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REPORT IPRF 01-G-002-05-1 AIRFIELD MARKING HANDBOOK

Photograph courtesy of NASA

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the Federal Aviation Administration. This report does not constitute a standard, specification, or regulation.
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The participants of the Roundtable Discussion held in June 2006, including the engineers, airport managers, airport maintenance and training directors, contractors, material manufacturers, FAA personnel, scientists, military personnel. (The results gathered from industry representatives formed the basis for the research conducted under this project.)

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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.” Although new marking schemes are intended to increase situational awareness for pilots and others operating on airfield surfaces, “tailor the markings to suit whatever is being done.” 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 work 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 airport project, they can pose as a significant problem when performance is shorted 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 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. In the early 1980s, Edward Hinze, a Michigan road commissioner, used the first road striping in the United States. In the late 1950s 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.”

In 1987, air traffic control and transportation departments initiated performance programs to improve pavement markings for motorists. Some airports have adopted 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. Airfield markings include the same type of materials as highway markings, but they are susceptible to different wear, weathering, exposure, stresses, and traffic.

Airfield marking maintenance, although recognized as an item on the manager’s to-do list, 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.

1.2 SCOPE OF THIS HANDBOOK

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

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 mark 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 binders 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 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 markings 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. These airports that adopt these best 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 also identify the airport’s name, which will benefit from that specific chapter. Table 1-1 summarizes the chapters from all chapters.

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

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Summary</th>
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<td>2</td>
<td>Covers the construction and maintenance activities for airfield markings.</td>
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<tr>
<td>3</td>
<td>Discusses the materials used in airfield markings.</td>
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<tr>
<td>4</td>
<td>Describes the surface preparation required for airfield markings.</td>
</tr>
<tr>
<td>5</td>
<td>Covers the removal processes for airfield markings.</td>
</tr>
<tr>
<td>6</td>
<td>Provides guidance on the application procedures for airfield markings.</td>
</tr>
<tr>
<td>7</td>
<td>Summarizes the inspection processes for airfield markings.</td>
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</table>
2 DESIGN AND SPECIFICATION DEVELOPMENT FOR CONSTRUCTION AND MAINTENANCE ACTIVITIES

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 (e.g., 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 terms best practice are highlighted in bold. Table 2-2 summarizes the best practices presented in this chapter.

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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, (e.g., 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.

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.

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

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.

2.3.2 Pre-Construction Conference

The inspector should verify that the documentation matches the unopened containers, and the quantity of material delivered: these are best practices.

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.

A safety plan should be developed to address the requirements of 14 CFR Part 139, FAA Advisory Circulars, FAA regulations. A safety plan should be developed to address the requirements of 14 CFR Part 139, FAA Advisory Circulars, FAA regulations.
2.4.2.1  Evaluation of Existing Markings

Existing markings are covered with faded colors or appearance. 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.

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:

- Material compatibility.
- Determine the composition of existing materials/oxidations 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.

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 is to quantify and describe the markings that need to be removed, the condition of the pavement under the markings, and (c) provide any other details that will help the contractor determine the necessity of the paint removal.

b. Quantify amount of any paint removal, degrees, and method(s) to be used – a best practice. Obsolete markings should be removed. From a safety standpoint, blacked-out markings can be misleading, particularly on a wet surface at night. From 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 markings, and (c) provide any other details that will help the contractor determine the necessity of the paint removal.

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 work.
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; and, it can provide an added measure of safety.

Chapter 3 addresses the materials 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 the chapter.

**TABLE 3-1. CHAPTER CONTENTS MAY BENEFIT:**

<table>
<thead>
<tr>
<th>Applicators</th>
<th>Airport Operators</th>
<th>Designers/Engineers</th>
<th>Inspectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

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

The ability to see a pavement marking at night is based on the retro-reflective characteristics of the material. Retro-reflectivity is the technical term that defines how much light is reflected back 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 (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. 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 light beam bends when it enters and leaves the glass bead at retro-reflecting light. The index of refraction (RI), between the bead and the air outside the bead. The higher the IOR, the more efficient the bead is at retro-reflecting light.

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 3-1 illustrates the 30 meter geometry.

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<table>
<thead>
<tr>
<th>Section Reference</th>
<th>Best Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.1 Water-Borne Paint, TT-P-1952, Type I, II or III</td>
<td>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.</td>
</tr>
<tr>
<td>3.1.2 Benefits and Limitations of Water-Borne Paints</td>
<td>- 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. - 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, and a more durable product, is comparable to the Type II formulation; it contains special fast-dry polymer binders that hasten the drying process.</td>
</tr>
</tbody>
</table>

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 vehicle tires. However, at this point, the markings are soft and will not withstand wear or rain. After more

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 3-1 illustrates the 30 meter geometry.

Figure 3-2 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 glass bead at retro-reflecting light. The light beam bends when it enters and leaves the glass bead at retro-reflecting light. The light beam bends when it enters and leaves the glass bead at retro-reflecting light. The light beam bends when it enters and leaves the glass bead at retro-reflecting light.
Each type of bead described, and compared in size in figure 3-3, has a different coverage rate, based on its size and specific gravity. Whereas Type I and Type III glass beads are suited to any material, Type IV is best suited for thicker mark materials at a specific gravity 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 or installation are provided in the figure as a guide for performance criteria.

FIGURE 3-3. SIZE COMPARISON OF THREE TYPES OF GLASS BEADS FOR AIRPORTS.

Retro-reflectivity of airfield markings ranges from 100 – 1300 mcd/m²/lux. The higher the retro-reflectivity, the brighter the marking appears, and the further away it can be seen.

Markings, 20-5, Chapter 3, 3.1.2.4 Type IV Low Index Beads (1.5 IOR)

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 600–900 mcd/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 300–500 mcd/m²/lux, reflectivity will drop below acceptable levels more quickly, thus requiring more frequent maintenance, more paint build up, etc. Figure 3-7 shows poor distribution, figure 3-8 shows excellent distribution.

FIGURE 3-7. POOR BEAD DISTRIBUTION OF TYPE III BEADS.

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

3.1.2.4 Type IV Low Index Beads (1.5 IOR).

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 range between 350–500 mcd/m²/lux at installation.

