An *IPRF* Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

REPORT IPRF 01-G-002-05-1

AIRFIELD MARKING HANDBOOK

Photograph courtesy of NASA

Program Management Office
5420 Old Orchard Road
Skokie, IL 60077

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ABBREVIATIONS

AC	Advisory Circular
ACC	Asphaltic Cement Concrete
ASTM	American Society of Testing and Materials
DOD	Department of Defense
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FOD	Foreign Object Debris
FOG	Foreign Object Generator
ICAO	International Civil Aviation Organization
IOR	Index of Refraction
OSHA	Occupational Health and Safety Administration
PCC	Portland Cement Concrete
PFC	Porous Friction Course
QCP	Quality Control Plan
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
UV	Ultraviolet
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

The focus on runway safety incorporates many initiatives to reduce runway incursions. Among such initiatives, airfield markings are being enhanced to increase visibility for those who need them: the pilots and others who operate on airfield surfaces. “Reducing the risk of runway incursions is one of the FAA's top priorities, as runway mishaps can prove catastrophic.”[1] Although new marking schemes are intended to increase situational awareness for pilots and others operating on airfield surfaces, *unless those markings are installed correctly*, the efforts may not help. Airfield markings for runways, taxiways, and apron areas can be expected to provide excellent performance for several years under a range of operational and site conditions. The practice of remarking the pavements once, twice, or more often each year can be revised to maintain as necessary, based upon criteria discussed herein. When **best practices** are employed initially and during each maintenance cycle, airports can reduce both the frequency of remarking and the life cycle costs of the markings, and enhance ***safety***.

Airfield markings are a small component of a large construction project; often they are incidental to the overall job. And as a maintenance item on an airport manager’s to-do list, markings are often either over or under maintained. A common misconception about the marking process is that it is easy and little can go wrong. As with anything worth doing, for markings, details must be monitored, procedures must be followed, results must be inspected, and most important, specifications must be enforced. When the process is done well, the markings can perform effectively for up to five years or more. When the process is done poorly, the markings can fail within weeks or months. So although markings may be an incidental item in a large airfield project, they can pose as a significant problem when performance is shortened and safety is compromised. The added cost to the airport’s budget to maintain the markings more often than necessary could be redistributed to other, more pressing needs.

The information presented here is a compendium of practices that, when used, result in longer-performing pavement markings. Good markings are the result of quality materials installed by appropriate equipment that comply with basic application requirements. The quality of newly installed airfield markings is a direct reflection of both quality workmanship and materials.

When quality is built into the marking, safety is enhanced, and the life cycle cost benefit is significantly enhanced.

There are cost implications related to employing the best practices of marking application, because qualified personnel and appropriate equipment may not be readily available. Airport owners, design engineers, and contractors must work together to achieve the proper balance between project cost and expected performance.

[1] Nicole Nelson. *Enhancing Runway Safety*. in Centerlines Magazine, Airports Council International - North America), January 2008, page 32.

1 INTRODUCTION

Since roads were put in use, efforts have been made to delineate paths for travel. The ancient Romans used recessed bricks to delineate the center of the road for the drivers of chariots. Light colored rocks were embedded in the center of roads in Mexico for the same purpose. In the early 1900s, Edward Hines, a Michigan road commissioner, used the first road striping in the United States. In the late 1930s the idea of using glass beads became widely known when the *Canadian Engineer* published "Luminous Markings for Highways." Its author stated that the "good visibility obtained and also the high abrasion resistance of the final product, made use of glass spheres advantageous." Then during World War II, the use of beaded lines on airfields helped permit planes to land during imposed blackouts. Afterward, the use of glass beads to provide nighttime delineation became widespread. In the late 1990s many state transportation departments initiated performance programs to improve pavement markings for motorists. Airports have adopted many highway standards, but most lag behind the improved performance levels utilized in highway applications.

Airport pavements are different than highway pavements, although both are composed of the same raw materials. Similarly, airport markings include the same type of materials as highway markings, but they are susceptible to different wear, weathering, exposure, stresses, and traffic.

> The key to unlocking the crucial advantages of airfield markings begins with recognizing their value.

Airfield marking maintenance, although recognized as an item on the manager's to-do list, often is met with the attitude that it is just painting the pavement. The truth is that it is *not* difficult to apply markings, but it can be difficult to apply them *well.* There are good methods and bad methods for applying airfield markings.

1.1 PURPOSE OF THE RESEARCH PROJECT

Airport environments do present challenges for markings. Some of the challenges are similar among airports; others are specific to the environment. The advantages and disadvantages of various application processes (noting environmental conditions, pavement surfaces, and material types) are the bases for this report.

Given the element of safety that good airfield markings provide, the major objective is to define the **best practices.** These practices will indicate the following:

1. The procedures that work and those that do not work.

2. The materials that are effective.

3. The comparison of a good marking versus a poor one.

Markings on airfield pavements can be applied efficiently and effectively so that they function as a safety enhancement for those operating on airfield pavements.

1.2 SCOPE OF THE RESEARCH PROJECT

This handbook presents practices that produce quality airfield markings. Specifically, this handbook includes the following:

1. Discussion of standard specifications set forth by the Federal Aviation Administration (FAA) and Department of Defense (DOD) (US Air Force, US Navy, US Army, US Marine Corps and US Coast Guard).

2. Documentation of construction techniques and practices that result in quality products, (i.e., longer lasting airfield markings).

3. Discussion of advantages and disadvantages of techniques or practices when more than one method is available.

4. Identification of practices that result in early aging, premature failures, and poor long-term performance of airfield markings.

5. Commonly encountered problems in meeting project specifications.

1.3 DISCLAIMER

This handbook is not a construction specification guide; it does not provide detailed instructions on conducting specific airfield marking activities. It does not constitute a standard, specification, or regulation. This handbook should not be used in lieu of a project specification. The specific requirements of plans and specifications for a project take precedence.

1.4 QUALITY IN CONSTRUCTION AND MAINTENANCE PROJECTS

A fundamental assumption is that quality airfield markings perform well. To attain quality markings, it is imperative for all involved (from manager to crewmember to inspector) to pay specific attention to surface preparation, quality materials, application, and inspection.

Good materials and good application practices are required to obtain quality, long-lasting airfield markings. Markings installed well will require less maintenance and have an extended life cycle. Construction and maintenance requirements and specifications must be well defined. Thus, it is important that each project is designed specifically for the needs of the airport and that the specifications be tailored to each project.

1.5 SUMMARY OF HANDBOOK ORGANIZATION

This handbook is organized into seven chapters, as described below. Each chapter addresses a major aspect towards attaining airfield marking quality, and can be read independently of the others.

- **Chapter 1-Introduction:** This chapter introduces the handbook and its organization.

- **Chapter 2–Specifications for Construction and Maintenance Activities:** This chapter addresses the specifications of markings, the construction/installation of markings, and the maintenance of markings. Key elements in the chapter include selecting proper specifications, evaluating existing conditions appropriately, and defining the scope of work based on the existing conditions.

- **Chapter 3–Materials:** This chapter identifies various materials that are used in airfield markings, including both binder and beads. It provides guidelines for the proper selection of materials under specific circumstances. Selecting the correct materials for a given airfield is important in establishing good marking performance.

- **Chapter 4-Surface Preparation:** This chapter describes the processes that can be used to prepare a surface for the application of airfield markings. Surface preparation includes either cleaning or removing *anything* that would reduce the bond between a newly applied material and the surface. Surface preparation is necessary any time markings are applied.

- **Chapter 5–Pavement Marking Removal:** This chapter identifies various practices that can be used to remove airfield markings from the pavement surface. Many factors determine which removal method is the best for a specific set of conditions. The proper removal method helps to minimize pavement scarring; removing the appropriate amount of marking can optimize the life of the new marking application and minimize confusion.

- **Chapter 6–Application Procedures:** This chapter describes the processes used to apply markings to an airfield pavement surface. Many factors that can have an impact on the quality of the installation and the performance of the marking are reviewed.

- **Chapter 7-Inspection:** This chapter describes ways to inspect various aspects of airfield marking application.

Throughout the handbook, best practices are identified by bold text (**a best practice**) within a chapter, and these are summarized in a table at the beginning of each chapter. The airports that adopt these practices will not only improve their marking program by providing longer-lasting, more-effective airfield markings, they will also save valuable maintenance funds. Tables at the beginning of each chapter identify who will benefit from that specific chapter. Table 1-1 summarizes the tables from all chapters.

TABLE 1-1. SUMMARY OF HOW CHAPTER CONTENTS MAY BENEFIT USERS

Users	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7
Applicators		★	★	★	★	
Airport Operators	★		★	★		
Designers/Engineers	★	★	★	★	★	
Inspectors	★	★	★	★	★	★

2 DESIGN AND SPECIFICATION DEVELOPMENT FOR CONSTRUCTION AND MAINTENANCE ACTIVITIES

TABLE 2-1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	
Airport Operators	★
Designers/Engineers	★
Inspectors	★

Many factors should be considered in the design and development of specifications for airfield markings, either as part of a larger construction project or for marking maintenance. Guidance literature for the prevailing jurisdiction (i.e., FAA, DOD, ICAO) are guides and they should not be copied and pasted into project specifications without due consideration of the specific conditions that exist at a particular airfield. The section that contains specifications pertaining to airfield markings should be based on the needs of a specific project, which is a **best practice**. For both new construction and for maintenance of existing markings, the engineer or other official should consider many different factors when evaluating, planning, and enforcing the project.

There are three aspects of marking projects: (1) designing and developing specifications, (2) planning activities, and (3) developing project plans. The factors described in this chapter take place well in advance of the installation of the markings. Table 2-1 indicates the users who will benefit the most from the material in this chapter. Where used, the term ***best practice*** is highlighted in bold. Table 2-2 summarizes the best practices presented in this chapter.

TABLE 2-2. BEST PRACTICES FOR SPECIFYING CONSTRUCTION AND MAINTENANCE OF AIRFIELD MARKINGS

Section Reference	Best Practice
2	Design specific to airport needs and conditions.
2.3.1	Pre-bid meetings benefit all stakeholders.
2.3.3	Verify material types and quantities.
2.3.3, 2.4.2.3d	Specify material arrives to project in unopened containers.
2.4.2.1, 2.4.2.1f	Evaluate actual site conditions, specify and quantify remediation.
2.4.2.2	Evaluate pavement under markings.
2.4.2.3.a	Prescribe surface preparation methods and quantities.
2.4.2.3.b	Determine amount, type and degree of marking removal.
2.4.2.3.c	Specify materials appropriate to airport environment.

When designing a project that either (a) includes airfield markings as part of the overall project or (b) is for the maintenance of airfield markings, the engineer must consider certain aspects of the work. Thus, the design of an airfield marking project, like other construction activities, includes:

1. Identify owner/user, (*i.e.*, FAA jurisdiction or a branch of the DOD).
2. Describe the project objectives.
3. Define the scope of work.

4. Specify methods, equipment, and materials in accordance with standards and per the needs of the airport.
5. Develop plans or blueprints.

> Appendix A presents a sample specification and a list of items to cover during the design stage.

2.1 STANDARD SPECIFICATIONS

> Differences between DOD and FAA documents exist, and care should be taken to design specifications pertinent to the owner/agency. Unless stated, discussion contained herein will refer to FAA criteria.
>
> A synopsis of standard specifications used by several agencies to design airfield marking projects is contained in this document as Appendix B.

Specifications for the application of airfield markings are maintained by different agencies. Additionally, some agencies support specifications for paint removal, rubber removal, and other related activities often associated with airfield markings.

2.1.1 Domestic Construction Specifications

Most domestic airport marking work in the United States is performed in accordance with the provisions of FAA Advisory Circular 150/5340-1: *Standards for Airfield Markings.* This advisory circular describes the different marking elements, their placement, color, and conspicuity (visibility).

Advisory circular, AC 150/5370-10, Standards for Specifying Construction of Airports, Item P-620, describes methods for the preparation of existing surfaces, and the installation of the markings. This handbook presents the methods to meet the requirements of project specifications.

2.1.2 Military Construction Specifications

Each DOD agency maintains its own specification for the design and installation of airfield markings. Efforts to adopt a single standard for all military installations to provide a uniform, standard marking system, (both in design and installation) are ongoing. The latest revision to UFGS 32 17 23 was published August 2016. However, each agency maintains separate specifications.

2.2 AIRFIELD MARKING ELEMENTS

A marking "element" is defined as a specific marking with a prescribed location, dimension, and purpose, including those on runways, taxiways, and aprons. Contained in each agency's guidance literature are descriptions of each element, its location on the airfield surface, the dimensions of the marking, its color, and other characteristics. Table 2-3 describes the markings required for visual, non-precision, and precision runways. Appendix C contains descriptions and pictures of most of the elements for both runways and taxiways. However, the following are key points to remember:

- White markings are associated with runways.
- Yellow markings are associated with taxiways, ramps and hazardous areas.
- Runway markings are symmetrical about the runway centerline.

TABLE 2-3. RUNWAY MARKING ELEMENTS

Table 1 from AC 150/5340-1J, page 3. ("par." references are to paragraphs contained in AC 150/5340-1J)

Marking Element	Visual Runway	Nonprecision Runway/ GPS Nonprecision	Precision Runway/ GPS Precision
Designation (par.7)	X	X	X
Centerline (par.8)	X	X	X
Threshold Marking (par.9)	X(1)	X	X
Aiming Point (par.10)	X(2)	X(2)	X
Touchdown Zone (par.11)			X
Side Stripes (par.12)	X(3)	X(3)	X

(1) Only required on runways used, or intended to be used, by international commercial transport.
(2) On runways 4,000 feet (1200 m) or longer used by jet aircraft.
(3) Used when the full pavement width may not be available as a runway.

Precision, non-precision and visual (basic) runway markings are associated with approach visibility requirements and navigational aid accuracy for a particular runway end.

2.3 DESIGN ACTIVITIES

Various phases associated with all construction or maintenance projects apply to an airfield marking project, whether the marking portion is (a) new construction, where the markings are considered an "incidental" part or (b) the maintenance of existing markings.

2.3.1 Pre-Bid Meeting

Pre-bid meetings, although not mandatory, can benefit all stakeholders. They provide a forum where questions can be asked about expected methods, schedules, and other aspects of the project. Pre-bid meetings are a **best practice**.

2.3.2 Pre-Construction Conference

A pre-construction conference is often the first occasion for the owner/designer to meet with the contractor, and it is often the first time any subcontractors see the project. Here, all stakeholders discuss project expectations and precautions. All submittal documentation has been or is submitted at the time of this meeting.

2.3.3 Material Selection, Certification, and Testing

Materials usually must be certified and/or tested before work can begin. If material certificates are an acceptable means of approval, they should be available when material is delivered to the job site, or earlier if they were delivered to another facility. When the material arrives, the inspector should verify that the documentation matches the ***unopened*** containers, and the quantity of material delivered: these are **best practices**.

2.3.4 Quality Control Plan (QCP)

Each airport is unique, and each marking project is different from others. Accordingly, a quality control plan should be planned to parallel the different stages of work: surface preparation, layout if necessary, and proper application rates of materials to the areas that will be marked. If markings will be removed, the expectations for the final product should be defined in the QCP.

The inspector should observe test strips to establish criteria for acceptance of the work to be performed. However, a test strip is only a "snapshot" of the finished work, and it should not be regarded as a measure of what will be done throughout the job. The quality control measures discussed in the sections to follow should be employed by the quality assurance person, whether the inspector or the applicator.

2.3.5 Safety Plan

A safety plan should be developed to address the requirements of 14 CFR Part 139, FAA AC 150/5370-2, *Operational Safety on Airports during Construction*, OSHA, EPA, local, and state regulations.

2.4 INSTALLATION OF NEW MARKINGS OR MAINTENANCE OF EXISTING MARKINGS

Airport engineers design projects that involve pavements, lighting, signage, markings, and many other aspects of airport construction. When designing a project that includes the application of airfield markings, one of two types will be involved.

- Installation of new markings as all or part of a new construction project.
- Maintenance of existing markings and/or changes to existing markings.

2.4.1 Designing a Construction Project Involving New Airfield Markings

- Describe the overall project.
- Describe the type of pavement being constructed, (i.e, bituminous asphaltic concrete or Portland cement concrete), or describe the surface condition.

- Identify requirements for any changes to existing markings.
- Identify the need for any paint removal.
- Schedule phasing of markings for a time of year when weather is conducive to application of marking materials.

2.4.2 Designing a Project for the Maintenance of Existing Markings

Airfield markings deteriorate over time from traffic wear, ultraviolet light, wind, rain, snowplowing, and sweeping, etc. The *Development of Methods for Determining Airport Pavement Marking Effectiveness*[2] was part of an effort to provide quantitative criteria for inspectors and airport operators to objectively determine the need for maintenance of airfield markings. Excerpts from this study are contained in Appendix D. Certain criteria should be evaluated to determine when markings require maintenance, because they do not *necessarily* need to be remarked each year. Some of those criteria are:

1. Faded colors or appearance.
2. Poor nighttime visibility or retro-reflectivity.
3. Existing markings are worn 50 percent or more.
4. Existing markings are covered with contaminants.

FIGURE 2-1. PEELING PAINT LAYERS

2.4.2.1 Evaluation of Existing Markings

Take photographs to document what is observed to establish conditions "before" work begins, and include the photographs in the project specifications to better inform contractors. As a **best practice,** evaluate existing markings for the following conditions:

a. Layers of paint from older markings, figure 2-1.
b. Rust discoloration.
c. Algae growth.
d. UV damage

[2] *Development of Methods for Determining Airport Pavement Marking Effectiveness,* Holly M. Cyrus, Report DOT/FAA/AR-TN03/22, Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ., March 2003.

FIGURE 2-2. MEASURE EXISTING MARKINGS TO DETERMINE COMPLIANCE WITH AC 150-5340-1.

FIGURE 2-3. MARKING DIMENSION IS OUT OF TOLERANCE.

FIGURE 2-4. MARKING IS OUT OF ALIGNMENT

e. The position and dimension of existing markings.

Existing markings should be measured to verify compliance with the appropriate element. The designation marking shown in figure 2-2 should measure 5-feet wide on the "stroke," but due to repeated remarking, it measures 6-feet, 4-inches, seen in figure 2-3. Because the dimension tolerance is 1-inch on a marking over 36-inches wide, this marking is out of tolerance per FAA AC 150/5370-10.

f. Evaluate the alignment of existing markings for compliance with standards.

All specifications state that markings shall not deviate from a straight line more than ½ -inch in 50 feet. If the markings are being repainted, the applicators should perform layout (see figure 2-4) and possibly remove the marking prior to repainting. Quantify the amount of layout and/or removal to be done to comply with alignment standards: a **best practice.**

g. Material compatibility.

Determine the composition of existing material/coatings and verify compatibility with specified materials. Information can be found in documentation from previous marking projects. Otherwise, a lab analysis of the existing coating may be necessary to characterize it.

2.4.2.2 Evaluate Pavement Conditions Under the Existing Markings

When planning for maintenance of airfield markings, it is a **best practice** to evaluate the condition of the pavement, whether asphalt, concrete, seal coat, rejuvenated asphalt, patched pavement, crack-sealed pavement, or other material. The integrity of pavement surfaces will affect the longevity of the new airfield markings, and this should dictate appropriate methods of surface preparation, paint removal, and/or types of material to be applied. Aged, cracked asphalt, for example, may not withstand certain methods of preparation or removal of markings, and in such cases a combination of methods may be appropriate.

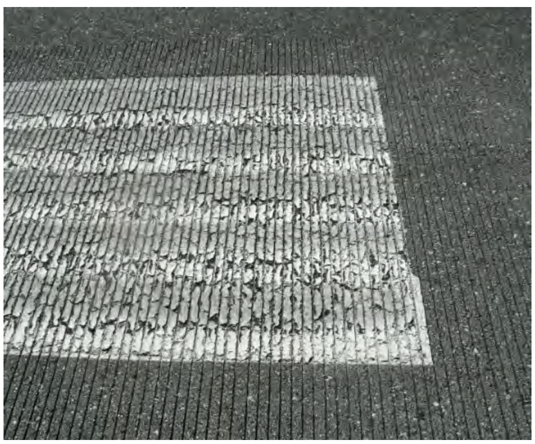


FIGURE 2-5. A PRE-EXISTING CONDITION OF POOR ASPHALT PAVEMENT.

FIGURE 2-6. RESULTS OF WATERBLASTING REMOVAL ON POOR ASPHALT SEEN IN FIGURE 2-5.

Even though pavement adjacent to the markings can be in good condition, pavement under the markings is often cracked, as seen in figure 2-5. If this condition is observed, the deteriorated pavement is considered a pre-existing condition. Figure 2-6 shows scarring that can be expected after waterblasting when the existing markings are cracked. The condition of the pavement under existing markings is a gauge of how well a new marking application will last.

2.4.2.3 Define the Scope of Work

By focusing on the conditions described previously, the designer can better define the work that needs to be done, thus minimizing confusion, surprises, and claims: a **best practice**.

a. Quantify surface preparation and prescribe method: a **best practice.** All specifications contain wording about "surface preparation." Methods such as sweeping, blowing with compressed air, or rinsing with water are prescribed. Airfield markings involve large areas of material that are exposed to sunlight, rain, snowplows, chemicals, etc. Some of the markings that are out of the traffic flow receive little wear. Evaluate the condition of existing markings and specify which markings need what type of surface preparation. Sweeping and blowing with compressed air should be used *after* the prescribed method of surface preparation. This will provide the airport with a good product, the installer with clear expectations, and the inspector with enforceable criteria.

> "The Engineer should specify any additional surface preparation required and should specify the type of surface preparation to be used when existing markings interfere with or would cause adhesion problems with new markings."
> Source: FAA AC 150/5370-10

b. Quantify amount of any paint removal, degrees, and method(s) to be used – a **best practice.** Obsolete markings should be completely removed. From a safety standpoint, blacked-out markings can be misleading, particularly on a wet surface at night. From a maintenance standpoint, as the black paint wears off, the old marking reappears, resulting in more maintenance for the same marking. Accurately (a) quantify and describe the markings that need to be removed, (b) describe the condition of the pavement under the marking, and (c) provide any other details that will help the contractor determine the difficulty of the paint removal.

> Old markings must be removed, not obscured with black paint, per FAA AC 150/5340-1.

c. Select appropriate materials relative to airport pavements, pre-existing conditions, and environment. A list of approved materials is found in the guidance literature for each agency, and each one has benefits and limitations. Specifying the right material based on the needs of the airport is a **best practice**.

d. Specify that materials arrive on the job in sealed, unopened containers to verify initial quantities planned for the project. This is a **best practice**. If the beginning inventory is known, both the contractor and inspector can verify material usage and coverage rates achieved during the course of the job.

> The materials for the job should not arrive already loaded in a truck with an indeterminate amount or type. They should arrive in sealed, unopened containers for verification.

3 MATERIALS

Many different marking materials are used for airfield markings. At the simplest level, airfield markings consist of a combination of a binder and glass beads. Selecting the right materials for the job is important. The airport environment, amount of traffic, safety issues, schedules of operations, types of pavement, and existing marking materials should be considered when determining which materials to use. Choosing the optimal materials may increase initial costs, but over the long term this should be more cost effective; it can provide an added measure of safety.

TABLE 3-1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	★
Airport Operators	
Designers/Engineers	★
Inspectors	★

Chapter 3 addresses the material used for airfield markings. This includes different types of both binders and glass beads. This chapter also provides information about the performance and compatibility of various material combinations. Table 3-1 indicates the users who can gain the greatest benefit from the content of this chapter, and table 3-2 summarizes the best practices presented in this chapter.

TABLE 3-2. BEST PRACTICES FOR MATERIALS

Section Reference	Best Practice
3.1.2	Glass beads selected are appropriate for the coating material.
3.3	Material compatibility is considered.
3.4	Temporary marking materials selected for "removability".
3.5	Materials are selected on the basis of airport environment.
3.6	Materials sampled from equipment guns.

Materials refer to the types of binders and glass beads selected for the project. Choices of binders include water-borne (Type I, II, or III), solvent-borne, epoxy, and methyl methacrylate. Choices of glass beads include TT-B-1325, Type I, III or IV.

3.1 MATERIALS COMMONLY USED

Water-borne paint (TT-P-1952, Type I, II, or III) and glass beads (TT-B-1325, Type I, III or IV) are used in 95 percent of airports, both DOD and domestic. A description of other approved materials is presented in Section 3.2.

Specification TT-P-1952 (Type I, II, or III) addresses types of water-borne paint.
Specification TT-B-1325 (Type I, III, or IV) addresses types of glass beads.

3.1.1 Water-Borne Paint, TT-P-1952, Type I, II or III

The majority of airports in the United States use water-borne paint conforming to Federal Specification TT-P-1952. Water-borne traffic paint is the coating of choice for airports, because it has good environmental characteristics, has a fast dry time, is easy to clean up, and does not generate hazardous waste.

3.1.1.1 Historical Perspective of Pavement Marking Paints

Pavement marking paints typically have been categorized into two types: solvent-borne and water-borne. Before the 1980s, solvent-borne paints were the most frequently used coatings. Currently in the United States, the use of water-borne paint far exceeds the use of solvent-borne paints. The initial driver for this conversion was the passage of environmental air quality regulations limiting the Volatile Organic Compounds (VOC) content in traffic markings. Typically solvent-borne paints were not in compliance with these new, low VOC limits.

As the conversion from solvent to water-borne continued, more retro-reflectivity retention data was collected, and water-borne paints became the preferred choice. Continual improvements in the chemistry of the acrylic polymer used as the "glue" in the water-borne paint only added to this preference.

As paint technology continued to advance, water-borne pavement markings have been modified to fill the needs of the users while retaining their environmentally friendly status; high build paints, and other durable paints provide new levels of performance, some of which can be applied at temperatures as low as 35 F.

3.1.1.2 Benefits and Limitations of Water-Borne Paints:

- Benefits of using water-borne paints include ease of use and clean up. Water is sufficient for all clean up, and no toxic chemicals are needed. Because the material is non-hazardous, it is safe to handle the material, and empty containers can be crushed and disposed of at a landfill. Fast-dry water-borne paints can be installed quickly and new markings can be driven over soon after installation.

- TT-P-1952F, Type I and II water-borne paints can cause the asphalt to lift or crack next to the marking edge due to stresses created during the curing of the paint. This usually occurs when the asphalt is freshly applied or when the water-borne paint is applied too thickly. Figure 3-1 shows a 24-hour old marking that was applied before the asphalt had cured. As the paint cured, the soft asphalt lifted.

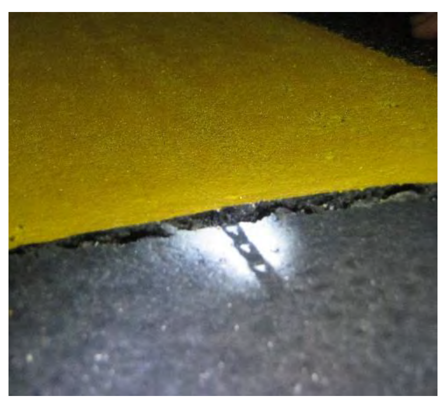


FIGURE 3-1. THE NEW PAINT ON YOUNG ASPHALT CAUSED THE ASPHALT TO LIFT.

- Limitations of using water-borne paints are weather related. TT-P-1952, Type I dries slowly when the humidity is high; it may take up to 30 to 45 minutes to dry. Type II is a faster drying material, and under humid conditions, drying can take up to 20-30 minutes.

- Type III, a high-build acrylic is a more durable product, and is comparable to the Type II formulation; it contains special fast-dry polymer binders that hasten the drying process. The resin used in the Type III formula produces a more flexible coating when cured. It can be applied up to 30 wet mils for a high-build coating.

The "glue" in water-borne paints is the dispersion of tiny (~0.2 micron) polymer particles that cure by physical rather than chemical processes. Initially, water-borne paints achieve a *no-track* condition after some of the water is evaporated from the applied marking. At the *no-track* stage, the marking is dry to the touch and resists tracking onto the pavement surface by vehicles traveling over it. However, at this point, the markings are soft and will not withstand wear or rain. After more water has evaporated, the water-borne paints become *dry through*. At this point, the marking will withstand light wear and rain.

After all the water evaporates, the water-borne paint continues to cure and harden (by coalescence of the polymer binder particles) to achieve full-wear resistance. Because water-borne paint cures through a combination of evaporation and coalescence, the curing time for paints depends on the following:

- Paint temperature–the higher the temperature, the faster the paint will cure.
- Pavement temperature–the higher the temperature, the faster the paint will cure.
- Humidity–the more humidity, the slower the paint will cure.
- Wind speed–the higher the wind speed, the faster the paint will cure.
- Paint thickness–the thicker the paint, the slower it will cure.

3.1.2 Glass Beads

The ability to see a pavement marking at night is based on the retro-reflective characteristics of the marking. "Retro-reflectivity" is the technical term that defines how much light is reflected from a light source back to a specific measurement or vantage point. The retro-reflective characteristics of a marking are associated with the glass beads applied to the marking material, the manner in which the beads are applied, and the characteristics of the marking binder.

Glass beads are round spheres of either recycled or virgin glass that provide retro-reflective properties when embedded into pavement markings. Embedment is the partial submersion of the glass bead in the marking material (binder). As the binder is applied to the pavement, the glass beads (about the size of a grain of sand) are dropped onto the binder. Ideally, they become submerged part way into the binder and are suspended as the binder dries (cures) around them. If the beads are over-embedded or under-embedded, the marking becomes less retro-reflective. But when the beads are embedded properly, the marking provides visual guidance during darkness or other low visibility conditions, thus making the pavement marking functional 24 hours a day.

The amount of light retro-reflected to the source is typically greatest along the *illumination axis* (the line from the light source to the marking). As the observer moves away from the light source, the amount of retro-reflected light decreases. Pavement marking retro-reflectivity is normally measured in units of millicandelas per meter squared per lux (mcd/m²/lux) using a standard 30 meter measurement geometry.[3]

The 30 meter measurement geometry established a standard arrangement for the light source, the marking, and the observer when measuring retro-reflectivity of the marking. It is based on the typical dimensions of a small European passenger car located 30 meters (98.4 ft) from a marking. For the 30 meter geometry, the entrance angle is 88.76° and the observation angle is 1.05°. Figure 3-2 illustrates the 30 meter geometry.

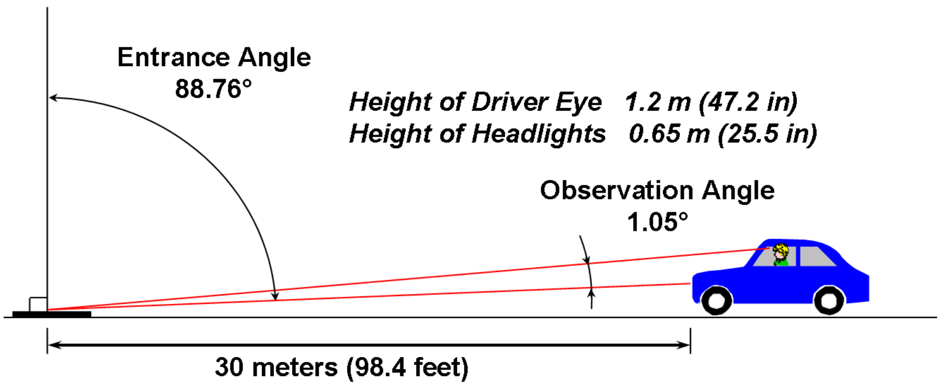


FIGURE 3-2. 30-METER GEOMETRY

Figure 3-3 illustrates how glass beads retro-reflect a light beam from a source, generally a headlight on a vehicle or aircraft, back to the source. The light beam bends when it enters and leaves the bead due to the difference in the index of refraction (IOR), also called the refractive index (RI), between the bead and the air outside the bead. The higher the IOR, the more efficient a bead is at retro-reflecting light.

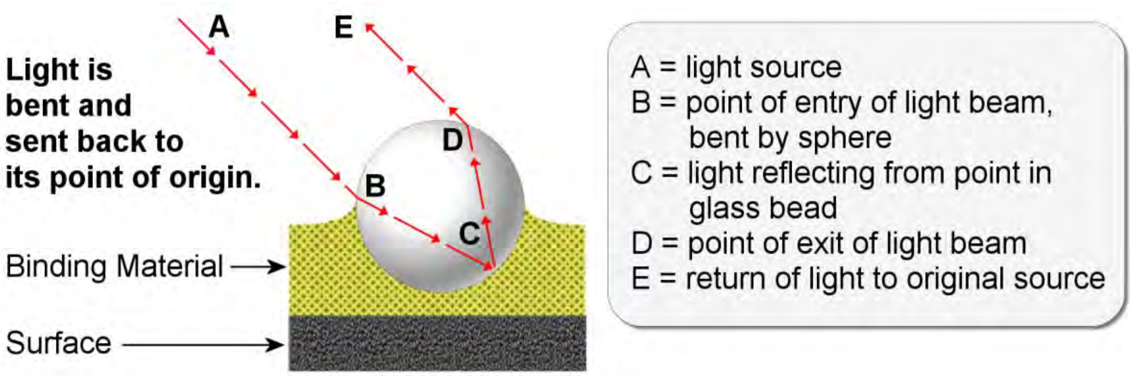


FIGURE 3-3. ILLUSTRATION OF INCIDENT LIGHT INTO GLASS BEAD AND RETURN TO SOURCE.

[3] 1 candela equals 1 lumen/steradian; 1000 millicandelas equals 1 candela. Lumens are units of Luminous Flux and they measure how much light actually falls on a surface. The Luminous Flux (lumens) from a light source is equal to the Luminous Intensity (candelas) multiplied by the solid angle over which the light is emitted, taking into account the varying intensities in different directions. Source: http://www.superbrightleds.com/led_info.htm

Three types of glass beads are approved by the FAA: TT-B-1325; Type I, Type III and IV. Type I and IV have the same IOR and both are made from recycled glass (or the direct melt process). Type III glass beads are made from virgin materials and have a higher IOR.

> **Important:** **Types I, II, and III beads are also used in highway applications. However, the classification of bead types is different for highway applications and airport applications. Users should ensure that the beads used on airport markings meet the TT-B-1325 bead type classifications and are not glass beads for highway applications.**

Each type of bead described next and compared in size in figure 3-4 has a different coverage rate, based on its size and/or specific gravity. Whereas Type I and Type III glass beads are suited to any material, Type IV is best suited for thicker materials because of its size and the need to properly embed it in the wet binder. Selecting the type of bead suitable to the binder being applied is a **best practice**. Retro-reflectivity ranges *at installation* are provided in the figure as a guide for performance criteria.

