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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 176

BRIDGE PAINT: REMOVAL, CONTAINMENT, AND DISPOSAL

TRANSPORTATION RESEARCH BOARD
National Research Council

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BRIDGE PAINT: REMOVAL, CONTAINMENT, AND DISPOSAL

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. FEBRUARY 1992

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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NCHRP SYNTHESIS 176

Project 20-5 FY 1988 (Topic 20-09)
ISSN 0547-5570
ISBN 0-309-05302-1
Library of Congress Catalog Card No. 91-067363

Price $9.00

Subject Areas
Maintenance

Mode
Highway Transportation

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Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to bridge painting contractors, bridge maintenance and construction engineers, environmental engineers, equipment manufacturers and suppliers, and others interested in bridge paint removal. Information is provided on current practices in bridge paint removal, containment, and disposal, with special attention paid to environmental, health, and cost issues, along with a discussion of current environmental regulations governing paint removal practices.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

The removal of bridge paint is a nationwide problem with sensitive environmental concerns and rapid changes in available technology and regulatory oversight. This report of the Transportation Research Board describes the current state of the practice for bridge paint removal, containment, and disposal, especially with regard to lead-based or other toxic paints. Additionally, current environmental regulations and health concerns in this area are examined.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Robert E. Skinner, Jr., Director for Special Projects. The Principal Investigators responsible for conduct of the synthesis were Herbert A. Pennock, Special Projects Engineer, Sally D. Liff, Senior Program Officer and Scott A. Sabol, Program Officer. This synthesis was edited by Linda Mason.

Special appreciation is expressed to Bernard R. Appleman, Executive Director, Steel Structures Painting Council, who was responsible for collection of the data and preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Robert L. Davidson, Chief Chemist, Pennsylvania Department of Transportation; Al J. Dunn, Engineer Administrator II, Louisiana Department of Transportation and Development; Win M. Lindeman, Administrator, Environmental Research and Training, Florida Department of Transportation; William M. Medford, Chemical Testing Engineer, North Carolina Department of Transportation; John W. Peart, Research Chemist, Federal Highway Administration; Lloyd M. Smith, S. G. Pinney & Associates; and Krishna K. Verma, Welding Engineer, Federal Highway Administration.

Crawford F. Jencks, Senior Program Officer, and Frank N. Lisle, Engineer of Maintenance, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

BRIDGE PAINT: REMOVAL, CONTAINMENT, AND DISPOSAL

SUMMARY

The problem of removing paint (especially lead-containing paint) is a significant threat to the ability of highway agencies to adequately maintain corrosion protection and structural capacity. The issue presents a classic dilemma in the allocation of resources between the need to protect the environment and the need to maintain bridges. This synthesis presents key aspects of the problem, including: strategies and choices faced by highway agencies; technology of removal and containment; regulations affecting bridge painting; and attitudes and input from contractors and suppliers. Also presented are some preliminary recommendations.

OVERVIEW OF PROBLEM

Approximately 80 percent of the more than 100,000 state-maintained steel highway bridges have been coated with lead-containing paints. In order to prevent advanced corrosion, normally it is necessary to remove the lead-containing paints and recoat the structure. Both removal and disposal of the paint and abrasive are now regulated by the U.S. Environmental Protection Agency (EPA) and local environmental agencies. These regulations and the steps necessary to comply with them have caused a major problem.

Although considerable progress has been achieved since the earlier National Cooperative Highway Research Program (NCHRP) Report 265 on the subject in 1983, for many bridges the techniques for containing debris during removal are still largely incapable of fully containing paint, abrasive, and dust fallout. For other bridges, such containment is achievable only at an extremely high cost. Thus, without the regulatory authorities' cooperation and the recognition that some lead pollution is unavoidable, bridge repainting can not be practically achieved with current technology.

Another aspect of the problem is disposal of the residue which typically contains paint waste and spent abrasives. These materials fall under the solid waste disposal regulations issued by EPA under the Resource Conservation and Recovery Act (RCRA). As of August 1990, however, land disposal of hazardous wastes is no longer permissible; all wastes must be treated (e.g., reused, recovered, or detoxified). Where detoxification is used, the resulting product is generally not classified as hazardous.

Based on the survey conducted for this synthesis and on previous surveys and findings, it is estimated that $100 to $130 million is spent annually on bridge painting. Approximately 10 to 20 percent of this total ($10 to $25 million) is incurred because of the requirements for containment. For an individual bridge, the increase in cost due to containment may be 50 percent or more depending on the containment requirement.

Thus, the overall percent of bridge painting costs incurred because of containment is expected to increase significantly as containment is required for a larger percentage of bridges being repainted. It is estimated that in 1989 approximately 30 percent of bridge painting debris (abrasive, paint, dust) was contained and collected. The estimated cost to dispose of those abrasives based on 1990 regulations is $11 to $21 million per year. The cost would escalate to $37 to $75 million per year if 100 percent of debris were collected.

SPECIFIC CONCLUSIONS

This synthesis developed several specific conclusions regarding equipment, containment, waste disposal, and the contractor's role in improving the bridge painting process.

Fully enclosed containment structures are considered capable of achieving 85 to 90 percent containment of abrasive and paint particles and dust for simple spans. This type of containment is not feasible for high trusses and other complex structures with current bridge containment technology. Simple containment devices such as tarpaulins, windscreens, platforms, and barges typically will achieve 40 to 75 percent containment. In addition, as containment structures and devices become more sophisticated, they require more involved design and engineering. The safety and structural integrity of such containment devices has emerged as a critical issue.

Several highway agencies, in conjunction with environmental agencies, have developed effective practical schemes for classifying bridges and containment requirements according to environmental sensitivity. For most of the nation, there is still a large amount of confusion, lack of overall direction, and non-uniform and inconsistent enforcement and monitoring of regulations. Most agencies' specifications are not sufficiently explicit regarding contractor requirements and responsibility. Areas requiring additional definition include: degree of containment required; methods of measuring and monitoring pollution and containment efficiency; methods of sampling, testing, and storing waste, and containment for waste disposal; and responsibilities for permits, transport, and disposal.

The pressure on highway agencies to reduce the volume of waste generated is expected to intensify because of pollution problems and restrictions on landfilling. Industry and highway agencies must place major emphasis on methods that reduce waste, eliminate abrasives, or reuse waste if cost-effective measures are to be provided. Under the new test method for classifying waste, the Toxicity Characteristic Leaching Procedure (TCLP) imposed in September 1990, it is likely that almost all abrasive and paint waste from lead-coated structures will be classed as hazardous. This is expected to greatly increase the cost, paperwork, and liability of agencies with regard to waste disposal. Under the "cradle-to-grave" philosophy, highway agencies will have ultimate responsibility for proper disposal of waste.

Bridge painting contractors are also faced with increasingly more stringent requirements on protecting workers against exposure to lead dust and particulates within containment. This will result in increased cost due to training, medical monitoring, hygiene, and personal equipment.

The experience and expertise of painting contractors is a major factor in determining the success or failure of a bridge containment project. Many contractors have a strong interest, commitment, and incentive in working with agencies to improve bridge painting activities. Highway agencies need to ensure competence, integrity, and responsibility of contracting firms because of potential damage to the environment and adverse publicity. If the problems of high contractor liability and risk, and lack of qualification standards are not addressed, the better contractors may abandon the painting of bridges that contain lead-based paints. This would drastically reduce the highway agencies' ability to effectively extend the life of bridges.

RECOMMENDATIONS

Some recommendations for highway agencies are suggested:

- *Recognize Extent of Problem.* A first step toward resolving the problems is recognition by highway agencies of the extent of the lead paint removal problem and the types of actions that are needed. The recognition and commitment must be made by top agency officials and be backed by the authority of legislators. Policies must be flexible to allow the agency to assess the situation continually and to adjust or revise procedures and programs.
- *Coordinate Policies Within Highway Agencies.* The agencies must establish procedures to coordinate policies and programs among the departments involved in bridge painting. Exchanges of information and experience with other highway organizations, industry associations, and private firms are also recommended.
- *Evaluate and Document Paint Removal Activities.* Agencies are urged to thoroughly evaluate and monitor removal, containment, and disposal activities and effectiveness. This will enable transportation agencies and the industry to build a data base to improve the technology.
- *Work With Environmental Agencies.* Since it is unacceptable to ignore the regulations and often is technologically not feasible to comply with the letter of the law, cooperation and accommodation are required.
- *Investigate Waste Treatment Options.* Because of land disposal restrictions, agencies must start immediately to evaluate and implement methods for stabilization of waste and reuse of abrasives. It should not be assumed that the waste management industry can solve all highway waste problems.
- *Prepare for Increased Costs of Regulation.* Containment techniques, waste treatments, and technologies are developing rapidly, but will require greater commitment of personnel time and direct costs. Environmental and health and safety regulations may be expected to become more stringent.

Ultimately, the choices made by legislators and the public will result from trade-offs between protecting and maintaining transportation structures, and protecting the environment and the general health and welfare. These trade-offs may be measured in terms of the costs of maintaining the structures, as well as the costs related to environmental damage and protection. The situation is complicated by competition for funds from other vital public causes. Also of concern are the uncertainties, costs and inefficiencies of containment, environmental regulations, degree of hazard, and enforcement. Progress toward resolution depends on the immediate coordinated effort by a number of key groups including regulators, highway agencies, contractors, equipment manufacturers, and trade associations.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

INTRODUCTION

Removal of lead and other toxic materials, such as chromates, from bridge painting operations is a critical issue confronting highway agencies. The issue is complex because of society's conflicting needs to prevent bridge corrosion and deterioration and to protect the environment from potentially toxic material with insufficient resources to fully address the needs of both concerns.

According to the present survey of state highway agencies conducted for this synthesis, approximately 80 percent of all existing steel highway bridges have been painted with lead compounds. These materials can cause chronic or acute health problems in humans and animals. Over the last 20 to 30 years, environmental and health and safety agencies have enacted numerous regulations to reduce the exposure risks to these materials. (See Appendix A for a review of environmental and other regulations.)

To properly maintain bridges and render them safe for operation, it is necessary to periodically remove the existing coating and apply new coating systems. While almost all new paints are lead- and chromate-free, the process of removal can result in significant contamination of the local environment (*1,2,3*). Each year, approximately 1,200 lead-coated bridges are cleaned (most often by abrasive blast cleaning) and repainted. The estimated annual cost is \$100–\$120 million with a substantial portion attributable to containment (see discussion in Chapter Five).

This activity generates an estimated 200,000 tons of lead-contaminated abrasives. In the past, the debris would be classified as hazardous about 50 percent of the time (*4,5*). Because of a new procedure introduced in 1990, virtually all debris from lead-containing paint is expected to be classified as hazardous (*6*). Proper disposal of the waste is another new and potentially costly element in the bridge painting picture (*7*).

The removal operation is governed by various environmental regulations on air quality, water quality, and solid waste disposal (*1*). Most of the regulations were developed as part of a general environmental act (e.g., Clean Air Act or Resource Conservation and Recovery Act) and were not enacted specifically to address the lead removal question.

To fully protect the environment, it would be necessary to completely enclose and contain the lead paint to prevent it from entering the water, falling onto the ground, or becoming airborne. Such containment, however, is a major added expense for most bridges and is technically unachievable for others. As discussed by Appleman, if EPA and local agencies were to strictly enforce the regulations for full containment, repainting existing bridges under currently accepted technology would no longer be possible (*2*).

In practice, of course, the situation is considerably more complex. For all but a handful of states, EPA relies on state and local agencies to monitor, enforce, and interpret the regulations. There are many questions related to lead paint containment that are not covered by the EPA regulations. In addition, there is a lack of uniformity and consistency in applying these regulations to different parts of the country. Thus, the actions taken by individual highway agencies are dependent on a number of variables, including the following (*2*):

- General pollution control policies required for bridge painting,
- Activities of local environmental agencies,
- Public reactions and complaints,
- Questions asked by local contractors, waste haulers, or landfill operators, and
- Information disseminated by organizations such as the Transportation Research Board (TRB), the Federal Highway Administration (FHWA), and professional associations and periodicals.

A wide variety of practices exists among the highway agencies, including the following: virtual shutdowns of bridge maintenance painting activities; special situations for different locations and bridge types; and continued unconfined blasting of structures (*4*). In almost all the state and local agencies, the contractors and the highway agency representatives (e.g., specifiers, engineers, materials personnel) experience great uncertainties regarding how to carry out their assigned responsibilities. This synthesis presents a version of this complex situation in an effort to sort out the key issues and to provide some guidance to the highway agencies and related industry groups.

HISTORICAL BACKGROUND

In the late 1970s and early 1980s, highway agencies started to address the potential hazards of lead- and chromate-containing paints. A few agencies, such as Louisiana and California, had programs dating to the 1960s. Tests of alternative materials were sought through a major pooled-fund highway planning and research (HP&R) study and parallel state highway programs (*8*). During this time, also, environmentalists in federal, state, and local agencies became more concerned about the deposition of lead paint that was already on bridges.

Of major concern was the effect of lead particles on streams, adjacent lands, and groundwater supplies. Consequently, in the mid 1970s, a number of highway agencies established requirements for preventing debris from surface preparation from being deposited in the environment. Containment presented a major technological and engineering challenge. Early efforts had limited success. In a few instances, problems arose because of activity in environmentally sensitive areas and strong attention by the news media.

In about 1978, the Transportation Research Board's National Cooperative Highway Research Program (NCHRP), supported by the American Association of State Highway and Transportation Officials (AASHTO), awarded a contract to investigate two aspects of the problem: First, to assess the environmental regulations concerning removing lead paint from bridges and the degree of risks posed by these structures; and second, to evaluate technology for removing and containing the residue from cleaning bridge structural steel.

The findings of the study include (*1*):

- In rural areas, lead paint debris may not pose a significant environmental threat. The removal of paints based on "red lead" and basic lead silicochromate were judged to have less impact on air and land quality in rural areas compared to urban areas where the potential for higher lead levels is present. No information was found in the literature implicating these compounds in signficantly affecting water quality.
- There was no proven technology for removal and containment of blasting debris on a practical, productive basis. Further equipment development was recommended.

The issue of removal, containment, and disposal of lead-based paints has become increasingly critical in the nine years since the publication of the NCHRP report. This is due to several causes, including revisions in regulations, stronger enforcement of regulations and ongoing critical examination of the hazards of lead-based paint wastes. States are required to meet the conditions of the Resource Conservation and Recovery Act (RCRA), which regulates the disposal of hazardous waste. Waste must be tested by a leaching procedure; if the leachate exceeds 5 parts per million (ppm) of lead, the waste is considered hazardous and must be treated prior to disposal (*2*). The cost of treatment and subsequent disposal may be extremely high, up to \$300 to \$500 per ton, which may be five times more expensive than disposal at an industrial waste site. In addition, there has been increased enforcement of air quality regulations and water quality regulations. The Clean Air Act of 1977 sets an upper limit on particulates and lead that can be discharged into the air over a certain time period. States and local jurisdictions may set even lower limits (*9*). Open abrasive blasting has been essentially eliminated in areas of the country where the regulations are being enforced (*10*). Containment or other surface preparation techniques must be used. Surface preparation over waterways is also being affected by regulations on surface water contamination or fish and wildlife preservation (*11*).