However, given the size of the glass bead (0.44–1.68 mm for Type A and 0.59–1.19 mm for Type 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 II). 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 13 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 dialogued them.

FIGURE 3-4. GREAT TYPE I BEAD DISTRIBUTION; READINGS AVERAGED 600-700 mcd/m²/lux.

FIGURE 3-5. GOOD TYPE I BEAD DISTRIBUTION; READINGS AVERAGED 500 mcd/m²/lux.

FIGURE 3-6. DEMONSTRATES THE GREATER RETURN OF LIGHT FROM THE 1.5 IOR (TYPE III GLASS BEADS) WHEN COMPARED TO THE 1.0 IOR (TYPE I OR TYPE IV GLASS BEADS).

FIGURE 3-9. NON-REFLECTIVITY.

Markings, 20-5, Chapter 3, 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. When initially installed in white paint, Type III beads should yield reflectivity values ranging between 600–1300 mcd/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 for a longer period.

FIGURE 3-10. TYPE IV BEAD DISTRIBUTION IS EXCELLENT ON BOTH EDGES, BUT POOR IN THE MIDDLE.

FIGURE 3-11. POOR TYPE IV BEAD EMBEDMENT.

FIGURE 3-12. TYPE I LOW INDEX BEADS (1.5 IOR)
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 pavement characteristics of the pavement markings in the binder systems approved for use on airport.”

- 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 3-12) 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 embedding, 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 3-9, 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 3-12. GLASS BEAD EMBEDED IN BOTH WET AND DRY PAINT FILM.**

**2.2 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.

**TABLE 3-3. MATERIAL COMPATIBILITY INDEX**

<table>
<thead>
<tr>
<th>Existing</th>
<th>Existing</th>
<th>Existing</th>
<th>Existing</th>
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<td>Existing</td>
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</table>

**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 permanently. 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 water-based curing compound 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.

**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 obliterates 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 contamination.
- 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 is applied. When restiping thick, durable markings, such as thermoplastic, methyl methacrylate, and epoxy, the build-up of material can quickly become an issue.
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 32.01.11.51 (Navy, Army, Marines) specify that only materials which are delivered to the job site, subject to the provisions of the container, are used for the surface. 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-1952E or TT-B-1325D).

Investigation has shown that some applicators thin the paint when loading it into the machines, from the containers does not detect this problem.

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.

### 4.1 Definition of Surface Preparation

Surface preparation is the cleaning and removal of anything that would reduce the bond between the surface and the new marking. This includes removing markings when the markings are no longer applicable or for other reasons. Chapter 5 addresses removing markings to improve the bond between the surface and the new marking. Chapter 6 addresses marking removal with removal of paint, asphalt, glass beads, and other substances. A range of practices can be used to clean (prepare) surfaces, depending on the specific requirements of a project.

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>
<thead>
<tr>
<th>Section Reference</th>
<th>Best Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.4.3.1</td>
<td>Wettability is best for surface preparation.</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Remove curing compound on new concrete.</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Remove curing compound on new concrete.</td>
</tr>
<tr>
<td>4.2.2.4.2</td>
<td>Remove asphalt, dont paint over it, use treated paint.</td>
</tr>
<tr>
<td>4.2.5</td>
<td>Paint removed by cleaning and modified paint formula.</td>
</tr>
<tr>
<td>4.2.8</td>
<td>Remove any obstacles before marking.</td>
</tr>
<tr>
<td>4.3.5</td>
<td>Sweep, broom with air, or rinse with water after cleaning.</td>
</tr>
<tr>
<td>4.4</td>
<td>Surface preparation is specified as an expense line item in project.</td>
</tr>
</tbody>
</table>

The benefits of preparing the surface before painting it are obvious, but it takes time and money.

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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 repeatedly painted over without adequate cleaning.

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### 4.3.6 Material Testing

Many airfield markings appear well bonded. However, when cleaned by waterblasting with only the waterblasting as a method of surface preparation is a best practice. Applying more paint without cleaning the marking only adds to the paint build-up, which results in delaminating of the paint layers. The marking will crack, and the paint layers will become FOD. The asphalt will crack as well, because the paint bonds better to the asphalt than the asphalt does to itself, evident in figure 4-6. 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.

### 4.4 Surface Preparation

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

Many airfield markings appear well bonded. However, when cleaned by waterblasting with only the waterblasting as a method of surface preparation is a best practice. Applying more paint without cleaning the marking only adds to the paint build-up, which results in delaminating of the paint layers. The marking will crack, and the paint layers will become FOD. The asphalt will crack as well, because the paint bonds better to the asphalt than the asphalt does to itself, evident in figure 4-6. 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.

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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 repeatedly painted over without adequate cleaning.
4.2.4 Algae

ALGAE expand/contract differently than the pavement, contributing to the cracking seen in figure 4-12. Changing practices to include surface preparation will provide longer-lasting markings, reduce build up of markings, and reduce the potential for FOG. Consistently performing surface preparation is a best practice. Whatever can be done in the time allotted should be done well.

4.2 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.

4.2.1 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 4-8. Most specifications state that all new concrete pavements shall be free of any curing compound before markings are applied.

Pavement marking contractors are normally hired by a general contractor to apply markings on newly constructed pavement. Although the marking contractor’s work should be free of any curing compound before markings are applied, 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 build up of markings, and reduce the potential for FOG. Consistently performing surface preparation is a best practice. Whatever can be done in the time allotted should be done well.

4.2.2 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. This 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 4-9. When the rubber cools, it hardens. When the pavement texture is covered with the rubber deposits, as seen in figure 4-9, the build up should be removed, figure 4-10. 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.

4.2.3 Loose and Flaking Marking Material

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 4-11 resulted when paint was applied non-uniformly, heavier in the middle of the lane, 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 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 4-12.

4.2.4 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 contamination, they become obscured, as observed in figure 4-13. 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 swab or cloth and rub the area. (2) Paint samples 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.

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When water charges the system, the force of the water spins the bar in a circular pattern so that the machine (see figure 4-34). The floor machine houses a rotor bar equipped with spray nozzles. The equipment that was used to clean the surface is a pressure washer attached to a floor after cleaning; and figure 4-35 is the same area and markings three and one half years later.