FIGURE 3-4. SIZE COMPARISON OF GLASS BEADS FOR AIRPORTS

Retro-reflectivity of airfield markings can range from 10 – 3000 mcd/m²/lux. The higher the retro-reflectivity, the brighter the marking appears, and the further away it can be seen. The FAA has established *minimum* reflectivity levels for *maintenance* in the 12/21/2018 edition of AC 150/5370-10H, Item P620 (attached as Appendix A). Bare concrete measures 30 mcd/m²/lux to provide some perspective.

FIGURE 3-5. FAIR TYPE I BEAD POPULATION; READINGS AVERAGED ONLY 135 mcd/m²/lux.

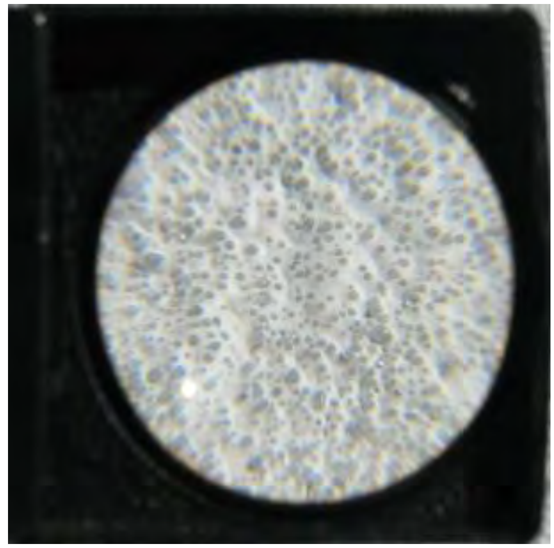


FIGURE 3-6. GOOD TYPE I BEAD POPULATION; READINGS AVERAGED 300 mcd/m²/lux.

3.1.2.1 Type I Low Index Beads (1.5 IOR)

The TT-B-1325, Type I low index beads have been used on highways for decades, and they were adopted by the FAA and USAF in the mid-1990s for use on airports. Made from recycled glass, Type I beads have the smallest diameter compared to the other approved beads.

Type I glass beads have a coverage rate of seven pounds per gallon of water-borne or solvent-borne paint. At *installatio*n, Type I, applied properly in a white binder, should yield retro-reflectivity readings ranging from 300–450 mcd/m²/lux. Figure 3-5 shows an example of *fair* Type I bead population, and figure 3-6 demonstrates *good* Type I bead population. *Excellent* bead population should yield up to 450 mcd/m²/lux at *installation.*

3.1.2.2 Type II Beads

Type II beads are no longer included in the specification and should not be used in airfield markings.

3.1.2.3 Type III High Index Beads (1.9 IOR)

TT-B-1325, Type III high index glass beads are made from virgin materials that provide a higher IOR; this results in a *concentrated* beam of returned light, (see figure 3-7). In comparison, Type I or Type IV beads return a diffused light beam. When installed in white paint, Type III beads should yield reflectivity values of at least 600mcd/m²/lux at *installation*, and they represent the highest potential reflective values of any of the specified glass beads. Type III beads are recommended when long-term performance is desired. When higher retro-reflectivity readings are achieved at installation, and the beads are well anchored and embedded, the marking will remain effective longer. The brighter the marking, the greater the distance recognition.

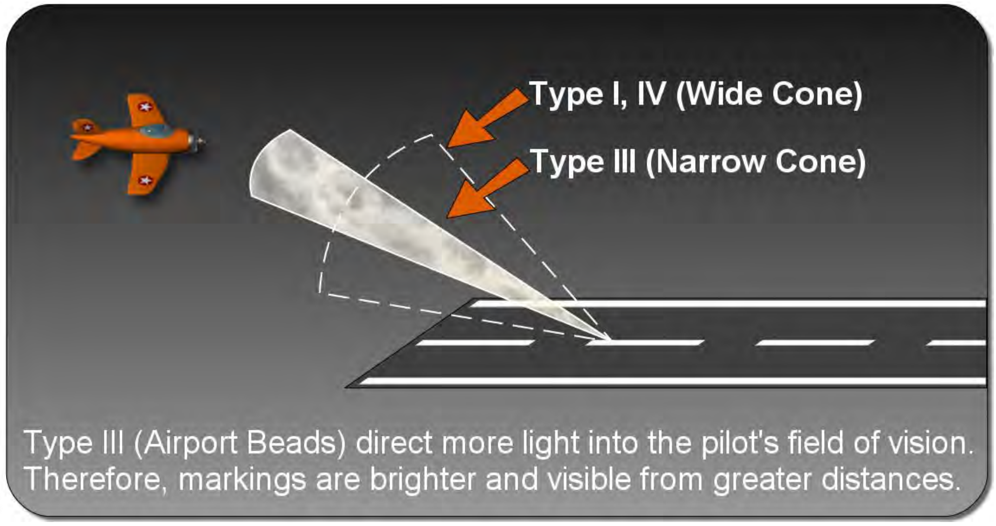


FIGURE 3-7. DEMONSTRATES THE GREATER RETURN OF LIGHT FROM THE 1.9 IOR (TYPE III GLASS BEADS) WHEN COMPARED TO THE 1.5 IOR (TYPE I OR TYPE IV GLASS BEADS).

Type III beads are the densest of the glass beads, and require distribution of ten pounds per gallon due to their high specific gravity. Although more expensive than either Type I or Type IV, Type III beads are expected to provide 1) better *initial* retro-reflectivity and 2) if applied properly, better *long-term* performance. For example, if markings have initial readings of over 800mcd/m²/lux, it will take longer for the markings to lose their effectiveness, resulting in less maintenance. Conversely, if the low index beads are installed properly with initial readings of 300 mcd/m²/lux, reflectivity will drop below acceptable levels more quickly, thus requiring more frequent maintenance, more paint build up, etc.

Studies conducted by FHWA and other agencies have concluded that, "minimum retro-reflectivity values are speed dependent. Preview or visibility distance is the distance that the delineation provides the driver to see changes in roadway alignment. Preview distance is important, especially at higher speeds [that occur during landings and take-offs of aircraft]. When drivers [or pilots] are provided with higher reflectivity values, longer preview distances are achieved, which is desirable from an information acquisition, information processing, and safety point of view". [4]

3.1.2.4 Type IV Low Index Beads (1.5 IOR), Gradation A and B

TT-B-1325, Type IV "big beads" were approved for use by the airport industry in 2005. Also made from recycled glass or by direct melt, they are larger than any of the specified glass beads. When applied in standard white water-borne paint, the reflectivity readings should be at least 350 mcd/m²/lux at *installation*.

However, given the size of the glass bead (0.84– 1.68 mm for Gradation A, and 0.59–1.19 mm for Gradation B), they are best suited for use in the high build acrylic binder with a specified wet film thickness of at least 25–30 mils (TT-P-1952, Type III). In contrast, TT-P-1952, Type I or II binder should only be applied between 12 and 16 mils to avoid cracking of the dry film and premature failure. When Type IV glass beads are applied to standard water-borne traffic paint at 15 mils wet film thickness, results are poor (see figures 3-9 through 3-11). Type IV glass beads are applied at the rate of eight pounds per gallon of water-borne or solvent-borne paint. After only six months of service, the markings in figure 3-9 are no longer functional at night. When the markings were applied, the coating thickness was insufficient to anchor the large glass beads, and normal traffic dislodged them.

FIGURE 3-8. NON-FUNCTIONAL MARKING DUE TO POOR REFLECTIVTY.

> **A considerably thicker wet film thickness (wft) must be applied to achieve proper bead embedment and anchoring with Type IV glass beads. Accordingly, TT-B-1325 Type IV beads should be used only with a TT-P-1952, Type III high build acrylic binder with a specified wet film thickness of at least 25-30 mils. TT-B-1325 Type IV beads should not be used with TT-P-1952 Type I or Type II binder.**

Figure 3-9 shows what happens when glass bead dispensers do not uniformly cover the marking being applied (Distribution). Figure 3-9 is an illustration of poor distribution and embedment of beads in an insufficient coating thickness. The magnified beads in figure 3-10 are poorly embedded, barely anchored in the binder, and they will dislodge with very little traffic, as seen in figure 3-8. Reflectivity readings were high (450 mcd/m²/lux) on the marking in figure 3-10. The readings would decrease to a range of 200-350 mcd/m²/lux for yellow markings if the beads were properly embedded in the paint. Under embedment results in higher retroreflectivity readings; but the higher readings will diminish as the beads dislodge.

[4] Transportation Research Board, NCHRP Synthesis 306, Long-Term Pavement Marking Practices, 2002, Project 20-5, Chapter 3, *Driver Needs, Retroreflectivity Requirements, and Information Through Word and Symbol Markings,* page 14. ,James Migletz and Jerry Graham, consultants.

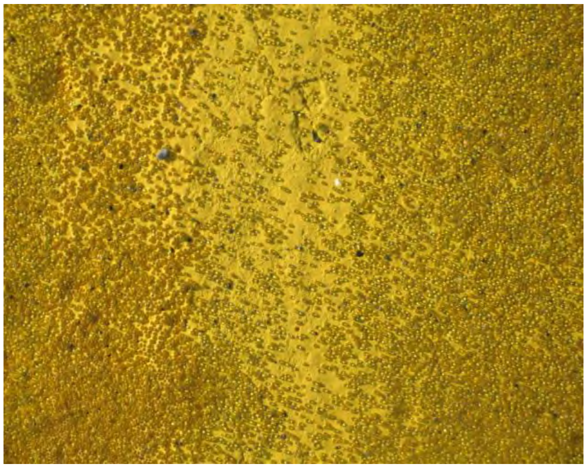


FIGURE 3-9. TYPE IV BEAD DISTRUBTION IS POOR.

FIGURE 3-10. POOR TYPE IV BEAD EMBEDMENT.

3.1.2.5 Coatings or "Coupling Agents" for Glass Beads

Coatings improve performance of glass beads and are recommended by the FAA in AC 150-5370-10, Section 620, Paragraph 2-3. Reflective Media: "*Glass bead treatments are specifically designed to enhance the performance characteristics of the pavement markings in the binder systems approved for use on airfields.*"

- **Adhesion coatings** improve the overall durability of the painted marking by promoting adhesion of the glass to the specified paint.

- **Flotation coatings** aid proper embedment of the beads in the marking material. Research has shown that beads embedded between 50 and 60 percent (figure 3-11) in the wet marking material will provide the optimal (brightest) retro-reflective values. The marking material "behind" the bead acts as a mirror. If there is too little or too much embedment, not enough light will reach the back of the bead and return to the observer. Additionally, beads that are not embedded deeply enough will dislodge from the marking, reducing the effectiveness of the marking during darkness and other low-visibility conditions, when they are needed most (figure 3-10, seen previously).

- **Moisture resistance coatings** repel moisture; they assist with flow properties and inhibit clumping or agglomeration of glass beads.

- **Dual coatings**, often recommended for water-borne paint, help promote both adhesion and flotation of beads.

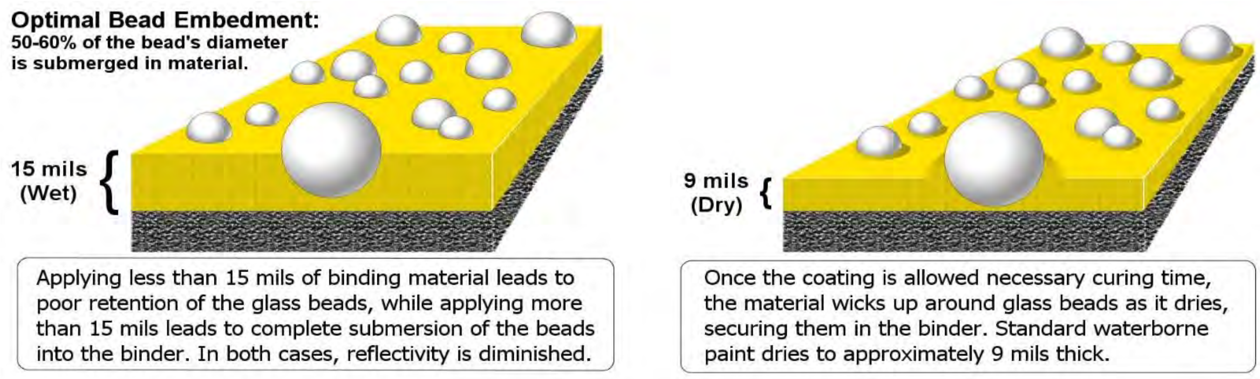


FIGURE 3-11. GLASS BEAD EMBEDMENT IN BOTH WET AND DRY PAINT FILM.

3.2 OTHER APPROVED MATERIALS

Other marking materials are approved in most guidance literature. Although water-borne paints are used predominantly on domestic, private, and military airports, some circumstances warrant the use of other approved materials.

3.2.1 Solvent-Borne Paint (A-A2886B, Type I or II)

Solvent-borne (oil-based) paint is a single-component paint containing alkyd resins, acrylic resins, chlorinated polyolefins, or chlorinated rubber. It typically contains volatile organic compounds (VOC) such as toluene, heptanes, VM&P (Varnish Makers & Painters) naphtha, and MEK (methyl ethyl ketone), all of which exceed the EPA limits for VOCs. The use of the solvent-borne paint may be warranted in cool, humid environments, because with solvent-borne paints, application restrictions are not as critical as with water-borne paints.

3.2.2 Durable Marking Materials

Three marking materials are commonly classified as *durable*, (i.e., their life expectancy is longer than that of water-borne or solvent-borne paints): epoxy, methyl methacrylate, and preformed thermoplastic. Used predominantly on highways, durable markings are effective on airfield pavements that are subjected to constant traffic and wear. Two warnings should be heeded about using durable materials on airfield pavements: (1) they are difficult to remove if they become obsolete, and (2) if subjected to snowplows, the glass beads may shear, causing the marking to lose reflectivity and effectiveness during darkness and other low-visibility conditions. This is a difficult problem to repair because of the durability of the material and the cost to remove and/or reapply it.

> Marking durability is the measurement of the staying power of the binder (i.e., resistance to abrasion from traffic, snowplows, and weather).

> Removal of obsolete durable markings on asphalt requires light milling or ginding to avoid serious scarring to the pavement. Durable markings should not be applied to grooved asphalt pavements.

3.2.2.1 Epoxy

Epoxy is a durable, two-component system consisting of a pigmented resin base and a hardener. During installation, both components are mixed at a ratio of 2 parts resin to 1 part hardener, and the material is applied with specialized equipment. This material is sprayed onto the surface at approximately 1200 psi with an airless system, because airless pumps can be set to deliver the two components at the correct ratio. Epoxy striping material is classified as 100 percent solids; this means that evaporation (of solvents or water) is not used to cure the material. Thus, without this evaporation process, a typical application rate at 60 square feet per gallon yields 30 mils wft and dries to 30 mils. Epoxy striping material is cured via a chemical reaction, and it can be applied at temperatures as low as 35 F. It can be applied over other epoxy materials, but only once. After a second application, the old material must be removed. For epoxy, Type I glass beads should be applied at 14 pounds per gallon, Type IV glass beads at 15 pounds per gallon, and Type III beads at 20 pounds per gallon.

3.2.2.2 Methyl Methacrylate

Methyl methacrylate is a two-component system; it is 100 percent solid material and chemically reactive, containing no volatile solvents. The components consist of a pigmented material (the "A" component) and a liquid or powder catalyst (the "B" component). The catalyst makes the material harden. The components are mixed together as they are applied, and this material can be installed at colder temperatures than conventional water-borne paint.

Specialized equipment is required when methyl methacrylate is used, and it should comply with the manufacturer's recommendations. This marking material should be applied to the pavement according to the manufacturer's recommended methods at 1.5 mm (60 mil) minimum thickness at a rate of 30 square feet per gallon. In this case, glass beads should be applied at 14 pounds per gallon for Type I, 15 pounds for Type IV, and 20 pounds per gallon for Type III beads.

3.2.2.3 Preformed Thermoplastic

Markings are composed of ester modified resins in conjunction with aggregates, pigments, and binders that have been factory produced as a finished product. The material must be impervious to degradation by aviation fuels, motor fuels, and lubricants. The markings can be applied in temperatures as low as 35°F.

Graded glass beads.

(a) The material contains a minimum of 30% intermixed graded glass beads by weight. The intermixed beads conform to Federal Specification TT-B-1325D, Type IV, Gradation B, with the exception that the roundness shall be 90% or better.

(b) The material has factory applied coated surface beads in addition to the intermixed beads at a rate of one (1) lb. (0.45 kg)(±10%) per 10 square feet (1 sq m). These factory applied coated surface beads conform to Federal Specification TT-B-1325D, Type IV, Gradation A, and Federal Specification TT-B-1325D, Type I, Gradation A, have a minimum of 90% true spheres, and a minimum refractive index of 1.50.

The material manufacturer must provide a method to indicate that the material has achieved satisfactory adhesion and proper bead embedment during application and that installation procedures have been followed. The material has a nominal thickness of 65 mils (1.7 mm) The material must demonstrate a uniform level of retro-reflection and should yield at least 225 mcd/m²/lux on white and at least 100 mcd/m²/lux on yellow. Multicolored markings must consist of interconnected individual pieces which, through a variety of colors and patterns, make up the desired design.

Preformed thermoplastic markings are subject to an Engineering life-cycle cost analysis prior to inclusion in specifications for AIP funded projects.

3.3 COMPATIBILITY OF MATERIALS

Existing Material (Old Coating)	Restripe (New) Material				
	Waterborne Paint	Solvent Paint	Epoxy	MMA	Preformed Thermoplastic
Waterborne Paint	✓	✗	✗	✗	✗
Solvent Paint	✓	✓	✗	✗	✗
Epoxy	✓	✓	✓	✗	✗
MMA	✓	✓	✗	✓	✗
Preformed Thermoplastic	✓	✓	✗	✗	✗

TABLE 3-3. MATERIAL COMPATIBILITY INDEX

Once the need for marking maintenance has been determined, the composition of the existing marking material should be identified. For best results, the new material must be compatible with the existing pavement marking material. Table 3-3 presents a material compatibility index. For example, water-borne paint is versatile, and it can be applied over any type of existing (old) material, provided it is in good condition, (i.e., well adhered and less than 40 mils of paint build up). However, epoxy, methyl methacrylate, and preformed thermoplastic can only be applied to themselves. Attention to material compatibility is a **best practice.**

3.4 TEMPORARY MARKING MATERIALS

The selection of temporary marking materials based on the ease of removal is a **best practice.** Temporary marking tapes are easily removed, but these can become foreign object debris (FOD) if they loosen prematurely. Water-borne paints are most commonly used for temporary markings because they are easier to remove than other binders.

One method that will facilitate removal of temporary markings from asphalt surfaces is to apply a layer of wax-based curing compound material prior to the application of the temporary markings. This curing compound sloughs (or flakes off) the pavement over a period of time, and it does not bond to the surface. If an applicator sprays curing compound on areas that will be temporarily marked, removal of the temporary markings can be facilitated in some cases, and reduce scarring to the pavement.

TT-P-1952B was an early generation of waterborne paint and has been used successfully as a temporary marking material that can be removed with a pressure washer.

3.5 MATCHING MATERIAL TO AIRPORT ENVIRONMENT

Different environments present unique challenges for airfield markings. Selecting appropriate materials for an airport is a consideration when designing a project; it is also important when resolving an issue related to the markings. Attention to existing conditions such as those described below is a **best practice**.

- Moist, warm, humid environments promote the growth of algae, which often covers and obscures airfield markings on non-trafficked areas. When needed, water-borne paints can be modified to resist algae growth.

- Some environments have high iron content in soils, ground water, or even in the pavement aggregate. Modifications to standard materials can be made to resist the staining of the markings caused by the iron contaminant.

- Other considerations, such as a short work window or application during cold temperatures may dictate the use of certain materials over others.

- As demonstrated in table 3-3, careful consideration must be given to the composition of an existing marking if a new coating will be applied. When restriping thick, durable markings, such as preformed thermoplastic, methyl methacrylate, and epoxy, the build-up of material can quickly become an issue.

3.6 MATERIAL TESTING

Material testing is performed at the option of the Engineer (per FAA AC 150/5370-10). Manufacturers' material certifications for each batch or lot are an accepted practice for verification of compliance.

Military guidelines ETL 97-18 (USAF) and UFGS 32 17 23 (Navy, Army, Marines) specify that when materials are delivered to the job site, they must be sampled by the contractor in the presence of the inspector, labeled, and sent to an independent laboratory for analysis and verification of compliance. Enforcement of this specification is inconsistent, but when it is required, the testing is both time-consuming and expensive. Each material specification contains testing requirements (i.e., TT-P-1952F, TT-B-1325D, etc.).

Some applicators thin the paint when loading it into the machines, thus causing the material to be out of compliance when applied. Sampling the material directly from the containers does not detect this problem.

Reliance on material certifications alone is expedient, but not advisable.

The other extreme of sampling and testing each batch by an independent laboratory is both time-consuming and expensive. When enforcement is inconsistent, there is a disparity in competitive bidding.

A **best practice** is to take a 1-quart sample of each batch from the striping machine, label and retain for the warranty period under manufacturer-recommended storage conditions. Material certifications will suffice unless there is a problem with the coating within the warranty period.

4 SURFACE PREPARATION

To perform as expected, pavement markings must adhere to the pavement surface. Thus, the pavement surface must be prepared properly prior to applying markings. Surface preparation and paint removal are two separate procedures. Surface preparation involves the cleaning of a variety of contaminants such as curing compound, rubber, loose and flaking material/paint, algae, rust, oil, dirt, and other substances. A range of practices can be used to clean (prepare) surfaces, depending on the specific requirements of a project.

TABLE 4-1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	★
Airport Operators	★
Designers/Engineers	★
Inspectors	★

Chapter 4 addresses the activities and methods associated with surface preparation prior to applying markings to airfield pavement. The types of contaminants that may need to be cleaned off and the methods that can be used to clean them are discussed. Chapter 4 addresses cleaning (preparing) markings to improve the bond between the surface and the new marking. Chapter 5 addresses removing markings when the markings are no longer applicable or for other reasons. Table 4-1 indicates the personnel who will gain the most benefit from the material in this chapter. Table 4-2 summarizes the best practices presented in this chapter.

TABLE 4-2. BEST PRACTICES FOR SURFACE PREPARATION

Section Reference	Best Practice
4.1, 4.3.1	Waterblasting is best for surface preparation.
4.1	Perform surface preparation before painting.
4.2	Clean in lieu of painting, marking rejuvenation
4.3.1	Remove curing compound on new concrete.
4.3.4, 4.5.2.4	Remove algae, don't paint over it; use treated paint.
4.3.5, 4.5.2.5	Rust remedied by cleaning and modified paint formula.
4.3.6	Remove oily substances before marking.
4.4.5	Sweep, blow with air, or rinse with water after cleaning.
4.5.1	Surface preparation is specified as separate line item in project.

4.1 DEFINITION OF SURFACE PREPARATION

Surface preparation is the cleaning and removal of *anything* that would reduce the bond between a newly applied material and the surface. All current guide specifications convey the *intent* to adequately prepare the surface, but the process is generally overlooked.

> "The Engineer should specify any additional surface preparation required and should specify the type of surface preparation to be used when existing markings interfere with or would cause adhesion problems with new markings."
> Source: FAA AC 150/5370-10

Surface preparation is a necessary step that should be completed prior to the application of any airfield marking.

Airfield surfaces should be cleaned before being repainted. Given the unusual conditions to which they are subjected, airfield markings can quickly become a maintenance problem when they are

Seventy-five percent of all coating failures are attributable to deficient surface preparation and/or application. The unit cost of repair is normally two and one half times higher than the original coating application unit cost and frequently results in lower quality due to adverse application conditions. This analysis does not include the potentially staggering cost of down-time and loss of facility production. Source: S.G. Pinney & Associates

S. G. Pinney & Associates is a protective coatings inspection firm. Although pavement markings are not protective coatings, they are prone to similar failures when surfaces are not properly prepared.

repeatedly painted over without adequate cleaning.

Many airfield markings appear well bonded. However, when cleaned by waterblasting with only 6,000–8000 psi as seen in figures 4-1 and 4-2, old paint that was oxidized and brittle yielded, having lost its "glue" and elasticity from UV deterioration. Waterblasting as a method of surface preparation is a **best practice**. Applying more paint without cleaning the marking only adds to

FIGURE 4-1. BEFORE CLEANING LOOSE AND POORLY BONDED PAINT.

FIGURE 4-2. AFTER CLEANING LOOSE AND POORLY BONDED PAINT BY WATERBLASTING.

paint build-up, which results in the conditions shown in figures 4-3 through 4-7. Figure 4-3 demonstrates that repeated painting on concrete

FIGURE 4-3. REPEATED PAINTING ON CONCRETE LEADS TO FOD.

without preparing the surface results in delaminating of the paint layers. Surface preparation will not "fix" the problem; the marking will require paint removal before repainting. When asphalt is repainted without cleaning the surface, the multiple layers of paint can crack, causing premature deterioration of the asphalt, seen in figures 4-4, 4-5, 4-6, and 4-7. New coatings are designed to bond well to the pavement. However, if they are applied on top of old layers, and if the old layers are weak, the fresh coating will cause the old layers to crack and pull apart. The asphalt will crack as well, because the paint bonds better to the asphalt than the asphalt does to itself, evident in figure 4-5. Water penetrates into the pavement and erodes the asphalt. The freeze-thaw cycle worsens the problem, and soon the asphalt surface qualifies as a *pre-existing, damaged condition.*

FIGURE 4-4. REPEATED PAINTING ON ASPHALT RESULTS IN PAINT BUILD UP, AND CRACKING OF PAINT AND PAVEMENT.

FIGURE 4-5. MAGNIFIED PHOTO OF FIGURE 4-4 SHOWS CRACKED ASPHALT WHERE WATER INVADES.

The benefits of preparing the surface before painting it are obvious, but it takes time and money. Busy airports give applicators limited time, mostly overnight, to maintain the markings. It is not unusual for them to reapply all of the markings three or more times per year. Some of the reasons for not performing proper surface preparation include the following:

1. A lack of equipment.

2. Difficulty in coordinating surface preparation operations and marking schedules.

3. The amount of time required to prepare the surface.

4. Interruption to airport operations.

Figure 4-6 shows a marking with a single coat of paint that is 30-months old, and the coating is cracked. It would benefit from cleaning prior to repainting. The life of the pavement under thick paint is much shorter than the life of an unpainted surface next to it (figure 4-7). When the markings are not cleaned before the application of more paint, the accumulating layers turn into chunks of paint, beads, and asphalt, which break apart and become FOD. The *voids* (missing pieces of the centerline marking) were chunks of paint, glass beads, and asphalt that dislodged and were loose on the runway.

FIGURE 4-6. THIS MARKING IS 30 MONTHS OLD AND CRACKED.

FIGURE 4-7. MANY LAYERS OF PAINT ON ASPHALT.

The old saying goes: "*If you always do what you always did, you'll always get what you always got.*" Changing practices to include surface preparation will provide longer-lasting markings, reduce buildup of markings, and reduce the potential for FOD. Consistently performing surface preparation is a **best practice**. Whatever can be done in the time allotted should be done well.

4.2 PAVEMENT MARKING REJUVENATION

FIGURE 4-8. MARKING REJUVENATION

Pavement marking rejuvenation is the process of cleaning a marking prior to painting, but then inspecting it for color, glass bead retention, and overall effectiveness and determining that repainting is not required. Seen in figure 4-8, the marking has been rejuvenated. Figure 4-9 and 4-10 demonstrate the glass beads before and after the cleaning operation. The marking seen in 4-10 is still fairly well populated and embedded with beads in the marking, thus still effective. This is a **best practice** as it reduces time, materials, and paint build up.

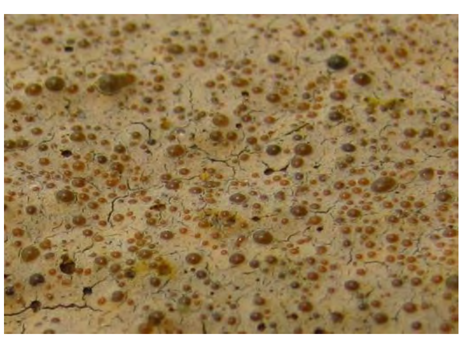


FIGURE 4-9 – BEFORE MARKING REJUVENATION

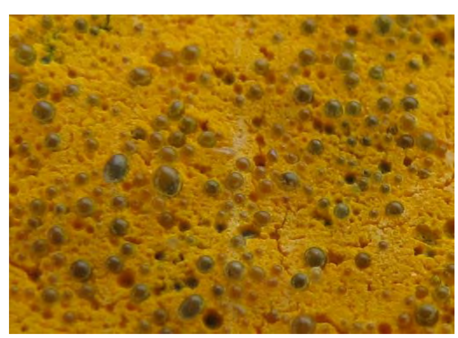


FIGURE 4-10 – AFTER MARKING REJUVENATION

4.3 CONTAMINANTS TO BE REMOVED

The term "contaminants" is used to describe surface conditions that should be corrected *before* applying marking materials to the pavement. Whether on a brand new surface or over existing markings, the surface must be prepared appropriately to ensure a good bond of the new markings to the pavement.

4.3.1 Curing Compound

A curing compound is sprayed on new concrete to produce a moisture-resistant membrane. The membrane generally wears off the concrete during the course of one year, depending upon traffic. If markings are to be applied, the **best practice** is to remove the membrane first. If paint is applied on top of the curing compound, it will flake off as the membrane sloughs off, as seen in figure 4-11. Most specifications state that all new concrete pavements shall be free of any curing compound before markings are applied.

FIGURE 4-11. EXAMPLE OF POOR REMOVAL OF CURING COMPOUND.

Pavement marking contractors are normally hired by a general contractor to apply markings on newly constructed pavement. Although the marking contractor's work should include the removal of the curing compound on new concrete pavement, this is sometimes done poorly or not at all. If this happens, the markings eventually flake off.

4.3.2 Rubber Deposits

Rubber builds up on the touchdown zone of a runway surface. As aircraft touch down, the stationary tires drag from zero to the speed of the landing aircraft almost instantly, which causes high heat and melting of some of the rubber from the tires. The hot rubber is spread onto the pavement and gradually fills the micro texture and eventually macro texture of the pavement, seen in figure 4-12. When the rubber cools, it hardens. When the pavement texture is covered with the rubber deposits, as seen in figure 4-12, friction coefficients are reduced, and the surface may become slippery when wet. Rubber deposits should be removed when the markings are obscured or when friction coefficients drop below acceptable levels as defined in AC 150/5320-12C,

FIGURE 4-12. BEFORE RUBBER REMOVAL.

Busy airports accumulate rubber deposits quickly, obscuring the centerline marking within days of being painted. At some airports, removal of rubber deposits may be scheduled to be performed monthly, but the centerline markings are repainted every one to two weeks in some cases. This is not a best practice, but it is a practical one, since the visibility of the runway centerline is important. Ideally, rubber deposits are cleaned before applying markings.

4.3.3 Loose and Flaking Marking Material

FIGURE 4-14. PAINT CRACKS WHEN APPLIED TOO THICKLY.

FIGURE 4-15. PAINT BONDS BETTER TO ASPHALT THAN ASPHALT DOES TO ITSELF.

Loose, flaking and poorly bonded material from previous marking applications is the most common condition dictating surface preparation. UV deterioration, jet blast, and freeze/thaw cycles affect markings and pavements, but the markings react differently compared to the pavement. Figure 4-14 resulted when paint was applied non-uniformly, heavier in the middle of the line, lighter on the edges. The thick paint in the middle cracked. If the stressed and damaged material is not removed through preparation of the surface, repeated coatings cause ***asphalt*** pavement to deteriorate prematurely. Most markings (coatings) absorb moisture and expand/contract differently than the pavement, contributing to the cracking seen in figure 4-15.

4.3.4 Algae

FIGURE 4-16. MARKINGS ARE OBSCURED BY ALGAE.

Algae grow in warm, humid environments, particularly on surfaces that have light traffic. Airport pavements out of the traffic path are susceptible to algae growth. Algae invade everything in their path, covering airfield markings and the pavement. When the markings become "gray" or "black" with the contaminant, they become obscured, as observed in figure 4-16. Although the markings may appear faded or gone, they are merely covered with algae. If new markings are applied over the algae-covered surface, the bond will be poor, and the algae that become sandwiched between the layers of paint will thrive when moist.

There are two methods that can be used to distinguish microbial (fungal and algal) growth from dirt on airport markings: (1) Wearing gloves and eye protection, spray household bleach on a portion of the area, where the airport markings have become darkened. If this discoloration turns lighter after the bleach has been applied, there is microbial growth. If the discoloration does not change color, it is dirt. (2) Spraying water on a darkened surface may eventually result in blooming effects such as a greenish tinge. If this occurs, algae are present.

FIGURE 4-17. WATER FROM THE AIRPORT'S FIRE TRUCK, WITH 150 PSI, RINSED THE SIDELINE.

FIGURE 4-18. THE SAME SIDELINE AND THRESHOLD MARKING EIGHTEEN MONTHS LATER.

Figures 4-17 and 4-18 were taken 18 months apart. The markings were washed off with water from the airport's fire truck prior to being painted by the contractor. As an expedient and cost-conscious measure, rinsing the algae-coated markings was better than doing nothing, but within a short time, algae covered the markings again, perpetuating the cycle.

On another project, the algae-covered surface was prepared with high-pressure waterblasting equipment before repainting. The "before and after" pictures in figures 4-19 and 4-20 demonstrate the value of thorough preparation. Not only was the algae washed off, so was all loose and poorly bonded paint: a **best practice.**

FIGURE 4-19. BEFORE WATERBLASTING: ALGAE OBSCURE MARKING.

FIGURE 4-20. AFTER WATERBLASTING, BUT BEFORE PAINTING.

On the same airport project, eighteen months after repainting most of the runway with an algae-resistant formulation, the "treated" threshold markings seen in figure 4-22 were free of algae,

FIGURE 4-21. PAINT USED WAS STANDARD TT-P-1952E.

FIGURE 4-22. PAINT FORMULATED TO RESIST ALGAE.

FIGURE 4-23. SAME MARKINGS AS IN FIGURES 4-21 AND 4-22, AFTER THIRTY MONTHS.

whereas the untreated markings shown in figure 4-21 supported new algae growth. Figure 4-23 shows the same threshold markings 30 months after they were painted. The algae growth is beginning to cover the untreated marking (on the left in figure 4-23). Figures 4-24 and 4-25 provide close-up photographs of the treated and untreated markings in figures 4-21 and 4-22 respectively, indicating the lack of algae growth on the treated markings and the presence of algae on the untreated markings. The biocide in the algae resistant formula breaks down after three years or so, but does improve the performance of the markings within that time.