In the early 1980s, a relatively small number of states was actively concerned with removal of lead and other toxic materials in paint. Starting in about 1986, however, additional states started paying considerable attention to the environmental regulations, particularly those concerning the disposal of hazardous waste and air pollution. One of those agencies was the Pennsylvania Department of Transportation (PennDOT), which in 1986 developed environmental guidelines as part of an increased emphasis on bridge painting and environmental compliance (*12*). PennDOT recognized the inadequacy of the existing technology of containment. Following meetings with contractors and regulators, a major HP&R research program was initiated. PennDOT hired a research contractor to evaluate four containment techniques on small highway bridges. The contractor was asked to determine the degree of containment efficiency, and the cleaning rate, and to quantify the amount of lead deposited in the soil, groundwater, and air. The project was completed in December 1989 (*13*). Other agencies that conducted studies around this time included the Virginia and North Carolina Departments of Transportation (*7*).

In 1987, a new committee was established at the Steel Structures Painting Council (SSPC) to address the need for standards in containment and disposal. Also about this time, the Federal Highway Administration (FHWA) became more actively concerned with lead paint removal. In February 1988, an FHWA workshop was held to address three key issues: regulations and the environment, containment techniques, and maintenance strategies (*14*). The workshop was preceded by a two-day symposium and an exhibition of products and services. Additional conferences were held in 1989, 1990, and 1991, indicating the great interest in the subject.

As a follow-up to the workshop, FHWA awarded a contract in October 1989 on a comprehensive research and development program to investigate the following aspects of the problem (*15*):

- Review and analysis of available information
- Identification of waste disposal sites and capacities
- Abrasive reclamation
- Waste reduction, control, and disposal options
- Containment methods and efficiencies
- Alternate (non-blast) cleaning methods
- Environmentally acceptable uses of maintenance debris
- Operational design criteria for negative pressure containment

From 1988 through 1990 there was also an increase in activities by individual highway departments, who were responding to the increased publicity generated by FHWA, SSPC, and the above-mentioned states, and from increased enforcement activity by local environmental agencies. The publicity also influenced a number of manufacturers, equipment suppliers, contractors, and research firms to develop new techniques and equipment for containment, recycling, disposal, and waste processing.

This synthesis is intended to assess all these diverse activities, including those by regulators, highway agencies, contractors, and research groups. The overall objectives are as follows:

- Assess the magnitude of the problem in terms of number of bridges, number of square feet painted, and anticipated costs,
- Assess the severity and impact of the new environmental regulations,
- Identify existing and developing techniques for removing, containing, and disposing of hazardous paint,
- Determine the activity and awareness of the highway community regarding lead paint removal, containment, and disposal,
- Examine the general capability of highway agencies to implement these techniques and how these activities affect bridge maintenance and protection of the environment, and
- Identify and discuss strategies and programs that can improve the agencies' ability to meet the above requirements.

CHAPTER TWO

ENVIRONMENTAL AND HEALTH CONSIDERATIONS

Traditional practices of bridge cleaning and painting have not addressed the environmental impact of these activities. It has, however, become evident in recent years that certain bridge painting operations must be severely modified to avoid violating environmental regulations on air quality and waste disposal. Also of concern is the impact of paint removal activities on worker health. A number of environmental regulations are cited in this chapter and are listed in Appendix A.

REGULATING AIR QUALITY

Conventional bridge cleaning by abrasive blast cleaning generates substantial quantities of air contaminants. These are alternately referred to as dust or particulates. Of major concern from a health standpoint are particles less than 10 microns in diameter (PM-10) because these can be trapped by the lungs. The most deleterious dusts are lead and silica, both of which have well-documented effects on human health. Silica particles can originate from certain non-metallic sand abrasives, while lead is often a major component of the paint being removed.

Lead particulates of any size can be hazardous. When they settle on the roadway or on public or private land, they can be absorbed or ingested by humans through various routes. Large particulates (greater than 10 microns) of non-hazardous substances may be cited as "nuisance dust" or "fugitive emissions" (anything not confined to a flue). Often a visual dust plume is what gains the attention of the public or local regulators.

As noted, the operation that produces the greatest amount of dust is open air abrasive blasting. The force of the abrasive particles impinges on the substrate, fracturing the abrasive as well as removing and fracturing the paint and corrosion products. The resulting dust cloud can completely obscure the work area and also produce visible emissions at substantial distances from the work area. The quantity of emissions, the particle size distribution, and the transport depend on a variety of factors, including friability and dusting characteristics of the abrasive, angle and pressure of blasting, brittleness of paint, extent of corrosion, structure configuration, and wind pattern.

Dust can be reduced by using low-dusting abrasives, abrasives of high cleaning efficiency (i.e., using fewer pounds per square foot of surface) or by incorporating water into or around the abrasive stream (see Chapter Three). Also discussed are use of vacuum blasting, power tools, and other methods for reducing the quantity of waste generated.

Most local and state agencies do not have specific restrictions on lead or silica particulates. Rather, these are controlled through general dust or nuisance ordinances. Under the Clean Air Act, EPA has established National Ambient Air Quality Standards (NAAQS) for certain pollutants, including lead. The maximum level for airborne lead is 1.5 $\mu g/m^3$ averaged over a calendar quarter. These standards are rarely enforced for bridge painting, as they were intended for more permanent operations, such as lead smelters. EPA has announced its intention to revise this standard. It is expected to lower the exposure limit and to reduce the time frame for averaging, both of which would increase the likelihood of exceeding the limitations during bridge painting.

National Ambient Air Quality Standards have also been established for PM-10 particulates at 150 $\mu g/m^3$ averaged over a 24-hr day. Some agencies, such as the Allegheny County (Pennsylvania) Health Department, have also established maximum exposure limits for lead and silica (*16*).

Dust can be monitored using special portable air monitoring devices. These are placed in a few strategic locations near the work area and in the local community to determine the extent to which dusts are being transported to the environment. The devices have a fan to draw air through a chamber and collect any debris on a filter. The filter pores determine the size of the particulates captured. The filter paper can then be taken to a laboratory for analysis of lead, silica, or total dust content. Additional information on monitoring of air particulates for bridge painting is given elsewhere (*9,16*).

REGULATING WASTE

The second major environmental area of concern is the collection and disposal of waste generated from paint removal operations. Again, the activity producing the greatest offense is abrasive blast cleaning, which often uses 4 to 10 lbs of abrasive per square foot of surface area cleaned. Blast cleaning abrasives are normally innocuous, inert materials; the primary source of hazardous material in blast cleaning is the paint, which may contain compounds of lead and chromium, two heavy metals regulated by EPA. The paint and other debris, surface dirt and iron oxides typically constitute 1 percent or less of the abrasive.

Because the waste produced from surface cleaning contains lead, a hazardous substance, EPA also restricts dumping or spilling the waste into the environment. Thus, highway and other agencies have been required to contain the waste to prevent this from occurring. The EPA limit on the amount of waste allowed to be "spilled" is very restrictive. The reportable quantity for lead is 1 lb total (*17*). Any operation in which more than 1 lb of lead is added to the environment and not contained or cleaned up is in violation of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). This particular regulation has not been widely enforced by EPA or state environmental agencies. If it were, it could result in the curtailment of any operation which does not achieve virtually 100 percent containment. For typical lead-containing bridge painting systems, 1 lb of elemental lead would be generated by removing the paint from about 40 ft^2 of surface on a 2- to 3- layer lead paint system.

The illegal "dumping" or "spilling" is thus governed by CERCLA, which addresses avoidance and cleanup of sites containing hazardous waste. Another regulation governs the treatment, handling, and disposal of hazardous (or suspected) waste. That is the Resource Conservation and Recovery Act (RCRA), enacted by Congress in 1976 and strengthened in 1984 by the Hazardous and Solid Waste Amendment (HSWA). RCRA and HSWA are intended to provide "cradle to grave" requirements for handling of potentially hazardous wastes, meaning that the waste is tracked from the time of its generation ("cradle") to the time of its disposal or treatment ("grave") (*18*).

EPA's concern under RCRA is not for the total amount of lead or chromium in the waste, but rather for the amount which is dissolved (leached) when the waste is placed in a special solution. This solution (acetic acid) is designed to simulate the most extreme conditions of municipal landfills.

In August 1990, EPA implemented the Land Disposal restriction portion ("Land Ban") of the Hazardous and Solid Waste Amendment (*19*). This act prohibited disposal of any hazardous waste in landfills. Thus, any waste that exceeds the toxic level must first be treated to render it non-hazardous.

TESTING AND SAMPLING OF SOLID WASTES

The EPA test for lead and other metals consists of adding acetic acid to finely divided solid waste to achieve a pH of 5. If the amount of lead dissolved after 24 hrs agitation is greater than 5 mg/l (5 ppm), the material is classified as hazardous.

TCLP and EP-TOX

Two test methods have been specified by EPA: the Toxicity Characteristic Leaching Procedure (TCLP), which in September 1990 became the official test for determining if a waste is hazardous (*20,21,22,23*); and the Extraction Procedure Toxicity Test (EP-TOX), developed by EPA in the late 1970s as a general test procedure to cover waste generated from a large number of industries (*20*). Compared with the earlier test, TCLP is easier and less expensive to run. It is claimed that TCLP provides greater reproducibility among labs and repeatability within a given lab.

The major difference in the testing procedures is the addition of a buffer solution to stablize the pH at 4.8 to 5.2 (*5*). Since the solubility of lead is greatly increased at lower pH, there is increased leachability using TCLP (*5*). The high solubility for TCLP increases the likelihood of lead-containing abrasives being classified as hazardous. Thus, whereas with EP-TOX less than 50 percent of the bridges blast cleaned with expendable abrasives were judged to be hazardous, with TCLP the figure is closer to 80 to 90 percent, based on the threshold level of 5 ppm.

EP-TOX may still be used under the following conditions: If a waste is determined to be hazardous by TCLP (greater than 5 ppm), it may be tested by EP-TOX. If found non-hazardous by EP-TOX (less than or equal to 5 ppm) it may be disposed at a hazardous (Subtitle C) landfill. This is an exception to the "Land Ban" provisions, which cover only lead and arsenic (*24*).

Origin of 5 PPM Level

The 5 ppm level is based on the permissible level of lead in drinking water which is established at 50 ppb, or 0.05 ppm. EPA's objective is to provide a safety factor of 100 for the prevention of solid waste leaching into ground water which may be used for drinking water. There has been some discussion at EPA about reducing the permissible level of lead in drinking water to 10 or 15 ppb. This could trigger an automatic reduction in the leachable level of lead allowed in solid waste. Such an action would almost guarantee that lead-containing abrasive waste would be classified as hazardous. It would also affect the techniques and economics of waste processing.

Sampling

EPA has also established criteria and techniques for sampling solid waste suspected of being hazardous. The sampling method required for TCLP is based on a general procedure developed by EPA for sampling hazardous waste. This is a rigorous, complex procedure, involving the procedure for obtaining representative samples and the number of samples needed for statistical validity (*25*).

A minimum of four samples is required for each waste stream. For bridge painting debris, the waste stream is considered the waste generated from one structure or from one or several days collection. Generally, it is not permissible to allow waste to accumulate for long periods of time over the course of a large job.

Highway agency officials, painting contractors, and many testing laboratories are largely unfamiliar with these procedures. Consequently, there is a great degree of variability in the type of sample obtained. Obviously, there could be a huge difference whether one takes the first or last sample of the day, or attempts to blend samples from different locations on the bridge.

If the average of the four samples is greater than 5 ppm, the entire waste stream is considered hazardous and must be treated in accordance with RCRA (see discussion below). For wastes less than 5 ppm, EPA has established a safety factor based on the confidence interval, a factor related to the statistical standard deviation. The average solubility must be at least one confidence interval less than 5 ppm. For example, a waste stream with an average leachable lead level of 3 ppm and a confidence interval of 2 would be acceptable (i.e., non-hazardous), but one with an average concentration of 4 ppm and a confidence interval of 2 would still be considered hazardous. In this case, additional samples would be needed to establish that the waste is non-hazardous based on a larger statistical sampling size.

A disadvantage of the EPA sampling method is that the number of samples required may not be determined until after the first set of samples (minimum of four) is analyzed in the laboratory. In some cases it may then be necessary to obtain additional samples, which could add greatly to the cost of testing (*25*).

Variability of Test Results

Because most abrasives are fairly similar in their physical properties and chemical reactivities, and most lead-containing bridge paints are based on similar resins and pigments, one might expect fairly comparable results from one bridge blasting to another. The actual situation is that the level of leachable lead from bridge blasting varies enormously, with results reported from undetectable (less than 0.1 ppm) to greater than 100 ppm (*2*). The volume of abrasive is not a major factor in this variation. Attempts to correlate the leachable lead levels with the total lead content on the bridge have been unsuccessful (*26*). Possible influential factors include the condition (e.g., brittleness) of paint, the type (e.g., hardness and shape) of abrasives, and the blasting pressure. The availability of a standard reference sample of lead-contaminated abrasive would at least enable the testing laboratories to determine the accuracy of their test. However, such a sample is not required by EPA.

Non-Hazardous Waste

In some instances, even non-hazardous waste disposal may be difficult. In Illinois, Maine, Pennsylvania, and other states, non-hazardous waste from blast cleaning is classified as an industrial waste. Disposal of industrial waste also requires a certain amount of manifesting and record keeping. Some waste site operators are reluctant to accept waste with any measurable lead content because of their own potential liability.

Degree of Hazard of Lead Bridge Paint

Still unanswered is a scientific determination of the actual degree of hazard posed by typical lead bridge paint in the environment versus the EPA definition of "hazardous". The latter is based on the model of paint residue being disposed of in a municipal landfill, which is thereby subject to acetic acid, a decomposition product of municipal waste. Because the compound lead acetate has appreciable solubility at a pH of 5 and below, lead paint residues have a relatively high likelihood of exceeding the 5 ppm limit in such an environment.

It should be noted, however, that abrasive paint residues normally are not hauled to municipal landfills, but rather, it is common construction practice that these residues are placed with other construction aggregate wastes. In these circumstances, the lead compounds, such as lead oxide or lead chromate, are extremely insoluble in rainwater (even highly acidic rainwater), in groundwater, or in freshwater lakes and streams. Thus, one can argue that the lead compounds in paint do not pose a significant or measurable threat to drinking water or other aspects of the environment, and should not be subject to the RCRA testing. An earlier report for NCHRP noted the immobility of lead in soil, and the unlikelihood of lead from buried waste leaching into groundwater (*1*).

WORKER HEALTH IN CONTAINMENT

The removal of lead-containing and other toxic paints or dusts from bridges can present a serious health risk to blasters and others involved in the operation. Thus, this has become an important area of concern for the Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH) and bridge officials, contractors, and their support groups.

OSHA and NIOSH have initiated projects recently to determine the extent and magnitude of the health hazard and to identify means for educating and protecting workers. At present, the OSHA construction industry standard allows exposures of up to 200 μg of lead/m^3 averaged over an 8-hr period (*27*). This subject is given relatively little attention in the construction industry standard. For workers involved with lead in the general industry (which includes lead smelter operations), on the other hand, the maximum exposure limit is set at 50 μg/m^3 (only one-fourth that of the construction standard) (*28*). Reducing the level of lead exposure in construction has become a major priority for OSHA with the end of 1992 being a proposed date for a new standard.

The primary indicator of lead exposure is lead level in the blood. At a level of 40 μg/100g the employer is advised to initiate preventive measures to protect the worker. According to OSHA, at a level of 60 μg of lead/100g of blood, the worker must be removed from the workplace.

