bead, Sieved vs Unsieved	12
8	Pull-Off Strength Test Results for Concrete	12
9	Pull-Off Strength Test Results—EWR, Asphalt	13
10	Pull-Off Strength Test Results—FAAWilliam J. Hughes Techincal Center, Asphalt Sieved and Unsieved	13
11	Friction Test, Asphalt	13

LIST OF ACRONYMS

AC	Advisory Circular
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
IAD	Washington Dulles Airport
ICAO	International Civil Aviation Organization
IOR	Index of refraction
PCC	Portland cement concrete
R&D	Research and Development
STL	Lambert-St. Louis International Airport

EXECUTIVE SUMMARY

Pavement markings must endure the harsh airport environment. Standard waterborne, epoxy, methacrylate, and solvent base markings require frequent repainting causing the life-cycle cost to increase significantly. An elastomer material used on highways, called polyurea, has been identified as a potential alternative to existing standard pavement marking materials.

This research effort was undertaken (1) to determine the effectiveness of the polyurea marking material for use on airport surfaces, (2) to determine if retro-reflective beads are compatible with the polyurea marking material, (3) to determine if grading or sieving the beads during application results in a better retro-reflectivity, and (4) to determine how well polyurea marking material bonds to the pavement if a seal coat is applied first.

Three manufacturers' products were applied at two locations: the Federal Aviation Administration William J. Hughes Technical Center and Newark Liberty International Airport. Both asphalt and concrete test surfaces were chosen. The polyurea marking material was applied at a thickness of 20 mil on each test surface. The Four types of beads applied to the polyurea marking material during the evaluation were Type I - 1.5 Index of Refraction (IOR), Type III - 1.9 IOR, Ceramic - 1.8 IOR, and Plus 9 - 1.9 IOR. During the 1-year test period, retro-reflectivity, chromaticity, pull-off strength, friction, and water recovery tests were conducted.

The results showed that:

- Polyurea is not effective in a high-traffic area on both asphalt and concrete surfaces when using Type III beads based on retro-reflectivity. Polyurea tested on concrete with Type I beads was still effective after 6 months, based on retro-reflectivity.

- Ceramic beads are not compatible with polyurea marking material in a high-traffic area. Plus 9 beads were found to be compatible with polyurea marking material when installed in a low-traffic area.

- Sieving the beads does not improve the retro-reflectivity.

- Polyurea marking material does not bond well to pavements if a seal coat is applied first.

It is recommended that additional tests be conducted to determine if polyurea marking material using Plus 9 beads is effective in high-traffic areas.

INTRODUCTION

PURPOSE.

This research effort was conducted to determine the effectiveness of polyurea marking material for use on airport surfaces. The Federal Aviation Administration (FAA) Airport and Aircraft Safety Research and Development (R&D) Division Airport Technology R&D Branch in response to a request from the Office of Airport Engineering Division, AAS-100, undertook this project.

OBJECTIVES.

The objectives of this research were to:

- determine the effectiveness of the polyurea marking material for use on airport surfaces.
- determine if ceramic and Plus 9 beads are compatible with the polyurea marking material.
- determine if a sieved bead application results in a better retro-reflectivity performance than the standard unsieved.
- determine how well polyurea marking material bonds to the pavement if a seal coat is applied first.

BACKGROUND.

Maintenance of pavement markings is a common problem for airports due to the frequency of repainting and life cycle cost. As a result, airports have been looking for an alternative marking material that will endure the harsh conditions of the airport environment, better than the standard waterborne, epoxy, methacrylate, or solvent based paints that are specified in the FAA AC 150/5370-10A, "Standards for Specifying Construction of Airports," Item P-620, "Runway and Taxiway Painting." One potential alternative marking material, called polyurea, has been presented to the FAA for consideration. The polyurea marking material is an elastomer material used for highway paint markings. Manufacturers have been postulating that the durability of the polyurea marking material surpasses current paint marking materials; however, polyurea had only been used for highway markings and needed to be tested on an airport surface.

A visual assessment was performed on the polyurea marking material at Washington Dulles Airport (IAD) and Lambert-St. Louis International Airport (STL). This assessment at IAD and STL showed that polyurea had potential as an alternative to the current paint marking materials used at airports. While the visual assessment proved to be a success, a formal evaluation needed to be conducted before officially implementing the new material at airports. As a result, the Port Authority of New York and New Jersey approached the FAA and requested that a formal evaluation of the polyurea marking material be conducted to determine if it can be incorporated into AC 150/5370-10A, "Standards for Specifying Construction of Airports," Item P-620, "Runway and Taxiway Painting."

In turn, the Airport Engineering Division Office requested that the Airport Technology R&D Branch conduct extensive testing of the polyurea marking material. Additionally, the airport engineering Division office also requested that various reflective media (glass beads) be tested for compatibility with the polyurea marking material. Glass beads are used in markings to reflect light toward the pilot, giving the pilot better visual acquisition of the marking during nighttime operations. Glass beads are characterized by their index of refraction (IOR), which is a scale index of the rate at which a material refracts light toward the source. The characteristics of the IOR vary depending on the type of glass used, whether it is virgin glass (never been used) or recycled. Virgin glass beads produce a higher IOR than recycled glass beads; recycled glass contain some color in them from previous use. Depending on the marking material used, the glass beads may not properly adhere. Three types of beads are detailed in the Federal Specification TT-B-1325C, i.e., Type I (1.5 IOR) Low Index Recycled glass bead, Type III (1.9 IOR) High Index Virgin glass bead, and Type IV (1.5 IOR) Low Index direct melt glass. The Type I bead is commonly referred to as a highway bead and the Type III is commonly referred to as an airport bead. The other two beads not in the Federal Specification that were evaluated are ceramic (1.8 IOR) beads and Plus 9 beads (1.9 IOR). The glass beads evaluated in this study were Type I, Type III, ceramic and Plus 9 beads. Currently Type I, Type III, and Type IV beads are approved for use on airport surfaces. In this study, ceramic and Plus 9 beads were tested as alternative reflective medias for possible inclusion in the current AC.

DISCUSSION.

The polyurea marking material was applied at the FAA William J. Hughes Technical Center and Newark Liberty International Airport (EWR) for an evaluation period of 1 year starting in May 2004. Three manufacturers provided the polyurea marking material for evaluation: Epoplex, ABC Specialty Products Inc., and 3M supplied their products LS90, AMP 100 with AE-4 Additive, and LPM 1200, respectively. From here on, the three manufacturers will be referred to as A, B, and C in random order to keep the results anonymous. Polyurea marking material was applied at 20-mil wet film thickness to each surface material (see table 1).

In addition to the tests stated in table 1, different application methods were evaluated on glass beads. When applying glass beads to pavement marking material, it is common practice for airports to not sieve (unsieve) the beads before application. Unsieved glass beads apply different sized beads to the pavement marking material. Using this method gives better IOR readings and maintains the retro-reflectivity longer. In this study, a sieved application was evaluated to determine if beads in the same size range resulted in a better retro-reflectivity performance. The size of the beads for unsieved ranged from 0.4-3 mm, and sieved were 0.4-1.25 mm. Only the Plus 9 beads were applied sieved and unsieved (see figure 1).

TABLE 1. TEST CONDUCTED AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER

Surface Material	Color	Beads	Sieved/Unsieved	Tests Conducted	Seal Coat
Hot-Mix Asphalt	Four White Centerline Markings (figure 1)	Plus 9	Sieved	Chromaticity, retro-reflectivity, outflow water meter, 2-liter water recovery, pull-off strength, friction, and baseline test	None
		Plus 9	Unsieved		
Concrete*	White	Type III		Chromaticity, retro-reflectivity, outflow water meter, and pull-off strength	None
	Yellow	Type I			None
	Black	No beads			None

* Installed in the National Airport Pavement Test Facility, an indoor testing facility that simulated a high-volume airport of approximately 21,000 operations during the 5-month period (Boeing 747 and 777).

FIGURE 1. FOUR WHITE CENTERLINE STRIPES ON HOT-MIX ASPHALT AT THE FAA WILLIAM J. HUGHES TECHNICAL CENTER

Due to heavy traffic flow, all three manufacturer's products (A, B, and C) were applied at the locations stated in table 2. On some portions of taxiways Yankee (Y) and Juliet (J), asphalt seal coat was applied prior to the installation of the polyurea marking material. Asphalt seal coat is used to prevent cracking of the asphalt pavement. Applying the asphalt seal coat before the paint is not a common practice for airports; usually the paint marking is applied, then a seal coat goes around the paint. This particular test was done to see how the marking material bonded to the pavement if the seal coat was applied first. However, after 3-6 months of in-service testing, the markings with the seal coat came up in big sheets and were replaced with standard paint material.

TABLE 2. TEST CONDUCTED AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Surface Material	Color	Beads	Tests Conducted	Seal Coat
Runway 4R (asphalt) (figure 2)	White Centerline	Type I, Ceramic	Chromaticity, retro-reflectivity, and baseline test	None
Taxiway Y (asphalt) (figure 3)	Yellow, Black	Type I, Type III, Ceramic	Chromaticity, retro-reflectivity, pull-off strength, and baseline test	Half of hold bar had seal coat
Taxiway J (asphalt) (figure 3)	Yellow	Type I, Type III	Chromaticity, retro-reflectivity, pull-off strength, and baseline test	Half of hold bar had seal coat

FIGURE 2. NEWARK LIBERTY INTERNATIONAL AIRPORT
RUNWAY 4R CENTERLINE

FIGURE 3. NEWARK LIBERTY INTERNATIONAL AIRPORT TAXIWAY WITH POLYUREA MATERIAL, RIGHT SIDE OF CENTERLINE SEAL COATED AND LEFT SIDE OF CENTERLINE NOT SEAL COATED

RELATED DOCUMENTS.