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 4-32 and 4-33 show areas before cleaning; figure 4-34 is after cleaning; and figure 4-35 is the same area and markings 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 4-36 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.

The equipment that was used to clean the surface is a pressure washer attached to a floor machine (see figure 4-34). The floor machine houses a rotor bar equipped with spray nozzles. When water changes 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.
4.3 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.

4.3.1 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>
<thead>
<tr>
<th>WATERBLASTING EQUIPMENT</th>
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<tbody>
<tr>
<td><strong>Water Pressure</strong></td>
</tr>
<tr>
<td><strong>Water Volume</strong></td>
</tr>
<tr>
<td><strong>Low Pressure</strong></td>
</tr>
<tr>
<td><strong>High Pressure</strong></td>
</tr>
<tr>
<td><strong>Ultra High Pressure</strong></td>
</tr>
<tr>
<td>Up to 1000 psi</td>
</tr>
<tr>
<td>10,000 psi</td>
</tr>
<tr>
<td>50,000 psi</td>
</tr>
</tbody>
</table>

4.3.1.1 Pressure Washers

A pressure washer is a type of waterblaster by definition. Good for small areas they attain pressures up to 3,500 psi. Pressure-washing systems can use floor machines (seen in figure 4-34), add detergents to the water tank, or can be used with a hand wand. By taking enough time, pressure washers can remove most contaminants, except for rubber deposits and curing compound.

4.3.1.2 Low-Pressure Waterblasters

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 mounted, using a straight bar with a series of tips (seen in figure 4-38).

4.3.1.3 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 paint removal from sound pavement surfaces. This system uses a high volume of water, up to 25 gpm, delivering water with hydraulic force to penetrate, lift, and clean contaminants from the surface.

4.3.1.4 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, ultra-high-pressure units can operate at half capacity (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.

4.3.2 Shotblasters

Shotblasters propel steel shot, walnut shells, or other abrasive material onto the surface to remove paint and prepare surfaces. Grouned 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.

4.3.3 Grinders

Grinders can be used for surface preparation. They are equipped with rotating drums that spin vertically, horizontally, 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, it can be used for surface preparation to remove loose and poorly bonded material. The surface must be flat for the grinders to strike all of the markings that will be prepared. Through clean up after grading is advisable, such as rinsing before the affected pavement. Water 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 QUALITY CONTROL

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

4.4.1 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.

4.4.2 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:

4.4.2.1 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, the equipment operator runs 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.

4.4.2.2 Rubber Deposits

Although considered a surface contaminant, rubber accepts a coating of water-based paint well. During operations to remove rubber, seen in figure 4-40, any coatings applied on top of the rubber will be removed during the rubber removal process.

4.4.2.3 Loosely and poorly bonded materials

A pull test, seen in figure 4-41, is a means of checking for loose materials, such as dust or debris, generated by a surface preparation or paint-removal process. Using a piece of sheet tape that is marked, pressing 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 markings material can be pulled up (see figure 4-42).

4.4.2.4 Algae

Algae can almost completely obscure the markings. Through brooming can remove the algae growing on the surface. However, if the paint is also peeling up, the Algae can also be cleaned through the pressure washing process.
4.4.2.5 Rust Discoloration

Iron stains can be removed, but some residual stain may remain. The active contaminant can be removed through waterblasting, providing a cleaner surface on which to apply a stain-resistant material. Figure 4-43 depicts a sidewalk that was painted over existing stains; the rusty color bled through the new coating. The best practice is to remove the majority of the stain and reaply the markings using a modified water-based paint that will resist rust staining.

4.4.2.6 Oils, Fat, Biro, 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 surface can be achieved. All visible oily contaminants should be removed.

4.4.3 When is "good enough" acceptable?

What may appear to be "adequate" surface preparation during the process may be "inadequate" once the 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.

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 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 previously damaged asphalt along with the markings.

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.

5.1 DEFINITION

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.

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 is 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 dictated 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 5-3. PAINT REMOVAL VERSUS SURFACE PREPARATION

<table>
<thead>
<tr>
<th>Surface Preparation</th>
<th>Paint Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Adequate</td>
</tr>
<tr>
<td>Adequate</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Inadequate</td>
<td>Needs removal</td>
</tr>
</tbody>
</table>

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 scaring. 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 85-85 Percent Removal

Removing 80 to 85 percent of existing markings is required prior to the application of a seal coat per FAA AC 150/5370-10C, Section 626-4.16. 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 and 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.”

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 beaded 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, misreading markings have the potential to confuse and contribute to surface incidents.

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 re-apply over the markings without removing them, whether the materials are 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.

5.3.3 Remove Markings Build-Up (i.e., Exhaust Layers)

When more than two coatings of markings have been applied to asphalt without surface preparation, the layers can start to lift, 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 continue buildup. Cracks become channels for water to penetrate the asphalt. The water erodes the pavement under the marking, resulting in premature deterioration. Coatings are designed to bond to a specific substrate, like asphalt, and often they bond better to the asphalt than to surfaces or materials that are not compatible.

5.3.4 Seal Coat or Other Surface Treatment

AC 150/5370-10C states, “Any painted stripes or markings on the surface of the runway or taxiway to be treated, shall be removed.” This means 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.

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 (quantity) of removal.
2. Type of pavement.
3. Condition of pavement.
4. Thickness and condition of material being removed.
5. Type of material being removed.

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

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Concrete</th>
<th>Asphalt</th>
<th>Poor Asphalt</th>
<th>Sealed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding, milling, or rototiller machines</td>
<td>Effective on asphalt, especially if aged and cracked</td>
<td>Effective on concrete, although the blades fade over time</td>
<td>Effective on other materials</td>
<td>Effective on sealed surfaces</td>
</tr>
</tbody>
</table>

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, milling, “Rototiller”

Grinding, milling, or rototiller machines are drum units that can be hand operated or mounted on a skid steer or other motorized vehicles. Figures 5-8 and 5-9 indicate acceptable scarring from grinding on asphalt and concrete. Scarring left on asphalt from the impressions of the grinding blades fade over time. 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.
- Scrapes and cuts the surface to remove paint.
- Can be manually operated.