There are several mechanisms by which a worker can become contaminated with lead. These include breathing lead-contaminated dust, ingesting lead by eating, drinking, or smoking lead-contaminated materials, and by being exposed to lead-contaminated clothing, tarpaulins, abrasives, or equipment (*29*).

Protection can be achieved by engineering controls and by personal protection. Engineering controls are generally preferred by industrial hygienists. This approach entails designing and operating the work area such that the workers are not exposed to lead dust or particulates. Examples include improved ventilation, vacuuming, or other collection of the debris before it is deposited into the environment. Full engineering controls on bridge painting or removal projects are often impractical. A major factor is that, because of the requirement for containing the debris, the concentrations of lead dust inside the containment area are increased. The use of recycled abrasive has also led to elevated exposure levels in the workplace.

Personal protection measures include use of respirators and other equipment and good hygiene practices. Abrasive blasters are normally required to use blasting hoods or helmets with supplied air as a general protection against dust. When lead dust is present, current practices and equipment may not provide adequate protection. Different types of respirators have different protection factors ranging from 10 to 1,000 or more. This is the ratio of the concentration of the dust or vapor outside the respirator to the level inside the respirator.

Personal hygiene covers practices and procedures for exiting and entering lead-containment areas, cleaning and maintenance of respirators and other equipment, use of washing facilities, and proper handling of lead-contaminated clothing and other materials.

In the last few years, there have been numerous instances reported where workers on lead paint removal projects had been exposed to excessive levels of lead, in dust or other forms (*30,31*). A number of organizations are actively working to alleviate this problem through both engineering controls and personal protection.

Examples of proposed engineering controls include improved equipment for separating lead paint chips and dust for recycled abrasives, better ventilation and design for containment structures, and use of methods that minimize the quantity and form of dust added to the work environment. Contractors and suppliers are developing improved respiratory equipment and procedures. Highway agencies and contractors are working with industrial hygienists, consultants, OSHA and NIOSH to establish improved hygiene programs. Finally, major efforts are being made to inform workers, contractors, and specifiers of the hazards of lead, and to increase means to protect against them.

CHAPTER THREE

REMOVAL AND CONTAINMENT TECHNIQUES

Protecting the environment from lead residues requires three operations: removal, containment, and recovery. Removal consists of dislodging paint, rust, and other debris from the structural steel surface. Containment is the prevention of the removed material from being released into the environment. Recovery is the operation whereby debris is captured from the containment material or structure for subsequent reuse or disposal.

In some instances, these three operations are performed by a single piece of equipment. For example, a vacuum blast system includes an abrasive blast nozzle for removing the paint and rust, and a vacuum head for containing the debris and conveying it back to a separator for recycling (Figure 1). More commonly, two or three separate operations are required; for example, a typical operation might use open blast cleaning as a method of removing the paint and rust, tarps or barges to contain the spent abrasive, and vacuuming or sweeping to capture the debris. For greatest efficiency, it is important that these three operations be integrated and made compatible with one another.

This chapter will first describe the techniques and systems for performing each of these operations, followed by descriptions or approaches for integrating or combining them.

METHODS FOR REMOVING PAINTS AND CORROSION PRODUCTS

Blast Cleaning

The most effective and productive method for removing paint and rust from steel has been abrasive blast cleaning. The paint removal rate is strongly dependent on the condition of the surface and the type of coating. For heavily rusted and pitted steel, the production rate may be only 50 to 100 ft^2/nozzle/hr to produce a near-white metal condition (i.e., in accordance with the SSPC Surface Preparation Specification No. 10 [SSPC-SP 10]). For surfaces with flaking paint, moderate scaling or rusting, and little or no mill scale, cleaning rates up to 200 ft^2/nozzle/hr can be achieved. The rate and degree of cleaning are also affected by equipment variables (e.g., air pressure, nozzle size and design, hose length and diameter, operating technique, and compressor size) (*32*).

Abrasives

Another important parameter in blast cleaning is the consumption rate of abrasives (usually reported in pounds of abrasive per square foot of area cleaned). Prior to concern for environmental issues, the consumption rate was not as critical an issue, because the abrasives were relatively inexpensive ($30–$60 per ton) and disposal was readily accomplished on road beds or landfills or elsewhere. In addition, traditionally for field work, contractors have used expendable non-metallic abrasives such as silica sand, and more recently, non-silica materials such as coal slag, copper slag, and staurolite.

Under the current regulatory climate, abrasives with low consumption rates are greatly favored because of their reduced volume for disposal. In some instances, however, contractors have sought abrasives with high consumption rate, in the fallacious belief that high quantities of abrasives would result in lower leachable lead levels (due to a dilution effect). Knowledgeable contractors seek low-consumption abrasives to reduce their abrasive and disposal costs. Unfortunately, for most of the abrasives marketed in the U.S., there are few substantiated data or even validated test methods for abrasive consumption rates.

The need to reduce the quantity of abrasives debris has spurred the use of recyclable abrasives. The principal recycled abrasives in use by the industry are metallic shot and metallic grit. Aluminum oxide and silicon carbide are also designed to be recycled. Each of these abrasives can be reused many times, sometimes as many as 100 or more. There are non-metallic abrasives such as copper slag or garnet that are also claimed to be recyclable, but typically the number of cycles is limited to two to five. Reuse of these materials frequently results in a reduced particle size giving reduced surface profile. It may be advantageous to reclaim this material to reduce fines and hazardous material. The resultant

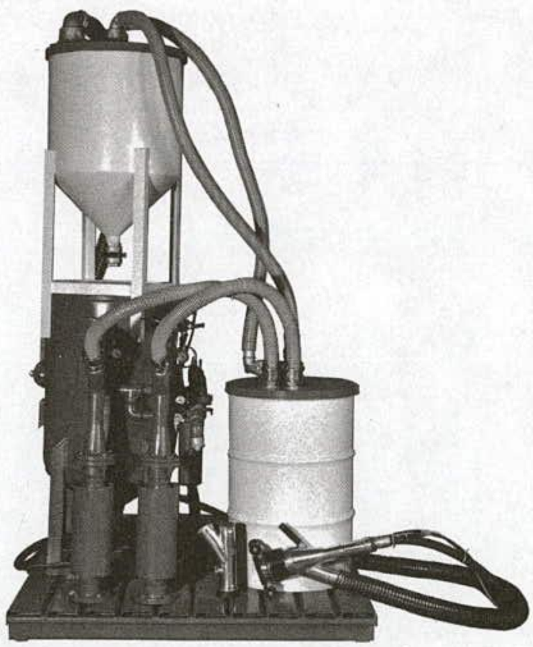

FIGURE 1 Vacuum blasting system (courtesy Inventive Machine Corp.).

clean angular product can be used as a filler in traction or anti-skid material.

Metallic abrasives are commonly used in fabricating shops where blast cleaning is accomplished by automatic centrifugal wheel machines or specially designed air blast rooms (*33*). An important parameter of these operations is the mechanism for recycling the abrasive. New steel is painted and finished in the fabricating shops and it is vital to remove the fine abrasive particles, residues of rust, mill scale, grease and other impurities from the collected debris. It is also necessary periodically to replenish abrasive particles to maintain a constant working mix, as particles tend to become more rounded and smaller as they are used for blasting. The selection of a proper working mix and suitable abrasive size, hardness, and shape is an important issue for those involved in using recycled abrasives. Some states (e.g., California) require recycled abrasive to be recertified prior to reuse for unconfined blast cleaning. Metallic (i.e., steel) abrasives are subject to rusting and "clumping". The specific equipment and systems for recycling abrasives in the field will be discussed.

Power Tool Cleaning

Even with the use of recyclable abrasives, a relatively large quantity of abrasives must be processed and collected. Power tool cleaning, on the other hand, is a mechanical means of abrading surfaces which does not require an abrasive medium. As a result, essentially the only debris generated is the material being removed (paint, rust, mill scale, and other surface debris). Thus, the quantity of material that must be disposed of is many times less than that in abrasive blasting. Using an estimate of 10 mils of paint with a specific gravity of 1.5, the mass of the paint is about 25 g/ft^2 (about one ounce), compared to the 4 to 10 lbs required for disposable abrasives.

Power tool cleaning has several inherent disadvantages. First, it is highly labor-intensive, and low in productivity. Cleaning rates range from 5 to 20 ft^2/hr, depending on factors such as complexity of steel, tenacity of coating and corrosive products, skill of operator, and particular tool used (*5*). Second, conventional power tools such as power wire brushing or disc sanders are not very effective at removing tightly adherent coatings, and generally are not capable of removing tight rust and mill scale. In addition, power discs may gouge or produce grooves in the steel. Some recently developed power tool systems have, however, demonstrated capabilities of removing tight rust, mill scale, and paint (*34*).

SSPC has developed a specification entitled "Power Tool Cleaning to Bare Metal" (SSPC-SP 11), describing the use of these tools (*35*). This specification is distinguished from SSPC-SP 3 (Power Tool Cleaning) which requires only removal of loose paint and rust. The tools in SSPC-SP 11 include abrasive-embedded rotary flap wheels, non-woven abrasive discs, certain coated abrasive discs, and needle guns. With the latter two, caution must be used to avoid damage to the steel substrate. These new power tools have not overcome the problem of low productivity. Also, most operators are unfamiliar with their use. In addition, power tools are sometimes incapable of cleaning irregular surfaces or edges or corners (*13*).

Pressurized Water Jetting

Water jetting uses high pressure water jets to dislodge paint, rust, and contaminants from the surface to be painted. A major advantage of water jetting is elimination of any abrasive or other solid medium to the paint or rust waste. In addition, a surface can be water jetted relatively rapidly, especially compared to power or hand tool cleaning. However, high pressure water jetting, even at 20,000 to 35,000 psi, cannot remove tight rust or mill scale except at exceedingly slow rates (*36*). The injection of small amounts of abrasive can correct this deficiency, but this detracts from the previous advantage.

There is some evidence that pressurized water jetting removes soluble salts and small particles from the surface, making it chemically cleaner (*37*). There is, however, little evidence that this will result in an increased paint life.

What is not in dispute is the benefit of water jetting in reducing the quantity of airborne dust. In some jurisdictions, the air pollution caused by dust clouds from blast cleaning is the most objectionable aspect of the repainting operation. However, for this technique as well as for air abrasive wet blasting (described below), it is still necessary to protect workers against dust, preferably with air-fed respirators (*36*).

Many users and specifiers of water jetting require the use of a soluble corrosion inhibitor to prevent flash rusting. The inhibitor itself may cause concern if it is allowed to enter ground or surface water sources, and an excess of inhibitor on the surface can influence paint performance. These inhibitors vary in composition and in toxicity, and are often proprietary

A final consideration in use of water jetting is disposal of the water, which will carry with it rust, paint, inhibitors, and any abrasive added to improve the cleaning efficiency. It may be necessary to test the water for lead content. Additional safety concerns include high operator thrust and noise level.

Air Abrasive Wet Blasting

In this related technique, water is added to the abrasive air stream. Depending on where the water is added and the quantity, the resultant stream can be either a slurry or slightly wetted abrasive particles. As with pressurized water jetting, wet abrasive blasting is usually very effective in reducing the dust generated when abrasives fracture upon hitting the surface (*38*).

The cleaning rate achieved with wet blasting is usually somewhat lower (15 to 30 percent) than corresponding dry blast units (*36*). This is due to the added complexity of the equipment, lack of operator familiarity, and increased operation and mechanical problems. Specific problems that have arisen include wet sand sticking to the cleaned surface, rebounding water reducing visibility, and increased difficulty of containing and disposing of waste slurry or wet solid waste (*38*). Spent wet abrasive may be classified as a wastewater waste according to RCRA. It would require different testing and treatment standards than solid abrasives, which are classified as non-wastewater waste.

Vacuum Blasting

This system, described briefly above, consists of an abrasive recovery head connected to and surrounding the blast nozzle. The intent is to use vacuum suction to capture the abrasive and paint residue directly from the surface. The captured abrasive is then conveyed to a separator to remove the dust and fine particles and recycle the recovered abrasive to the blast nozzle.

Portable vacuum blasting units have been available for more than 30 years, but never have been considered practical for large-scale field maintenance work. The major disadvantages have been small cleaning heads, difficulty in cleaning irregular surfaces, and low productivity. In some instances, the separation units have malfunctioned because of moisture, inadequate power for vacuuming, or poor design.

Vacuum blasting eliminates the need for external containment, and reduces the abrasive waste generated. Because of these advantages, manufacturers and contractors are reexamining the use of vacuum blasting for cleaning lead paint-containing bridges (*39*). One practical problem of note is that contractor employees accustomed to blast cleaning are frustrated by the slow cleaning rate achieved with vacuum blasting and often tend to back the unit off several inches from the surface. This increases the cleaning rate but defeats the purpose of vacuum blasting.

New developments in technology include units with larger vacuum heads and wider cleaning paths, and a versatile variety of attachments to permit cleaning of inside and outside corners and other geometric irregularities of the structure (Figure 2).

Novel Cleaning Methods

Several other novel cleaning methods have been proposed, including chemical stripping, dry ice blasting, laser jetting, and water soluble abrasives.

Chemical stripping involves applying a chemical paste containing alkaline or acidic solvent materials. The paste is troweled or sprayed on the surface, followed by application of a special laminated polyethylene blanket. The dissolved paint is absorbed by the paste, which will also bond to the polyethylene blanket. The paint/paste and blanket are intended to be removed (stripped) and disposed of as a monolithic sheet (Figure 3)(*40*). For intricate shapes and configurations, the laminating blanket may not be suitable, and other means are required for removing the paint.

The main advantage of the system would be reducing the volume of waste. There are numerous questions which must be answered before this technique is practical or even feasible. These include the time required for solubilizing the paint and hardening the film, the efficiency of paint removal, the application rate of the paste and laminated backing, environmental or health effects of the paste, the cost, source of supplies, and applicability to different types of structures, and compatibility of chemicals with rust or scale and new coating formulations.

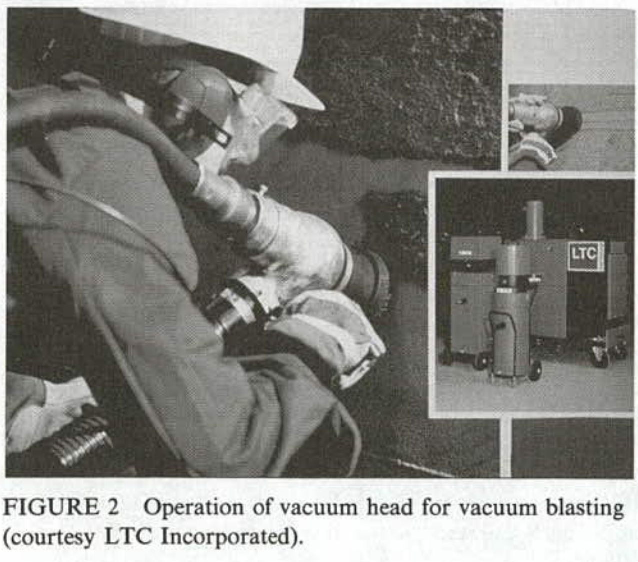

FIGURE 2 Operation of vacuum head for vacuum blasting (courtesy LTC Incorporated).

FIGURE 3 Demonstration of chemical stripper for paint removal (Louisiana Department of Transportation and Development).