Related documents regarding this evaluation project are:

- ASTM-E-2380-05, "Standard Test Method for Measuring Pavement Texture Drainage Using an Outflow Meter."
- ASTM-D-2177-01, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers."
- ASTM-E-2177-01, "Standard Test Method for Measuring the Coefficient of Retro-reflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness."
- DOT/FAA/AR-TN03/22, "Development of Methods for Determining Airport Pavement Marking Effectiveness," March 2003.
- DOT/FAA/AR-02/128, "Paint and Bead Durability Study," March 2003.
- DOT/FAA/AR-TN96/74, "Follow-On Friction Testing of Retro-Reflective Glass Beads," July 1996.
- DOT/FAA/CT-94/119, "Evaluation of Alternative Pavement Marking Materials," January 1995.

- DOT/FAA/CT-94/120, "Evaluation of Retro-Reflective Beads in Airport Pavement Markings," December 1994.

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

- FAA AC 150.5320-12C, "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces," March 18, 1997.

- FAA AC 150/5370-10A, "Standards for Specifying Construction of Airports," Item P-620, "Runway and Taxiway Painting," February 17, 1989.

- International Civil Aviation (ICAO) Annex 14, Volume I, "Aerodrome Design and Operation," August 9, 2000.

- Specification TT-B-1325C, "Beads (Glass Spheres) Retroreflective," June 1, 1993.

EVALUATION APPROACH

The Airport Technology R&D team conducted monthly chromaticity and retro-reflective readings at EWR and on markings at the FAA William J. Hughes Technical Center. Upon initial application of the polyurea marking material, outflow water meter, 2-liter water recovery, pull-off strength, friction tests, and a baseline test were performed. The following is a brief description of equipment used and the participants who conducted the tests:

- Equipment Description

  - Spectrophotometer, Color-guide 45/0, BYK-Gardner USA, 20 mm, 6805-SVC, built by BYK-Gardner of Germany

  - Retro-Reflectometer, Flint Trading, Inc., 30-meter geometry, LTL 2000 built by Delta Lights and Optics of Denmark

  - Skidabrader Outflow Meter

  - Dyna-Meter Z16 Pull-Off Tester

  - Saab Friction Tester ASTM 1551 Tire at 30 psi

- Evaluation Participants

  - The project team consisted of the FAA, Port Authority of New York and New Jersey, individuals from the three manufacturers of polyurea marking materials, and one bead manufacturer.

METHOD.

BASELINE TEST. At initial application, baseline measurements were taken of the polyurea marking material, on asphalt and concrete, for each color: yellow (beaded), white (beaded), and black (unbeaded). Once the material was applied to the pavement, color and retro-reflective readings were taken using a spectrophotometer and retro-reflectometer.

CHROMATICITY TEST. The Chromaticity test was conducted using a spectrophotometer. Two readings per marking were taken by placing the instrument on the pavement marking and activating the device. Color readings were performed after initial application of the paint marking material was completed and continued monthly thereafter for 1 year.

RETRO-REFLECTIVITY TEST. Retro-reflectivity was obtained with the use of a retro-reflectometer. Six readings per paint marking were taken by placing the instrument on the pavement marking and activating the device. Prior to each use, the instrument was calibrated and had an accuracy of ±5%. Readings were taken after initial application of the paint marking was completed and continued monthly thereafter for 1 year.

TWO-LITER WATER RECOVERY TEST. The 2-liter water recovery test was performed on the polyurea marking material to determine the wet weather recovery rates for each type of bead. A retro-reflectometer reading was taken to obtain an initial baseline measurement of the marking material. A 2-liter bucket of water was poured on the marking until it was completely covered. The team then took retro-reflective readings at 5-minute intervals for 40 minutes until the readings returned to approximately the initial baseline retro-reflective measurement. This test was performed in accordance with ASTM-E-2177-01.

OUTFLOW WATER METER TEST. The outflow water meter test was used to determine the extent of pavement irregularity of both the Portland cement concrete (PCC) and hot-mix asphalt where the polyurea marking material was applied. During this test, a Skidabrader water meter was used. This is a cylindrical device that was placed on top of the polyurea marking material. First, water was poured through the cylindrical tube until the tube was completely filled. Second, the plunger in the device was lifted and an electronic timer was activated. The water was discharged through the bottom of the tube. The team then recorded the time it took for the water to discharge from the tube to the pavement. This test was performed in accordance with ASTM-E-2380-05.

PULL-OFF STRENGTH TEST. The pull-off strength test was used to determine the tensile strength of the bond between the polyurea marking material and hot-mix asphalt or PCC. Using a Dyna-Meter Z16 Pull-Off Tester, a metal disc was glued to the polyurea marking material and allowed to cure for 24 hours. The Dyna-Meter Pull-Off Tester was connected to the disc via a draw bolt. The instrument was adjusted to level, via adjustable legs. The instrument was then turned on and the crank was turned until the metal disc separated from the pavement. This test was performed in accordance with ASTM-D-4541-02.

FRICTION TEST. Using a Dyna-Test 6850 Runway Friction Tester, housed in a Dodge Caravan, multiple test runs were conducted. Testing took place at the FAA William J. Hughes

Technical Center, where four test stripes each with a length of 150-feet were located. Three of the four stripes were tested due to close proximity of highway edge reflectors. The friction runs were conducted at 40 mph with the water turned off since it had just rained.

DATA COLLECTION.

BASELINE TEST. Color readings were taken producing (Y, x, y) to obtain the base measurement of the polyurea marking material. In addition, retro-reflectivity readings were taken producing millicandela per meter squared per lux readings.

CHROMATICITY TEST. Color readings were taken with a spectrophotometer, which produces (Y, x, y) coordinates for its readouts. The readings were then charted on an ICAO standard illuminant D65 chromaticity chart. This chart is found in ICAO Annex 14 Volume I – Aerodrome Design and Operations, pages 131 and 132. This chart has been modified to address the aviation yellow used on airports. The FAA boundaries for aviation yellow are not the same as for ICAO yellow. The region for FAA in-service yellow was obtained and is documented in figure A-5 in appendix A of DOT/FAA/AR-TN03/22, "Development of Methods for Determining Airport Pavement Marking Effectiveness." The region for white is the same for ICAO as well as FAA. A white data point that falls outside of the ICAO white region is considered failed. A yellow data point that falls outside of the FAA in-service aviation yellow region is considered failed.

RETRO-REFLECTIVITY TEST. The retro-reflectometer produced millicandela per meter squared per lux readings. Currently, the FAA has no standard for retro-reflectivity limits. A paint marking study conducted by the Airport Technology R&D Branch team determined that the recommended minimum was 100 $mcd/m^2/lx$ for white and 70 $mcd/m^2/lx$ for yellow. The report, entitled "Development of Methods for Determining Airport Pavement Marking Effectiveness," DOT/FAA/AR-TN03/22, elaborates on this test method.

TWO-LITER WATER RECOVERY TEST. A 2-liter, ASTME-E-2177 water test was performed on the lines to determine how the polyurea with beads performed in wet-weather conditions. The wet retro-reflectivity readings were documented, analyzed, and graphed (appendix A, figure A-16).

OUTFLOW WATER METER TEST. Data was collected using a Skidabrader Outflow meter. The data produced by the outflow meter is in the unit of time. The time measured indicated how long it took for the water to discharge from the meter to the pavement, which varies according to surface texture. The faster the water flows off the marking material, the greater the texture depth, the better the material sheets water.

PULL-OFF STRENGTH TEST. This test determined whether there was an internal failure of the marking material, or an external failure of the pavement material (asphalt or concrete). When the marking material failed there was a cohesive failure. When the polyurea marking material failed, there was a cohesive failure. When the asphalt or concrete failed, there was an adhesive failure. The tensile strength readings were measured in psi. the best result shoud end in a pavement failure (adhesive) rather than a pavement marking failure (cohesive).

FRICTION TEST. The data output of the Friction Tester produced Mu (μ) readings. The readings for friction can range from 0 to 1 μ, with 1 μ being the best possible friction reading.

TEST RESULTS

BASELINE TEST.

The chromaticity readings for white, yellow, and black polyurea marking material all fell within their acceptable ranges. (See appendix A for additional data.)

The retro-reflectivity readings for white markings on asphalt and concrete all fell within their acceptable ranges. The yellow markings fell within their acceptable range on concrete and asphalt except for manufacturers B product on Taxiway J at EWR, which had readings of 66 mcd/m^2/lx for markings with Type III beads and had readings of 26 mcd/m^2/lx for markings with Type I beads, which are both below the recommended range of 70 mcd/m^2/lx for yellow markings with beads. (See appendix A for additional data.)

The polyurea marking material at EWR was removed from taxiway J and Y after 6 months and from runway 4R after 3 months. The reason for removal at taxiway J and Y was due to poor bonding on the asphalt seal coat side of the installation. The reason for removal at runway 4R was due to lose of beads since it was a high-traffic area. The evaluation was suppose to last 1 year, thus insufficient data was collected during the test. The only markings that remained for the 1-year evaluation period were located at the FAA William J. Hughes Technical Center.

CHROMATICITY TEST.

The acceptability range for the white x coordinate is 0.2895 to 0.3442 and the y coordinate is 0.3100 to 0.3650. The acceptability range for the yellow x coordinate is 0.4261 to 0.5266 and the y coordinate is 0.4300 to 0.5346. The acceptability range for the black x coordinate is 0.2610-0.3890 and the y coordinate is 0.2790-0.3910. Pass or fail is based on the last data point that could be obtained. (See appendix A for additional data.) (See table 3.)

RETRO-REFLECTIVITY TEST.

The recommended minimum is 100 mcd/m^2/lx for white and 70 mcd/m^2/lx for yellow. The only marking that lasted on asphalt for the entire study was Plus 9 beads (white) located at the National Airport Pavement Test Facility. Ceramic and Plus 9 beads were designed specifically for polyurea material (see tables 4 to 7).