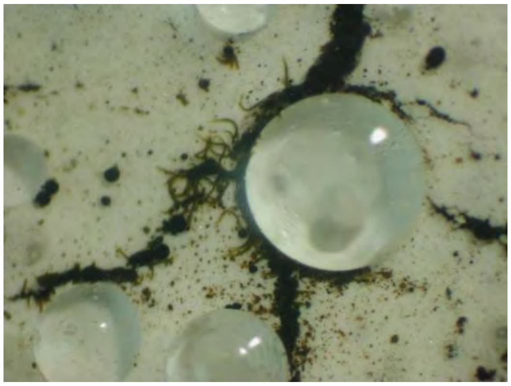


FIGURE 4-24. MAGNIFIED PAINT SAMPLE FROM FIGURE 4-21

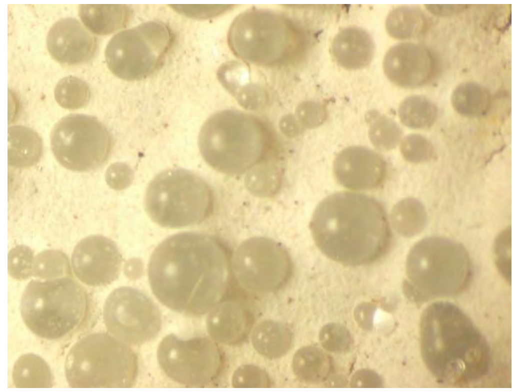


FIGURE 4-25. MAGNIFIED PAINT SAMPLE FROM FIGURE 4-22.

Photographs of figures 4-24 and 4-25 courtesy of Rohm and Haas.

Waterblasting the markings as a form of surface preparation 24 hours prior to restriping provides a clean surface, preserves the pavement, and prolongs the life of the markings; it is a best practice. After waterblasting, inspecting the surface for residue or other debris may reveal the need for sweeping or blowing it with compressed air prior to the application of new markings, or it may reveal no additional painting is necessary.

4.3.5 Rust Discoloration

Iron present in aggregate and in underground soils and water stains white airfield markings, affecting compliance with the color standards maintained by all governing agencies. The iron contaminants on the pavement surface are transported by rainwater across the runway. The standard water-borne paint is porous, and it absorbs the rust contaminant, but generally where it first comes in contact with the paint. In other words, the leading edge of the painted marking is affected the worst, as seen in figure 4-26. Figure 4-27 shows depressions where water flows or stands, and the rust discoloration appears heavy there as well.

FIGURE 4-26. STAINED LEADING EDGE OF MARKING FROM IRON CONTAMINANTS.

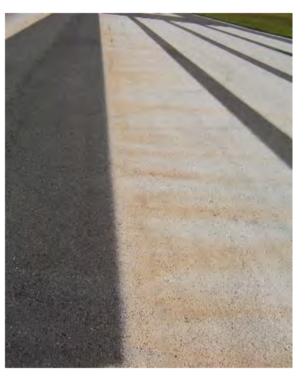


FIGURE 4-27. STAINED LEADING EDGE AND LOW AREA ALONG JOINT WHERE WATER FLOWS.

Where the pavement is grooved, rust stain is noticeable in the grooves, but not as much on the surface. Where the grooves end before the sideline, the rust discoloration becomes more obvious again. The "whiter" sideline next to the aiming point marking seen in figure 4-28 is further evidence that this stain is caused from rainwater runoff, the leading edge of the marking is stained the most.

FIGURE 4-28. GROOVED SURFACE MAKES STAIN LESS NOTICEABLE.

In some instances the rust discoloration enters the markings from the bottom up, and the entire marking is discolored, as seen in figure 4-29. Figures 4-30 and 4-31 illustrate the benefits of a stain resistant formula that maintained the white color for at least seven years. Figures 4-30 through 4-32.

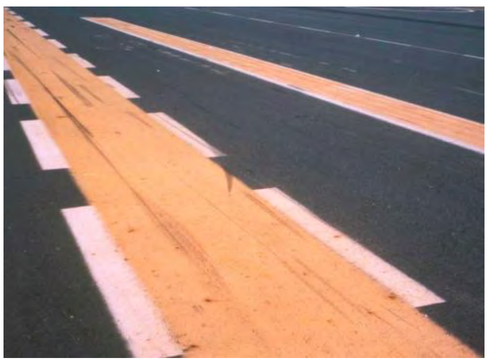


FIGURE 4-29. WHITE CENTERLINE LOOKS YELLOW.

FIGURE 4-30. AFTER THREE YEARS USING STAIN RESISTANT FORMULA

FIGURE 4-31. AFTER SEVEN YEARS

FIGURE 4-32. CENTERLINE IN FIGURE 4-31 THAT HAD CRACK SEAL AND "TOUCH UP" PAINT APPLIED.

When remarking rust-discolored markings, cleaning them to remove as much of the rust deposits as possible is a **best practice**. Figure 4-33 is an example of a stained marking that was not cleaned before it was repainted. Within a few months, the stain bled through and the marking became discolored again.

FIGURE 4-33. REPAINTING WITHOUT CLEANING THE STAIN RESULTS IN BLEED-THROUGH.

A commercial rust remover was tested on severely rust-discolored markings. As seen in figures 4-34 and 4-35, the chemical agent that removed the rust also damaged the glass beads, making them ineffective during darkness.

FIGURE 4-34. RUST REMOVER WHITENS STAINED MARKING WHERE "TLINE" WAS PRINTED.

FIGURE 4-35. RUST REMOVER DAMAGED GLASS BEADS, MAKING THEM INEFFECTIVE.

<u>4.3.6 Oil, Jet Blast Residue, and Similar Substances</u>

Oily substances coat the pavement and the markings; and they prevent a new coat of paint from bonding. Whenever these substances are encountered, removing them before applying new markings is a **best practice**. Figures 4-36 and 4-37 show areas before cleaning; figure 4-37 is after cleaning; and figure 4-38 is the same area and markings three and one half years later.

FIGURE 4-36. THE OILY STAIN WILL PREVENT NEW COATING FROM BONDING.

FIGURE 4-37. ANOTHER VIEW OF THE OIL-STAINED MARKING IN FIGURE 4-36.

The equipment that was used to clean the surface is a pressure washer attached to a floor machine (see figure 4-37). The floor machine houses a rotor bar equipped with spray nozzles. When water charges the system, the force of the water spins the bar in a circular pattern so that the floor machine cleans a swath of pavement as it is pushed along the surface. A small amount of detergent added to the water helps break down the oils both on the surface and in depressions in the pavement. A vacuum attachment recovers the oily wastewater for proper disposal.

FIGURE 4-38. THE PROCESS USED TO REMOVE OIL STAIN.

FIGURE 4-39. THE SAME AREA THREE AND ONE-HALF YEARS LATER.

Jet blast residue is another contaminant that accumulates at thresholds and in areas where aircraft test their engines. Figure 4-40 shows the difference between pavement with jet blast residue and pavement where the residue has been cleaned by waterblasting. It is a **best practice** to clean off jet blast residue before applying more material to the marking.

FIGURE 4-40. TAXIWAY SHOULDER MARKING WAS CONTAMINATED WITH OILY JET BLAST.

FIGURE 4-41. COMPRESSED AIR REMOVES FINE RESIDUE AFTER PAINT REMOVAL OPERATION.

4.3.7 Dirt and Loose Rocks

Loose materials are more obvious and are generally cleaned before markings are applied. Figure 4-41 shows how a paint-removal process leaves dust that must be blown off, and then vacuumed before the new markings can be painted. The surface to be marked should be free of *anything* that would prevent the marking material from bonding to the surface.

4.4 EQUIPMENT

Different types of equipment can be used to prepare surfaces prior to applying markings. The method of cleaning should be selected based on the conditions. In all cases, the experience and skill of the equipment operator can affect how well the surface preparation is performed.

4.4.1 Waterblasters

Several kinds of waterblasting equipment are appropriate for surface preparation. Which one to select will depend on the amount and extent of cleaning needed and the time that is allotted to do the work. Table 4-3 is a matrix of the various types of waterblasting equipment. Waterblasting equipment is differentiated by the pressure attained and the volume of water used in the operation. All waterblasters, from pressure washers to ultra-high machines, use pressurized water to do the work.

TABLE 4-3. WATERBLASTING EQUIPMENT

Waterblasting Method	Pressure Ranges	Water Volume
Pressure Washing	1,000 - 3,500 psi	5 - 10 gpm
Low Pressure	Up to 10,000 psi	15 - 20 gpm
High Pressure	Up to 20,000 psi	15 - 25 gpm
Ultra High Pressure	Up to 50,000 psi	4 - 16 gpm

The following sections provide a brief description of each type of waterblaster with general capabilities, but all types represent a **best practice** for preparing surfaces when followed by sweeping or vacuuming.

4.4.1.1 Pressure Washers

A pressure washer generally refers to low pressure machines typically up to 8,000 psi, but most pressure washers are in the 3,000 – 4,000 psi range. Such low pressure machines are good for cleaning dirt and mildew or preparing a surface to accept coatings by removing any loose paint that may simply be sitting on top of the surface without having any or very little adhesion to it (figure 4-42). Pressure-washing systems can use floor machines (seen in figure 4-38 and 4-43) that may result in added productivity to a larger area. Pressure washing can be effective at cleaning dirt or mildew from surfaces including paint, MMA and thermoplastic markings but cannot be used to remove such markings. Curing compound begins to loosen from new concrete surfaces at around 7,000 psi but requires extended dwell time to do so. However; hot water will loosen curing compound at a much lower pressure. The nozzles in this category are almost always fan nozzles producing between 15 and 25 degree spray pattern.

FIGURE 4-42 – PRESSURE WASHER, BY HAND.

FIGURE 4-43 - PRESSURE WASHER WITH FLOOR ATTACHMENT

4.4.1.2 Low-Pressure Waterblasters

FIGURE 4-44. LOW-PRESSURE WATERBLASTER.

Low-pressure waterblasters can reach pressures up to 10,000 psi and they are sometimes available at equipment-rental establishments. Good for surface preparation, this system can be truck or trailer mounted, (seen in figure 4-44) or used with a hand wand or weighted floor machine, similar to the one seen in figure 4-38.

4.4.1.3 High-Pressure Waterblasters

High-pressure waterblasters reach pressures up to 20,000 psi, and they are good for surface preparation of curing compound, rubber removal, and can remove paint from sound pavement surfaces. This system uses a high volume of water, up to 30 gpm, delivering water with hydraulic force to penetrate, lift, and clean contaminants from the surface. The large volume of water requires separate vacuum systems to recover the water and debris. Flushing or allowing the water to run across the pavement (and other markings) is not recommended. If the water is allowed to remain on the pavement, the contaminants may stay once the water evaporates, negating the effort.

4.4.1.4 Ultra-High-Pressure Waterblasters

Ultra-high-pressure waterblasters attain pressures up to 50,000 psi, and they work well for removing contaminants on any surface. When used for surface preparation or marking rejuvenation, ultra-high-pressure units can operate at half the pressure (or 25,000 psi) and they move faster than they would during a paint removal operation. These systems often include an integrated vacuum system to collect the water and debris during the cleaning process.

4.4.2 Shotblasters

Shotblasters propel steel shot, walnut shells, or other abrasive material onto the surface to remove paint and prepare surfaces. *Grooved* pavements (cut into runways to prevent hydroplaning) can present some issues for shotblasters since the shot escapes the vacuum system and some will remain on the surface where it will rust. An integrated vacuum system must be functioning properly to recover the shot to reduce the likelihood of it becoming FOD. If the surface is uneven, a magnetized bar should be used to sweep the prepared surface, picking up most of the remaining shot.

4.4.3 Grinders

Grinders can be used for surface preparation. They are equipped with rotating drums that spin vertically, horizontally (rotary-type), or both ways. Each drum is fitted with a series of steel tips, tungsten carbide steel tips, leather tabs with steel tips, or other abrasive material that, when lowered to the ground, cuts into the coating. They scarify a pavement marking, and if this is done lightly or with a suitable attachment, it can be used for surface preparation to remove loose and poorly bonded material. The surface must be relatively flat to strike all of the marking that will be prepared. Thorough clean up after grinding is advisable, such as rinsing the affected pavement with water or blowing with compressed air to remove any residue.

The use of grinders to remove algae is not effective, because the paint would be removed in the process. The same is true of rust discoloration. However, for removing loose and poorly bonded paint, a light pass with a grinder can be effective.

4.4.4 Sandblasters

Sandblasters have been used for many years to prepare surfaces and remove existing coatings. This method, although potentially messy because of broadcasting sand or other blasting media around the work area, is effective and useful. Sandblasting equipment is available for rent from most locales, and it comes equipped with the personal protective equipment that is necessary for safe operation, since the silica in the sand is a health hazard for the workers. There are substitutes for sand, such as "black beauty" or other blasting media, which does not contain silica.

4.4.5 Brooms, Vacuum Equipment/Air Compressors

Brooms and vacuum sweepers are used to remove loose debris, dirt, and other material from surfaces. A **best practice** is to use them *after* other methods of surface preparation to remove the residue from those operations. Air compressors or leaf blowers (figure 4-45) also can be used to remove the loose particulate from areas that have been cleaned before they are marked.

FIGURE 4-45. LEAF BLOWER CLEANS LOOSE RESIDUE AFTER SURFACE PREPARATION.

4.5 QUALITY CONTROL

Quality control is important during the surface preparation process to ensure that pavement, fixtures, and joints are not damaged. The process must effectively remove contaminants that would prevent the new coatings from bonding to the surface.

4.5.1 Well Defined Specifications

Specifications that are well defined are necessary to communicate expectations to the applicator. They also provide the inspector with the criteria to enforce compliance. Include surface preparation as a separate line item; this alerts the contractor of project expectations and is a **best practice**.

4.5.2 Measurable Criteria

Measurable criteria should be used to evaluate the effectiveness of the surface preparation. The result of cleaning the contaminants, discussed previously, can be monitored for the following specific results.

4.5.2.1 Curing Compound Removal

Current specifications call for the removal of all visible curing compound material from the pavement. New concrete appears white when the curing compound is present. When it is properly removed, the concrete appears gray or tan. If there is still evidence of the “white” curing compound, have the equipment operator run another pass over the area to see if more can come up. If the white stain resists a second attempt, the membrane is unlikely to cause a problem.

4.5.2.2 Rubber Deposits

Although considered a surface contaminant, rubber accepts a coating of water-borne paint well. During operations to remove rubber, seen in figure 4-46 and 4-47, any coatings applied on top of the rubber should be removed during the rubber-removal process.

FIGURE 4-46. HEAVY RUBBER DEPOSITS WERE REMOVED FROM THIS CENTERLINE MARKING WITH ULTRA HIGH-PRESSURE WATERBLASTING.

FIGURE 4-47 – ULTRA-HIGH-PRESSURE WATERBLASTER WITH 6-FOOT PASS AND FULL WATER RECOVERY.

4.5.2.3 Loose and poorly bonded materials


FIGURE 4-48. PULL TEST.

A pull test, seen in figure 4-48, is a means of checking for loose materials, such as dirt or debris, generated by a surface preparation or paint-removal process. Using a piece of duct tape that is pressed onto the surface, pull up to expose any remaining grit or debris that should be cleaned, swept, or blown off before applying markings. A scraper can also be used to spot check areas that have been prepared to see if any areas larger than a 1-inch square of old marking material can be pulled up (see figure 4-49).

FIGURE 4-49. LOOSE PAINT FOUND AFTER SURFACE PREPARATION. PAINT REMOVAL WAS NEEDED.7

4.5.2.4 Algae

Algae can almost completely obscure the markings. Thorough brooming can remove the visible algae growing on the surface. However, pressurized water that is recovered removes the algae and any loose and poorly bonded paint. It is a **best practice** to remove all algae, otherwise it will return within months and begin to obscure the markings again.

When the surface is cleaned completely and remarked with a paint formulated to resist algae, evidence has shown no sign of algae after thirty months, therefore adding longevity to the marking; this is a **best practice**.

4.5.2.5 Rust Discoloration

Iron stains can be removed from the markings, and some residual stain may remain. The iron contaminant can be removed through waterblasting, providing a cleaner surface on which to apply a stain-resistant material. Figure 4-50 depicts a sideline that was painted over existing stains; and the rusty color bled through the new coating. The **best practice** is to remove the majority of the stain and reapply the markings using a modified water-borne paint that will resist rust staining. Waterblasting is the best method when the water from the cleaning operation is recovered and removed from the pavement.

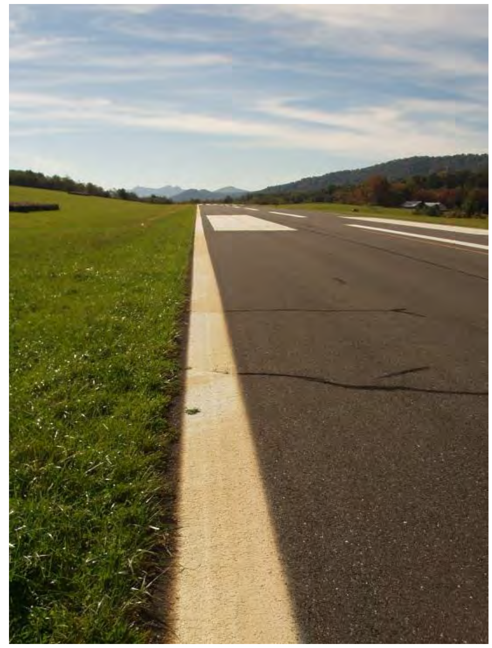


FIGURE 4-50. RUST STAIN BLED THROUGH NEW COATING.

4.5.2.6 Oils, Jet Blast, and other similar contaminants

Oily residue must be visibly removed. Oils penetrate the surface and can leach back up over time. High-pressure waterblasting will remove the surface contaminants, but used in combination with detergent and a vacuum attachment, deeper penetration into the pavement removes the oils and is more effective. All visible oily contaminants should be removed.

4.5.3 When is "g*ood enough*" adequate?

What may appear to be "adequate" surface preparation during the process may be "inadequate" once the new marking is applied. Visual inspections, the "grid" method, a scraper, or other device are the only methods currently employed for quality control. There are no tools, nor ASTM methods for determining the amount of surface preparation required before applying new markings, neither are there specific types of waterblasters or pressures needed to prepare a pavement surface. Although it remains somewhat subjective, experienced and/or trained inspectors and equipment operators can make determinations about what to use to prepare surfaces.

5 PAVEMENT MARKING REMOVAL

The previous chapter addressed preparing (cleaning) the pavement surface so that the newly applied marking will bond to the pavement and/or existing markings. This included cleaning of loose and flaking marking material from the pavement surface, which removes *some* of the paint, but only what is poorly bonded. In addition to cleaning the surface, it may also be necessary to remove markings from pavement surfaces for various reasons.

TABLE 5 1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	★
Airport Operators	★
Designers/Engineers	★
Inspectors	★

Chapter 5 addresses the removal (obliteration or eradication) of airfield markings from the pavement surface. The chapter describes some of the reasons for paint removal, the amount (degree) of removal that may be required, and the methods that can be used to remove markings. The desired level of removal depends on the type or condition of pavement *under* the markings. Portland cement concrete (PCC) and asphaltic cement concrete (ACC) are the two basic pavement types. PCC is more resistant and "forgiving" to a paint removal operation; it can withstand the aggressive pressures needed to remove markings. New ACC will withstand a paint removal operation with less scarring than old, cracked, brittle asphalt. Because ACC is more prone to deterioration as a result of repeated remarking and the stresses exerted by the coatings, the removal process will remove any damaged asphalt along with the marking.

Table 5-1 indicates the personnel who will gain the most benefit from the material in this chapter. Where used, the term “best practice” is highlighted in bold. Table 5-2 summarizes the best practices presented in this chapter.

TABLE 5-2. BEST PRACTICES FOR PAINT REMOVAL

Section Reference	Best Practice
5.2	Degree of removal is defined in specifications.
5.3.1	Markings are removed, not "blacked out".
5.4	The right equipment is selected based on the conditions.
5.4	Experienced equipment operators are used.
5.4.3	Shotblasting is best used on non-grooved surfaces.
5.4.4	Waterblasting is used on any surface.
5.5.4.4	The scar is thoroughly cleaned before application of new coating.
5.5.5	Test strips demonstrate capability of equipment and operator.
5.5.7	Waste water and debris are contained and properly disposed of.

5.1 DEFINITION

Pavement marking removal is the mechanical eradication of markings from the pavement to a specified degree. An airport may need to remove markings for many reasons, and each reason will dictate the degree of eradication. Table 5-3 illustrates the differences between *paint removal* and *surface preparation*; it shows the benefits that can be realized through regular preparation.

TABLE 5-3. PAINT REMOVAL VERSUS SURFACE PREPARATION

PAINT REMOVAL	SURFACE PREPARATION
Removal is the mechanical obliteration of markings from the pavement to a specified degree.	Surface preparation is cleaning the markings or pavement before the application of more materials.
Removal should be performed after five marking cycles to prevent FOD.	Surface preparation should be performed at least every other marking cycle.
Paint removal costs between $1.00 and $5.00 or more per square foot, depending on project quantity and other conditions.	Surface preparation costs between $0.20 and $0.50 or more per square foot, depending upon project quantity and other conditions.
Paint removal will leave visible scars and may damage pavement.	Surface preparation merely cleans the existing marking and does not penetrate the surface.
Paint removal takes longer and will interrupt airport operations.	Surface preparation will prevent the need for paint removal due to excessive build up of paint layers, thus preserving the pavement.

5.2 DEGREES OF REMOVAL

Different *types* of marking removal and *degrees* of removal can be specified**.** Not all of removal situations require 100 percent, 95, or even 85 percent removal of the markings. Two key factors are included in a successful removal operation: (1) specifying in the construction documents/specifications what process(es) is (are) expected and (2) explaining exactly where and how much of the markings will be removed. If marking removal is needed in more than one area and for more than one reason, the degree of removal should be clearly defined for each area. This information prepares the contractor, provides expectations for the owner, enables the inspector to validate results, and is a **best practice.** The *degree* of removal is determined by the reason for conducting the paint removal. Different *types* are defined in Table 5-4 along with the recommended degree of paint removal.

TABLE 5-4. TYPES AND DEGREES OF MARKING REMOVAL

Types of Marking Removal	Degrees of Removal
Obselete markings and changing marking patterns	95 - 100%
Seal coats or other surface treatment	80 - 85%
Marking build-up and/or excessive layers	85 - 90%
Changing paint colors	90 - 95%
Incompatible materials	85 - 100%

5.2.1 100 Percent Removal or Complete Eradication

In 100 percent removal, all of the marking is removed. Depending upon the condition of the pavement under the marking, 100 percent removal has the potential of causing the most scarring. If the underlying pavement can sustain the forces of the removal operation and complete eradication is specified, then 100 percent removal should be achieved. If pavement damage begins to occur with one method, the process should stop and the engineer/inspector should consider other methods or *combinations of methods* that may achieve the desired result without causing damage to the underlying pavement.

5.2.2 90 – 95 Percent Removal

After 90 to 95 percent of an existing marking is removed, a small amount of marking material will remain after the removal operation is complete. In contrast to 100 percent removal, 90–95 percent removal of markings can spare the pavement from damage. Between 90–95 percent removal is recommended when changing marking colors, and between 85–90 percent removal is appropriate to remove excessive marking build up.

5.2.3 80-85 Percent Removal

Removing 80 to 85 percent of existing markings is recommended prior to the application of a seal coat. Leaving 15 to 20 percent of an existing marking will expose enough pavement so that a seal coat or other surface treatment will bond to the underlying pavement.

5.2.4 85-100 Percent Removal

When an incompatible material is applied over different and existing markings, the degree of removal depends on the new coating. For example, if epoxy markings are being applied over anything except epoxy, 100 percent of the existing marking must be removed. However, if solvent-borne paint is being applied over water-borne paint, removing 85 percent of the existing coating would be acceptable.

5.3 TYPES OF MARKING REMOVAL

Different reasons exist for removing markings from pavement, including the following:

1. A new pattern or configuration will make older markings obsolete. The old markings must be completely obliterated to prevent confusion.
2. Markings should be removed prior to overlaying asphalt or applying a seal coat. Leaving the markings may prevent a good bond of asphalt or sealant to the painted surface. Removal of some but not all of the existing marking would ensure a better bond.
3. Similar reasons for removing markings are outlined next, and the recommended degrees of removal are given for each instance.

5.3.1 Obsolete Markings and Changing Marking Patterns

In 1999, the FAA published AC 150/5340-1H, which called for a change to the industry practice of obscuring unwanted markings with black paint:

"Pavement markings that are no longer needed should be physically removed by sand blasting, chemical removal or other means, not painted over. Painting over the old markings merely preserves the old marking, will require additional maintenance, and in certain conditions, can be misleading to pilots." [5]

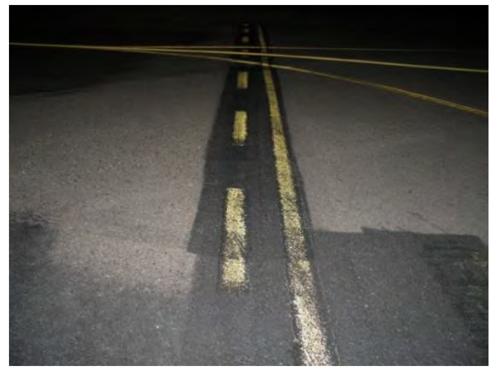


FIGURE 5-1. BLACKED-OUT NON-MOVEMENT BOUNDARY LINE IS VISIBLE AT NIGHT.

Markings that are no longer needed are considered "obsolete." Since "blacking them out" is no longer an acceptable practice, 95 to 100 percent of the markings should be removed and this is a **best practice**. Black paint and seal coat will wear off over time allowing the old marking to reappear. With black paint, even if the marking looks obscured during the daytime, the glass beads in the old marking will shine through at night, as shown in figure 5-1. Additionally, under low visibility conditions, especially when the pavement is wet, a blacked-out line looks like a normal line. Because markings convey information, *misleading* markings have the potential to confuse and contribute to surface incidents.

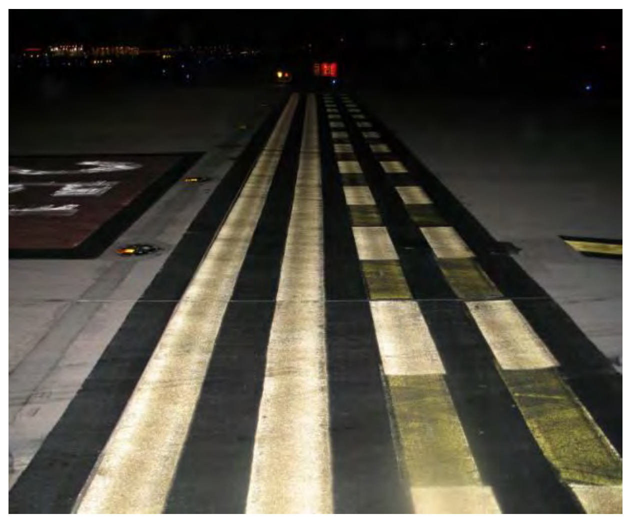


FIGURE 5-2. BLACK PAINT WEARS OFF, AND THE UNDERLYING COATING SHOWS THROUGH.

If markings are to be applied over a different color, the underlying markings must be removed before applying the new color. Often the new marking will wear off, exposing the other color below. The holding position marking shown in figure 5-2 has been painted over with a black background. As the black wore off, the underlying yellow markings showed through, potentially causing confusion. At least 90 to 95 percent of a different-colored marking should be removed before a new color is applied.

5.3.2 Marking Over Non-Compatible Materials

Markings applied over non-compatible materials can cause the new coating to fail, or they may react with the underlying coating, causing it to fail. The industry practice has been to apply layer after layer of material over pavement markings, because it has been "more cost-effective and convenient" to restripe over the old markings without removing them, whether the materials are

[5] FAA AC 150/5340-1H, August 31, 1999.

compatible or not. Good adhesion can be obtained if like materials are applied to each other. If the existing coatings are incompatible with the specified new material, the **best practice** is to remove 85 to 100 percent of the old marking.

FIGURE 5-3. CRACKED AND PEELING MARKINGS –

5.3.3 Remove Marking Build Up (i.e., Excessive Layers)

When more than two coatings of markings have been applied to asphalt without surface preparation, the layers can start to curl, split, spall, or crack, as seen in figure 5-3. In this case, at least 85 percent of the marking should be removed before remarking to reduce reflective cracking and continued build up. Cracks become channels for water to penetrate the asphalt. The water erodes the pavement under the marking, resulting in premature deterioration.

FIGURE 5-4. CRACKED MARKINGS WITH DETERIORATED ASPHALT UNDERNEATH IS A PRE-EXISTING CONDITION.

FIGURE 5-5. MAGNIFICATION OF CRACKED MARKINGS AND ASPHALT FROM FIGURE 5-4.

Coatings are designed to bond to a specific substrate, like asphalt, and often they bond better to the asphalt than the asphalt does to itself, as seen in figures 5-4 and 5-5.

FIGURE 5-6. HEAVY PAINT BUILD UP ON CONCRETE.

Portland cement concrete is less susceptible to erosion from moisture through cracks in the marking. However, moisture will accumulate between the concrete surface and the initial layer of paint. Layer after layer of paint exerts tension over the marking. Once the initial layer of paint loosens from the surface, chunks start to break up, and the markings become a foreign object generator (FOG), seen in figure 5-6.

Operations for removing paint build up could be eliminated if the surface is adequately prepared before more marking materials are applied.

5.3.4 Seal Coat or Other Surface Treatment

AC 150/5370-10C stated, "*Any painted stripes or markings on the surface of the runways or taxiways to be treated, shall be removed.*"[6] This meant that markings must be removed before applying a seal coat or other surface treatment. Removing 80 – 85 percent of the markings exposes pavement, providing a better surface for the sealant to bond. A seal coat is generally used to preserve and extend the life of pavement. Removing more than 80 to 85 percent of the markings may cause damage to pavement that is already in fair to poor condition. Applying a seal coat over old, scaling paint will cause the layers to pull apart, as seen in figure 5-7.

FIGURE 5-7. PAINT IS PEELING OFF OF REJUVENATOR APPLIED OVER OLD MARKINGS.

5.3.5 Blocking out

AC 150/5340-1 was changed in 2013 to include a requirement to "remove markings in a predetermined larger pattern" to prevent the remaining scar from replicating the old marking. The results from this practice are different on concrete than they are on asphalt; the latter surface is more susceptible to erosion of the binder, exposure of aggregate, and deterioration of the pavement.

An evaluation of the pavement under the markings to be removed should be conducted to determine what type of equipment should be used, what level of removal can be achieved without damaging the pavement, and whether a subsequent seal coat should be planned to cover the scarred pavement rather than "scarring" the unpainted areas with additional "removal".

5.4 EQUIPMENT

Equipment designed to remove markings is available by purchase, lease, or contract, depending upon an airport's locale and budget. Selecting the right equipment is a **best practice,** and is based on many factors, including:

1. Amount of removal.
2. Type of pavement.
3. Condition of pavement.
4. Thickness of material being removed.
5. Type of material being removed.

[6] AC 150/5370-10C, Section 626-4.4

Different types of equipment are listed in table 5-5. As with surface preparation, the skill and experience of the equipment operator determines the quality of the removal product. A **best practice** is getting references from the paint removal equipment operator or contractor to ensure the capability of the operator.

TABLE 5-5. RECOMMENDED MARKING REMOVAL EQUIPMENT ON DIFFERENT TYPES OF PAVEMENT UNDER VARIED CONDITIONS

Equipment Type	Concrete		Asphalt		Poor Asphalt		Sealcoat
G=grooved U=ungrooved	G	U	G	U	G	U	
Grinder	✗	✓	✗	✓	✗	✓	✓
Shotblaster	✗	✓	✗	✓	✗	✓*	✗
Sandblaster	✓	✓	✓	✓	✓	✓	✓
Waterblasters:							
Low Pressure, up to 10K psi	✓	✓	✓	✓	✓*	✓*	✓*
High Pressure, up to 20K psi	✓	✓	✓	✓	✓*	✓*	✓*
Ultra High, up to 40K psi	✓	✓	✓	✓	✓*	✓*	✓*

✓* - Use in combination with grinding or other methods to minimize potential damage to poor pavements.

Marking removal equipment is similar, if not identical, to equipment that is used for surface preparation. However, a few important differences exist:

1. A slower speed is needed to remove the marking.

2. Higher pressures are required when using water.

3. Special care must be taken to avoid damage to the underlying pavement.

Marking removal will leave a visible scar. Depending upon the integrity of the pavement under the paint, pre-existing conditions can compound damage to the pavement. All markings that will be removed must be carefully evaluated, which will indicate the method of removal, degree of the removal, and the expectations for the project.

5.4.1 Grinding/Rotary Grinding/Milling/"Rotopeen"

Grinding, milling, or rotopeen machines are drum units that can be hand operated or mounted on a skid steer or other motorized vehicles. **Drum grinders** rotate vertically, strike the pavement with "teeth" or "picks" to remove the paint from the pavement. **Rotary grinders** are planetary removal systems used for pavement marking removal. They are equipped with one single rotary spindle as a walk behind unit or a low flow skid mount, as well as the triple head Hi-flow or gas powered skid steer attachment. Each spindle is equipped with a set of three carbide planetary pin cutters or planing bits that is effective on a concrete or asphalt surface. These setups break through the marking to leave a sound surface profile. Rotary Grinders may be used to remove thermoplastic, tapes, and other types of marking materials with the different rotary spindle options. A vacuum system is highly recommended for dust control during the removal process, followed by a sweeper truck or low pressure power washing to prepare for new markings.

Some of the characteristics of grinding as a method of paint removal follow:

- Effective on asphalt, especially if aged and cracked. Effective on concrete, although the scars are permanent. Rotary grinders will reduce the scarring of the pavement.
- Scrapes and cuts the surface to remove paint.
- Can be manually operated.
- Is a slow process – 500 SF per hour typically, depending on thickness and type of material. The skid-mounted rotary grinders have higher removal rates.
- Is not recommended for grooved surfaces.

FIGURE 5-8. MINIMAL GRINDER SCARS ON ASPHALT AFTER REMOVING 90 PERCENT.

FIGURE 5-9. ROTARY GRINDER RESULTED IN A SMOOTHER PROFILE.

5.4.2 Sandblasting

Sandblasting combines compressed air, sand or other abrasive material, which is propelled toward the surface. A relatively slow process for removing airfield markings, it can be used for small areas when other equipment is difficult to acquire. Some of the characteristics of sandblasting as a method of paint removal are as follows:

- Suitable for removing paint on any surface.
- Precise maneuvering and control of wand is beneficial.
- Is a relatively slow process.

- Protective gear is required.
- Considerable cleanup is required.

5.4.3 Shotblasting

FIGURE 5-10. BEFORE PAINT REMOVAL.

FIGURE 5-11. AFTER PAINT REMOVAL WITH A SHOTBLASTER ON GROOVED ASPHALT.