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

5.5 PREPARED SURFACE

5.5.1 Preparation of Existing Coatings

When more than two coatings of markings have been applied to asphalt without surface preparation, the layers can start to lift, 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 continue buildup. Cracks become channels for water to penetrate the asphalt. The water erodes the pavement under the marking, resulting in premature deterioration. Coatings are designed to bond to a specific substrate, like asphalt, and often they bond better to the asphalt than to surfaces or materials that are not compatible.
• Is a slow process – 500 SF per hour typically, depending on thickness and type of material.

• Is not recommended for grooved surfaces.

**FIGURE 5-9. ON CONCRETE, CARE MUST BE TAKEN TO AVOID REMOVAL OF THE CEMENT SURFACE.**

**FIGURE 5-10. BEFORE PAINT REMOVAL.**

5.4.2 Shotblasting

Shotblasting 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 shotblasting 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 clean up is required.

**FIGURE 5-10. BEFORE PAINT REMOVAL.**

5.4.3 Shotblasting

Shotblasters propel 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. However, the pavement under the markings was already deteriorated, and

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.

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.
- Economical; only water is used.

**TABLE 5-6. WATERBLASTING EQUIPMENT DESCRIPTIONS FOR PAINT REMOVAL.**

<table>
<thead>
<tr>
<th>Waterblasting Method</th>
<th>Pressure Ranges</th>
<th>Water Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Pressure</td>
<td>Up to 2,000 psi</td>
<td>5 - 10 gpm</td>
</tr>
<tr>
<td>High Pressure</td>
<td>Up to 10,000 psi</td>
<td>10 - 20 gpm</td>
</tr>
<tr>
<td>Ultra-High Pressure</td>
<td>Up to 50,000 psi</td>
<td>4 - 5 gpm</td>
</tr>
</tbody>
</table>

The disadvantage of waterblasting is that it leaves a damp or wet surface after the work has been completed. The surface must dry before new markings can be applied.

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 markings. When the operator uses a straight bar or weighted “floor” machine, the removal can proceed faster. Characteristics of low-pressure waterblasting follow:

- Yields pressures up to 10,000 psi.
- Uses 5-20 gpm of water.
- Can remove a light coating of paint.
- Can remove up to 1000 SF per hour.
5.5.1 Scarring
aggregate diameter uniformly across the pavement, and without loosening the aggregate. without exposing more than 25 percent of the depth (vertical dimension) of the nominal-size under those markings, and (3) the depending upon: (1) the
5.4.4.3 Ultra High-Pressure Waterblasting
Ultra high-pressure waterblasting is the predominant system used by contractors today. 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. For ultra high-pressure waterblasting, the pressure is so high and the volume of water so low that the removal process is similar to milling. The machine shaves off the coating and a few milliseconds of the surface during the removal process. This system is generally equipped
5.5.3 Removal of Durable Markings
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 damage.
FIGURE 5-18. HIGH-PRESSURE WATERBLASTING IS EFFECTIVE FOR CLEANING LOOSE, AND POORLY BONDED PAINT (SURFACE PREPARATION).

In any marking removal operation, aggregate will be exposed because the paint is bonded to the material around the aggregate. As the coating is removed, the pavement breaks apart, as seen in figure 5-24.

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.

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.
- Is good on most surfaces.

5.4.4.2 High-Pressure Waterblasting
High-pressure waterblasting is normally truck-mounted, and it is available through a contractor. However, this equipment 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.
- Capable of pressures up to 20,000 psi.
- Uses approximately 15 to 25 gpm of water.
- Results in a hydraulic effect from the force of water.
- Removes debris and water through a separate follow-behind vacuum system.
- Maneuvers around fixtures to avoid damage (silicone joint materials are susceptible to damage).
- Is excellent for removing rubber deposits and preparing surfaces prior to applying paint, seen in figure 5-18.
- Removes markings on smooth or grooved concrete.
- Removes markings on asphalt in sound condition.
- Can remove existing markings up to 1000 SF per hour, depending upon the thickness and type of material.

In any marking removal operation, aggregate will be exposed because the paint is bonded to the material around the aggregate. As the coating is removed, the pavement breaks apart, as seen in figure 5-24. Figure 5-24 is a section of runway centerline equipment, the pavement breaks apart, as seen in figure 5-24. 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.

5.5.1 Scarring
Scarring will always result from marking removal; the objective is to keep it to a minimum. Scares on asphalt 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.

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 a 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 is a pre-existing condition.

5.5.3.1 Thermoplastic
Thermoplastic is used primarily on asphalt, and, although it is not often used on airfields, it can be used on taxiways or ramp areas. This plastic material becomes a viscous liquid when heated to 400 F and melts the bitumen on the asphalt surface when it is applied. As the plastic cools, it bonds to the surface. Any thermoplastic removal process on asphalt will remove both the
marking and the asphalt to which it bonded. Grinders are the best method to remove thermoplastic because they prevent erosion of surrounding pavement.

5.5.3.2 Epoxy
Epoxy is a durable material that hardens and is difficult to remove. Grinders or milling machines are recommended for removing epoxy markings. Other removal methods may deflect or bounce off the hard epoxy marking and erode the surrounding pavement instead.

5.5.3.3 Methyl Methacrylate
Methyl methacrylate, similar to epoxy in its durability, would be best removed with grinders.

5.5.3.4 Polyester
Any method of removing polyester coatings from concrete is acceptable. If polyester markings are being removed from asphalt, grinding is the best method to use. In the durable marking category, polyester marking paints are two-component, field-reactive formulations with >99 percent paint solids.

5.5.3.5 Permanent Tape
Permanent tape is usually applied with an adhesive, making its removal difficult, depending upon length of time it has been in place, the kind of traffic to which it has been subjected, and the type of surface it is on. Grinding or heating and scraping would be the best methods of removal. Permanent tape should not be used on movement areas where the potential for it to loosen and become FOD exists.

5.5.4 Different Types of Pavement and Condition
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 5-23) 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
Asphalt that is 1 to 5 years old, as seen 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, because it has been shielded from ultraviolet light by the marking.