TABLE 3. CHROMATICITY TEST RESULTS

Surface Material	Location	Total Evaluated	Pass	Fail	Markings Removed Prematurely[1]
Asphalt (yellow)	EWR	4	0	4	-
	FAA William J. Hughes Technical Center	-	-	-	-
Concrete[3] (yellow)	EWR	-	-	-	-
	FAA William J. Hughes Technical Center	1	0	1[2]	-
Asphalt (white)	EWR	3	2	1	2
	FAA William J. Hughes Technical Center	3	2	1	-
Concrete[3] (white)	EWR	-	-	-	-
	FAA William J. Hughes Technical Center	1	1	0	1
Asphalt (black)	EWR	2	2	0	2
	FAA William J. Hughes Technical Center	-	-	-	-
Concrete[3] (black)	EWR	-	-	-	-
	FAA William J. Hughes Technical Center	1	1	0	1

[1] Marking was removed prior to failure.

[2] Failed during baseline test after initial installation.

[3] Installed in the National Airport Pavement Test Facility and trafficked for approximately 21,000 operations during the 5-month period (simulated Boeing 747 and 777 main landing gear configuration).

TABLE 4. RETRO-REFLECTIVITY TEST RESULTS FOR CERAMIC AND PLUS 9 BEAD

Bead Type (color)	Duration (months)	Location	Initial Retro-Reflectivity	Final Retro-Reflectivity	% Retro-Reflectivity Remaining
Ceramic (white)	3	Runway 4R (asphalt)	582	3	0.5
Ceramic (yellow)*	6	Taxiway Y (asphalt)	465	167	36
Plus 9 (white)	12	FAA William J. Hughes Technical Center (asphalt)	355	201	57

* Markings removed due to failure.

TABLE 5. RETRO-REFLECTIVITY TEST RESULTS FOR TYPE I BEAD

Color	Duration (months)	Location/Surface	Initial Retro-Reflectivity	Final Retro-Reflectivity	% Retro-Reflectivity Remaining
White	3	Runway 4R (asphalt)	442	4	1
White	3	Runway 4R (asphalt)	560	3	0.5
Yellow[1]	6	Taxiway J (asphalt)	261	84	32
Yellow[1]	6	Taxiway Y (asphalt)	442	70	15
Yellow[1, 2]	5	FAA William J. Hughes Technical Center (concrete)	201	157	78

[1] Markings removed prior to failure.

[2] Installed in the National Airport Pavement Test Facility, which simulated a high-volume airport of approximately 21,000 operations during the 5-month period (Boeing 747 and 777).

TABLE 6. RETRO-REFLECTIVITY TEST RESULTS FOR TYPE III BEAD

Color	Duration (months)	Location/Surface	Initial Retro-Reflectivity	Final Retro-Reflectivity	% Retro-Reflectivity Remaining
White[1, 2]	5	FAA William J. Hughes Technical Center (concrete)	1061	134	13
Yellow[1]	6	Taxiway Y (asphalt)	456	96	21
Yellow[1]	3	Taxiway J (asphalt)	595	115	19

[1] Markings removed due to failure.

[2] Installed in the National Airport Pavement Test Facility, which simulated a high-volume airport of approximately 21,000 operations during the 5-month period (Boeing 747 and 777).

TABLE 7. RETRO-REFLECTIVITY TEST RESULTS FOR PLUS 9 BEAD, SIEVED VS UNSIEVED

Bead Type (color)	Duration (months)	Location/Surface	Initial Retro-Reflectivity	Final Retro-Reflectivity	% Retro-Reflectivity Remaining
Plus 9 Sieved (white)	12	FAA William J. Hughes Technical Center (asphalt)	1052	261	12
Plus 9 Unsieved (white)	12	FAA William J. Hughes Technical Center (asphalt)	355	201	57

TWO-LITER WATER RECOVERY TEST.

This test was conducted but did not have a direct bearing on the objectives of this study. See appendix A (table A-19 and figure A-15) for test results.

OUTFLOW WATER METER TEST.

This test was conducted but did not have a direct bearing on the objectives of this study. See appendix A (tables A-20 and A-21) for test results.

PULL-OFF STRENGTH TEST.

A past study was conducted on waterborne paint (DOT/FAA/AR-02/128, "Paint and Bead Durability Study") in which yellow waterborne paint had an average tensile strength of 77 psi and white waterborne paint had an average tensile strength of 86 psi. Both markings were tested on asphalt. Tables 8, 9, and 10 show the tensile strength of polyurea on concrete and asphalt.

TABLE 8. PULL-OFF STRENGTH TEST RESULTS FOR CONCRETE*

Bead Type (color)	Tensile Strength (psi)	Cohesive/Adhesive
Type I (yellow)	214	Cohesive
Type III (white)	13	Cohesive
No Bead (black)	200	Cohesive

* Installed in the National Airport Pavement Test Facility, which simulated a high-volume airport of approximately 21,000 operations during the 5-month period (Boeing 747 and 777).

TABLE 9. PULL-OFF STRENGTH TEST RESULTS—EWR, ASPHALT

Bead Type (color)	Tensile Strength (psi)	Cohesive/Adhesive
Ceramic (yellow)	480	Adhesive
Type I (yellow)	349	Adhesive
No Bead (black)	387	Adhesive

TABLE 10. PULL-OFF STRENGTH TEST RESULTS—FAA WILLIAM J. HUGHES TECHINCAL CENTER, ASPHALT SIEVED AND UNSIEVED

Bead Type (white)	Tensile Strength (psi)	Cohesive/Adhesive
Plus 9 Sieved	225	Adhesive
Plus 9 Unsieved	349	Adhesive

FRICTION TEST.

The readings for friction can range from 0 to 1 μ, with 1 μ being the best possible friction reading. Friction readings were taken after initial installation. This test was only conducted at the FAA William J. Hughes Techincal Center on asphalt (see table 11).

TABLE 11. FRICTION TEST, ASPHALT

Description	Average (μ)	Average Speed (mph)
Bare, Wet Pavement	0.90	38.3
Plus 9 Unsieved	0.96	36.4

CONCLUSIONS

Based on this report, the following was found:

- Based on retro-reflectivity, the polyurea marking material was not effective in a high-traffic area on both asphalt and concrete surfaces when using Type III beads.
- The polyurea marking material tested on asphalt with Type I beads was not effective. However, on concrete with Type I beads, the polyurea marking material was still effective after 6 months. Because the test markings were removed before tests were completed, the effectiveness of the Type I beads could not be determined.

- Ceramic beads were not compatible with the polyurea marking material in a high-traffic area. The beads were installed with the polyurea marking material at a high-traffic area and failed based on retro-reflectivity after 3 months.

- Plus 9 beads were installed with the polyurea marking material in a low-traffic area and were found to be compatible based on retro-reflectivity.

- Sieving the beads did not improve the retro-reflectivity. Plus 9 beads were the only bead type tested for a sieved versus unseived application. The sieved Plus 9 beads had 12% retro-reflectivity remaining, while the unsieved Plus 9 beads had 57% retro-reflectivity remaining at the end of 1 year.

- It was not recommended that an asphalt seal coat be applied prior to the application of the polyurea marking material. Areas where the asphalt seal coat was applied before the polyurea marking material prevented the polyurea marking material from adhering properly to the pavement, which caused the polyurea marking material to come off in sheets.

RECOMMENDATIONS

Based on the results of this study, it is recommended that further evaluation of this material applied to a concrete surface using Type I beads be conducted to determine if the polyurea marking material will be effective. Since the Plus 9 beads were not installed with the polyurea marking material in a high-traffic area it is also recommended that the polyurea marking material using Plus 9 beads be studied.

This evaluation will provide data that will determine the acceptability of polyurea marking material for use on a concrete surface with Type I or Plus 9 beads as an alternative marking material for the airport environment.

APPENDIX A—DATA COLLECTED

The following tables and graphs show the data collected for the polyurea marking material project over the course of a year.

TABLE A-1. BASELINE TEST FOR CHROMATICITY READINGS AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Hot-mix Asphalt			Portland Cement Concrete		
Bead	X-Reading	Y-Reading	Bead	X-Reading	Y-Reading
Plus 9 Sieved	0.3176	0.3359	Black (no beads)	0.315	0.3321
Plus 9 Unsieved	0.3156	0.3359	White (Type III)	0.3361	0.344
			Yellow (Type I)	0.4919	0.4271

TABLE A-2. BASELINE TEST FOR CHROMATICITY READINGS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Taxiway Y (Hot-Mix Asphalt)			Runway 4R (Hot-Mix Asphalt)			Taxiway J (Hot-Mix Asphalt)		
Bead	X-Reading	Y-Reading	Bead	X-Reading	Y-Reading	Bead	X-Reading	Y-Reading
Type I	0.5000	0.4394	Type I	0.3157	0.3326	Type I	0.4909	0.4387
Type III	0.4361	0.5021	Ceramic	0.3169	0.3350	Black	0.3153	0.3143
Ceramic	0.4372	0.5050						
Black	0.3221	0.3339						

TABLE A-3. BASELINE TEST FOR RETRO-REFLECTIVITY AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Hot-Mix Asphalt		Portland Cement Concrete	
Bead	(mcd/m^2/lx)	Bead	(mcd/m^2/lx)
Plus 9 Sieved	1052	White Type III	1061
Plus 9 Unsieved	355	Yellow Type I	201

TABLE A-4. BASELINE TEST FOR RETRO-REFLECTIVITY AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Taxiway Yankee (Hot-Mix Asphalt)		Runway 4R (Hot-Mix Asphalt)		Taxiway Juliet (Hot-Mix Asphalt)	
Bead	(mcd/m^2/lx)	Bead	(mcd/m^2/lx)	Bead	(mcd/m^2/lx)
Type I	442	Type I (manufacturer C)	442	Type I (manufacturer A)	261
Type III	456	Type I (manufacturer A)	560	Type III (manufacturer A)	335
Ceramic	465	Ceramic	582	Type III (manufacturer B)	66
				Type I (manufacturer B)	26

TABLE A-5. COLOR READINGS (WHITE) FOR PLUS 9 BEADS SIEVED AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
May	0.3176	0.3359
April	0.3454	0.3446

