

Project No. 09-19

**AIRFIELD PAVEMENT MARKINGS —  
EFFECTIVE TECHNIQUES FOR REMOVAL AND  
TEMPORARY APPLICATIONS**

FINAL REPORT

Prepared for  
Airport Cooperative Research Program  
Transportation Research Board  
of  
The National Academies of Sciences, Engineering, and Medicine

TRANSPORTATION RESEARCH BOARD  
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## **ABSTRACT**

Airfield markings are critical visual cues for the safe and efficient movement of vehicles on runways and taxiways. During airfield construction and maintenance activities, the existing pavement markings may need to be removed or obliterated and temporary markings installed. The removal operations can leave pavement scarring or traces of the preexisting marking material behind, which may be confusing to observers and reduce the safe and efficient movement of vehicles. Researchers conducted a literature review, field evaluations, and a survey to gather information on airfield pavement marking removal and temporary marking applications. Field evaluations occurred around the country and included marking removal and temporary marking applications. This report contains the results of the literature review, field evaluations, and survey.

A primary objective of this research was to develop a standalone airfield guide for airport operators and engineers to identify and develop best practices for the efficient, safe, cost-effective, and environmentally acceptable techniques concerning pavement marking removal and temporary marking applications. The developed airfield guide addresses permanent marking removal, temporary marking applications, and temporary marking removal. The guide provides information and best practices to improve pavement marking removal at all airport types and on all pavement surfaces. Researchers also developed a field inspection guide to be used by inspectors and contractors to improve marking removal. These guidance documents are provided separately from this report.

## EXECUTIVE SUMMARY

Airfield markings are critical visual cues for the safe and efficient movement of vehicles on runways and taxiways. During airfield construction and maintenance activities, the existing pavement markings may need to be removed or obliterated and temporary markings installed. The removal operations can leave pavement scarring or traces of the preexisting marking material behind, which may be confusing to observers and reduce the safe and efficient movement of vehicles. Marking removal may also damage pavement surfaces, reducing their effective life. Effective pavement marking removal and temporary marking applications are needed to maintain a safe environment and preserve pavement quality.

Pavement marking removal is complicated in that there is not a simple solution that can be applied to all situations. Each job requires careful consideration of numerous factors to determine the best approach to remove the markings. The marking then needs to be removed by an experienced operator such that the marking is removed to an adequate level and the pavement is not damaged.

A primary objective of this research was to develop a standalone airfield guide for airport operators and engineers to identify and develop best practices for the efficient, safe, cost-effective, and environmentally acceptable techniques concerning pavement marking removal and temporary marking applications. The guide addresses permanent marking removal, temporary marking applications, and temporary marking removal. The guide provides information and best practices to improve pavement marking removal at all airport types and on all pavement surfaces. Researchers also developed a field inspection guide to be used by inspectors and contractors to improve marking removal.

To meet the research objectives, researchers conducted a comprehensive literature review, nationwide survey, and field visits to inspect markings removal and temporary marking applications. The literature review included all relevant literature to airfield pavement marking removal and temporary marking applications. Researchers expanded the literature review to include removal and temporary marking application from highways due to similarities to removal and temporary markings on airfields. The research team conducted a nationwide online survey that received 29 responses and included four follow-up virtual interviews. The research team visited 12 field sites to gather information on various pavement marking removal and temporary marking operations. Multiple sites had temporary marking applied and were visited twice to witness the application and subsequent removal. This research report documents the results of the various information gathering efforts.

The researchers used the information gathered to develop the “Airfield Guide for Engineers” and “Field Inspection Guide.” These two standalone documents contain findings and best practices to improve pavement marking removal and temporary marking applications. The “Airfield Guide for Engineers” provides guidance to engineers and others tasked with removing airfield markings from a variety of pavements by using a variety of methods and mitigating the appearance of scarring and reducing pavement damage from marking removal. The airfield guide includes best practices for efficient, safe, cost-effective, and environmentally acceptable techniques for marking removal and temporary marking applications. The airfield guidebook includes a comparative matrix of removal techniques and associated challenges along with innovative methods and materials to improve results by reducing confusion caused by remaining marking material and scarred pavement created by removal operations. The field inspection guide is developed for use in the field when inspecting pavement marking removal operations on

airfield pavement markings. Contractors will benefit by using this guide to help improve removal operations.

## CHAPTER 1. INTRODUCTION AND OVERVIEW

Airfield pavement markings are critical to safe and efficient movement of vehicles on the airfield. Airfield construction and maintenance activities often results in airfield pavement markings needing to be removed or obliterated and temporary markings installed. Removal operations can leave pavement scarring or traces of the preexisting marking material behind, which may be confusing to observers and reduce the safe and efficient movement of vehicles. Confusion may be greater in some viewing conditions compared to others (e.g., wet/dry, day/night/glare) and may also be influenced by viewing geometry determined by vehicle type. The scarring may also damage the pavement surface, reducing its effective life.

This project was developed to better understand airfield pavement marking removal methods and temporary marking applications that minimize the potential for confusion to help prevent accidents and incidents on airfields. The primary objective of this research is to develop an airfield guide for airport operators to identify and develop best practices for the efficient, safe, cost-effective, and environmentally acceptable techniques concerning pavement marking removal and temporary marking applications. The guide will address permanent marking removal, temporary marking applications, and temporary marking removal. The goal is to improve pavement marking removal practices at all airport types and on all pavement surfaces.

Airfield markings are a vital component to navigating runways and taxiways for many vehicle types. Aircraft of varying sizes, emergency vehicles, motor vehicles, and service vehicles (e.g., baggage tugs and tow vehicles) rely on pavement markings to “convey the proper message” to those different users. The markings must be visible under all conditions.

Over the years the airport industry has been challenged to provide airfield markings that are effective. The Federal Aviation Administration (FAA) and other government agencies support guidance for airport operators to maintain markings. While the challenges are many, they can be reduced to one key and vital characteristic: visibility.

The *Airfield Marking Handbook*, originally published in 2008, addresses many of the challenges facing the airport industry and remains a leading document for best practices in the installation and maintenance of airfield markings (1). However, new policy introduced by the FAA in 2013 with respect to the removal of airfield markings has ushered in new challenges.

The current, FAA Advisory Circular on *Standards for Airport Markings 150/5340-1M* includes the following directive for marking removal:

“The physical removal of any old marking(s) must include a pre-determined larger size and shape of a removal area that encompasses the old marking(s) and by grouping adjacent markings together into a larger rectangular removal area. The rationale behind this practice is to eliminate the continued visual appearance of the removed marking(s).” (2)

Airfields are frequently subjected to reconstruction to rehabilitate the pavement surface, extend a runway or taxiway, or add a taxiway, among others. During any of these efforts, existing airfield markings can be subject to realignment and removal during phasing of the construction project. Temporary markings are often required to displace a threshold or detour traffic around a construction area. Those temporary markings are sometimes required to be removed, often from new pavement, resulting in scars. These scars can result in permanent damage to the pavement surface and often times result in texture or color changes that take years to resolve due to natural wear.

## **RESEARCH OBJECTIVES**

The research objective is to prepare an airfield guide for airport operators to identify and develop best practices for the efficient, safe, cost-effective, and environmentally acceptable techniques for (1) permanent marking removal and (2) application and removal of temporary markings to ensure aviation operational safety and to minimize the adverse impact on airfield pavement. A second objective was to develop a field guide to be used by inspectors and contractors when out in the field conducting marking removal or temporary marking applications.

To meet these objectives, researchers conducted a comprehensive literature review, nationwide survey, and field visits to inspect markings removal and temporary marking applications. This report contains the results of those efforts. Researchers used those results to develop the “Airfield Guide for Engineers” and “Field Inspection Guide.”

## **REPORT ORGANIZATION**

This report documents the research activities conducted to meet the research objectives. Chapter 1 provides an overview of the research topic and objectives. Chapter 2 documents relevant literature and practices. Chapter 3 documents the results of a nationwide survey of airfield pavement marking removal and temporary marking applications. Chapter 4 summarizes site visit evaluations of pavement marking removal and temporary marking applications. Chapter 5 provides findings, best practices, and suggested research. References and two appendices are also provided. Appendix A provides the full list of survey questions documented in Chapter 3. Appendix B provides additional information from the site visits described in Chapter 4. In addition to this report, there are two separate guidance documents that can be downloaded. These documents are the “Airfield Guide for Engineers” and “Field Inspection Guide.” The “Airfield Guide for Engineers” is intended to provide guidance to airport operators, engineers, and others tasked with removing airfield markings from a variety of pavements by using a variety of methods and mitigating the appearance of scarring resulting from marking removal. The “Field Inspection Guide” is developed for use by inspectors and removal crews in the field when conducting and inspecting pavement marking removal and temporary marking applications on airfields.

## CHAPTER 2. SYNTHESIS OF LITERATURE AND PRACTICE

### BACKGROUND

Airfield markings are a vital component to navigating runways and taxiways for many vehicle types. Aircraft of varying sizes, emergency vehicles, motor vehicles, and service vehicles (e.g., baggage tugs and tow vehicles) rely on pavement markings to “convey the proper message”(3) to those different users. The markings must be visible under all conditions.

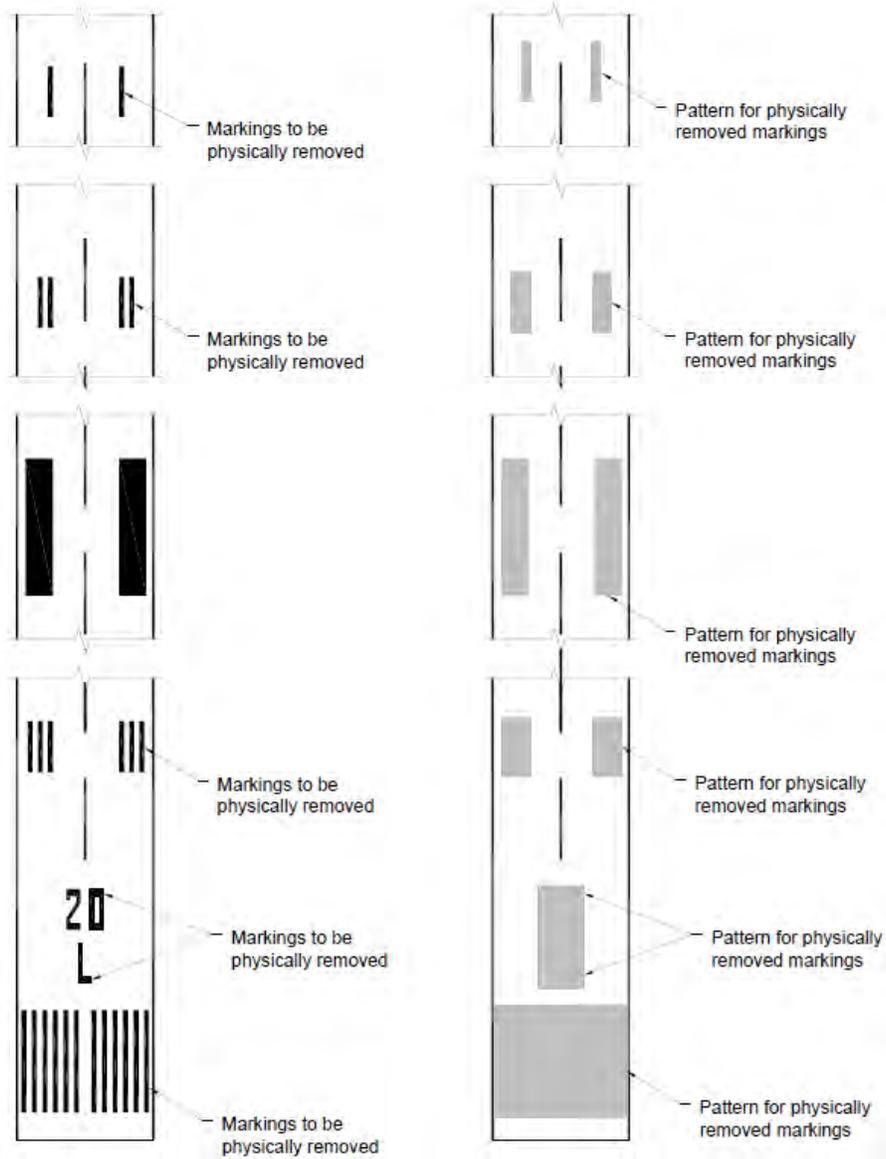
Over the years the airport industry has been challenged to provide airfield markings that are effective. FAA and other government agencies support guidance for airport operators to maintain markings. While the challenges are many, they can be reduced to one key and vital characteristic: visibility.

### CURRENT STANDARDS AND DOCUMENTATION

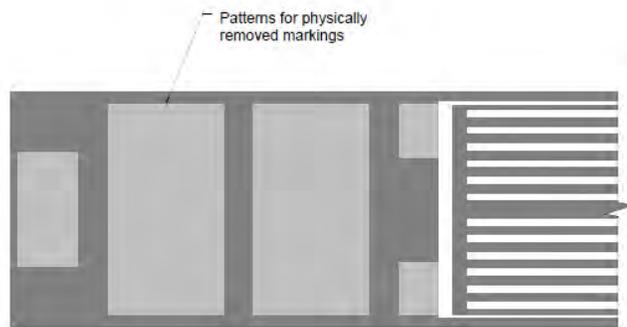
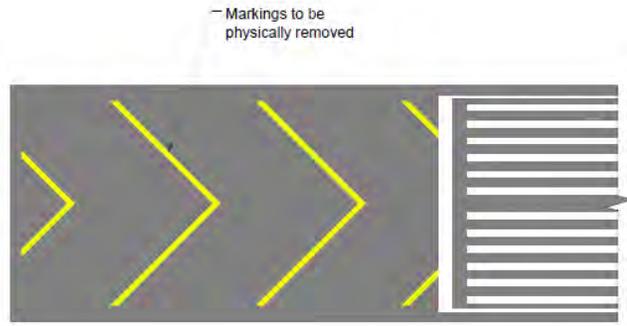
The *Airfield Marking Handbook (1)*, originally published in 2008, addresses many of the challenges facing the airport industry and remains a leading document for best practices in the installation and maintenance of airfield markings. However, new policy introduced by the FAA in 2013 with respect to the removal of airfield markings has ushered in new challenges.

In May 2019, FAA Advisory Circular 150/5340-1M was published (2). This advisory circular updated the 2013 version which included specific new information concerning pavement marking removal. The following directive for marking removal is in the document Section 1.3, Surface Marking Practices, subsection 1.3.6, Removal of Markings:

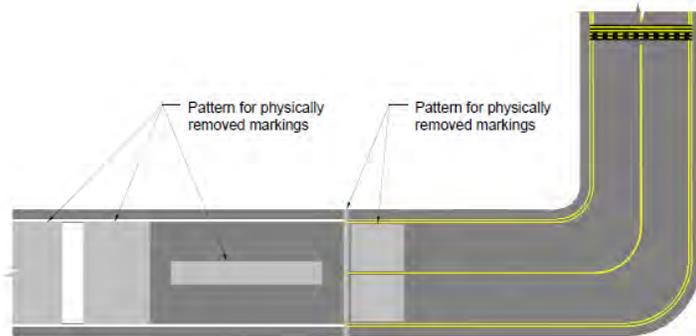
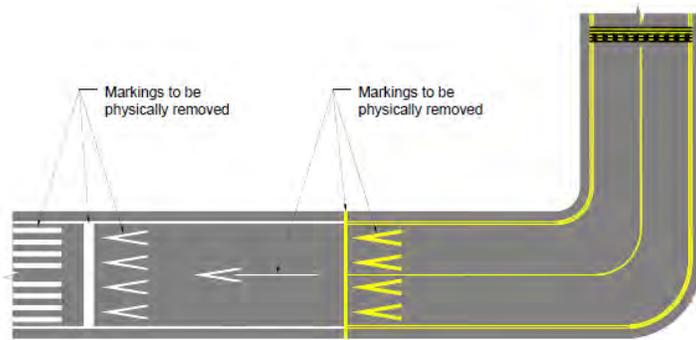
“Pavement markings that are no longer needed are not to be painted over but instead are to be physically removed. The FAA does not endorse painting over the old markings because this inadequate practice merely preserves the old marking which, in some cases, has misled pilots and required extra maintenance. Physical removal of markings is achieved by water blasting, shot blasting, sand blasting, chemical removal, or other acceptable means that do not harm the pavement. The physical removal of any old marking(s) must include a predetermined larger size and shape of a removal area that encompasses the old marking(s) and by grouping adjacent markings together into a larger rectangular removal area. The rationale behind this practice is to eliminate the continued visual appearance of the removed marking(s) (2).” Several figures providing examples of how to remove different marking patterns are included in the document (see Figure 1, Figure 2, and Figure 3).



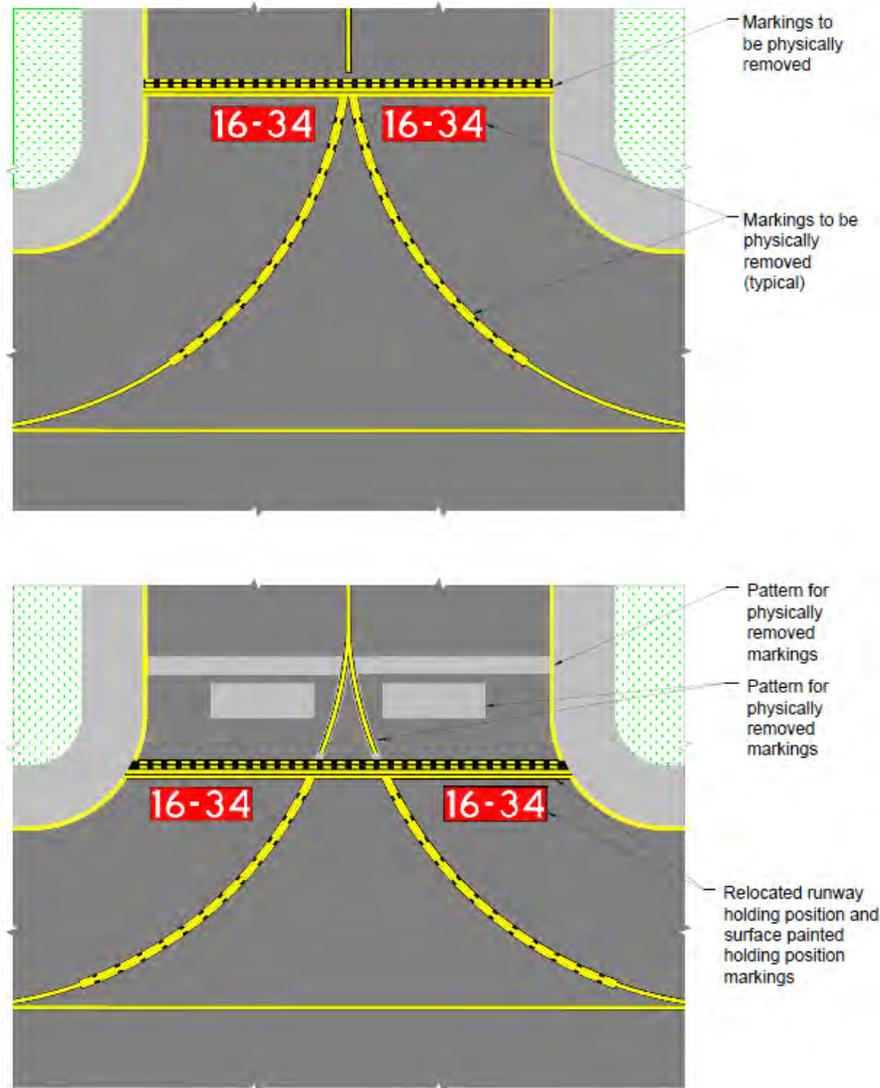
**Figure 1. Example of Marking Removal Pattern (2).**



**Figure 2. Example of Marking Removal Pattern (2).**



**Figure 3. Example of Marking Removal Pattern (2).**



**Figure 4. Example of Marking Removal Pattern (2).**

The 2019 FAA Advisory Circular 150/5340-1M also includes new subsection 1.3.8 (2). The new subsection states that, “Personnel involved in the application of airfield surface markings should complete training which includes surface preparation, removal and application of surface markings, and maintenance standards.”

Marking removal is unique to an airport’s “airside” versus “landside.” Attention to the type and thickness of the material to be removed, as well as the type and condition of the pavement surface, must be considered when prescribing a method(s) for removing markings on both roadways and airfields. Unique to airfields are challenges related to foreign object debris (FOD), grooved surfaces, and increased marking width, among others.

“Scarring will occur when paint is removed from the pavement surface (1).” The binder (coating) is bonded to the microtexture of the surface; therefore, removing the coating will remove some of the fines (microtexture) from the pavement, resulting in a scar. The remaining scar is visible based on the method of removal, the degree of removal required, the condition of the pavement under the coating, and even the skill of the operator of the removal equipment.

Scarring as the result of marking removal was the motivation behind the 2013 update to the advisory circular for airport markings.

The degree of removal required depends on the reason for the removal. Like highways, paint builds up from repeated remarking efforts, resulting in thick paint. However, unlike highway markings, airfield markings must be at least partially removed periodically to reduce the likelihood of paint and glass bead chunks from becoming FOD. The removal does not have to be complete if the marking will be reapplied in the same place. However, if the marking to be removed is obsolete, more complete removal would be required to reduce the likelihood of confusion resulting from the partial visibility of the old marking.

Portland Cement Concrete (PCC) pavements are more resilient to removal operations than Asphaltic Concrete Cement (ACC) pavements, but visible scars that replicate the old markings are still possible on PCC. Joints in PCC pavements must be protected during removal operations to prevent damage. More care must be exercised on ACC, especially on grooved pavements and pavements that have been treated with crack seal.

Airfields are frequently subjected to reconstruction to rehabilitate the pavement surface, such as extending the runway or taxiway, or add a taxiway, among others. During any of these efforts, existing airfield markings can be subject to realignment and removal to facilitate safety in phasing during the construction project. Temporary markings are often required to displace a threshold or detour traffic around a construction area. Those temporary markings are sometimes required to be removed, often from new pavement, resulting in scars. These scars can result in permanent damage to the pavement surface, and often result in texture or color changes that take years to resolve due to natural wear.

## **AIRFIELD STANDARDS AND SPECIFICATIONS**

### **Removal**

Several different organizations are responsible for the specification of airport surface markings. These organizations include FAA, the International Civil Aviation Organization (ICAO), and the United States Department of Defense (DoD). Through these organizations, the design of airport markings is standardized throughout the world. Documents of interest in the literature review include the ICAO Aerodrome Design Manual, FAA Advisory Circulars, and the DoD Military standards for the operation of military airfields.

These documents are continuously updated. For example, the FAA Advisory Circular 150/5340-1M- Standards for Airport Markings (2) was most recently updated in 2019, after being previously updated in 2013. The major update regarding marking removal in the 2013 document was due to removal scarring that creates a rougher texture than the rest of the runway surface. Under certain circumstances (e.g., specific weather and sun angles), these textures can be mistaken by pilots as current markings. Blending the removed area into the surrounding pavement to reduce clear edges between the removed marking area and the surrounding pavement was seen to be beneficial from a visibility perspective.

Effective Airfield Markings (4) points out that pavement surfaces must be cleaned by water blasting, shot blasting, or mechanical method to remove paint, followed by sweeping, blowing, or other method to remove debris. The *Airfield Marking Handbook (1)* recommends surface preparation using water blasting to remove loose paint, algae, oils, and other debris prior to marking application. The authors recommend shot blasting for non-grooved surfaces, water

blasting for all surfaces (pressures from 10–40K psi depending on type of water blasting system). However old pavement in poor condition (cracked, worn) requires extra care to prevent damage. Table 1 illustrates the recommended practices for grooved and ungrooved pavements for asphalt, concrete, and poor asphalt (1). For poor condition asphalt, a combination of methods should be used to minimize damage as shown by the note in Table 1.

**Table 1. Matrix of Processes for Marking Removal Versus Surface.**

	Grooved concrete	Ungrooved concrete	Grooved asphalt	Ungrooved asphalt	Grooved poor asphalt	Ungrooved poor asphalt	Sealcoat after
Grinder	No	Yes	No	Yes	No	Yes	Yes
Shotblaster	No	Yes	No	Yes	No	Yes*	No
Sandblaster	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Waterblaster (all pressures)	Yes	Yes	Yes	Yes	Yes*	Yes*	Yes*

Yes\*—Use in combination with other mechanical methods such as grinding in order to minimize the damage on poor asphalt.

The Standard Specifications for Construction of Airports (5) AC 150/5370-10H specifies removal of markings with rotary grinding, water blasting, or other for minimal pavement damage. It also specifies applying a seal coat (heated asphalt or tar applied in a thin layer or fog seal (asphalt emulsified in water) to obscure the scars and ghost markings. The U.S. DOT Advisory Circular for Standard for Airport Marking (2) AC 150/5340-1M specifies marking removal again water blasting, shot blasting, but also mentions sand blasting, chemical removal, or any other method that does not harm pavement. AC 150/5370-10H has a minor conflict with AC 150/5340-1M concerning removing an area larger than the marking. AC 150/5370-10H indicates that, “The removal area may need to be larger than the area of the markings to eliminate ghost markings.” AC 150/5340-1M indicates that the removal “must include a predetermined larger size and shape of a removal area.” The difference between the two documents is a “may” vs a “must.” One document allows some flexibility based on site conditions whereas the other does not. Removing a larger area can reduce the identification of the scarring as operational markings but may cause unnecessary damage to the pavement (2, 6).

## Temporary Markings

FAA Advisory Circular 150/5370-2G: Operational Safety on Airports during Construction (6), describes methods for providing temporary markings and other signage to prevent aircraft from overrunning or undershooting the active, available runway length during construction. Case studies of specific events are referenced, including: Le Bris, G. Safety of the Runway Operations with a Temporary Displaced Threshold during Construction Works. Presented at Transportation Research Board 93rd Annual Meeting, 2014 (7).

New runway thresholds should be denoted with yellow chevron bar for shortened runways (7, 8, 9, 10). Barricades with red lights, and flags and cones identify construction zones and new traffic patterns. Orange construction signage have been recommended to convey important messages to pilots and to prevent pilot confusion (8, 9). Multiple sources recommend Lighted X structures (fabric and wood, moveable), or painted markings (x's) in yellow covering initial threshold which denote runway closed (8, 9, 10). Mobile lighted fabric and wood was common to all three sources. Permanently closed runways marked with yellow X.

The Standard Specifications for Construction of Airports (5) specifies that the allowed paint types for temporary markings include waterborne, epoxy, methacrylate, solvent-based, and preformed thermoplastic. Operational Safety on Airports during Construction (6) specifies that closed runway markings can be painted or fabric, colored plastic, painted sheets, plywood, etc. Type II paints should be used for temporary markings. Type II paints are defined as fast drying waterborne paint (11). The *Airfield Marking Handbook* (1) specifies markings should be painted with water-borne paint III (11). Temporary markings should be placed with a thinner layer of water-borne paint or with a layer of wax-based curing compound on pavement first. Black border should be used (for light pavements) to contrast with markings (12).

## AIRFIELD LITERATURE

There is limited literature specific to airfield marking removal and temporary marking applications. Literature including guidance documents and criteria that were found have been summarized.