Dry ice (solid carbon dioxide) pellets have been used recently to clean aluminum aircraft hulls. Although improvements apparently have been made in the means of producing pellets and in the delivery system, the ability to remove tight paint and rust from steel has yet to be demonstrated (*41*). Dry ice pellets also fail to provide a satisfactory surface profile for many coatings.

Similarly, laser jet cleaning is being developed for use in aircraft coating removal, primarily by robots. A prototype was developed that successfully removed several layers of paint from steel test panels (*42*). The combusted and volatilized lead was vacuumed from the surface. Upgrading this unit to production scale is still a number of years and several hundred thousand dollars in the future. The major advantage of these methods is the reduction of residue. Carbon dioxide cleaning leaves only paint and rust, while laser cleaning leaves only a dark inert residue on the surface.

Water soluble abrasives such as sodium bicarbonate have been proposed as an easy clean-up method for removing coatings from steel and other substrates. The abrasive is propelled at standard blasting pressures (85 to 100 psi). Dry blasting with sodium bicarbonate is quite dusty, so it is usually used as a wet slurry. The major advantage is that the abrasive is water-soluble and can be easily cleaned up. However, when removing lead-containing paint, it might be necessary to filter the waste water to remove lead and other solid residues for proper disposal. Another disadvantage is that water soluble abrasives will not produce a profile and are not capable of removing tight rust or mill scale. Thus, if a bare metal or profiled surface is specified, a second step of conventional abrasive blasting would be required (*43*).

CONTAINMENT OF PAINT AND ABRASIVE DEBRIS

Containment of debris usually requires construction of enclosures or barriers. These are normally placed or attached onto the bridge itself. In certain instances, devices are placed on the ground (tarps) or water (e.g., barges, containment booms). The containment devices differ considerably in type of materials, method and extent of assembly required, complexity, cost, and degree of effectiveness. In the present stage of technology, there are no standard methods or specifications for the type of containment system or its efficiency. The SSPC Committee on Lead Paint Removal is planning to issue a guide for containment in the near future (*44*). This guide has established a preliminary list of methods and materials upon which some of this discussion is based (*45*).

Containment Devices

Free-Hanging Enclosures

This technique includes the use of tarps, drapes, plastic sheeting, screens or rigid panels in a manner whereby only two corners, or one side, of the sheeting or panel is supported. All other surfaces are unsupported or not connected to additional material (Figure 4). Problems have arisen because of the "sail effect" from high wind loads which can rip tarps from their supports. These also cause a safety hazard and negate the ability to contain. Thus, placing tarps on large, high bridges has not been effective. Air-permeable screens can alleviate this problem somewhat, but require a careful selection to ensure the proper combination of strength and permeability. The heavier screens also reduce visibility inside the work area (Figure 5).

Free-hanging enclosures have been used quite frequently because they are relatively inexpensive and have often been required as a part of the general construction housekeeping to prevent contamination of nearby houses and businesses. These materials are not intended to collect or support large loads of abrasive debris. They act primarily to deflect abrasives away from public areas and toward collection points normally located on the ground.

FIGURE 4 Freehanging tarpaulin on bridge (courtesy Eagle Industries).

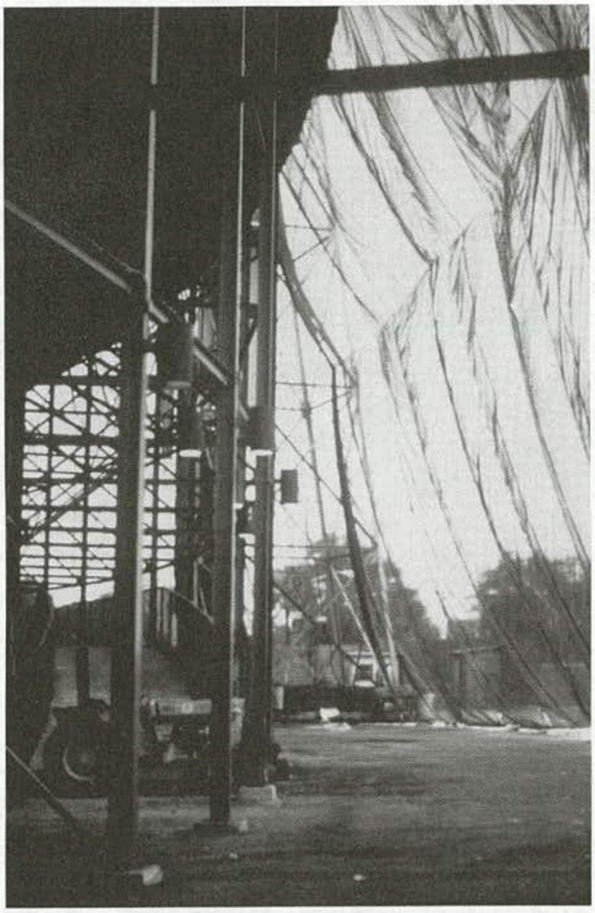

FIGURE 5 Example of visibility inside semipermeable containment screen (courtesy Eagle Industries).

Consequently, the use of tarps or screens by themselves results in relatively low containment collection efficiency. The actual efficiency depends on the particular bridge, with most effective containment achieved for small overpasses and the lowest on high structures over water or land features. For the latter, essentially none of the material can be effectively contained. For the former, probably no more than 50 percent would be achievable, although no hard figures have been identified.

Total Structural Enclosures

Tarps, drapes, screens, plastic sheeting, or rigid panels are attached to a rigid structure which totally encloses the work area. Structures can be steel framework, wood framework, scaffolding, or existing walls (Figures 6 and 7). According to the proposed SSPC Guide, enclosure material must be secured at least every 100 ft^2, and enclosure material must make a seal between overhead and roof area and floor, deck, or ground. The floor or collection point must be designed to withstand the loads of spent abrasives (Figure 8). Spent abrasives can also affect the load balance for movable bridges, which may be cleaned while in service.

FIGURE 6 Example of rigid enclosure over portion of structure (J.M. Lunardini).

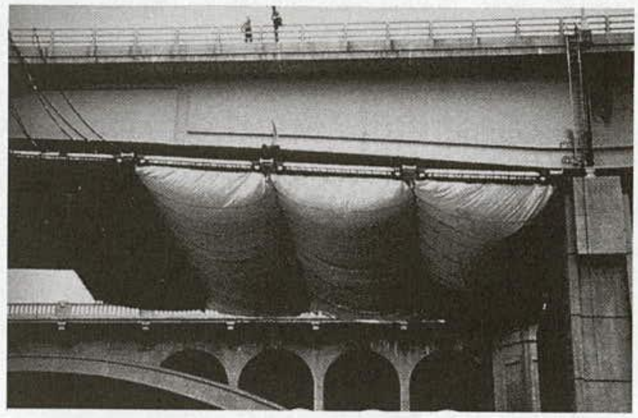

FIGURE 8 Example of specially designed floor system for bridge containment (courtesy Cor-Con, Inc.)

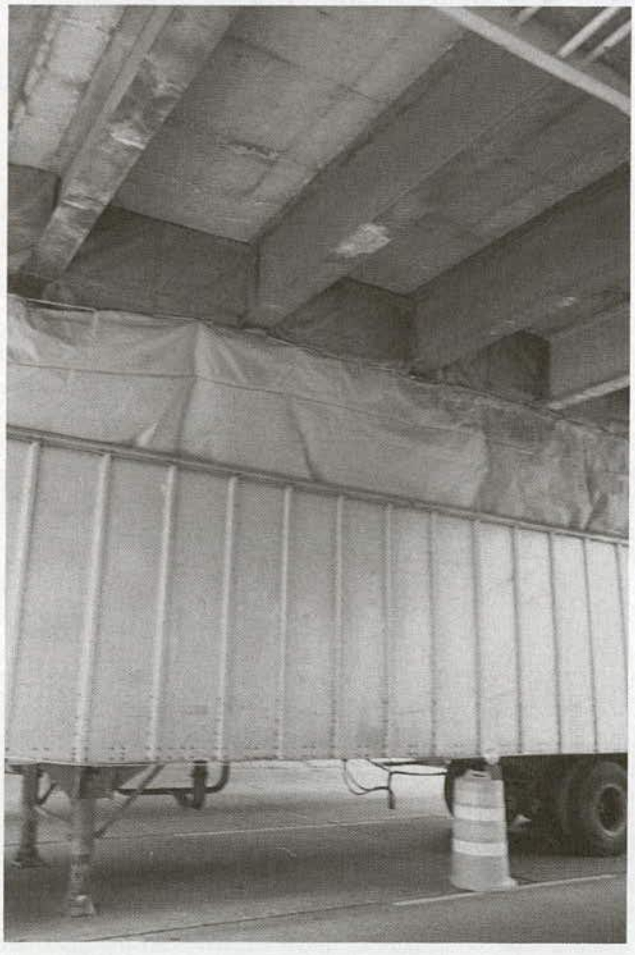

FIGURE 7 Diaphragm closures between girders (Louisiana Department of Transportation and Development).

Another important consideration for enclosed areas is visibility, because the enclosure materials normally cut off some of the natural light. In addition, the blasting procedure generates considerable quantities of dust, further reducing operator visibility. The protective hood and plastic face screens further exacerbate this problem. Consequently, it is normally advisable to provide artificial lighting for enclosed structures.

When blasting, the nozzle is adding several hundred cubic feet per minute of pressurized air to the enclosed area. This air must eventually escape the enclosure. Thus, unless a negative pressure is provided (see discussion below), air and dust will leak from the enclosure. Unless the excess air is directed properly, it could result in highly visible pollution to the surrounding area or damage to the walls or seams of the enclosure. There are several areas of concern regarding safety in the construction and use of enclosures. These include the following:

- Structural adequacy of enclosure itself (i.e., does it provide support for workers, abrasive load, wind load?)
- Quality of air provided for worker in confined locations: OSHA regulates the exposure limits of lead, silica, carbon monoxide, and other substances. Within the containment work area very high levels of lead and dust may be attained.
- Difficulty of working in confined space with cumbersome equipment (Figure 9). This, as noted previously, limits the visibility. In addition, there is concern for footing and getting too close to edges or corners while working on elevated structures. Also, it is necessary to consider the safety of supervisors and inspectors while working in or around the enclosures.
- Ripped tarps or snapped cables from high wind gusts or heavy steady winds.

Another important characteristic of enclosure systems (partial or full enclosure) is the degree of portability and reusability of enclosure. On large bridges and those with repeated structural elements (multiple spans) one can use modules which can be easily assembled, disassembled, and moved to a new location on the bridge. In some instances, the entire bridge is enclosed at the outset and the enclosure is not taken down until the blasting and painting are essentially completed. In Germany, on a major river

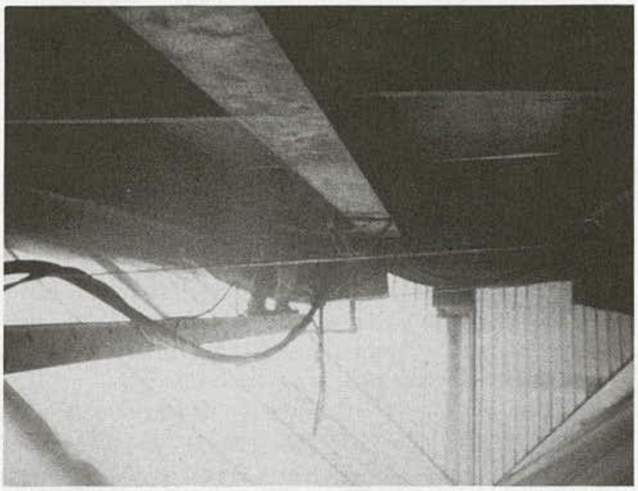

FIGURE 9 Inside negative pressure containment structure (courtesy Harrison Industrial Technologies).

crossing, two separate enclosures (boxes) were used, one strictly for the blast cleaning, the other for painting (Figure 10)(*46*).

Each bridge blast cleaned and repainted may require a separate system design. There are presently no standard modules or designs available that can be used readily on a variety of structures. FHWA is investigating design concepts for a negative-pressure containment system that could be used on various bridge types and sizes (*15*). Until that is accomplished by FHWA or a private equipment manufacturer or contractor, an individual design and construction plan should be prepared for each bridge containment job. Frequently, this results in an increased cost to the owner because of the extra design, construction labor, and materials cost required for this containment structure.

Negative Pressure Containment

In order to effectively prevent dust particulates from escaping the enclosure, it is necessary to establish negative pressure. This requires drawing outside air into the enclosure, across the surface being prepared, and through a filter system to exit the enclosure. This air movement must be sufficient to counteract air pressure put into the enclosure during blast cleaning, and to offer sufficient operator visibility.

Thus, air must continuously be evacuated from the enclosure. This, in principle, eliminates leakage of abrasives and paint dust into the environment, because the air outside the enclosure is continually drawn inward. In practice, however, it may be difficult to ensure that constant negative pressure is maintained throughout the enclosure area.

Other major benefits of continual air change in the enclosure are improved worker visibility, reduced health hazards from exposure to dust, and less dust on the steel being cleaned and on operator equipment. Thus, negative pressure allows for a more efficient blast cleaning operation (Figure 11) (*47,48*).

Negative pressure requires special equipment which may be cumbersome and expensive. These include a blower to generate a vacuum and a dust filter to remove the fine particulates from the air. There are many important considerations, including placement of air intakes, placement of exhaust ducts, type of scrubber used (wet vs. dry), and geometry of the blast enclosure. To date, little has been done to transfer the information available in industrial ventilation handbooks to the design of negative pressure containment structures for bridges.

A problem that has surfaced recently is the health hazard to workers involved in removing lead-based paints. Elevated blood lead levels have been reported for people working both inside and outside containment. These reports have come from contractors working with full enclosure, negative pressure systems. Comparable blood lead level data for open blasting are not available, so it is not possible to prove that containment is solely responsible. However, it does point out that more attention is needed in areas of containment design, worker hygiene practices, and collection or recycling equipment design.

FIGURE 10 Example of totally enclosed bridge from Germany (courtesy J. Hauck, Mobay).

FIGURE 11 Exterior of negative pressure containment structure (Michigan Department of Transportation).

Containment for Power Tool Cleaning Methods

In power tool cleaning, the total amount of debris is less than in blast cleaning, but the volume of lead paint is the same. Thus, the particles removed are highly concentrated in lead. From an environmental standpoint, it is especially important to prevent escape of paint dust into the air, water, or onto uncovered ground areas. The major difference in containment strategies for power tool cleaning or chemical cleaning is that the containment structure does not need to withstand heavy loads due to abrasives. Recovery and cleanup are much easier for power tool cleaning because of the reduced volume of material. As discussed below, vacuum attachments can further simplify the containment and recovery requirements.

Containment Materials

Screens and Tarps

Tarpaulins (tarps) are coarse, coated cloth, specially designed to be impermeable to air, moisture, and dust particles. Tarps usually are selected to be as strong and heavy as possible to resist tearing. Screens, on the other hand, are manufactured materials woven to allow air flow but to retain airborne particulates. Typically, these screens are constructed of polypropylene fabric and stabilized to resist degradation by ultraviolet light. Important physical characteristics include burst strength (ranging from 200 to 600 psi), fabric weight (4 to 6 oz/yd^2), puncture resistance, and design and construction of seams and hems. Some screens are designed to contain dust and paint overspray, but some can contain limited quantities of spent abrasives (*47*).