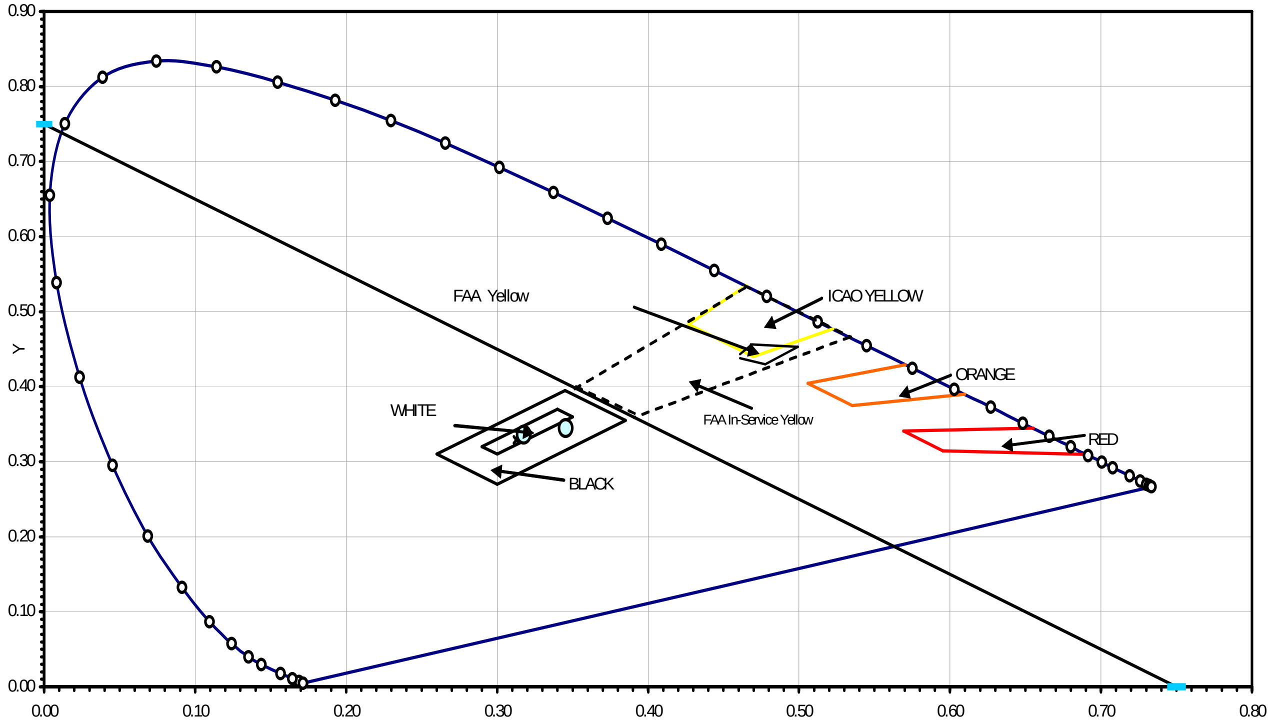

FIGURE A-1. COLOR READINGS (WHITE) FOR PLUS 9 BEADS SIEVED AT THE WILLIAM J. HUGHES TECHNICAL CENTER

TABLE A-6. COLOR READINGS (WHITE) FOR PLUS 9 BEADS UNSIEVED AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
May	0.3156	0.3359
April	0.3279	0.3482

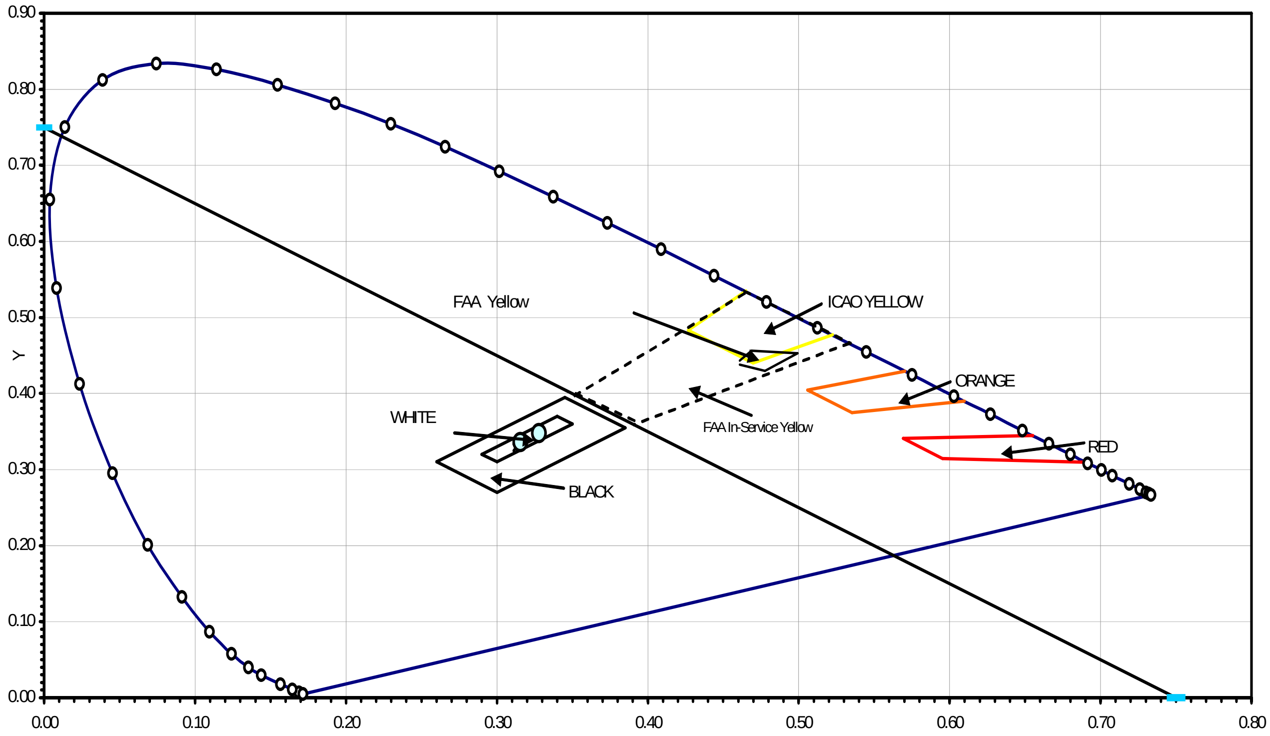

FIGURE A-2. COLOR READINGS (WHITE) FOR PLUS 9 BEADS UNSIEVED AT THE WILLIAM J. HUGHES TECHNICAL CENTER

TABLE A-7. COLOR READINGS (BLACK) AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

Month	Acceptability Range (0.2610-0.3890) X-Reading	Acceptability Range (0.2790-0.3910) Y-Reading
June	0.315	0.3321
December	0.3144	0.3325

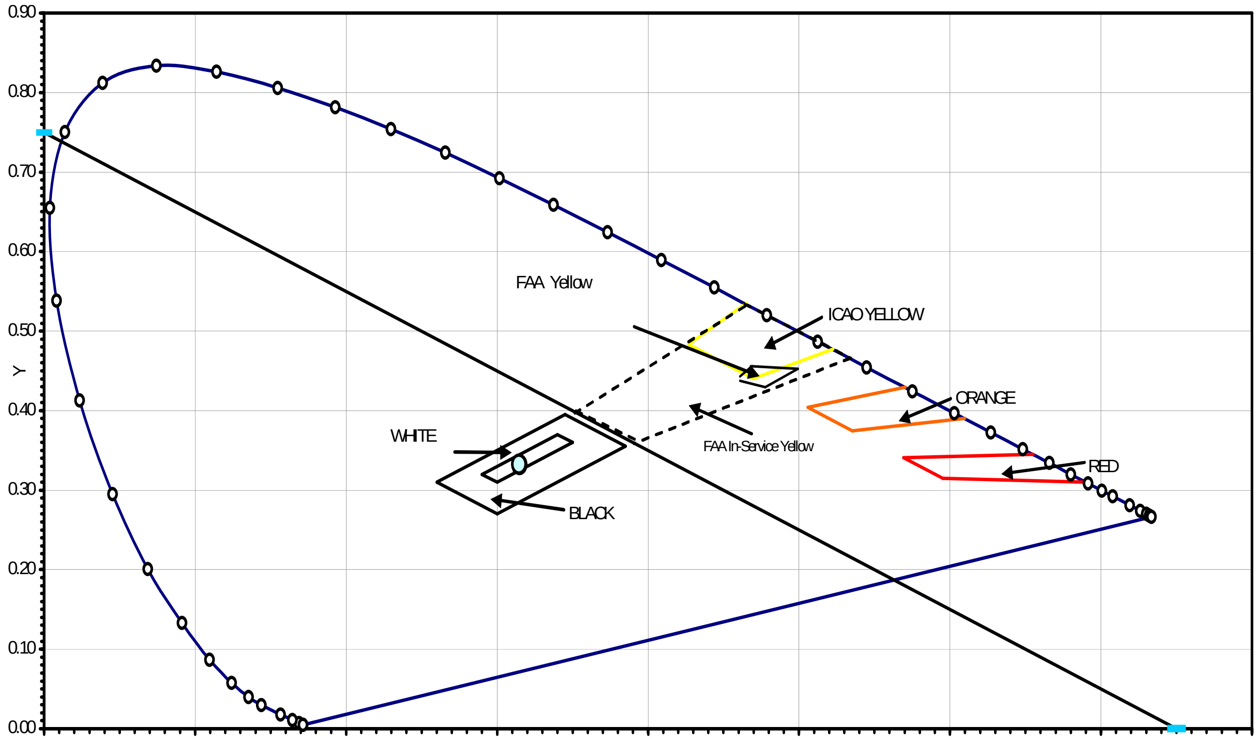

FIGURE A-3. COLOR READINGS (BLACK) AT THE WILLIAM J. HUGHES TECHNICAL CENTER

TABLE A-8. COLOR READINGS (WHITE) FOR TYPE III BEADS AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
May	0.3361	0.3440
December	0.3297	0.3461