### Removal

The literature is clear that relocated markings are hard to distinguish. Many recommend removing the old threshold markings completely or covering (13). Black/gray paint is recommended to temporarily cover extraneous markings (14). However, the *Aerodrome Design Manual, Part 4: Visual Aids* (15) states that markings cannot be removed by obscuring with black/gray paint due to the potential of the marking to be seen in certain conditions, i.e. glass beads showing through the covering paint. Sandblasting recommended for all markings, high-pressure water blasting recommended for some, and grinding not recommended at all. Chemical removal recommended where allowed. Removal by burning is not recommended. Included in the *Aerodrome Design Manual* are in-depth recommendations for the selection, painting, and removal of paint markings; Part 4, Appendix 3 (15).

The most recent update in the literature (based on the 2013 update to the advisory circular standard for airport markings (2)) has been that the removal must be in large square/rectangle since all removal results in scarring or discoloration of some kind (16). Beyond the initial scarring and discoloration asphalt pavements lighten with age and concrete pavements (Portland Cement Concrete or PCC) darken with age (17). This is likely due to a combination of factors: sunlight bleaching, rubber and dirt deposition, and surface texture wear.

Water blasting, shot blasting, or grinding are recommended for removing marking paint (18). Another source suggests using water blasting to clean all markings (19). "Denver International Revamps Pavement Markings Program" from *Airport Improvement Magazine* (20) states that over-maintenance had been a problem and recommended refreshing the pavement

before deciding to repaint using water blasting. High pressure water blasting, high pressure air blasting, and grinding should be used to remove high build paints (21).

High pressure water blasting at 40,000psi and vacuuming can be used to remove rubber, epoxy, tape, thermoplastic, cure compound, and paint from asphalt and PCC. The technology also cleans runways and markings (22). The waste is dehydrated and stored (23, 24). Paint stripe and rubber removal services have been offered using mechanical grinding combined water-blasting at 40,000 psi (25).

## **Temporary Markings**

A Quick Reference to Airfield Standards (16) summarized many of the marking standards. Temporarily closed runways must be demarcated with lighted, yellow X at all times (can be constructed of wood and fabric, plastic, paint, etc.). Partially closed runways be demarcated with yellow chevrons at all times (can be constructed of wood and fabric, plastic, paint, etc.).

Airfield and Heliport Markings (14) specifies marking permanent markings with lead-free pavement-marking paints at 12-14 mils thickness but specifies marking temporary markings with lead-free pavement-marking paints at 4-6 mils thickness. It states thermoplastics or preformed tapes can be used on taxiways and aprons. For construction, lighted barricades, traffic cones, or portable markers can be used. Use black/gray paint to temporarily cover extraneous markings. Again, this paper states temporarily closed runways marked with a large, lighted X (painted/wood and fabric).

Surface painted signs need edges that contrast pavement color (26) and a black border is always needed for markings on PCC, but only for asphalt 2+ years old (16). Some information should be displayed on variable message signs because they are easier to change than painting (27). Again, ICAO indicates large, yellow X (painted/fabric and wood) is specified to denote closed pavement and surface painted signs need edges that contrast pavement color (27). Markings must be painted with oil (alkyd) base paint or water emulsion base paint on PCC or asphalt (15).

During a surface markings durability study project (28), water-based I, water-based II, water-based III, methyl methacrylate (MMA), structured MMA, and preformed thermoplastic in yellow, white, red, and black with and without beads were tested on asphalt and PCC. Retroreflectivity, chromaticity, rubber coverage, and friction tests were completed. White and black markings maintained color over time, red and yellow faded, Type III beads are most reflective, and cleaning rubber off markings does not return them to their original reflectivity/chromaticity.

## **HIGHWAY LITERATURE**

There is much more literature related to highway marking removal and temporary markings compared to airfield specific literature. Much of the removal equipment and temporary marking material are very similar between highways and airfields. The biggest differences are in the marking patterns, FOD, and pavement surfaces. Grooved surfaces are more prevalent on airfields than they are on highways. Literature that was specific to highway pavement marking removal and temporary marking applications has been summarized as there are best practices and lessons to be learned to benefit airfield activities. Not all highway applications will be applicable to airfield applications.

## Removal

National Cooperative Highway Research Program (NCHRP) Report 759: Effective Removal of Pavement Markings explored methods and best practices for removing markings from highways (29). The report documents the advantages and disadvantages of current and emerging marking removal systems. Since roadway and airport surfaces are similar, this report should be directly applicable to this project. There is considerable information provided on best practices to minimize pavement damage while removing the markings and leaving a surface that is not confusing to observers. Some of that information is summarized below:

- Factors to consider when selecting removal method:
  - o What marking material is being removed?
  - o What road surface is the material on?
  - o How much of the material needs to be removed (what is the purpose of the removal)?
  - o Is speed of removal important?
  - o What removal techniques are available and at what cost?
  - o Are there special environmental conditions that need to be considered?
  - o How long will the removed area be viewed by drivers (will a new surface be installed, or markings restriped in the future)?
  - o Will the removed area be in a location where confusion could lead to an accident?
  - o Are there other measures that can be taken to minimize confusion to the driver?
- Removal should be specified based on the percent removal required which should relate to the purpose of the removal. See Table 2 from the report.

**Table 2. Suggested Percentage Removal Based on Purpose of Removal.**

<b>Purpose of Pavement Marking Removal</b>	<b>Suggested Percent Material Removed</b>
Change marking patterns	90–95 (100 percent may be necessary in some instances)
Remove and replace compatible materials	70–90 Follow new marking material manufacturer guidelines
Remove and replace incompatible materials	80–100 Follow new marking material manufacturer guidelines
Apply surface treatment or new surface overlay	Follow state guidelines

- Obscuring scarring
  - o Fog/Slurry seals work to blend in marking removal scars on asphalt roads.
  - o Larger area washed/cleaned with high-pressure water blasting system to obscure scarring on PCC.
- Consideration of removal technique advantages and disadvantages, see Figure 5.

Removal Method	Advantages	Disadvantages
Grinding	<ul style="list-style-type: none"> <li>• Fast and economical</li> <li>• Depending on the system configuration (effective vacuum system installed to remove dust), dust created by removal can be contained</li> <li>• High availability</li> <li>• Effective at reducing the thickness of thick marking materials such as thermoplastic or multiple layers of paint prior to restriping</li> </ul>	<ul style="list-style-type: none"> <li>• Damage to pavement surface</li> <li>• Scarring with full marking removal</li> <li>• Minimizing damage to roadway may leave marking material behind</li> <li>• Orbital flailing may result in less noticeable scarring than drum flailing due to tapered edges</li> <li>• Non-vacuum systems can create dust clouds and be hazardous</li> <li>• Tape removal can be messy</li> </ul>
High-Pressure Water	<ul style="list-style-type: none"> <li>• Byproduct does not create dust and is contained within the equipment</li> <li>• Little to no scarring on good PCC</li> <li>• With the exception of drying time, the pavement surface is prepped for pavement marking reinstallation</li> <li>• Relatively fast for a blasting method especially for thin marking materials</li> <li>• Large vehicle mobile systems available with additional utility carts for smaller nearby areas</li> </ul>	<ul style="list-style-type: none"> <li>• Limited to above-freezing conditions</li> <li>• May polish surface aggregate and/or clean the surrounding pavement, creating a color contrast</li> <li>• May remove some surface asphalt and fines that could lead to water penetration</li> <li>• Potential for damage to pavement joints</li> <li>• Proper equipment operation critical to achieve good results</li> <li>• Currently not widely available, higher costs</li> </ul>
Sand Blasting	<ul style="list-style-type: none"> <li>• Minimal pavement degradation</li> <li>• Little to no scarring</li> <li>• Hand-operated precision</li> <li>• Effective on thin markings</li> </ul>	<ul style="list-style-type: none"> <li>• Creates considerable byproduct</li> <li>• Creates considerable dust</li> <li>• No current large vehicle mobile system, therefore slower than mobile methods</li> <li>• Health hazards depending on blast media</li> <li>• Less effective on thick markings</li> </ul>
Shot Blasting	<ul style="list-style-type: none"> <li>• Minimal pavement degradation</li> <li>• Little to no scarring</li> <li>• Minimal byproduct</li> <li>• Byproduct does not create dust and is contained within the equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Shot recovery can be problematic especially on uneven surfaces</li> <li>• Cannot be used in wet conditions</li> <li>• Can be slow especially for thicker markings</li> <li>• Can cause pavement damage on non-smooth surfaces</li> <li>• Limited availability of equipment</li> </ul>
Other Media Blasting (Dry Ice, Soda, etc.)	<ul style="list-style-type: none"> <li>• Minimal pavement degradation</li> <li>• Little to no scarring</li> <li>• Minimal environmental concerns with respect to debris generated</li> <li>• Marking can be completely removed</li> <li>• Hand-operated precision</li> </ul>	<ul style="list-style-type: none"> <li>• Can create a moderate amount of byproduct</li> <li>• Can create considerable dust</li> <li>• Can be slow especially for thick markings</li> <li>• Only useful on some markings, typically paint only</li> <li>• Dry ice is a difficult medium to handle and store</li> <li>• Very noisy</li> <li>• No current large vehicle mobile system</li> </ul>
Chemical	<ul style="list-style-type: none"> <li>• Byproduct does not create dust</li> <li>• Can get complete removal without scarring</li> </ul>	<ul style="list-style-type: none"> <li>• Potential to damage pavement surface if incorrect removing agents are used</li> <li>• Requires at least one additional pass to remove residue</li> <li>• Slow, need to wait for chemical to react then proceed with removal</li> <li>• Some chemicals may pose an environmental risk</li> <li>• No current large vehicle mobile system</li> <li>• Only useful on some markings, typically paint</li> </ul>
Masking	<ul style="list-style-type: none"> <li>• No damage to road surface</li> <li>• Existing markings can be temporarily covered with tape that matches the road surface color and texture, and later reused when the tape is removed</li> <li>• Removed areas can be masked to help blend in scarring or surface color changes</li> <li>• Can be used in lane-shift areas to reduce driver confusion due to ghost markings or scarring</li> </ul>	<ul style="list-style-type: none"> <li>• Can be expensive</li> <li>• Material may wear away, exposing the markings being covered</li> <li>• Difficult to match color and texture with tape</li> <li>• Tape is for temporary purposes only</li> <li>• Cannot use marking materials other than tape to cover a marking</li> </ul>

**Figure 5. Advantages and Disadvantages of Removal Methods (29).**

A study on the effectiveness of methods for removing temporary pavement markings (30, 31) states that results were significantly influenced by operator skill and experience, thickness of marking, and type of equipment used. Using a chemical stripper (no MeCl) left little/no paint when removing 12/20 mils of water-based paint/solvent-based paint on concrete or asphalt. Water blasting worked the well on concrete when removing 12 mil water-based paint. Shot blasting removed 12 mils water-based paint completely from asphalt with minimal/no scarring. Water blasting removed tape from asphalt completely with minimal/no scarring. Scarifying, heat torch, shot blasting, dry ice blasting, and water blasting all removed the tape with minimal/no scarring, but due to weather during installation the tape adhesion may have not been acceptable.

In another study, dry ice blasting removal resulted in minimal pavement degradation on concrete and no shadow lines, but very slow and pitted the chip seal. Carbide grinding was the fastest, but degraded PCC and asphalt and left shadow lines. Diamond bit (COMAX) grinding fast, but also degraded PCC and asphalt and left shadow lines. The hydroblaster was fast, left no shadow lines, and caused less pavement degradation than the grinding methods. The hydroblasting was the most effective of the methods tested. Soda blasting showed lowest pavement degradation and no shadow lines, but slow and created a lot of dust (32).

Development of Improved Procedures for the Removal of Pavement Markings during FDOT Construction Projects (33) tested: water blasting at high pressures, grinding, and a combination of both. Ultra-high-pressure low volume water blast worked best for 20 mil water-based paint, 100 mil of thermoplastic, 90 mil of thermoplastic, and 35 mil temporary tape in speed, degree of removal, and minimal scarring.

Methods for Removal of Pavement Markings (34) summarized several approaches to removal:

- Sandblasting: good on paint and epoxy, slow on thermoplastic, ineffective on plastic tape, and very slow on foil tape.
- High-Pressure Water: good on paint and epoxy, slow on thermoplastic, ineffective on plastic tape, and ineffective on foil tape.
- Hydroblaster: good on paint and epoxy, slow on thermoplastic, ineffective on plastic tape, and ineffective on foil tape.
- Grinding: good on paint and epoxy, good on thermoplastic, ineffective on plastic tape, and ineffective on foil tape.
- Excessive-Oxygen Burner: good on thin lines of paint; ineffective on epoxy, thermoplastic, and plastic tape; and good on foil tape.
- Chemicals: slow on paint; ineffective on epoxy, thermoplastic, plastic tape, and foil tape.
- Hand Removal: not applicable on paint and epoxy, very slow on thermoplastic and plastic tape, and ineffective on foil tape.
- Sandblasting or water blasting: completely remove lines with little color and texture changes to pavements.

In older references, a combination of sandblasting and kerosene and linseed oil was most successful on concrete and bituminous (asphalt) pavements (35). Regular pavement marking paint (used in Minnesota) has been removed by gas and oxygen burner followed by light scarification (36). Lower-pressure water blaster has been used to remove marking paint from asphalt without removing the aggregate (36).

A semi-automated stripe removal system that could be used on road or airports to remove markings from asphalt and PCC was developed using CO<sub>2</sub> (dry ice) blasting. While removal performance was slower than other methods, the testing showed the concept could work to

remove paint markings. The paper did not discuss the impacts to the pavement and if the surface texture was change as a result of the removal or not (37). A grinder with torch is the most widespread technique used in Korea (38). The grinder removes the bulk of the marking and the torch is used to remove residue. The experiment replaced the torch with dry-ice blasting and compared to other approaches (38). Soda blasting was slow, but cleanly removes markings. Scarifying fast, but damages pavement (planer had similar results). Sand blasting more effective than grinder, water blaster, and grind and water blaster because the effectiveness of water blasting dependent upon spray pattern. Optimal dry-ice blasting is when a wide nozzle is 5cm from the surface at a 60° angle at 10 bars of pressure is used. Research on Improvement of System for Automatic line Stripe removal using dry ice blaster (2014) (39) further developed the removal system using CO<sub>2</sub>/dry ice blasting by using a larger spray tip and incorporating a needle scaler to damage the marking prior to the dry ice blasting. The best paint removal from asphalt was by a dry ice blaster with a wide nozzle (85mm), 7cm above roadway, and at a 90° angle with a needle scaler (residue removed with pneumatic system). The removal was still slow and not feasible for a large job that needs to be completed quickly.

A CO<sub>2</sub> laser-based removal system was tested on standard yellow latex enamel paint (40) and resulted in complete ablation of the marking on asphalt pavement with no scarring or damage to the pavement itself at production rate of 0.44 square inches/sec (264 ft/hr). The laser ablation was slower than grinding, sand blasting, and water blasting, but better at removing line with no pavement damage or ghost lines on concrete pavements and HMA (hot mix asphalt) pavements.

Another laser-based removal experiment used a Nd: YAG laser to remove paint by outgassing the paint matrix (41) and causing it to chip off. The removal used short-pulse lasers that didn't heat paint above temperatures of 100°C. A 3M striping machine was modified to carry the large Nd: YAG laser apparatus; the expected prototype cost ~\$100,000. Removal was slow and caused some smoke. The removal quality was inconsistent and recommendations to develop a system to monitor marking thickness to remove thick areas more effectively were proposed.

The New Zealand Line-Removal-Guide (42) gives removal guidance on quite a few relevant pavement types. The following table (Table 3) shows recommendations for paint type vs. pavement type. The numerical coding is below:

1. High Pressure Water Cutting/Milling.
2. Grinding/Scabbing.
3. Abrasive Blasting.
4. Water Blasting—Sodium Bicarbonate System.
5. Chemical Paint Removers.
6. Heat Lance.
7. Permanent Overlay.\*
8. Mechanical Destruction.
9. Void Concealment following 1, 2, 3, or 4.

Any combination of removal technique that needs # 9 “Void Concealment” implies pavement surfaces are scarred by the recommended technique.

**Table 3. Matrix of Removal Techniques vs Marking and Pavement Type (42).**

	Chip Seal	Open Graded Asphaltic Concrete	Dense Graded Asphaltic Concrete	Concrete	Pavers
Solvent-Borne Paint	1,3,4	(1 or 4) + 9	(1,2,3,4) + 9 (2+7)	1,2,3,4,5	1,3,4,5
Water-Borne Paint	1,3,4	(1 or 4) + 9	(1,2,3,4) + 9 (2+7)	1,2,3,4, or 5	1,3,4,5
Thermoplastic	1,3,6+8	1,3 8+(1 or 3)	1,2,3,2+7, 6+8,8+(1 or 3)	1,2,3,5 8+(1 or 3)	1,3,4,5
Preformed Thermoplastic	1,3	1,3 8+(1 or 3)	1,2,3,2+7, 8+(1 or 3)	1,2,3,5 8+(1 or 3)	1,3,4,5
Cold-applied Plastic	1,7	1,7	1,7	1,2,3	1,3
Temporary Tape	7	6	6	6	6
Permanent Tape*	1,7	1,6	1,2	1,2	1,7

\*Permanent overlay (paint, tape, etc.) is okay to use in New Zealand, not in the United States.

High temperature burning with excess oxygen can remove paint lines from asphaltic concrete or PCC (43) with minimal damage to pavement and no ghost lines. However, PCC surfaces may “surface spall” from the excess heat so an experienced operator may be needed. The technique removed 20 mil of paint per pass. Burned residue should be removed with wire brush, hydro brooming, or light sandblasting (preferred). Any remaining residue gets “driven off” in 30–90 days. The technique will not remove foil tape, thermoplastic, or preformed plastic marking material, likely due to the inability to oxidize these materials.

Hydroblasting removes thermoplastic with no debris or smoke (44) when operated at 40,000 psi with vacuum system. Waterjet removal of temporary paint markings was superior (lower cost and better markings/removal) to using adhesive removable temporary tape on asphalt (45). Some references recommend that scarifiers/grinders are good for asphalt or concrete where the line is to be removed and immediately repainted (46, 47) because full removal and scarring are not an issue.

Development of improved procedures for managing pavement markings during Florida Department of Transportation (FDOT) highway construction projects (48) investigated the use of sand seal coat materials versus temporary tape to cover existing markings on asphaltic (asphalt) pavement. Literature was reviewed for chemical methods, excess-oxygen burning, grinding, high-pressure water jet, hot compressed-air burning, hydro-blasting, and sandblasting on asphaltic pavement:

- Chemical methods caused chemical damage to pavement.

- Grinding results in scars.
- Water blasting removed aggregates.
- Hot compressed air burning creates a scar and damages pavement.
- Hydro-blasting results in scars and scours/polishes aggregate surface.
- Sandblasting damages pavement.
- Motor grader causes tremendous damage.
- Black paint wears off quickly.
- Laser removal far too expensive at this time.

Sand seal coat covering temporary markings was quick, easy, and inexpensive, left no scars, obscured completely, and was durable. Covering tape was also successful at obscuring markings on asphalt pavement (48).

British guidelines recommend hot compressed-air lance, mechanical scabbling, or shot blasting for line removal, or the use of 40mm thin surfacing for temporary markings (49).

All options for removing pavement markings leave ghost lines, scarring etc., and are not a good option for temporary lines, instead cover lines with a construction-only color. Fluorescent orange MMA paint catches driver attention and is applicable on asphaltic pavement and PCC (50).

Special-Color Pavement Marking for Highway Work Zones (51) investigated use of orange pavement markings to overcome typical issues with marking removal. The intent was that the orange temporary markings would be more noticeable than scarring or marking residue left by typical removal operations. Results from NCHRP Report 759 (29) were reviewed to help justify the need for better work zone markings. Removal types reviewed included high-pressure water blasting (heavy/light), flailing (heavy/light), and orbital flailing (heavy/light). All left visible scarring and/or ghost lines on asphalt. Black line masking tape hard to match to existing pavement color and wears out quickly. Gray/black paint can be customized to match color surface but wears away quickly. Sealing and microsurfacing can cover up scars/ghost lines or existing lines. Micromilling cuts entire pavement surface down less than one inch to obscure ghost lines or scars but must be across the entire lane or lanes.

A Roundabout Way of Striping (52) found that shot blaster damaged asphalt (removed aggregates and caused pitting). Scarifier became clogged with thermoplastic and was not efficient. Heat torch and heated shovel, followed by a rotary grinder equipped with sanding pads removed the thermoplastic cleanly from the asphalt but was very slow.

Hydraulic sandblasting was developed during another effort to remove markings from asphalt (53). The result was minimal asphalt removal and no polishing, but ghost lines were still present. MacDonald Scabbler is a type of grinder to remove lines but leaves scars. Hydroblaster can remove lines or clean them. Hydroblasting leaves no scar (54).

The report on Traffic Stripe Removal (55) provides guidance on reducing the scarring or ghost marks left from marking removal.

- Chemical (followed by water jet)
  - best for 10-12mil thickness on PCC
  - may require repeated application.
- Grinding
  - effective on asphalt and PCC; leaves scars/damage
  - not recommended for Open-Graded Asphalt Friction Course (OGAFC)
- High-pressure water jet
  - effective on PCC,

- less effective on asphalt (~90% of line remains)
  - Cannot remove thermoplastic from asphalt;
  - not recommended for OGAFc
- High temp burning
  - effective on PCC,
  - less so on new asphalt
  - Excellent results on older asphalt
  - may require repeated application
- Hydroblasting
  - very effective on PCC,
  - less effective on asphalt
  - Not effective for thermoplastic
- Sandblasting
  - fair to excellent results on asphalt and PCC based on operator skill/experience
  - Not effective for OGAFc
- Grinding + chemical or high temperature burner
  - removes all surface paint with very little damage
  - Best option is grinding + chemical
- Chipping
  - removes thermoplastic
  - very slow

## Temporary Markings

Development of Improved Procedures for the Removal of Pavement Markings during FDOT Construction Projects (33) tested: paint, thermoplastic, and temporary tape on asphalt concrete. Found that 20 mil water-based paint, 100 mil of thermoplastic, 90 mil of thermoplastic, and 35 mil temporary tape allowed ultra-high-pressure low volume water blast to perform well in speed, degree of removal, and minimal scarring.

Temporary Road Markings Working Group Findings (56) found:

- Hot applied thermoplastic road markings are durable, cost effective, conspicuous, and easy to apply, but are very hard to remove. Must be removed with mechanical scabbling.
- Temporary tape markings are durable for 0–3 months and conspicuous, but expensive and slow to apply. Can remove by hand or with mechanical chipping.
- Road marking paint is cost-effective with comparable conspicuousness to tape, but not as conspicuous or durable as thermoplastic. Paint sinks into the pours of asphalt, so cannot be removed completely without damaging the surface. Therefore, covering is the only option to reduce scarring. Paint can be removed from PCC with some difficulty.

Orange Work Zone Pavement Marking Midwest Field Test (17) tested use a work zone only orange temporary pavement marking tape. In another study fluorescent orange spray-applied MMA was used and was less costly than line removal, effective, applicable on asphaltic pavement and concrete pavement. Fluorescent orange MMA paint catches driver attention and is applicable on asphaltic pavement and PCC (50). Fluorescent orange non-wet reflective tape, wet reflective tape, and spray-applied MMA can be used to denote new traffic patterns during construction (51).

Evaluating the Effectiveness of Temporary Work-Zone Pavement Marking Products (57) evaluated temporary tape from three manufacturers and temporary paint on asphalt and PCC.

- Temporary paint failed in 15 days because it was being driven over.
- Tape that was driven over was much harder to remove than non-driven over tape.
- Tape easier to remove from PCC than asphalt.

Evaluation of Temporary Pavement Marking Materials and Methods (58) evaluated conventional products Latex paint (water based) and alkyd paint (solvent based) can be applied to PCC and asphalt but adhere to asphalt better. Durable products tested were thermo-sets, thermoplastics, and proprietary tapes. These results were:

- Thermo-sets: epoxy lifetime of up to four years and are suitable for PCC or asphalt.
- Thermoplastics: lifetime 4–8 years but perform better on PCC and new asphalt. does not adhere well to old asphalt.
- Proprietary tapes: lifetime 4–8 years and easy to remove. Best for PCC.

Water based temporary paint has been investigated that washes off cleanly with special remover (59). Others had endeavored to make a paint that was effectively and cleanly removed by excess oxygen burning. The project was ultimately abandoned because the processes needed to achieve the desired result made the paint/paint fumes highly toxic (60).

## **SUMMARY WITH GAPS IN KNOWLEDGE AND HOW THIS RESEARCH WILL ADVANCE THE PRACTICE.**

The majority of the pavement marking removal and temporary marking research found was related to highways. Only a few documents were related to airfield markings. Much of the highway related research is transferable to the airfield so the highway information was thoroughly reviewed. The following sections provide a summary of the findings relating to marking removal and temporary markings as well as gaps in knowledge are presented.

### **Removal**

The literature review revealed that there are significant issues with removing markings from any paved surface. Research has been performed on both asphalt and PCC, however less so on grooved pavement. Most sources seem to default to water blaster for most surface conditions and marking materials with the exception of poor pavement conditions. The most recent research has shown promising results using “softer” blasting technologies (sand and dry ice) resulting in clean removal with little if any scarring. However, the softer blasting takes more time and the performance versus cost may not be of higher value than the water blasting. Some technologies have tried to add liquid oil solvents or utilize heat to heal the damage to asphalt surfaces, but these technologies do not apply to PCC. In fact, heat may cause PCC to spall increasing the damage.

One of the key points is that there are five factors that affect the ability to remove the markings from the pavement without damaging, scarring, or leaving ghost lines:

1. Presence of grooving—Grooving requires a removal technology that can get into the grooves to remove the marking without removing surface material.
2. Type of Pavement—PCC is harder and less likely to be damaged by removal methods than asphalt. However, both types of pavement exhibit color change over time and can be reduced in strength over time.
3. Surface Strength of Pavement—Older pavement can be of lower strength (referred to as “condition” in the literature) and more susceptible to damage from more aggressive removal methods.

4. Marking Material—Marking materials vary in strength. The biggest difference appears to be between paints and the other more durable materials. The thickness of the markings is a major factor as well. Even though paint maybe less durable, many layers of paint may be more difficult to remove than a single layer of a more durable material.
5. Age/Color of Pavement—Color of the pavement changes over time – asphalt gets lighter, and PCC darkens.

The effect of age on color of the pavement may be critical to determining the best approach to marking removal. Since pavement color changes with age, even perfect removal of a marking with no damage to the pavement surface may still result in ghost lines on existing pavements. This is because the pavement under the surface is not exposed to the same wear and environmental conditions. Therefore, a seal coat or other measures may be required to minimize the visual impact of any marking removal.

The following table (Table 4) combines marking removal recommendations for marking type vs pavement type from airport and roadway sources. These recommendations do not consider specifics of a single job such as thickness of the marking being removed, availability of equipment, desire for fast removal, etc. The pavement and marking types have been limited to those that are found on airfields. The numerical coding is below:

1. High Pressure Water Blasting.
2. Grinding.
3. Abrasive (Sand) Blasting.
4. Shot Blasting.
5. Chemical Paint Removers.
6. Heat.
7. Void Concealment following 1, 2, 3, or 4.