5.5.4.3 Asphalt That is 1 Year
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.

After sufficient time has elapsed, remove the temporary markings as well as the curing compound. Suggested treatments are indicated in figure 5-31. Recommended 8 to 12 weeks elapsed 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 (300 ft-lb) of water-based paint. After sufficient time has elapsed, remove the temporary markings as well as the curing compound. Thoroughly rinse the area again prior to applying the permanent markings if any residual debris is observed.

5.5.4.5 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.

5.5.4.6 PCC That is Aged
PCC that is 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.

5.5.4.7 Crack Sealing on Pavement
Repair of cracked pavement with crack seal is a sign of pavement deterioration. 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, grinders 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.

5.5.4.8 Crack Sealing on Pavement
Repair of cracked pavement with crack seal is a sign of pavement deterioration. 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, grinders 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 not recommended that it be done.
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-206- Sealing Compounds, Two Component, Elastomeric Polymer Type, Air-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.

- **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, being able to protect it from damage 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. Gridding should not damage the joint material if it is recessed from the surface of the pavement.

### 6.1.1 Surface Preparation: Curing Compound or Construction Debris Removal

6 APPLICATION PROCEDURES

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 6-1. Chapter Contents May Benefit:

<table>
<thead>
<tr>
<th>Section Reference</th>
<th>Best Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.12</td>
<td>Layout is provided to maintain proper dimensions and alignment.</td>
</tr>
<tr>
<td>6.14, 6.16, and 6.42</td>
<td>A &quot;pre-cast (temporary) coat&quot; is applied for new asphalt, or under existing conditions.</td>
</tr>
<tr>
<td>6.16, 6.16.4.1</td>
<td>Close attention is paid to proper roadway edges.</td>
</tr>
<tr>
<td>6.2</td>
<td>Adequate surface preparation is performed.</td>
</tr>
<tr>
<td>6.54</td>
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</tr>
<tr>
<td>6.64</td>
<td>Blown excess is removed from the surface.</td>
</tr>
<tr>
<td>6.7</td>
<td>Pressure is applied to the surface to remove dust.</td>
</tr>
<tr>
<td>6.8</td>
<td>Concrete containing the proper admixture is used.</td>
</tr>
<tr>
<td>6.8.1</td>
<td>Hardened concrete is used to prevent material displacement.</td>
</tr>
<tr>
<td>6.7.1</td>
<td>Used to determine the location of the markings.</td>
</tr>
<tr>
<td>6.7.2</td>
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</tr>
<tr>
<td>6.7.3</td>
<td>Calibration of material gaps and monitoring of material usage is practiced.</td>
</tr>
<tr>
<td>6.7.6</td>
<td>Thickness of the joint material is within the limits of the marking materials.</td>
</tr>
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<td>6.8.3</td>
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</tr>
<tr>
<td>6.8.4</td>
<td>The layout is performed in cooperation with the marking material company.</td>
</tr>
<tr>
<td>6.8.5</td>
<td>Materials are used to prevent material displacement.</td>
</tr>
</tbody>
</table>

6.5.6 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.

6.5.7 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.

**TABLE 6-2. BEST PRACTICES FOR APPLICATION PROCEDURES**

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</table>

**FIGURE 6-1. CURING COMPOUND PROPERLY REMOVED FROM NEW CONCRETE.** 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 wait period of 8 to 12 weeks before applying markings to new concrete to avoid gas bubbles escaping through the paint.

**FIGURE 6-2. CONSTRUCTION DIRT MUST BE CLEANED.** Other contractors working on the project may deposit contaminants that should be removed to ensure the paint. 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 those 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.

**FIGURE 6-3. LAYOUT WITH CHALK LINES ENSURES PROPER PLACEMENT AND ALIGNMENT.** 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**
6.2.2 Application on Different Pavement Types

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. See 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.

6.2.3 Application of Markings on Grooved Surfaces

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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 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.

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 specifications. The inspector should check the layout for correct placement and dimension.

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 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 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 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.

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.

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-based paints perform well. Water-based 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-based 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, thermoplastic is a popular material because it melts the asphalt and bonds to it as both the surface and the marking coat. But for airfields, current thermoplastic formulations are confined to narrow markings, i.e., vehicle runways, taxiway lines, or apron markings. Currently no agency lists thermoplastic as an approved material for airfield markings.

6.2.2.3 Seal Coat

Water-based 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.

Water-base 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-base paint is applied too thickly. Figure 6-12 shows a one-year-old marking applied when the asphalt was new. Cracking is evident where paint guns overlapped.

Solvant paints (TT-P-115 and TT-P-85) were a government standard until the mid 1980s when the water-base paints were introduced in response to environmental concerns. Solvent paints caused severe cracking of both paint and asphalt, as seen in figures 6-10 and 6-11.
6.2.4 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 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.

6.2.5 Crack Sealant

Crack sealant is made of bituminous material, and paints do not bond well to it. Additionally, crack sealant discolors the white markings, as oils are still present in it, evident in figure 6-13.

6.3 STRIATED MARKINGS

Striated markings are stripes of even width separated by spaces of even width 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 more quickly than the 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 the sun more quickly than the 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

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 size, 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 course 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 around the temporary markings. However, since the "no track" condition happens faster, the glass beads will "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 peel off prematurely.

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 pickup 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, pump-style air spray, and pressured-tank air spray.

6.5.1 General Characteristics of Pavement Marking Equipment

Whether pneumatic or airless, striping equipment has similar characteristics and challenges.

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 peel off prematurely.

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. Heating the paint affects the material temperature at the point of application, but does not affect the temperature in the tank or the temperature of the paint as it leaves the tank. 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. Waterborne paints should not remain in the tanks, pumps, or lines for longer than 1 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 solvents. 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. 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 flow rate of material from the tank. The equipment is optimized for applications where the paint is applied simultaneously, pictured in figure 6-29 and 6-25.

6.5.2 Airless Equipment

The term “airless” refers to a pumping system that applies paint at approximately 1100–3300 psi without “atomizing air” to disperse the paint particles in a line. An airless gun has a small tip, as seen in figures 6-18 and 6-19. The tips are identified with a three-digit code, (e.g., 421). The “4” represents half of the maximum line width expected from the tip, or 8 inches. However, it is advisable to multiply that number by one and one-half for the recommended line width (6 inches), because striving for 8 inches results in a thinner paint film on the edges of the line. The heralded two digits (“21”) represent the size of the aperture of the tip in thousandths of an inch. The greater the size of the tip the higher the paint volume and conversely, the smaller the size the lower the paint volume.