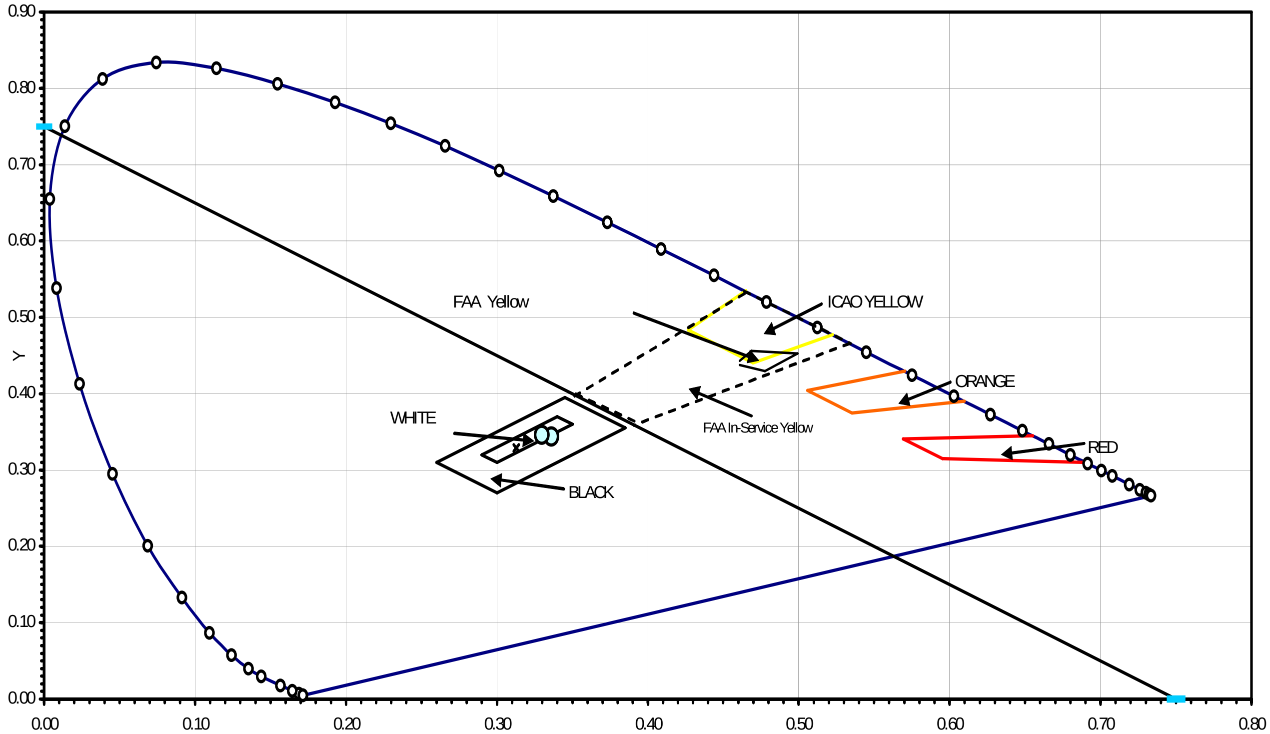

FIGURE A-4. COLOR READINGS (WHITE) FOR TYPE III BEADS AT THE WILLIAM J. HUGHES TECHNICAL CENTER

TABLE A-9. COLOR READINGS (YELLOW) FOR TYPE I BEADS AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.4919	0.4271
December	0.3836	0.3743

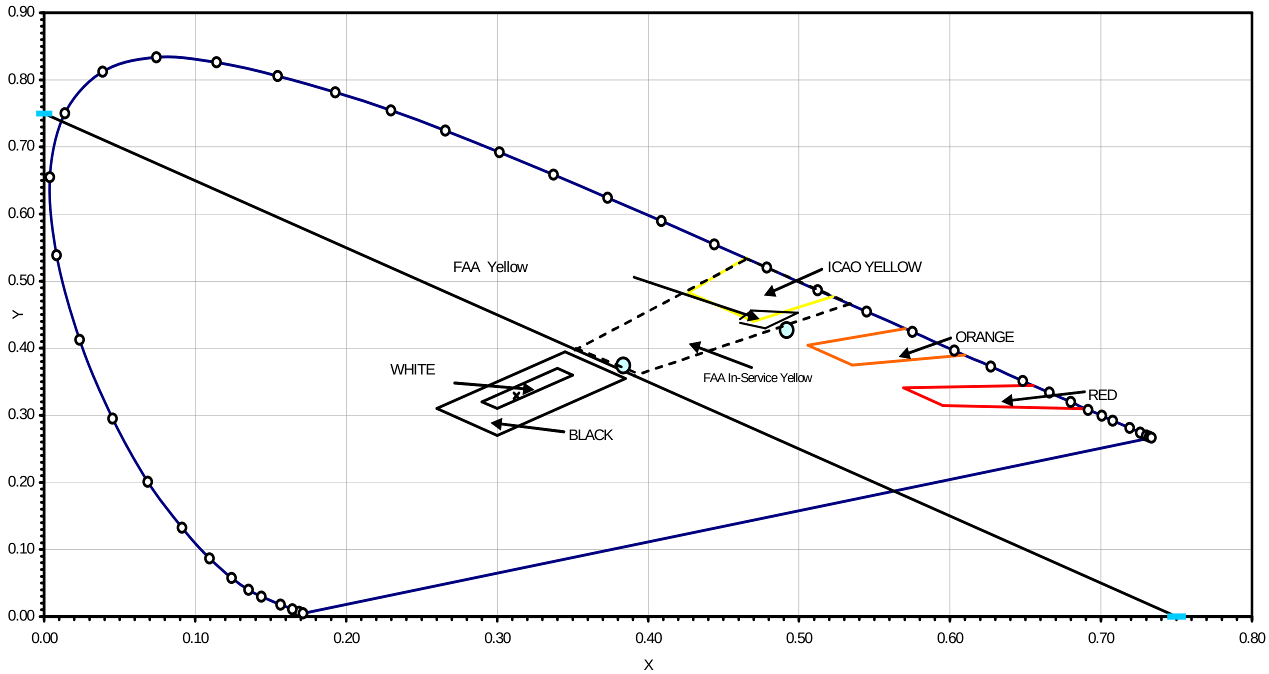

FIGURE A-5. COLOR READINGS (YELLOW) FOR TYPE I BEADS AT THE WILLIAM J. HUGHES TECHNICAL CENTER

TABLE A-10. COLOR READINGS (YELLOW) FOR TYPE I BEADS AT TAXIWAY YANKEE AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.5000	0.4394
November	0.4717	0.4212

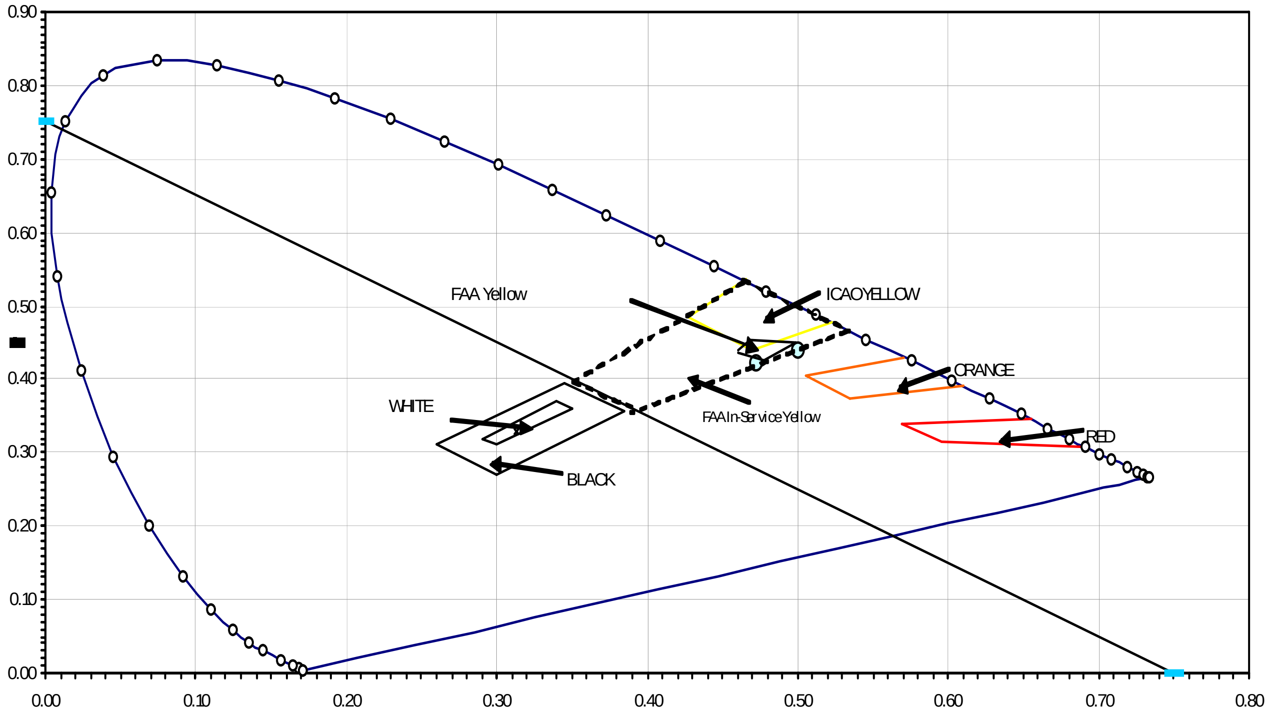

FIGURE A-6. COLOR READINGS (YELLOW) FOR TYPE I BEADS AT NEWARK LIBERTY NATIONAL AIRPORT

TABLE A-11. COLOR READINGS (YELLOW) FOR TYPE III BEADS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.4361	0.5021
November	0.4716	0.4260