Any combination of removal technique that needs # 7 “Void Concealment” implies pavement surfaces will be scarred/damaged by the recommended technique. Repair or concealment of the removed area may be necessary. Other combinations of marking, removal technique, and pavement surface may also require repair or concealment.

**Table 4. Matrix of Roadway Marking Removal Techniques Versus Marking Type and Pavement Type.**

	Solvent-Borne Paint	Water-Borne Paint	Epoxy	Preformed Thermoplastic	Cold-applied Plastic (MMA)
Grooved concrete	1,3,5	1,3,5	1,3	1*,3*	1*,3*
Ungrooved concrete	1,2,3,5	1,2,3,5	1,2,3	1*,2,3*	1*,2,3*
Grooved asphalt	1,3,5	1,3,5	1,3	1*,3*	1*,3*
Ungrooved asphalt (Dense Graded Asphaltic Concrete)	1,2,3,5	1,2,3,5	1,2,3	1*,2,3*	1*,2,3*
Grooved poor asphalt	1,3,5	1,3,5	1,3	1*,3*	1*,3*
Ungrooved poor asphalt	1,2,3,4,5	1,2,3,4,5	1,2,3,4	1*,2,3*,4*	1*,2,3*,4*
Open Graded Asphaltic Concrete	1+7,3,5	1+7,3,5	1+7,3	1*+7,3*	1*+7,3*
Seal coat/Chip seal	1,2,3,5	1,2,3,5	1,2,3	1*,2,3*	1*,2,3*

\*Use in combination with other mechanical methods such as grinding in order to minimize damage and increase removal efficacy. May be necessary for paints or epoxy if there are many built up layers.

## Temporary Markings

Temporary markings go hand in hand with the removal of markings since most temporary markings overlay existing or old markings and must be removed after a relatively short period of time. Partially closed runways are demarcated with yellow chevrons at all times (can be constructed of wood and fabric, plastic, paint, etc.). Closed runways are marked with yellow X's. Barricades with red lights, and flags and cones identify construction zones and new traffic patterns. Orange construction signage have been recommended to convey important messages to pilots and to prevent pilot confusion.

The allowed paint types for temporary markings are the same as permanent markings and include waterborne paint, epoxy, methacrylate, solvent-based paint, and preformed thermoplastic. Closed runway markings can be painted or fabric, colored plastic, painted sheets, plywood, etc. Type II and Type III waterborne paint should be used for temporary markings. Temporary markings should be placed with a thinner layer (4–6 mils) of water-borne paint or with a layer of wax-based curing compound on pavement first. The thinner markings and curing compound will reduce the durability of the markings making them easier to remove. Finally, black border should be used (for light pavements (PCC or asphalt 2+ years old) or white border (for dark pavements) for contrast.

High traffic areas (signs, runway thresholds) will affect the markings wearing through thin painted markings reducing their durability. The markings need to be installed to last the length of the project or be restriped during the project to maintain their color and retroreflectivity. Preformed thermoplastic markings may get pressed deeper into asphalt or grooved surfaces in high traffic areas making removal more difficult.

## Gaps

There is a lot of general information about marking removal, but specifics are lacking. This is partially due to the complexity of removal and needing to achieve a balance of sufficient removal while not damaging the pavement surface. Even when minimal damage to the surface is achieved, discoloration or minor surface textural changes may be confusing to observers. Each removal job will be unique and requires specific methods and operations to achieve the best removal possible.

High pressure water blasting seems to be the prevalent answer for all marking materials and pavement types, though aging pavements may be susceptible to damage and pavements in good condition can be damaged with poor operation. Discoloration and textural changes on the pavement surface often necessitate the removal of a larger area of surface material as recommended in FAA Advisory Circular 150/5340-1M (2) to help obscure the removed area. However, the depth or amount of material to be removed is not defined well. Additionally, it is not clear which removal process or combination of processes is best for each surface. The balance of additional pavement damage resulting from removing a larger area vs reduction in confusion of the removed area is not addressed. Removing a larger area on asphalt surfaces may still leave some level of scarring. Based on experience current practice seems to be to apply a sealant (GSB-88) on the asphalt scars to mitigate raveling of the pavement and to help obscure the scars.

For temporary markings, it is not clear how much material to use or what material to use in high traffic areas. The only information given is that thermoplastic becomes more difficult to remove, and the recommended 4–6 mils of paint will wear through, but no time frame is given. FDOT determined material thicknesses that are durable but can be easily removed with water blasting from asphalt pavement, but no similar guidance exists for PCC or grooved versions of either PCC or asphalt. Finally, no visibility information is found regarding the recommended 4–6 mils of waterborne paint with no retroreflective glass beads.



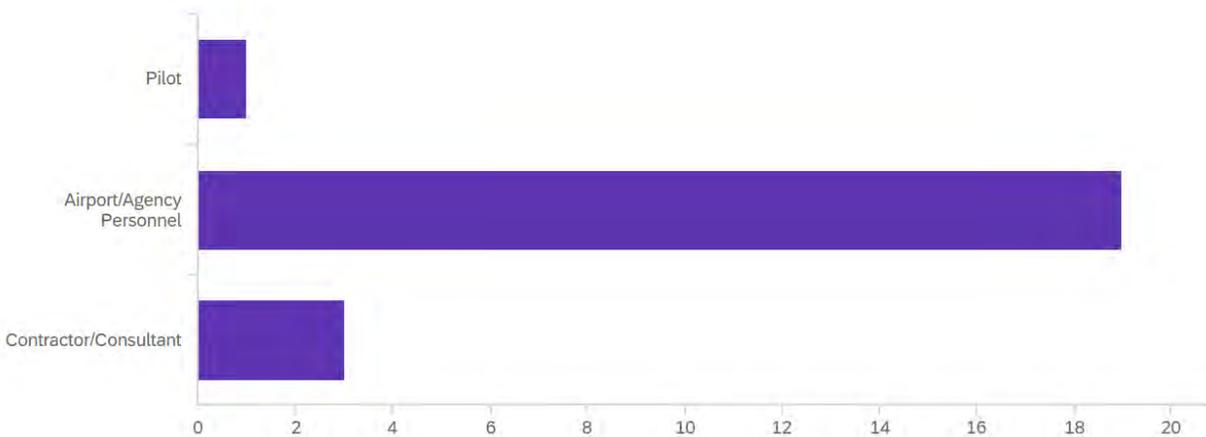
## CHAPTER 3. SURVEY

Researchers conducted a nationwide survey to collect information on the impact of pavement marking removal and temporary pavement marking applications to better understand how users view the markings and removed areas and to determine if results from one method or another are more or less effective. Researchers distributed surveys to manufacturers, contractors, pilots, airport personnel, and other industry representatives to gather as much information as possible on innovative techniques and best practices for removal and temporary marking applications. Information on the survey development and a complete list of questions asked are provided in Appendix A.

### ONLINE SURVEY RESULTS

The online survey response included 29 total respondents, 15 of whom fully completed the survey. This low full response rate is likely due to the amount of text box entries in the survey. A complete set of responses to the online survey are provided in Appendix B. A summary of key survey responses are provided in this chapter of the report.

Seventeen respondents recorded that they had a pavement marking project in the last five years but of those 17, only nine indicated a temporary marking project in the last five years. Nineteen of the respondents were airport/agency personnel as shown in Figure 6. There were two pilot respondents: one completed the survey, the other did not. Three contractor/consultants responded to the survey but none of those indicated recent experience in the past 5 years.



**Figure 6. Distribution of Respondents by Type.**

#### Pilots

The pilot respondent indicated that they had experienced marking visibility issues and that the placement of markings were sometimes confusing but that they had not reported the issue. Another comment provided was that “Some hold short lines are confusing when paired with instrument landing system (ILS) critical area hold short”.

## Contractor/Consultants

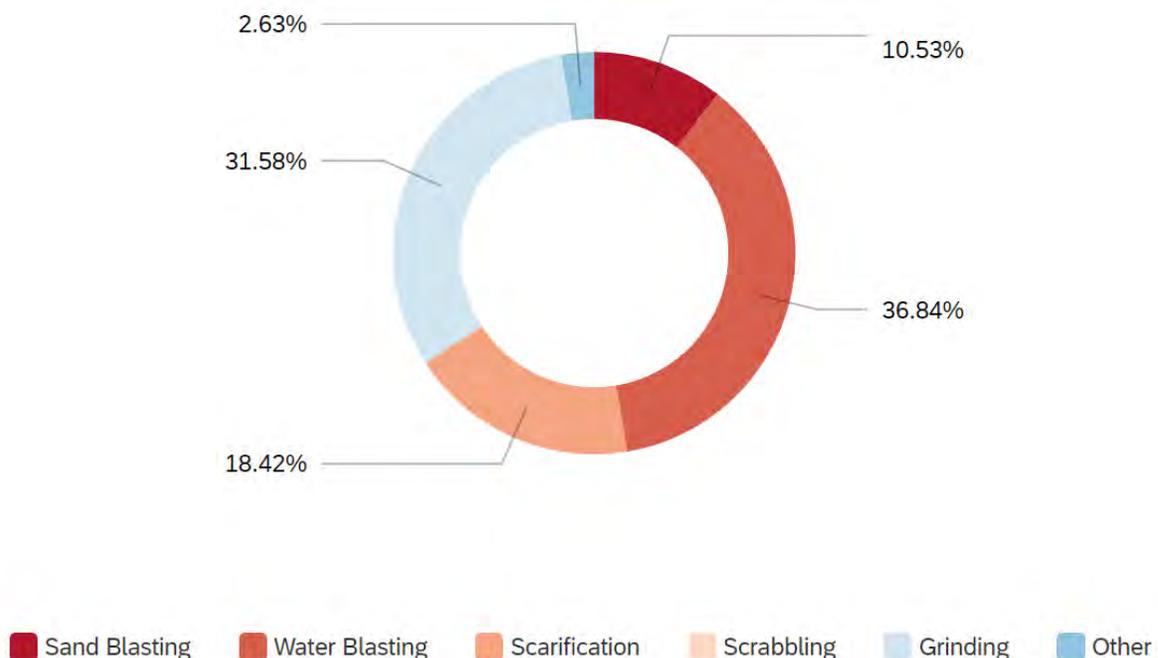
From the three contractor/consultants, only one gave information on the performance of the removal methods in the last 5 years. The one respondent utilized Scarification, Scrabbling, and Grinding. This is dependent on pavement type. The preferred methods were described as dependent of pavement type. Performance of each was not specified.

- For PCC pavements, water blasting was preferred (at appropriate pressures) while protecting joints.
- For asphalt pavements, scarifying/scrabbling/grinding was preferred.
- Water blasting was not allowed on asphalt pavements.

Under unique methods, they had worked with local contractor to incorporate an "erasing" technique for airfield pavement markings on a grooved asphalt pavement, but no other details were given (an alternate name for the rotary grinding is erasing, this is likely the method the contractor was referring to). The contractor/consultant followed the United Facilities Guide Specification (UFGS) 32 01 11.51 Rubber and Paint Removal from Airfield Pavements. This specification allows multiple removal types and should be edited by designer/specifier prior to issuing a contract.

## Airport/Agency Personnel

For the 17 Airport/Agency Personnel respondents that had removal projects in the last five years, the methods used included in water blasting, grinding, scarification and sand blasting as well as one other (Figure 7). The one other type utilized was "painted over with black". For the "other" removal method of painting over lines with black paint, the user was not satisfied with the method.



**Figure 7. Marking Removal Types Used.**

For the question: **Were you satisfied with the amount of pavement damaged caused by the marking removal? How did level of satisfaction differ between pavement surfaces or removal methods?** The answers were:

- Yes. No difference. Water blasting is better than grinding.
- Pretty satisfied with concrete surfaces, but after a second and third removal it really starts to damage the concrete. Asphalt gets beat up after one removal.
- With a good operator and a well running machine I believe water blasting to be the superior method for removing markings off concrete. On asphalt I worry I am seriously impacting the overall useful life of the pavement with all methods, but with water blasting and its removal of binders and oil I have more concerns. However, you can use sealers and other topical products to help seal the scars & damage on asphalt more easily than concrete.
- Yes to the first question. I was satisfied. Highest (damage) when they had lower water pressure and made several passes. Lowest satisfaction when the pressure was higher and wanted to remove the paint marking in one pass.
- I am not satisfied with any damage to the pavement surface. All methods strip the top paste layers off, exposing aggregate and creating an area that will accelerate the pavement damage/breakdown over time. From what I have seen, I'd prefer in this order, 1. Water blasting at controlled levels 2. Grinding 3. Scarification—this method is the most damaging.
- The markings were never removed just covered up. It only took a few weeks of snow removal to uncover the old markings to its original state. That during snow events or fog confusing pilots
- Mixed results for grinding as referenced in prior questions.
- No matter which type of removal you use there will always be some type of pavement damage.
- All of them caused pavement issues and it is more based on contractor experience and equipment usage. For temporary markings we should bring back painting over temporary markings. Especially for shorter duration phased work (less than 30 days).
- Yes, with water and sand blasting. No with scarification.

For the question: **Do you require specific removal methods on specific surfaces? Please specify if so. If not required do you have a preferred method for each surface type?** The answers were:

- Water blasting is a superior removal technique, less damage and much faster. A experienced operator can find the perfect water pressure and speed to do minimal damage on any surface.
- The majority of our markings are on concrete and water blasting is the only method I will allow. A cold planer with a finish style drum would probably be my preferred method with asphalt with a SS1h or equivalent sealer applied over the whole area, not just the scaring after the markings removal is complete.
- Yes we do. Verbalize the Plan. Have a person performing the work (in the truck) and another one looking at the work on the ground. Assess with Airport Operations on satisfaction and compliance.
- We require water blasting at PHX airport.
- No we did not require specific removal on the surfaces.

- We will employ water blasting or grinding on asphalt surfaces and typically just grinding on concrete. We do regular rubber removal with a psi of 8000-1000 to prevent loss of fines.
- I prefer water blasting.
- Bring back temporary paint to temporarily block out markings!
- No. Sand blasting is preferred.

## **FOLLOW-UP VIRTUAL INTERVIEWS**

Ten participants expressed interest in a follow up interview regarding the content of the online survey. Four of those participants completed the virtual interview. A summary of the results of the follow up interviews are provided in the following sections. The complete list of virtual interview questions and responses can be found in Appendix A and B.

### **Marking Removal**

In general, the interviewees utilized water blasting and grinding to remove existing markings. The markings removed were typically waterborne paint with retroreflective beads. All respondents indicated that removal methods damage both PCC and asphaltic concrete but that the damage level was lower on concrete and depended highly on the skill of the operator as well as the amount of time available to perform the removal. *The damage level was inversely correlated to the amount of time available to perform the work.*

None of the respondents indicated that the damage to the concrete had resulted in any incidents due to confusion. The biggest concern of the interviewees was the integrity of the concrete, especially asphaltic, due to the damage and subsequent water ingress into the concrete, especially asphaltic due to the damage before installation of new markings. Multiple respondents indicated that they applied a seal coat to the damage before installation of new markings. For older asphaltic concrete, the removal of markings usually resulted in significant damage to the surface requiring as much as 2 inches of asphalt removal and resurfacing with new asphaltic concrete.

The interviewees expressed concern that the FAA Advisory Circular 150/5340-1M did not allow for exceptions especially when the temporary and/or permanent markings are going directly back in the same location. One interview expressed that in those situations, the removal area could be smaller, and that in particular the runway numbers could be obscured utilizing much smaller areas. The main desire was to reduce the damage to the asphalt. Another interviewee stated that the use of black paint to cover existing markings should be reevaluated for certain situations. For example, when new markings are going to be installed overtop of old markings that are still in good physical shape (such as faded markings) then it would be more desirable to black out and reinstall new markings than try to remove the old markings and cause significant damage to the older concrete surfaces. Since the markings are not changing locations, then there is minimal risk for confusion.

### **Temporary Markings**

For temporary markings, the interviewees utilize waterborne paint with or without retroreflective beads depending on the situation. None of the interviewees were aware of any incidents related to the visibility of the temporary markings. All interviewees indicated that the

temporary markings were utilized for no more than 30 days. During that time, visibility and durability were fine. For temporary markings removal is avoided if the marking is not moving, they would install the permanent markings on top of the temporary markings. If being moved, water blasting or grinding would be used with a sealing coat reapplied or the surface would be repaved after removing 2 inches of material for older asphaltic concrete.

## **SURVEY SUMMARY**

Water Blasting is still the leading method of pavement marking removal method particularly for PCC surfaces. Water blasting is still being used in some cases for removal on ACC surfaces but causes enough damage to the surface to reduce the life of the pavement. To preserve the durability of the asphalt pavement, grinding is used more often and almost always followed by a seal coat at a minimum or a resurfacing. Neither survey nor interviews revealed any difference in approach whether the pavement is grooved or not.

The resounding themes regarding water blasting use was that the effectiveness of the technique and reduction of damage to the pavement required experienced operators and an un-rushed timeframe. These factors were more important than the water pressure utilized.

Three alternate approaches were found to be utilized rarely. One technique is line eraser utilizing a modified form of grinding (rotary grinding). Shot blasting was mentioned during one interview, but it is not widely used. Finally, two respondents mentioned that the FAA could reconsider blacking out of the old markings as a viable method of removal.

Universally, waterborne paint of the same formulation as permanent markings was typically used, just at a lower application rate. One respondent mentioned utilizing beads, while the remainder did not. The majority of respondents simply painted over the temporary markings with the permanent markings. If removed, the temporary markings were removed with same techniques utilized for the permanent markings: water blasting or grinding.

## **SURVEY FINDINGS**

The survey and the interviews highlighted several points:

- With all techniques there is damage to the surface that may need to be resealed.
- Water blasting is utilized on PCC surfaces whether grooved or not.
- Grinding is utilized more often on ACC surfaces whether grooved or not because water blasting can be too damaging to ACC.
- Older pavement is more subject to damage and likely will need a resurfacing treatment afterwards.
- With all techniques, operator experience and the amount of time available greatly impacts the quality of the removal and resulting damage to the pavement.
- Temporary markings are not always removed if the permanent markings go in the same place. When removed, they are removed with the same methods as the permanent markings.
- Temporary markings are usually applied without retroreflective beads and utilizing waterborne paints utilizing a lighter coating than permanent.
- Sealant or curing compound applied before any temporary marking might make removal easier with less surface damage but by the same token reduces the life of permanent markings.

- The current guidance on the removal area is probably larger than required especially for runway numbers.
- The biggest concern among airport personnel was that surface damage from marking removal significantly reduces the life of the pavement especially for ACC. Older ACC is often chip coated or resurfaced to a depth of 2 inches if markings need to be removed.
- The use of blackout paint was suggested to cover over temporary markings as opposed to removing the markings to prevent damage and life reduction of the existing surfaces when runways are shortened.
- The one pilot that responded did not seem to think that the removal methods caused confusion as much as the placement of the temporary markings especially when the runway is shortened. However, the pilot did not think they had been confused by any markings.

## CHAPTER 4. SITE VISITS

The research team visited 12 different field sites to inspect airfield pavement marking removal and temporary marking applications. The temporary marking locations were visited twice to witness the application and removal of the temporary markings. Table 5 lists the 12 different geographically diverse field sites that were visited.

**Table 5. Site Visit Locations.**

<b>Airport</b>	<b>Code</b>	<b>State</b>
Pope Army Airfield	POB	North Carolina
Easterwood Field Airport	CLL	Texas
Sterling Airport	3B3	Massachusetts
Midland International Air and Spaceport Airport	MAF	Texas
St. Pete-Clearwater International Airport	PIE	Florida
Niagara Falls International Airport	IAG	New York
McGhee Tyson Airport	TYS	Tennessee
Reno-Tahoe International Airport	RNO	Nevada
Salt Lake City International Airport	SLC	Utah
Gooding Municipal Airport	GNG	Idaho
Millington-Memphis Airport	NQA	Tennessee
Cochran Airport	48A	Georgia

### REMOVAL EVALUATION TECHNIQUES

The research team utilized several techniques to evaluate the removal quality. These techniques are qualitative and quantitative. Visual observation as to the overall appearance of the removal, the estimated percent of material remaining, and estimated pavement damage were noted. The team captured various angles of each removal in photographs. These visual observations are the most common inspection form and with adequate training can yield reliable and consistent information. Quantitative evaluation techniques included retroreflectivity measurements, color measurements, percent material remaining, and scar depth. Not all qualitative techniques were used at all sites or for all markings evaluated. Site restrictions, such as the time when the researchers can be on the airfield or the ambient lighting levels, impacted the team's ability to conduct observations across a range of conditions.

### EVALUATION OF PAVEMENT MARKING REMOVAL

The following sections describe the removal and temporary marking application inspections. The inspections resulted in many images and generated numerous findings. The results of the visit(s) to each site listed in Table 5 are described.

## **Pope AAF (POB), North Carolina**

The Pope AAF project was just getting completed as the research team was getting ready to start site visits. The surface was grooved asphalt with paint markings. This project used rotary grinding to remove the surface marking and a second device with cutting blades spaced at the groove spacing to clean out the grooves. Everyone was very happy with the results. The research team visited the site in November to observe the results of the removal in person. This site is being considered as a location for survey of pilots and other users to get their feedback. See Figure 8 through Figure 11 for images of the removal equipment and results. This was a unique combination of methods to achieve good removal on a grooved asphalt surface. The drawback is the equipment had to be setup for the specific spacing of the grooves and it was a slow process.



**Figure 8. Rotary Grinding and Saw Cut Cleaned Out Grooves on Grooved Asphalt.**



**Figure 9. Grooving Device Used to Clean Paint Out of the Grooved Asphalt.**



**Figure 10. Rotary Grinding to Remove Surface Marking. Later Saw Cut to Clean Out Grooves on Grooved Asphalt.**



**Figure 11. Removed Area and New Markings.**

### **Easterwood Airport (CLL), Texas**

The project team visited Easterwood Airport to discuss upcoming work activities, explore the potential to use the airport as a study area, and to evaluate past removal projects. During the visit the airport operations manager brought the research team around the facility to view marking removal that occurred for various reasons including decommissioning a runway and moving markings. Several issues were encountered during their removal projects. These issues included joint damage, pavement surface damage, and inadequate removal. Pavement damage led the contractor to switch from high pressure water blasting to mechanical flailing. Observation of the results did not seem to show any improvement, and possible even worse results in some areas. The airport had removal on ungrooved asphalt of various ages and conditions and grooved and ungrooved concrete. The high-pressure water blasting on either concrete surface was good other than some joint damage. The results on the asphalt were ok to poor. Images showing the removal results are provided in Figure 12 through Figure 20.



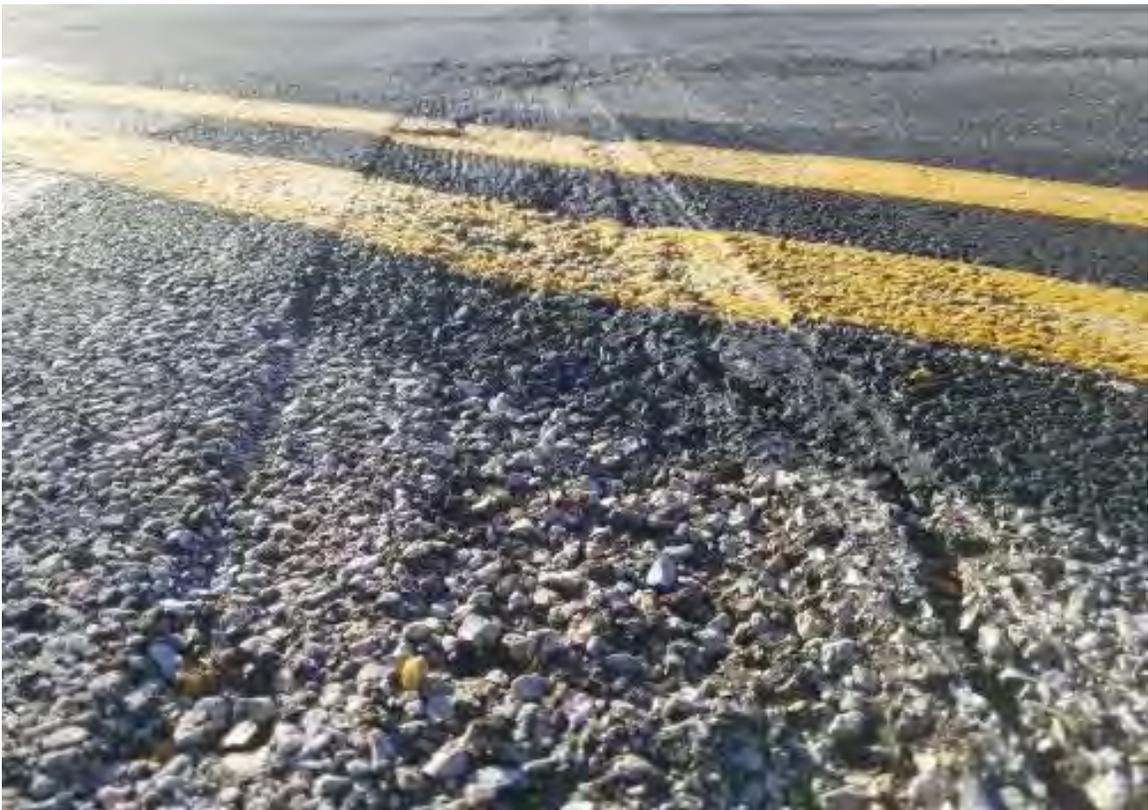
**Figure 12. Grinding (background), Water Blasting (foreground).**



**Figure 13. Same Water Blasting Area from Figure 12.**



**Figure 14. Wider Path Water Blasting Followed by Grinding Along Marking Area.**



**Figure 15. Wider Path Water Blasting Followed by Grinding Along Marking Area. Pavement Damage is Evident.**



**Figure 16. Water Blasting Along Joint. Clean Pavement Noticeable Compared to Surrounding Area.**



**Figure 17. Damage to Joints from Water Blasting.**



**Figure 18. Removal for Runway Closure. Large Area Removed to Blend Discoloration.**



**Figure 19. Joints Not Affected by Water Blasting.**



**Figure 20. Water Blasting on Grooved Concrete. Removal was Hardly Noticeable.**

### **Sterling Airport (3B3), Massachusetts**

Massachusetts Department of Transportation Aeronautics Division conducted a project to remove airfield markings, crack seal, apply an asphalt sealer and repaint the markings on selected airports throughout the Commonwealth. Sterling Airport in Sterling, Massachusetts, was on the list.

A research team member traveled to Massachusetts to witness the paint removal operation. Project specifications required the use of rotary grinders. Drum grinders with reasonable success. Water blasting equipment was also brought in and used.

Work began with grinders with automated drivers (see Figure 21) maneuvering over the markings, beginning on the southern end of the runway (Runway 34). The runway surface was not grooved, and the grinders were a good option for paint removal.

Arrowheads, a displaced threshold bar, and runway designation markings were removed by the grinders on the south end. Removal then began on the centerline, moving up the runway in tandem. A vacuum sweeper truck worked around the grinders but propelled a lot of dust and debris into the air rather than containing it in the sweeper's hopper (see Figure 21). The grinders were effective in removing the paint from the surface and did not remove a "larger pre-determined area." The scars appeared like the old marking (see Figure 22).