In addition to the tip size, 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 figure 6-20 and 6-21.

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 6-22.

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 6-22.

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 useful for airports that must maintain non-movement boundary markings with the 3-foot dash pattern, or the enhanced taxiway centerlines with the 9-foot dashes and 3-foot spaces seen in figure 6-23.

6.5.3 Pneumatic or Air-Atomized Striping Systems

Pneumatic or air-atomized striping systems use (1) air compressors that pressurize tanks, pushing the material through supply lines and down to the guns, 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.

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. Pneumatic systems are suitable for waterborne 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. 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 flow rate of material from the tank.
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 airlss 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.

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.

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 droplets 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 adhering when 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 screens 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.

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 “filled over,” preventing proper embedment, and (3) the glass beads are broadcast on the surrounding pavement, increasing the clean up that will be needed, as well as creating a potential risk of someone slipping.

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.

Routeful 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.

6.6 HAND MACHINES

Hand machines are used for detail markings, such as surface-painted signs, holding position markings, and sometimes runway designation materials. 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.

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 6-inch 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 “slurry” or motored cart attached to the machine converts it to a self-propelled unit, seen in figure 6-39. Very maneuverable, a two-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.

6.6.2 Pneumatic Air-Atomized Equipment

An-atomized push equipment, which functions like the truck-mounted systems, is generally equipped with a single material gun. A large compressor is necessary to operate two paint guns, making the machine bigger and heavier. It is important 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 airlss systems can be included, but the operators often disable those 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, soil, 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 airlss 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 airlss machine with a 12-inch bead dispenser that operates 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 10-to 20-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 airlss 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.
6.7 COMPLIANCE WITH EQUIPMENT SPECIFICATIONS

Guide specifications for all government agencies provide basic requirements in the way equipment should be used to achieve quality airfield markings. If 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 from02 mm (4 inches to 1 m (3 feet))” in a single pass. All applicants, 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) Stippling 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 (tall) and shall apply markings of uniform cross sections and clear-cut edges without running or spattering and without over spray.”

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).

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

**FIGURE 6-43. AIRLESS LINES HAVE SHARPER EDGES.**

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 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 Used

Material flowing through a tip or fluid nozzle is abrasive. The orifice begins to wear 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. The orifice tip 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.

**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.**

6.7.2.2 Material Guns have Line Width Limitations

In many instances, stripping 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 figure 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.

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

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

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; thus the thinner markings will be compromised for nighttime visibility soon after application.

**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 6-48 would look like (far right). In an air-atomized system, different-sized fluid nozzles will yield a greater or lesser volume of air. 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. The orifice tip 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.

6.7.3 Width of Line in Small Pass

The U.S. Air Force ETOL 97-18 prescribes the stripping 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 “extruding” 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.

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.

Figure 6-51 and 6-52 demonstrate the use of a mirror in front of the material guns to guide the driver.

Hand-thrown beads are a poor practice. See 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.

The “4” seen in figures 6-51 and 6-52, is visible both during daylight and darkness. The numeral was applied with an air-atomized truck, spraying a 3-foot pass with automatic, pressurized head dispensers: all best practices.

FIGURE 6-51. DAYTIME VISIBILITY IS EXCELLENT.

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

6.5.5 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.

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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-born 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 ethyl ketone 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, clean up 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-born 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, these 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-born 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. 13

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 “hazardous” 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. 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 task 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 bead. (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 in a 10-second interval, and this is a best practice. The amount collected in the container seen in figure 6-59 is compared to the specified coverage rate. If the coating is too high, the gauge is pressed into the coating at a 90-degree 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 40 mils, the side reading “35, 40, 45 through 80” 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.

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-degree 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 40 mils, the side reading “35, 40, 45 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.

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 over-embed, and the reflectivity values will drop below levels the light cannot enter the bead and return effectively.

Close monitoring of the markings during application is essential, and it is a best practice.
6.10.4.4  Flashlight

A magnifying glass can help in diagnosing other issues, such as poor performance of marking materials. In figure 6-66, the paint film disintegrated after only having been in place for 24 hours. A magnifying glass can help in diagnosing other issues, such as poor performance of marking materials. In figure 6-66, the paint film disintegrated after only having been in place for 24 hours.

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

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

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### 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 or duct tape 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 tooth having paint on it and the next longest tooth 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 puddling 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 glass 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.

### 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.

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. If the removal is less than 25 percent of the vertical depth of the nominal size aggregate is exposed, and some aggregate could loosen.

### 7.3.6 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.

### 7.3.7 Marking Application Inspection

Correct marking application involves several criteria, all of which contribute to an effective marking.
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 shade of the Federal Standard 595B color. Other colors shown in figures 7-11 represent the five 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.](image)

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 be equal to the usage recorded during the course of the day. Take into account circumstances should material arrive to the project already loaded in the equipment tanks.

7.3.5 Embedment

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 poor population and embedment.

![FIGURE 7-8. OPTIMUM BEAD EMBEDMENT.](image)

![FIGURE 7-10. USE OF MAGNIFYING GLASS.](image)

BIBLIOGRAPHY

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.

<table>
<thead>
<tr>
<th>Source Title</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Aviation Administration Standards for Airport Markings, AC 150-334D-1</td>
<td>April 29, 2005</td>
</tr>
<tr>
<td>Federal Aviation Administration Operational Safety on Separation During Construction – AC 150/5370-3F</td>
<td>January 17, 2003</td>
</tr>
<tr>
<td>Department of the Army Marking of Army Airfield-Helipad of National and Maintenance Facilities – TM 5-823-4</td>
<td>October 22, 2005</td>
</tr>
<tr>
<td>U.S. Army Corps of Engineers Unlined Facilities Guide Specifications—Section 32 17 24 00 10 – Pavement Markings</td>
<td>July 1987</td>
</tr>
</tbody>
</table>

Airfield Marking Handbook 100 | September 2008

Airfield Marking Handbook 101 | September 2008

Texas Department of Transportation Pavement Marking Manual: Various | August 2004

Texas Transportation Institute, Pavement Marking Handbook, H. Gene Hawkins, Jr., Timothy J. Gates, Elizabeth R. Rose Various | Various

SASI 950, e.g., Virginia, Missouri, Maryland, Texas Various | Various


Airfield Marking Handbook 102 | September 2008

Airfield Marking Handbook 103 | September 2008

BIBLIOGRAPHY
APPENDIX A—FAA AC 150/5370-10C

The following guidance specification is a modified version of Item P-520 that incorporates the recommendations included in the handbook. Indicated sections are recommended changes to the AC.