To avoid wind load, it is desirable to have an open mesh that allows air to pass through it. Open mesh screens are more transparent to light, but also allow fine dust particles to escape (Figure 5). In addition, they have a reduced tear strength and load capacity compared to heavier gauge and tighter mesh screen.

Many contractors and specifiers are not knowledgeable about types and ratings of screens and may tend to purchase screens on the basis of price or weight alone. There are apparently no standards for selecting or procuring screens in the industry. Responsible manufacturers and distributors recognize the need to test materials and to provide proper instructions and precautions in their usage.

Plastic Sheeting

This material is often used to provide a transparent barrier. Unlike screens, however, plastic is impermeable to wind, and thus could be susceptible to damage by wind loads. Various grades of polyethylene or polypropylene sheeting are available including single and double ply, heavy wall construction, and fiber or wire mesh reinforced (Figure 4). Plastic sheets are also used on the ground or on the bottom of platforms as a cover or catchment. It is much easier to sweep or vacuum debris from a smooth plastic sheet than from a rocky or irregular terrain or nailed plywood boards. Sheeting can also be used to protect equipment, materials, or surfaces from becoming contaminated with dust or abrasive residue. If plastic sheeting is to be used to contain falling abrasives, a load-bearing capacity must be ascertained.

Construction Framing

A variety of construction materials can be used to build the frame of a rigid enclosure, including wooden beams, aluminum, fiberglass, or thin-gauge steel panels. Similarly, for the walls and flooring, plywood, plastic, aluminum, or fiberglass panels can be used. The floor must be designed to hold the weight of equipment, operators, and spent abrasive. The platform usually is supported by the bridge itself or by scaffolding (*49*).

In one containment project, contractors designed and patented a platform that rides on heavy steel cable used to rig the bridge (Figure 8) (*50*). This is placed under the bridge in areas below girders, common chords, or other structural members. Aluminum scaffolds of various lengths are connected to each other with specially designed brackets. This simple pattern can be constructed in any number of segments to give more length or width to the containment platform.

RECOVERY OF ABRASIVE AND PAINT DEBRIS

There are several methods for collecting the debris generated by abrasive blast cleaning and other coating removal techniques. These include:

- Capture from surface at point of cleaning (e.g., vacuum blasting)
- Capture from containment enclosures (e.g., sweep or vacuum)
- Capture from ground or water (e.g., ground tarps, barges, or containment booms)
- Channeling debris during cleaning to specified collection points

Vacuuming at Point of Surface Preparation

In this technique, the cleaning tool is surrounded by a shroud equipped with a suction hose. Cleaning tools can include vacuum shrouded blast nozzles, mechanical throwing wheels, rotary flap wheels, needle descalers (needle guns), abrasive bit grinders, and disc sanders. For use with power tool cleaning (or for one-time use abrasives) debris is carried to the container for direct disposal. Recyclable abrasives are conveyed to a reclamation system to remove the fines, dust, and paint chips and deliver the abrasives for subsequent usage.

A key parameter of vacuum blasting is the efficiency of the recovery (Figures 12 and 13). The efficiency depends on factors such as the size of the vacuum head, the draw (power) of the vacuum, and the effectiveness of the seal, particularly around edges, angles, and joint areas.

Other important concerns for vacuum blasting are the cleaning rate, the worker fatigue factor from holding the equipment, and the possibility of abrasives becoming contaminated with paint residue or other surface debris. The following recent advances in vacuum blasting have addressed several of these concerns:

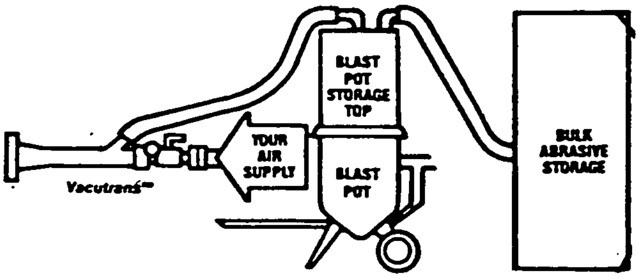

FIGURE 12 Schematic of vacuum blast system (courtesy Vacu-Trans.).

- One equipment manufacturer has produced a unit with a larger size vacuum, which produces a 6-in wide cleaning path. It is claimed to allow several hundred square feet of cleaning per hour (Figure 1)(*51*).
- New separators or scrubber systems have been developed that are claimed to be more efficient in removing fines and dust (Figure 14)(*52*).
- A wider assortment of brushes and special nozzle holders and adaptors has been developed to allow vacuum blasting to be used on more intricate shapes and with quicker connecting and disconnecting.

Most of these new features have not been adequately evaluated by contractors under different job conditions. The current consensus among contractors is that vacuum blasting is not practical for most structures, particularly those with large amounts of intricate steel shapes such as latticework and angles. The low productivity greatly increases the cost and the time to complete the job. The need to change heads and fittings on the job can further reduce a unit's field practicability.

On the other hand, vacuum blasting could greatly reduce the need to construct expensive and elaborate enclosures, which heretofore have been the only means to accomplish abrasive blast cleaning while containing the rebounding debris.

Power Tools and Vacuuming

Equipping power tools with vacuum heads offers another approach for removing and containing hazardous paint without requiring full enclosure. The major advantage of this technique is that it generates a minimal quantity of debris to be disposed of, and eliminates or minimizes the need for containment (Figure 15)(*53*). One of the major disadvantages of power tool cleaning is its slow cleaning rate compared to blast cleaning. This rate can be greatly increased if it is required to remove the paint only (which contains the lead), rather than removing all rust and mill scale. This was the basis for a two-step cleaning operation

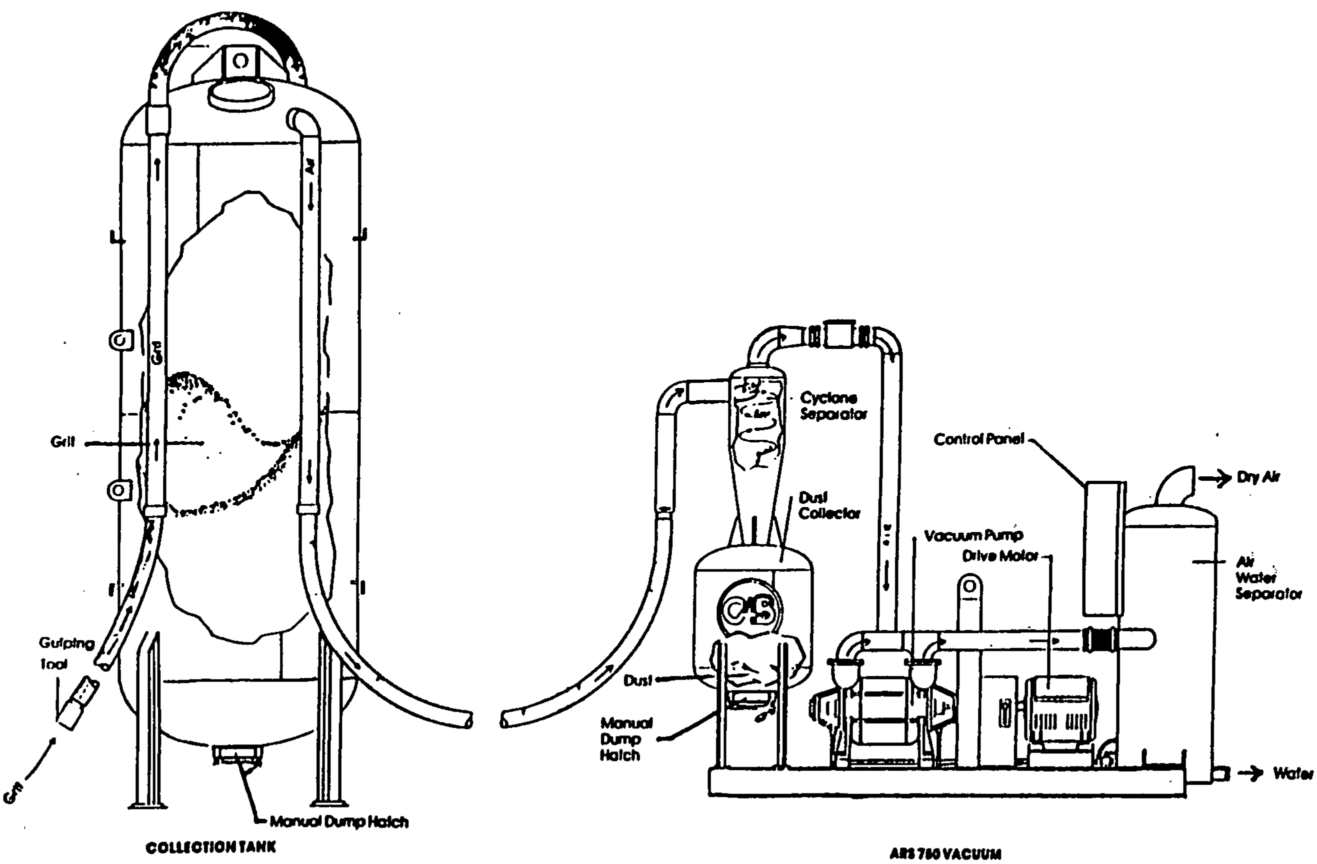

FIGURE 13 Detailed schematic of vacuum recovery system (courtesy CAB Systems).

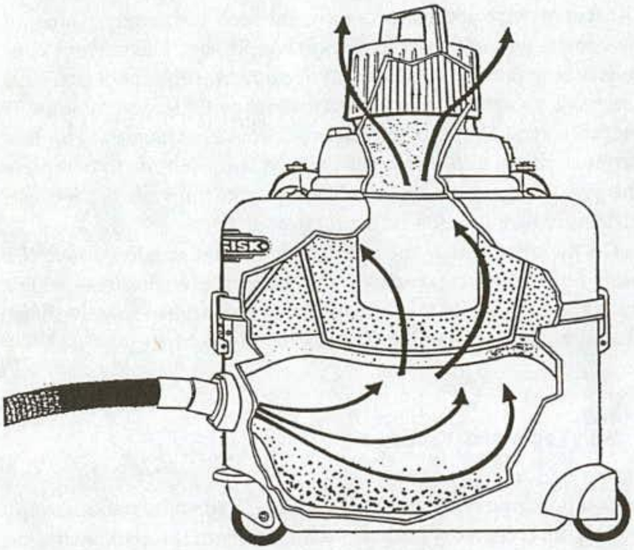

FIGURE 14 Schematic of dust separator (courtesy of Nilfisk).

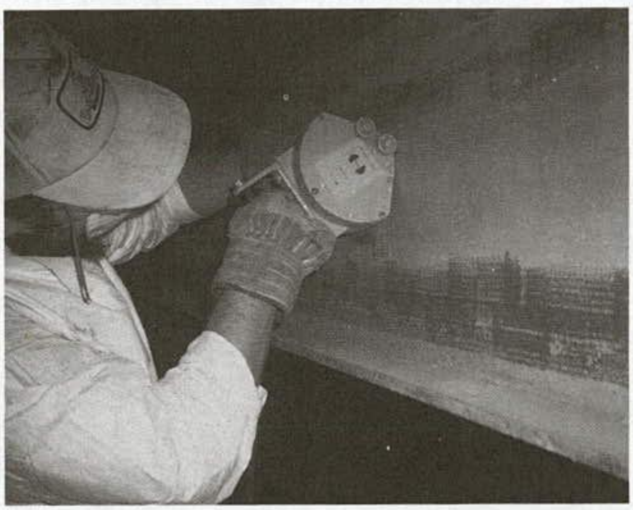

FIGURE 15 Example of power tool rotary cleaning (North Carolina Department of Transportation).

evaluated in a recent highway agency test (*7*). The surface was first cleaned by abrasive-embedded rotary flaps with and without vacuum attachments to remove old paint. Then, to achieve a near-white condition, this step was followed by an open abrasive blast cleaning using partial containment to reduce the dust level.

Another consideration is that certain power tools are larger than blast nozzles and are more difficult to shroud in a vacuum head. Moreover, as little design work has been done, the systems evaluated have not been engineered as an integrated cleaning system. This cleaning system might not be suitable for edges of beams, inside corners, or other hard-to-access locations.

One manufacturer has developed a system for vacuum enshrouded needle scalers (needle gun) (Figure 16). The scaler includes 28 high-strength alloy needles, and is designed to be used on corners or flat surfaces. The reported cleaning rates are 10 to 30 ft^2 for flat areas and 30 to 60 linear ft/hr (2-in wide path) (*54*).

The vacuum can be connected directly to a unit which filters the debris and deposits it into a standard 55-gal drum. The High Efficiency Particulate Air (HEPA) vacuum filtration is claimed to remove more than 99.9 percent of all particulates above 0.3 microns. The unit was originally developed for concrete decontamination, but also has applications for cleaning steel.

Capture from the Containment Structures

Various types of full and partial enclosures are built to contain the abrasive. If the abrasive is not collected at the surface where generated, it will rebound into the enclosure, resulting in the debris being piled and accumulated on the floors of the containment structures. It will also accumulate along the walls in corners, crevices, seams, and folds of the enclosure material.

The abrasive debris may be collected by vacuuming, shoveling, sweeping, or mechanical conveying. The abrasive should be collected on a regular basis at least once per day, and more frequently if the abrasive waste is a concern for the containment structural strength or to avoid spills. The contractor should be aware of the need to properly package, label, and store waste that may be classified as hazardous. Abrasives can also be collected on tarps or screens erected to deflect the abrasive. Too great an accumulation can exceed the load capacity of these devices.

There are several vacuum cleaning systems available for handling large quantities of abrasives. The vacuum systems may require electrical or diesel-driven vacuum systems. They come

FIGURE 16 Power tool (needle gun) with vacuum head and recovery system (courtesy Pentek, Inc.).

in various sizes and capacities, portabilities, and costs (Figure 17) (*55*).

One recently developed system employs an air-powered unit that uses an air jet/venturi induction concept to provide vacuum conveyance of the abrasive. It is claimed to produce up to 22-in mercury of vacuum at 150 or 300 CFM (cubic feet per minute). Its power source is the same air compressor used for the blast nozzle. The system also has a noise silencer, dust containment drums with water or cloth filters, and connecting hoses. There is also a variety of pickup tools including flared tools, crevice tools for evacuating hard-to-reach sections, and wall brush tools for flat vertical surfaces (*31*).

Capture From Ground

Vacuuming, sweeping, and shoveling also are used for cleaning abrasives from the ground, with the same considerations for proper handling and placement in barrels or dumpsters. Areas requiring cleaning may be considerably larger than containment structures, particularly on high bridges, when blasting under windy conditions, or where there are inefficient containment materials. Normally, it is necessary to extend the tarps or drop cloths beyond the area under the bridge.

For bridges over water, barges have been used to collect debris (*1*). In this case, it is recommended that tarps or shields from the barge be attached to the side of the bridge or the work platform. Otherwise, almost invariably, large quantities of abrasives will be deposited in the water. In some cases, ground covers can be partially extended over the water under the bridge. These can be attached to the pavement under the structure, to barges, or to bridge piers or footings. As noted in an earlier publication, although this technique is relatively inexpensive and easily installed, it is not very effective when the wind blows. In addition, retrieval of this debris from the covers may be awkward and labor-intensive.