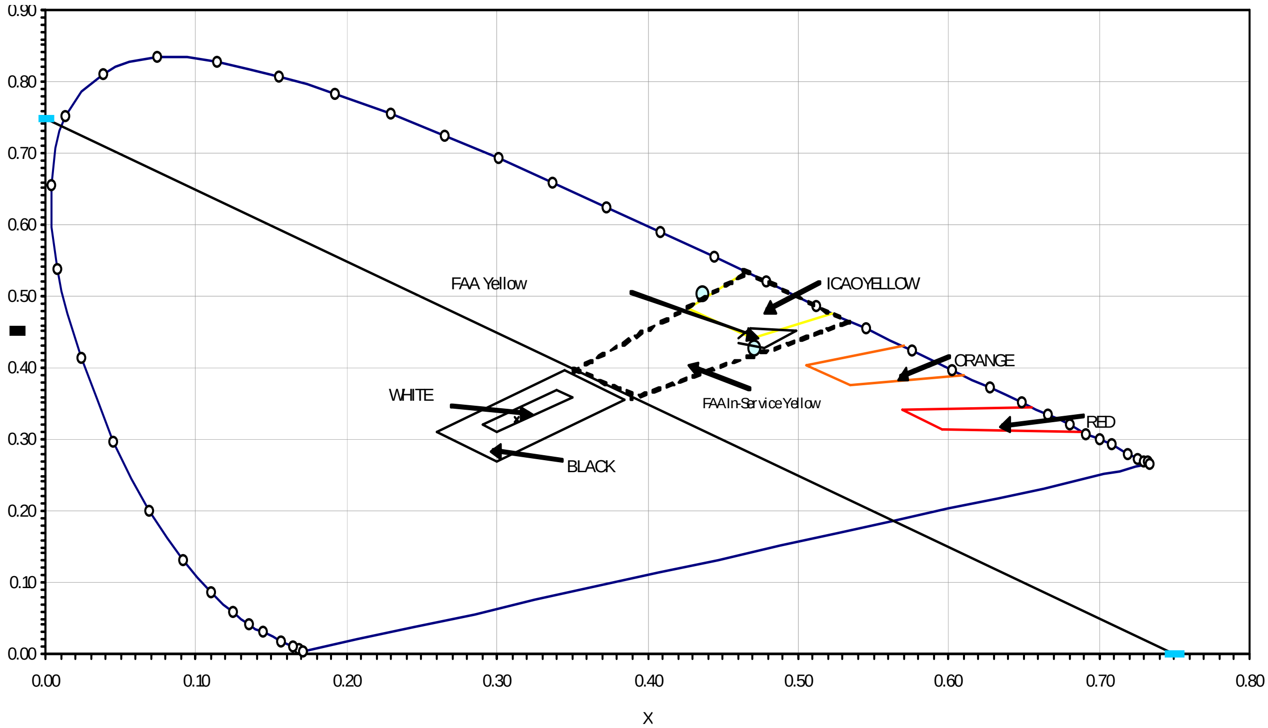

FIGURE A-7. COLOR READINGS (YELLOW) FOR TYPE III BEADS AT THE NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-12. COLOR READINGS (YELLOW) FOR CERAMIC BEADS AT TAXIWAY YANKEE AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.4372	0.5050
November	0.4771	0.4288

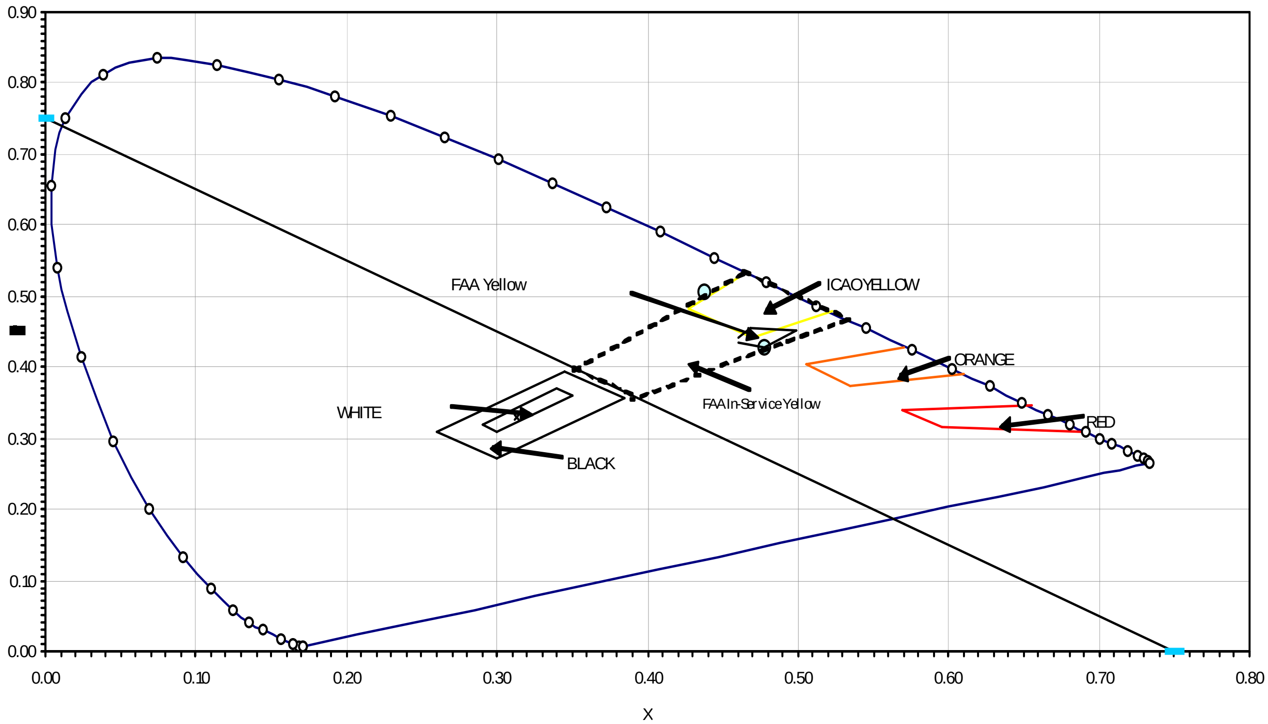

FIGURE A-8. COLOR READINGS (YELLOW) FOR CERAMIC BEADS AT THE NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-13. COLOR READING (BLACK) TAXIWAY YANKEE AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.2610-0.3890) X-Reading	Acceptability Range (0.2790-0.3910) Y-Reading
June	0.3221	0.3339
October	0.3165	0.3268

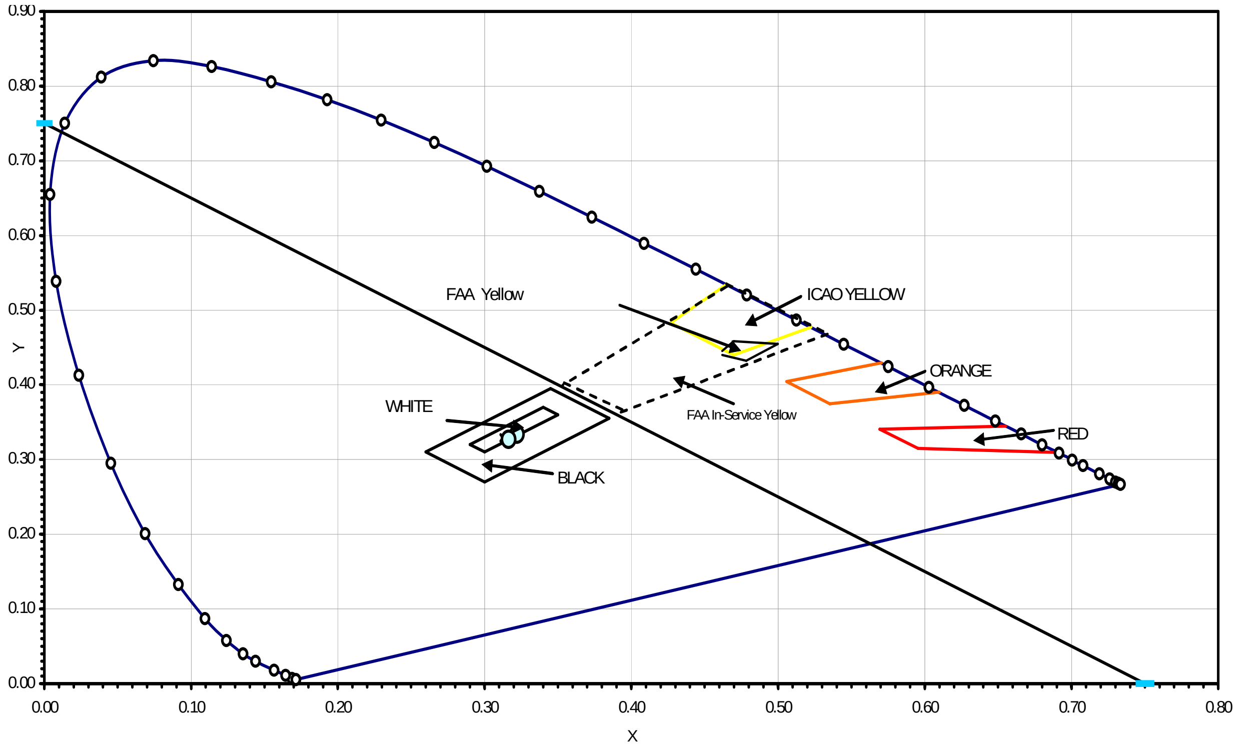

FIGURE A-9. COLOR READING (BLACK) AT NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-14. COLOR READING (YELLOW) FOR TYPE I BEADS AT TAXIWAY JULIET AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.4909	0.4387
November	0.4676	0.4283