**ITEM P-520 RUNWAY AND TAXIWAY PAINTING DESCRIPTION**

620-4.1 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 their specifications and at the locations shown on the plans, or as directed by the Engineer.

This guidance specification for designing an airfield marking project should be modified to specifically address the needs of the airport, its environment, its operational requirements, and the desires of the owner.

**MATERIALS**

620-2.1 MATERIAL ACCEPTANCE. The Contractor shall obtain 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. The reports can be used for material acceptance or the Engineer may perform verification testing. The reports shall not be interpreted as a basis for payment. The Contractor shall notify the Engineer upon receipt of a shipment of material to the site. All material shall arrive in sufficient quantities for inspection by the Engineer: Material shall not be loaded into the equipment until inspected by the Engineer.

620-2.2 PAINT. Paint shall be [Waterborne, Epoxide, Methacrylate, or Silane-based] in accordance with the specifications. 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:

<table>
<thead>
<tr>
<th>Color</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>x: 0.475, y: 0.475</td>
</tr>
<tr>
<td>Yellow</td>
<td>x: 0.501, y: 0.470</td>
</tr>
</tbody>
</table>

595.

The Engineer shall specify paint type and appropriate paragraph number. The Engineer shall insert the colors to be used on a project from the following list:

- White—7925 Red—3313 Yellow — 33538 Black—7370
- Pink—1 part Red—5114 to 2 parts White—37295

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.

For Type D-1952 and A-2006 paints, the Engineer shall specify the type required. Type III is intended for locations where sliver tracking in not a problem. Type III is intended for striping locations where faster curing is desirable. Type III requires the use of a cross linking resin that will produce a thicker, more durable coating.

620-2.3 WATERPROOF. Paint shall meet the requirements of Federal Specification TT-P-1952E, Type I, Type II or Type III.

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The Engineer should consult with the paint and bead manufacturer on the use of adhesion, flow promoting, and/or filmston additives.

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**ITEM P-520-2**

b. EPOXY. Paint shall be a two component, minimum 99 percent solid type system conforming to the following:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Trinitium Dioxide, ASTM D 476, type II shall be 18 percent minimum (18.5 percent minimum at 100 percent purity).</td>
</tr>
<tr>
<td>Yellow</td>
<td>Trinitium Dioxide, ASTM D 476, type II shall be 14 to 17 percent. Organic yellow, other colors, and tinting as required to meet color standard. Epoxy resin shall be 14 to 17 percent.</td>
</tr>
</tbody>
</table>

595.

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.

The daylight directional reflectance of the white paint shall not be less than 75 percent (relative to magnesium oxide), when tested in accordance with Federal Test Method Standard No. 141D, Method 6121. The x and y value 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:

<table>
<thead>
<tr>
<th>Color</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>x: 0.475, y: 0.470</td>
</tr>
<tr>
<td>Yellow</td>
<td>x: 0.501, y: 0.470</td>
</tr>
</tbody>
</table>

595.

Epoxy and Silane-based paints shall require not less than 150 liters of sand for the removal of the paint films.

595.

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The Manufacturer shall certify that the paint and bead manufacturer on the use of adhesion, flow promoting, and/or filmston additives.

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CONSTRUCTION METHODS

620-3.1 WEATHER LIMITATIONS. The painting shall be performed only when the surface is dry and when the surface temperature is at least 65°F (18°C) and rising, and the pavement surface temperature is at least 65°F (18°C) above the dew point. [Painting operations shall be discontinued when the surface temperatures exceed ___ degrees F, ___ degrees C.] Markings shall not be applied when the pavement temperature is greater than 100°F. Markings shall not be applied when the wind speed exceeds [10 ft/sec unless windscreen are used to abate the material潇潇。]

The Engineer may specify minimum and maximum surface temperatures based on paint manufacturer’s recommendations.

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 amusing spray-type or aerosol type marking machine suitable for application of traffic paint. It shall produce an even and uniform film thickness in the required coverage and shall apply markings of uniform cross sections and clear-cut edges without blurring or feathering over spray.

620-3.3 PREPARATION OF SURFACE. Immediately before painting, the surface shall be dry and free from dirt, grime, oil, moisture, or any foreign material that would reduce the bond between the paint and the pavement. The area to be marked shall be cleared by sandblasting, shotblasting, grinding or sanding practice required to remove all contaminants without damage to the pavement surface. Use of any chemical or impact abrasion during surface preparation shall be approved in advance by the Engineer. After the cleaning operations, street sweeping, brooming, 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.

[Paint shall not be applied to Portland cement concrete pavement until the areas to be painted are clean of grit or other debris left from the cleaning process.

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 adhesives shall be shown on the plans.

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.

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 adhesives shall be shown on the plans.

Glue beads improve connectivity and the friction characteristics of markings. When markings are part of an AIP or PFC funded project, at a minimum, the Engineer shall indicate the following locations to receive glue beads:

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### BASIS OF PAYMENT

620-5.1 Payment shall be made at the respective contract [price per square foot (square meter)] [lump sum price] for the respective contract, including all work, materials, labor, equipment, tools, and incidentals necessary to complete the item. Payment will be made under:

- Item P-620-5.1-1 Runway and Taxiway Painting performed non-reflectorized [square foot (square meter)] [lump sum]
- Item P-620-5.1-2 Runway and Taxiway Painting performed reflectorized [square foot (square meter)] [lump sum]
- Item P-620-5.1-3 Surface Preparation [square foot (square meter)] [lump sum]

The Engineer shall include a pay item for each paint and bead type material specified.