Shotblasters propels steel shot, walnut shells, or other abrasive material onto a surface at a high rate of speed. The shot pulverizes the markings and an integrated vacuum system picks up most of the shot and debris. The shot is separated from the debris and recycled into a hopper. Figures 5-10 and 5-11 show before and after pictures of a grooved asphalt surface where the markings were being removed. The process of using the shotblaster eroded the grooves in the asphalt, as shown in figure 5-12. Grooved pavement will also reduce the effectiveness of the integrated vacuum system to recover the steel shot, resulting in the potential for FOD. Some of the characteristics of shotblasting as a method of paint removal follow:

- Do not use on a grooved surface; this is a **best practice**.
- Cuts (width) range from 6-inches to 6-feet, depending on the size of the machine. Figure 5-13 shows a shotblaster with a 10-inch cut that was rented by the airport. Figure 5-14 shows the scar on both ungrooved asphalt and concrete after markings were removed with a shotblaster.
- Captures the majority of shot and dust as the removal proceeds.
- May loose some of the shot; this can be a FOD issue, especially on grooved surfaces.
- Can remove paint 1000 to 3000 SF per hour.

- Leaves surface dry, although rinsing with water before applying new markings is advisable to remove residual grit.

- Recovers most of the stray shot with a bar equipped with a magnet.

- Can be a source of rust spots on a new marking if stray shot remains. Evidence of residual shot is seen in figure 5-15 where it has already stained the pavement.

FIGURE 5-12. AFTER REMOVAL OF THE MARKINGS ON GROOVED PAVEMENT WITH SHOTBLASTING.

FIGURE 5-13. SHOTBLASTER WITH A 10-INCH CUT.

FIGURE 5-14. USED FOR REMOVAL ON NON-GROOVED SURFACES, SHOTBLASTING CAN BE A BEST PRACTICE.

FIGURE 5-15. A CLOSE-UP OF FIGURE 5-14 SHOWS RUST AREAS WHERE SHOT REMAINED.

Shotblasting used for *rubber removal* causes cumulative damage to the grooves in the pavement, as seen in figures 5-16 and 5-17. Each rubber removal operation eroded a few millimeters of the concrete, not noticeable after each operation. But over 10 years of repeated rubber removal operations, the damage is apparent.

FIGURE 5-16. BEFORE SHOTBLASTING

FIGURE 5-17. AFTER TEN YEARS OF SHOTBLASTING TO REMOVE RUBBER DEPOSITS.

5.4.4 Waterblasting

Waterblasting can be categorized by pressure and water volume, as compared in table 5-6. Each type of equipment has its advantages and disadvantages, but waterblasting represents a **best practice** for removing markings from airfield surfaces. All waterblasting systems offer the following advantages:

- No airborne dust particles, lead, or other toxic substances.
- Clean surface when followed by vacuum sweeper or has integrated vacuum recovery system.
- Economical; only water is used.

TABLE 5-6. WATERBLASTING EQUIPMENT DESCRIPTIONS FOR PAINT REMOVAL

Waterblasting Method	Pressure Ranges	Water Volume
Low Pressure	Up to 10,000 psi	15 - 20 gpm
High Pressure	Up to 20,000 psi	15 - 25 gpm
Ultra High Pressure	Up to 50,000 psi	4 - 16 gpm

The disadvantage of some waterblasting is that it may leave a damp or wet surface after the work has been completed. The surface must dry before new markings can be applied. Some systems have very effective integrated vacuums which leave the surface clean, dry, and ready to paint within a short period of time.

5.4.4.1 Low-Pressure Waterblasting

Low-pressure waterblasting is normally a trailer-mounted system, and occasionally it is available at equipment rental facilities. Equipped with a hand wand, the operator can direct the pressurized stream of water more precisely at the marking. When the operator uses a straight bar or weighted "floor" machine, the removal proceeds faster. Characteristics of low-pressure waterblasting follow:

- Yields pressures up to 10,000 psi.
- Uses 15-20 gpm of water.
- Can remove a light coating of paint.
- Can remove up to 1000 SF per hour.

5.4.4.2 High-Pressure Waterblasting

High-pressure waterblasting is normally truck-mounted, but is not as readily available in the industry as the ultra-high-pressure system. Characteristics of high-pressure waterblasting follow.

- Uses pressures beginning at 15-16,000 psi, depending upon the thickness of the coating and condition of the surface.
- Uses approximately 15 to 30 gpm of water.
- Results in a hydraulic effect from the force of water.
- Recovers debris and water through a separate follow-behind vacuum system.
- Uses either a rotary system or straight bar mounted on the truck.
- Maneuvers around fixtures to avoid damage (silicone joint materials are susceptible to damage).
- Removes markings on smooth or grooved concrete.
- Removes markings on asphalt in sound condition, seen in figure 5-18.

FIGURE 5-18. HIGH-PRESSURE WATER BLASTING IS EFFECTIVE FOR REMOVING PAINT ON SOUND ASPHALT SURFACES AS WELL AS ON CONCRETE.

- Can be used as a water broom to remove debris from grooves and rough surfaces prior to painting.

- Can remove existing markings up to 1000 SF per hour, depending upon the thickness and type of material.

5.4.4.3 Ultra-High-Pressure Waterblasting

Ultra-high-pressure waterblasting is the predominant system used in the industry today, as it is the least aggressive and fastest method for removing markings. The system's pumps supply water to a spray apparatus, which can be mounted to a truck, a skid steer, a weighted "floor machine," or a hand-held wand. The main differences between the high-pressure method and the ultra-high method are the pressures used and the volume of water consumed. Ultra-high pressure waterblasting method removes the paint from the microtexture of the pavement during the removal process, and leaves a light shadow in the form of a "scar" which disappears over time. This system is generally equipped with an integrated vacuum, so that the water and debris can be picked up simultaneously, leaving a clean but damp surface that can dry in a short period of time. Characteristics of ultra-high-pressure waterblasting follow.

- Uses pressures from 28,000 to 38,000 psi, and can be rated to 40,000 psi.

- Can remove markings from concrete or asphalt surfaces; the level of scarring depends on pre-existing conditions.

- Uses approximately 5-12 gpm.

- Removes up to 6,250 SF of paint per hour and up to 40,000 SF of rubber per hour, depending upon the thickness and type of material, and the condition of the surface.

- It is the least aggressive method of removal on grooved or uneven surfaces.

- All waterblasting removal can be done in the rain.

- The equipment can evacuate the runway in 30 seconds in the event of an emergency, leaving no debris behind.

5.4.5 Chemicals

Chemicals designed to remove paint are a viable option, but these are generally restricted to be used in small areas. Characteristics of chemical-removal follow.

- Can be caustic and thus must be contained. Read the label.

- Can be environmentally safe, but slow to react, and remove one layer at a time.

- Tend to be expensive.

- Is a slow process.

- Leaves a residue that can be cleaned up with pressure washing. Both chemicals and the water must be contained, tested, and disposed of.

- Will be diluted in the event of rain.

5.5 DEFINING "DAMAGE" TO PAVEMENT, LIGHTS, JOINTS, ETC.

Scarring will occur when paint is removed from the pavement surface. *Scarring* is when some of the texture is removed and portions of the aggregate are exposed. *Damage* occurs when more than 25 percent of the nominal aggregate diameter is exposed in the vertical dimension in a uniform manner, such that the aggregate could loosen. Scarring is not considered damage.

> **Scarring is removal of the texture that leaves some aggregate exposed.**
>
> **Damage occurs when more than 25 percent of the depth (vertical dimension) of the nominal-sized aggregate diameter is uniformly exposed across the pavement, and some of the aggregate could loosen.**

In any marking removal operation, aggregate will be exposed because the paint is bonded to the material around the aggregate (microtexture). As the coating is removed, the microtexture, either Portland cement or bitumen, will erode**.** Some degree of scarring will occur depending upon: (1) the **thickness** of the markings being removed, (2) the **pavement condition** under those markings, and (3) the **composition** of those markings. Paint should be removed without exposing more than 25 percent of the depth (vertical dimension) of the nominal-size aggregate diameter uniformly across the pavement, and without loosening the aggregate.

5.5.1 Scarring

Scarring will *always* result from marking removal; the objective is to keep it to a minimum. Scars will fade over time as ultra violet light oxidizes the pavement, blending it in with the adjacent surface; this is evident in figure 5-19.

Figures 5-20 and 5-21 shows scarring with some of the aggregate exposed.

FIGURE 5-19. REMOVAL DONE ONE YEAR EARLIER; THE DARK SCAR HAS OXIDIZED AND FADED.

FIGURE 5-20. A SCAR FROM ULTRA-HIGH-PRESSURE WATERBLASTING ON GOOD ASPHALT.

FIGURE 5-21. CLOSE UP OF SCAR IN FIGURE 5-20.

5.5.2 Pre-Existing Pavement Damage

When there is cracking of both markings and pavement, any method of removal will remove pavement along with the marking. Figure 5-22 depicts before and after conditions; the section on the top was already removed with ultra-high-pressure waterblasting. Figure 5-23 shows evidence of both paint and asphalt cracking, indicating a pre-existing condition. When the paint is removed, the deteriorated asphalt will be removed in the process.

FIGURE 5-22. MARKING BEFORE (BOTTOM) AND AFTER (TOP) REMOVAL.

FIGURE 5-23. EVIDENCE OF BOTH PAINT AND ASPHALT CRACKING INDICATES PRE-EXISTING CONDITION.

Asphalt that has softened as a result of oil or fuel spills can be further damaged during marking removal. Such damage is not always noticeable upon inspection, but when subjected to removal equipment, the pavement breaks apart, as seen in figure 5-24.

Figure 5-24 is a section of runway centerline where the old, thick markings were being removed. When the ultra high-pressure waterblaster removed paint in these areas, asphalt came up in large chunks, leaving a two-inch hole. The softness of the asphalt around the hole indicated that a fuel spill had damaged the asphalt. This was a pre-existing condition.

FIGURE 5-24. PRE-EXISTING CONDITION CAUSED BY OIL SPILL THAT SOFTENED THE ASPHALT.

5.5.3 Removal of Durable Markings

Durable markings are by definition designed to last at least three years. Removal of durable markings from *asphalt* should be avoided on runway pavements. Durable markings, described below, should be designed into an airfield project only if they are applied on concrete, or areas that are unlikely to change, (e.g., sidelines).

5.5.3.1 Preformed Thermoplastic

Preformed Thermoplastic has been used in the airport industry since 2009. Currently, preformed thermoplastic is restricted to be used on taxiways. It is heated by an infrared heater and melted onto the surface. Preformed thermoplastic bonds to the surface as it cools. Any thermoplastic removal process on asphalt will remove both the marking and the asphalt to which it bonded. Waterblasters can remove the material from concrete surfaces; but rotary grinders are the best method to remove thermoplastic from asphalt because they reduce erosion of the binder from the aggregate, and leave a smoother profile. A combination of both methods could be considered.

5.5.3.2 Epoxy

Epoxy is a durable material that hardens and is difficult to remove. Waterblasting is the fastest method of removing epoxy and some other durable markings depending on the thickness. Rotary grinders can be used in conjunction with ultra-high waterblasting to break up the thick coating and increase production time while reducing damage to the pavement. .

5.5.3.3 Methyl Methacrylate

Methyl methacrylate, similar to epoxy in its durability, would be best removed with rotary grinders or a combination of methods that would include ultra-high pressure waterblasting

5.5.3.4 Polyester

Any method of removing polyester coatings from concrete is acceptable. If polyester markings are being removed from asphalt, rotary grinders in conjunction with ultra-high pressure waterblasting are the best methods to use. In the durable marking category, polyester marking paints are two-component, field-reactive formulations with >99 percent paint solids.

5.5.4 Different Types of Pavement and Condition

FIGURE 5-25. REMOVAL OF MARKINGS FROM NEW ASPHALT RESULTS IN EXPOSED AGGREGATE (SCARRING).

There are two basic pavement types: Portland cement concrete (PCC) and asphaltic cement concrete (ACC). PCC is more resistant and "forgiving" to a paint removal operation, it can withstand the aggressive pressures needed to remove markings. New ACC will withstand a paint removal operation with less scarring than old, cracked, and brittle asphalt. Because ACC is more prone to deterioration due to continual layering of new coatings on the markings, the removal process will remove the damaged asphalt along with the marking. The following paragraphs describe what can be expected during paint-removal operations for both PCC and ACC at different ages and in different conditions.

5.5.4.1 New Asphalt

New asphalt (seen in figure 5-25) should withstand a paint removal operation well. Aggregate will be slightly exposed; all methods will leave a scar.

5.5.4.2 Asphalt That is 1 to 5 Years Old

FIGURE 5-26. THE SCAR IS THE DARK PORTION OF THE ASPHALT THAT WAS SHIELDED FROM UV.

Asphalt that is 1 to 5 years old, as in figure 5-26, has faded to gray. If the markings have no more than two coats of paint, the paint should come up with minimal scarring. The newly exposed pavement will be black in comparison to the surrounding pavement when waterblasting is used, because it has been shielded from ultraviolet light by the marking. Since the pavement was not grooved, a rotary grinder would have removed the marking with little evidence of scarring.

5.5.4.3 Asphalt That is Aged

Old asphalt showing severe cracking and exposed aggregate (as seen in figures 5-27, 5-28, 5-29, and 5-30) is an example of pre-existing pavement damage, and it is the most difficult surface to assess for marking removal. In figure 5-27, the aiming point marking was on new asphalt and was a single coat of paint, whereas the sideline was on old asphalt with multiple layers of paint. Figure 5-29 and 5-30 are close-ups of the sideline, before and after removal. The thickness of the paint and how well it is adhered to the pavement should indicate the method(s) of removal as well as the degree of removal that can be used before the pavement is damaged. Removal of the paint will include removal of the deteriorated, underlying asphalt, a pre-existing condition that can result in damage.

FIGURE 5-27. BEFORE PAINT REMOVAL.

FIGURE 5-28. AFTER PAINT REMOVAL.

FIGURE 5-29. CRACKED PAINT INDICATES PRE-EXISTING PAVEMENT DETERIORATION.

FIGURE 5-30. REMOVAL OF MULTIPLE LAYERS ON DETERIORATED ASPHALT.

5.5.4.4 Preparing the Surface of Pavement After Paint Removal

Paint removal operations leave residue, grit, or other surface contaminants in the scars. A heavy stream of water is an effective method to remove the debris. The water lifts and blows the debris out of the scar, and the sweeper moves any lingering water away so debris does not float back onto the area, seen in figures 5-31 and 5-32. This is a **best practice**.

FIGURE 5-31. CLEANING THE REMOVAL SCAR BEFORE APPLICATION OF NEW MARKINGS.

FIGURE 5-32. A BLAST OF HIGH-PRESSURE WATER REMOVES DEBRIS FROM SCAR.

5.5.4.5 New Portland Cement Concrete (PCC) Pavement

New PCC pavement is susceptible to more scarring than older PCC surfaces. If paint or curing compound must be removed from new concrete, care should be taken to use lower water pressures to prevent gouging of the surface. For new concrete, material manufacturers recommend that 8 to 12 weeks elapse before markings are applied. The curing compound should be removed prior to installing markings, so it is best to remove the curing compound after the suggested 8 to 12 weeks. If the pavement must be used before this time, temporarily mark the pavement over the curing compound with a light coat (230 SF /gallon) of water-borne paint. After sufficient time has elapsed, remove the temporary markings as well as the curing compound. Thoroughly rinse the area again before applying the permanent markings if any residual debris is observed.

5.5.4.6 Portland Cement Concrete (PCC) That is 1 to 5 Years Old

PCC that is 1 to 5 years old is the best surface from which to remove markings. At that age, the concrete is fully cured and "more forgiving." Aside from the different color of the pavement seen in figure 5-33, there should be little evidence of removal.

FIGURE 5-33. THE VISIBLE SCAR IS CLEANED PAVEMENT.

Picture courtesy of NASA.

5.5.4.7 PCC That is Aged

PCC that is aged, cracked, and/or crumbling is susceptible to damage from a paint-removal operation. Depending upon the purpose of the paint removal, some methods may be better than others, but the surface will give way along with the markings.

5.5.4.8 Crack Sealing on Pavement

Repair of cracked pavement with crack seal can be a sign of pavement stress. The removal of more than two or three layers of paint from cracked surfaces must be done with care; this may take more time, and it may require more than one removal method. For example, grinding around the cracks to avoid disturbing the seal combined with waterblasting or sandblasting is advisable. If the old pavement is grooved, however, grinding would erode the grooves.

Several types of materials, ASTM D3405, ASTM D3581, and silicone sealants are used to seal cracks. All sealants are susceptible to being damaged or removed during a paint-removal process.

5.5.4.9 Joint Sealant

Joint sealant in concrete pavement is susceptible to damage during a marking-removal operation. Damage is defined as any rupture of the sealant from the edge of the pavement. In all cases, the inspector and contractor should evaluate existing conditions prior to beginning the removal operation. Covering the joints with re-bar or metal strips can protect them; however, it is imperative to retrieve all re-bar or metal strips to prevent FOD. The primary types of joint sealant found on airfields include: epoxy, silicone, bitumen, and compression.

- **Federal Spec. SS-S-200**–Sealing Compounds, Two Component, Elastomeric Polymer Type, Jet-Fuel-Resistant, Cold Applied. The epoxy sealant maintains ductility, and it would be susceptible to being scored or damaged during a paint-removal operation. Care should be taken to protect the joints.

- **Silicone joint sealant**–Silicone joint sealant is the most susceptible to damage during a marking-removal operation. Waterblasting will score it, but this process also may tear it. If the markings being removed are thick, damage is likely. Placing re-bar or metal strips in the joints will help protect them from the blasting process, as seen in figures 5-34.

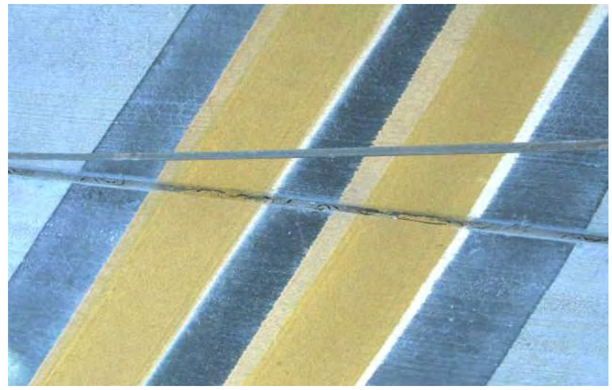


FIGURE 5-34. METAL STRIPS IN JOINTS PROTECT JOINT MATERIAL DURING PAINT REMOVAL OPERATION.

- **ASTM D 3406**–This is a hot poured, elastomeric type joint sealant installed in prepared joints with underlying backerod to fill the cavity. When it is new, it is elastic; as it ages, it becomes brittle and cracks, and is susceptible to damage during a marking-removal process. This sealant material often bulges above the surface, making the use of re-bar or metal strips difficult. If the joint material is not recessed, protecting it during a paint- removal operation is unlikely.

- **Compression seals**–Compression seals are not easily damaged during the removal of markings. Quite durable and secure in the joint, they withstand the highest water pressure without damage. Shotblasting will embed shot into the joint material, and it makes the shot difficult to recover. Grinding should not damage the joint material if it is recessed from the surface of the pavement.

<u>5.5.5 Test Strips</u>

A test strip, as seen in figure 5-35, is a **best practice,** and should always be performed on the area(s) to be removed in order to determine:

- The degree of paint removal that will be satisfactory.

- The ability of the equipment to do the work.

- The ability of the operator to run the equipment.

- The extent of scarring that will occur.

FIGURE 5-35. TEST STRIP.

5.5.6 Quality Control

Quality control during a paint-removal operation must be continuous. The operator and the inspector must monitor the process. This ensures the work is being performed in accordance with the agreed standards that were determined during the test strip stage. It is also important to monitor the scarring and cease operations if damage occurs.

5.5.7 Hazardous or Non-Hazardous Waste

Hazardous waste can be generated from any operation, and this should be factored into any removal project. The materials removed during a paint-removal operation are generally considered "hazardous" until a laboratory analysis proves otherwise. However, whether hazardous or non-hazardous, it is a **best practice** to collect and contain the waste in accordance with local and federal regulations.

6 APPLICATION PROCEDURES

TABLE 6-1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	★
Airport Operators	
Designers/Engineers	★
Inspectors	★

The successful application of airfield markings requires knowledge and experience in a wide range of areas, including standards, specifications, equipment, materials, procedures, and quality control. Each of these areas can have a significant impact on the overall quality of the final markings.

Chapter 6 addresses the process of applying markings to an airfield pavement surface. The factors described in this chapter relate directly to the application of markings by a contractor, airport personnel, or others. Table 6-1 indicates the personnel who can gain the greatest benefit from the material in this chapter. Where used, the term "best practice" is highlighted in bold. Table 6-2 summarizes the best practices presented in this chapter.

TABLE 6-2. BEST PRACTICES FOR APPLICATION PROCEDURES

Section Reference	Best Practice
6.1.2	Layout is provided to maintain proper dimension and straightness.
6.1.4, 6.4.1, and 6.4.2	A "primer" coat (temporary coat) is applied to new asphalt, or under adverse conditions.
6.1.5, 6.10.4.1	Close attention is paid to proper coverage rates.
6.2.1	Adequate surface preparation is performed.
6.5.4, 6.5.5	Glass beads are dispensed automatically with the coating.
6.5.4, 6.7.4	Pressurized glass bead system is used.
6.6.1, 6.6.2	Hand machines are equipped with automatic bead dispenser(s).
6.6.3	Windscreens are used to prevent material displacement.
6.7.1	Two or more colors are applied simultaneously.
6.7.2	Uniform, specified film thickness across the width of the marking.
6.7.2, 6.10.2, 6.10.4.1	Calibration of material guns and monitoring of material usage is practiced.
6.7.2.2	Uniform thickness of 36-inch marking achieved with multiple paint and bead guns.
6.7.3	Markings are applied from 6-36 inches in a single pass.
6.7.5	Pointer system is used for accurate placement of markings.
6.9	Good "housekeeping" methods are practiced.
6.9.1	Test lines are performed in designated areas or on tar paper or mats.
6.10.3	Documentation of marking operations is a daily function.

Of all of the techniques used to prepare and apply markings, the best are those where close attention is paid to details, where data is recorded and documented, and where quality materials are used. The following paragraphs will highlight the important details of applying airfield markings.

There are two scenarios for applying airfield markings:

- Installing new markings on a new surface.
- Maintaining existing markings.

6.1 NEW MARKINGS

Installation of new markings involves procedures that are not used in the remarking process.

6.1.1 Surface Preparation: Curing Compound or Construction Debris Removal

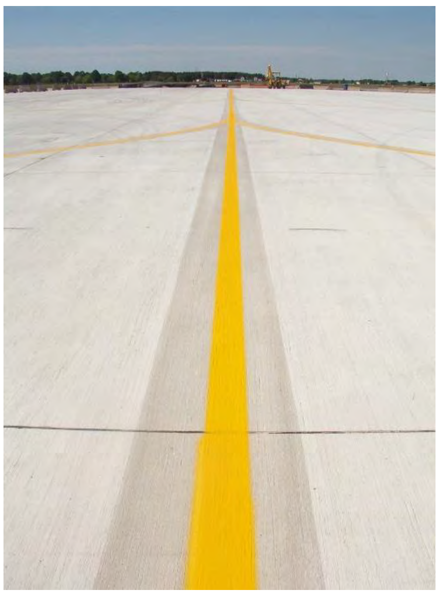


FIGURE 6-1. CURING COMPOUND WAS PROPERLY REMOVED FROM NEW CONCRETE.

FIGURE 6-2. CONSTRUCTION DIRT MUST BE CLEANED.

If the new pavement is Portland cement concrete, removing the curing compound is vital to ensure a proper bond of the marking material to the pavement (figure 6-1). Material manufacturers recommend a waiting period of 8 to 12 weeks before applying markings to new concrete to avoid gas bubbles erupting through the paint.

Other contractors working on the project may deposit contaminants that should be removed to ensure the bond of the markings to the pavement. Caked mud, for example, evident crossing the laid-out runway centerline in figure 6-2, will dissolve over time, leaving some spots unpainted where mud had been. Dried slurry from a grooving operation on the edge of the pavement may be in the path of the sideline or other markings. From a contractual standpoint, cleaning these contaminants would be the responsibility of the general contractor, because surface preparation of *new asphalt* would not be anticipated in the original bid. However, if the new surface is Portland cement concrete, removing the curing compound also will remove other contaminants.

6.1.2 Layout of Markings

Layout is important for the proper placement of the markings. It is a **best practice** for both placing new markings or for straightening existing markings. Pre-marking the pavement with chalk lines and paint spots (seen in figures 6-3 and 6-4) provides the equipment operator with guide marks, which is especially important when striated markings are installed. Layout marks also allow the inspector to check the layout for correct placement and dimension.

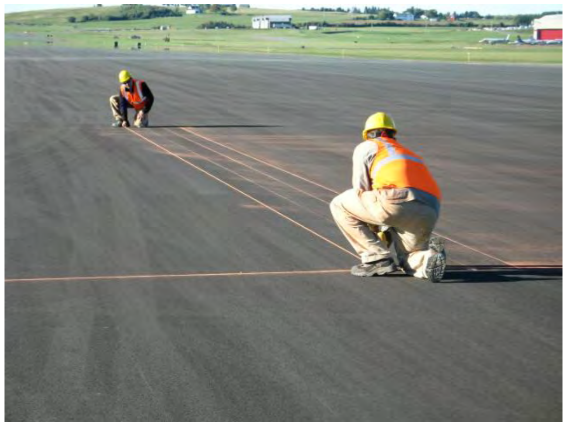


FIGURE 6-3. LAYOUT WITH CHALK LINES ENSURES PROPER PLACEMENT AND ALIGNMENT.

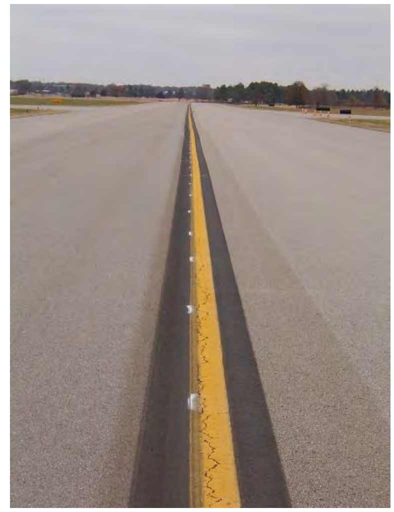


FIGURE 6-4. LAYOUT WITH PAINT SPOTS TO STRAIGHTEN EXISTING MARKINGS.

6.1.3 Application of Markings on Grooved Surfaces

Markings are installed on grooved surfaces in the same way they are applied on non-grooved surfaces. The automated equipment, whether hand machines or truck-mounted, will paint only one side of the groove. Seen in figure 6-5, from a distance, the unpainted side is not evident. Only with close inspection can the unpainted side be seen, as in figure 6-6.

FIGURE 6-5. THE UNPAINTED SIDE OF THE GROOVES IS NOT NOTICEABLE FROM A DISTANCE.

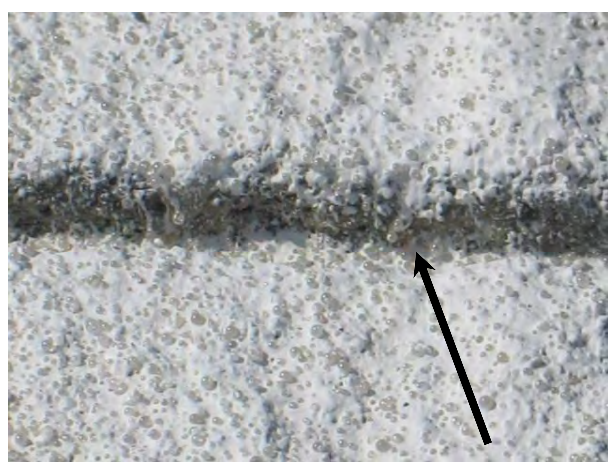


FIGURE 6-6. UNDER MAGNIFICATION, THE UNPAINTED SIDE OF THE GROOVE IS NOTICEABLE.

Grooved pavement removes water from the surface to prevent hydroplaning. Continued remarking of grooved pavement causes the grooves to fill up with paint, thus diminishing their effectiveness, seen in figure 6-7. Waterblasting to prepare the surface before reapplying markings improves this situation.

FIGURE 6-7. MULTIPLE LAYERS OF PAINT FILL THE GROOVES.

6.1.4 Application of Markings on Porous Friction Course (PFC)

Installing markings on PFC is generally done in two passes, one in each direction, in order to coat all sides of the larger aggregate designed in the PFC asphalt mix. An initial coat applied in one direction at half rate without glass beads, followed by a second coat in the other direction applied at full rate with glass beads, coats all sides of the aggregate in the asphalt. Additionally, the first coat acts as a primer, which is a **best practice**. It seals the oils in the asphalt, keeping the white paint from turning brown.

6.1.5 Coverage Rates

Coverage rates (film thickness or bead distribution) of the material are important. Most manufacturers recommend coverage rates expected from a gallon of material or a pound of beads. Local government agencies occasionally specify their own coverage rates, which can differ from those recommended either by the manufacturer or the guidance literature. A project designer should be wary of specifying different coverage rates than those recommended by the manufacturer or the guidance literature. In most cases, either more or less than recommended by these two sources is not advisable.

Coverage rates can be greatly affected by the speed of the equipment. If the speed is too fast, the film thickness will be too thin to anchor glass beads, and the coating will wear too quickly. If the equipment moves too slowly, the resulting heavy film may cause the coating to crack or not cure properly, as seen in figures 6-8 and 6-9. Close attention to proper coverage rates is a **best practice.**

FIGURE 6-8. TOO MUCH PAINT WAS APPLIED IN OUTLINED AREA.

FIGURE 6-9. THICK COATING CRACKED, CAUSING PAVEMENT TO CRACK AS WELL.

6.2 REPAINT EXISTING MARKINGS

"Repaint" means painting over existing markings after cleaning the surface. In this case, layout for the markings being applied will be minimal, unless the preparation obscured their location. If more than 10 percent of the markings require layout to straighten those out of alignment, this should be stated in the plans and/or specifications for the applicator to plan to make time to do it.

6.2.1 Surface Preparation

The most overlooked condition requiring surface preparation is the condition before repainting markings. Airfield markings are exposed to all of the worst elements: rain, heat, extreme cold, chemicals, heavy loads and/or infrequent use, ultra violet light, algae, and other stresses. Each element can individually stress the markings on the pavement; but in combination, they can result in the marking materials becoming aged, faded, brittle, cracked, and worn. Removing the existing layers affected by such elements gives the new coating a better surface on which to bond, and this is a **best practice**. (See Chapter 4 – Surface Preparation)

Many airports repaint their markings at least once per year. Some only do "high-maintenance" markings, such as the runway and taxiway centerlines, but in most cases very little if any surface preparation is performed. The results are varied, but all perpetuate the maintenance cycle.

Based on case studies, adequate surface preparation done ***before*** remarking:
- prolongs the life of the marking project
- saves valuable airport funds
- reduces paint build up and FOD

6.2.2 Application on Different Pavement Types

Airport pavements are made up of two basic types: Portland cement concrete (PCC) and asphaltic cement concrete (ACC). As the pavements wear, other surface treatments are applied, all of which accept the application of markings, but some react differently than others. The following paragraphs describe some of the different surfaces encountered and the observed performance of markings on them.

6.2.2.1 Concrete

If concrete is new or unmarked, epoxy performs well and is very durable. Solvent and water-borne paints perform well. Water-borne paints have been improved: better polymers have been developed that improve the bond of the material to the pavement and provide greater flexibility and elasticity of the marking. As long as the water-borne marking is installed correctly, its life expectancy should be two years or longer, depending on the volume of traffic.

6.2.2.2 Asphalt

Most materials bond well to asphalt, but asphalt is more susceptible to damage due to different stresses of the coatings on the surface.

For highways, durable markings increase the longevity of the pavement markings. Although some of the durable markings used on highways are approved for use on airports, some are not. Most durable markings should be reserved for taxiways and non-movement areas; not used on runways.

TT-P-1952, Type III paint was designed to compete with the durable materials on highways, but has proven to be a good choice for asphalt surfaces on airports. The Type III, or "high-build acrylic" paint contains a crosslinking resin that results in a paint film that is more flexible and moves with the asphalt, thus resisting the cracking that is typical of Type I and Type II formulas. Type III paint can be applied from 7 mil wet film thickness (wft) up to 30 mil wft.

Solvent paints (TT-P-115 and TT-P-85) were a government standard until the mid 1980s when the water-borne paints were introduced in response to environmental concerns. Solvent paints caused severe cracking of both paint and asphalt, as seen in figure 6-10. A-A-2886-B is the current approved solvent paint specification approved for use by the FAA.

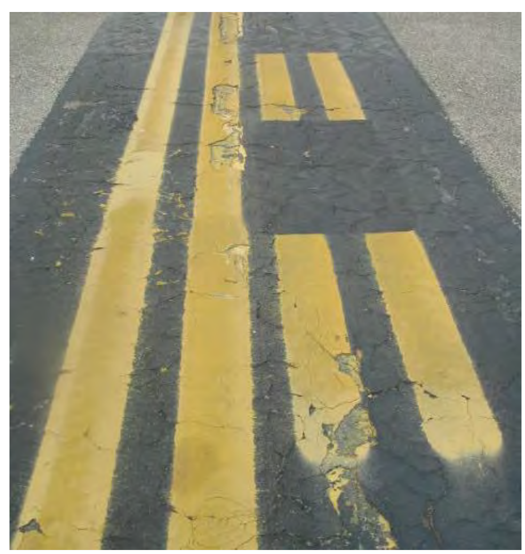


FIGURE 6-10. SOLVENT PAINT CRACKED THE ASPHALT.

6.2.2.3 Seal Coat

Water-borne paints are the best material to use on seal coats, due to their lack of "reactivity." In some locales where rust discoloration is an issue, the application of a seal coat inhibits the rust discoloration on white markings. Coating the asphalt aggregate keeps the contaminants sealed, preventing the iron from affecting the markings.

Prior to the application of the seal coat and after the markings have been 80-85% removed, ensure the surface is free from any contaminant or debris that would prevent the bond of the sealcoat or the markings applied to it.

6.2.2.4 Pavement Rejuvenator

Rejuvenator is generally applied ***around*** markings, not over them, because neither one will bond well to the other. Pavement rejuvenator is designed to penetrate into the asphalt, restoring life to the pavement. Any paint coating will present a barrier to the rejuvenating products, so it must either be 80 to 85 percent removed, or circumvented.

6.2.2.5 Crack Sealant

Crack sealant is made of bituminous material, and paints do not bond well to it. Additionally, crack sealant discolors the white paint, as oils are still present in it, evident in figure 6-11.

FIGURE 6-11. JOINT MATERIAL DISCOLORS THE WHITE PAINT.