**Figure 21. Grinder with Drive System and Sweeper Operation.**



**Figure 22. Marking Areas Removed by Grinding.**

There was debris left behind after the sweeper had “cleaned” the area, and it was acknowledged that the area would need to be washed with water before the sealant could be applied. A water blaster was brought in for additional removal. When it arrived, they started removing markings on the north end (Runway 6) by water blasting.

The north end was also displaced with four arrowheads, a threshold bar, and runway designation markings 16. The water blaster removed all of the markings on the 16 threshold. The remaining scars exhibited more exposed aggregate, left considerable dirty water trails, and was not as effective at removing all the paint due to the concern about excessively damaging the surface (see Figure 23).



**Figure 23. Marking Areas Removed by Water Blasting.**

The project team was unable to witness the cleaning operation attempted by the water blaster on the areas removed by the grinding equipment. The prime contractor acknowledged that the surfaces would need to be flushed thoroughly prior to the seal coat which was scheduled to be applied after the crack sealing was completed the next day.

The existing paint was old, but not thick and the grinding operation did a good job in removing the markings without excessive damage to the pavement. The water blasting operation exposed more aggregate than necessary and would have been better used for a cleanup operation since the vacuum sweeper was not able to remove all the debris. However, the water blasting operation may not have succeeded in cleaning up the debris either, given the fact it was unable to vacuum up all the water and debris from its own operation. It is assumed that the prime contractor flushed the area to remove the debris from the surface prior to the seal coat being applied.

### **Midland International Air and Space Port (MAF), Texas**

The research team traveled to the Midland International Air and Space Port in West Texas to observe removal operations. The airport was contracting work to remove all markings, seal all cracks, and apply a P-608 sealant to a runway and taxiway. The airport had conducted similar work on other areas of the airport the previous year. Figure 24 shows current markings on the previous year's seal coat. Adjacent to the marking the removal efforts from the previous year are slightly visible. The seal coat helps blend the color, but some minor surface texture changes are visible.



**Figure 24. Previous Area of Removal, Seal Coat, and Restripe.**

Figure 25 shows an area where this year's work was taking place. Scarring from previous grinding removal activities are clearly evident in the areas where the markings are present. The time since the previous removal occurred was three years.



**Figure 25. Markings to be Removed with Preexisting Removal Scars.**

A full size three headed grinding truck was used for the majority of the removal (Figure 26). The three heads on the device were offset to remove a wider footprint on each pass. Touchup work was conducted with hand operated grinders, some of the grinders were mounted to ride on units (Figure 27).



**Figure 26. Full Size Three Headed Grinding Truck with Vacuum System.**



**Figure 27. Touchup Work with Hand/Ride on Grinder.**

The grinding was mostly effective at removing the marking due to the pavement not being grooved. The existing pavement was cracked, the old paint was cracked and distressed. The selected method of removal did not further damage the pavement. There were areas where the marking was not fully removed by the full-size truck. These remaining areas were mostly removed by the hand operated equipment. The nature of the work did not require 100% removal. Consideration needs to be made as to the purpose of the removal and how much pavement damage is acceptable. Being that the removal operations purpose was to allow the seal coat to bond better with the pavement, there should not be a requirement to completely removing the marking if pavement damage would occur. This would reduce the likelihood of the scars being visible through the seal coat.

There were two specific areas of removal that were notable. One notable area was with respect to the viewing conditions after the removal operations occurred. Figure 28 shows a portion of the markings to be removed. The runway designation numbers were removed in a block pattern to help blend in the removal scarring. Figure 29 shows the results of the removal when looking toward the sun. At the angle and distance of the photo the removal seems adequate in that the surface texture of the removed area is mostly uniform, the markings seem to be completely removed, and the number is not visible. Figure 30 is the same location but from the opposite direction with the sun behind the observer. The removal looks completely different which highlights the need to evaluate results in different conditions to make sure they are acceptable. Some marking is now visible and the color difference between the removed area and surrounding pavement is more noticeable. Being that this area is going to get seal coated over, these removal results are acceptable.



**Figure 28. Markings to be Removed.**



**Figure 29. Toward Sun View of Removed Area.**



**Figure 30. Sun Behind View of Removed Area.**

Another notable observation during the removal was the quality of the removal with respect to surface damage and evenness of the pavement scarring. The research team noted early in the observations that the grinding truck was not evenly removing the marking with all three grinding heads. This was relayed to the operator who modified their approach to the removal to even out the results. Figure 31 shows the removal of a marking with a single pass of the three headed grinding unit. The middle grinding unit was not level and was grinding too deep on the right side. This resulted in an unnecessarily deep groove and a nonuniform removed area. After modifying the unit, the removal was much more uniform, see Figure 32. This observation covers several important topics that need to be addressed when conducting marking removal. The first is that test areas need to be conducted so that the quality of the removal can be observed on a small representative area. This will allow the operator to make changes if needed. The second area is inspection and expected results of removal operations. The operators need to know what the expected results are so that they can try to achieve those results. Inspectors need to check to make sure those results are being achieved.

The standards included in FAA Advisory Circular (AC) 150/5340-1M, a predetermined larger size (than the existing marking) was not removed (for the threshold markings), just the markings themselves. The scars under the sealcoat may be evident, however, markings will be installed in the same locations. A larger area was removed under the runway designation numbers as shown in previous figures. It was determined that at least 85 percent of the existing paint was removed from the surface to receive a seal coat, in conformance with AC 150/5370-10H, Item P101.



**Figure 31. Uneven Removal and Pavement Damage.**



**Figure 32. Removal Finish That is More Uniform.**

Considerable cleanup was required to provide a good surface for the sealcoat. The contractor used several ride-on blower units to blow the removal debris off the pavement (Figure 33). The blowers removed most of the large and small aggregate but did leave behind some residue. It is necessary to make sure the surface is prepared to the level required by the seal coat application type and method.



**Figure 33. Blowing Off Runway to Remove Debris from the Marking Removal.**

## St.Pete-Clearwater International (PIE) Florida

Runway 18-36 rehabilitation project: Work had been completed on the north end (Runway 18), and a temporary displaced threshold had been installed on the south end (Runway 36). Work had already been completed in the intersection of Runway 4-22. The remaining work was the removal of the temporary displaced threshold markings on Runway 36, the application of a seal coat over the removal scars, and installation of the permanent markings on the entire runway.

Phase 1 displaced Runway 36 threshold approximately 2700 feet so that a 100-foot runway extension could be constructed on intersecting Runway 4-22. The closed area of Runway 36 was milled and overlaid during Phase 2. Phase 3 restored another displaced threshold on the 36 end and displaced the threshold on Runway 18 by approximately 3200 feet. The north end of the runway was profiled (milled) during Phase 4. Phase 5 restored the threshold on Runway 18 to its original location; the temporary markings were removed during the milling/reconstruction operation in Phase 6. Phase 7A included the overlay of the runway surface from Taxiway A6 to the north end of the runway, thus covering all removal scars from both the original markings on Runway 18 as well as the temporary displaced threshold. Phase 7B occurred while the research team was there observing and included the removal of the temporary relocated threshold that had been installed during Phase 4. Phase 7C and 8 occurred during the second or third week of November and restored all final markings after seal coat and grooving operations were complete.

Displaced threshold markings were removed from non-grooved asphalt on Runway 36 by water blasting. Water pressure was 39,000 psi, the head rotation speed was 2200 rpm, and the truck moved approximately 30–35 feet per minute. The rotor bar 12-tip configuration included a combination of tip diameters ranging from 0.007 to 0.011 inches, with a median nozzle diameter size of 0.009 inches, in a cohesive stream. The tip array was designed to put larger tips on the outside of the rotor bar and smaller tips toward the center to give the scar an even profile. The outer tips have less “dwell time” on the paint compared to the interior tips, thus the larger size cuts more aggressively.

The paint being removed was a single coat, likely applied at about 150 square feet per gallon for a dried film thickness of 5–7 mils. No glass beads had been applied.

It was apparent that the binder in the asphalt surface was eroded, exposing the aggregate (Figure 34). This is a common occurrence on asphalt from a water blasting operation. However, most of the asphalt surfaces during this study that have endured a removal operation were later coated with a sealcoat, most often GSB-88 and covered by AC 150/5370-10H, Item P608. The sealcoat serves to bind the aggregate and obscure any scars that may cause confusion.

The standards included in FAA Advisory Circular (AC) 150/5340-1M, a predetermined larger size (than the existing marking) was not removed, just the markings themselves (Figure 35). The scars under the sealcoat may be evident.

The method of removal was typical for temporary markings on asphalt pavements. Since the runway surface was not grooved, perhaps rotary grinders could have been used with less aggregate exposure, but the process would have likely taken longer, and clean up would have required flushing with water prior to the sealcoat.



**Figure 34. View of Removed Area and Temporary Marking.**



**Figure 35. Removal of the Temporary Threshold Markings.**

## Niagara Falls International Airport (IAG), New York

Representatives from Niagara Frontier Transportation Authority had claimed damage had been done to the pavement from a previous removal operation. The research team was interested in learning more about the existing conditions, the method of paint removal, and the resulting scars to the pavement, and plans for future work.

The scope of work for the project in question was to remove existing markings from grooved asphalt on Runway 28R to include Threshold Bar, Threshold Markings, Runway Designation Markings 28R, Touchdown Zone Markings, Aiming Point Markings, Centerline Markings, Edge Markings, and a LAHSO holding position marking. Approximately 45,000 square feet of markings were removed.

The U. S. Army Corps of Engineers designed the plans and specifications and work requirements for the project. UFGS 32 17 23—Pavement Markings and UFGS 32 01 11.51—Rubber and Paint Removal from Airfield Pavements were included in the project specifications. Although several methods of paint removal were included within the specifications, ultra-high pressure water blasting was the only method that would achieve the desired level of removal in the 36 hours (originally 24) permitted in the schedule. In UFC 3-260-04—Airfield and Heliport Marking guidance is provided regarding the thickness of existing coatings. Paragraph 3-1.2.1 indicates that it is undesirable for painted markings to build up beyond a total thickness of approximately 40 mils.

The research team visited the job site and inspected the scars left from the water blasting operation (Figure 36). (It was noted by members of the contractor's team that the only test line conducted prior to commencing the removal was performed on the edge marking. The pavement under the edge markings is not grooved, so the removal trial was not representative of most of the removal to be done. The water blasting contractor was not permitted to perform a test line on grooved areas of the runway. This is an issue that needs to be considered for future work.

Per FAA Advisory Circular (AC)150/5340-1M, during full scale removal, a predetermined larger size pattern beyond the existing marking was removed to reduce the appearance of the old marking. However, as seen in the following picture (Figure 36), the area where the old marking was is still evident. It is clear that the removal of the unmarked areas was not as aggressive as the marked areas. This removal resulted in some blending, but the marking removed area was still much darker.

Based on information provided by the contractor's representatives, the standard pressure of 32,000 psi was used for removal. The tip array in the spray bar included a combination of tip diameters ranging from 0.007 to 0.011 inches with a median nozzle diameter size of 0.009 inches, in a cohesive stream.



**Figure 36. Results of Marking Removal.**

Once the work was finished on Taxiways A and A3, the markings were to be reapplied in the same location; and the 1300-foot displaced threshold was supposed to be removed and reinstalled at the original location approximately two months after removal.

Markings on the west end of the runway (Runway 10L) were also inspected, as they were presumed to be representative of the markings removed on Runway 28R (Figure 37). The paint was thick, measuring over 100 mils, and on the runway centerline paint nearly filled the grooves in some areas, indicating over 250 mils, evident in the pictures below. Pavement under the runway centerline was damaged from previous operations (Figure 38). Pre-existing damage of pavement under the paint is an indicator of potential further damage during a paint removal operation. Areas on the pavement not painted previously indicated damage (Figure 39).



**Figure 37. Markings Representative of What Were Removed.**



**Figure 38. Pavement Under the Markings had Some Preexisting Damage.**



**Figure 39. Areas with Pavement Damage Not Related to Markings or Removal Activities.**

### *Takeaways from Niagara Falls Inspection*

1. Existing markings on Runway 28R were over 40 mils and were well bonded to the micro and macrotexture of the asphalt pavement.
2. When airfield markings are painted over and over, paint buildup occurs. The paint bonds better to the asphalt than the asphalt does to itself. When paint must be removed, the microtexture to which the paint is bonded will be removed along with the paint.
3. Given the condition of the underlying pavement, the thick paint, and the duration of the displacement, a different method of removal or another way of obscuring the markings should have been given serious consideration.
4. The specifications provided by the United States Army Corps of Engineers (USACE) were standard for the removal of pavement markings from airfield pavements. The industry is learning that a close inspection of the pavement and pavement markings prior to a paint removal operation can help to determine the appropriate method, likely result, and length of time required to remove the markings to the desired degree.
5. There is evidence of loose aggregate in the areas where paint was removed, an indication of pavement damage. However, the damage was unavoidable given the length of time permitted for the removal, the degree of removal required, and the pre-existing damage evident.
6. The root cause of the damage was compromised asphalt conditions that were not conducive to the removal of thick paint from the surface within a short period of time.

### *Summary of Initial Niagara Falls Inspection*

Asphalt pavements are more susceptible to erosion of the asphalt binder from a water blasting operation. Grooved asphalt pavements present a challenge to any removal operation, requiring time and often a combination of methods to properly remove thick (over 40 mils) paint from the surface.

A temporary displaced threshold of a short duration should permit an application of gray or black paint or physical barrier to obscure the markings. If the thick markings are deemed to require removal, a combination of rotary grinding to remove the thick buildup, followed by either ultrahigh pressure water blasting or another acceptable method to remove the paint from the grooves could reduce the erosion of the asphalt binder, even on compromised surfaces.

### **Niagara Falls International Airport (IAG), New York (Visit No. 2)**

The research team traveled to Niagara Falls, New York, to observe the removal of temporary paint applied during the displacement of Runway 10L. Threshold relocation was required due to work to be done on Taxiway A which is within the runway safety area of Runway 10L.

The government decided to try a new method of mitigating damage to the old asphalt pavement while removing the temporary markings. The idea was to apply a black background, then apply the white markings over the black. Additionally, black paint was applied to existing

markings beyond the runway numerals to obscure the markings and black plastic and black sandbags were used to cover the old threshold markings and bars.

### *Inspection*

The research team observed the test areas where removal was conducted. An ultrahigh pressure water blaster with two rotors, equipped with 7 mm nozzles to be the least aggressive as possible was used. Three separate test areas were conducted:

1. On the temporary aiming point markings where black paint had been applied under the temporary white. A pressure of 31K psi was needed with two rotors stacked, traveling at approximately 4 mph, rotation speed of 1500 rpms with stacked rotors. The result was approximately 95 percent removal of both the white and the black paint with very little scarring seen in Figure 40. Opening up the rotors to be less aggressive produced an unsatisfactory result with too much paint remaining.
2. On the existing markings that had been blacked out, the removal of the black was done with 32K psi at 1600 rpms, stacked rotors in one pass.
3. The markings west of the numerals were within the barricaded work area and were covered with tarps and sandbags, Figure 41.



**Figure 40. Single Pass, 95 Percent Removal.**



**Figure 41. Closed Area of Runway; Markings Covered with Tarps and Sandbags.**

### *Findings*

1. Existing markings on Runway 10L were over 40 mils and were well bonded to the micro and macrottexture of the asphalt pavement.
2. Since the markings would be restored in their original location within a two-month period of time, the use of black paint to obscure the distance markings and the runway numeral was considered acceptable.
3. Placing the black paint under the temporary markings afforded the pavement little, if any, protection from the removal operation. Both the white temporary and the black undercoat were removed in a single pass. The scarring from the removal was negligible and acceptable from everyone's perspective.

### *Summary of Second Niagara Falls Inspection*

Asphalt pavements are more susceptible to erosion of the asphalt binder from a water blasting operation. Grooved asphalt pavements present a challenge to any removal operation, requiring time and often a combination of methods to properly remove thick (over 40 mils) paint from the surface.

The choice of covering the majority of the markings with tarps and sandbags for the short duration seemed to work, although constant monitoring of the tarps and sandbags was required.

A temporary displaced threshold of a short duration should permit an application of gray or black paint to obscure the markings. If the thick markings are deemed to require removal, a combination of rotary grinding to remove the thick buildup, followed by either ultrahigh pressure water blasting or another acceptable method to remove the paint from the grooves could reduce the erosion of the asphalt binder, even on compromised surfaces.

### **McGhee Tyson Airport (TYS), Tennessee**

Temporary taxiway centerline and edge markings had been installed across intersections between Runway 5L-23R (under reconstruction) Taxiway B at cross taxiways G4 and G8. The pavement was new grooved concrete. A preconstruction meeting was held to review the work plans of the striping subcontractor. Some of the concrete had been installed over one year earlier, and the subcontractor was only planning to sweep the areas to receive paint with a steel bristle

broom. Additionally, the striping subcontractor planned to use grinders to remove the taxiway centerlines and edge markings from the new grooved concrete. The consulting engineer and airport personnel urged the contractor and their striping subcontractor to use ultrahigh pressure water blasting to remove the remaining curing compound.

The research team accompanied the inspector to the work site to observe the removal of the taxiway markings with the rotary grinders. After considerable discussion, the striping subcontractor decided not to perform any work that day, and entirely withdrew from the project the following day.

The prime contractor, negotiated the work to be done with other contractors. The removal of the taxiway lines was rescheduled. The research team was not able to witness the rescheduled removal but returned to observe the scars left from the removal operation that used ultrahigh pressure water blasting (Figure 42). The removal was acceptable with scarring but no damage.



**Figure 42. Removal Scar from Water Blasting Temporary Taxiway Edge Marking.**

### **Reno-Tahoe International Airport (RNO), Nevada**

Terminal apron work was finished six years prior, and paint removal of lead in lines to the terminal had been removed and relocated. Scarring from that project was observed to determine the effect of time and weather on the scars.

Runway 16R-34L was undergoing a rehabilitation of the center keel. Markings outside the new concrete (all of the distance markings and edge marking) were being removed and reapplied in the same location. New runway centerline markings would be installed on the new concrete.

## *Inspection*

The research team visited the airport of the scars from the terminal apron work as well as onto Runway 16R-34L that was under construction to observe removal operations.

Markings on the runway were thick (over 100 mils) and were being removed by ultrahigh pressure water blasting. At all joints, markings had been scarified with drum grinders (Figure 43) so that the water blaster would not dwell on those areas and damage the joint material (Figure 44), a good practice.

Since the majority of the markings would be installed in the same area, scarring of the pavements would not be evident to users. However, the methods of removal and the subsequent scarring prior to painting was observed and deemed to be good, causing minimal scarring.



**Figure 43. Joints Were Scarified with Drum Grinders to Mitigate Joint Damage During Water Blasting Operation.**

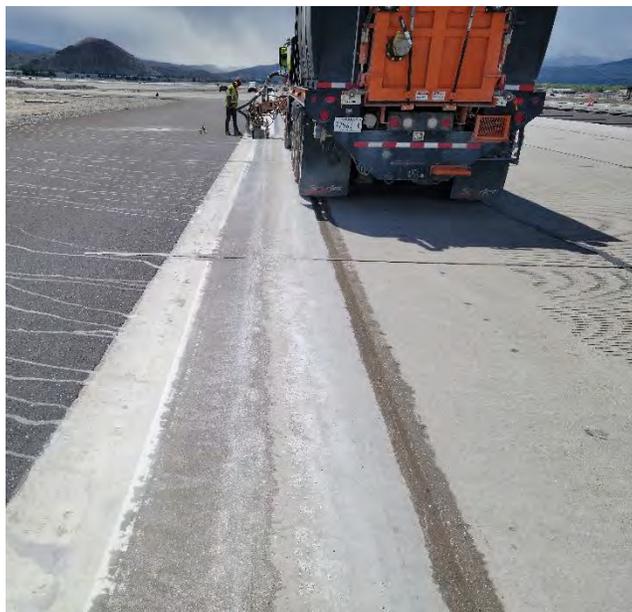


**Figure 44. Paint Removed Over Joint Without Damage to Joint Material.**

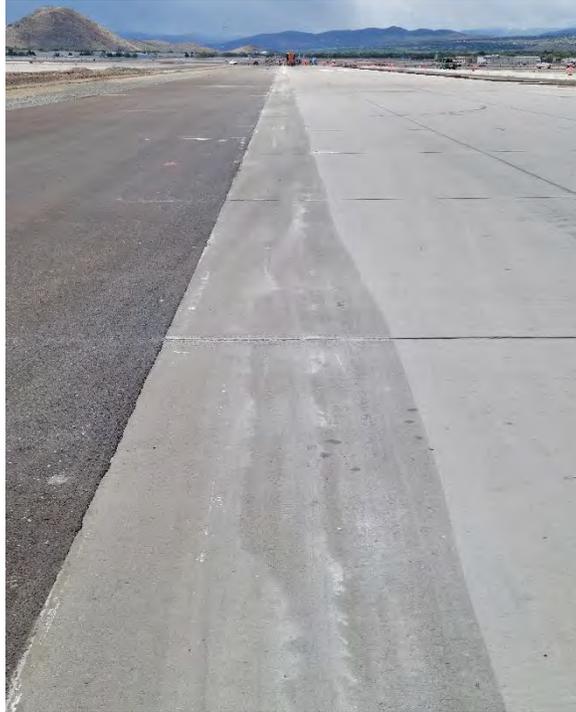
The paint on some areas of the side stripe had been peeling (Figure 45), but removal of the remaining sections was a slow process. The most aggressive configuration of the water blaster was to set up the blasting heads in tandem to remove the old paint in a single, slow pass, only 12 inches wide (Figure 46). The completed removal showed evidence of a scar, but pavement damage was minimal (Figure 47).



**Figure 45. Thick Paint on Some Side Stripe Areas Was Peeling.**



**Figure 46. Thick Paint Removed by Ultra-high Pressure Water Blasting.**



**Figure 47. Scar was Evident, but Not Damaging.**

The runway markings would shift ten feet toward the runway threshold in compliance with FAA requirements that there should only be a 10-foot separation between the runway threshold bar and the runway threshold markings. The result of this new separation requirement was that all markings from the center of the runway back toward the runway threshold would shift 10 feet (Figure 48).



**Figure 48. The Old Marking Configuration Prior to the Rehabilitation Project Showing a 20-foot Separation from the Threshold Bar to the Threshold Markings. (Map Data: Google)**

An aerial view of the triple touchdown zone markings revealed the majority of paint had been removed on the north side in a larger, predetermined pattern in compliance with FAA AC 150/5340-1M (Figure 49). The distance markings were shifting ten feet toward the threshold also in compliance with FAA requirements.



**Figure 49. Aerial View of Removal Pattern. (Map Data: Google)**

Figure 50 shows the results of curing compound removal prior to placing new markings on new grooved concrete. Figure 51 shows the results of removal of various markings and the resulting scarring. The removal of the aiming point marking shows scarring of grooved concrete pavement. The new aiming point marking had been installed over the removal scar, as had the runway side stripe.

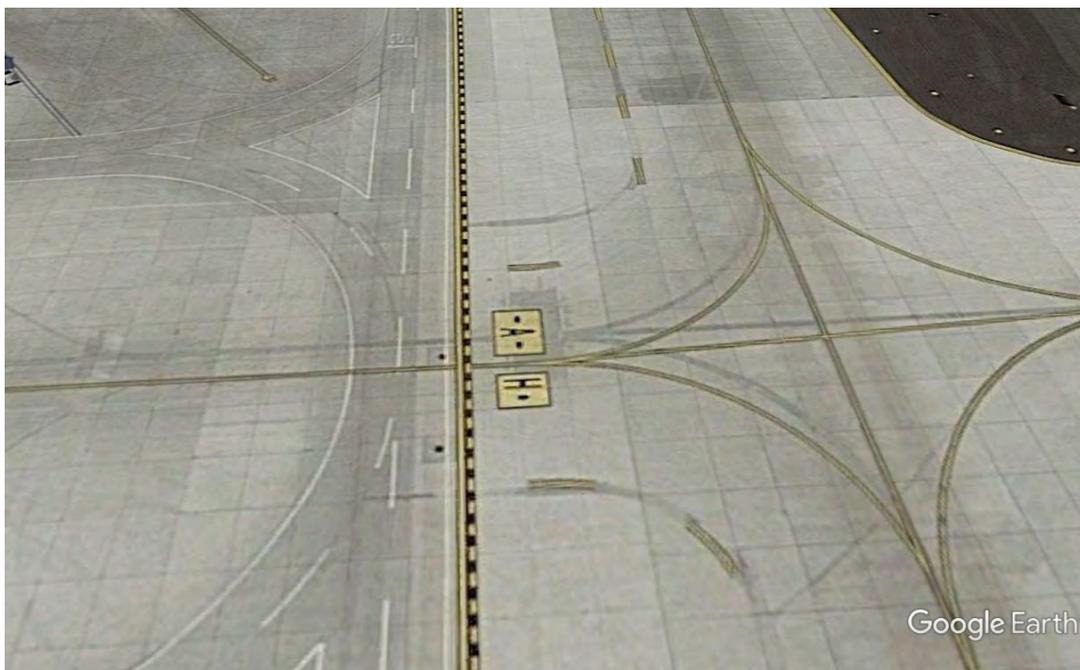


**Figure 50. Curing Compound Removed from New Concrete by Ultrahigh Pressure Water Blasting Prior to New Markings Being Installed.**



**Figure 51. Marking Removal and Subsequent Restriping.**

The terminal apron had scars from marking removal to reconfigure lead in lines into the apron area and to the gate areas. The removal had been done six years prior (Figure 52), and the resulting scars had faded considerably (Figure 53). A close inspection of the scar reveals more pronounced surface cracking because the cracks expanded during the removal (Figure 54). However, surface cracking is present in the surrounding concrete as well.



**Figure 52. Aerial Image from 2015 After Removal Reveals Scarring that Could be Confusing. (Map Data: Google)**



**Figure 53. Old Scars Six Years Later.**



**Figure 54. Close Up Inspection of 6-year-old Removal Area.**

## *Findings*

The removal operation on the runway was successfully removing the thick paint from the concrete surface. Only a 10-foot section of some of the distance markings (Aiming Point and Touchdown Zone Markings) would leave a section of scarred pavement without new paint applied over it. All the other scars would have markings reapplied over them, so the chances of the scars creating any confusion is unlikely.

The removal of the curing compound left a distinct color difference from the areas of new pavement with the curing compound compared to the areas where it had been removed to accommodate the new markings. Although the other curing compound will slough from the pavement over time, the immediate visual difference is noticeable.

Six-year-old scars from a removal operation in 2015 were faded and almost imperceptible. The scars shown in Figure 52 when the removal was done initially were much more noticeable and may have caused confusion. The research teams contact at the airport was not aware of any incidents as a result of the paint removal from 2015.

## **Salt Lake City International Airport (SLC), Utah**

The research team traveled to Salt Lake City, Utah, to observe scarring from previous paint removal operations on concrete during the new terminal construction and the new terminal apron. Additionally, paint removal was being performed by in-house personnel to remove thick paint from concrete taxiway surfaces.

A new terminal apron was constructed during the construction of the new SLC passenger terminal in 2019 and 2020. Upon completion of the new terminal apron, new taxiway and gate markings were installed leading to the new gate areas. Old, now obsolete, markings were removed by water blasting in most cases, particularly on concrete surfaces. Very few markings were removed on asphalt surfaces, but when they were, diamond grinding was used.