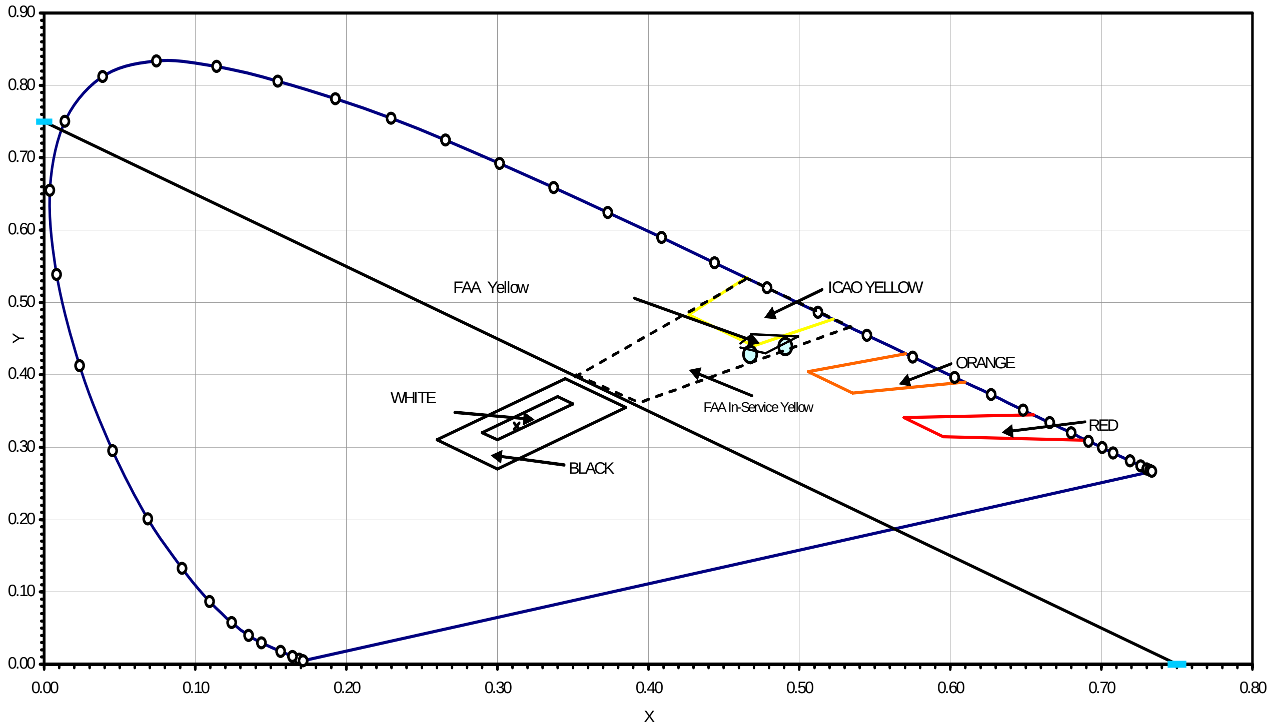

FIGURE A-10. COLOR READING (YELLOW) FOR TYPE I BEADS AT THE NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-15. COLOR READING (YELLOW) FOR TYPE III BEADS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
May	0.4909	0.4387

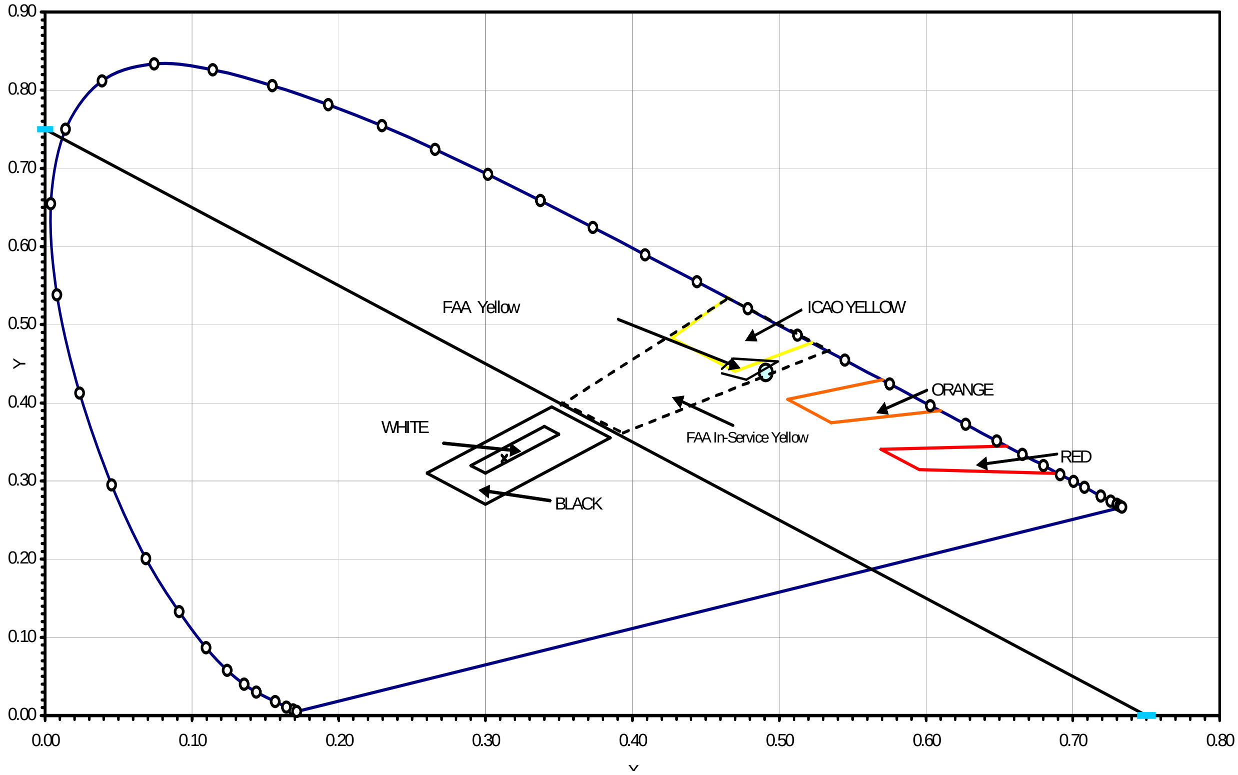

FIGURE A-11. COLOR READING (YELLOW) FOR TYPE III BEADS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-16. COLOR READINGS (BLACK) AT TAXIWAY JULIET AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.2610-0.3890) X-Reading	Acceptability Range (0.2790-0.3910) Y-Reading
July	0.3153	0.3143
November	0.3144	0.3286

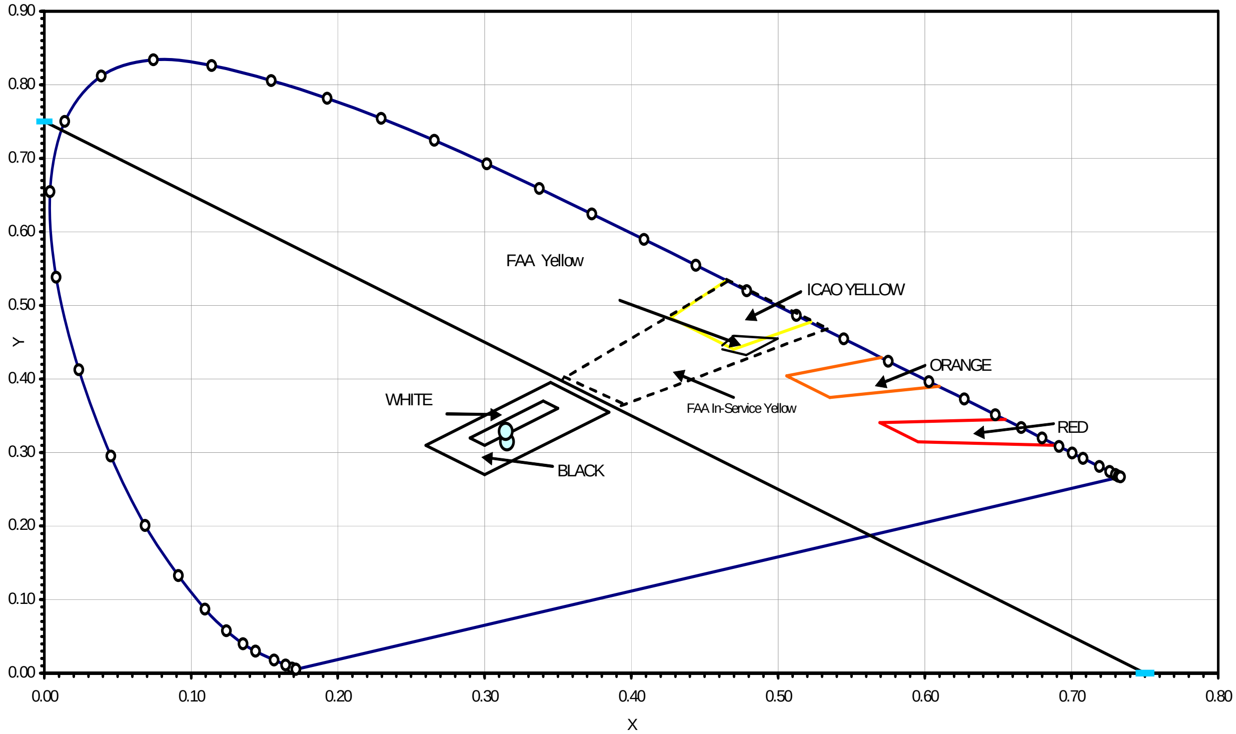

FIGURE 12. COLOR READING (BLACK) AT NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-17. COLOR READINGS (WHITE) FOR TYPE I BEADS AT RUNWAY 4R CENTERLINE AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
May	0.3157	0.3326
August	0.3059	0.2972