### TESTING REQUIREMENTS

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C 158</td>
<td>Serve Analysis of Fine and Coarse Aggregates</td>
</tr>
<tr>
<td>ASTM C 177</td>
<td>Wire Cloth Serve Analysis of Non-Plastic Ceramic Powders</td>
</tr>
<tr>
<td>ASTM D 711</td>
<td>Test Method for Flash and Fire Point by Cleveland Open Cup</td>
</tr>
<tr>
<td>ASTM D 1213-54T</td>
<td>Test Method for Cracking Resistance of Glass Surfaces</td>
</tr>
<tr>
<td>ASTM D 1652</td>
<td>Test Method for Epoxy Content of Epoxy Resins</td>
</tr>
<tr>
<td>ASTM D 2240</td>
<td>Test Method for Rubber Products-Durometer Hardness</td>
</tr>
<tr>
<td>ASTM D 3173</td>
<td>Operating Light and Water-Exposure Apparatus (Fluorescent Light Apparatus UV-Condensation Type) for Exposure of Nonmetallic Materials.</td>
</tr>
</tbody>
</table>

### 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/](http://www.faa.gov/airports_airtraffic/airports/airport_safety/signs_marking/supplement/)

FAA AC 150-5340-1J, published April 29, 2005 (Change 1 published 3/31/08)

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 applications. Most of the markings are mandatory for use on FAA Part 139 Certificated airports, that receive AIP or FPC 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 150-5370-1C, Part 2 (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.

### 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 Support Agency. Similar to FAA AC 150-5340-1J, 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 97-17 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 expediential 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, helipads, helipads, related permanent facilities, as well as the navigational air space surrounding these facilities. Sponsored by the USAF and AFCEA, 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 24 00-18** is a new 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 150/5340-1J and USAF ETL 04-2, this document provides guidance on design and marking projects for military installations.

- **UFGS 32 01 11 51-1** 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 150/5370-1C 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., sandblasted crater deck for fixed wing and rotary wing aircrafts.

The U.S. Army uses USAEC TM 5-820-4, 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.
Demarcation Bar is a 3-foot wide, yellow bar that extends across the width of the blast pad, stopway, or taxiway. Located on the blast pad, stopway, or taxiway at the point of intersection with the runway, the marking delineates a runway with a displaced threshold that precedes the runway. If a runway 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, 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 150/5340-1J, figures 6 and 8) 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.

Arrows and Arrowheads are used to identify a displaced threshold area and are useful for centerline guidance for takeoffs and/or rollouts. (FAA AC 150/5340-1J, page 7) 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 150/5340-1J, pages 25 and 27 of that document) that convey other information to pilots and surface operators.

Holding Position Markings on Taxiways 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.

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.

Taxiway centerlines are six- to 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 re-painted for nighttime visibility. On airports with designated Surface Movement Guidance Control Systems (SMGCS) routes, the taxiway centerlines are twelve-inches wide and take precedence over runway markings.

Intermediate Holding Position Marking is a "taxiway-taxiway" hold marking, designed to provide a place on a taxiway for a pilot to wait for another aircraft taxiing on an intersecting taxiway. They are to be outlined in black on light colored pavements, and are 3-foot wide by 1-foot long dashes and spaces. The taxiway centerline should be spaced 6-12 inches from the intermediate holding position marking.

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.

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.

Taxiway centerlines are six- to 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 re-painted for nighttime visibility. On airports with designated Surface Movement Guidance Control Systems (SMGCS) routes, the taxiway centerlines are twelve-inches wide and take precedence over runway markings.
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 may 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 can provide guidance information to an operator.

- The sign with the black background and yellow lettering is a location sign.
- The red and white sign is a surface painted holding position marking.

The arrow within the director sign with the yellow background and black lettering indicates the direction of Taxiway W8.

**FIGURE 1 - Thirty-meter geometry measurement for retro-reflectivity evaluation.**

A retrometer is shown in the picture below and is measuring the retro-reflectivity of the white airfield marking. By establishing performance criteria that include target reflectivity values at installation, inspectors can record readings to ensure compliance. When this measure is used, nighttime visibility will be enhanced.

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 to the right.

**CHROMATICITY**

Measuring or comparing the color of markings to standards (maintained by all government agencies) will indicate if the marking paints have degraded (i.e., faded, paled, etc.). The colorimeter pictured on the previous page provides coordinates that can be plotted on the grid shown as Figure A-1 and A-2 in the FAA report. Figure A-1 and A-2 show the color ranges that are acceptable for non-reflective and reflective markings respectively. Outside of that range is unacceptable. The use of color chips corresponding to the Federal standards can be used to compare colors at installation, but have not been developed for use as a determination for maintenance.

**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 cross sections of transparent material inscribed within a grid of 100 equal squares can be used as a tool for quantitative measure of specified percentage of coverage. The grid concept came from the US Air Force where it is 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. For a 12-inch line, a grid of 10 x 10 is suggested. Count the squares that have no paint. As an example, 3 squares without paint represents 3% of the paint gone, or 97% coverage.

Use the following 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.

**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.

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 inspection 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.

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 (remaining paint) marking using a transparent grid.

**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.)
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.

**AUTOMATED METHOD—VAN-MOUNTED RETRO-REFLECTIVE CHECK**

The automated method for determining reflectivity values is faster, more advanced, and more accurate; it requires little "downtime" on the airfield surfaces. However, the van-mounted retro-reflectometer has an accuracy of ±5 percent, whereas the manual reflectometer has an accuracy of ±15 percent.

The automated inspection system increases the speed and sample size. The automated inspection system has the following objectives:

- Evaluate 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.

### Checklist for Inspecting 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 under 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 if marking removal causes some scarring of pavements, the definition of pavement damage should be defined.
  - Identity 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 under which 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
      - Corrosion compound
      - Rubble deposits
      - Rust deposits/dissolution
    - Check the adherence 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.

### 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 under 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 if marking removal causes some scarring of pavements, the definition of pavement damage should be defined.
  - Identity 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 under which 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
      - Corrosion compound
      - Rubble deposits
      - Rust deposits/dissolution
    - Check the adherence 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 nights 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 a uniform distribution of glass beads with proper embedment.

- Specify all other requirements from the prevailing guidance literature pertinent to the project.