## *Inspection*

The research team visited the airport to see the remnants of the scars from the terminal apron construction. A vehicle service road had been painted on the concrete surface in Figure 55. Figure 56 through Figure 61 show various observations of previous removals that generally resulted in little pavement damage but may have not removed enough marking or left a contrast scar.



**Figure 55. Removal of Service Road Markings.**



**Figure 56. Removed Double Yellow Dashed Taxiway Edge Marking.**



**Figure 57. Removed Taxiway Lead in Line to a Gate Area.**



**Figure 58. Removed Taxiway Centerlines Leading Toward Old Gates.**



**Figure 59. Removed Lead in Lines Toward Old Gates.**



**Figure 60. Vehicle Service Road Removed by Water Blasting.**



**Figure 61. Diamond Grinding Removal on Asphalt.**

A section of asphalt with scars leading to the new terminal resulted from a combination of water blasting and diamond grinding, the latter being preferable (Figure 62).



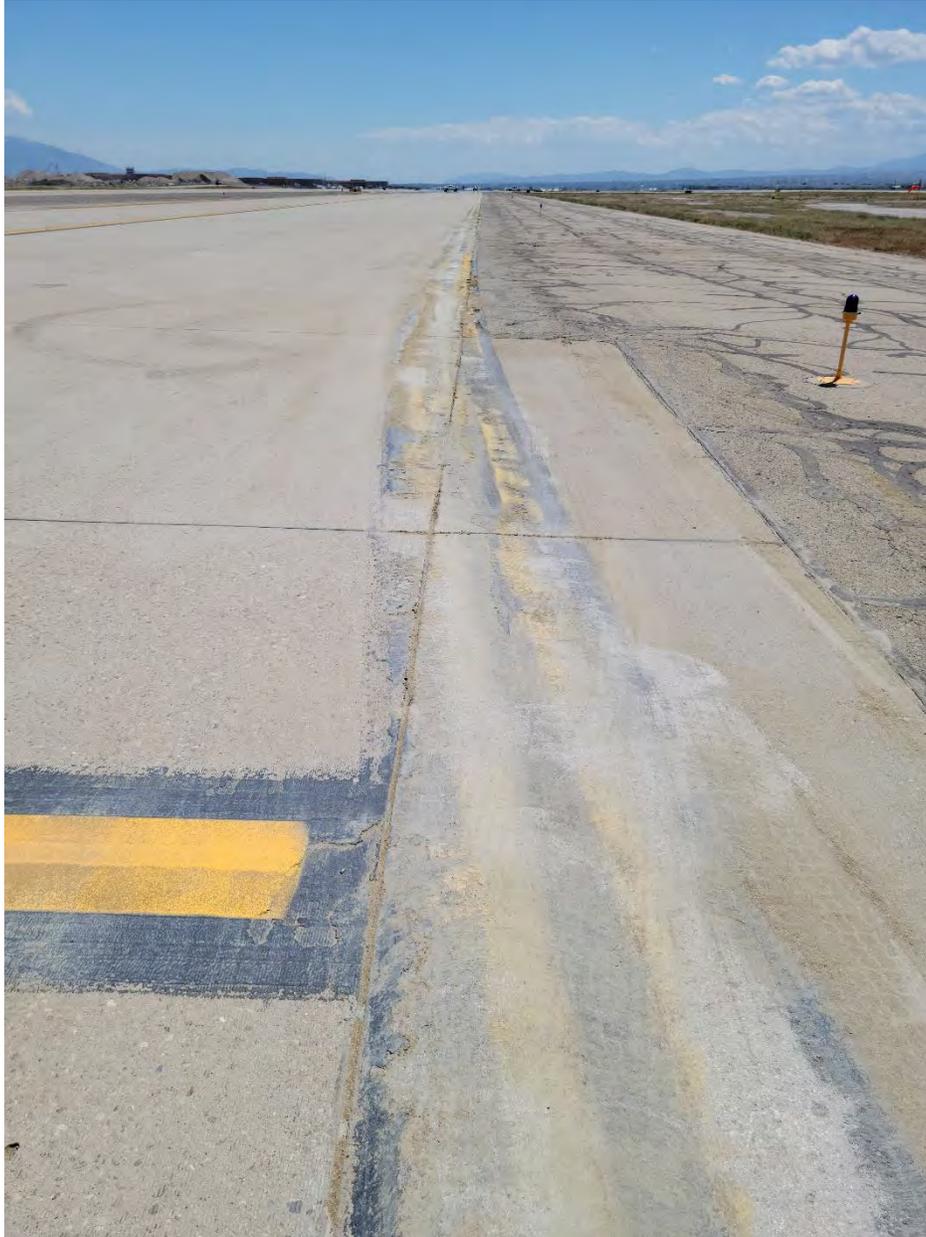
**Figure 62. Close up of Diamond Grinding and Water Blasting on Asphalt.**

The research teams airport operations contact at SLC inquired about any reports of pilots or other airport operators being confused by the scars from the new terminal work and related taxiway centerline removal. To their knowledge, no one had reported any problems with the scars.

After observing many of the scars from the terminal ramp construction, observations were made where the in-house crews were in the process of removing a section of thick paint on taxiway edge markings was being removed by in-house personnel with a rotary grinder mounted on a high-hydraulic flow skid steer (Figure 63). Clean up was achieved by a vacuum sweeper, but still required pressure washing or light water blasting to remove remaining dusty residue (Figure 64).



**Figure 63. Thick Paint on Taxiway Edge Marking Being Removed with Rotary Grinder and Generating a Lot of Paint Debris.**



**Figure 64. Paint Chips Removed with Vacuum Sweeper.**

## **EVALUATION OF TEMPORARY PAVEMENT MARKING PAINT**

### **Gooding Municipal Airport (GNG), Idaho**

Project team members traveled to Gooding, Idaho, to observe marking removal and temporary marking activities. The work occurred at Gooding Municipal Airport. The construction activities at the airport were to extend the runway. This required the removal of existing markings and displacing the threshold for Runway 7. Figure 65 and Figure 66 show plans for the marking removal and temporary markings.

Ultra-high pressure water blasting was used to remove the aiming point markings (20 x 150), runway numeral “7”, three centerline bars (120 x 1.5) and six threshold markings. Both

aiming point markings were removed 95 to 100 percent; the runway numeral was removed 95 percent in a rectangle (in a larger size to obscure the scar) and each threshold marking was removed, 90–95 percent. All the removal scars were to be coated (at the end of construction) with GSB-88 under FAA specification 150/5370-10H, P608. The existing pavement surface was an older ungrooved asphalt.

The aiming point marking removal is displayed in Figure 67. The change in surface color between the removed area and adjacent area is noticeable during the day. Most of the marking was removed. The removal resulted in some damage to the pavement surface with removal of some asphalt and fine aggregate. The removal resulted in some surface texture change.

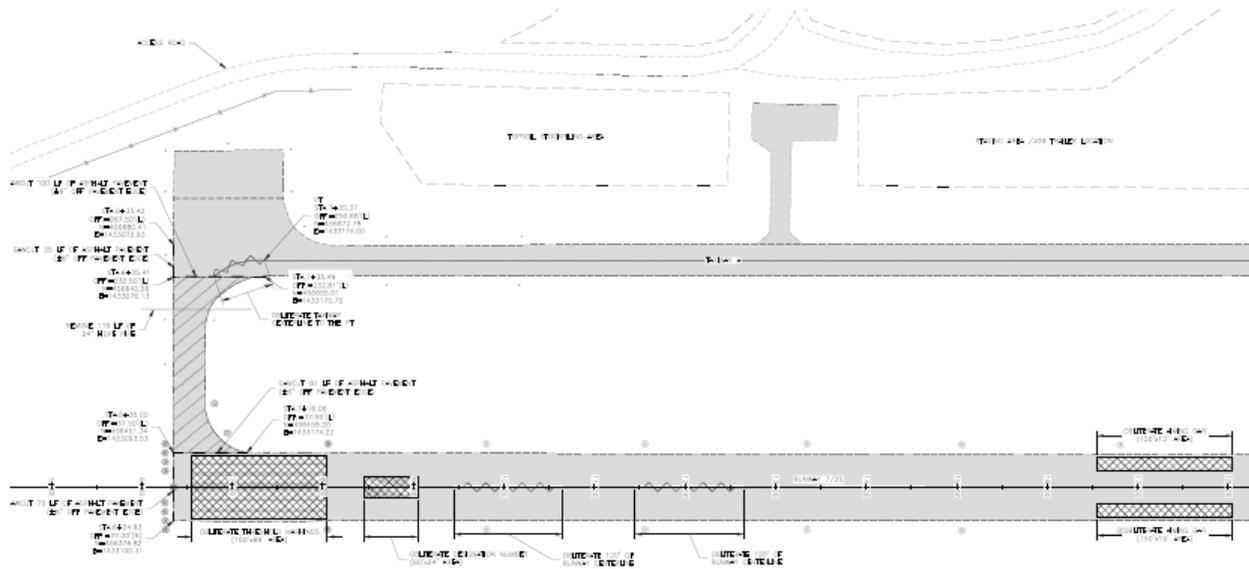


Figure 65. Plan Drawing Showing Removed Areas.



up when not on the marking to minimize damage to the pavement. Figure 68 shows quite a bit of the marking remaining. The operator made a second pass over the marked area going along the direction of the marking. This removed most of the marking while causing as little damage to the surrounding pavement as possible. Figure 69 provides an image of the final result. The removal resulted in some damage to the pavement surface with removal of some asphalt and fine aggregate. The removal resulted in some surface texture change.



**Figure 68. Runway Designation Marking Removal.**



**Figure 69. Removed Runway Designation Marking.**

The threshold marking removal is displayed in Figure 70. The change in surface color between the removed area and adjacent area is noticeable during the day. Figure 71 provides an image of the final result. The removal resulted in some damage to the pavement surface with removal of some asphalt and fine aggregate. The removal resulted in some surface texture change. A larger block of removal was not conducted to minimize pavement damage and to serve as a potential survey point for the impact of removing the markings in a larger block pattern or just removing the markings themselves.



**Figure 70. Threshold Marking Removal.**



**Figure 71. Removed Threshold Markings.**

The temporary Runway Landing Designation Marking and the Threshold Bar were applied using a standard white TT-P-1952F, Type II waterborne paint. Five gallons of temporary yellow paint was manufactured by Safety Coatings and shipped to the airport. The intent was that this temporary paint material (similar to the older TT-P-1952B materials) would meet the same performance as the other yellow marking used but be easier to remove. The goal was to apply the specially formulated temporary yellow paint to two of the chevrons to determine if the formulation might be more easily removed than the standard Federal Specification TT-P-1952F, Type II which was used to apply the third chevron. Due to time constraints the contractor was unable to purge the striper prior to apply the second paint formulation. This resulted in a mix of paint being applied to the third chevron. The standard Type II paint was added to about 2 gallons of the temporary yellow before painting the third chevron. The paint was applied very thinly on the third chevron. Removal of the chevrons should be achieved without severely scarring the pavement. The removal of chevrons will be compared to the removal of threshold and designation markings to determine if the marking formulation had an impact on removability. The marking performance characteristic will also be evaluated at the end of their temporary service.

Figure 72 shows some of the temporary marking installation. Samples of the markings were collected on aluminum plates to evaluate marking thickness, bead coverage, color, and retroreflectivity. Figure 73 shows some of the completed temporary markings.



**Figure 72. Chevron Application with Sample Plate.**



**Figure 73. Completed Temporary Markings.**

A second trip to Gooding, Idaho, occurred so that the removal of the temporary markings could be observed. The temporary markings were installed on August 11, 2020, and removed on October 16, 2020, approximately two months from the installation of the temporary markings. Ultra-high pressure water blasting was used to remove three chevrons, a threshold bar, and the number “7”. Table 6 describes the different parameters for the removal process on the markings that were removed. The rotor bar rotated at 2600 RPM. The tip array in the rotor bar was set up with tip sizes ranging from 12 mm to 9 mm.

**Table 6. Temporary Marking Retroreflectivity and Removal Information.**

Marking	Chevron #1	Chevron #2	Chevron #3	Threshold Bar	Numeral 7
Color	Yellow	Yellow	Yellow	White	White
Type of paint	1952B	1952B	1952F	1952F	1952F
Retroreflectivity value mcd/m <sup>2</sup> /lx	112	93	86	163	185
Water blasting Pressure (psi)	14K/22K	16K/22K	16K/22K	22K	22K
Number of passes	3/1	2/1	2/1	1	1
Level of scarring	Good	Good	Good	Good	Good

Chevrons #1 and #2 (closest to the threshold bar, chevron #1 can be seen in Figure 73) had been applied with an experimental waterborne paint similar in formulation to TT-P-1952B, an early waterborne specification (mid 80s). The goal was to determine if a lesser pressure would be effective in removing the temporary paint to reduce scarring of the asphalt.

Chevron #3 (Figure 74) which had used the standard TT-P-1952F yellow waterborne paint was first to be removed. As indicated in Table 6, 16,000 psi was used and effectively removed 98 percent of the marking with two passes at that pressure.

Chevron #2 (Figure 75), having been applied with the experimental waterborne, was removed using 14,000 psi to see if it would come up more easily. It took three passes to remove the paint to the same 98 percent with similar scarring.



**Figure 74. Chevron #3, First Leg Removal.**



**Figure 75. Chevron #2, Removal at 14,000 psi, Second Pass.**

The first leg of chevron #1 (Figure 76) was removed using 16,000 psi with two passes. It had also been painted using the experimental yellow waterborne paint. After the removal of the

first leg of chevrons #2 and #1, it was apparent that an equal amount of pressure and number of passes was needed to remove the experimental paint as well as the standard waterborne paint.



**Figure 76. Chevron #1, 16,000 psi, Two Passes.**

The threshold bar, runway designation marking, and numeral 7 were removed with 22,000 psi and was able to remove approximately the same percentage of paint with a single pass. Although the pressure was almost 50 percent higher, a single pass produced a similar profile achieved with 16,000 psi and two passes, see Figure 77 and Figure 78.

An asphalt sealer, GSB-88 (AC 150/5370-10H, P608) was planned to be applied over all pavement where removal of either original markings or temporary markings had occurred. The overall scarring, although evident, was not severe. Closeups of the removal are provided in Figure 79 and Figure 80.



**Figure 78. Temporary Displaced Threshold Bar Removed at 22,000 psi, Single Pass.**



**Figure 77. Runway Designation Marking Removed at 22,000 psi, Single Pass.**



**Figure 80. Profile of Pavement Where #7 had been Removed, 22,000 psi, Single Pass.**



**Figure 79. Profile of Pavement Where First Leg of Chevron #1 had been Removed, 16,000 psi, two passes.**

### *Gooding Idaho Summary*

Removal of the existing markings with an ultra-high water blaster produced an acceptable profile without loosening the nominal-sized aggregate. Existing markings removed in August had been considerably thicker than the temporary markings removed in October, but the resulting profile was acceptable.

The threshold markings removed in August were not removed in a larger area than the markings themselves and should provide a comparison for textural changes or visible scarring as compared to the runway designation marking, even after the sealer is applied.

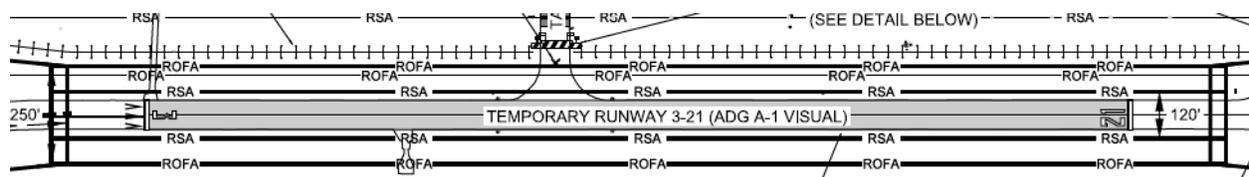
The experimental waterborne paint did not prove to be any easier to remove than the standard waterborne paint. All temporary markings removed in a single pass at 22,000 psi resulted in an acceptable and similar profile of the pavement microtexture.

## Millington-Memphis Airport (NQA), Tennessee

The project team coordinated with the airfield manager in order to use a custom temporary marking paint to apply temporary runway markings to a taxiway while the runway was rehabilitated for an approximate 6-month duration. Rather than close the airfield which serves as a reliever to Memphis International Airport, the airfield manager wanted to keep operations going for the flight school located on site. Marking the parallel taxiway as a runway would enable the flight school to continue training.

After several meetings and telecons, all agreed that the temporary marking material would be custom formulated by Safety Coatings of Foley, Alabama. The resin had to be specially ordered once all agreed. Based on the quantities of temporary markings to be installed, 70 gallons of white and 15 gallons of yellow were ordered.

The striping contractor used the temporary paint to apply numerals 3 and 21 as well as two threshold bars and a runway centerline, 12 inches wide. Taxiway markings in the way of a holding position marking, taxiway centerline and three displaced threshold arrowheads would be applied prior to the temporary runway surface. Figure 81 provides a diagram of the marking layout.



**Figure 81. Temporary Marking Layout.**

### *Project Execution*

No one from the research team was able to mobilize to the worksite to observe the marking installation, given the uncertain timing of the work. A preconstruction conference was held, and it was determined the temporary markings would be applied either on March 29th or April 5th. The research team was in communication with the airfield manager prior to Tuesday, March 29th concerned about approaching rain predicted for Tuesday, the 29th and Wednesday, the 30th. The airport manager reported that the contractor would apply the markings the night of Monday, March 28th to try to beat the rain. The temporary paint would probably not withstand rain within 24 hours, but the attempt was made, using the custom white paint for the runway markings. Standard yellow paint was used for the holding position marking, taxiway centerline and displaced arrow heads.



**Figure 82. Installed Temporary Markings.**

The next day, the rain came and washed away a large portion of the white temporary paint (see Figure 83). The contractor returned and applied standard white paint over the runway markings.

#### *Lesson Learned*

The temporary paint does not contain fast drying solvents and is designed to be removed easily with low pressure water. It is not advisable to apply the temporary paint when inclement weather is predicted within 12–24 hours.



**Figure 83. Temporary Marking Loss Due to Rain.**

### **Cochran Airport, Cochran (48A), GA**

The research team traveled to Cochran, Georgia, to apply temporary paint to Runway 5 at Cochran Airport. The project resulted from the need to find an airport willing to apply a new formulation of the experimental temporary paint within the time limits of the research project. The Georgia Department of Aviation accommodated this study by allowing the installation of a temporary displaced threshold on an existing runway surface. The existing four threshold markings, runway numeral “5” and part of a centerline were blacked out with temporary black paint. The displacement was 140 feet, including three arrowheads, a partial tail, a threshold bar, four threshold markings and a numeral “5”. The temporary marking applications were expected to be in place for two weeks.

Temporary paint developed by Safety Coatings, Inc. was delivered to the striping contractor. This version of the temporary paint, (referred to as removable paint throughout the remainder of this document) contained a weaker resin designed to release more easily. The material safety data sheet for the removable paint is provide in Appendix C. Black paint was used to obscure all markings within the displaced area not covered with white paint.

The existing markings were blacked out with temporary black paint, omitting areas to be painted white. The weather was a mild 64°F, and the surface temperature was 75°F. Once all the black paint was applied, the white was installed. The paint was thick but sprayed well.



**Figure 84. Temporary Arrowheads and Threshold Bar Were Painted. Black Paint Obscured the Existing Threshold Markings.**



**Figure 85. Beginning of Displaced Threshold on Runway 5. Black paint Obscures Existing Threshold Markings.**



**Figure 86. Temporary Runway Numeral “5” Painted Over Blacked Out Centerline.**

Removal of the temporary markings was accomplished two weeks after installation with an ultra-high pressure water blaster using 14,800 psi, non-aggressive tip array (eight 12-mm nozzles and ten 10-mm nozzles), spinning the 19-inch bar approximately 2500 rpm. The white markings were removed first, and there was no scarring of the distressed pavement (Figure 87), indicating the paint released easily from the surface. The black markings that had been painted over the existing white markings were removed last and did remove some of the existing white markings (Figure 87 and Figure 88), indicating it is advisable to plan to repaint any markings covered with black paint since the removal process may disturb the existing markings meant to remain.

There was some traffic that had landed on the temporary markings, but it is not known after this short trial how long the temporary paint will last. Further testing is needed, but the initial finding is the marking removes easily without scarring.



**Figure 87. Removal of Removable Paint.**



**Figure 88. Removal of Temporary Black Paint from Existing White Markings Resulted in the Need to Repaint the White Markings.**

### **Experimental Temporary Marking Application Results**

Two types of temporary marking paint were developed for this study that were applied at 230 SF/gal (50 percent rate).

- The first temporary coating was similar to the original waterborne TT-P-1952B, an early federal specification when waterborne paint was first introduced. Removal of the marking required two to three passes at 14K psi and one pass at 22K psi. The removal required removal pressures and passes similar to the standard TT-P-1952F, Type II paint, and thus was not considered a successful option. Scarring of the asphalt was similar between the tested temporary paint and the standard paint.
- The second temporary coating (removable paint) contained a weaker resin designed to release more easily. The paint was very viscous but sprayed well through an airless paint machine. The marking was removed with 14,800 psi without scarring or disturbing the crack seal. The project involved blacking out the existing markings, using temporary black paint. When the black was removed, some of the existing markings were disturbed.



## CHAPTER 5. FINDINGS, BEST PRACTICES, AND SUGGESTED RESEARCH

### FINDINGS

The research team completed a comprehensive literature review, a nationwide survey, and field visits around the country. The research findings are based on information collected from each of these areas. The research findings are broken down by marking removal and temporary marking applications.

#### Airfield Marking Removal

- Different pavement types, pavement conditions, marking materials, and the reason for the removal should be considered during the specification development portion of project planning when marking removal will be part of the project.
- The main consideration of the type of marking to remove is the marking thickness. Paint markings are applied in thin layers but often reapplied numerous times. This paint can build up a thicker layer that is more difficult to remove than a single paint layer (i.e., temporary paint markings). Durable marking such as epoxy, MMA, and preformed thermoplastic are thicker and more difficult to remove.
- Blasting techniques do not work as well on thicker markings. Grinding techniques are more effective for thicker markings so long as the marking is not below the pavement surface. In situations where there is a thick buildup of marking and the surface is grooved or a porous asphalt, a combination of a grinding technique followed by a blasting technique will often yield the best results.
- Not all of a marking may need to be totally removed. One hundred percent removal will result in the highest degree of scarring and possible damage. Different reasons for removing a marking should dictate the degree of removal required.
- Condition of the pavement under the markings should be evaluated to determine what method of removal will do the least damage. Correlation of pavement condition under the markings with pavement condition index (PCI) provides some guidance on the ability of the pavement to sustain the mechanical method(s) of paint removal.
- Scarring is inevitable when removing paint from pavements since the coating is bonded to the microtexture of the pavement. Minimizing scarring and preventing damage to the pavement is the goal of a high-quality marking removal.
- Marking removal from concrete surfaces should only use water blasting or scarification above the surface followed by water blasting to remove marking below the surface. Scarification or grinding of concrete surfaces to remove 100 percent of coatings is not suggested due to the permanent scarring of the pavement.
- Discoloration of the pavement where removal occurred can be blended with the surrounding pavement (by removing an area larger than the marking area) to reduce confusion. This additional removal should be light such that scarring does not occur. Scarring and damage to concrete pavements is difficult to repair since it cannot easily be concealed below a seal coat.

- Marking removal from asphalt surfaces will leave a scar that fades over time due to ultraviolet light. The use of seal coats to obscure the scars and residual paint is a typical practice.
- Removing an inadequate amount of an obsolete marking may result in a ghost marking. A ghost marking is the remnants of a previous marking that may still be mistaken for a marking. The reason for the marking removal and associated target removal percentage should be defined. Applying highly visible replacement markings or temporary markings will help alleviate confusion caused by ghost markings, scarring, or pavement damage.
- Safety is the greatest concern if markings are inadequately removed. The visibility of the removed markings and replacement markings needs to be evaluated in both day and night conditions. In addition, the marking should be viewed during different times of the day (the sun angle can impact visibility) and during different weather conditions (dry vs. wet). Viewing the removed areas and replacement markings in these different conditions from typical observer perspectives is the best way to determine if their removal will result in confusion. If it is determined the removal may cause confusion, additional removal or corrective actions need to take place to improve the areas where the removal occurred.

### **Temporary Airfield Markings**

- The removal of the permanent markings (if applicable), the application of temporary markings, and removal of the temporary markings need to be considered when developing project plans that include temporary markings.
- The application of temporary markings typically follows the removal or concealing of permanent markings. Temporary markings are not intended for a long period of service; they are often applied using paint at lower application rates than permanent markings.
- Temporary markings are customarily applied with waterborne paint at a 30 to 50 percent coverage rate, but removal of those temporary markings often results in scarring on asphalt pavements.
- When paint is applied at lower coverage rates, glass beads will typically not stick. Temporary markings not in compliance with AC 150/5340-1 will require a Notice to Air Mission (NOTAM) regarding any non-standard marking (e.g., temporary markings without beads). If nighttime visibility of the markings is critical, glass beads and a standard paint rate should be applied.
- Specially formulated temporary paint is a viable method of applying temporary markings that will remove easier than standard paint. The second formulation of temporary paint “Removable Paint” proved successful. It contained a weaker resin designed to release more easily. The paint was very viscous but sprayed well through an airless paint machine. The marking was removed with 14,800 psi without scarring or disturbing the crack seal. The ease of removal was considered a success.
- Application of temporary markings over curing compound has been successful on concrete. The markings may flake off prematurely depending on the age of the curing compound and duration of the temporary markings. Curing compound can be applied to asphalt prior to application of temporary markings in an effort to improve

removability of the temporary markings without damaging the pavement. This process is not as successful as it is on new concrete. The curing compound has to be applied thickly, and the temporary markings often flake off as the curing compound sheds.

- Similar to applying curing compound, a black paint was applied prior to the application of temporary markings. Black paint was applied to asphalt surfaces where the temporary white markings would be installed. Removal of the white paint resulted in removal of the black paint as well and the resulting scarring was similar to applications that did not have the black paint applied. There did not appear to be a benefit of the black paint under the temporary markings.
- In situations where the temporary markings will be removed and the previous marking pattern will be reapplied in the same location, the previous markings can be covered in black paint or potentially concealed with a physical barrier. Thick markings may need to be partially removed by grinding to reduce the thickness prior to the application of black paint. Any black overpainting should be checked periodically during the temporary marking life to ensure glass beads are not showing through, making them visible during darkness.
- If the permanent markings that need to be temporarily removed are in areas closed to traffic, then the markings can be physically concealed. As part of the project an area of markings on asphalt runway were covered with black tarps and black sandbags. The choice of covering the majority of the markings with tarps and sandbags for the short duration seemed to work, although constant monitoring of the tarps and sandbags was required. When the work was over the markings were exposed, and there was no resulting damage to the pavement.
- If temporary markings are applied to an area where old markings were removed, all residue remaining from the removal operation must be thoroughly removed. Cracks and crevices in the removal scar will hold debris and prevent any new permanent or temporary coating from adhering.
- The installation of temporary markings should meet applicable installation requirements. Typical requirements include:
  - Color needs to meet requirements for the specific marking type and location.
  - Coverage of the material should be uniform.
  - Glass beads can typically not be applied to temporary markings since the marking is typically applied at 30 to 50 percent coverage rate. The temporary coating is too thin to embed and hold the glass beads.
  - If a temporary marking is required to be reflective (if it will be in place for a long period of time), a full coverage rate using TT-B-1325D Type I glass beads should be used.
  - If used, removable paint should be applied under good weather conditions, preferably during daytime hours. Its formulation does not include the fast-drying solvents found in standard waterborne paint and requires at least one hour to dry at 50°F and rising, less than 85 percent humidity, and no rain in the forecast for at least 12 hours. Coverage rate should be 230 SF/gal without glass beads. Paint equipment should be cleaned out so that no other formulation mixes with the temporary paint.