6.3 STRIATED MARKINGS

Striated markings are stripes of even width separated by spaces of even width to the stripe within the area of a standard runway marking. The theory of the striated marking is that the space exposes pavement that absorbs heat from the sun and UV more quickly than the solid, white marking. In areas of the country where frozen precipitation is common, the exposed pavement hastens the melting of the ice or snow, helping to prevent "frost-heave" of the pavement.

There is not a specific stripe width for the striations, but they can be between 4 to 8 inches wide. A painted stripe is to begin and end within the width of the marking; in other words each edge of the painted marking is to be a painted stripe.

Seen in figures 6-12 and 6-13, when a striated marking is remarked, the existing striations are often not matched exactly. Eventually, no pavement is exposed, which negates the reason for the striations.

FIGURE 6-12. 4-INCH STRIATIONS.

FIGURE 6-13. 6-INCH STRIATIONS.

Striated markings are less visible, particularly at night, because half the standard marking dimension is bare pavement. For this reason, the FAA states that more frequent maintenance is required to keep this marking effective.

> **"Since striated markings have a reduced visibility, more frequent maintenance is required to provide an acceptable marking system. Striated markings are not used on Category II and Category III precision runways."**
> **Source: FAA AC 150/5340-1J**

"*More frequent maintenance*" means more paint applications, which leads to paint build up. The striations become ridges, susceptible to being scraped off by snowplows. As the markings are scraped off during the course of the winter, they become even less visible during either day or night, resulting in the loss of the markings as an effective navaid. As seen in figure 6-14, the leading edge of the marking has been virtually removed by the snowplow. "*More frequent maintenance"* should include surface preparation to remove loose and poorly bonded paint. In more severe cases, where paint has been allowed to build up, paint removal should be required.

From a pilot's perspective, the "acquisition" of a runway with striated markings, on a clear night without the benefit of runway centerline lights, happens within the last 100 feet of elevation. The markings seen from the ground (figure 6-15) are poor, reducing nighttime visibility.

FIGURE 6-14. LAYERED STRIATIONS ON THE SIDELINE WERE SCRAPED OFF BY SNOWPLOWS.

FIGURE 6-15. STRIATED MARKINGS ARE NOT AS VISIBLE AS SOLID MARKINGS; AND WHEN BEADS ARE POORLY APPLIED, THEY ARE DIFFICULT TO SEE DURING LOW-VISIBILITY.

> Careful attention to glass bead distribution during the marking operation will provide markings that are as visible in darkness as they are in daylight.

6.4 TEMPORARY MARKINGS

Temporary markings are by definition being applied for a limited period of time. The coverage rate and choice of materials depend on several factors.

- The length of time the markings will be needed.
- The kind of traffic or wear they will sustain.
- Prevailing weather conditions.
- Whether or not they will be removed.
- Whether it is a thin "temporary" (primer) coat in the permanent location.

Most temporary airfield markings are installed using the standard water-borne traffic paint, TT-P-1952. Thinning the paint is ***not*** recommended. Applying it at half the coverage rate is standard for temporary markings, (i.e., 230 square feet per gallon versus the full rate of 115 square feet per gallon).

6.4.1 Coating Thickness (Film Thickness) of Temporary Markings

The coverage rate and film thickness of temporary markings will be based on the length of time the markings must be in place. If the temporary markings must be visible at night, glass beads may be needed, and a 12–15 mil wet film thickness is required for anchorage of the spheres, assuming TT-B-1325, Type I or III glass beads is used.

Coating thickness can be altered by increasing the speed of application, changing the gun tip sizes, changing the pressure on the pump or tank, or a combination of these methods. The thinner the coating, the easier it is to remove in most cases. Much depends upon the coarseness of the pavement, or how absorbent it was when the marking was applied. A coarse or rough pavement will have peaks and valleys. Wet coatings will gravitate toward the valleys, leaving the peaks with thinner coatings. New asphalt is absorbent, and coatings soak into the fresh pavement. A primer (temporary) coat at half thickness without glass beads will seal the pavement, and is a **best practice**.

One method to facilitate removing temporary markings is to apply a layer of curing compound on the pavement before the temporary markings are installed, whether the pavement is concrete or asphalt. The wax-based curing compound acts as a "temporary bond" to the pavement, and until it flakes off or is intentionally removed, the paint will adhere to it. If the temporary marking is subjected to heavy traffic, the marking may have to be reapplied if it flakes off prematurely.

Another temporary coating that is easily removed is the earliest generation of waterborne paint: TT-P-1952B. Applied in a thin coat, it can be removed with a pressure washer.

6.4.2 Application of Markings Under Adverse (Cold) Weather Conditions

There will always be situations when markings must be applied to open an airfield surface to traffic to comply with a schedule or safety requirement. If the markings are applied under adverse, (e.g., cold or wet conditions), a **best practice** is to install the markings with a temporary coating; then when weather conditions are better, the permanent markings can be applied. If the temporary coating is not well bonded, remove the peeling portions before applying the permanent coating.

6.4.3 Glass Beads

Glass beads usually are not used on temporary markings. However, if traffic will use the area during darkness or low-visibility conditions, consideration should be given to applying a full coat ***with*** glass beads to enhance visibility ***and*** situational awareness.

6.5 MARKING EQUIPMENT

Equipment for applying pavement markings falls into two general categories: (1) airless systems and (2) pneumatic or air-atomized systems. Either type can be mounted on trucks; skids that can be loaded and unloaded onto pickups or flatbed trucks; small tractors or vehicles; and hand push machines. The airless and air spray categories include features such as hydraulic-powered airless, air-powered airless, pumper-style air spray, and pressurized-tank air spray.

6.5.1 General Characteristics of Pavement Marking Equipment:

Whether pneumatic or airless, striping equipment has similar characteristics and challenges, which are described next.

6.5.1.1 Heated Systems

The permanently configured striping truck can be equipped with heat exchangers. Heat exchangers warm the material to approximately 100–120 F. Heating the paint accelerates the "dry to no track" time to approximately one minute, preventing other construction traffic from tracking the markings. However, since the "no track" condition happens faster, the glass beads must be applied simultaneously with the paint application to ensure the beads will anchor and not bounce off the dry film.

Paint viscosity thins when heated, flowing more uniformly. When the material is cold, it thickens, resulting in changed line widths and restricted paint flow.

Heating the paint does not alter the requirements of either the air or the surface temperatures. If the outside temperature is below 50 F, application of the standard water-borne or solvent-borne paints is not advisable, regardless of the temperature of the material. When the heated material contacts cold pavement, the paint quickly cools to the pavement surface temperature, which if below 50 F, compromises the durability of the marking.

6.5.1.2 Housekeeping of the Equipment

Good housekeeping is vital for the efficient operation of striping equipment. Water-borne paint should not remain in the tanks, pumps, or lines for longer than 3 to 4 hours, especially when they are partially filled and exposed to high heat, because doing so may cause the paint to harden, resulting in considerable clean out before the equipment can be used again. Using in-line filters or strainers is important to keep the paint free of debris that can clog the paint guns or lines, restricting flow. On an airless system, the most critical location for a Y-strainer is at the inlet of the high-pressure paint pump. For an atomized system, the strainer should be placed before the material manifold leading to the guns.

Different binders should not be mixed together. If a solvent paint is in the system, water-borne paint should not be added until the tanks and lines are thoroughly cleaned. Traffic paint manufacturers often recommend a multiple-step procedure involving a series of compatible flushing liquids to perform this switchover.

A very small amount of all-purpose cleaner in the clean-out (water) tank helps remove water-borne paint from the tanks and lines, thus preventing a build up of paint film, which can restrict the flow of the material through the system.

6.5.2 Airless Equipment

The term "airless" refers to a pumping system that applies paint at approximately 1500–3300 psi without "atomizing air" to disperse the paint particles in a line. An airless gun has a small tip, as seen in figures 6-16 and 6-17. Tips are identified with a numerical code, (e.g., 421) which represents the suggested line width and the size of the orifice.

FIGURE 6-16. RAC 5 AIRLESS SPRAY TIP.

FIGURE 6-17. AIRLESS FAN WITH TIP.

The speed of the machine installing the marking as well as the pump pressure will affect the volume of material flow and the film thickness of the line. If multiple guns are set up to paint wider markings, the film thickness where the guns overlap must be uniform with the rest of the marking.

On truck-mounted units, glass bead guns are arranged to apply the beads onto the wet paint simultaneously, pictured in figures 6-18 and 6-19.

FIGURE 6-18. PNEUMATIC PAINT GUNS AND GLASS BEAD GUNS MOUNTED TO TRUCK ON CARRIAGE.

FIGURE 6-19. AIRLESS PAINT GUNS AND BEAD GUNS APPLYING MATERIAL TO PAVEMENT.

6.5.2.1 Skid-Mounted Equipment

Some skid-mounted equipment can be moved on and off a truck. This equipment is capable of applying two colors simultaneously, making it quite attractive to the airport maintenance crew responsible for outlining yellow taxiway markings with black for contrast, figure 6-20.

The equipment also can be set up with skip-mechanisms, allowing the operators to dial in a marking pattern that will activate the paint and glass bead guns automatically when the truck begins to move. This is particularly useful for airports that must maintain non-movement boundary markings with the 3-foot dash patterns, or the enhanced taxiway centerlines with the 9-foot dashes and 3-foot spaces seen in figure 6-23.

FIGURE 6-22. SKID MOUNTED PAINT RIG APPLIED BLACK BACKGROUND FOR TAXIWAY CENTERLINE IN FIGURE 6-23.

FIGURE 6-23. THREE PAINT GUNS AND FOUR BEAD GUNS APPLIED THE YELLOW PATTERN IN ONE PASS.

6.5.2.2 Permanently Truck-Mounted Equipment

Truck-mounted equipment (seen in figure 6-24) is more expensive for airports to own, because it is specialized and can only be used for one purpose. However, at busy airports the equipment is used frequently, and not having to reconnect equipment to the truck each time is helpful. Pavement-marking contractors usually have truck-mounted systems, which hold a larger volume of material, making the equipment more productive. Like the skid-mounted unit, this equipment can apply multiple colors simultaneously with or without glass beads. Generally the truck-mounted equipment has a movable carriage, and the operator can steer around radii on the taxiways, turning onto other taxiways and runways.

FIGURE 6-24. TRUCK-MOUNTED AIRPORT STRIPING EQUIPMENT.

For both the skid-mounted large truck and the permanent truck-mounted equipment seen in figure 6-25, larger supplies of material can be loaded onto the truck, allowing more production time before stopping to "re-load" or fill with more material.

Trucks can load from "totes," seen in figure 6-26, or large paint storage tanks to reduce the amount of waste resulting from 55-gallon drums. Drums, although great for trash barrels, are not cost-effective to recycle, and they must be disposed of at landfills. Totes can be recycled with the manufacturer several times, contributing to conservation. However, it is difficult to quantify amounts of material in the totes, so verifying material usage can be a problem.

FIGURE 6-25. TRUCK MOUNTED STRIPING EQUIPMENT WITH LARGE MATERIAL TANKS.

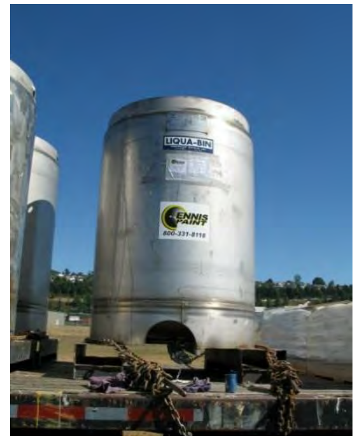


FIGURE 6-26. LARGE MATERIAL TOTE.

6.5.2.3 Other Long-Line Machines

Equipment manufacturers have developed smaller units (as shown in figure 6-27), which are suitable for most applications, depending upon the skill of the operator. However, the shorter the striping unit and the closer the carriage is to the front of the vehicle, the more difficult it is to keep lines straight. Speed also becomes more variable unless a device is installed to regulate it. Speed affects coverage rates.

FIGURE 6-27. OTHER LONG-LINE STRIPING EQUIPMENT.

6.5.3 Pneumatic or Air-Atomized Striping Systems

FIGURE 6-28. FOUR PNEUMATIC (ATOMIZED) PAINT GUNS APPLYING A 3-FOOT WIDE PATTERN.

Pneumatic or air-atomized striping systems use (1) air compressor(s) that pressurize tanks, pushing the material through supply lines and down to the gun(s), figure 6-28, or (2) pumper-style units. According to one equipment manufacturer, the pumper unit can integrate a material-monitoring system, utilizing stroke counters to provide gallon readings. One advantage of the pumper-style units is the zero-pressure material tanks, which are not as heavy as pressure pots. Pumper systems use the diaphragm-loading pumps, seen in figure 6-29, to pressurize the paint lines leading to the guns on the carriage. At the gun, atomized air is introduced at the tip, just past the fluid nozzle where the material enters a chamber. Air breaks up the paint particles, forcing them through the gun tip in a fan pattern, (seen in figure 6-28).

FIGURE 6-29. PNEUMATIC TRUCK-MOUNTED SYSTEM.

Pneumatic systems are suitable for water-borne and solvent paints. Using the waterborne paint (TT-P-1952) requires the use of stainless steel tanks and compatible paint lines to prevent the paint from reacting with the metal tanks, hoses, or other plumbing. Not as susceptible to clogged paint guns and tips as with airless systems, the pneumatic system has larger orifices through which the material is sprayed (figure 6-30). The volume of material sprayed through an air-atomized gun can be controlled by pressure on the paint tank and it can be fine-tuned by increasing or decreasing the atomized air. An increase in atomized air will restrict the flow of material; a decrease in air will increase the flow. When marking with multiple guns in an airless unit, it is sometimes difficult to get a uniform film thickness across the marking. With an air-atomized system, fine-tuning the flow of each gun makes this less of an issue.

FIGURE 6-30. ATOMIZED MATERIAL GUN AIR NOZZLE AND FLUID NOZZLE.

6.5.4 Pressurized Glass Bead System

Pressurized guns deliver the most uniform flow of beads to the marking, are automatically triggered when the paint guns are activated (a **best practice)**, and achieve the best distribution and embedment (as seen in figure 6-31). The marking in the upper portion of figure 6-31 was applied using gravity-drop bead guns. The marking in the lower portion of the picture was applied using pressurized bead guns. The pressurized method is more uniform, and is a **best practice**.

FIGURE 6-31. PRESSURIZED BEAD APPLICATION IN FOREGROUND, GRAVITY-DROP IN BACKGROUND.

Pressurized glass beads are susceptible to moisture, which accumulates in the bead tank. Water vapor collects from humidity in the air or from the warm, compressed air as it expands in the bead tank. Glass beads are very susceptible to moisture and will clump when damp, making bead flow problematic. A series of water traps throughout the pressurized air system will help keep the air free of moisture. A remedy is to put a "pinch" of cornstarch in the tank of beads as they are being loaded. The cornstarch migrates, covering the beads and helping to prevent them from becoming damp.

6.5.5 Gravity-Drop Glass Bead System

A gravity-drop glass bead system can be effective on any striping equipment if the glass bead guns are activated simultaneously with the paint guns, which is a **best practice**. However, as seen in figure 6-31, the circular-type bead guns in a gravity-drop system do not always provide the best results. Modifications to improve distribution include tilting the guns or installing screens to help break up the circular pattern, as seen in figure 6-32.

Gravity-drop glass beads are applied to the wet marking within seconds of the material being applied. The glass beads, not under pressure, are not as susceptible to becoming damp, but they will be prone to wind displacement and turbulence from the painting operation just in front of it. The metal screen between the paint and bead guns (seen in figure 6-32) prevents the air turbulence from displacing the beads. The bead guns are activated by air, allowing the beads to drop onto the line. When the air stops, the guns close. The bead guns can be adjusted to delay opening or closing, thus timing them to cover all of the marking.

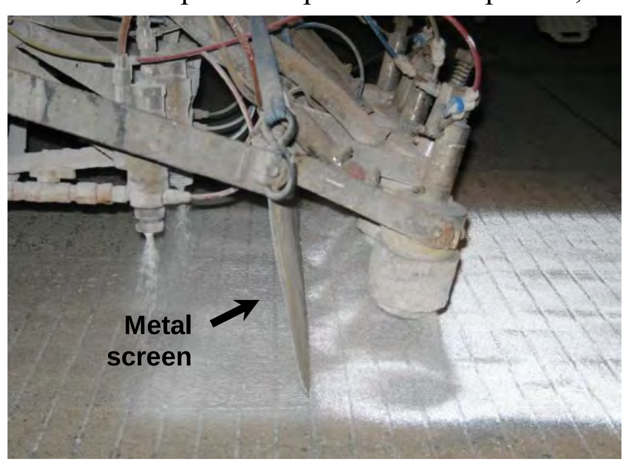


FIGURE 6-32. METAL SCREEN REDUCES BEAD DISPLACEMENT BY AIR TURBULENCE FROM PAINT GUNS.

6.5.6 Hand-Applied Method

The hand-applied method of applying glass beads must be used in some cases. However, hand-throwing glass beads, demonstrated in figure 6-33, should be avoided as much as possible. (1) They are seldom "thrown" evenly, (2) they are often thrown after the paint has already "filmed over," preventing proper embedment, and (3) the glass beads are broadcast on the surrounding pavement, increasing the cleanup that will be needed, as well as creating a potential risk of someone slipping.

FIGURE 6-33. HAND-THROWN GLASS BEAD APPLICATION IS UNEVEN, POORLY DISTRIBUTED, AND POORLY EMBEDDED.

The holding position marking in figure 6-34 is new, yet hand-thrown beads appear uneven. Only some of the hand-thrown beads remain (as shown in figure 6-35), after just six months of wear.

FIGURE 6-34. NEW HOLDING POSITION MARKING WHERE BEADS WERE HAND-THROWN.

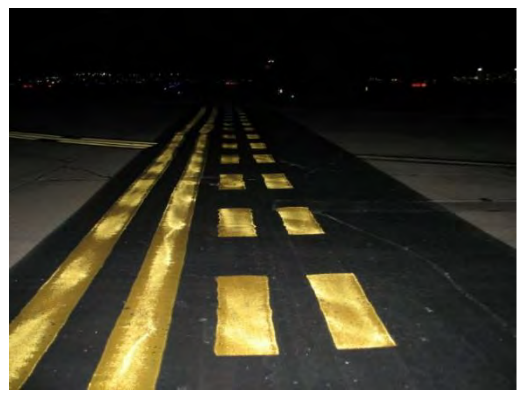


FIGURE 6-35. SIX-MONTH OLD HOLDING POSITION MARKING WHERE BEADS WERE HAND-THROWN.

Resourceful airport personnel and contractors have developed "low-tech" methods for applying beads. Using a modified fertilizer spreader, seen in figure 6-36, is difficult to judge coverage rate; and bead embedment is still an issue. Because it is mounted on wheels, the applicator must exercise caution when moving this equipment over wet paint.

FIGURE 6-36. FERTILIZER SPREADER WAS MODIFIED TO APPLY GLASS BEADS.

6.6 HAND MACHINES

Hand machines are used for detail markings, such as surface-painted signs, holding position markings, and sometimes runway designation numerals. Some airports use these small machines, (either push-type or self-propelled) to border larger markings that are then filled in with a larger paint truck, evident in figure 6-37. Figure 6-38 is the same marking seen in daylight. The difference in application of the border with hand-thrown beads is evident at night.

FIGURE 6-37. BORDER WAS APPLIED WITH HAND-MACHINE AND BEADS WERE HAND-THROWN.

FIGURE 6-38. THE SAME MARKING AS IN FIGURE 6-37 DURING DAYLIGHT.

6.6.1 Airless Hand Machines

Airless hand machines, similar to the truck- mounted systems, can be pushed or self-propelled. When equipped with large pumps, these machines can paint a line up to 12-inches wide or they can paint two to three lines simultaneously. Lines that are applied wider than 12 inches in a single pass must be carefully monitored for uniform film thickness across the entire line.

A motorized machine is seen in figure 6-39. Very maneuverable, a two to three gun airless machine can work quickly. This equipment, traveling at an appropriate speed and applying materials at the right coverage rate is effective, especially when equipped with glass bead guns that automatically dispense the beads in the paint, a **best practice.**

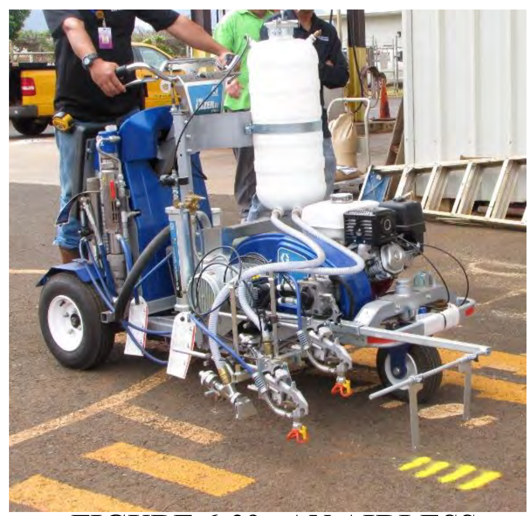


FIGURE 6-39. AN AIRLESS MACHINE WITH PRESSURIZED GLASS BEADS.

6.6.2 Pneumatic (Air-Atomized Equipment)

Air-atomized push equipment, which functions like the truck-mounted systems, is generally equipped with a single material gun. A larger compressor is necessary to operate two paint guns, making the machine bigger and heavier. It is able to paint detail work that truck-mounted systems cannot do as effectively. Automatic glass bead dispensers are integral to the air-atomized hand machine, a **best practice,** because the air supply needed to activate the bead gun is part of the system.

6.6.3 Hand Machines and Glass Bead Application

Glass bead systems for hand machines generally fall into two categories: gravity fed or hand-thrown. However, at least one equipment manufacturer supplies a pressurized system requiring a compressor and pressurized bead tank, making the machine heavy.

Gravity-fed systems use either cable or air activation to trigger the beads. Bead dispensers for airless systems can be included, but the operators often disable these when the apparatus malfunctions. A bicycle brake cable is normally used to activate the bead gun at the same time the paint gun goes on. As dirt, paint, dust, oil, and other substances accumulate on the cable, the trigger begins to slip, failing to activate the bead gun. A considerable percentage of airport personnel using airless hand machines disable the bead dispensers, and use watering cans, fertilizer spreaders, or their hands to throw the beads on the markings, a poor practice.

Figure 6-40 depicts an airless machine with a 12-inch bead dispenser that opens automatically when the paint gun comes on. Notice the hand-built windscreen (shroud) around the bead dispenser that blocks the wind from displacing the beads, a **best practice**.

Pneumatic or air-atomized machines generally have a 5 to 10-gallon paint tank and an integrated glass bead hopper with a bead dispenser. The beads are activated by compressed air that triggers the bead gun, shown in figure 6-41, and they can be delayed to go on and off with the turn of a valve. A gravity-fed system is usually used for both airless and pneumatic small paint machines; a much larger compressor would be needed to pressurize a tank. Weight is a main consideration when equipment is pushed and maneuvered by hand.

FIGURE 6-40. GLASS BEAD DISPENSER HAS BEEN MODIFIED WITH A CARDBOARD WINDSCREEN.

6.7 COMPLIANCE WITH EQUIPMENT SPECIFICATIONS

FIGURE 6-41. GLASS BEAD DISPENSER ON AN ATOMIZED HAND MACHINE.

Guide specifications for all government agencies provide basic requirements in the way equipment should be used to achieve quality airfield markings. Wording like "uniform film thickness," a glass bead "dispenser … properly designed for attachment to the marking machine and suitable for applying glass beads" (AC 150/5370-10), are part of the specifications intended to standardize application methods. The U.S. Air Force specifies that marking machinery ". . . shall be capable of applying lines . . . in widths of (from102 mm (4 inches) to 1 m (3 feet))" in a single pass.[7] All applicators, whether contractors or airport personnel, must comply with equipment requirements; engineers or inspectors must enforce the specifications as a first step toward achieving quality installations.

6.7.1 Airless and Pneumatic (Air-Atomized) Striping Systems

Either airless or air-atomized systems are suitable for applying markings to airfields. Specific material may dictate what type of equipment is used, since airless systems apply water-borne, solvent, and epoxy coatings, whereas air-atomized equipment only applies water-borne or solvent paints. Both systems can apply two or more colors simultaneously, a **best practice.**

"*The mechanical marker shall be an **atomizing or airless** spray type marking machine suitable for application of traffic paint. It shall produce an even and uniform film thickness at the required coverage* [rate] *and shall apply markings of uniform cross sections and clear-cut edges without running or spattering and without over spray*."[8]

[7] Engineering Technical Letter (ETL) 97-18: Guide Specification for Airfield and Roadway Marking, HQ AFCESA/CES, 1997.
[8] FAA AC 150/5370-10C, P620.

The most significant and visible difference between air-atomized and airless systems can be seen in the edge of the marking. Pressurized air breaks up (atomizes) the paint into small globules in a pneumatic spray system, leaving a slightly fuzzy edge (noticeable in figure 6-42). The airless spray uses higher pressure and smaller orifices to break the paint into smaller globules and lays the marking down like a ribbon of paint with sharper edges (seen in figure 6-43). However, when 14-16 mils of paint is applied with an airless machine, edges are less sharp.

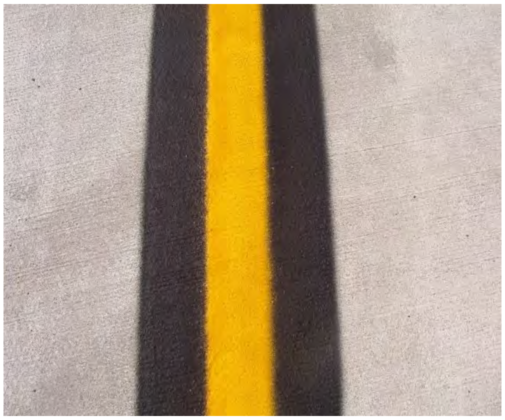


FIGURE 6-42. THE EDGES OF AN ATOMIZED LINE ARE LESS SHARP THAN AN AIRLESS

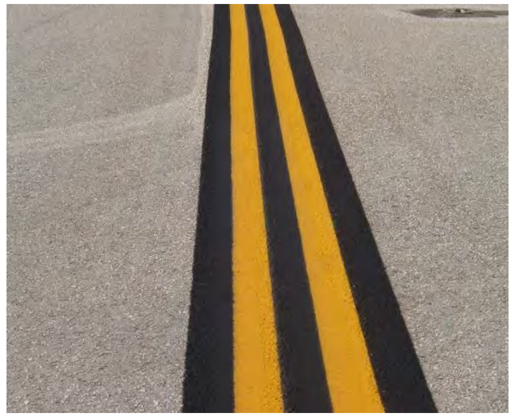


FIGURE 6-43. AIRLESS LINES HAVE SHARPER EDGES.

Over spray: The "fuzziness" of the air-atomized system does not constitute over spray. Over spray occurs when conditions are windy and the striping machine does not have adequate shrouds to keep the materials from being displaced. The yellow haze to the left of the taxiway edge line in figures 6-44 and 6-45 is an example of over spray. Another cause of over spray can be from thinning the paint. Specifications as well as material suppliers state that the "paint shall not be thinned" since it changes the composition of the material, resulting in longer dry time and coverage (dry film thickness), as well as under-embedment of the glass beads.

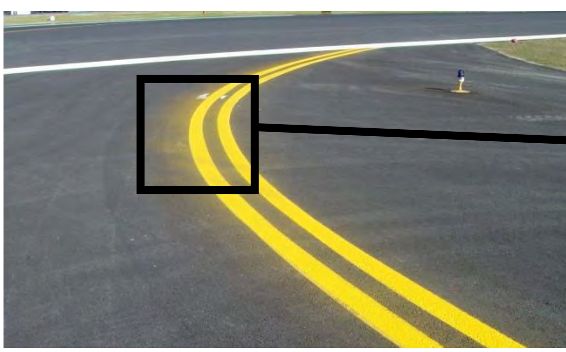


FIGURE 6-44. OVER SPRAY CAUSED BY WIND OR THINNED PAINT, OR BOTH.

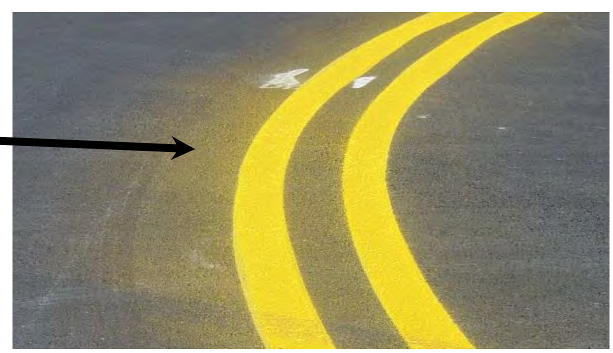


FIGURE 6-45. CLOSE UP OF OVER SPRAY IN FIGURE 6-44.

6.7.2 Uniform Film Thickness and Cross-Section

Guidance literature recommends using between 100 to 121 square feet per gallon of both the water-borne and solvent paints. That coverage rate computes to a 12 to 16 mil wet film. A wet film thickness gauge can be used to measure the wet coating ***without glass beads***. Each paint gun must be calibrated to apply the proper coverage rate, and is a **best**

The recommended film thickness should be uniformly applied across the entire marking.

practice. This process will help to achieve uniform film thickness across the entire marking, which is also a **best practice.** In many cases, markings can be applied using the right coverage rates in terms of square feet per gallon, but the markings, from six inches to thirty feet wide, may not exhibit a uniform film thickness. The following factors contribute to this issue.

6.7.2.1 Material Fluid Tips Are Worn

Material flowing through a tip or fluid nozzle is abrasive. The orifice begins to wear after many gallons of material pass through, and it should be monitored closely for signs of wear. Also, when cleaning out the material lines and guns, remove the tips first, because the water flow will contribute to faster wear. Though new tips are expensive, replacing them regularly improves the quality of the markings. Worn airless tips can exhibit an unevenness of the line, (either heavy material in the middle and lighter material on the edges, or lighter in the middle and heavier on one or more edges). Worn pneumatic tips result in "fuzzier" edges with heavier material in the middle or edges of the line. When the wet film thickness is not uniform across the entire width of the line, the marking wears unevenly. The thinner areas will wear off faster, and if glass beads are used, proper embedment will only occur on the areas of the line with proper film thickness.

6.7.2.2 Material Guns have Line Width Limitations

In many instances, striping machines are set up to apply the widest marking possible out of a single gun, and the result is that the line does not produce a uniform film thickness. Local highway marking contractors are often hired to maintain airfield markings**.** Their equipment is designed to apply four- to six-inch road lines, not the wider airfield markings. Observed in figures 6-46 and 6-47, this equipment is equipped with two airless paint guns on the left carriage.
In figure 6-46, two paint guns are raised to paint a 19-inch line. Only in the middle of each sprayed line is the paint of sufficient film thickness. The use of more material guns, will improve the likelihood of uniform film thickness across the entire marking; this is a **best practice.** A larger tip size in an airless system also will increase the amount of material flow, as does increasing the pump pressure. Naturally, the speed of the machine can affect the film thickness too.

The glass bead guns in figure 6-47 are raised and spray upward and backward from the paint spray to achieve a wider spray of beads. Wind easily displaces the light glass beads; occasionally they miss the marking entirely. Glass beads cannot embed in an insufficient film thickness; thus the thinner markings will be compromised for nighttime visibility soon after application.

FIGURE 6-46. UNEVEN MATERIAL DISTRIBUTION, LIGHT ON THE EDGES OF EACH PAINT GUN.

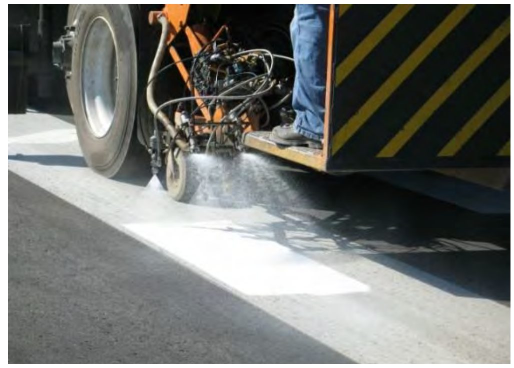


FIGURE 6-47. GLASS BEAD DISPENSERS ADJUSTED TOO HIGH.

FIGURE 6-48. IRREGULAR FILM THICKNESS ACROSS THE LINE PERFORMS POORLY.

Figure 6-48 shows two raised paint guns (far left); the graphic demonstrates what a cross section of figure 6-46 would look like (far right).

In an air-atomized system, different-sized fluid nozzles will yield a greater or lesser volume of material, as will adjusting the needle setting, increasing the material tank pressure, adjusting the proportion of atomization air to the paint, or just slowing down the machine.

6.7.2.3 Equipment Moves Too Fast

The normal tendency is to drive or walk too fast, resulting in a wet film thickness too thin to support the glass beads being dropped onto it, and the marking wears prematurely. One of the more common reasons for repeated maintenance is excessive speed during application, which causes inadequate film thickness and poor bead distribution and embedment. High speed also causes glass beads to hit and roll, coating them with wet paint, thus reducing retro-reflectivity by preventing light from entering the glass sphere and returning to the source.

> One of the more common reasons for repeated maintenance is excessive speed during application, which causes inadequate film thickness and poor bead distribution and embedment.

6.7.3 Width of Line in Single Pass

As stated previously, the U.S. Air Force ETL 97-18 prescribes the striping equipment shall be capable of applying a marking from four to thirty-six inches in width in a single pass. This is a **best practice** and should be adopted in all specifications for the following reasons:

- On a precision-marked runway, more than half of the markings are three-feet wide, and can be painted in a single pass.
- The markings appear to be more uniform with fewer "retracing" deviations.
- A wider spray pattern equates to less time on the airfield, reducing the amount of "down time" for operations.
- There is better use of time and resources for airport personnel who apply their own markings.
- Caution should be exercised if fewer than four material guns are being used for a 36-inch wide marking. Monitor for the material being applied at the specified film thickness and uniformity. Speed also will affect the film thickness of the material.

6.7.4 Glass Beads

The specified and proper application of glass beads by all applicators will serve the pilot or others operating on the airfield surface during darkness or low visibility conditions. In the daytime, markings appear uniform and convey information to the pilot or airfield operator. At night, only properly applied glass beads will give the surface operators the same information.

> Markings should appear as visible during darkness as they do during daylight hours.
>
> *"Markings that cannot be seen by pilots and others operating on marked surfaces are useless."*
>
> FAA AC 150/5340-1, "Visibility of Markings"

Figure 6-49 demonstrates markings that are barely visible at night but visible during daylight (figure 6-50). When the application of the markings is done poorly, their life expectancy is short, and visibility to the pilot is greatly reduced at night.