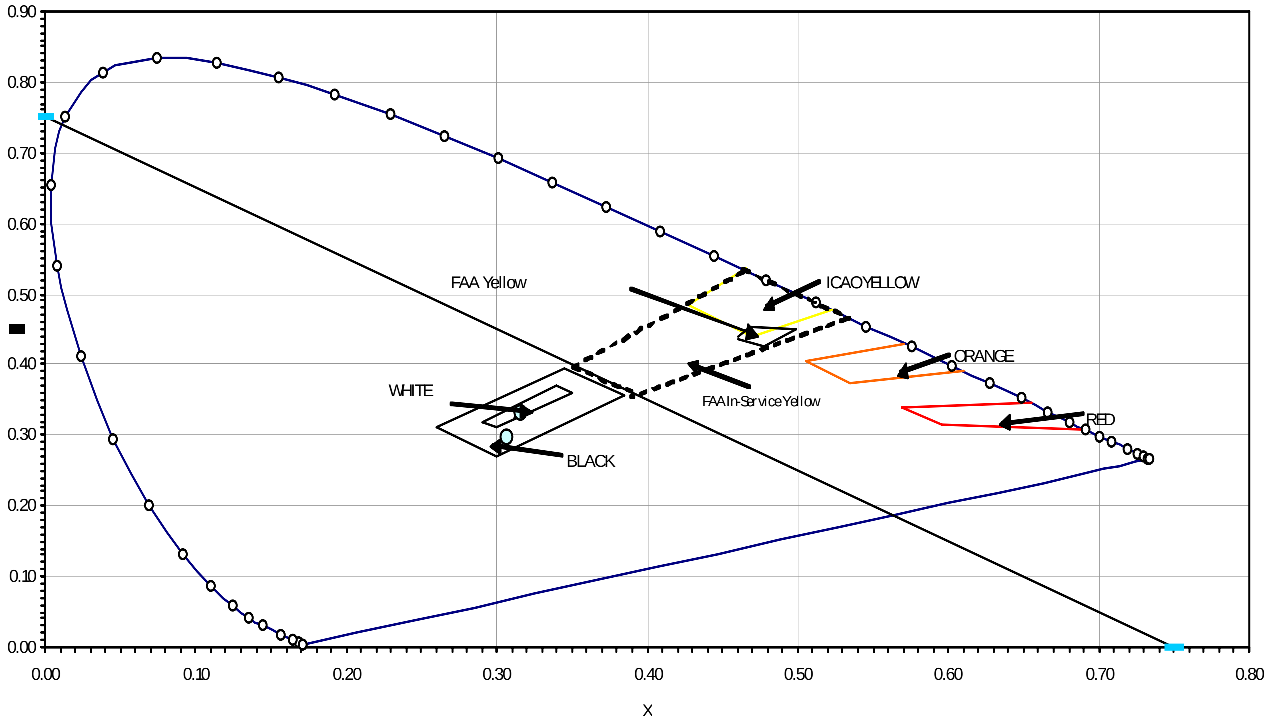

FIGURE 13. COLOR READINGS (WHITE) FOR TYPE I BEADS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-18. COLOR READINGS (WHITE) FOR CERAMIC BEADS AT RUNWAY 4R CENTERLINE AT NEWARK LIBERTY INTERNATIONAL AIRPORT

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
May	0.3169	0.3350
August	0.3147	0.3300

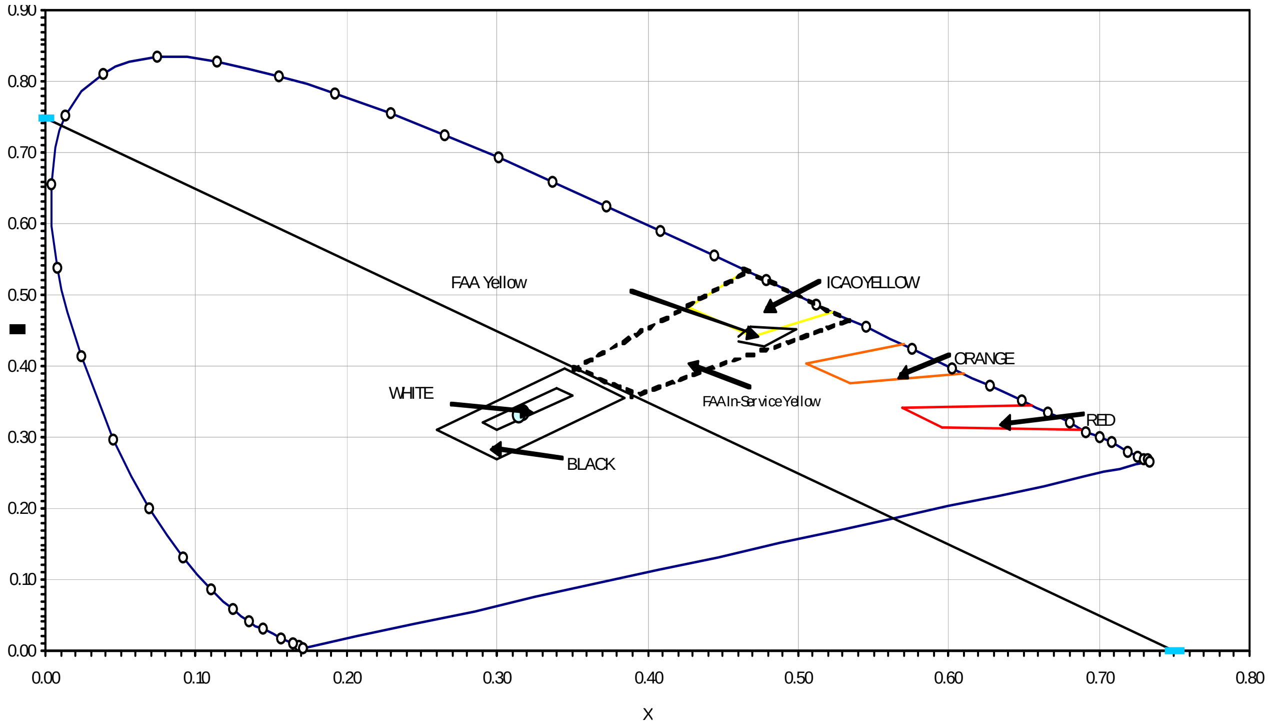

FIGURE A-14. COLOR READINGS (WHITE) FOR CERAMIC BEADS AT NEWARK LIBERTY INTERNATIONAL AIRPORT

TABLE A-19. TWO-LITER WATER RECOVERY TEST RESULTS

2-Liter Water Recovery Test (White)		
Minutes	Plus 9 Beads Sieved	Plus 9 Beads Unsieved
Dry (Baseline)	220	326
0	14	61
5	24	161
10	60	177
15	107	210
20	103	248
25	149	277
30	180	319
35	137	342
40	180	331

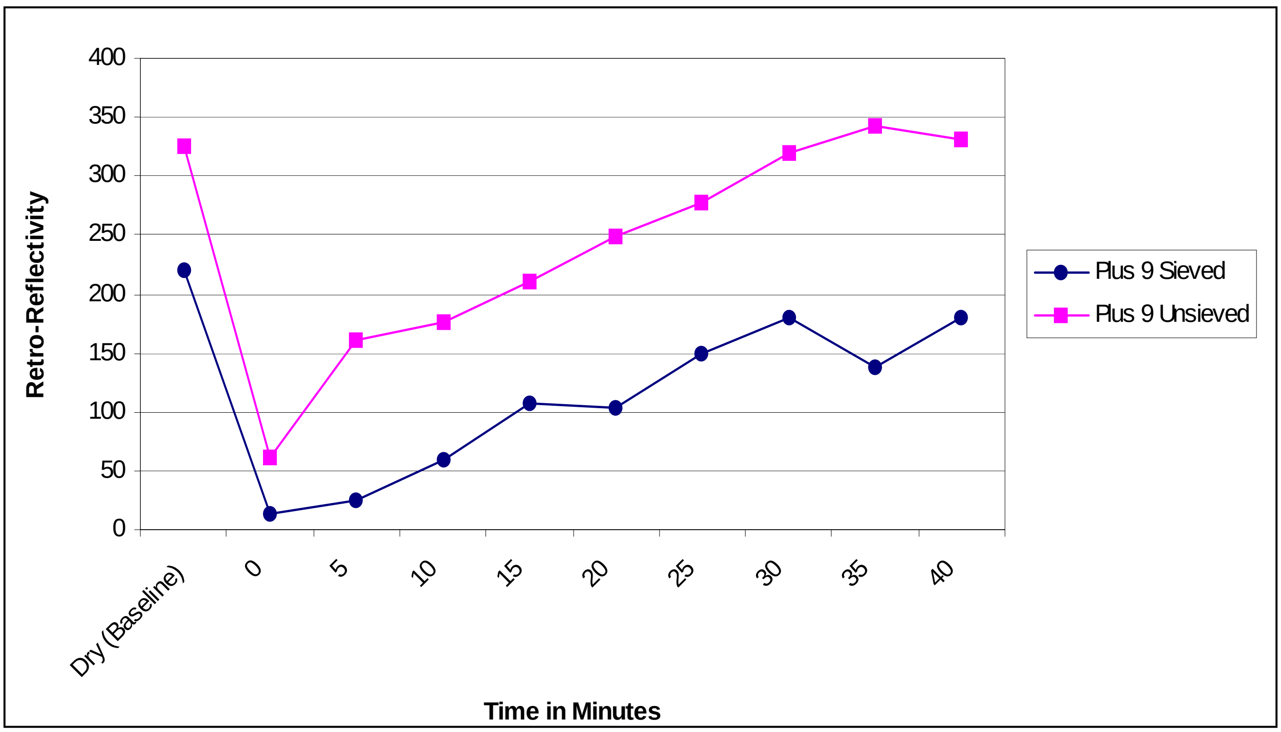

FIGURE A-15. TWO-LITER WATER RECOVERY TEST RESULTS

TABLE A-20. OUTFLOW WATER METER TEST RESULTS AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Asphalt	
	Time (Seconds)
Plus 9 Sieved	11
Plus 9 Unsieved	5

TABLE A-21. OUTFLOW WATER METER TEST RESULTS AT THE WILLIAM J. HUGHES TECHNICAL CENTER

Concrete		
Color	Type of Bead	Time (Seconds)
Black	No Bead	11
White	Plus 9 Sieved	28