- The removal of temporary markings is similar to that of permanent markings. The biggest difference is that temporary markings are almost always thinly applied paint which should be easier to remove than thicker permanent markings.

## **BEST PRACTICES**

Researchers summarized their findings and best practices in the development of the Airfield Pavement Markings—Effective Techniques for Removal and Temporary Applications “Airfield Guide for Engineers” and the “Field Inspection Guide.” The research team suggests distribution and implementation of these two documents. The developed best practices for airfield marking removal and temporary marking applications are provided in the following sections.

### *Airfield Marking Removal Best Practices*

1. During the design phase of the project, analyze the condition of the markings to be removed and the condition of the pavement under the markings (compare to most recent PCI of the subject pavement).
2. Specify the type(s) of equipment to be used based on the analysis of the markings to be removed. Bidders on the removal project should submit a list of equipment to be used on the project that conforms to the specifications.
3. Removal test lines should be performed with all types of equipment to be used on the project. Pictures of acceptable results should be taken and used as an example of the degree of removal and acceptable level of scarring. Different degrees of removal may be required on the same project. Removal test lines should be performed on all types/degrees of removal with each type of equipment to demonstrate the capability of both the equipment and the operator. Different pavement surfaces may require different removal techniques.
4. Removal should result in the desired level of marking being removed while minimizing damage to the pavement surface. Removal in grooves requires a blasting technique or grooving machine to minimize pavement damage.
5. On asphalt surfaces, determine if the need to remove a “larger predetermined area” of the marking is necessary to reduce confusion from the remaining scar or color changes. Experience has demonstrated that adherence to this guidance found in AC 150/5340-1M on asphalt surfaces does not always achieve the desired result and erodes the surrounding pavement unnecessarily. A sealant should be specified in the event scars are objectionable and could be confusing.
6. Debris from removal operations should be continuously contained and disposed of in accordance with local and Federal environmental regulations.
7. If markings are to be applied in any area where removal operations were conducted, ensure the surface is clean and free of any and all debris to ensure a good bond of the coatings to the pavement.
8. Conduct a “pull” test with duct tape or other adhesive material by pressing tape onto surface where removal was done. Pull tape up to see if any residual debris is stuck to the tape. If debris is present, further cleaning (sweeping or rinsing with pressurized water) is necessary.
9. Inspectors should refer to the “Field Inspection Guide” developed for use in the field when inspecting pavement marking removal operations on airfield pavement markings.

## *Airfield Temporary Marking Best Practices*

Best practices for temporary pavement marking application and removal varies by the pavement surface and condition. A physical barrier to conceal markings that will go back into service after the temporary markings are removed should be considered on both concrete and asphalt pavements. The following sections provide best practices for concrete and asphalt pavements.

### *On Concrete Pavements*

- Apply temporary markings at half (230 SF/gal) or at a full rate with glass beads if reflective markings are required.
- If temporary markings will be in place for less than 30 days, apply over curing compound or use removable paint.
- Removal by water blasting should be accomplished with little difficulty.

### *On Asphalt Pavements*

- If the pavement is in fair condition and grooved, a temporary removable paint should be used to avoid damage to the pavement that may result when the markings are removed. A seal coat should be planned into the project to cover the area in the event aggregate loosens.
- Removable paint should be applied under good weather conditions, preferably during daytime hours. Its formulation does not include the fast-drying solvents found in standard waterborne paint and requires at least one hour to dry at 50°F and rising, less than 85 percent humidity, and no rain in the forecast for at least 12 hours. Removal using 14,800 psi left no scarring, even on poor pavement.

## **SUGGESTED RESEARCH**

This project explored many aspects of airfield pavement marking removal and temporary marking applications. The COVID-19 pandemic limited some aspects of the research, but those limitations had minimal impact on the final results.

The research team explored specifically formulated temporary removable paint that was easily removed from an asphalt surface. Further exploration into this paint formulation to determine its durability and removability from a larger variety of surfaces is warranted. If successful, this specifically formulated temporary paint could provide great benefits to temporary marking applications by making the marking easier to remove and limiting damage to the pavement surface.

The vast majority of removal operations use water blasting or grinding. The research team explored unique removal methods but were unable to find any other than when rotary grinding used in combination with a groove cutting machine. The rotary grinding was used to remove the surface marking and the groove cutter was used to clean out the grooves. This dual method approach could also have been accomplished with water blasting to remove the marking from the grooves after the bulk of the material was removed with the grinding method. Continued exploration of innovative removal methods or combinations of methods is warranted as new technologies and methods are developed.

One perspective that is not in the survey was that of pilots. From a safety standpoint their opinions are critical. Not only their observation of the marking removal and temporary markings while they are on the ground, but also when they are on approach to the airfield. Feedback from pilots to better understand their perspective is warranted.

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## **APPENDIX A. SURVEY DEVELOPMENT**

The research team anticipated a multifaceted approach to gathering the survey information. The original approach consisted of surveys on a web-based platform, follow-up calls based on survey responses, in-person surveys/interviews at field data collection sites, and in-person focus groups at select locations where pilots or airport personnel can provide direct feedback on satisfaction with removal and temporary marking activities at that specific airport. The Covid-19 situation removed the opportunity to conduct the in-person surveys and focus groups. The research team had to rely on the online surveys and follow-up emails and web-based interviews to collect the survey information.

Multiple items were developed to facilitate the online survey. The survey questions had to be developed, the questions had to be put into a web-based survey platform, a recruitment email for the online survey was developed, an introduction to the survey questions was developed, a survey information sheet to provide information to the respondents was developed, and an Institutional Review Board (IRB) application for the survey work was developed as both Texas A&M University and Virginia Tech require that their University IRB programs review the survey work prior to conducting the survey.

Figure 89 provides a screenshot of the survey introduction slide. The survey was developed utilizing the QualtricsXM interface. This interface allows the survey to be completed on a computer or mobile device. Figure 89 is a screenshot of the first slide of the survey as viewed on a computer. Figure 90 is an example of what the survey would look like on a mobile platform.

The distributed survey questions were specific to the type of occupation of the survey respondent. Specific survey questions were developed for pilots, airport/agency personnel, and contractor/consultants. The research team developed the survey questions to cover a wide range of topics concerning pavement marking removal and temporary marking applications. The full list of online survey questions and virtual interview questions are provided in this appendix.

Eight organizations were approached to distribute the online survey of which three agreed to distribute the survey. The research team also reached out to airport management contacts, contractors, and other contacts to directly distribute the survey link.

Greetings!

The Texas A&M Transportation Institute (TTI) and Virginia Tech Transportation Institute (VTTI) are conducting a survey as part of ACRP sponsored research project 09-19 "Airfield Pavement Markings – Effective Techniques for Removal and Temporary Applications." The goal of the survey is to gather information to improve airfield pavement marking removal and temporary marking applications.

The survey should take approximately 15 minutes (length dependent on survey responses) and will cover a variety of questions regarding airfield pavement markings, marking removal, and temporary pavement marking applications. Participation in this survey is optional, and respondents are not required to answer all questions to take part in the survey. Additional information about taking the survey is contained in the survey consent – information sheet (see [information sheet](#)).

Please select begin survey to start the survey.

Please contact either or both of us if you have any questions.

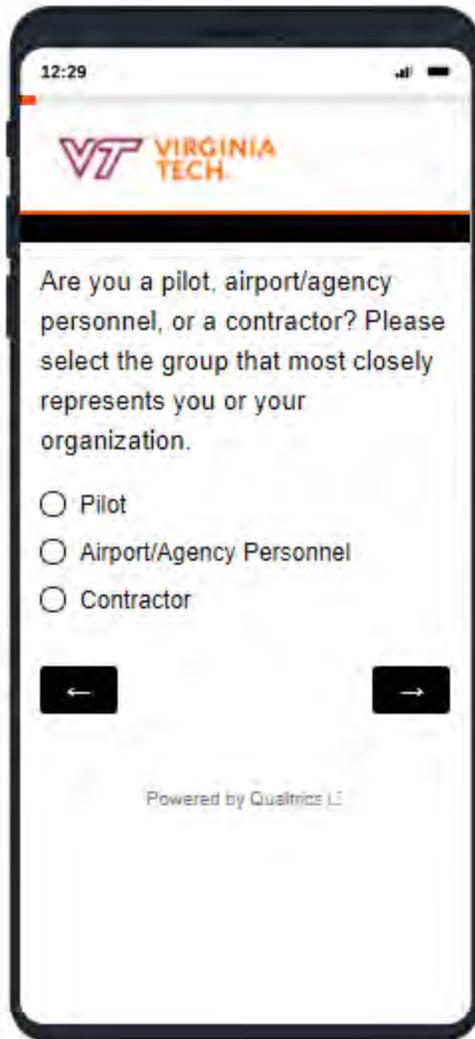
Many thanks, Adam and Matt

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Your participation is completely voluntary. Would you like to proceed with the survey?

- Yes  
 No

**Figure 89. First Slide of Online Survey.**



**Figure 90. Mobile Based Survey Interface.**

### **Online Survey Questions**

1. Please indicate your age:
  - Less than 18 years old (selecting this option will skip to the end of the survey).
  - 18 years old or older.
2. Are you a pilot, airport/agency personnel, or a contractor? Please select the group that most closely represents you or your organization.
  - Pilot.
  - Airport/Agency Personnel.
  - Contractor.
  - Other (selecting this option will skip to the end of the survey).

Yes/No for each or checkbox

The selected answer will then lead to the specific questions for that category.

### **Pilots**

3. Which airport do you use the most / is your home airport?
  - Comment box.
4. Have you had problems with the visibility of airport pavement markings while piloting an aircraft? Visibility considering the following conditions, day or night, inclement weather, construction areas, etc.
  - Comment box.
5. If yes, is the visibility of the markings related to day or night conditions or other weather conditions? Please indicate when the visibility problems occur such as on approach or while taxiing. Which markings tend to have the most visibility related issues?

If no, could the markings be improved? How so?

  - Comment box.
6. Have you been confused by areas where pavement marking removal has occurred? Do you remember any specific airport locations or marking types that led to confusion? What was the cause of the confusion, i.e. pavement scarring (removal left the pavement damaged where the previous marking was), previous marking still visible, color differentiation between removed area and adjacent surface? Please indicate if the problems are on approach or while taxiing.
  - Comment box.
7. Have you been confused by areas where temporary markings have been installed? Do you remember any specific airport locations or marking types that led to confusion? What was the cause of the confusion, i.e. poor day or night visibility, poor color, etc.? Please indicate if the problems are on approach or while taxiing.
  - Comment box.
8. Have you reported pavement marking issues when you have had problems?
  - Yes/No.
  - Comment box.
9. Do you have any general thoughts on airport pavement markings and their removal?
  - Comment box.
10. Can we contact you for more detailed answers to the questions? If Yes, please click the link below to complete a separate survey to provide your contact information. Your contact information will not be tied to the results from this survey.
  - [Link to contact info survey.](#)

### **Airport/Agency Personnel**

3. Have you had runway/taxiway/apron projects where pavement marking removal occurred in the last 5 years?
  - Yes/No.
  - Comment box.
4. What removal methods were used?
  - Provide list of options here, including ability to enter their own answers.
5. Were you satisfied with the quality of the marking removal? Did level of satisfaction differ between removal methods, pavement surface type, or by type of marking removed?
  - Comment box for each specific removal method indicated.
  - General comment box for comparison of methods, surfaces, markings.
6. Were you satisfied with the amount of pavement damaged caused by the marking removal? How did level of satisfaction differ between pavement surfaces or removal methods? Please think about which combinations of pavement surface type and removal method resulted in the highest and lowest satisfaction.
  - Comment box for each specific removal method indicated.
  - General comment box for comparison of methods.
7. Do you require specific removal methods on specific surfaces? Please specify if so. If not required do you have a preferred method for each surface type?
  - Yes/No.
  - Comment box.
8. Have you tried any unique removal methods?
  - Yes/No.
  - Comment box.
9. Is evidence of past removal activities still visible on the pavement? How old is the removal work?
  - Yes/No.
  - Comment box.
10. Have you had runway/taxiway/apron projects where temporary pavement markings have been installed in the last 5 years?
  - Yes/No.
  - Comment box.
11. What types of temporary pavement marking materials have been used?
  - Comment box.
12. Were you satisfied with the quality of the temporary markings?
  - Comment box.

13. Have you experienced visibility issues with the temporary pavement markings? Color fading, not bright at night, they do not look like the permanent markings, etc.?
  - Comment box.
14. How long are the temporary markings typically installed prior to removal?
  - Comment box.
15. Does removal of temporary markings differ from the removal of permanent markings? Are different methods or techniques used?
  - Comment box.
16. Were you satisfied with the quality of the temporary marking removal? Did level of satisfaction differ between removal methods?
  - Comment box.
17. Were you satisfied with the amount of pavement damaged caused by the temporary marking removal? Did level of satisfaction differ between removal methods?
  - Comment box.
18. Have you had any incidents related to the visibility of pavement marking? If yes, were any incidents related to areas where marking removal has occurred or areas where temporary markings were applied?
  - Comment box.
19. Have you received feedback from pilots, ground personnel, or others about visibility of pavement markings? Is this feedback related to areas where marking removal has occurred or areas where temporary markings were applied?
  - Comment box.
20. Do you have any projects where permanent pavement marking removal is scheduled to occur within the next 8-months?
  - Comment box.
21. Do you have any projects where temporary markings are scheduled to be installed within the next 8-months?
  - Comment box.
22. Do you have any projects where temporary markings are scheduled to be removed within the next 8-months?
  - Comment box.
23. Do you have any general thoughts on improving airport pavement markings, temporary markings, and marking removal?
  - Comment box.

24. Can we contact you for more detailed answers to the questions? If Yes, please click the link below to complete a separate survey to provide your contact information. Your contact information will not be tied to the results from this survey.

- Link to contact info survey.

### **Contractors**

3. Have you conducted runway/taxiway/apron pavement marking removal in the last 5 years?

- Yes/No—Skip to 12 if no.

If yes, did you have any notable jobs that may be beneficial to our research project? Please list location(s) and why notable.

- Comment box.

4. What removal methods were used?

- Provide list of options here, including ability to enter their own answers.

5. What pavement marking removal method do you prefer? Why?

- Comment box.

6. Which removal method removes the marking the best? Does it depend on the pavement surface type? Does it depend on the pavement marking type?

- Comment box.

7. Which removal method causes the least damage to the pavement? Does it depend on the pavement surface type? Does it depend on the pavement marking type?

- Comment box.

8. Do you use or are you required to use specific removal methods on specific surfaces? Please specify if so.

- Yes/No.
- Comment box.

9. Have you tried any unique removal methods?

- Yes/No.
- Comment box.

10. Do you follow the marking removal guidelines specified in FAA Advisory Circular 150/5340-1M, Standards for Airport Markings, dated 5/10/2019?  
[https://www.faa.gov/airports/resources/advisory\\_circulars/index.cfm/go/document.current/documentNumber/150\\_5340-1](https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5340-1)

If not, what specification or guidance do you utilize?

- Yes/No.
- Comment box.

11. Are there any modifications to the removal guidelines you utilize?
  - Comment box.
12. How much additional area do you remove surrounding markings on runways, taxiways, and aprons to reduce confusion associated with the removed area (ghost markings)?
  - Comment box.
13. Have you installed temporary runway/taxiway/apron markings in the last 5 years?
  - Yes/No—Skip to 18 if no.
14. What types of temporary pavement marking materials have been used?
  - Comment box.
15. How long are the temporary markings typically installed prior to removal?
  - Comment box.
16. Does removal of temporary markings differ from the removal of permanent markings?
  - Comment box.
17. Have you received feedback from airport operators about your removal activities? Please provide any comments that could benefit our research.
  - Comment box.
18. Have you received feedback from airport operators about your temporary marking activities? Please provide any comments that could benefit our research.
  - Comment box.
19. Do you have any projects where permanent pavement marking removal is scheduled to occur within the next 8-months? Please indicate location and timeframe.
  - Comment box.
20. Do you have any projects where temporary markings are scheduled to be installed within the next 8-months? Please indicate location and timeframe.
  - Comment box.
21. Do you have any projects where temporary markings are scheduled to be removed within the next 8-months? Please indicate location and timeframe.
  - Comment box.
22. Can we contact you for more detailed answers to the questions? If Yes, please click the link below to complete a separate survey to provide your contact information. Your contact information will not be tied to the results from this survey.
  - [Link to contact info survey.](#)

## Virtual Interview Questions

Virtual interview questions are only provided for the airport/agency personnel category as they were the only category with successful virtual interviews.

### Airport/Agency Personnel

1. Airport personnel—What airport or airports are you employed and in what capacity?  
Agency personnel—What agency are you employed and in what capacity?
  - Comment box.
2. What pavement marking removal methods have been used in the last 5 years?
  - Provide list of options here, including ability to enter their own answers.
3. What types of pavement markings have been removed?
  - Waterborne paint.
  - Solvent base paint.
  - Epoxy.
  - Methyl methacrylate (MMA).
  - Preformed thermoplastic.
  - Comment box.
4. On what types of pavement surfaces has marking removal occurred?
  - Grooved asphalt.
  - Ungrooved asphalt.
  - Grooved concrete.
  - Ungrooved concrete.
5. The removal technique is good at removing the marking. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5
6. The removal technique minimizes surface damage. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5
7. The area removed is enough to mask the previous markings so that they are no longer confused as the intended markings. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5

8. Removing a larger area to blend in the removed area for all marking types to the surrounding pavement would reduce confusion. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5

Please provide thoughts on removing a larger area to blend in the removed area with the surrounding pavement.

- Comment box.
9. Please provide your general thoughts on how marking removal results differ between removal methods, pavement surface type/condition, or type of marking removed.
- Comment box.
10. Does level of pavement damage differ between pavement surfaces and removal methods? Are pavement surface repairs needed after the removal? Please comment on issues you have encountered.
- Comment box.
11. Do you require specific removal methods on specific surfaces? Please specify if so. If not required do you have a preferred method for each surface type?
- Yes/No.
  - Comment box.
12. Have you tried any unique removal methods?
- Yes/No.
  - Comment box.
13. Is evidence of past removal activities still visible on the pavement? How old is the removal work?
- Yes/No.
  - Comment box.
14. What types of temporary pavement marking materials have been used?
- Comment box.
15. Were you satisfied with the quality of the temporary markings?
- Comment box.
16. Have you experienced visibility issues with the temporary pavement markings? Color fading, not bright at night, they do not look like the permanent markings, etc.?
- Comment box.
17. How long are the temporary markings typically installed prior to removal?
- Comment box.

18. Does removal of temporary markings differ from the removal of permanent markings?  
Are different methods or techniques used?

- Comment box.

19. Were you satisfied with the quality of the temporary marking removal? Did level of satisfaction differ between removal methods?

- Comment box.

20. Were you satisfied with the amount of pavement damaged caused by the temporary marking removal? Did level of satisfaction differ between removal methods?

- Comment box.

21. Have you had any incidents related to the visibility of pavement marking? If yes, were any incidents related to areas where marking removal has occurred or areas where temporary markings were applied?

- Comment box.

22. Have you received feedback from pilots, ground personnel, or others about visibility of pavement markings? Is this feedback related to areas where marking removal has occurred or areas where temporary markings were applied?

- Comment box.

23. Have you seen the recent work (removal or temporary markings) on, (name specific location)?

- Yes/No.
- Comment box.

For the next two questions consider the visibility and effectiveness of the temporary markings or the results of the marking removal operations.

24. (The marking removal was effective and resulted in a removed area that blended into the surrounding pavement.) or (The temporary pavement markings are clearly visible and effective.)

Please include comment and rating.

Separate rating for evaluation during: Dry Daytime, Wet Daytime, Dry Nighttime, Wet Nighttime.

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5

- Comment box.

25. The (removed marking or temporary marking) area is confusing?

Please include comment and rating.

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5

- Comment box.
- Repeat 21 through 23 as necessary for different locations at the airport.

26. What would make the markings more visible/clearer at this airport?

- Comment box.

27. Are there any other markings at this airport that are not visible or are confusing and can you explain?

- Comment box.

28. Is there something that you would like to share about your marking experience that you think is relevant

## APPENDIX B. COMPLETE SURVEY RESPONSES

### ONLINE SURVEY RESPONSES

#### Pilots

4. Have you had problems with the visibility of airport pavement markings while piloting an aircraft? Visibility considering the following conditions, day or night, inclement weather, construction areas, etc.
  - Yes.
5. If yes, is the visibility of the markings related to day or night conditions or other weather conditions? Please indicate when the visibility problems occur such as on approach or while taxiing. Which markings tend to have the most visibility related issues?  
If no, could the markings be improved? How so?
  - Markings are sometimes confusing on how they are placed.
6. Have you been confused by areas where pavement marking removal has occurred? Do you remember any specific airport locations or marking types that led to confusion? What was the cause of the confusion, i.e. pavement scarring (removal left the pavement damaged where the previous marking was), previous marking still visible, color differentiation between removed area and adjacent surface? Please indicate if the problems are on approach or while taxiing.
  - Not answered.
7. Have you been confused by areas where temporary markings have been installed? Do you remember any specific airport locations or marking types that led to confusion? What was the cause of the confusion, i.e. poor day or night visibility, poor color, etc.? Please indicate if the problems are on approach or while taxiing.
  - Comment box.
8. Have you reported pavement marking issues when you have had problems?
  - No.
  - Never noticed any problems.
9. Do you have any general thoughts on airport pavement markings and their removal?
  - Some hold short lines are confusing when paired with ILS critical area hold short.

#### Airport/Agency

4. a. For Water Blasting were you satisfied with the quality of the marking removal? Did level of satisfaction differ between removal methods, pavement surface type, or by type of marking removed?
  - Water blasting is tricky as it takes just the right amount of pressure and then leaves scarification easily seen. The satisfaction was good because the paint marking was a temporary paint so only half the application and easily to remove. Also, the asphalt was also new and very little spawling.

- Yes the satisfaction of removal with this method is definitely higher on concrete. That type of pavement holds up much better to the process especially with removal of a thermoplastic marking as it takes much more time and effort to remove those. Water blasting on asphalt is tough to do without significant damage depending on the age of the pavement. You definitely need to use more care when performing removals off of asphalt and the scarring is usually significant.
- Yes, I was somewhat satisfied. Yes, the removal has been done by in-house personnel and contractors. In-house seems to be much more cognizant of the damage being done to the pavement surface, sometimes requiring to go over it more than once to complete the removal. Contractors tend to not care so much about the pavement surface damage and are much more likely to crank up the pressure and get the removal completed in one pass.
- Yes, but some of the markings were not removed as completely as other methods.
- We do not employ sand blasting in the airfield environment. Water blasting has historically worked well for us with minimal gouging of the surface.
- Very good removal, very clean, the only negative was its rough on the silicone joints and asphalt surfaces.
- For asphalt pavements the water blasting damages the pavement. Both new and old asphalt and significantly decreases the life of the pavement. Especially for temporary removals this is a bad application. Maybe for permanent marking removals it is okay. For PCC the issue isn't as big a deal, but still have to watch the contractor closely.
- Depends on thickness of paint and weather it is on concrete or asphalt.
- Pavement was left scared due to pressure used to remove markings

**4. b.** For Grinding were you satisfied with the quality of the marking removal? Did level of satisfaction differ between removal methods, pavement surface type, or by type of marking removed?

- It all comes down to contractor experience. Again okay for a permanent removal but shouldn't be used for temporary as too many iterations damage existing pavement surface.
- Grinding has had varied results depending on the equipment and operator. My preference is grinding with Schibeci head, if possible.
- Can depend on type of grinder used, rotary or drum. Rotary has a smoother finish where using the drum type it can leave grooves if you are not using the right kind of cutters.
- Better than scarification, but still creates damage to surface
- This is my least favorite as it is very time consuming but best when you have very old asphalt. Yes, the satisfaction was good.
- depending on the type of grinding equipment determines the level of scarring, but overall I have not been satisfied with large grinding machines and their ability to remove a marking as well as water blasting or scarification. Profile grinders take a lot of material as most pavement surfaces are not perfectly flat. Planers have very aggressive teeth and do more damage and remove more pavement materials than a scarifier.

- Cheap and easy to use equipment, a little less damaging than the scarifier but the grinding wheels clog up with paint pretty quick.
- We were satisfied. It did leave a halo effect of the old marking.

**4. c.** For Sand Blasting were you satisfied with the quality of the marking removal? Did level of satisfaction differ between removal methods, pavement surface type, or by type of marking removed?

- Yes, seems to be the better of 3 methods, as markings were removed with least damage to pavement.

**4. d.** For Scarification were you satisfied with the quality of the marking removal? Did level of satisfaction differ between removal methods, pavement surface type, or by type of marking removed?

- It all comes down to contractor experience. Again okay for a permanent removal but shouldn't be used for temporary as to many iterations damage existing pavement surface.
- Yes, markings were removed, but so was a portion of the pavement.
- Concrete was easier to remove paint than asphalt.
- No, not at all. Too much damage done to the concrete surface.
- The scarification was expected and we applied a seal coating to cover and up the scare and protect the asphalt. Very satisfied.
- "Scarification works, but it leaves a harsh scar on both concrete and asphalt. I've used many different types of tips on our machine to try to minimize the damage, but the differences in tips vs. scars is minimal.
- With scarification on asphalt vs. water blasting at least you aren't removing binder or oil from the pavement.
- Cheap and easy to use equipment, but pretty hard on the surfaces.

**5.** Were you satisfied with the amount of pavement damaged caused by the marking removal? How did level of satisfaction differ between pavement surfaces or removal methods? Please think about which combinations of pavement surface type and removal method resulted in the highest and lowest satisfaction.

- Yes to the first question. I was satisfied. highest when they had lower water pressure and made several passes. Lowest satisfaction when the pressure was higher and wanted to remove the paint marking in one pass.
- With a good operator and a well running machine I believe water blasting to be the superior method for removing markings off concrete. On asphalt I worry I am seriously impacting the overall useful life of the pavement with all methods, but with water blasting and its removal of binders and oil I have more concerns. However, you can use sealers and other topical products to help seal the scars & damage on asphalt more easily than concrete.
- I am not satisfied with any damage to the pavement surface. All methods strip the top paste layers off, exposing aggregate and creating an area that will accelerate the pavement damage/breakdown over time. From what I have seen, I'd prefer in this order,

1. Water blasting at controlled levels, 2. Grinding, 3. Scarification—this method is the most damaging.

- Yes, with water and sand blasting. No with scarification.
- Mixed results for grinding as referenced in prior questions.
- Pretty satisfied with concrete surfaces, but after a second and third removal it really starts to damage the concrete. Asphalt gets beat up after one removal.
- All of them caused pavement issues and it is more based on contractor experience and equipment usage. For temporary markings we should bring back painting over temporary markings. Especially for shorter duration phased work (less than 30 days).
- No matter which type of removal you use there will always be some type of pavement damage.
- The markings were never removed just covered up. It only took a few weeks of snow removal to uncover the old markings to its original state. That during snow events or fog confusing pilots.