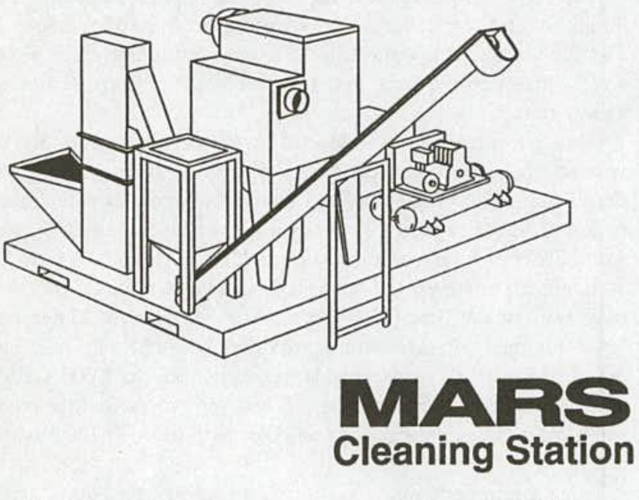

FIGURE 17 Abrasive recovery system (courtesy of Clemco Industries).

Containment Booms

Containment booms or floating paint skimmers are designed to collect floating debris, although some states use booms to sink materials. Floating debris primarily consists of paint chips and fines, as abrasives usually will sink (*56*), and, since lead particulates are denser than water, some paint will also sink. Thus, the main function of these containment booms is to prevent materials from being transported downstream (Figure 18). If there is upstream surface water movement due to wind conditions, it may be necessary to place a containment boom upstream of the structure as well. The booms must be carefully monitored to prevent their damage from floating refuse, strong current, or degradation due to weathering or overloading with debris (*13*). Booms are not very effective when there are rocks or other obstructions within about 6 in of the surface, or where there is boat traffic resulting in significant wave action, since water movement affects stability. Booms can be cleaned by carefully skimming contents or by removing or disposing of a debris-laden boom section. It is important to use complete booms, not sections. A detailed specification for floating paint skimmers has been developed (*56*).

Channeling Debris During Cleaning

An efficient means for collecting debris and preparing it for disposal is to channel it directly to disposal containers (Figures 19 and 20). Early blast booths used in Massachusetts were tapered at the bottom and directed to a funnel through a flexible tube to a covered truck positioned under the bridge. The blast enclosure was small (6 × 6 × 6 ft) and mounted on wheels that rode along the top of the handrails. The truck was moved to coincide with the position of the blast enclosure (*1*). The California Department of Transportation (Caltrans) has used burlap funnels to enclose the scaffold. The bottom of the funnel is then fitted to a cylindrical snorkel-like containment suspended from the enclosure to the ground (*1*). The Ontario Ministry of Transportation specifies that spent abrasive be collected on a plywood platform floor. The abrasive is then fed via flexible tube drop chutes or hoses into the waste disposal container for transportation directly to the disposal site or to a stockpile on the ground below the structure. The stockpile is covered with plastic sheets until it is loaded and removed to the disposal sites. When work-

FIGURE 18 Floating silt barrier (containment boom) (Florida Department of Transportation).

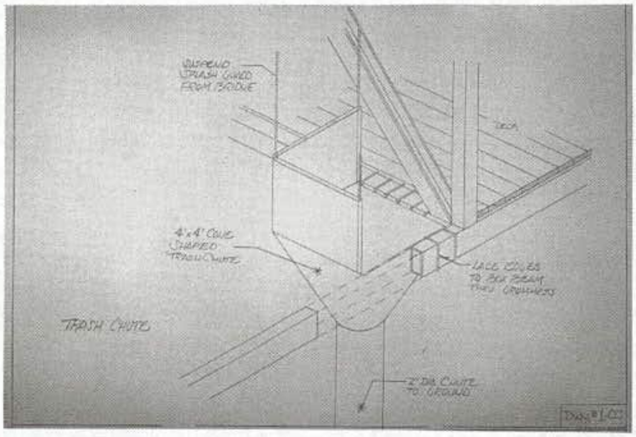

FIGURE 19 Schematic design for funnel to channel debris from bridge (courtesy Eagle Industries).

FIGURE 20 Trailer-mounted enclosure with funnels (Louisiana Department of Transportation and Development).

ing on large spans over water, it is usually necessary to manually move the residue over the platform to a drop chute located at the shore (*56*).

When barges are used to support the work platform, the abrasive is conveyed to the barge through chutes. The barges transport the debris to shore for off-loading into waste containers. To contain debris when working on bridges over water, the Michigan Department of Transportation requires contractors to tarp the sides of barges used under work areas. If the structure is too shallow for a barge, contractors must erect some type of temporary work platform or tarpaulin to collect spent material or direct it to the bank for collection. The spent material must be picked up daily and stored in covered containers (*4*).

ABRASIVE RECYCLING

Because of the national problem of waste disposal, a strong emphasis is placed on waste minimization. One of the most significant methods for reducing the amount of waste is recycling abrasives. Other approaches are discussed in Chapter Four.

Abrasive recycling entails several major steps and associated types of equipment. The abrasive is delivered to a blast nozzle at pressures of 90 to 110 psi and propelled against the surface. The resulting spent abrasives, paint, rust, and mill scale must then be recovered, either at the nozzle (i.e., vacuum blasting) or after blasting (i.e., by vacuuming, sweeping, etc.). Vacuum blasting was discussed earlier in this chapter. The collected debris is transported to a separate chamber(s) for removal of dust, paint, and abrasive fines, then cleaned abrasive is delivered back to the hopper or blasting machine for reblasting. The mechanics and engineering are crucial at each stage of this process. Equipment manufacturers, contractors, and others have expended considerable resources to design, develop, and evaluate integrated systems and modular systems of various sizes, capacities, and degrees of sophistication. Yet improvements are still needed in operation and efficiency of cleaning.

Abrasive Recovery

Abrasives being recovered for recycling require somewhat different handling procedures than abrasives recovered for disposal. For the former, it is important to avoid mixing the spent abrasives with dirt or debris, and to prevent them from becoming wet or damp.

Abrasive recovery rates depend on air flow rate, amount of vacuum, hose diameter, distance debris is being conveyed, and density and size of the material being conveyed. For distances over 100 ft, the capacity for recovering abrasives decreases substantially. For a unit of about 125 to 150 CFM, and a length of 50 ft, approximately 3 to 5 tons per hour of non-metallic abrasive (e.g., sand or slag) can be conveyed. The rate is about 25 percent lower for steel abrasives and approximately doubles for a 250 to 300 CFM unit. Considerably larger units, 600 to 1,000 CFM, are needed to provide substantial recovery rates for distances over 150 ft. Commerical units as large as 1,700 CFM are available (*55*).

Some equipment manufacturers and contractors have been working with mechanical conveyance of the debris. With these systems, either the sides of the containment are angled at the bottom or a trough is placed just below the centerline of the containment. A continuous belt on the bottom trough carries the debris to one end of the containment structure either to a container or to another belt, which carries the material to the recycling unit.

Abrasive recovery units can be part of an integrated system or separate components. At least two commercial conveyor vacuum systems are designed to operate off a contractor's own air supply, thus, the compressor can be used first for blast cleaning, then for cleanup. For mechanical conveyance, there are no distance limitations.

Reclaimer/Separator

For recycling, the abrasive must be conveyed to a reclaimer to separate out the reusable abrasive (Figure 21). There are three common methods for separating the usable abrasives from the abrasive fines, dust, paint, and other debris. These are air-wash separators, cyclone separators, and rotary vibratory screen separators (*57*).

In an air-wash separator system, the light paint particles and the dust and smaller abrasive particles are removed by air blowing through a curtain of falling abrasive. This air must then be directed to a dust collector for ultimate disposal (*58*).

A cyclone separator uses centrifugal action to throw heavier particles to the cyclone walls, where it falls to the bottom, leaving finer particles and dust to be drawn to the top of the cyclone (Figure 22).

A rotary screen separator uses a rotating screen which is fed by screws contained in a feed trough. The residue from a separator is a mixture of paint chips, dust, and fine abrasives that must be removed and stored for eventual waste disposal. Because of the high likelihood of the material being classified as hazardous, it should be stored in appropriate containers with labels and otherwise comply with regulations.

Separation systems are another area where further development is needed. Incomplete separation of the fines from reusable abrasive particles results in a dusty abrasive. The same dust may be recycled many times through the system. Dust in the abrasive results in poor visibility within containment structures when blasting, and contributes to the health hazard to workers. Further development on separation equipment has been identified as a high-priority item by contractors.

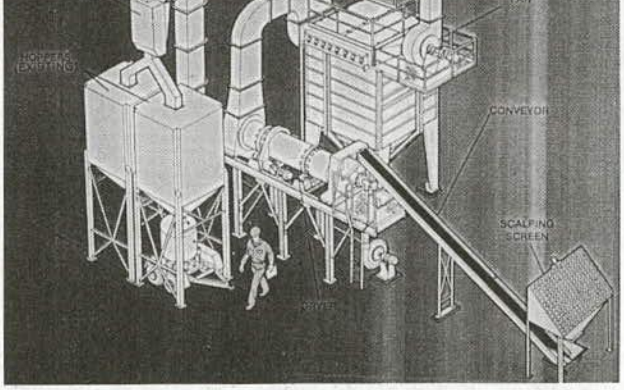

FIGURE 21 Slag abrasive reprocessor developed for use at shipyard (courtesy Apache Abrasives).

Dust Collectors

Considerable quantities of dust are generated during abrasive blast cleaning operations, even when using steel abrasives. For example, the abrasive blasting pulverizes rust and paint particles. In a closed area, this dust must be removed to provide a work environment with adequate visibility and for worker productivity and safety (*59*).

Dust collectors are also needed following the separation of the fines from the abrasive debris to be reused, to prevent this dust from being vented to the atmosphere or damaging the equipment. For the latter, the dust collector operates as a vacuum cleaner while pulling air through the reclaimer. These dust collectors are similar to those connected to blast cabinets typically used in other industrial applications. Normally, they are operated between 150 to 600 CFM, depending on the size of the blasting and reclaiming units.

Dust collectors used for purifying air in containment areas require considerably larger capacities, with volumes of 10,000 CFM or greater. The volume depends on maintaining sufficient air flow through containment to keep airborne levels below OSHA requirements. The minimum OSHA requirement is 100 CFM /ft^2 of cross-sectional area when blasting a surface which will generate a lead-containing dust (Figure 23) (*60*).

Dust collectors use cloth filter tubes through which air is drawn to deposit dust on one side of the cloth tube. In some units this dust is deposited on filter cartridges and cleaned by reverse pulse jets. Some units are also fitted with a removable dust tray for easy disposal (*37*). Wet scrubbers are also used to remove dust particles.

Integrated Systems

Several manufacturers have developed completely self-contained systems for portable abrasive blasting and recovery. Most of these use steel grit as the recycling medium. One important type of integrated system is the vacuum blasting system described earlier. The other major type is the open blast and recovery (*13*).

Those systems that use open air blast machines and rely on containment to recover the abrasive generally deliver higher production rates than vacuum systems. Several manufacturers offer skid- or trailer-mounted units to house each of the major components for the system, including blast machine and nozzles, vacuum recovery system, and dust collector (Figure 24).

These systems range in size depending on the size of the job, site accessibility, power supply, size and configuration of structure, and environmental constraints. Smaller units have capacities of 300 CFM with approximately 600 to 1,000 lb blast pots and require approximately 75 hp engines. Larger units in use commercially have capacities of 10,000 to 16,000 CFM and can operate with 20–ton capacity blast pots. They also have much higher power requirements, often requiring several diesel engines.

One manufacturer has developed a system claimed to have a unique air and abrasive flow pattern. This system features a

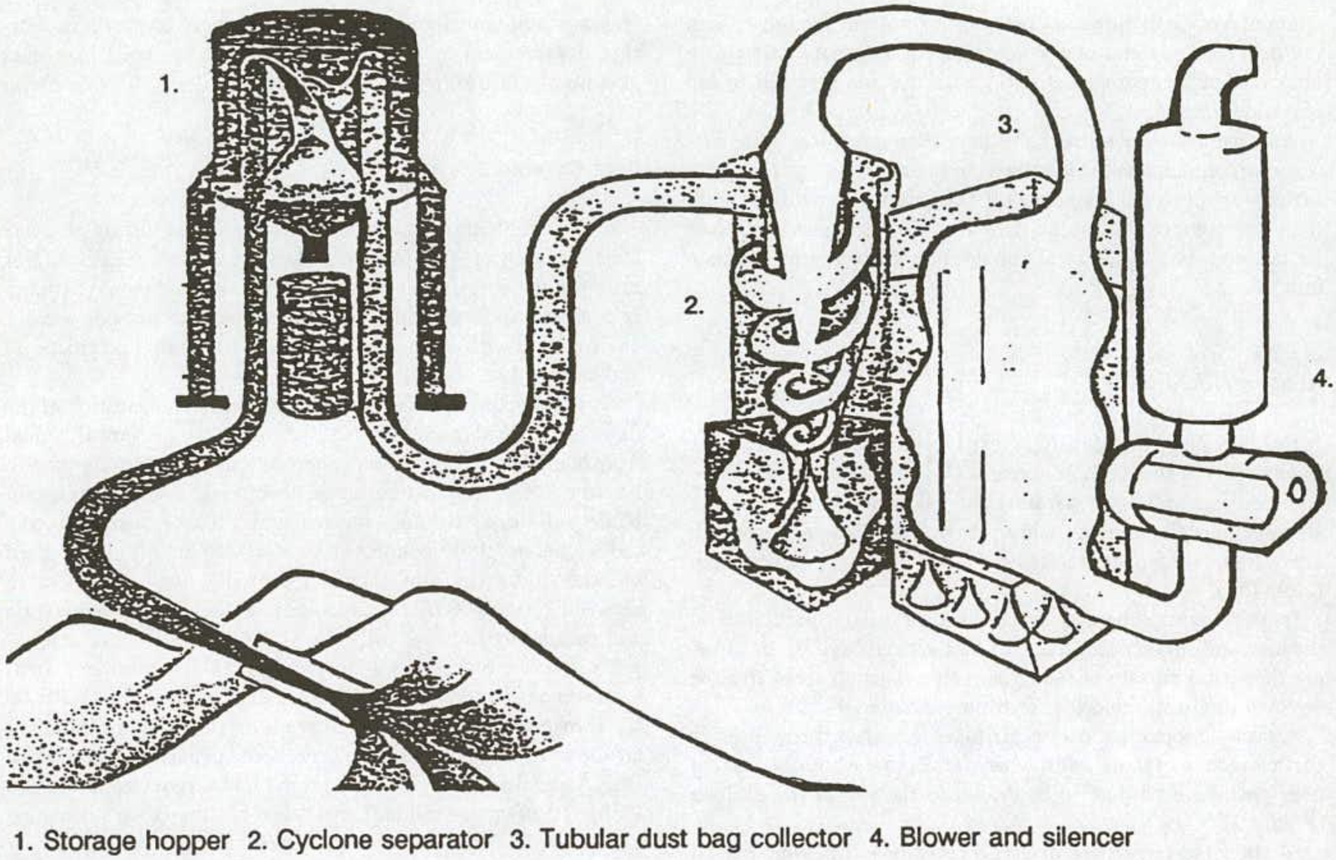

FIGURE 22 Schematic of recovery system using cyclone separator (courtesy Clemco Industries).