Hand-thrown beads are a *poor practice.* Seen in figure 6-49 and 6-50, the "R" was hand-sprayed, the paint gun moved too quickly, and proper wet film thickness was not achieved. The beads were hand-thrown unevenly and were not embedded well in the thin coating. The paint forms a dry "no track" film quickly, preventing hand-thrown glass beads from anchoring or embedding properly. Frequent remarking becomes necessary due to reduced performance, resulting in paint build up, traffic interruptions, extra labor, and increased material usage, as well as poor nighttime visibility, and compromised safety.

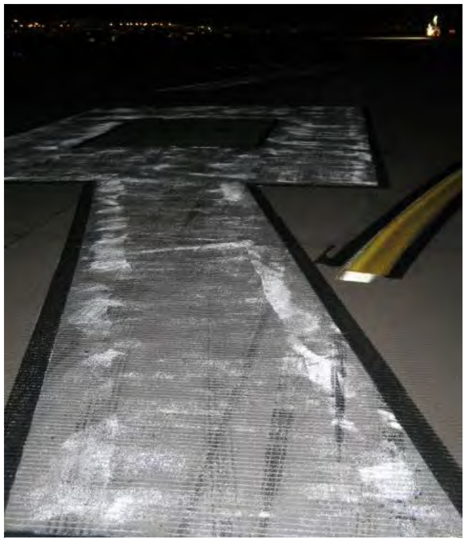


FIGURE 6-49. VISIBILITY OF THE "R" IS POOR AT NIGHT.

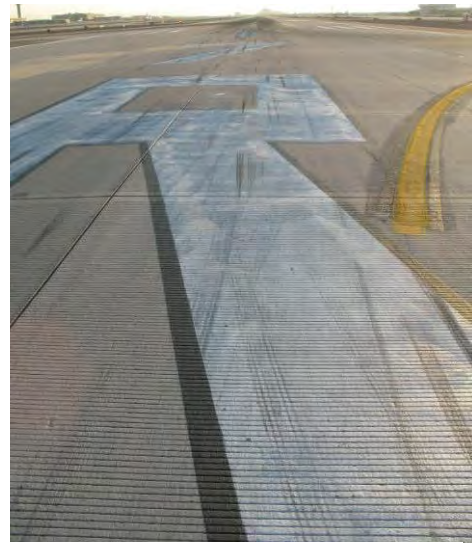


FIGURE 6-50. THE "R" IS VISIBLE IN THE EARLY MORNING LIGHT.

The "4" seen in figures 6-51 and 6-52, is visible both during daylight and darkness. The numeral was applied with a truck, spraying a 3-foot pass with automatic, pressurized bead dispensers: all **best practices**.

FIGURE 6-51. DAYTIME VISIBILITY IS EXCELLENT.

FIGURE 6-52. NIGHTTIME VISIBILITY OF FIGURE 6-51.

6.7.5 Straightness Tolerance

Painting markings straight or in compliance with specification standards generally can be attributed to the existing markings or layout being straight. However, it can also be a function of the skill of the driver/operator as well as the effectiveness of a pointer system, which can be seen in figures 6-53, 6-54, 6-55 and 6-56. Effective pointer systems are a **best practice**.

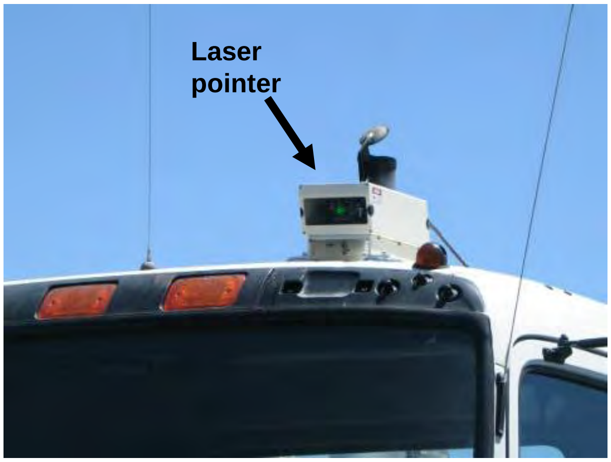


FIGURE 6-53. LASER POINTER.

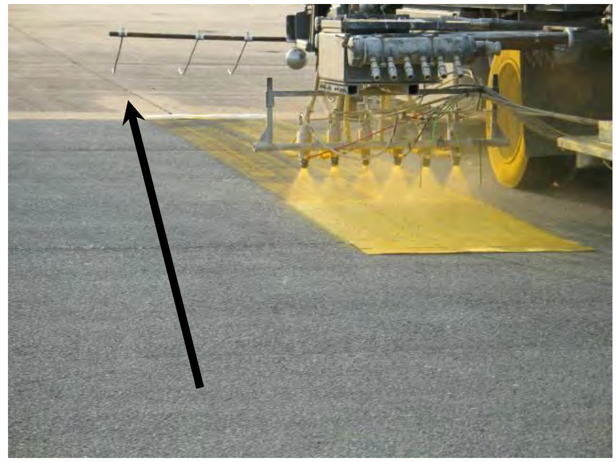


FIGURE 6-54. MECHANICAL POINTER.

Pointer systems help the driver or equipment operator keep the marking within the specified straightness tolerance (no deviation greater than ***½-inch in 50 feet***). Laser pointers can follow an adjacent line to create one that is parallel, and mechanical pointers can be suspended either from a truck or track on a wheel extended in front of a truck. Mechanical pointers are mounted on a part of the equipment within view of the driver. In all cases, pointers are essential equipment that assist in good alignment and are a **best practice.** Other types of guidance systems include closed-circuit projection of the carriage in the cab of the truck for the driver to follow. Figure 6-55 demonstrates the use of a mirror in front of the material guns to guide the driver.

FIGURE 6-55. POINTER WITH MIRROR.

FIGURE 6-56. PORTABLE LASER POINTER.

The portable laser pointer shown in figure 6-56 was observed being used on a motorized airless machine; it was then moved to the side-view mirror frame on the paint truck. It is battery powered and projects a green laser beam onto the pavement to help the operator track the line.

6.8 EQUIPMENT COMPATIBILITY

Specific equipment is needed to properly apply different materials. Airless equipment is used for water-borne paint, solvent paint, and epoxy. Also, for epoxy, calibrated pumps mix the two components during the airless application process.

Water-borne paint (U.S. Federal Specification TT-P-1952) is the predominant material used on all U.S. airports, both domestic and military. The paint requires the use of stainless steel tanks, plumbing, and Teflon®-coated material lines. This paint reacts with regular steel, brass, and galvanized metals. Allowing paint to remain in the tanks or lines may cause it to thicken or harden; this is especially true in hot temperatures and when lines or tanks are partially filled. Good housekeeping prevents problems on the job.

6.9 HOUSEKEEPING

Housekeeping is a necessary chore with any operation. Developing a discipline of good habits, from keeping the work area clean to cleaning out equipment, leads to better production and is a **best practice.**

6.9.1 Clean Up of Excess Materials or Spills

Clean up of excess materials or spills is a good practice for any industry. When working in an *airfield* environment, it is especially important to remain focused on such details. At least one airport incident involved the ingestion of glass beads into jet engines, precipitating a lengthy debate and great expense to determine if the engines were damaged. The incident raised the awareness of the need for clean up after an airfield marking project. Additionally, preventing spills of paint or other materials prevents an unsightly mess.

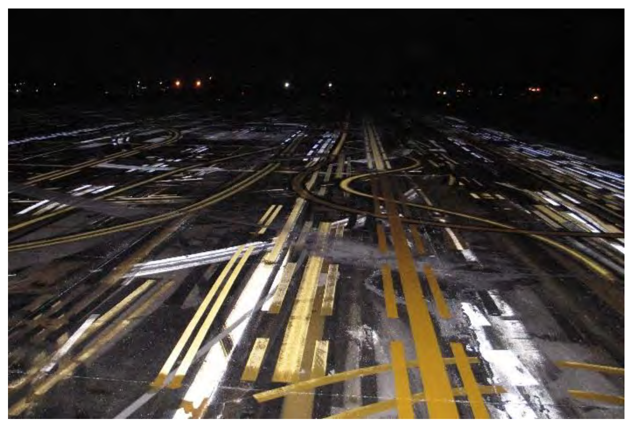


FIGURE 6-57. TEST AREA FOR EQUIPMENT SET UP.

Some airport personnel who apply their own airfield markings have a designated test striping area for setting guns and marking patterns, checking glass bead distribution, and overall quality of the markings. Resembling a modern work of art (seen in figure 6-57), the test pavement area is a great asset for the installers and is a **best practice**.

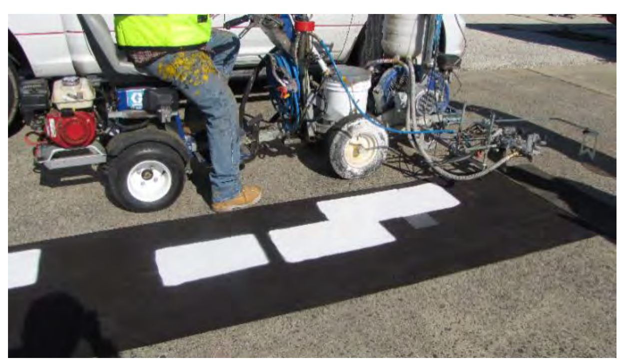


FIGURE 6-58 TEST LINES ON TAR PAPER.

Contractors seldom have the luxury of applying test lines to the pavement, and often they have issues as to where to set up the material guns. One contractor was observed using tar paper to run test lines and adjust both paint and bead guns (seen in figure 6-58). This method prevented unwanted markings and drips from getting on the pavement. This is a **best practice**.

6.9.2 Check for FOD, Dropped Tools, Materials, Etc.

Attention should be paid to any object that does not belong on airfield pavements, whether it came from the marking operation or not. Hand tools, in particular, should be routinely returned to a specific place (on the truck or in the toolbox) to make certain they are not left on the pavement.

Sometimes boards, roofing shingles, light covers, or other materials are used at the ends of markings or to cover lights to prevent unwanted material from getting on surfaces. Metal strips, rebar, or other materials used to protect concrete joints during cleaning or removal operations must be collected to prevent FOD. Checking and double-checking to make certain all of these materials and supplies are picked up at the end of the work shift is extremely important.

6.9.3 Environmental Issues

Attention to the details of compliance with environmental regulations is recommended. It is incumbent upon all to comply with the standards established by federal and local governments, including airports. Although water-borne paint is "environmentally friendly," in liquid form it can pose a health issue due to its methanol and ammonia content. Careful handling of all materials is important.

6.9.3.1 Hazardous Materials

Hazardous materials, such as solvent, epoxy, and methyl methacrylate paints require special handling and care. In the material storage area and when loading or cleaning out equipment, precautions must be taken to contain and mitigate spills or unintended contact with skin or eyes.

Additionally, cleanup of those materials requires the use of toluene, MEK, naphtha, or other solvents; all of these are hazardous and require personal protective equipment to avoid contact with skin and eyes. These toxic materials become hazardous waste, and they must be contained and disposed of properly.

One of the benefits of using water-borne paint is that it is non-hazardous, although there is a "Health" factor of 1 on the label because it includes methanol and ammonia solvents. Once dry, those solvents have evaporated, and the coating is environmentally safe. Clean up of equipment is accomplished with water. Containment of the wastewater is generally required, even though it is considered non-hazardous.

6.9.3.2 Hazardous Waste

Hazardous waste generated from an airfield-marking project adds to the cost of the job. However, if a durable marking like epoxy is specified, the additional cost of dealing with both the hazardous material and waste will be included in the planned expenses for the project.

Another form of hazardous waste may originate from debris resulting from a paint-removal operation. Most coatings on airfields are lead-free water-borne paint. However, occasionally airfield markings may still contain lead-based paint. All paint removal debris should be tested through a *TCLP* analysis. This "Toxicity Characteristic Leaching Procedure (TCLP) is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. If a 'solid waste' fails the test for one or more of these compounds, the waste is considered to be a characteristic hazardous waste – unless an exemption applies. Bear in mind that a characteristic waste may also be a 'listed' hazardous waste."[9]

During the process of removing the markings, some of the pavement surface, dirt, and other debris can mix with the old paint, thus diluting the debris, and reducing the likelihood of it being characterized as hazardous. Although generally not considered hazardous, the majority of water runoff from waterblasting operations for rubber removal, surface preparation, or paint removal should be collected and contained along with other debris. The waste hauler will require a profile of the debris to be removed; profile information will be listed on the manifest. This profile is created from the TCLP analysis.

6.9.3.3 Non-Hazardous Waste

Non-hazardous waste falls below the toxicity thresholds for the 40 listed contaminants. Most waste disposal companies require a TCLP analysis to identify the waste before they will move any container. Even if it tests as non-hazardous, some landfills may require special treatment because it is "paint" or because it came from an airport environment.

6.9.3.4 Material and Waste Containers

Material containers, whether material totes, drums, or paper bags should be contained and properly disposed of. Totes are often available from paint manufacturers and can be recycled. Additionally, dumpsters, roll-off containers, drums, pails, etc., are often required to be covered at all times, and secondary containment systems may need to be put in place.

6.10 QUALITY CONTROL BY APPLICATOR

Quality control in the application of airfield markings is an important aspect of a marking project. Writing good specifications specific to the airport project is beneficial to the airport. All airports are unique; they have different environments, pavements, requirements, and related issues. Verifying that the specified material is being used, applying it at the correct coverage rates, and checking the alignment and position of the markings are elements of good quality control. If these steps are practiced and specifications are enforced, the probability of achieving a quality marking application is greatly increased.

6.10.1 Quantify Completed Work

Quantify completed work on a daily basis. The total amount of footage applied should be recorded, including which markings were applied, the amount of material used, and any associated issues.

[9] http://www.ehso.com/cssepa/TCLP.htm

Such documentation will serve the airport well in the event of any incident where the markings are scrutinized.

6.10.2 Calculate Material Usage

To calculate material usage, first count all material at the beginning of the work shift. Determine the remaining amount of material at the end of the work shift. The difference will be what was used. Materials in the tanks at the beginning and end of the work shift also should be calculated into the quantities.

Record the completed work after a material tank is completely emptied, and/or at the end of the day. With the known amount of square footage installed, divide by the amount of material used, and compare it to the specified coverage rate. Then divide the amount of glass beads used by the volume of paint or other coating used, and compare this to the specified coverage rate for that type of glass beads. (1) square footage ÷ gallons = paint coverage rate, (2) pounds ÷ gallons = bead coverage rate. If the coverage rates are off, adjustments should be made to pressures, material guns, and/or the speed of the equipment. This monitoring of material usage and coverage rates should be continuous throughout the project, and it is a **best practice**.

6.10.3 Documentation

Documentation is an important detail that many airports do not maintain. Keeping daily records of what was done, who did it, with what equipment, and how much material was used is an indication of being diligent about this important element of airfield safety, and it is a **best practice**.

6.10.4 Quality Control Tool Kit

There are tools and devices that help in maintaining quality control and enforcing standards.

6.10.4.1 Calibration Bucket

Calibration is a means of ensuring the correct material flow based on the speed of the machine applying the markings. Both paint and glass bead guns can be measured for the volume of material that flows through each gun at a 10-second interval, and this is a **best practice.**

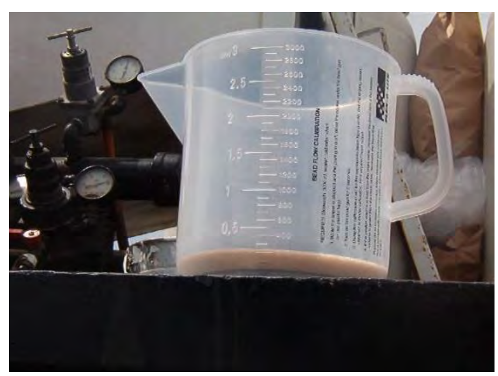


FIGURE 6-59. CALIBRATION BUCKET FOR GLASS BEADS.

The amount collected in the container seen in figure 6-59 is compared to an integrated chart. If the amount collected is too little, the gun should be adjusted to allow more material to flow; if the amount collected is too great, the gun should be adjusted to reduce material flow. Each gun should be tested in this manner. It is assumed that each gun in positioned to apply the same width line as the others.

Figure 6-60 shows the calibration bucket being used to check material flow from each bead gun.
Close attention must be paid to the speed of the vehicle throughout the course of the work because even a slight increase in speed will affect material coverage rates.

Clogs of paper, clumped beads, or other debris may restrict material flow during marking activities. Close monitoring of the markings during application is essential, and is a **best practice.**

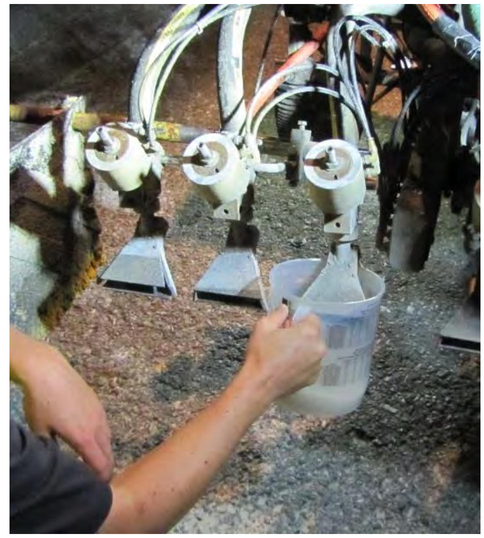


FIGURE 6-60. CALIBRATION OF GLASS BEAD GUNS.

6.10.4.2 Wet Film Gauge

A wet film gauge (figure 6-61), although not exact, is a tool used to check the wet film thickness of the paint. This should be done on a relatively smooth surface, such as a metal plate or duct tape applied to the pavement when the test lines are being applied. It should be measured **without** glass beads. Instructions are found on the gauge. To determine the wet film thickness being applied, the gauge is pressed into the coating at a 90° angle, figure 6-62. If the desired film thickness is 15 mils, the side reading "14, 16, 18, through 30" is used. If the desired film thickness is 60 mils, the side reading 35, 40, 45 through 80" is used. For 15 mils, the coating should cover the "14" tab, but not the "16" tab. If multiple guns are being used, each paint gun should be checked, and if one gun is applying a line greater than 8-inches, the entire line width should be checked for uniformity.

FIGURE 6-61. WET FILM GAUGE.

FIGURE 6-62. USE OF WET FILM GAUGE.

6.10.4.3 Magnifying Glass

A magnifying glass is used to check for correct glass bead embedment. If the material film is too thin, the glass beads may not embed properly, and they will dislodge from traffic or other mechanical wear. If the material film is too thick, the glass beads may over-embed, and the reflectivity values will drop because the light cannot enter the bead and return effectively.

In figure 6-63, a magnifying glass is used to check glass bead distribution and embedment. In this case, there is poor glass bead distribution and embedment.

A magnifying glass detects other problems, such as excessive "wicking" of the paint over the bead (figures 6-64 and 6-65). Paint gathers up around the bead, giving it a "tree trunk" effect; this reduces reflectivity by covering the glass sphere and preventing light from entering it. This problem can be caused by the absence of a suitable bead coating or the paint formulation.

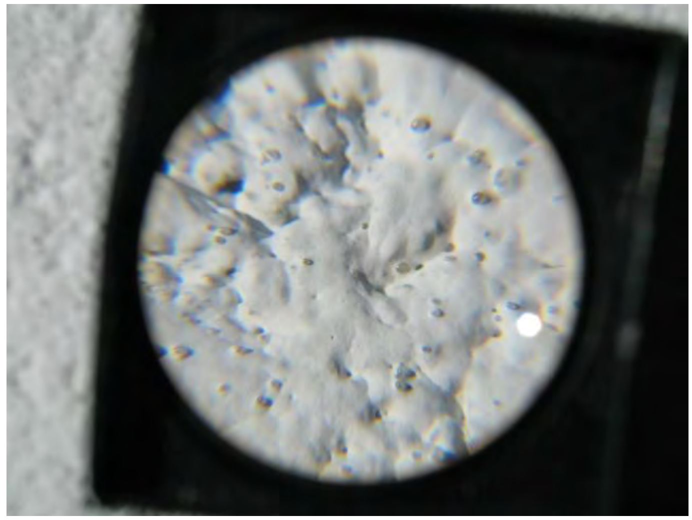


FIGURE 6-63. MAGNIFYING GLASS.

FIGURE 6-64. EXCESSIVE WICKING OF PAINT OVER BEADS.

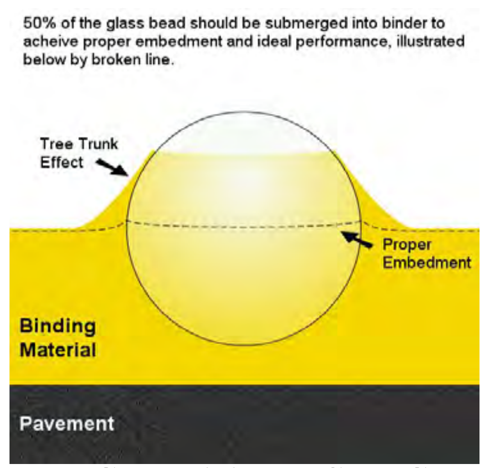


FIGURE 6-65. WICKING MATERIAL OVER BEAD.

A magnifying glass can help in diagnosing other issues, such as poor performance of marking materials.

6.10.4.4 Flashlight

A flashlight is always useful to keep in the toolbox, because many marking projects are done and inspected at night.

6.10.4.5 Metal Coupons and Duct Tape

Metal coupons are useful in gauging film thickness of material. Place a metal coupon (as in figure 6-66) in the path of the material guns. Immediately after the material is applied, insert the mil gauge vertically in the wet coating. Different materials have different coverage rates; therefore, they have greater or lesser wet film thickness requirements.

FIGURE 6-66. WET FILM GAUGE ON A METAL COUPON.

FIGURE 6-67. PULL TEST.

Duct tape can be used to check surfaces that have been prepared or had paint removed may need additional sweeping or vacuuming before being remarked. Spread a strip of tape across a cleaned area, press into the pavement (see figure 6-67 – top), then pull the tape up and inspect the underside for signs of grit or other debris, as seen in figure 6-67 (bottom).

6.10.4.6 Retro-reflectivity Measurement

Airfield marking retro-reflectivity is measured with a calibrated instrument known as a retro-reflectometer, as seen in figure 6-68. Originally retro-reflectometers were developed for highway use and measure marking retro-reflectivity using a 30-meter viewing geometry. This geometry represents how the driver of a small passenger car would see a pavement marking located 30 meters (98.4 ft) in front of the vehicle. Although the geometry is not the same for aircraft, the device still serves as a relative measure that conveys the effectiveness of an airfield marking for nighttime visibility.

It is advisable to take readings at least 24 – 48 hours after installation of the markings. Beads that are partially adhered or not adhered can be detected. Waiting for one or two days to take readings gives water-borne paints enough time to cure so that loose beads can be brushed off the marking prior to taking readings without damaging the film. A new, cured marking lightly swept typically yields higher readings.

FIGURE 6-68. RETROMETER.

6.10.4.7 Color Measurement

A colorimeter is a device that measures chromaticity. "The International Commission of Illumination (CIE) has developed the methodology for describing and tabulating colors in a numerical system that is based upon a standard observer. The standard observer is defined by small groups of individuals (about 15–20) that have normal human color vision."[10]

FIGURE 6-69. COLORIMETER

The coordinates recorded by the colorimeter in figure 6-69 correspond to a chart designed by the CIE and adopted by the FAA. Recorded readings are plotted on the chart to determine compatibility with the color standards. Color ranges at installation for those normally used on airfields (e.g., white, yellow, red, and green) vary almost imperceptibly.

Colors for airports are different than those required for highways. At installation, the markings must fall within the tolerances adopted by the FAA. Another method for comparing colors without expensive equipment and plotting of readings to a chart is the use of color chips. Seen in figure 6-70, three color chips are compared to a red marking; the marking is compared visually for compliance. There are three shades of red; the lightest is on the top of the panel, the exact match is in the middle, and the darkest is on the bottom.

FIGURE 6-70. RED COLOR CHIP COMPARED TO RED MARKING.

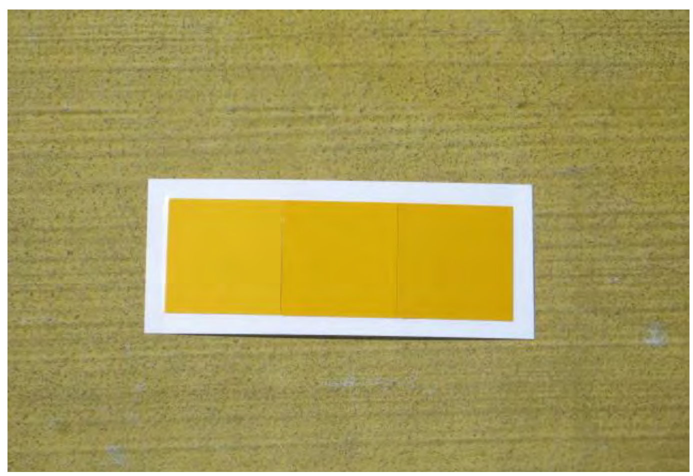


FIGURE 6-71. YELLOW COLOR CHIP COMPARED TO YELLOW MARKING.

Figure 6-71 displays a yellow marking that, when compared to the color chip, is out of tolerance. The three color chips are more apparent in the yellow coupon; the lightest is on the left, the exact match is in the middle, and the darkest is on the right of the coupon.

[10] *Development of Methods for Determining Airport Marking Effectiveness,* Holly M. Cyrus, DOT/FAA/AR-TN03/22, March 2003.

6.10.4.8 Grid for Determining Compliance with Degree of Paint Removal

A grid with 100 equal squares can be used to measure the degree of paint removal that has been accomplished. If 85 percent paint removal has been specified, only 15 squares or less should contain any of the old coating. In the remaining squares the old coating should have been removed.

The grid shown in figure 6-72 is an example of one that can be used for this purpose.

FIGURE 6-72. GRID FOR COMPLIANCE WITH DEGREE OF PAINT REMOVAL.

7 INSPECTION

Observing test lines at the outset of a marking project, and knowing material quantities, does not ensure that the markings were applied correctly. Inspection plays an essential role in the successful application of airfield markings by contractors. Inspection is necessary to ensure that (1) the proper markings are applied, (2) the markings are applied at the correct location, (3) the proper materials are used at the correct coverage rates, and (4) the quality of the marking application meets the appropriate criteria.

TABLE 7-1. CHAPTER CONTENTS MAY BENEFIT:

Applicators	
Airport Operators	
Designers/Engineers	
Inspectors	★

Chapter 7 describes visual inspection guidelines for monitoring airfield markings. These guidelines identify activities that inspectors should perform as contractors or airport marking personnel apply markings. Table 7-1 indicates the personnel who will gain the greatest benefit from the material in this chapter. Where used, the term "best practice" is highlighted in bold. Table 7-2 summarizes the best practices presented in this chapter.

TABLE 7-2. BEST PRACTICES FOR INSPECTION

Section Reference	Best Practice
7.1	Inspect prepared surface prior to repainting.
7.2.2	Inspect areas receiving paint removal to detect pre-existing conditions before removal begins.
7.3.1 and 7.3.2	Verify dimension and location of markings prior to repainting.
7.3.3	Check each material gun for uniform application of the coating.
7.3.4	Calibrate glass bead guns.
7.3.5	Inspect bead embedment with magnifying glass.
7.3.6	Continuously monitor material usage.
7.3.7	Compare paint colors with color chips.

7.1 SURFACE PREPARATION INSPECTION

The surface must be clean and free of loose materials, including old flaking paint, dirt, rocks, oils, etc. It is a **best practice** to inspect prepared surfaces prior to a marking application. A visual inspection coupled with a pull test (duct tape or other adhesive material will detect loose materials) or other contaminants that may prevent the new coating from bonding to the surface.

If removing curing compound from a new concrete surface, all visible curing material should be removed prior to applying the permanent coat of paint.

If paint has been removed and new markings are being applied over the scarred pavement, carefully inspect the area, because residue from the removal operation tends to settle in the scar. A burst of air and/or a pull test with duct tape in several areas should indicate if the surface is clean enough.

7.2 PAINT REMOVAL INSPECTION

Inspectors should consider two factors when inspecting paint removal: the degree of removal and the pavement scarring associated with the removal.

7.2.1 Degree of Paint Removal

The degree of paint removal specified can be verified by the grid method. The grid used to measure a 6-inch marking is shown in figure 7-1; 12-inch and larger is shown in figure 7-2. The grid contains 100 equal squares.

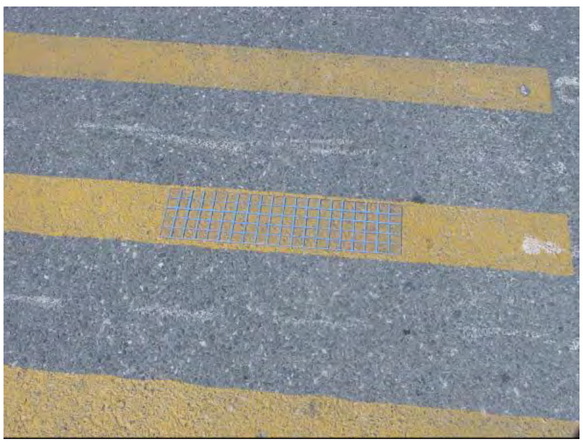


FIGURE 7-1. 6-INCH GRID.

FIGURE 7-2. 12-INCH GRID.

Once the removal has been completed, place the appropriate sized grid on a random area on the scar. Count the number of squares containing any remnants of the old marking. If the percentage of removal is 85 percent, only 15 squares should contain old paint; for 90 percent, 10 squares should contain old paint; for 100 percent, no squares should contain old paint.

7.2.2 Pavement Scarring and Pavement Damage

Evaluation of the markings to be removed will indicate if there is pre-existing pavement damage. This is a **best practice**. If there is no pre-existing pavement damage, there will be some level of scarring of the underlying pavement. Scarring is removal of some of the pavement texture while exposing some aggregate. Pavement damage is removal of the pavement texture where more than 25 percent of the vertical depth of the nominal size aggregate is exposed, and some aggregate could loosen.

7.3 MARKING APPLICATION INSPECTION

Correct marking application involves several criteria, all of which contribute to an effective marking.

7.3.1 Location

The location of the markings should be compared with plans and/or the governing jurisdiction's marking standard (e.g., FAA 150/5340-1, U.S. Air Force ETL 97-18). Check the marking location to verify compliance prior to painting, a **best practice**. Permitted tolerances or waivers due to special circumstances may allow deviation from the standard.

7.3.2 Dimension

Markings must be of the specified length and width within the dimension tolerances contained in the prevailing guide specifications. Check the marking dimension to verify compliance prior to painting, a **best practice**.

7.3.3 Uniform Film Thickness

When the material guns are being set up, metal coupons placed in the path of the equipment captures a test line *without glass beads.* To use a wet film gauge, press the gauge into the wet coating at a 90-degree angle (vertically). Withdraw the gauge straight up and note the longest tab having paint on it and the next longest tab that is not coated with paint. The true wet film thickness lies between these two readings. The entire width of the marking should be of even thickness, without excessive build up in the center or at the edges of the line. Each paint gun should be checked in this fashion; it is a **best practice**.

7.3.4 Glass Bead Distribution and Population

Glass beads should cover the entire marking (population) and be evenly distributed, as shown in figure 7-3. Calibrating each glass bead gun to ensure the correct and even flow of beads is a **best practice** and should be conducted by the applicator and observed by the inspector prior to painting. An insufficient bead population is shown in figure 7-4. A malfunctioning bead gun can cause the conditions illustrated in figure 7-5 and 7-6. All four figures represent a view from directly above the marking.

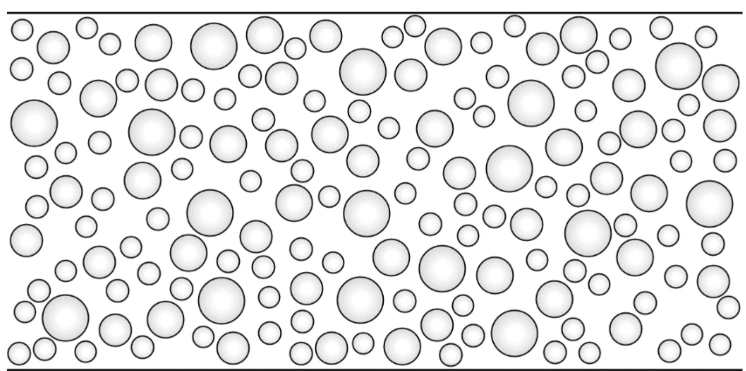


FIGURE 7-3. GOOD BEAD DISTRIBUTION AND GOOD BEAD POPULATION.

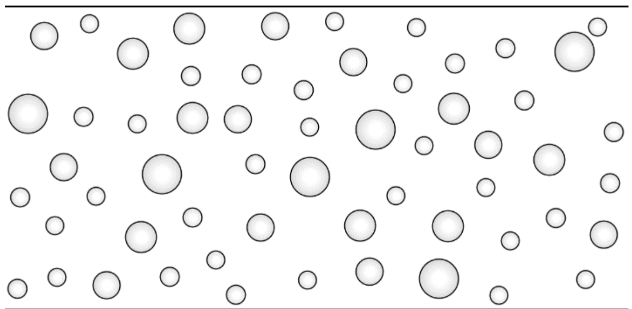


FIGURE 7-4. POOR BEAD POPULATION, BUT EVEN DISTRIBUTION.

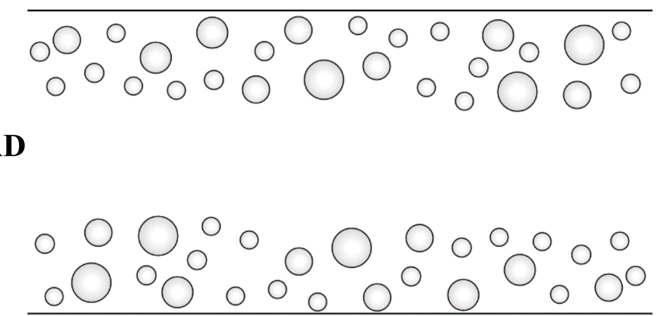


FIGURE 7-5. POOR BEAD DISTRIBUTION

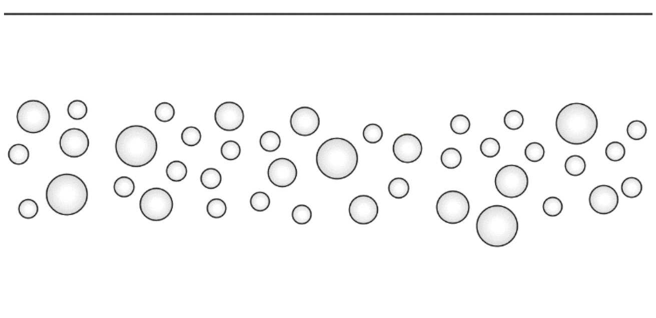


FIGURE 7-6. POOR BEAD DISTRIBUTION

7.3.5 Glass Bead Embedment

Beads should be embedded into the marking material at 50–60 percent of their diameters. A marking that fails the visual inspection for glass bead embedment exhibits one of the following conditions:

- Most or all of the beads are buried in the marking material.
- Beads are insufficiently embedded and are predominantly on the surface of the coating.