6. Do you require specific removal methods on specific surfaces? Please specify if so. If not required do you have a preferred method for each surface type?

- The majority of our markings are on concrete and water blasting is the only method I will allow. A cold planer with a finish style drum would probably be my preferred method with asphalt with a SS1h or equivalent sealer applied over the whole area, not just the scaring after the markings removal is complete.
- We require water blasting at our airport.
- No. Sand blasting is preferred.
- We will employ water blasting or grinding on asphalt surfaces and typically just grinding on concrete. We do regular rubber removal with a psi of 8000-10000 to prevent loss of fines.
- Water blasting is a superior removal technique, less damage and much faster. An experienced operator can find the perfect water pressure and speed to do minimal damage on any surface.
- Bring back temporary paint to temporarily block out markings!
- I prefer water blasting.
- No we did not require specific removal on the surfaces.

7. Have you tried any unique removal methods? Please specify if so.

- 11 NO.
- I worked with local contractor to incorporate an "erasing" technique for airfield pavement markings on a grooved asphalt pavement.

What unique methods were used or attempted?

- A heavy-duty rotating head with carbide teeth (schibeci) for removing thick beaded paint buildup, 1/2 inch thick, runway center lines.

8. Is evidence of past removal activities still visible on the pavement? How old is the removal work?

- Yes, on concrete I have some areas that are upwards of 10 years old and the scars are still visible. They have faded over time, but really stand out when wet.
- Yes, in all of the areas on the airport. Some of the removal areas are now 15+ years old.
- Yes, a bobcat grinder with attachment was used when the markings at the threshold changed configuration in 2006. The operator gouged the concrete quite badly, but the effect was mostly aesthetic and no water intrusion or loss of performance could be noted. We have various grinding/water blasting areas where the removals are visible but not distracting.
- Very aggressive, works good for the purpose, but leaves a lot of damage.
- Yes the pavements are scarred. We have had to go back and do multiple surface treatments on asphalt pavements.
- Depends on if you do a sealcoat finish after removal on asphalt. and with concrete the removal is always visible unless you can do a thin set finish on top of it. In most areas of high traffic the thin set will not last long and will over time start to chip away.
- Yes, newly removed
- Yes 2 years old.

**9.** Is there evidence of past removal activities still visible on the pavement? How old is the removal work?

- Yes, a bobcat grinder with attachment was used when the markings at the threshold changed configuration in 2006. The operator gouged the concrete quite badly, but the effect was mostly aesthetic and no water intrusion or loss of performance could be noted.
- We have various grinding/water blasting areas where the removals are visible but not distracting.
- Yes, several years.
- Depends on if you do a sealcoat finish after removal on asphalt. and with concrete the removal is always visible unless you can do a thin set finish on top of it. In most areas of high traffic the thin set will not last long and will over time start to chip away.
- Yes, 1 year.
- Yes, in all of the areas on the airport. Some of the removal areas are now 15+ years old.
- Yes, newly removed
- Yes, 2 years old.
- Yes, On concrete I have some areas that are upwards of 10 years old and the scars are still visible. They have faded over time, but really stand out when wet.
- Very aggressive, works good for the purpose, but leaves a lot of damage.
- Just a little 3 years old.
- Yes, 2 years.

**10.** Have you had runway/taxiway/apron projects where temporary pavement markings have been installed in the last 5 years?

- Nine YES, two NO.
- That is not my typical mode of phasing for temp markings that will eventually be removed. We have been able to NOTAM obscured or obliterated for projects. We do apply a modified temporary marking for first coat applications prior to final striping.

**11. What types of temporary pavement marking materials have been used?**

- Waterborne paint.
- Typically Type 3 or 4 beads on type 1 or 2 paint modified.
- Taxiway.
- At our airport we usually refresh and paint back markings right after removal.
- No.
- Same paint that is used for permanent paint projects. We have experimented with some traffic tape as well, 3M brand, it has done on OK job. Peels very easy.
- Half application with no beads. Follow the Advisory Circular.
- Traffic Paint.
- Paint.
- Tape and paint.
- Water based traffic paint.

**12. Were you satisfied with the quality of the temporary markings?**

- Seven YES, 1 No.
- Regular paint, yes, but do not like the shadowing left after its been removed.
- Tape has been an issue getting it to stick. Often times the concrete cure is still on the fresh concrete and it will not stick well.
- Yes. We specify all temporary markings need to meet the minimum standard that a permanent marking should meet.

**13. Have you experienced visibility issues with the temporary pavement markings? Color fading, not bright at night, they do not look like the permanent markings, etc.?**

- Of course and why you need inspections. But temporary is temporary and permanent should be in place with a few months.
- No, we use the same standards to paint temp markings as we do for our regular markings.
- Yes, but personally I am okay with that.
- The only time is if we do not put back reflective beads because it is a temporary marking.

**14. How long are the temporary markings typically installed prior to removal?**

- About 30 days. Not removed, but painted over with final.
- Less than 30 days.
- No longer than a couple of weeks.

**15.** Does removal of temporary markings differ from the removal of permanent markings? Are different methods or techniques used?

- No.
- N/A.
- No.
- Basically the same.
- Not on the runway. But water jet on apron is not an effective way at JNU because it is chip-seal and continues to unravel to this day.
- Not usually since most of our markings are standard.
- Yes.
- Temporary has half paint application and no beads.
- Permanent is thicker and has beads.
- Same methods and same scarring depending on the ability of the operator and machine.
- Yes.
- No.

**16.** Were you satisfied with the quality of the temporary marking removal? Did level of satisfaction differ between removal methods?

- As we always specify water blasting I am generally satisfied with the removals.
- They all damage my brand new pavements. Don't put beads on temporary pavements and then just paint over them.

**17.** Were you satisfied with the amount of pavement damaged caused by the temporary marking removal? Did level of satisfaction differ between removal methods?

- No. They all are bad.
- A little less damage but basically the same.
- Not happy at all. Created more of an issue.
- Typically I am satisfied with the amount of damage. Generally the amount of damage is reflective due to the age of the pavement. Older pavement holds up much better to newly installed concrete. With asphalt it is the exact opposite.
- Yes. Good as could be expected.

**18.** Have you had any incidents related to the visibility of pavement marking? If yes, were any incidents related to areas where marking removal has occurred or areas where temporary markings were applied?

- We will sometimes have obscurity during the time of construction. No incidents have resulted.
- No issues from removal areas, just issues from heavy traffic areas and the snow equipment is pretty hard on markings.
- Yes we had old markings that were covered up and after a couple weeks of snow removal the paint that was used to cover old markings up was gone and so was the new paint. So the old lead in lines where all that was visible and multiple planes came close to running off the taxiway intersection into the safety area because the intersection had been moved.

**19.** Have you received feedback from pilots, ground personnel, or others about visibility of pavement markings? Is this feedback related to areas where marking removal has occurred or areas where temporary markings were applied?

- We are pretty strict about ensuring all markings installed meet the standards provided by the current AC. I have not heard of any negative feedback due to poor temporary markings.
- No but we also put a NOTAM out.
- No negative comments or otherwise I am aware of regarding pavement marking visibility of temporary markings.
- Some positive feedback from the tower traffic controllers or an occasional pilot, usually shortly after fresh paint has been installed.
- The Airside Operations team has a higher standard than the FAA P-620 requires. This causes great frustration on any new install of pavement markings on AIP funded projects. Our contractor and engineer believe they have met the specification, but our Airside Ops is unsatisfied...mostly related to the bead application and longevity.
- Yes. Several near misses with planes in fog or snow events with improper markings running off into safety areas.

Questions 20-22 were to determine potential study locations only.

**23.** Do you have any general thoughts on improving airport pavement markings, temporary markings, and marking removal?

- Not answered.

### **Contractors**

**4.** What removal methods were used?

- Scarification, Scrabbling, Grinding.

**5.** Which removal method removes the marking the best? Does it depend on the pavement surface type?

- Does it depend on the pavement marking type?
- This is dependent on pavement type.
- Primarily for airfield pavements.
- For PCC pavements, I prefer water blasting (at appropriate pressures) while protecting joints.
- For asphalt pavements, I prefer scarifying/scrabbling/grinding.

**6.** Which removal method causes the least damage to the pavement? Does it depend on the pavement surface type? Does it depend on the pavement marking type?

- This is dependent on pavement type, condition of pavement and thickness of pavement markings proposed for removal.

**7.** Which removal method causes the least damage to the pavement? Does it depend on the pavement surface type? Does it depend on the pavement marking type?

- This is dependent on pavement type, condition of pavement and thickness of pavement markings proposed for removal.

8. Do you use or are you required to use specific removal methods on specific surfaces? Please specify if so.

- Yes; "I specify water blasting on PCC pavements and grinding/scarifying/scrabbing on asphalt pavements. More specifically, I do not allow water blasting on asphalt pavements."

9. Have you tried any unique removal methods?

- Yes, I worked with local contractor to incorporate an "erasing" technique for airfield pavement markings on a grooved asphalt pavement.

10. Do you follow the marking removal guidelines specified in FAA Advisory Circular 150/5340-1M, Standards for Airport Markings, dated 5/10/2019?

[https://www.faa.gov/airports/resources/advisory\\_circulars/index.cfm/go/document.current/documentNumber/150\\_5340-1](https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5340-1)

If not, what specification or guidance do you utilize?

- No, I follow the United Facilities Guide Specification (UFGS) 32 01 11.51 Rubber and Paint Removal from Airfield Pavements. This specification allows multiple removal types and should be edited by designer/specifier prior to issuing a contract.

11. Are there any modifications to the removal guidelines you utilize?

- Not answered.

12. How much additional area do you remove surrounding markings on runways, taxiways, and aprons to reduce confusion associated with the removed area (ghost markings)?

- Usually try to limit additional marking removal beyond existing markings to minimize pavement impact. Depending on marking type and location, I specify to block out markings as required in industry guidance.

13. Have you installed temporary runway/taxiway/apron markings in the last 5 years?

- No—Skip to 18 if no.

14. Have you received feedback from airport operators about your temporary marking activities? Please provide any comments that could benefit our research.

- Not answered.

## **VIRTUAL INTERVIEW RESPONSES**

Virtual interview responses are only provided for the airport/agency personnel category as they were the only group to successfully participate in the virtual interviews.

### **Airport/Agency Personnel**

1. Airport personnel—What airport or airports are you employed and in what capacity?
  - a. Airport locations are identifiable and not reported.

- b. Manager over the airports, airfields, roads and grounds maintenance.
  - c. Supervisor over pavement marking.
  - d. Vice president of planning and engineering.
  - e. Deputy director of an Airport.  
Agency personnel—What agency are you employed and in what capacity?
  - f. Department of defense (DOD).
  - g. We handle all the technical criteria for airfield pavements, concrete and asphalt. We also handle a lot of the other specifications regarding asphalt surface treatments, rubber removal and paint removal on airfields. We also do just pavement markings in general.
2. What pavement marking removal methods have been used in the last 5 years?
- a. Removing the asphalt, water blasting, grinding.
  - b. Primarily, water blasting has been used. They've done a little bit of we've done a little bit of grinding here. Mostly that's when our maintenance guys will do it in house. If we're doing it as part of a project we have typically specified water blasting.
  - c. We've used grinders with abrasive teeth on them, we've used the water blaster. We used to use bead blasters, which shoot out lead shot into the paint. But it's pretty much the last five years has been grinders and water blasters.
  - d. We've specified you know, particularly for Fort Bragg, we've specified ultra high pressure water we've specified. Basically a mechanical means which was here, you know, erasing his what sort of the product data you know others may consider that like a grinding type technique. Ultra high pressure water is probably been the. Predominant one, not necessarily the preference, but the predominant one that we've specified just due to the expedient nature of it. Uh, you know, just since in those same tones a lot of the work that that we do for the Department of Defense has forensic base so. You know periodically will get brought into projects where ultra high pressure water is then used for airfield pavement marking removal, and you know to the detriment of the pavement. It's you know, either strictly. The cement or the mortar from the from the aggregates and in the same tone? You know the asphalt bitumen getting stripped from the from the aggregates causing raveling. So we've been involved in many forensic cases where cultural pressure water has, you know, calls an issue and you know we've for the most part when possible, especially on asphalt pavements. We try to. Recommend other alternatives to Ultra high pressure water, such as you know, racing or the grinding method we don't allow shot blasting on airfield pavements. So we don't. I don't have a whole lot of experience with that or I have no experience with that. But you know, I do have a good amount with Ultra high pressure water and you know the grinding method. More mechanicals but I and to that same topic. I don't have any experience with, you know, chemicals, chemicals being used just because of the. Uh, I guess from my understanding, just

the slow nature of which, though those would occur, doesn't lend itself to keeping an air filled operational.

3. What types of pavement markings have been removed?
  - a. It's whatever they advisory circular makes us put down.
  - b. Uh, for the most part, waterborne markings. We are starting to put in some of the uh, what are they called the thermal plastic on some of our hold bars now so we do have some thermoplastic we haven't had to remove any of those yet. But everything else has been waterborne at the airport.
  - c. All paint pretty much yeah. Pretty much all paint we did. A little thermal plastic removal but not really on the air side right yeah? Waterborne. We've done some epoxy right. Yeah, yeah, for our pink spots a couple years ago, yes small amount of epoxy but some.
  - d. Yeah, but mostly waterborne paints. That's historically what we use on air films, you know, with reflective media so. Uh, you know the mil thickness associated with those waterborne paints you know varies from airfield, which also derives you know what? What method may be used for removal or the time spent in removing those pavement markings?
4. On what types of pavement surfaces has marking removal occurred?
  - a. Grooved asphalt, ungrooved asphalt.
  - b. asphalt, concrete (doesn't specify grooved or ungrooved).
  - c. We've got both, and it's pretty much all grooved, yeah. (concrete based asphalt or tar based asphalt.
  - d. Uh, just generally speaking, you know, you know, as far as just pavements in general, yeah, you know, concrete grooved ungrooved as well as asphalt, grooved and ungrooved. It's been a mix of just generally speaking, where we remove paint from, you know, a lot of our lot of the runways within the DoD or. Uh, you know, within the 1st 1000 feet at the threshold is concrete and then it'll switch over at what we called the Type C traffic. You know, really just dynamic loading. Not a whole lot of static loads through those sections. So a lot of the lot of the Sinner kill sections of the runway are asked, you know, grooved asphalt runways. Again, the grooving primarily for. You know to prevent some hydroplane and get the water off the surface into the grooves and then out to the extents of the pavement. We typically don't. Use a cruise for friction. Although some may think that it does, but in general terms it's you know a kind of a mix of both pavement types.
5. The removal technique is good at removing the marking. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)
  - As long as you don't rush the removal, I think the removal techniques work very well.
  - Water blasting, asphalt – Well, it's good at removing the paint, but it also removes a lot of the asphalt, so I guess it yes and no in my opinion. Grinding, asphalt – We do in locations. I mean it, it really comes down to operator. I mean same thing

with the water. It really depends on the operator. Water blasting and grinding, concrete – didn't respond. Old age pavement – Well, in older pavement they all work.

- Would you say that the high pressure water is good at removing? I would say that my preference. I again I don't. I guess it would define you know how would we define good? You know I guess overall what I consider a good pavement marking removal is removed as little of the actual pavement as possible while removing the markings would be. Did they overall goal you know if it is a grooved pavement, you know we want to leave the grooves and as intact as possible. Uh, you know here recently what we've tried on certain airfields is coming back after the removal process and regrooving. That had some success. I'm not going to say that would work everywhere, but with adequate inspection and the right contract or the right tools, I felt like it was possible on this particular project. The ultra high pressure water I will limit to just the rigid pavement so concrete pavements I usually don't allow ultra high pressure water on asphalt pavements, primarily because of the issues that I've seen.
6. The removal technique minimizes surface damage. (repeat for each technique selected in #2 and surface combination indicated in #4) (add comment box to allow for further comment on pavement conditions such as age, condition, crack sealing, etc.)
- so there's different methods of grinding if you really put it down there and thinking you're gonna grind that, grind that paint all in one swoop, that's not gonna happen. Same thing with the water blasting. If you put it and dial up to the highest you could possibly have that water, sure it's going to remove it, but it's gonna remove the top base and aggregate along with it. So the key factors is It's very time consuming to remove markings and it's very... Just, you just gotta keep on going over until that marking is pretty much all removed. And then, uhm, we put a sealer down. And that sealer pretty much locks in whatever that area that was, uh, whatever that marking area was removed. That way I know that my asphalt has not been, uh, deteriorated any former way before we put down that paint marking. So, is the sealer required? No, it's not if you wanna remove and replace, but I highly recommend it. Ah, yes, and also, uh, it kind of re seals that marking. Because think about it, that asphalt is not like a sheet of paper. It's not smooth. Asphalt is like a sponge so that marking to remove it that marking properly you are actually removing the top layer and a little bit of that actual aggregate because that's the only way that you're going to be able to remove that marking. And uh, the advisory circular says that you could remove it and then replace. But, so if you remove it and then when you add that paint, that paint kind of goes seeps in to the asphalt. So you're kind of um putting more paint down than what is really required, but paint is not a sealer and it's not a glue. Paint is just a coating. So by putting that actual sealer, you're filling in where all that um water

blasting and grinding that you removed and then now you're sealing the asphalt and then now you're almost having that asphalt where it's as close to that sheet of paper as possible, so then you don't have to put as much paint on the asphalt, if that makes more sense.

- Water blasting and grinding, asphalt – I mean it, it really comes down to operator. You know a lot of times this work is getting done at 3:00 o'clock in the morning under a very shortened time window, and that's typically when everyone gets a little bit rushed, and they may start out doing a good job. When you're kind of, you know, keeping an eye on him. But as things progressed through the evening or we get close to having to get the runway, reopen all this or the taxiway reopened, and that's when we tend to have issues. Water blasting and grinding concrete – I mean they do damage to the concrete. The damage is of more aesthetic in nature. I don't know that you know other than at the joints, which, again, if they're doing it correctly, we typically don't. You know, if they're putting some sort of protection down, the joints aren't as bad, but yeah, the it's mostly aesthetic on the concrete where on the asphalt it's really doing damage to the pavement itself. Old age asphalt – water blasting we have a huge problem on our older asphalt pavements. You know, just because of being oxidized and whatnot, you know we've pretty much had to always require them to come in and seal coat it after they after they do the marking removal because they just take off so much of the you know and it's an older pavement. We've even had to go through when we've done water blasting on some older payments then have to go back in and do a, you know, 2 inch mill and overlay. Just because it's beyond even sealcoating at that point.
- Uh, so you know we've had instances, either due to rubber removal or pavement marking removal where you know they will stretch, will try pressure water. You know, was rant, you know the pressures are just way too high for the pavement. It'll strip all the bitumen awfully just the aggregate. And you know, now we have a, uh, a Rubik FOD concern, or for an object concern on the runway and you know in certain cases that's called the runway to be shut down and Fort Bragg was one of those back in 2011. So you know, we you know, just prior to my involvement at Fort Bragg the contractor came out with old try pressure water ran it way too high. Basically raveled the surface of the pavement where the rubber removal was being done and we had to shut down the runway till an emergency mill and overlay could be done. So I historically tried to stay away from ultra high pressure water on asphalt pavements I have I've had a lot more success especially on concrete pavements where we can, you know, run those pressures, you know a little higher without as much potential for damage and in certain cases you know the whole trap pressure water acts as a construction benefit to the project as well in regards to if we have The joint sealant or something we want you know that's

anticipated to be removed. Well, we can. You know, sometimes we can use that ultra high pressure water just to blast those that joint sealant material out of the joint reservoir, making the clean up process a little easier. But on the other side of that is, you know we've also seen it where we want to protect the joints where the joints are in great shape and will try pressure water then destroys the joints. So I guess it's a mix. And we've kind of seen it all.

7. The area removed is enough to mask the previous markings so that they are no longer confused as the intended markings.
  - Yes.
  - Yes.
  
8. Removing a larger area to blend in the removed area for all marking types to the surrounding pavement would reduce confusion.
  - Possibly already removing too much.

Please provide thoughts on removing a larger area to blend in the removed area with the surrounding pavement.

- Lining back up with old markings again, it just never looks good. So what we do is we try to do a full complete section. So if we start from say a starting point of an intersection, then we would just continue to go all the way up to where it would meet the runway.
- I think you know, and I guess I'll caveat it with my biggest concern with the specification in general is the difference between permanent removal of markings versus temporary removal of markings. And mostly my concern with it is on the... You know markings that we have to temporarily remove because of phase construction that are ultimately going to go back in place and those areas, if it's uh, if it's only temporary in nature, I think we remove too much. I mean I get the you gotta block it out and you gotta make it not look just like a shadow of the existing marking you were removing, but I think there's ways to do that without having to remove these giant squares and again damage the pavement. Especially in a temporary condition where the markings are going to be going back in place in the exact same location. Whenever a phase piece of work is done, say and you know 4-6 weeks or two months. "Do you have an idea on how much you would shrink the area if you if you could make a recommendation?" -- Well, I think you would just try to create a pattern, a minimal pattern, so that it can't be confused. So I think the way the specs written right now you just do rectangles. But there's ways I would say that you could, especially when you're talking the numbering, probably shrink it down and minimize the amount you gotta block out without having to make it just one big rectangle, if you will.

9. Please provide your general thoughts on how marking removal results differ between removal methods, pavement surface type/condition, or type of marking removed.
- a. Relies on the skill of the operator and not necessarily the marking removal method.
  - b. Well, in older pavement they all work orders, but water blasting we have a huge problem on our older asphalt pavements. You know, just because of being oxidized and whatnot, you know we've pretty much had to come in and seal coat it after they after they do the marking removal because they just take off so much.
  - c. Usually the grinder first to get to kinda get down into the paint a little bit. We just last year we started doing some pretty heavy removal on some on some paint that had probably 20 years worth of layers of paint. And some of that stuff if you just try and water blast it right from the get go it. It's a really, really slow process. Getting it to get through it and. We found that going over it with the grinders was kind of a Kind of kickstarts it so that water blaster can get inside there and it comes off quite a bit quicker. If you have one to five layers of paint, the water blaster does it just fine by itself. Do you think there's any disadvantages to using the water blaster? No, as far as far as paint removal goes, I think the water blasting used by far the most efficient way to do it. The only the only downside to water blasting on the asphalt is it pulling the oils out and if you've got to get right back in and repainted in and puts a regulatory marking, you've got some dry time that you have to wait on. Water blasting is definitely more operator comfort, 'cause they're sitting in the cab of a vehicle versus Out there in the elements.
10. Does level of pavement damage differ between pavement surfaces and removal methods? Are pavement surface repairs needed after the removal? Please comment on issues you have encountered.
- a. Relies on the skill of the operator and not necessarily the marking removal method.
  - b. Water blasting we have a huge problem on our older asphalt pavements. You know, just because of being oxidized and whatnot, you know we've pretty much had to always require them to come in and seal coat it after they after they do the marking removal because they just take off so much of the you know and it's an older pavement. We've even had to go through when we've done water blasting on some older payments then have to go back in and do a, you know, 2 inch mill and overlay. Just because it's beyond even sealcoating at that point.
  - c. Where, where the grinders would probably do more damage, especially to concrete than what it's really worth. (vs Water) The water blaster definitely is less impactful to concrete. As far as the asphalt goes, really, it's speeds and operation of it, the pressures on the asphalt, you have to you have to turn the pressures down on that water blaster and have to go a little bit quicker. Otherwise you pulled the oil up out of the asphalt and then it does a little bit of damage pretty quickly. Most of that is operate operator error. On the concrete, the concrete's pretty...Pretty good. It's a lot more difficult to do the damage to the concrete than it is on the asphalt. Little more water blasting, a little more tolerant. Now let me restate that.

Concrete is a little more tolerant to variation and water blasting than the asphalt is. "So the other thing I think I heard you say and I want to make sure I say it in my own words so I got it straight is that the, the, the time you have for the time you spend on the asphalt and operator, uh, skill determines how much damage you do to the asphalt." Yes, Sir. But I mean, uh, the grinders scarify the top and they can cause some issues if somebody isn't really, really cautious getting into it. So the water blaster overall is the preferred method.

**11.** Do you require specific removal methods on specific surfaces? Please specify if so. If not required do you have a preferred method for each surface type?

a. No, water blasting first followed by grinding.

**12.** Have you tried any unique removal methods?

a. No.

b. I have been a proponent, I haven't gotten my folks to buy off on it, but one thing I really love the FAA to consider again is again on these temporary markings and not so much on runway numerals. I know you get, but really, what kills us the most are these on the taxiway. You know entrance and exits to taxiways and runways, you know where you're just or you know where you're obliterating an enhanced centerline or you're obliterating just that lead in line. We really need to get back to allowing black paint over the top of those things that you know. I know in long term beads come through and things come through, but for a short-term application from a both a cost effectiveness and a pavement preservation perspective, I personally think if we need to get back on at least for temporary removals doing you know either black or grey or whatever the color to match the kind of the pavement. So we have done that in some of our areas where it's not technically part 139. You know if you're on an apron or attacks, you know apron space or something that's outside of the true part 139 or if it's not funded with FAA money, because obviously then we can't do it. But in some of those other areas were for temporary blackout of pavements we still think markings are a better way to go than actually obliterating. I wouldn't recommend doing it on runways or but, but certainly on taxiways when you're in relatively slow-moving areas where the you know the risk is relatively minor.

c. Yeah, do you guys ever go back with a seal coat or uh, resurface asphalt after you do the marking removal? No, we don't. We don't have the equipment in house. If it's been a bigger job or on a on a newer piece of asphalt that was in connection with a, uh, a construction job that they brought in an outside person. They might go back through into a fog seal or something over the top. But just due to the time constraints we have and then most of that stuff we're talking about is on the airfield, so you're really restricted on what you can put over it. You know not all fog and slurry seals or approved for airfield work. I mean, if we've got new paint that's just one layer we have some pressure washers that sometimes will take off a layer of paint, but as far as chemicals and stuff that that dissolved the paint and stuff we have not. One of the biggest problems with the bead Blaster is. For one, it throws a lot of the shot kinda in places where it could be considered maybe a little bit of a safety. Issue for bystanders. It also is kind of a high maintenance

thing. Every time you use your shot, you have to go through and you have to run a magnet across the ground to pick up all your shot that you didn't pick up. So it's just really for a older process, before some of these new advancements in paint removal come out, it was maybe a good thing, but I think for especially in our case it's just kind of outdated and is not time efficient. Also on that there's some silica exposure that that has to be mitigated and that turns into another makes that process a little bit more difficult. Yeah, you're talking about respiratory exposure. Yeah, because when it breaks up that concrete it breaks that silica sands out and obviously breathing that in can have long term health issues. It completely remove it worked well, it it's overall removed, the markings very well. "How much? How much damage do you think it did say compared to the water blasting?" I think concrete it probably was worse from what I seen. We didn't use it a whole lot when I first started. So you could. I mean, again, it was a. It was an operator skill issue. If you sat in one place it would groove concrete and groove asphalt. Uh, so operator skill. You had to keep it moving. You maybe had to do multiple passes over to completely take the paint up, but it would bring it completely out and look fairly similar to a grinder or something along that. Those lines running over it. So it was. It was a fairly similar process in those aspects, but a lot of it. You know that it was maybe slightly better than water blasting is on asphalt, 'cause it didn't take up the oils. But it was. It could be far more abrasive if you didn't really watch your speed and everything as you're running over it, it could. It could really grind down into it.