FIGURE 23 Portable dust filter and collector for cleaning exhausted blasting air (courtesy W.W. Sly).

storage hopper designed to discharge heavy abrasive particles to the bottom of the hopper, leaving dust and fines to be pulled into the hopper outlet. According to the manufacturer, the abrasive flow is then fed to a cyclone separator that splits the majority of the fines and dust from the airstream by centrifugal force. The dust is collected in a tubular bag dust collector. The final stage, a blower and silencer, discharges the clean filtered air back into the atmosphere.

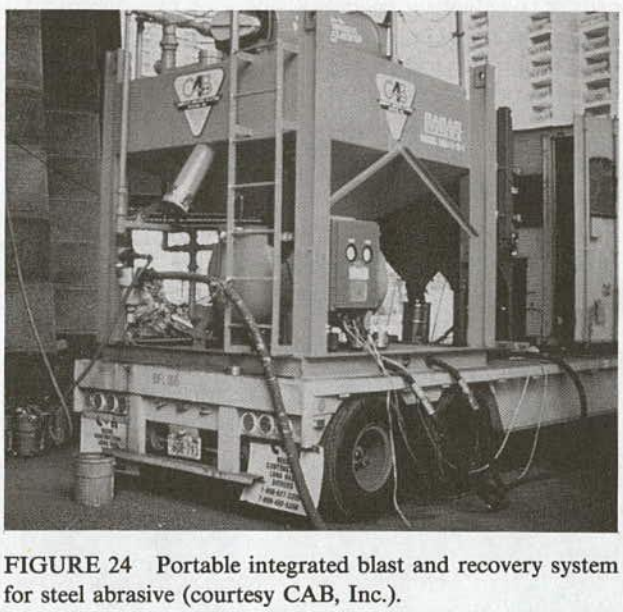

FIGURE 24 Portable integrated blast and recovery system for steel abrasive (courtesy CAB, Inc.).

Another integrated system uses a cyclone separator fitted directly onto a hopper mounted over the blast machine. According to the manufacturer, reusable grit is separated from the debris and fines and deposited in a storage portion of the hopper. Larger pieces of trash are delivered to the waste barrel under the dust collector via a trash chute. Fines are conveyed pneumatically from the separator to the dust collector, where the fines are separated by cartridge filters. Clean air is then drawn through a high-volume (e.g., 10,000 CFM) blower and exhausted to the atmosphere. A list of equipment and manufacturers is available (*55*).

CHAPTER FOUR

DISPOSAL AND REUSE ALTERNATIVES

Traditionally, spent abrasive was hauled away by the contractor and used for landfilling, deposited on roadways or in rivers, or used along with other construction aggregate waste. Today, these options are no longer available. Contractors and facility owners have a responsibility to ensure that waste material is properly disposed of and accounted for. The material can be either disposed of as a waste or reused as a construction or filler material.

As a waste product, the spent abrasive has a negative value—to ship it and bury it in a landfill will cost money. The U.S. EPA and state and local agencies have enacted regulations to protect the environment from contamination by solid waste that can affect drinking water and otherwise adversely effect public health and welfare (see Appendix A).

There are a number of factors that affect the cost and difficulty of disposing of solid waste. Most important is whether or not the waste is classified as hazardous. Hazardous waste is subject to especially stringent requirements for handling, packaging, storing, transporting, testing, and landfilling. These restrictions result in greatly increased costs for the owner of the hazardous waste.

RESIDUE PROCESSING FOR DISPOSAL AS NON-HAZARDOUS WASTE

Because of the "Land Ban", which prohibits the land disposal of hazardous waste, procedures are being sought to detoxify the lead-containing residue. The major requirement is that the leachable lead content of the residue be reduced below 5 ppm based on current (1991) treatment standard. This should be based on the TCLP, which is the more stringent test, and has become the governing test method. Several approaches may be suitable; these include methods for separating out the hazardous fraction, or for converting the lead (or other hazardous material) to a non-hazardous (i.e., non-leachable) form. Both physical and chemical methods have been proposed. An important consideration is whether these processes can be performed on-site.

Physical Methods

Physical methods include separation based on particle size (i.e., by screening), physical reduction (e.g., crushing or grinding), air wash (gravimetric) methods (based on differences in density), flotation and separation based on affinity for detergents or other surfactants, or magnetism (to enhance steel abrasive recovery). For example, metallic abrasives are separated from paint and rust and fine abrasives by an air-wash filtration system. This process may be less effective for non-metallic abrasives because of the smaller density difference between non-metallic abrasive fines and paint and rust particles than between metallic fines and paint and rust particles.

A Pittsburgh-based firm developed a patented dry physical separation process based on differences in density between paint, rust, and abrasive particles (*61*). This is a multiple field unit that separates spent abrasive into three fractions: coarse abrasives for reuse as abrasives; fine abrasives for other potential reuse; and hazardous waste.

Chemical Processing

Chemical methods for processing waste may be based on solubilizing heavy metals, high-temperature incineration (i.e., to vaporize lead or the lead compounds), and other chemical reactions. For example, chemical processes have been proposed which will "fix" the lead (rendering it insoluble).

Conventional Techniques

Waste treatment and processing firms have traditionally used alkaline material such as portland cement, lime, fly ash, and cement kiln dust to stabilize heavy metals. A recent study has indicated that the addition of 10 percent or less portland cement is capable of reducing the leachable lead content of abrasive blast residue from 50 ppm to less than 0.5 ppm (*62*).

EPA has established requirements for lab packs for treating small quantities of hazardous waste. For lead waste EPA allows stabilization of the waste with 20 percent portland cement (*63*).

Innovative Techniques

EPA and waste processing firms are continually seeking new technologies that would increase effectiveness or reduce costs of waste treatment.

One patented process mixes the residue with soluble silicates to produce an insoluble metal silicate complex (*64*). This results in a higher pH, greatly limiting the leachability of lead in the TCLP and EP-TOX tests. The proprietary chemicals are added to the abrasives in an on-site flow-through treatment unit, which according to the manufacturer, produces a clay-like substance.

EPA has evaluated a number of technologies for treatment or processing of hazardous waste under the Superfund Innovative Technology Evaluation (SITE) program (*64*). These represent a wide array of innovative technologies from thermal treatment and bioremediation to soil washing, solvent extraction, and in-situ stripping. EPA identifies the various stages of technology development as follows:

• "Available" technologies are fully proven and in routine commercial use.
• "Innovative" technologies are fully developed technologies for which cost and performance information is incomplete and therefore require field testing.
• "Emerging" technologies are those that have involved laboratory testing and some pilot scale testing.

Several solidification/stabilization processes have been identified that have the capability of immobilizing heavy metals such as lead and reducing their leachate levels by a factor of 100 or more. Some of the techniques are developed to treat contaminated soils and may require preprocessing to achieve proper aggregate sizes. The on-going SITE program is designed to promote development and use of innovative technologies to clean up Superfund sites across the country. The results could have major applications for the problem of disposing of spent abrasives as well (Figure 25).

There are undoubtedly processes that can chemically extract or insolubilize or physically separate lead from abrasive residues. A critical question is the economic viability of these processes.

ON-SITE TREATMENT OF WASTE

Treating waste on-site may be a viable alternative in certain instances. The objective is to render the waste non-hazardous. The handling, transportation, and disposal of non-hazardous wastes are not subject to the stringent controls and record-keeping requirements of RCRA.

General Requirements

Normally, any treatment or processing of hazardous waste requires a license or permit by EPA. Acquiring such licenses is a long and costly proposition. However, under the following conditions, the waste may be treated without a permit:

• The waste must be stored in special "90-day" holding tanks, which are described by EPA.
• The waste must be treated within 90 days of its generation.
• The treater or generator must file a Waste Analysis Plan (WAP) with the regional EPA administrator. The WAP must be submitted 30 days prior to treatment. If the WAP is not disapproved in that time period, treatment can be performed. However, EPA reserves the right to disapprove the plan after the 30 days, if official approval had not been given.
• The state environmental agency should also be notified because of variations in state requirements.

Approaches for Treating Hazardous Waste On-Site

Several materials can be added to the lead-containing waste to render it non-hazardous. These include portland cement, kiln dust, pozzolanic materials, and steel grit. The first three are similar to the materials used in off-site treatment facilities. However, the mechanics and engineering of the on-site processing may differ significantly from production scale facilities. Factors that must be addressed are the ratio of additives to the lead-contaminated waste, the method and efficiency of mixing, the vessel for processing and mixing, sampling and testing, protec-

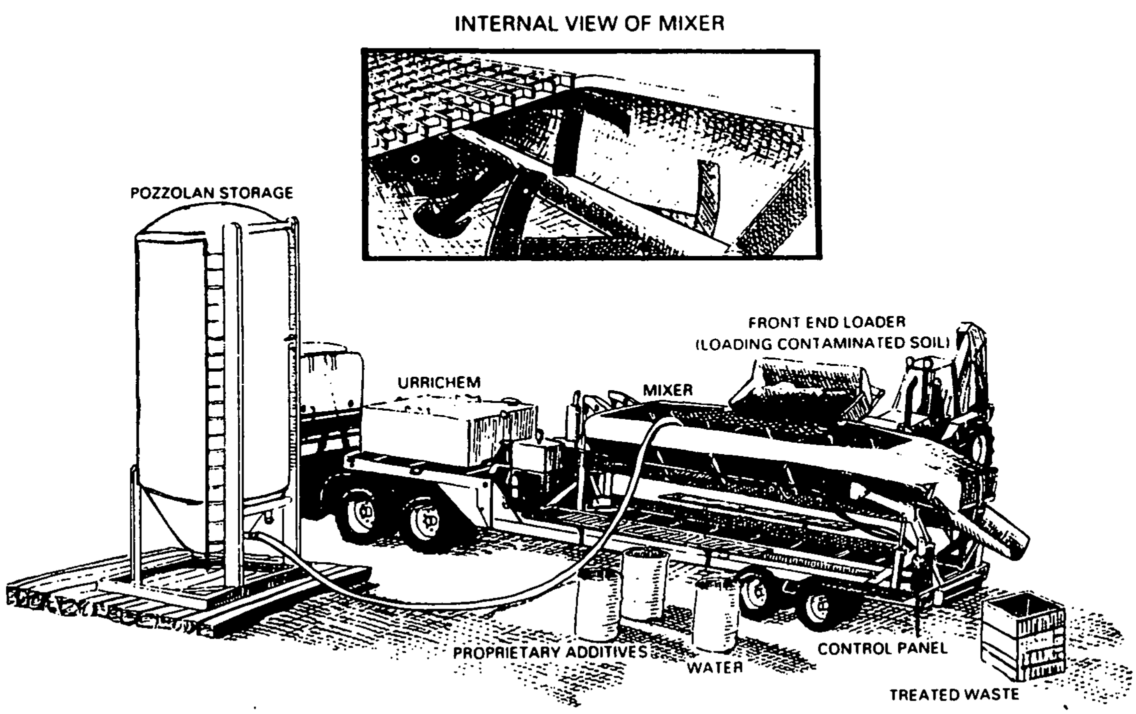

FIGURE 25 Example of solidification/stabilization processing facility (courtesy Solidtech, Inc.).

tion of personnel involved in treatment, and timeliness of procedure (i.e., within the 90 days).

A recent FHWA report described laboratory tests on the effect of different treatments on the stabilization of lead-contaminated coal slag and sand abrasive. In this study, portland cement and fine steel grit proved most effective (*62*). However, additional work is necessary to verify these preliminary findings.

Upon completion of the treatment, the generator or treater must still dispose of the waste. The waste will no longer be considered hazardous, but it will still contain lead, and possibly be subject to special requirements by the state environmental agency or the disposal facility.

Pre-Blast Additives to Abrasives

The previously described treatments are effective because the additives (e.g., portland cement, steel grit) react or complex with the lead rendering it insoluble (i.e., TCLP level of less than 5 ppm) in the leaching solution. Another alternative is to treat or modify the abrasive itself, prior to blast cleaning. The intent is to incorporate sufficient steel grit (or other stabilizer) into the abrasive to prevent the lead from becoming solubilized during the TCLP extraction. In other words, the additive results in the generation of a non-hazardous rather than a hazardous waste.

If the waste is non-hazardous, handling and disposal would not be governed by RCRA, and the generator would avoid the manifest (paper trail) required by EPA. This process has considerable appeal, but there are some concerns. Any adulteration of the abrasive with a water-soluble additive such as portland cement or lime could affect the paint lifetime. Water-soluble salts are often the cause of osmotic blistering in paints applied over steel. Moreover, addition of significant quantities (5 percent or more) of such materials could adversely affect the performance of the abrasive or the operation of the abrasive blasting equipment. There is also a question about whether environmental agencies would accept such a procedure if the sole purpose of adding the portland cement or lime were to reduce leachability of the lead.

Thus, small additions of steel grit, which is in itself a widely used abrasive, would seem to be the best candidate to avoid these problems. Questions, though, have been raised about the long-term effectiveness of treatments using steel grit before or after blast cleaning. The steel's tendency to oxidize could alter the chemistry of the mixture and cause lead solubility to increase over time.

Combining Pre- and Post-Blast Treatments

A novel remedy to this problem using both pre-and post-blast abrasive treatments has been proposed. In this scheme, prior to blasting one adds sufficient amounts of steel grit (3 to 10 percent) to ensure that the waste generated is non-hazardous in accordance with TCLP. The non-hazardous waste is then treated a second time with portland cement or another proven stabilizer to produce a permanently stabilized product.

Preliminary DOT Experiences

Several state departments of transportation (DOTs) are evaluating the above treatment options. One DOT has been treating the lead-contaminated waste with portland cement to produce concrete blocks. The blocks are used as rip-rap in construction projects. Reportedly, the state environmental agency has approved this procedure.

Another DOT is adding approximately 10 percent steel grit to the sand abrasive (*65*). The resulting non-hazardous lead-containing waste is incorporated into asphaltic mixtures and used as a sub-base in road construction. The environmental agency of this state has approved this procedure.

In some states, the environmental agencies are reluctant to approve schemes for on-site waste treatment. In at least one state, a detailed plan must be approved by the state agency prior to conducting any on-site treatment, although this is not a requirement of EPA.

ABRASIVE REUSE

Partial or complete reuse of spent abrasives for construction or other purposes is an extremely appealing option. It accomplishes one of RCRA's major goals, namely, to reduce or minimize the amount of waste generated (*18*). An important provision of RCRA is that if material from an operation (e.g., abrasive blast cleaning) can be used directly as a raw material for another process, it is not necessarily classified as a waste, and does not fall under the waste treatment regulations. In the case of abrasive debris, this means that if the abrasive can be reused, it may not need to be tested for leachable lead content. Abrasive recycling is discussed in Chapter Three. This section focuses on use of spent abrasives for other (non-blast) applications.

A key factor in meeting RCRA's requirements is that the waste being generated must be either processed where it was generated, or placed in a container or vehicle specifically intended for input to a processing facility. Also, the processing must begin within 90 or 180 days of the time the waste is generated, or a hazardous waste storage permit may be required. If the spent abrasive is designated as a raw material for reuse in another process, classification as a waste may not be required. In this situation, the generator has 365 days before a permit is required for transport or processing (*66*). The rules in the EPA regulations are not very clear on the conditions under which material must be classed as a waste. Clarifications may be needed on how well the sequence of steps for treatment must be defined to qualify under the provisions.