- Beads have missed the marking material due to wind displacement or other issues.

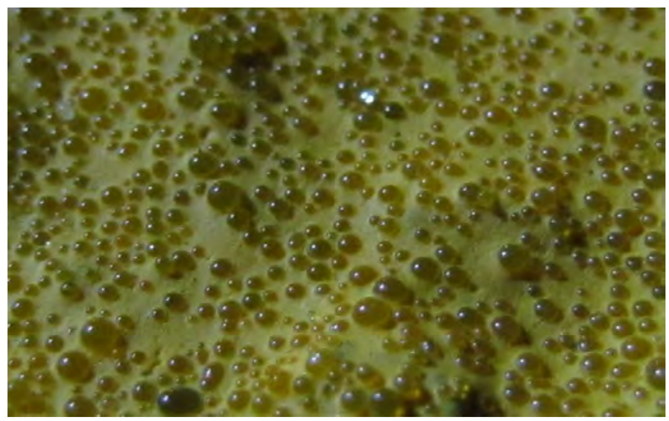
- The material film thickness is too thin in figure 7-7. This results in under-embedment or when less than 50–60 percent of the bead diameter is exposed.

FIGURE 7-7. POOR BEAD EMBEDMENT: BEADS ARE UNDER-EMBEDDED.

- The material film thickness is too thick in figure 7-8. This results in over-embedment of the beads, or when more than 50–60 percent of their diameter is submerged in the binder.

FIGURE 7-8. POOR BEAD EMBEDMENT: BEADS ARE OVER-EMBEDDED.

- Figure 7-9 depicts optimal bead embedment, or when 50 – 60 percent of their diameter is submerged in the binder.



A magnifying glass should be used to inspect both distribution and embedment of the glass beads once they have been applied to the marking, a **best practice**. The inspection requires the viewer to kneel on the ground and hold the magnifying glass at a 45-degree angle to the marking with the sun or other light source in front of the viewer. The glass beads seen in figure 7-10 indicate even distribution, but fair population and embedment.

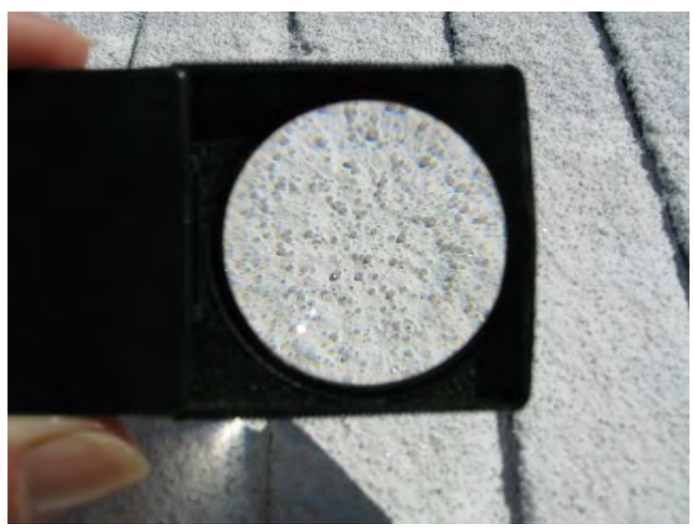


FIGURE 7-10. USE OF MAGNIFYING GLASS.

7.3.6 Material Coverage Rates

Inspectors and applicators should continuously monitor material usage, a **best practice**. To determine material usage, calculate the amount of material at the beginning of each day's application. Identify the material used each time the machine is refilled with paint and glass beads and compare the quantities used with the amount of work completed with that material. If materials are light, the applicators should adjust paint guns, bead guns, tank pressures, etc. At the end of the day, calculate the remaining material. The difference between the beginning and ending amounts should equal the usage recorded during the course of the day. Take into account materials remaining in the equipment at the beginning and end of each day as well. Under no circumstances should material arrive to the project already loaded in the equipment tanks.

7.3.7 Color

Using a color chip, a **best practice**, can serve to visually check color. At installation, the color must be within one ΔE, a measurement of color variance, of the Federal Standard 595B color. The color chips shown in figure 7-11 represent the six color standards predominantly used at airports. Ultra violet light will degrade organic pigments used in water-borne paints, causing the colors to fade. But *at installation*, the colors should match the color chips.

FIGURE 7-11. FEDERAL STANDARD 595B COLORS FOR AIRFIELD MARKINGS

BIBLIOGRAPHY

The documents used in the preparation of the manual are listed below. The information from these documents was incorporated with the project team's field observations and other experiences as well as feedback received from several reviewers of the manual.

Source	Title	Date
Federal Aviation Administration	Standards for Airport Markings, AC 150-5340-1	April 29, 2005 Updated, September 2013
Federal Aviation Administration	Standards for Specifying Construction of Airports – AC 150-5370-10, Item P-620	July 2014
Federal Aviation Administration	Operational Safety on Airports During Construction – AC 150-5370-2E	January 17, 2003
Federal Aviation Administration	DOT/FAA/AR-TN03/22 – *Development of Methods for Determining Airport Marking Effectiveness* – Holly M. Cyrus	March 2003
Department of the Air Force	Standard Airfield Marking Schemes – Engineering Technical Letter (ETL) 04-2	July 19, 2004
Department of the Air Force	Guide Specification – Paint and Rubber Removal from Roadway and Airfield Pavements – ETL 97-17	December 1, 1997
Department of the Air Force	Guide Specification for Airfield and Roadway Marking – ETL 97-18	December 5, 1997
Department of the Air Force	Standards for Marking Airfields - Air Force Instruction (AFI) 32-1042	October 27, 2005
Department of the Army	Marking of Army Airfield-Heliport Operational and Maintenance Facilities – TM 5-823-4	July 1987
U.S. Army Corps of Engineers	Unified Facilities Guide Specifications – Section 32 17 23.00 10 – Pavement Markings	August 2016
U.S. Army Corps of Engineers	Unified Facilities Guide Specifications – Section 32 01 11.51 – Rubber and Paint Removal from Airfield Pavements	August 2016
Transportation Research Board	NCHRP Project 20-5 – Long-Term Pavement Marking Practices. *Driver Needs, Retro-reflectivity Requirements, and Information Through word and Symbol Markings.* James Migletz and Jerry Graham	2002
Transportation Research Board	Record No. 1692, Traffic signing, Visibility, and Rail-Highway Grade Crossings. *Driver Preview Distances at Night Based on Driver Eye Scanning Recordings as a Function of Pavement Marking Retro-reflectivities.* Thomas Schnell, Helmut T. Zwahlen	January 30, 2007

Texas Department of Transportation	Texas Transportation Institute, *Pavement Marking Handbook*, H. Gene Hawkins, Jr., Timothy J Gates, Elizabeth R. Rose	August 2004
State DOTs (e.g. Virginia, Missouri, Maryland, Texas)	Pavement Marking Manuals	Various
Safety Coatings, Inc., The Sherwin Williams Company, Aexcel, Inc., Flex-O-Lite, an affiliate of PQ Corp., Rohm and Haas Company, S. G. Pinney and Associates	Technical product information, and company websites.	Various

Appendix A - Item P-620 Runway and Taxiway Markings

DESCRIPTION

620-1.1 This item shall consist of the preparation and painting of numbers, markings, and stripes on the surface of runways, taxiways, and aprons, in accordance with these specifications and at the locations shown on the plans, or as directed by the Resident Project Representative (RPR). The terms "paint" and "marking material" as well as "painting" and "application of markings" are interchangeable throughout this specification.

MATERIALS

620-2.1 Materials acceptance. The Contractor shall furnish manufacturer's certified test reports for materials shipped to the project. The certified test reports shall include a statement that the materials meet the specification requirements. This certification along with a copy of the paint manufacturer's surface preparation; marking materials, including adhesion, flow promoting and/or floatation additive; and application requirements must be submitted and approved by the Resident Project Representative (RPR) prior to the initial application of markings. The reports can be used for material acceptance or the RPR may perform verification testing. The reports shall not be interpreted as a basis for payment. The Contractor shall notify the RPR upon arrival of a shipment of materials to the site. All material shall arrive in sealed containers that are easily quantifiable for inspection by the RPR.

620-2.2 Marking materials.

TABLE 1. MARKING MATERIALS

Paint[1]				Glass Beads[2]	
Type	Color	Fed Std. 595 Number	Application Rate Maximum	Type	Application Rate Minimum
*	*	*	*	*	*
*	*	*	*	*	*

[1] See paragraph 620-2.2a

[2] See paragraph 620-2.2b

****

Make the appropriate selections for paint type, color, Fed Std 595 number, application rates, and glass bead type and application rates and inserted into Table 1. Asterisks denote insert points.

****

a. Paint. Paint shall be **[** `waterborne` **] [** `epoxy` **] [** `methacrylate` **] [** `solvent-base` **] [** `and` **] [** `preformed thermoplastic` **]** in accordance with the requirements of this paragraph. Paint colors shall comply with Federal Standard No. 595. **[___]**

****

The Engineer must specify paint type (s), colors and glass beads to be used for the project and populate that information above in Table 1. When more than one paint type is specified, the plans should clearly indicate paint type, paint color and bead type required for each marking.

Select type of paint.

Types: Waterborne, Epoxy, Methacrylate, solvent-base, or preformed Thermoplastic

For waterborne or solvent based paints, specify Type I, II, or III:

- **Type I intended for locations where slower tracking is not a problem.**
- **Type II intended for locations where faster curing is desirable.**
- **Type III intended for locations that require a thicker, more durable coating***

**** Type III can also be applied at the same rates as Type I or II.***

1. **Select paint color(s) from the following Table:**

Paint Color	Fed Std. No 595 Color Number
White	37925
Red	31136
Yellow	33538 or 33655
Black	37038
Pink	1 part 31136 to 2 parts 37925
Green	34108

Waterborne or solvent base black paint should be used to outline a border at least 6 inches (150 mm) wide around markings on all light-colored pavements. Preformed thermoplastic markings shall have a non-reflectorized black border integral to the marking.

Select appropriate application rates for type of paint and bead selected:

APPLICATION RATES FOR PAINT AND GLASS BEADS FOR TABLE 1

Paint		Glass Beads		
Type	**Application Rate Maximum**	**Type I, Gradation A[1] Minimum**	**Type III Minimum**	**Type IV[1] Minimum**
Waterborne Type I or II or III	115 ft^2/gal (2.8 m^2/l)	7 lb/gal (0.85 kg/l)	10 lb/gal (1.2 kg/l)	--
Waterborne Type III	90 ft^2/gal (2.2 m^2/l)	7 lb/gal (0.85 kg/l)	8 lb/gal (1.0 kg/l)	
Waterborne Type III	55 ft^2/gal (1.4 m^2/l)		6 lb/gal (.8 kg/l)	5 lb/gal (.7 kg/l)
Solvent Base	115 ft^2/gal (2.8 m^2/l)	7 lb/gal (0.85 kg/l)	10 lb/gal (1. 2 kg/l)	--
Solvent Base	55 ft^2/gal (2.2 m^2/l)	--	--	5 lb/gal (.7 kg/l)
Epoxy	90 ft^2/gal (2.2 m^2/l)	15 lb/gal (1.8 kg/l)	20 lb/gal (2.4 kg/l)	16 lb/gal (1.9 kg/l)
Methacrylate	45 ft^2/gal (1.1 m^2/l)	15 lb/gal (1.8 kg/l)	20 lb/gal (2.4 kg/l)	16 lb/gal (1.9 kg/l)
Methacrylate Splatter-Profile	24ft^2/gal. (0.6 m^2/l)	8 lb/gal. (0.1 kg/l)	10 lb/gal. (1.2 kg/l)	10 lb/gal (1.2 kg/l)
Temporary Marking Waterborne Type I or II or III	230 ft^2/gal (5.6 m^2/l)	No beads	No beads	No beads

[1]Glass bead application rate for Red and Pink paint shall be reduced by 2 lb/gal (0.24 kg/l) for Type I and Type IV beads.

The Engineer shall specify the time period in paragraph 620-3.5 in order to allow adequate curing of the pavement surface. The Engineer should contact the paint manufacturer to determine the wait period. A 24- to 30-day waiting period is recommended for all types of paint used for pavement marking. The final application should occur after the waiting period has passed. The final marking application must be at a rate equal to 100% of the full application rate with glass beads.

Markings may be required before paving operations are complete. The Engineer may wish to specify waterborne or solvent-based materials for temporary markings at 30% to 50% of the specified application rates. Glass beads will not adhere well at the low application rates for temporary markings.

CAUTION: Prior to reopening pavements at Part 139 airports verify that all markings comply with Part 139 requirements. Temporary markings not in compliance with AC 150/5340-1 will require a NOTAM regarding any non-standard marking be issued. For example, temporary markings without beads.

When painting Porous Friction Course, the paint should be applied to the pavement in two coats from opposite directions. The first coat should be applied at a rate equal to 50% of the full application rate with no glass beads. The second coat

should be applied from the opposite direction at a rate equal to 100% of the full application rate with glass beads.

Preformed thermoplastic pavement markings shall yield at least 225 mcd/m²/lux on white markings at installation and at least 100 mcd/m²/lux on yellow markings at installation.

Retroreflectivity shall be measured by a portable retroreflectometer according to ASTM E1710 and the practices in ASTM D7585 shall be followed for taking retroreflectivity readings with a portable retroreflectometer and computing measurement averages. A vehicle-mounted retroreflectometer may also be used.

****

[**Waterborne.** Paint shall meet the requirements of Federal Specification TT-P-1952F, [Type I] [Type II] [Type III]. The non-volatile portion of the vehicle for all paint types shall be composed of a 100% acrylic polymer as determined by infrared spectral analysis. [The acrylic resin used for Type III shall be 100% cross linking acrylic as evidenced by infrared peaks at wavelengths 1568, 1624, and 1672 cm-l with intensities equal to those produced by an acrylic resin known to be 100% cross linking.] **If using Type III paint, samples should be drawn from the paint guns and tested to ensure compliance with the standard.**

[**Epoxy.** Paint shall be a two component, minimum 99% solids type system conforming to the following:

(1) Pigments. Component A. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 18% minimum (16.5% minimum at 100% purity).

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 14 to 17%.
- Epoxy resin shall be 75 to 79%.
- Organic yellow, other colors, and tinting as required to meet color standard.

(2) Epoxy content. Component A. The weight per epoxy equivalent, when tested in accordance with ASTM D1652 shall be the manufacturer's target ±50.

(3) Amine number. Component B. When tested in accordance with ASTM D2074 shall be the manufacturer's target ±50.

(4) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR

1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(5) Daylight directional reflectance.

(a) White: The daylight directional reflectance of the white paint shall not be less than 75% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 55% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(6) Accelerated weathering.

(a) Sample preparation. Apply the paint at a wet film thickness of 0.013-inch (0.33 mm) to four 3 × 6-inch (8 × 15 cm) aluminum panels prepared as described in ASTM E2302. Air dry the sample 48 hours under standard conditions.

(b) Testing conditions. Test in accordance with ASTM G154 using both Ultra Violet (UV-B) Light and condensate exposure, 72 hours total, alternating four (4) hour UV exposure at 140°F (60°C), and four (4) hours condensate exposure at 104°F (40°C).

(c) Evaluation. Remove the samples and condition for 24 hours under standard conditions. Determine the directional reflectance and color match using the procedures in paragraph 5 above. Evaluate for conformance with the color requirements.

(7) Volatile organic content. Determine the volatile organic content in accordance with 40 CFR Part 60 Appendix A, Method 24.

(8) Dry opacity. Use ASTM E2302. The wet film thickness shall be 0.015 inch (0.38 mm). The minimum opacity for white and colors shall be 0.92.

(9) Abrasion resistance. Subject the panels prepared in paragraph 620-2.2b(6) to the abrasion test in accordance with ASTM D968, Method A, except that the inside diameter of the metal guide tube shall be from 0.747 to 0.750 inch (18.97 to 19.05 mm). Five liters (17.5 lb (7.94 kg)) of unused sand shall be used for each test panel. The test shall be run on two test panels Both baked and weathered paint films shall require not less than 150 liters (525 lbs (239 kg)) of sand for the removal of the paint films.

(10) Hardness, shore. Hardness shall be at least 80 when tested in accordance with ASTM D2240.]

[**Methacrylate.** Paint shall be a two component, minimum 99% solids-type system conforming to the following:

(1) Pigments. Component A. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 10% minimum.
- Methacrylate resin shall be 18% minimum.

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 1% minimum.
  Organic yellow, other colors, and tinting as required to meet color standard.
- Methacrylate resin shall be 18% minimum.

(2) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(3) Daylight directional reflectance:

(a) White: The daylight directional reflectance of the white paint shall not be less than 80% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 55% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(4) Accelerated weathering.

(a) Sample preparation. Apply the paint at a wet film thickness of 0.013-inch (0.33 mm) to four 3 × 6-inch (8 × 15 cm) aluminum panels prepared as described in ASTM E2302. Air dry the sample 48 hours under standard conditions.

(b) Testing conditions. Test in accordance with ASTM G154 using both Ultra Violet (UV-B) Light and condensate exposure, 72 hours total, alternating four (4) hour UV exposure at 140°F (60°C), and four (4) hours condensate exposure at 104°F (40°C).

(c) Evaluation. Remove the samples and condition for 24 hours under standard conditions. Determine the directional reflectance and color match using the procedures in paragraph 3 above. Evaluate for conformance with the color requirements.

(5) Volatile organic content. Determine the volatile organic content in accordance with 40 CFR Part 60 Appendix A, Method 24.

(6) Dry opacity. Use ASTM E2302. The wet film thickness shall be 0.015 inch (0.38 mm). The minimum opacity for white and colors shall be 0.92.

(7) Abrasion resistance. Subject the panels prepared in paragraph 620-2.2c(4) to the abrasion test in accordance with ASTM D968, Method A, except that the inside diameter of the metal guide tube shall be from 0.747 to 0.750 inch (18.97 to 19.05 mm). Five liters (17.5 lb (7.94 kg)) of unused sand shall be used for each test panel. The test shall be run on two test panels Both baked and weathered paint films shall require not less than 150 liters (525 lbs (239 kg) of sand for the removal of the paint films.

(8) Hardness, shore. Hardness shall be at least 60 when tested in accordance with ASTM D2240.

(9) Additional requirements for methacrylate splatter profiled pavement marking. Pavement markings of this type shall comply with all above requirements for methacrylate paint, except as noted below:

(a) The thickness of the marking will be irregular ranging from 0.000 to 0.250 inches (0.00 to 6.4 mm), applied in a splatter pattern which comprises a minimum of 80% of the visible line (when traveling at 5 mph the line appears to be solid.).

(b) The hardness shall be 48 Shore D minimum.]

[**Solvent-Base.** Paint shall meet the requirements of Commercial Item Description [A-A-2886B Type I, Type II, and Type III].]

[**Preformed Thermoplastic Airport Pavement Markings**. Markings must be composed of ester modified resins in conjunction with aggregates, pigments, and binders that have been factory produced as a finished product. The material must be impervious to degradation by aviation fuels, motor fuels, and lubricants.

(1) The markings must be able to be applied in temperatures as low as 35°F without any special storage, preheating, or treatment of the material before application.

(a) The markings must be supplied with an integral, non-reflectorized black border.

(2) Graded glass beads.

(a) The material must contain a minimum of 30% intermixed graded glass beads by weight. The intermixed beads shall conform to Federal Specification TT-B-1325D, Type I, gradation A and Federal Specification TT-B-1325D, Type IV.

(b) The material must have factory applied coated surface beads in addition to the intermixed beads at a rate of one (1) lb (0.45 kg) (±10%) per 10 square feet (1 sq m). These factory-applied coated surface beads shall have a minimum of 90% true spheres, minimum refractive index of 1.50, and meet the following gradation.

Preformed Thermoplastic Bead Gradation

Size Gradation		Retained, %	Passing, %
U.S. Mesh	µm		
12	1700	0 - 2	98 - 100
14	1400	0 - 3.5	96.5 - 100
16	1180	2 - 25	75 - 98
18	1000	28 - 63	37 - 72
20	850	63 - 72	28 - 37
30	600	67 - 77	23 - 33
50	300	89 - 95	5 - 11
80	200	97 - 100	0 - 3

(3) Heating indicators. The material manufacturer shall provide a method to indicate that the material has achieved satisfactory adhesion and proper bead embedment during application and that the installation procedures have been followed.

(4) Pigments. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 10% minimum.

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 1% minimum.
- Organic yellow, other colors, and tinting as required to meet color standard.

(5) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(6) Daylight directional reflectance.

(a) White: The daylight directional reflectance of the white paint shall not be less than 75% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 45% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(7) Skid resistance. The surface, with properly applied and embedded surface beads, must provide a minimum resistance value of 45 BPN when tested according to ASTM E303.

(8) Thickness. The material must be supplied at a nominal thickness of 65 mil (1.7 mm).

(9) Environmental resistance. The material must be resistant to deterioration due to exposure to sunlight, water, salt, or adverse weather conditions and impervious to aviation fuels, gasoline, and oil.

(10) Retroreflectivity. The material, when applied in accordance with manufacturer's guidelines, must demonstrate a uniform level of nighttime retroreflection when tested in accordance to ASTM E1710.

(11) Packaging. Packaging shall protect the material from environmental conditions until installation.

(12) Preformed thermoplastic airport pavement marking requirements.

(a) The markings must be a resilient thermoplastic product with uniformly distributed glass beads throughout the entire cross-sectional area. The markings must be resistant to the detrimental effects of aviation fuels, motor fuels and lubricants, hydraulic fluids, deicers, anti-icers, protective coatings, etc. Lines, legends, and symbols must be capable of being affixed to asphalt and/or Portland cement concrete pavements by the use of a large radiant heater. Colors shall be available as required.

(b) The markings must be capable of conforming to pavement contours, breaks, and faults through the action of airport traffic at normal pavement temperatures. The markings must be capable of fully conforming to grooved pavements, including pavement grooving per advisory circular (AC) 150/5320-12, current version. The markings shall have resealing characteristics, such that it is capable of fusing with itself and previously applied thermoplastics when heated with a heat source per manufacturer's recommendation.

(c) Multicolored markings must consist of interconnected individual pieces of preformed thermoplastic pavement marking material, which through a variety of colors and patterns, make up the desired design. The individual pieces in each large marking segment (typically more than 20 feet (6 m) long) must be factory assembled with a compatible material and interconnected so that in the field it is not necessary to assemble the individual pieces within a marking segment. Obtaining multicolored effect by overlaying materials of different colors is not acceptable due to resulting inconsistent marking thickness and inconsistent application temperature in the marking/substrate interface.

(d) The marking material must set up rapidly, permitting the access route to be re-opened to traffic after application.

(e) The marking material shall have an integral color throughout the thickness of the marking material. **]**

****

Thermoplastic airport markings will be subject to an Engineering life-cycle cost analysis prior to inclusion in specifications.

****

b. Reflective media. Glass beads for white and yellow paint shall meet the requirements for Federal Specification TT-B-1325D [Type I, Gradation A][Type III][Type IV, Gradation ~~A~~ **B**].
Glass beads for red and pink paint shall meet the requirements for [Type I, Gradation A][Type IV, Gradation ~~A~~ **B**].
Glass beads shall be treated with all compatible coupling agents recommended by the manufacturers of the paint and reflective media to ensure adhesion and embedment.
Glass beads shall not be used in black and green paint.
Type III glass beads shall not be used in red and pink paint.

****

The Engineer should insert all that will be used in the project. When more than one bead type is specified, the plans should indicate the bead type for each marking.

Federal Specification TT-B-1325D, Type I, gradation A shall be used when remarking on a frequent basis (at least every six months), and typically yield 300 mcd/m^2/lux on white markings at installation and 175 mcd/m^2/lux on yellow markings at installation.

Federal Specification TT-B-1325D, Type III. Initial readings typically yield 600 mcd/m^2/lux on white markings and 300 mcd/m^2/lux on yellow markings at installation and once in service, the reflectance values are approximately the same as Type I beads.

Federal Specification TT-B-1325D, Type IV, gradation A shall be used with TT-P-1952F, Type III paint. The glass beads are larger than either Type I or Type III, thus requiring more of the coating material to properly anchor. The Engineer should consult with the paint and bead manufacturer on the use of adhesion, flow promoting, and/or flotation additives.

Preformed thermoplastic pavement markings should yield at least 225 mcd/m^2/lux on white markings at installation and at least 100 mcd/m^2/lux on yellow markings at installation.

****

CONSTRUCTION METHODS

620-3.1 Weather limitations. Painting shall only be performed when the surface is dry, and the ambient temperature and the pavement surface temperature meet the manufacturer's recommendations in accordance with paragraph 620-2.1. Painting operations shall be discontinued when the ambient or surface temperatures does not meet the manufacturer's recommendations. Markings shall not be applied when the wind speed exceeds 10 mph unless windscreens are used to shroud the material guns. Markings shall not be applied when weather conditions are forecast to not be within the manufacturers' recommendations for application and ~~dry~~ cure time.

620-3.2 Equipment. Equipment shall include the apparatus necessary to properly clean the existing surface, a mechanical marking machine, a bead dispensing machine, and such auxiliary hand-painting equipment as may be necessary to satisfactorily complete the job.

The mechanical marker shall be an atomizing spray-type or airless type marking machine with automatic glass bead dispensers suitable for application of traffic paint. It shall produce an even and uniform film thickness and appearance of both paint and glass beads at the required coverage and shall apply markings of uniform cross-sections and clear-cut edges without running or spattering and without over spray. The marking equipment for both paint and beads shall be calibrated daily.

620-3.3 Preparation of surfaces. Immediately before application of the paint, the surface shall be dry and free from dirt, grease, oil, laitance, or other contaminates that would reduce the bond between the paint and the pavement. Use of any chemicals or impact abrasives during surface preparation shall be approved in advance by the RPR. After the cleaning operations, sweeping, blowing, or rinsing with pressurized water shall be performed to ensure the surface is clean and free of grit or other debris left from the cleaning process.

a. Preparation of new pavement surfaces. The area to be painted shall be cleaned by broom, blower, water blasting, or by other methods approved by the RPR to remove all contaminants, including PCC curing compounds, minimizing damage to the pavement surface.

b. Preparation of pavement to remove existing markings. Existing pavement markings shall be removed by rotary grinding, water blasting, or by other methods approved by the RPR minimizing damage to the pavement surface. The removal area may need to be larger than the area of the markings to eliminate ghost markings. After removal of markings on asphalt pavements, apply a fog seal or seal coat to 'block out' the removal area to eliminate 'ghost' markings.

c. Preparation of pavement markings prior to remarking. Prior to remarking existing markings, loose existing markings must be removed minimizing damage to the pavement surface, with a method approved by the RPR. After removal, the surface shall be cleaned of all residue or debris.

Prior to the application of markings, the Contractor shall certify in writing that the surface is dry and free from dirt, grease, oil, laitance, or other foreign material that would prevent the bond of the paint to the pavement or existing markings. This certification along with a copy of the paint manufactures application and surface preparation requirements must be submitted to the RPR prior to the initial application of markings.

****

Loose markings should always be removed prior to remarking, whether or not existing markings need to be removed is up to the Engineer and the Airport Operator. The type of removal method used depends upon whether you need to remove loose markings or all existing markings.

****

620-3.4 Layout of markings. The proposed markings shall be laid out in advance of the paint application. The locations of markings to receive glass beads shall be shown on the plans. **[** The locations of markings to receive silica sand shall be shown on the plans. **]**

****

Glass beads improve conspicuity and the friction characteristics of markings. At a minimum, the Engineer shall indicate the locations to receive glass beads per AC 150/5340-1, Standards for Airport Markings.

****

620-3.5 Application. A period of **[___]** days shall elapse between placement of surface course or seal coat and application of the permanent paint markings. Paint shall be applied at the locations and to the dimensions and spacing shown on the plans. Paint shall not be applied until the layout and condition of the surface has been approved by the RPR.

****

Select timeframe between placement of surface course or seal coat and application of the paint based on type of surface course or seal coat in the project and environment at the project location. The typical timeframe is 30-days for volatiles and moisture vapor to dissipate.

****

The edges of the markings shall not vary from a straight line more than 1/2 inch (12 mm) in 50 feet (15 m), and marking dimensions and spacing shall be within the following tolerances:

MARKING DIMENSIONS AND SPACING TOLERANCE

Dimension and Spacing	Tolerance
36 inch (910 mm) or less	±1/2 inch (12 mm)
greater than 36 inch to 6 feet (910 mm to 1.85 m)	±1 inch (25 mm)
greater than 6 feet to 60 feet (1.85 m to 18.3 m)	±2 inch (50 mm)
greater than 60 feet (18.3 m)	±3 inch (76 mm)

The paint shall be mixed in accordance with the manufacturer's instructions and applied to the pavement with a marking machine at the rate shown in Table 1. The addition of thinner will not be permitted.

Glass beads shall be distributed upon the marked areas at the locations shown on the plans to receive glass beads immediately after application of the paint. A dispenser shall be furnished that is properly designed for attachment to the marking machine and suitable for dispensing glass beads. Glass beads shall be applied at the rate shown in Table 1. Glass beads shall not be applied to black paint or green paint. Glass beads shall adhere to the cured paint or all marking operations shall cease until corrections are made. Different bead types shall not be mixed. Regular monitoring of glass bead embedment and distribution ~~should~~ shall be performed.

620-3.6 Application--preformed thermoplastic airport pavement markings.

[Preformed thermoplastic pavement markings not used.]

[To ensure minimum single-pass application time and optimum bond in the marking/substrate interface, the materials must be applied using a variable speed self-propelled mobile heater with an effective heating width of no less than 16 feet (5 m) and a free span between supporting wheels of no less than 18 feet (5.5 m). The heater must emit thermal radiation to the marking material in such a manner that the difference in temperature of 2 inches (50 mm) wide linear segments in the direction of heater travel must be within 5% of the overall average temperature of the heated thermoplastic material as it exits the heater. The material must be able to be applied at ambient and pavement temperatures down to 35°F (2°C) without any preheating of the pavement to a specific temperature. The material must be able to be applied without the use of a thermometer. The pavement shall be clean, dry, and free of debris. A non-volatile organic content (non-VOC) sealer with a maximum applied viscosity of 250 centiPoise must be applied to the pavement shortly before the markings are applied. The supplier must enclose application instructions with each box/package.]

****

The Engineer will make the appropriate selection for thermoplastic markings.

****

620-3.7 Control strip. Prior to the full application of airfield markings, the Contractor shall prepare a control strip in the presence of the RPR. The Contractor shall demonstrate the surface preparation method and all striping equipment to be used on the project. The marking equipment must achieve the prescribed application rate of paint and population of glass beads (per Table 1) that are properly embedded and evenly distributed across the full width of the marking. Prior to acceptance of the control strip, markings must be evaluated during darkness to ensure a uniform appearance.

620-3.8 Retro-reflectance. Reflectance shall be measured with a portable retro-reflectometer meeting ASTM E1710 (or equivalent). A total of 6 reading shall be taken over a 6 square foot area on each marking with 3 readings taken from each direction. The average shall be equal to or above the minimum levels of all readings which are within 30% of each other.

MINIMUM RETRO-REFLECTANCE VALUES

Material	Retro-reflectance mcd/m²/lux		
	White	**Yellow**	**Red**
Initial Type I	300	175	35
Initial Type III	600	300	35
Initial Thermoplastic	225	100	35
All materials, remark when less than[1]	100	75	10

[1] ‘Prior to remarking determine if removal of contaminants on markings will restore retro-reflectance

620-3.9 Protection and cleanup. After application of the markings, all markings shall be protected from damage until dry. All surfaces shall be protected from excess moisture and/or rain and from disfiguration by spatter, splashes, spillage, or drippings. The Contractor shall remove from the work area all debris, waste, loose reflective media, and by-products generated by the surface preparation and application operations to the satisfaction of the RPR. The Contractor shall dispose of these wastes in strict compliance with all applicable state, local, and federal environmental statutes and regulations.

METHOD OF MEASUREMENT

620-4.1a The quantity of surface preparation shall be measured by **[** the number of square feet (square meters) for each type of surface preparation specified in paragraph 620-3.3 **][** lump sum **]**.

620-4.1b The quantity of markings shall be paid for shall be measured **[** by the number of square feet (square meters) of painting **] [** by lump sum **].**

620-4.1c The quantity of reflective media shall be paid for by **[** the number of pounds (km) **][** lump sum **]** of reflective media.

620-4.1d [The quantity of temporary markings to be paid for shall be **[** the number of square feet (square meters) of painting **][** lump sum price **]** performed in accordance with the specifications and accepted by the RPR. Temporary marking includes surface preparation, application and complete removal of the temporary marking. **][** Temporary markings not required. **]**

[620-4.1e The quantity of preformed markings to be paid for shall be **[** the number of square feet (square meters) of preformed markings **] [** lump sum **]]**.

****

Separate pay items for surface preparation, marking, and reflective media is recommended, however on small jobs, lump sum pay items is acceptable.

****

BASIS OF PAYMENT

620-5.1 This price shall be full compensation for furnishing all materials and for all labor, equipment, tools, and incidentals necessary to complete the item complete in place and accepted by the RPR in accordance with these specifications.

620-5.1a Payment for surface preparation shall be made at the contract price for **[** the number of square feet (square meters) for each type of surface preparation specified in paragraph 620-3.3 **][** lump sum **]**.

620-5.2b Payment for markings shall be made at the contract price for **[** the number of square feet (square meters) of painting and the number of pounds (km) of reflective media **][** by the number of square feet (square meters) of painting **][** by lump sum **]**.

620-5.3c Payment for reflective media shall be made at the contract unit price for **[** the number of pounds (km) of reflective media **][** lump sum **]**.

620-5.4d Payment for temporary markings shall be made at the contract price for **[** the number of square feet (square meters) of painting **][** lump sum price **]**. This price shall be full compensation for furnishing all materials and for all labor, equipment, tools, and incidentals necessary to complete the item. **[** Temporary markings are not required. **]**

[**620-5.5e** Payment for preformed markings shall be made at the contract price for [the number of square feet (square meters) of preformed markings][lump sum price].]

Payment will be made under:

Item P-620-5.1a	Surface Preparation [per square foot (square meter)][lump sum]
Item P-620-5.2b	Marking [per square foot (square meter)][lump sum]
Item P-620-5.3c	Reflective Media [per pound (km)][lump sum]
Item P-620-5.4d	Temporary runway and taxiway marking [per square foot][per square meter][lump sum].
[Item 620-5.5e	Preformed markings per [the number of square feet (square meters) of preformed markings][lump sum price].]

REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM International (ASTM)

ASTM D476	Standard Classification for Dry Pigmentary Titanium Dioxide Products
ASTM D968	Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
ASTM D1652	Standard Test Method for Epoxy Content of Epoxy Resins
ASTM D2074	Standard Test Method for Total, Primary, Secondary, and Tertiary Amine Values of Fatty Amines by Alternative Indicator Method
ASTM D2240	Standard Test Method for Rubber Property - Durometer Hardness
ASTM D7585	Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments
ASTM E303	Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester
ASTM E1710	Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer
ASTM E2302	Standard Test Method for Measurement of the Luminance Coefficient Under Diffuse Illumination of Pavement Marking Materials Using a Portable Reflectometer
ASTM G154	Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

Code of Federal Regulations (CFR)

40 CFR Part 60, Appendix A-7, Method 24
Determination of volatile matter content, water content, density, volume solids, and weight solids of surface coatings

29 CFR Part 1910.1200 Hazard Communication

Federal Specifications (FED SPEC)

FED SPEC TT-B-1325D Beads (Glass Spheres) Retro-Reflective

FED SPEC TT-P-1952F Paint, Traffic and Airfield Marking, Waterborne

FED STD 595 Colors used in Government Procurement

Commercial Item Description

A-A-2886B Paint, Traffic, Solvent Based

Advisory Circulars (AC)

AC 150/5340-1 Standards for Airport Markings

AC 150/5320-12 Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces

END OF ITEM P-620

APPENDIX B: Description of Standard Specifications

STANDARD SPECIFICATIONS

Civil (FAA or ICAO) Construction specifications for airfield markings are governed by the Federal Aviation Administration through the use of Advisory Circulars, Signs and Marking Supplements (SAMs), and occasionally via the local jurisdiction's preferences due to experience and other considerations.
[http://www.faa.gov/airports_airtraffic/airports/airport_safety/signs_marking/supplement/]

FAA AC 150-5340-1L, published September 27, 2013 with Errata Sheet dated 5/20/2014.

This document describes the different marking elements on a commercial or general aviation airport. Detailing the dimensions, placement, colors, function, and other criteria for the markings, this circular serves as a guide for both design engineers and airfield marking applicators. Most of the markings are mandatory for use on FAA-Part 139 Certificated airports that receive AIP or PFC funding, as outlined in grant assurances. Some design changes are permitted under special conditions when approved by the local FAA Regional or Area District Office in the form of a written waiver.

FAA AC 150-5370-10H (Item P-620)

This guide specification provides instruction for the design engineer, the applicator, and inspection team as to the types of materials that can be used, coverage rates, straightness, and dimension tolerances, as well as equipment approved for use. Many of the **best practices** discussed in this Handbook were included in the revision dated December 21, 2018. Other *recommended modifications* are included as Appendix A.

MILITARY CONSTRUCTION SPECIFICATIONS

There are efforts to adopt a single standard for all military installations to provide a uniform, standard marking system, both in design and installation. However, at the present time, criteria vary from one branch of the service to the other; and identifying the correct specifications for the owner is essential.

U. S. Air Force is governed by several specifications:

~~**Engineering Technical Letter (ETL) 04-2** was implemented in February 2004 and is sponsored by the Air Force Civil Engineering Command. Similar to FAA AC 150-5340-1L, the ETL describes the different marking elements, their size, color, function, and position on the airfield, among other criteria. The document is to be used by designers when developing plans for airfield markings on USAF installations.~~

ETL 97-18–provides guidance to the designer in specifying the proper material requirements, testing, and submittal requirements, surface preparation methods, equipment to be used, and application methods for USAF installations.

ETL 97-17–provides guidance to the designer in specifying the proper method for removing either rubber or paint or both from airfield surfaces, including compliance criteria.

ETL 97-16–provides guidance to the designer in specifying application of airfield markings under low temperature conditions, specifically with the use of Methyl-Methacrylate. It was developed initially by the Air Force for application on expeditionary airfields in cold conditions.

Air Force Instructions (AFI) 32-1042 dated 27 October 2005 provide specific guidance on changes that need to be implemented without reconstructing the entire ETL. Comments and other information also are made in the form of Engineering Briefs published and distributed to U.S. Air Force engineers throughout the system.

UFC 3-260-01 prescribes dimensional and geometric layout criteria for safe standards for airfields, landing zones, heliports, helipads, related permanent facilities, as well as the navigational air space surrounding these facilities. Sponsored by the USAF and AFCEC, it serves all military facilities in establishing uniform standards for operation.

The U. S. Navy uses several specifications to describe its airfield marking standards:

UFGS 32 17 23.00 10–is a Unified Facilities Guide Specification sponsored by the U.S. Navy to combine common practices of Navy, Air Force, and Army in identifying marking elements, dimension, and location of the markings on military installations. Similar in purpose to FAA AC 150/5340-1L and USAF ETL 04-2, this document provides guidance when designing airfield marking projects for military installations.

UFGS 32 01 11.51–provides guidance to the design engineer in specifying the proper material requirements, testing and submittal requirements, surface preparation methods, and application methods for U.S. Navy installations. This document is similar to FAA AC 150/5370-10 and USAF ETL 97-18.

The Navair Manual, sponsored by the U.S. Navy, provides guidance to the designer of marking standards specific to the Navy, (e.g., *simulated carrier decks for fixed wing and rotary wing aircraft).*

The U.S. Army uses USACE TM 5-823-4, which describes the different marking elements, dimensions and locations of the markings that are installed on U.S. Army airfields.

Projects on **U.S. Marine installations** generally utilize the Unified Facilities Guide Specifications sponsored by the U.S. Navy and Army Corps of Engineers.

Differences between military and FAA documents do exist; and care should be taken to design specifications responsive to the owner or agency. Unless stated, discussions within the Handbook refer to FAA criteria.

APPENDIX C: Airfield Marking Elements

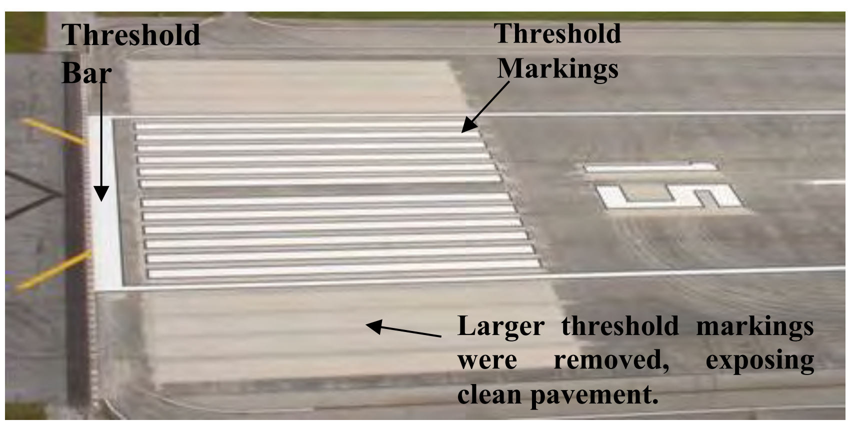
Runway Designation Numerals represent the "whole number nearest one-tenth of the magnetic azimuth when viewed from the direction of approach." (FAA AC 150/5340-1) In other words, the runway numbers represent degrees on a compass closest to the orientation of the line of travel.

In the picture shown of Runway 9R, the letter "R" has been added indicating a parallel runway, because both runways have the same compass coordinates. In order to distinguish parallel runways, a letter is added to indicate a "right" (R), "left" (L), or "center" (C), layout on the airfield.

Runway Centerline markings designate the center of the runway. The centerline bars are measured from both ends toward the center; any irregularity in measurement is absorbed in the center of the runway, where it will be less noticeable.

Runway Threshold markings designate the beginning and end of the runway. The number of threshold marking bars depends on the width of the runway; as the width of the runway decreases, the outer bars are eliminated; as the width increases, outer bars are added. In the picture below, an old threshold marking configuration was removed, and the new pattern was installed. Even though the pavement is 300-feet wide, the owner wanted to restrict the usable runway pavement to 150-feet wide.

Runway Threshold Bar: Seen in the picture below, "the threshold bar delineates the beginning of the runway that is available for landing when there is pavement aligned with the runway on the approach side of the threshold." (FAA AC 150/5340-1L) All measurements for the aiming point and touchdown zone markings begin at the base of the **threshold markings**, not the threshold bar or edge of pavement.

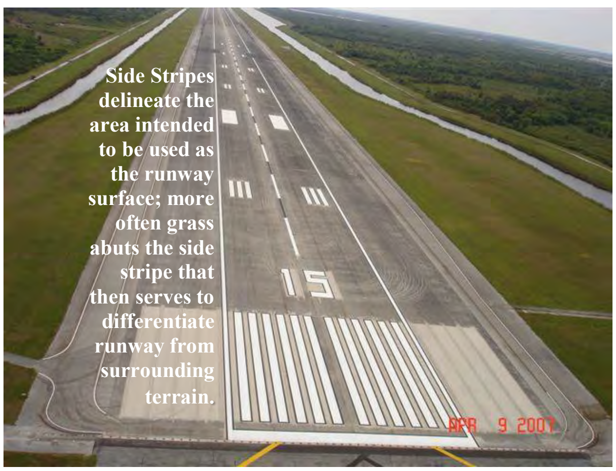


Picture courtesy of NASA

Runway Aiming Point markings serve as a visual aiming point for landing operations. These large rectangular blocks are very conspicuous to the pilot approaching a runway for landing. The width of these markings varies depending upon the width of the runway; the length is almost always 150 feet

Runway Touchdown Zone markings identify the touchdown zone for landing operations. Consisting of groups of one, two, and three rectangular bars symmetrically arranged about the runway centerline, they are used on precision-marked runways to provide distance information to the pilot, and they are spaced every 500 feet in the touchdown area.

Runway Side Stripe markings provide a visual contrast between the runway and the surrounding terrain and delineate the width of the paved area that is intended to be used as a runway. The stripes meet the threshold bar, if one exists, or they extend to the base of the threshold markings if not.



Picture courtesy of NASA

Pictures courtesy of NASA

Arrows and Arrowheads "are used to identify a displaced threshold area and are useful for centerline guidance for takeoffs and/or rollouts." (FAA AC 150/5340-1L) They are used in permanently displaced thresholds in advance of the threshold bar, further highlighting the beginning of a runway. When the arrows and arrowheads are white in conjunction with a white side stripe, they denote that the surface can be used for takeoffs or rollouts; but the landing area is restricted to beyond the threshold bar. However, when the arrows are yellow, the pavement prior to the threshold is not available for takeoff or rollout. There

are other uses of arrows and arrowheads that can be found in the FAA AC 150/5340-1L that convey other information to pilots and surface operators.

Chevrons identify pavement areas unusable for landing, takeoff, and taxiing. They are located on pavement areas that are aligned with and contiguous to the runway; they are yellow and may be reflective. Chevrons placed on a blast pad extend the full width of the pavement with a five-foot separation from the edge. Chevrons placed on a stop way are contained within the confines of the runway width as seen in the figure below, left.

What appear to be black chevrons were old ones, removed since they conflicted with the new layout. Ultraviolet light will soon fade the unexposed, black asphalt to gray.

Pictures courtesy of NASA

Demarcation Bar is a 3-foot wide, yellow bar that extends across the width of the blast pad, stop way, or taxiway. Located on the blast pad, stop way, or taxiway at the point of intersection with the runway, the marking delineates a runway with a displaced threshold that precedes the runway. It is three feet wide and extends the full width of the pavement.

Taxiways:

Next is a brief description and picture of some of the elements found on **taxiways** per the FAA.

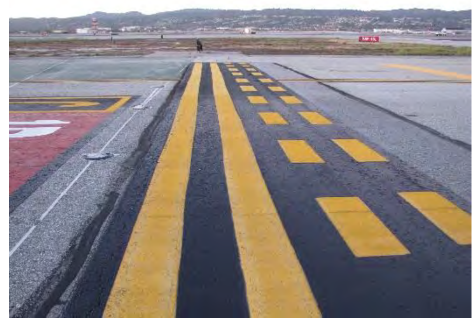
Holding Position Markings are a position on or at the movement area where the pilot or surface operator must to stop before getting clearance from Air Traffic Control (ATC) to proceed.

Pattern A:

Case 1: In terms of taxiing on a runway, an aircraft will need to hold short of an intersecting

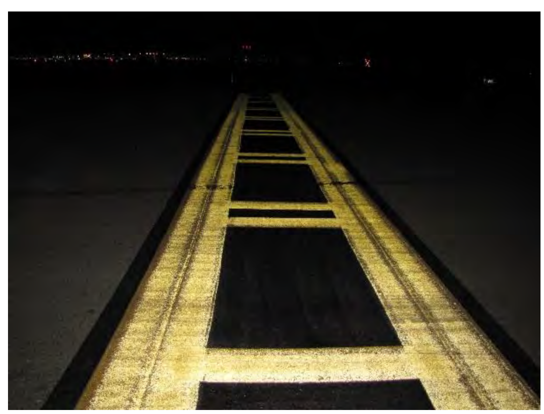
Case 2: Holding Position Markings on Runways are installed on a runway where an aircraft is to stop when the runway is normally used as a taxiway or used for Land and Hold Short Operations (LAHSO). They are the standard design and size of the holding position marking; however, they take precedence *over* any runway markings with which they intersect.

Case 3: Holding Position Markings on Taxiways indicate where an aircraft is to stop before gaining clearance from Air Traffic Control (ATC) to cross or enter the runway. Holding Position Markings have been widened, extended over or beyond the edge markings and black-bordered to improve the conspicuity of these markings to improve situational awareness and prevent runway incursions.



Pattern B:

Case 4: In terms of taxiing on a taxiway, an aircraft will need to hold short before entering the critical area of an Instrument Landing System (ILS)/Microwave Landing System (MLS).

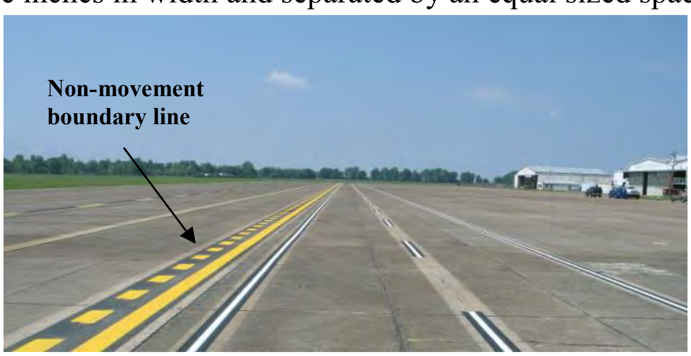


Case 5: In terms of taxiing on a taxiway, an aircraft or vehicle will need to hold short before entering the critical area of an Precision Obstacle Free Zone (POFZ) Although the surface marking pattern is the same as Case 4, the pattern in many applications may be L-shaped, instead of only linear shaped.

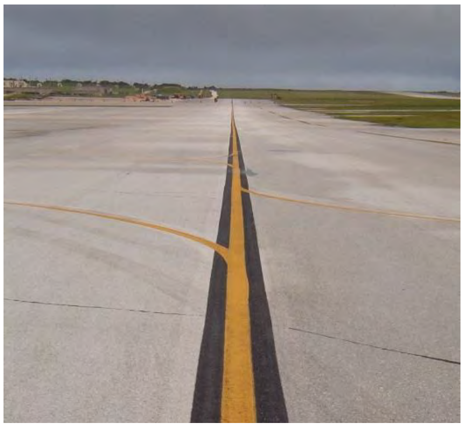
Pattern C:

Case 6: Intermediate Holding Position Marking is a "taxiway/taxiway" hold marking, designed to provide a place on a taxiway for a pilot (or driver) to wait for another aircraft taxiing on an intersecting taxiway. It can also be used as part of a Surface Movement Guidance Control System (SMGCS) route in conjunction with a Geographic Position Marking (GPM). They are twelve inches wide by three-foot long dashes and spaces and are to be outlined in black on light colored pavements. The taxiway centerline should be spaced six to twelve inches on both sides of the intermediate holding position marking.

Non-Movement Boundary Line is the point at which a surface operator or pilot has specific authorization to enter the *movement area* of the airfield. Free movement is permitted without specific authorization or clearance from the ATC within the gate area, inside the boundary line. The **movement area** of the airfield is any area regulated by ATC. The **non-movement area is** not regulated by the ATC. The marking consists of a solid and a three-foot dashed line either six or twelve inches in width and separated by an equal sized space.



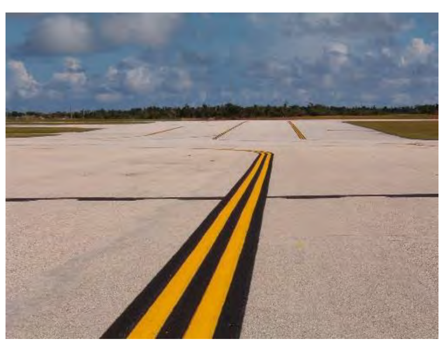
Taxiway centerlines are six- or twelve-inches wide and designate the center of the taxiway. Serving the pilot in maneuvering between the apron or gate area and the runway, the taxiway centerline is one of the most critical markings on an airfield. Outlined in black on light colored pavement, the maneuvering aid is quite conspicuous. The line is always yellow and is reflectorized for nighttime visibility. On airports with designated Surface Movement Guidance Control Systems (SMGCS) routes, the taxiway centerlines are twelve-inches wide, bordered in black, and take precedence over runway markings.

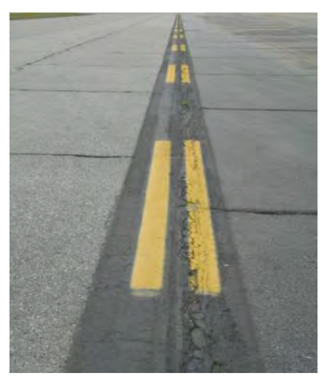


Twelve-inch taxiway centerline is painted over runway markings when it designates a SMGCS route.

Enhanced Taxiway Centerlines are designed to reduce runway incursions by alerting pilots (and vehicle drivers) of their approach to a runway. The pattern changes the taxiway centerline with an enhancement of six-inch by nine-foot dashes symmetrically placed about the centerline beginning at the holding position marking and extending for a 150-feet or within five feet of an intersecting taxiway centerline. Various geometries are described in AC 150/5340-1L that address most taxiway intersections. For unusual situations, contact your FAA inspector for a determination about design and installation. The yellow marking is required to be reflective and bordered with black on light colored pavement.

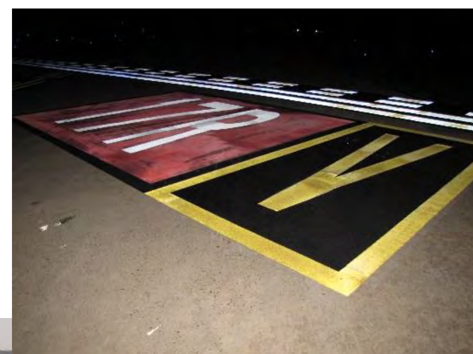
Taxiway side lines, if used, denote the edge of usable pavement on the taxiway. If solid, the line should not be crossed; if dashed, as along a parking apron, the line can be crossed. Dashed lines are permissive, solid lines are restrictive.





Surface Painted Signs are among other markings appearing on taxiways to augment vertical and lighted signs that are positioned along the taxiway edge. Surface painted signs aid the pilot and other drivers during low visibility conditions when the signs may be difficult to see, or when a taxiway exceeds certain widths; they provide guidance information to an operator.

Surface Painted Holding Position Signs are required to be installed at all holding position markings on at least the left side and in most instances on both sides of the taxiway centerline. The red background is required to be reflective, and the reflective white inscriptions should mimic the vertical lighted sign on the side of the taxiway. The inscriptions must be twelve feet tall unless the taxiway is too narrow. All stencil marks must be filled in to reduce confusion and improve conspicuity and situational awareness.



Location Signs identifies on what taxiway the pilot is taxiing. It has a black background with a yellow, reflective, twelve-foot inscription with a six-inch border around the edge of the sign, and should have an additional black border on light colored pavement. It is generally placed on the right side of the taxiway centerline, can be co-located with a Surface Painted Holding Position Sign or with a Direction Sign.

Direction Signs indicate the orientation of an upcoming taxiway. It has a reflective yellow background with a non-reflective, twelve-foot, black inscription and an arrow pointing in the direction of the described taxiway. The sign is placed on the side of the taxiway centerline that corresponds to the direction of the arrow.

The arrow within the *direction sign* with the yellow background and black lettering indicates the direction of Taxiway W8.

The placement of all of the surface painted signs and inscriptions are explained in detail in AC 150/5340-1L.

APPENDIX D: Criteria for Maintenance

Criteria for maintenance of airfield markings should be considered whenever the airfield marking project is for *maintenance or modification of existing markings.*

> ***"Development of Methods for Determining Airport Pavement Marking Effectiveness"*** is available at the Federal Aviation Administration William J. Hughes Technical Center's Full-Text Techincal Reports page: actlibrary.tc.faa.gov in Adobe Acrobat portable document format (PDF). This document has not been adopted by the Federal Aviation Administration.
>
> Quotes from this document are shown in *italics*.

Airport pavement markings on runways, taxiways, and ramps play an important role in safely navigating aircraft and vehicles around the airfield, as well as helping to prevent runway incursions. Airport paint markings, however, deteriorate in terms of their conspicuity and must be replaced over time. Presently, the functionality of the markings is determined by visual inspections of segments of these markings, but the validity of these inspections is often subjective.

A study was undertaken by the FAA to develop a method for a quick and accurate evaluation of paint markings. A manual method was required for eliminating subjectivity in the current method, and an automated method was developed for evaluation of larger surface markings over a vast airport area. In addition, the study also established a threshold pass/fail limit for white and yellow paint.

It was found that for the manual method, three devices are required:


Colorimeter

1. A retrometer is required for determining the retro-reflective value of the glass beads. *At a minimum**, the value should be at least 70 mcd/m²/lux for yellow and at least 100 mcd/m²/lux for white. [Note that bare concrete pavement has a value of approximately 30 mcd/m²/lux and that gray asphalt has a value of 15 mcd/m²/lux. In contrast, highly reflective markings, applied using TTB-1325D, Type III glass beads, have values as high as 1400 mcd/m²/lux on white at installation.]
2. A colorimeter is used to determine color values as a means of determining compliance with color requirements established by an international agency.
3. A transparent grid is used to determine coverage of the paint. The threshold pass/fail limit is 50 percent.

If any one of these three tests fails, the pavement marking fails.

* These readings are considered *minimums*; by comparison, non-reflective white paint yields a reading of 60 mcd/m²/lux, bare concrete yields 30 mcd/m²/lux, and black asphalt yields 6 mcd/m²/lux. At installation, even low-index glass beads generally yield 300+ mcd/m²/lux.

RETROMETER EVALUATION.

30-meter geometry retrometers are commonly used by the highway industry, because 30 meters is the standard distance from the headlights of a vehicle to the pavement; this is the standard used by highway departments. It is acknowledged that the airport users have substantially different geometries of light sources to pavements, but the highway technology is the current standard. (See figure 1).

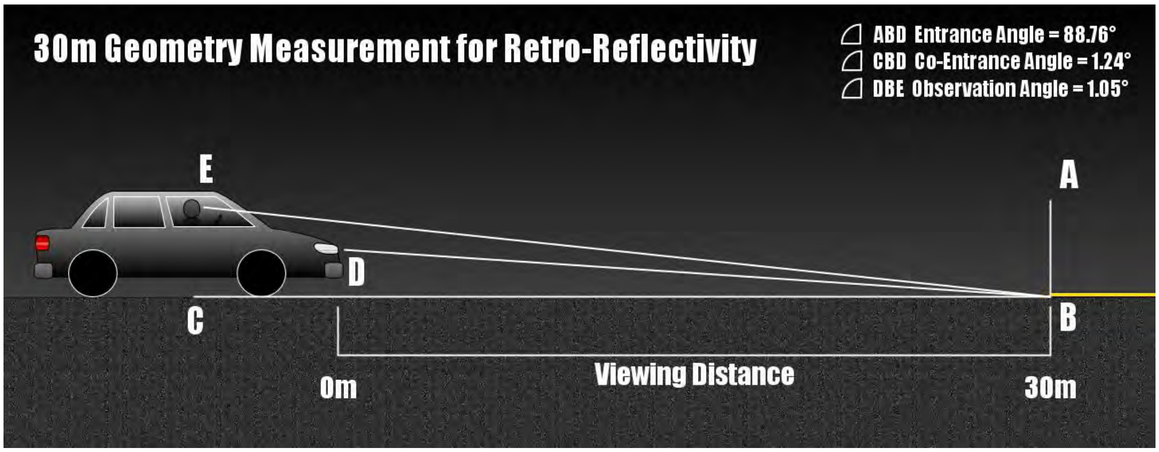
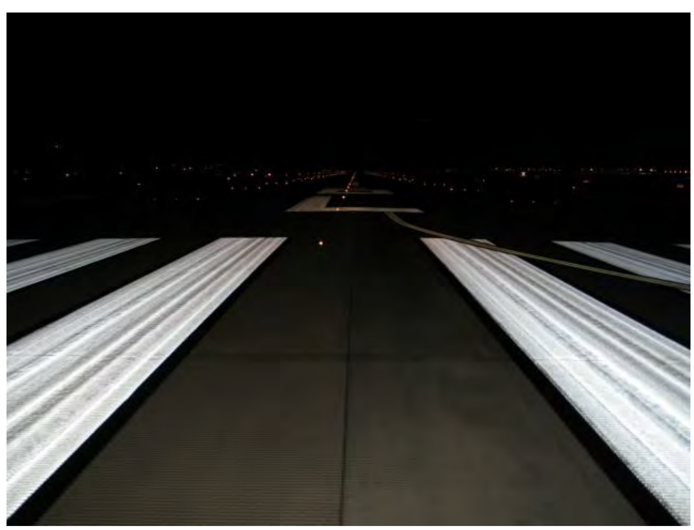


FIGURE 1 - Thirty-meter geometry measurement for retro-reflectivity spectrophotometer evaluation.

A retrometer is shown in the picture. By establishing more stringent reflectivity criteria for installers of reflective markings, nighttime visibility can be enhanced. [AC 150/5370-10, P620 now has reflectivity standards *at installation* for new markings.]

Although most airports might not invest in this equipment, many airport operators can detect substandard retro-reflectivity by observing airfield markings during a nighttime inspection. Uniform reflectivity of a marking is the goal, as seen in the picture below.



The pavement markings can be evaluated in three ways:

1. By checking the retro-reflectivity with a retrometer.
2. By checking the chromaticity (paint pigmentation) with a colorimeter or comparing to color chips.
3. By visually inspecting the uniformity of coverage of the entire marking using a transparent grid.

Coverage Check.

This inspection evaluates the integrity of the marking, such as paint cracking or peeling, and whether or not the marking has adequate coverage.

One-square-inch sections of transparent material inscribed within a grid of 100 equal squares will be used as a tool for quantitative measure of specified percentage of coverage. The grid concept came from the Air Force, where it was used for measuring rubber coverage on pavement. For a 6-inch line, it is suggested that a grid of 5 x 20 inches be used, and for a twelve-inch line, a grid of 10 x 10 inches. Count the squares that have no paint, e.g., 3 out of 100 squares equal 3% of the paint gone or 97% coverage, see figures 2 and 3.

FIGURE 2. A 5- x 20-inch grid for a six-inch line.

FIGURE 3. A 10 x 10-inch grid for a twelve-inch li

Use the following the steps to take the readings of the pavement markings.

1. Using either the 10- x 10-inch grid or the 5- x 20-inch grid, place the grid on the line to be evaluated.

2. Count the squares that have no paint.

3. The number of squares without paint will be the percentage of missing paint. For example, if 30 out of 100 squares do not have paint, then 30 percent of the paint is gone.

By using these three evaluations, one can determine whether or not the paint marking passes or fails. If the readings for any one of the three tests (the chromaticity, retro-reflectivity, or percentage of coverage) fail, **the pavement marking automatically fails.** The automated method for determining reflectivity values is faster, more advanced, and expensive; it requires little "downtime" on the airfield surfaces:

AUTOMATED METHOD—VAN-MOUNTED RETRO-REFLECTIVE CHECK.

The automated inspection system increases the speed and sample size. The automated inspection system has the following objectives:

- Evaluate the complete, or entire, painted marking configuration (i.e., inspection of the full length of runway centerline markings).
- Accomplish the evaluation within a limited timeframe (i.e., minimal runway downtime).
- Take contrast of runway with adjacent surfaces (i.e., concrete, asphalt, or black paint) into account.
- Discriminate between reflective beaded surfaces and non-reflective, non-beaded surfaces.

A van-mounted retro-reflectometer has an accuracy of ±15 percent, whereas the manual retro-reflectometer has an accuracy of ±5 percent.

REPAINT CRITERIA IDENTIFICATION.

In order to use the retro-reflective readings for evaluation, a pass/fail threshold limit needed to be established for yellow and white pavement markings. Several DOT organizations and the Federal Highway Administration (FHWA) were consulted. Through these communications, it was learned that the retro-reflective values of 70 mcd/m^2/lux for yellow paint and 100 mcd/m^2/lux for white paint are in the process of being accepted for the **failure limits** of yellow and white pavement markings in project TE-29 of the FHWA.

****
It should be noted that none of these criteria have been adopted by the FAA as of the writing of this document. However, it is the opinion of this research team that reflective values **at installation** of new markings may serve to provide a measured benchmark; when those values drop below a certain percentage, i.e., 50%,of their original value, maintenance should be initiated.

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APPENDIX E: Checklists

Checklist for Inspecting an Airfield Marking Project

- ❑ Provide an experienced inspection/quality control individual to monitor all aspects of the airfield marking project.

- ❑ Monitor surface preparation activities to ensure adequate cleaning of the surfaces to receive new markings.

- ❑ Calibrate equipment and/or have crew do test strips of the various activities.

- ❑ Ensure all marking removal personnel are experienced in the operation of the equipment being used.

- ❑ Ensure that all environmental considerations have been addressed, that containment of debris and other effluents is done. Check waste containment areas to ensure compliance with local, state, and federal laws.

- ❑ Check all layout for proper alignment, position, and dimension of markings.

- ❑ Check material upon delivery to the jobsite to ensure proper quantity and type.

- ❑ Closely monitor material usage to ensure compliance with coverage rates.

    - ☑ Count initial material inventory.
    - ☑ Compute quantity (square footage) of material applied.
    - ☑ Divide square footage by amount (gallons) of paint (or other binder) applied. For example, 11,500 square feet were applied; 100 gallons of paint were used; coverage rate was 115 square feet per gallon.
    - ☑ Divide amount of glass beads (pounds) applied by amount of paint (binder) applied. For example, assuming 700 pounds of Type I beads were used; 100 gallons of paint were used; coverage rate was 7 pounds of Type I glass beads per gallon.

- ❑ Periodically check wet film thickness of material being applied.

- ❑ Periodically check for correct glass bead population, distribution, and embedment.

- ❑ Calculate quantity of markings applied and compare to amount of materials used.

- ❑ Ensure that any paint removal or surface preparation process has left the surface clean and free from FOD. If markings are being reapplied in the same location, make certain all debris and grit are removed from the scarred pavement before applying new markings.

- ❑ During marking operations, make certain good alignment is maintained.

- ❑ Require documentation of each day's activities, noting:

  - ☑ Quantity of work completed satisfactorily.
  - ☑ Location of completed work.
  - ☑ Amount of materials used.
  - ☑ Personnel hours.
  - ☑ Equipment used.
  - ☑ Any other details that should be noted.
  - ☑ If there are any discrepancies or unsatisfactory work, those areas should be noted and scheduled for rework.
  - ☑ Weather conditions.

- ❑ Maintain a journal and document with digital photographs. The journal shall be submitted to Client at the end of the project.

Checklist for Designing an Airfield Marking Project

- ❑ Determine user agency and funding jurisdiction.

- ❑ Visit the airfield to assess and evaluate the scope of work.

- ❑ Identify markings that are being changed.
    - Note conditions of markings to be removed.
    - Note condition of pavement <u>under</u> markings to be removed.
    - Determine percentage of removal based on situation.
    - Take photographs of markings to be removed.
    - Provide airport personnel as well as potential contractors with clear expectations of results, noting that *all* marking removal causes *scarring* of pavements.
    - Identify types of removal equipment to be specified, taking into account pavement conditions, thickness and types of material to be removed, and the time of year or environment the work will be done.

- ❑ Identify composition of existing marking materials.

- ❑ Determine quantity of markings to be repainted without removal.
    - Note condition of markings to be repainted (take pictures).
        - Check existing markings for surface contaminants:
            - Algae growth
            - Oil substances
            - Dirt, grass
            - Curing compound
            - Rubber deposits
            - Rust deposits/discoloration
        - Check the adhesion of the existing markings:
            - Note the number of layers of marking material.
            - Perform an adhesion test on representative areas to be repainted.
            - Determine the condition of the pavement under the markings.
            - Consider the environment and level of UV deterioration.
        - Check for proper alignment of existing markings (if out of alignment, is removal required? If so, layout may also be required, and should be stated in the job description.)
        - Check for proper position and dimension of markings. (If incorrect, is removal required? If so, layout may also be required, and should be stated in the job description.)

- ❑ Determine quantity of markings requiring surface preparation, distinguishing between the areas needing different types of preparation. Identify methods of surface preparation to be employed.

- Establish total quantity of markings to be repainted:
  - Reflective and non-reflective markings.
  - Different color quantities.

- Select a marking material that is compatible with existing materials unless they are being removed.

- Select materials appropriate to the needs of the airport environment.
  - Are the markings stained with rust contamination?
  - Are the markings affected by algae growth?
  - Are there night operations that would warrant the use of high index glass beads?
  - Are there areas that may benefit from a durable marking material?

- Determine the type of equipment to be used.
  - If there are short work windows, truck-mounted equipment capable of applying 3-foot wide markings is desirable to reduce the amount of time operations will be disturbed.
  - Automatic glass bead dispensers should be used to provide optimum embedment of glass beads to the marking and to enable calibration and correct coverage rates.

- Schedule the work for a time of year, based on the environment, conducive to the application of the selected materials.

- Specify that materials should arrive in unopened containers, along with paperwork to match the batch numbers. (Equipment shall not be pre-loaded with materials.)

- If layout will be required, provide a description and magnitude of what is expected.

- Specify that the material be applied in accordance with manufacturer's recommendations, including coverage rates, temperatures, etc.; and state that equipment shall be calibrated and/or test strips shall be performed.

- Specify that material shall be applied in a uniform manner with an even cross section of paint and glass beads across the entire line.

- Specify all other requirements from the prevailing guidance literature pertinent to the project.