- d. Sure, yeah, I can understand all that. So then the other technique that racing. He used that more on my asphalt and how pleased are you with that technique? I was very pleased with it. I guess conceptually, the ultimate goal was to minimize the pavement damage, with also removing the pavement markings so you know we limited the pavement marking removal to the erasing method. You know we still at least majority of the time. I tried to specify rubber removal through detergent based products. Uh, and if we you know associated if we have to remove pavement markings or you know do to mil thickness I will try to specify you know a grinding or a racing method so you know in my mind if we do have to get into the pavement. To a certain extent, for the pavement markings, there's always a little bit of migration into the. You know, the macro and micro surface texture of the pavement. If we have to get into the pavement somewhat, I'd rather remove a little bit of that. You know I'm not talking, you know, the large aggregate pieces. But if we need to remove it, it's a small bit of the surface with the bitumen. That's my preference. So we're removing, you know, the aggregate you know. Again, a very small amount. You know we're grinding that off with the with the bitumen versus removing just the bitumen and leaving the aggregate expose you know to you know as a potential for fog there. Yeah, I think grinding in the sense of grinding. You know, some people may perceive grinding as you know, uh Rotary grinder, such as like a side grinder you may put on a hand tool or you know commercial. You know much larger pieces of equipment that have like a Rotary grind. You know when the air filled world grinding, maybe you know more vertical stack blades. You know where we may have a high spot in the pavement and we're grinding that off. You know the I've and I guess other people

may think that that's more of a planning type operation as well. I think there are kind of similar terms they're erasing. At least in this context, you know we did a trial. It worked out really well I've only done it on one project with one contractor, but overall in that one project this racing method was mounted to A piece of equipment that had a HEPA vac on it. You know for silica containment and it would you know, wasn't your typical grinding that would create you know these you know nice Peaks and valleys. You know, linear peaks and valleys. Trying to figure out how to properly explain it to you without showing you a picture, but it's basically three rotating discs with little knobs on and they're basically just impacting the pavement you know at a certain pressure and at a certain speed controlled by the equipment to control the removal of the pavement and the spacing of the little knobs or the teeth on those bearings depends on the surface texture you're left with, so the more the more teeth, the smoother texture, the less teeth you know the coarser texture, so you know those are those were all options to us and we worked with the contractor to define, you know, really what surface texture we were looking for, which was on the smoother side, but not all the way all the way on the smooth. This end of the scale either. So we, we did try to consider, you know, production along with, you know the desired texture in the end along with the grooves that were present on the runway. Uh, basically you've got you know 11 rotating motor that these three independent bearings and spin you know basically just using the surface friction there and depending on the pressure they applied to the surface depends on you know what level of impact it's having on the pavement. So again, that's my understanding of how it works. We talked pretty significantly with the contractor and the manufacturer of the piece of equipment. Yeah, I think the most kind of unique removal was probably the erasing. I think that that was you know, outside the norm of what you know as current, you know what I would see is currently available. You know, ultra pressure water I think is predominantly used. Almost airfields. Uh, you know whether on concrete or asphalt pavements. We haven't really pursued chemical again just because of time. You know, I don't know of any other, you know, rapid means to remove pavement markings other than, you know, more mechanical means, which is what we tried on. Uh, on a project again with success. So I would say that erasing was probably the most innovative thing we've done because you know we could control the surface texture we. We then followed that up with, you know in areas where we did do removal, we did regroup just to make sure that you know we didn't. We didn't damage the grooves or roll the grooves over too much. In that sense, that was probably the most innovative that I've been with pavement marking removal.

**13.** Is evidence of past removal activities still visible on the pavement? How old is the removal work?

- a. Well, again, I think you know mostly in a case where like as an example, when we go in and water blast it on a taxiway lead-in line, we have to go in and seal coat it right afterwards, because it takes up so much of the asphalt surface, it really kind of almost as the same thing as painting it. The sealcoat typically isn't doing a very good job and we end up going in and doing a kind of a thin over mill and overlay a 2 inch or something. our biggest problem is just trying to get these

guys right now. Just getting anybody scheduled with the right equipment, I mean there's just not that many of these big water blasting pieces of equipment around, and they're so busy. So in order to get them scheduled in to do the work, they're on a very limited time window, and that's usually where it causes the issues, because these contractors are coming in with a four hour window to get so much work done, and they probably should really be scheduled for twice as long, but they just they're scheduled on their next job kind of thing and it's just very time consuming work to be done right and unfortunately there are constraints we put on them or there are job constraints that make it difficult to do it correctly.

- b. We just go with the, a full marking removal. There shouldn't be any ghosting. There shouldn't be any paint leftover when it's done. It should be completely removed. And then as long as that marking that you put in is crisp and clean and nice and visible, there really. There's no chance of somebody getting confused.
- c. Yeah, so you know, I guess in more recent years, we've made a lot more of an attempt to block out the markings were removing. You know if we're removing a, you know azimuth numeral up on the runway, you know in years past I would say we just remove the numeral themselves. But over the last few years, we've definitely been more cognizant of the pilots' views of what they're seeing on approach. And really incorporating what I think the FAA's intent is with their diagrams as well as the DoD where possible within the department of defense, where we're applying those same standards of blocking out, so you're not having that that ghosting of markings. Or we try to stay away from blacking out as well where, where possible and where cost effective as well. But in general terms, yes. So, we do our best to try to block out a significant area outside of the pavement marking removal area, primarily depending on the feature as well. If we're just removing a linear line, then we'll try to stay productive, but you know something that the aircraft would see an approach such as azimuth, sore VFR, hold lines or something like that. We try to remove more in a block fashion versus exactly where the pavement marking lies. I think it depends, so I guess just to kind of answer that based upon some of my experience. You know some of our airfields have converted from a fixed wing capable runway to a Rotary wing only. So going from airplanes to helicopters you know our runway design or our pavement marking design changes in those circumstances so, just based on my experience, I think the area that we remove, if new pavement markings are going back, is satisfactory, especially if we're adding a surface treatment to the pavements you know, and not all cases we are adding surface treatments. But in some we are. I would think that in general terms the block out that we're doing, I haven't heard of any issues with it, especially as we're, you know, adding surface treatments. Well, water possible when we're removing pavement working, so I guess to answer your question, I think what we're doing is adequate for now.

**14. What types of temporary pavement marking materials have been used?**

- a. Whatever advisory circular says on paint type.
- b. waterborne is our go to for temporary markings. "Do you include beads or no?" -- It depends on the location and the application. A lot of times, no. But we have

sometimes, I think. I can't remember the difference when we have and when we haven't.

- c. Yeah, we'll do blackouts over areas that are going to be under construction temporarily. For temporary markings, we pretty much use the same materials that we use every day, the waterborne paint. If it's gotta normally have beads in it, then we're going to put beads in it.
- d. Well, we are governed under our UFC United facilities criteria. So in general terms, you know in that document it's UFC3 - 260.04 is the criteria for airfield pavement markings that we have to follow. So in that document it discusses temporary pavement markings and you know we'll use a different reflective media if it's required to be reflective for operational purposes. But in in general terms, it's just a lighter application of the pavement markings and in some cases it's applied on top of the curing compound. If it's, you know concrete related that's asphalt related. Again, it's mainly just done by the applicant. So the type 1A beads are what we would typically use I believe in our temporary pavement markings.

**15. Were you satisfied with the quality of the temporary markings?**

- a. I'm satisfied with the quality of the markings because I have trained my staff that we are quality control. Now with markings are so important and it's a skill set. And like I want to go back to where it's pretty sad that you have brand new, basically brand new canvas and, Uh, and when markings go down wrong on a brand new canvas, you could you could understand that frustration level, right? So we actually have a full complete meet paint meeting. We talk about compliance. We talked about layout, we talk about, uh, how we're going to do it. We talk about weather, we talk about wind speeds because I've seen it where they're putting markings are rushing to put markings on and wind starts to come effect and it kind of bleeds all into an area and it makes it non-compliant even though they have it at the right adjustment levels. So having that preparation of knowing that, um, discussion beforehand and then going back out there and knowing that there's going to be a quality control. And then obviously our construction managers or the designers the one thing they know at for Saint Pete is how particular we are, and we will physically go out there with our rulers or our tape measures and physically check like every 50 feet you know as they're going through and if something is not being compliant, we immediately stop.
- b. I am. I'm not sure our airside operations folks and or our maintenance folks necessarily agree, but from a construction perspective, I think it's adequate. "Why do you think the Maintenance folks wouldn't agree?" -- Well, I don't think it's the material so much to be quite honest. I think it comes down to more so the FAA's construction specification for markings does not very well align to a lot of the training that's coming out of the part 139 side of the house, both temporary and permanent markings. I would say that the construction specification is a nice minimum, but the training they're doing on part 139 side of the House for putting you know, good markings and markings that last a very long time Is a great standard to achieve to, but I think our FAA specification does not necessarily lend itself to that there's no long-term durability of the FAA spec. I mean I know it's

baked into the material spec, but it doesn't. There's such an art to placing markings and placing beads down that I think we have issues mostly on the permanent markings but sometimes even on the temporary markings about how good of an application it was.

- c. Yeah. I mean, all that stuff subject to many different circumstances. I mean your temperatures in which you put those temporary markings down or going to affect how well the beads stick into the paint. How well the paint holds up. I mean the rate of speed that you put it down the mils of paint that you put down the amount of traffic. But most of the time with the time frame that those temporary markings are in place the methods that we use are more than sufficient to keep up with our reflectivity standards.
- d. I specifically haven't heard any complaints about the application rate or the reflecting media. Definitely wouldn't recommend putting like a Type 3 bead or anything on a temporary pavement marking, but you know, I don't know what's done across the industry. But yes, I, you know, I, haven't heard any complaints from, you know the operational end or the contractors. At least the government criteria is doing what it can to kind of balance the mission with the financial side as well, the economics of the project. So yes, I'm satisfied.

**16.** Have you experienced visibility issues with the temporary pavement markings? Color fading, not bright at night, they do not look like the permanent markings, etc.?

- a. Not reflective. Don't use beads in temporary markings. As long as you have your airport diagram out, you should understand and if you have a landing light or a taxi, light should be able to see the temporary markings. Plus there's also a notice to airmen stipulating that there's temporary markings in that area.
- b. I don't know that we've had a big enough issue that it's been prevalent. I think most of the times when it happens, everyone just kind of acknowledges that it's a temporary condition. I don't think we've had any pilot errors because of it.
- c. It's been my experience that you can, you can paint in 50 degree weather. The problem that you have is it does not cure well by the time you get to the later hours of the day, it doesn't maintain the temperatures that it needs to cure properly. and there's instances where that's just what we have to do to get the markings put on. And we know that we will have to repaint it again. Your asphalt and your concrete temperatures might be 130 degrees and you get a point where your top layer of your paint will dry and it will crust over, which keeps your inner layer of paint wet for hours. paint should be a season should be done at specific times. Sometimes there's just things that come up. And we have painted in every single month out of the year, just knowing certain months that paint is not going to last.
- d. I don't. When possible, we try to, have the life of the pavement down or the pavement down long enough to where we don't have to do temporary but for the temporary pavement markings I've been associated with, It's never been reported back to me of you know visibility issues or any issue with that whatsoever during that 30 day timeline or hopefully less. But if the temporary pavement markings

were applied right after the pavement then, yeah, I haven't been associated with any of those issues with the temporary pavement markings.

**17. How long are the temporary markings typically installed prior to removal?**

- a. Minimum 30 days, but normally we keep it on there a little longer than that because the asphalt starts to turn gray in around 90 days and that's when I like to put on the permanent markings.
- b. Usually it's 30 days. You know if it's an application where we just put an as- you know did an asphalt placement and you know it hasn't had that per the spec, the 30 days kind of initial cure. Then you know that, but we have to get the pavements reopen. That's when we'll do the temporary application. or if it's a phased construction project where we just putting in a temporary centerline or temporary, you know something temporary that you know, same thing.
- c. I wouldn't say much more than six months at the most.
- d. 30 day timeline or hopefully less.

**18. Does removal of temporary markings differ from the removal of permanent markings? Are different methods or techniques used?**

- a. We don't remove temporary markings because at that point after usually after about 60 days - Uh, and again you only put anywhere between a 30% up to a 50% application down - they're beginning to fade themselves and going back over them and then applying the beads, it would do more harm than it would do good removing any temporary markings.
- b. I should say that if the temporary markings are being placed on new pavement and the permanent marking is going in the exact same location as the temporary marking, we do not require removal before placement of the permanent markings. Uh, unless they didn't do a very good job on their layout on the temporary marking. Sometimes they've had to kind of go in and kind of clean up some, you know, corners or clean up some you know if the radius wasn't exactly correct on the temporary, they may have to, you know clean up the edges kind of thing, but usually you can make that up, but the you know the black outlines and whatnot that you may put in there and not have to physically water blast the pavement. Water blasting is probably the most prevalent we've seen.
- c. Kind of the same that we used to do the permanent ones just generally it's only one layer of paint, so we can go a little quicker and take it up a little bit faster. I would almost say that it's more challenging to control the water blasting for the temporary markings just because they don't have the time frame to, to go slower because you don't have near the mils of paint that you're trying to breakthrough. you almost can't go fast enough and the pressure low enough to not cause damage.
- d. But I think it would be dependent upon what pavement type it is. So if it would be asphalt then yes, I would install the permanent on top of the temporary if it was. If it was concrete, I would think that they would, especially if it's installed on curing compound, remove the existing pavement markings from the concrete and then apply the permanent. I try pressure water to kind of categorize you know say like

a stripe, pog or something like that but you know we especially with young concrete you know we would want to limit the pressures to where it would not cause a raveling issue or so? On concrete pavements I would try to protect the joints.

19. Were you satisfied with the quality of the temporary marking removal? Did level of satisfaction differ between removal methods?
  - a. Yes.
20. Were you satisfied with the amount of pavement damaged caused by the temporary marking removal? Did level of satisfaction differ between removal methods?
  - a. Don't remove temporary markings.
  - b. Well, if it's on new pavement, it's still doing long term damage, but in the immediate term, usually the pavement is new enough that it's not causing any immediate issues where we would seal coat it.
  - c. You almost can't go fast enough and the pressure low enough to not cause damage.
  - d. Especially with young concrete you know we would want to limit the pressures to where it would not cause a raveling issue or so? On concrete pavements I would try to protect the joints.
21. Have you had any incidents related to the visibility of pavement marking? If yes, were any incidents related to areas where marking removal has occurred or areas where temporary markings were applied?
  - a. No, we have not had any incidents due to due to markings.
  - b. We have areas that are kind of troubled spots due to high traffic. We get areas that are that for whatever reason or a little bit more of an abrasive concrete and if you go in and you put a new marking down on that just because of the abrasiveness of the concrete that's underneath it. Your paint will wear down faster as traffic goes over it, those tires go over it and kind of grind it into that abrasive material.
22. Have you received feedback from pilots, ground personnel, or others about visibility of pavement markings? Is this feedback related to areas where marking removal has occurred or areas where temporary markings were applied?
  - a. If anything, it's always positive. I really don't ever hear feedback.
  - b. We're under a pretty big rebuild out here. So a lot of what our new markings have come across brand new concrete. Necessarily, it could be dusty, could have some sealant left on it so a lot of that markings haven't been holding up the way you'd want them to. So yeah, we get a little bit of that. You know, a lot of lot of returns on why these markings are not lasting as long and it's one of those. Generally once we go and clean them with the water blaster and repaint it. It works. Works out quite a bit better, but now for the most part, we don't get much feedback.
  - c. I mean, I guess just to answer the question, you know the ghosting has been relayed back to me. You know prior to us you know blocking out, you know on

approach you know most of that feedback was given by airfield manager. So as a little more indirect than straight from pilots but we've been given that. I think that's about the only feedback in regards to pavement marking removal that we've had. That's not involved. You know other pavement topics like surface treatments or anything like that, but I haven't received any feedback at all on. You know the visibility on temporary pavement markings.

**23.** Have you seen the recent work (removal or temporary markings) on, (name specific location)?

- No answers.

For the next two questions consider the visibility and effectiveness of the temporary markings or the results of the marking removal operations.

**24.** (The marking removal was effective and resulted in a removed area that blended into the surrounding pavement.) or (The temporary pavement markings are clearly visible and effective.)

- Uh, I mean I think the method. Yeah, the using waterborne they do. Yeah, it's effective in removing the pavement so I would give it a four I guess on that.

**25.** The (removed marking or temporary marking) area is confusing?

Please include comment and rating.

Disagree	Moderately Disagree	Neutral	Moderately Agree	Agree
1	2	3	4	5

- Ah, generally disagree. I'd probably put it at like a 2.

**26.** What would make the markings more visible/clearer at this airport?

- The FAA Construction specification acceptance is all based on, you know, right after placement as far, especially when you're talking beads and reflectivity and so we've had many times where, you know, we look at it within a few days of placement or right after placement and reflectivity looks good. But then within Two or three weeks or a month later, the beads have already started to come up. And so we get into arguments with our contractors. And again, our part 139 guys on what's an acceptable level of degradation in, you know in it mostly in the beads. It's not typically been the paint itself. It's mostly in the bead placement. And so that's been our biggest issue of FAA construction specs. Either needs to have You know something that says after 30 days the reflectivity must you know still be X or? You know, maybe it's even longer than that so that we have a warranty claim on to the contractor. There's a very big disconnect between the FAA spec and in the teachings that are occurring based on the pavement marking AC and some of the stuff the FAA is putting out on the on the Part 139 side so I would love to see a little better alignment. I don't. I don't know which way it needs to go, but I think one way or the other it needs to become a more aligned on what those expectations are.
- whenever I scope projects I try to order all of our pavement markings with a black border. You know you know we work with the owner of the facility. You know

where this Air Force, Army Navy to kind of understand budget you know and do where appropriate. But you know especially on concrete pavements, providing a black border, it goes a long way. But I think just the black border. I think the black border pays for itself over time, especially in daytime operations you know at night time a lot of times the reflective medial kind of capture the eye of the pilot or at least that's my understanding anyway, of what the pilots were seeing. I'm not a pilot myself, so I don't. I don't know, but I think during just daytime OPS the black border goes a long way so I guess in general terms, that's what I would say.

27. Are there any other markings at this airport that are not visible or are confusing and can you explain?

- No answers.

28. Is there something that you would like to share about your marking experience that you think is relevant

- I think um definitely taking a course and refresher courses in markings is key. I think having your own quality control and not relying on the company that's doing the markings. Having that discussion beforehand. Especially about weather. Making sure that everything is in compliance and reviewing the advisory circular compliance levels since different markings have different compliance levels is important.
- many years ago the tolerances were very kind of loose and not very well enforced and so we had markings that were extremely poor if you will, and they were all over. There were certainly places where it could have been a foot or two off, but you know now we've gotten the specs so tight that contractors are on a 10,000 foot runway where a planes traveling 150 miles an hour. And oh, that's centerline marking is 3 inches off I gotta go out and obliterate and redo it because it's off and now I'm causing more damage to the pavement. So there's just trying to find the right balance point there. I think we've swung too far to the it's got to be perfect, otherwise it's getting redone, which just causes you know long term pavement damage when we try to, you know, redo markings multiple times so. I think there's a sweet spot to be achieved there, and I think we've gone from one extreme to the other, and we're not in that sweet spot yet.
- I think the biggest thing that we're seeing is cleaning the surface before you paint on it. You know when they put in brand new concrete they put a sealer on it. Uh, obviously for good reason, but then the paint doesn't adhere to it as well and it and it goes away pretty quickly. So yeah, if it's a temporary marking, put it on with that sealer under. It's great 'cause it cleans right up and goes away. It's gone forever and you never. There's not even a halo of it, but it for permanent markings that sealer prevents that permanent marking from lasting through its full life, full expected life cycle.

# APPENDIX C. REMOVABLE PAINT SAFETY DATA SHEET



## SAFETY DATA SHEET

### Section 1 – Product Identification and Company Details

<b>Product Name:</b>	Removable Waterborne Traffic Paint White	<u>Paint – Liquid: Not Regulated</u>	
<b>Product Code(s):</b>	RW-340	<b>Contact:</b>	Stacey Campbell
<b>Manufacturers Name:</b>	Safety Coatings, Inc.	<b>Email:</b>	scampbell@safetycoatings.com
<b>Address:</b>	20180 Safety Lane, Foley, Alabama, 36535		
<b>Telephone Number:</b>	(251) 943-1638	<b>For Emergency:</b>	1-800-424-9300 - Chemtrec
<b>Fax Number:</b>	(251) 943-3689		
<b>Date Prepared:</b>	2/20/14	<b>Date Revised:</b>	7/8/2021

### Section 2 – Hazards Identification

<b>Appearance:</b>	White– Light Ammonia Scent	<b>HMIS:</b>	<b>H</b>	<b>F</b>	<b>R</b>	<b>P</b>
<b>Exposure Routes:</b>	Inhalation, Skin, Ingestion		1	0	0	
<b>Eye Contact:</b>	Severe irritation with redness and blurred vision.					
<b>Skin Contact:</b>	Moderate irritation, defatting, and dermatitis.					
<b>Inhalation:</b>	Nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache.					
<b>Ingestion:</b>	Possible blindness and upset stomach.					
<b>Carcinogenicity:</b>	<b>NTP:</b> No.	<b>ARC Monographs:</b> No.	<b>OSHA Regulated:</b> No.			
<b>Chronic Overexposure:</b>	This product contains <b>METHANOL</b> , which has been suggested as a cause of eye damage if swallowed.					

### Section 3 – Composition / Information on Ingredients

<u>Hazardous Components</u>	<u>CAS Number</u>	<u>OSHA PEL</u>	<u>ACGIH TLV</u>	<u>OTHER</u>	<u>%</u>
Oxygenated Hydrocarbon (Texanol)	25265-77-4	N/A	N/A	None	1-2
Titanium Dioxide	13463-67-7	15 mg/m <sup>3</sup>	10 mg/m <sup>3</sup>	None	5-7
Calcium Carbonate	1317-65-3	N/A	10 mg/m <sup>3</sup>	None	59-64
2 HydroxMethyl-Amino	52299-20-4	N/A	N/A	None	0.1

#### Non-Hazardous Components

VOC – 0.14# / GAL. 17g / Liter

<u>Non-Hazardous Components</u>	<u>OSHA PEL</u>	<u>ACGIH TLV</u>	<u>OTHER</u>	<u>%</u>
Water	N/A	N/A	None	15-17
Acrylic Polymer	N/A	N/A	None	15-17
Soap Dispersion	N/A	N/A	None	0.2-0.4

\* Refer to "Section 15" for **SARA TITLE III – SECTION 313 – REPORTABLE CHEMICALS** \*

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#### **Section 4 – First Aid Measures**

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<i>Eyes:</i>	Flush eyes with water. If symptoms persist, seek medical attention.
<i>Skin:</i>	Thoroughly wash skin and clothing with soap and water. If symptoms persist, seek medical attention.
<i>Ingestion:</i>	If swallowed, do not induce vomiting. Get medical attention.

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#### **Section 5 – Fire Fighting Measures**

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<i>Flash Point:</i>	Non-combustible	<i>LEL:</i>	N/A
<i>Flammable Limits:</i>	Non-flammable	<i>UEL:</i>	N/A
<i>Extinguishing Media:</i>	Foam / Carbon Dioxide / Dry Chemical / Halon / Water		
<i>Special Fire Fighting Procedures:</i>	None		
<i>Unusual Fire and Explosion Hazards:</i>	None		

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#### **Section 6 – Accidental Release Measures**

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<i>Personal Precautions:</i>	For personal protection, see "Section 8". Persons not wearing protective equipment should be excluded from area of spill until clean-up has been completed. Ensure adequate ventilation.
<i>Environmental Precautions:</i>	Prevent spreading over a wide area. Do not let product enter drains. Do not flush into surface water or sanitary sewer system. Local authorities should be advised if significant spillages cannot be obtained.
<i>Methods for Clean Up:</i>	Soak up with absorbent material and place in safe container. Thoroughly wash area with water before material dries. Dispose of according to Local, State, and Federal regulations (see "Section 13").

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#### **Section 7 – Handling and Storage**

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<i>Handling and Storage:</i>	Keep from freezing.
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#### **Section 8 – Exposure Controls / Personal Protection**

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<i>Ventilation:</i>	Local Exhaust:	Special:
	Yes	None
	Mechanical (General)	Other:
	Yes	None
<i>Respiratory Protection:</i>	Paint Mask	
<i>Protective Gloves:</i>	Yes	
<i>Eye Protection:</i>	Yes	
<i>Other Protective Clothing or Equipment:</i>	None	
<i>Work / Hygienic Practices:</i>	Wash hands thoroughly after use.	

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### Section 9 – Physical and Chemical Properties

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<i>Appearance:</i>	Liquid, White	<i>Solubility in Water:</i>	Dilutable
<i>Odor:</i>	Light Ammonia Scent	<i>Vapor Density: (AIR=1)</i>	<1
<i>Boiling point/ boiling range:</i>	210-220° F	<i>Specific Gravity: (H<sub>2</sub>O=1)</i>	1.6-1.7
<i>Melting Point:</i>	Liquid	<i>Evaporation Rate: (Butyl Acetate = 1)</i>	<1
<i>Flash Point:</i>	Non-Combustible	<i>Vapor Pressure: (mm HG.)</i>	20

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### Section 10 – Stability and Reactivity

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<i>Stability:</i>	Stable
<i>Conditions to avoid:</i>	None
<i>Incompatibility: (Materials to Avoid)</i>	Organic Solvents
<i>Hazardous Decomposition or Byproduct:</i>	None
<i>Hazardous Polymerization:</i>	Will not occur.

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### Section 11 – Toxicological Information

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Refer to "Section 2"

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### Section 12 – Ecological Information

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Refer to "Section 6, Environmental Precautions"

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### Section 13 – Disposal Information

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Disposed of according to State, Local, and Federal Regulations.

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### Section 14 – Transport Information

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Paint, Liquid - Not Regulated

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### Section 15 – Regulatory Information

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*Section 313: Supplier Notification*

*\*Consult "OSHA Guide 1910" for U.S. Federal Regulations\**

*These chemical(s) are subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act or 1986 (40 CFR 372):*

	<u>CAS Number</u>	<u>Chemical Name</u>	<u>% By Weight</u>
N	O	N	E

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### Section 16 – Other Information

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**\*\*Disclaimer\*\***

The information contained herein is based on data available at the time of preparation of this data sheet and which Safety Coatings, Inc. believes to be reliable. However, no warranty is expressed or implied regarding the accuracy of this data. Safety Coatings, Inc. shall not be responsible for the use of this information, or of any product, method, or apparatus mentioned and you must make your own determination of its suitability and completeness for your own use, for the protection of the environment, and the health and safety of your employees and users of this material.