Several organizations have proposed or evaluated methods for reusing spent abrasives. The North Carolina DOT has developed a process in which spent silica abrasives are used as an asphalt sub-base for highway road construction (Figure 26). By using state asphalt plants, North Carolina was able to expedite the environmental approvals and right-of-way needed for transportation. The paving tests were accompanied by a battery of laboratory tests to verify that the asphalt concrete formed from the relatively fine aggregate silica would meet chemical and physical criteria (*67*). Other states including California and Georgia also have evaluated this option.

The use of spent blasting abrasive in portland cement concrete was initially determined to be less viable than for asphalt because of the aluminum in the residue. The aluminum, which is a component of certain topcoats, may be chemically attacked by the high pH of the concrete, resulting in degradation of the concrete properties.

A private waste processing firm proposed using spent abrasives as a feed stock for cement kilns. The kiln firing operation incorporates iron and silicates into portland cement products, while lead and other heavy metals are either fumed to a baghouse product or incorporated into the cement. Currently the procedure is being evaluated in Canada (*68*).

Another suggested use for spent abrasives is for backfill in embankments or other construction sites. New ideas and approaches are expected to surface over the next several years. Several specific research and development programs have been undertaken by PennDOT, FHWA, and others to examine the merits of these approaches (*13,61*).

Off-Site Processing for Reuse

In certain instances, it will be advantageous to construct centralized permanent processing facilities for treating abrasive waste rather than portable on-site units. Off-site treatment offers advantages of larger scale equipment and facilities, larger and more modern utilities and power sources, adjacent laboratory facilities, use of existing transportation facilities (e.g., barge, rail, highway) and readily available support staff. The major disadvantage is the cost to transport the material from the site to the processing plant. Permits may be required for storage and transportation of hazardous waste, and most likely more record-keeping and testing will be required. Off-site treatment also involves an additional handling step. Such central processing facilities are more likely to be constructed when viable reprocessing techniques are developed, when extremely large volumes of abrasive debris are produced, and when the type of regulation and degree of enforcement are better defined and implemented.

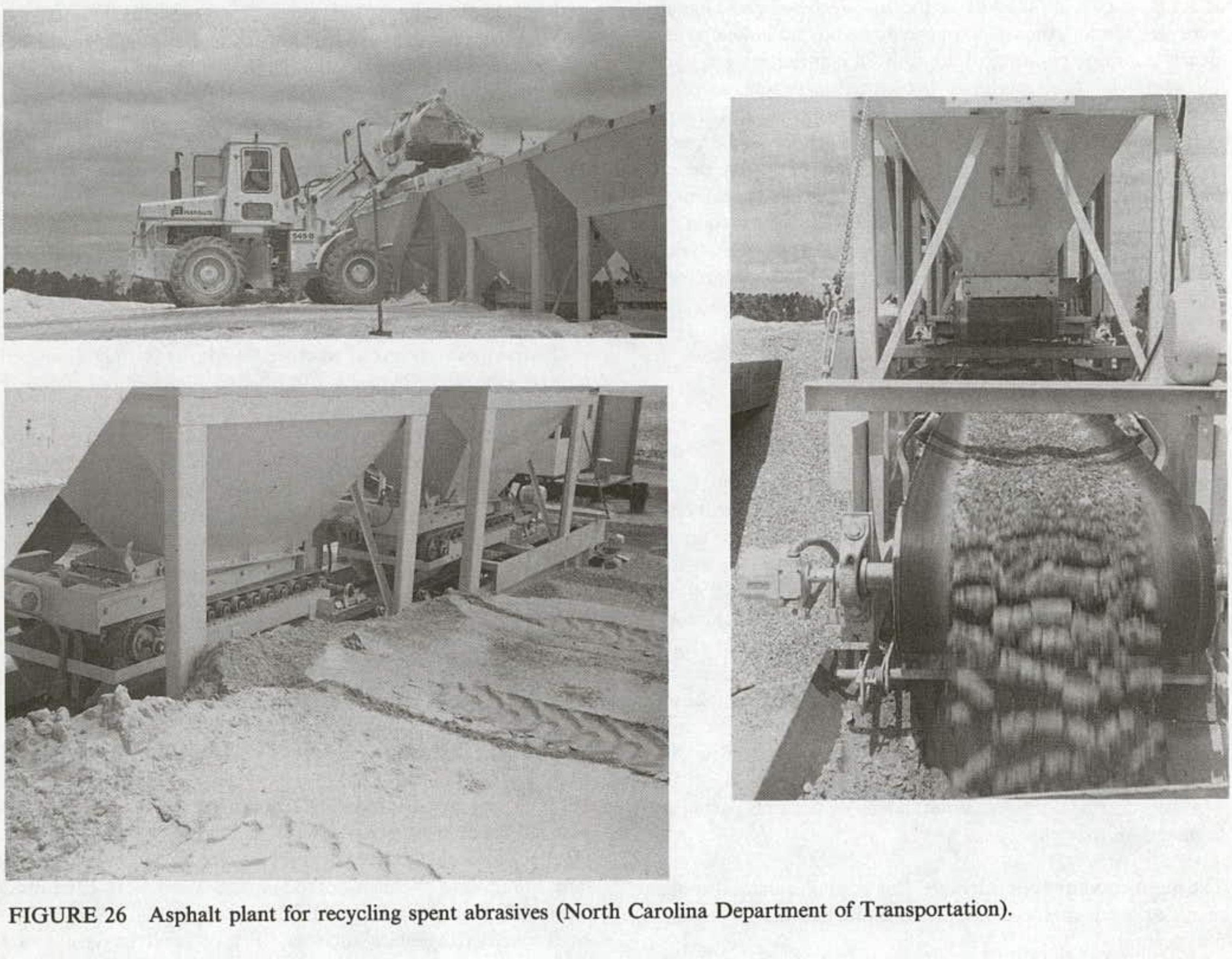

FIGURE 26 Asphalt plant for recycling spent abrasives (North Carolina Department of Transportation).

CHAPTER FIVE

REVIEW OF HIGHWAY PRACTICES AND COSTS

This section presents results of surveys on the practices of painting contractors and highway agencies with regard to lead paint removal. Cost estimates of containment and disposal are also provided.

SURVEY OF CONTRACTORS

Survey forms were distributed to painting contractors at a 1988 conference on lead paint removal in Arlington, Virginia. In addition, as part of the research for this synthesis, questionnaires were sent to more than 100 contractors who had indicated experience in bridge painting. A total of 18 contractors responded. The survey included questions on contracting practices, containment methods, and a separate form for case histories. A compilation of the responses is presented in Appendix B. Because of the small size of the sample, these results may not be valid representations of the industry practice. The results also may be skewed by the fact that the contractors were those who had some involvement with SSPC (i.e., attending a conference or member or on mailing list) and are likely to be among the better informed contractors.

Degree of Containment Required, Bridge Type, and Cost

Seventy percent of the bridges painted by contractors in the survey required some type of containment (either partial or total). Of that total, about two-thirds required total containment, and one-third partial containment. Partial containment consists primarily of hanging tarps and screens. Almost all the contractors reported having done work on both river crossings and overpasses. These two bridge types were selected as among the most common structures and having widely divergent requirements. Contractors reported large cost increases resulting from containment. The median increases reported were as follows:

- Overpass: total containment, 80 percent; partial containment, 30 percent
- River Crossing: total containment, 80 percent; partial containment, 40 percent

The numbers varied considerably. For example, on total containment for overpasses, the cost increase ranged from 25 percent to 500 percent.

Containment Devices

Contractors were asked about the frequency of use and effectiveness of 10 different containment devices. The device most frequently used was tarpaulins, followed by windscreens. Tarpaulins were mostly rated as good, with several contractors pointing out problems due to wind. Windscreens are used frequently by about one-third of the contractors, who reported a wide range of effectiveness. More than half the contractors have used barges and/or rigid platforms. The barges were primarily rated good to excellent, with the platforms receiving somewhat lower ratings. Two of the more sophisticated methods, negative pressure containment and closed cycle blasting with metallic abrasives, received only occasional use by a few contractors, with mixed ratings of effectiveness. Two other techniques, wet abrasive blasting and vacuum blasting, also had only occasional use, and ratings of poor, fair, or good. Wet blasting also received negative comments based on safety concerns and potential for flash rusting. All contractors who used vacuum cleaning commented on the low production rate. Power tool cleaning also received mixed ratings from the few contractors who had tried it.

Approaches to Improving Contracts

Contractors were asked whether they favor or oppose several types of contract provisions. Contractors surveyed unanimously favor mandatory pre-bid meetings for bridge painting. Also, all but one of the contractors supported the need for a certification for contractors, such as SSPC's Painting Contractor Certification Program (*69*). Three-fourths of the contractors would prefer that they, rather than the state agency, be allowed to select the containment. A majority also supported third-party inspection of bridge painting contracts. Contractors were about evenly split on whether contractors should have responsibility for dust monitoring and for disposal of waste.

Other Information Obtained

The contractors surveyed also reported containment experience in working with water tanks, industrial plants, box cars, pipelines, wastewater treatment facilities, pulp and paper plants, tank linings and chemicals. Trade associations were cited most frequently as sources of information on regulations, followed by environmental agencies such as EPA or local environmental departments. Neither environmental or regulatory publications were used frequently by any of the contractors. Several contractors obtained regulatory information from the specifications. Comments provided by the contractors emphasized the need for agencies to provide more specific requirements and to tighten inspection, monitoring, and enforcement of regulations.

Contractor Case Histories

In addition to the preceding questions, contractors were asked to submit data on case histories of removing lead paint from bridges. The 20 case histories submitted included a wide range of geography (Massachusetts to California to Canada), size (5,000 to 250,000 ft^2) and containment techniques.

Most of the bridges were river crossings and hence were more than 200 ft from homes and businesses. In all but a few cases, the bridges were completely blast cleaned, most frequently to near-white metal (SSPC-SP 10) (*70*). Inorganic zinc was by far the most commonly specified repaint coating system, with either a vinyl or an epoxy/urethane topcoat. Other coating systems used were epoxy aluminum mastic, waterborne acrylic, organic zinc with vinyl topcoat, coal tar epoxy, lead-free alkyd, and even a lead-containing alkyd.

As indicated elsewhere in this synthesis, tarps and windscreens are the most common methods of containment. On a river crossing, simply using tarps and screens will not prevent abrasives from dropping into the water. About half the contractors also used rigid platforms. More sophisticated techniques described include the following:

- Build platform under bridge, then vacuum sand at lunch break and end of day.
- Use tarps from handrail down 50 ft and on ground to contain debris, and collect it using a "super-sucker." In the area over the river, sand fell into the river.
- Complete enclosure for under-deck structure, partial enclosure for superstructures

Seven of the bridges were fully contained according to the contractors.

The sampling and testing of abrasive waste was very sporadic. Most of the contractors did not take samples every day. Only two reported taking more than one sample per day. Typically, samples were taken every 2 to 5 days. Most contractors had little information about the testing to determine if the waste was hazardous. The leachate level of the few samples taken by contractors range from 3.2 to 490 ppm, based on the EP-TOX method. About a third of these residues was determined to be hazardous.

The painting contractor has major responsibility for disposing of the waste, but the permitting and sampling were assigned to both contractor and state on an approximately equal basis. Only one contractor reported any monitoring of air quality.

In only four of the 20 contracts reported did the contractor exceed the estimated time to complete the job. Only one contractor reported having lost money. Profits ranged from 5 percent to over 100 percent, with the typical range being 10 to 30 percent.

Because of this small sampling, however, and the fact that these case histories were selected by contractors, these data should not necessarily be taken to typify bridge paint containment contracts. However, the data do provide a good representation of contractor perspectives. Major problems encountered by contractors were wind effects, traffic controls, and lack of definitive specification. Additional details are provided in the tables in Appendix C.

HIGHWAY DEPARTMENT SURVEYS

Forty-six state highway agencies, including the District of Columbia, and four port or turnpike authorities responded to the questionnaire.

Maintenance Planning

The numbers of bridges painted in the period 1986-1989 are shown in Table 1. The factors for selecting bridges for painting were ranked as follows (greatest to least important):

1. Condition of existing paints on structure
2. Condition of critical components
3. Availability of funds in district
4. Criticality of bridge location
5. Visibility to public
6. Ease of access, traffic control, and location

Typical times for planning bridge painting are 12 months (22 responses) and 6 months (15 responses). Only five agencies plan maintenance painting 2 or more years in advance.

The DOTs were also questioned about their participation in the FHWA Bridge Maintenance Painting Program (*71*). This program, announced in 1987, permits DOTs to use a portion of the federal allocation for maintenance painting, provided that a dedicated state bridge maintenance painting program is in effect. About half the agencies were not aware of this program. Seven states have participated, and another six states are planning to participate. The remaining states are aware of the program but have not yet decided to participate.

Contract Maintenance Painting

The second part of the survey was intended for those directly involved in the contract maintenance painting area. The fifty-four agencies that responded reported the following procedures when asked how they dealt with paint containment requirements:

- included in bid documents—34/54 (63 percent)
- included as special guidelines or procedures—19/54 (35 percent)
- included as special provisions—33/54 (61 percent)
- require pre-bid meetings—12/54 (22 percent)
- require pre-job meetings—21/54 (39 percent)

Twenty-three states have incorporated paint containment requirements into their contracts within the last four years, and nine within the last two years. Four DOTs (California, Louisiana, Minnesota, and Florida) have had some sort of containment requirement since the 1970s.

The survey indicated differing responsibilities for various activities regarding bridge paint containment. About half the agencies allow contractors to select their own containment tech-

TABLE 1
BRIDGES PAINTED BY RESPONDING AGENCIES

Year	No. Bridges Painted	No. Containing Lead	Containing Lead (%)
1986	2,000	1,600	80
1987	1,800	1,530	85
1988	1,450	1,230	85
1989	1,900	1,600	84
Total	7,150	5,960	83

niques. Only one-third of the time is the contractor permitted to select the technique for waste sampling or assigned responsibility for doing lead leachate testing. Most DOTs require contractors to obtain permits and dispose of both hazardous and non-hazardous waste. The assignment of responsibility for being the generator of waste was broken down as follows:

- contractor - 10/44 (23 percent)
- highway agency - 13/44 (30 percent)
- both contractor and agency - 8/44 (18 percent)
- don't know - 13/44 (30 percent)

There is, apparently, a great deal of variability and confusion regarding designation of the waste generator. RCRA regulations designate the owner (e.g., highway agency) as generator, no matter who is responsible for removal and disposal. Some states have chosen to designate the removal contractor as co-generator.

Maintenance personnel were also asked the number of bridges requiring containment, the type of bridge for which containment was required, and the containment equipment and techniques. The results showed 119 bridges painted under total containment, 1,700 bridges under partial containment, and 1,300 bridges with no containment provisions. These figures are based on the last three years, so there is strong correspondence with the data on total bridge painting presented earlier. It is interesting to note that although 80 percent of the bridges contained lead, more than 40 percent were painted with no provision for containment of the debris.

The highway agency representatives were asked questions similar to those asked of contractors regarding the type of containment use and the degree of effectiveness. The bridge types were divided into girder (urban); girder (rural); and truss. These classifications were based on suggestions from DOT representatives who received advance copies of the questionnaire, and were different from the contractor questionnaire. The criteria for degree of containment efficiency were as follows: highly effective (greater than 80 percent containment), moderately effective (40 to 80 percent containment), and not effective (less than 40 percent containment). For productivity, high was defined to be at least 75 percent of dry blast, moderate to be 30 to 75 percent of dry blast, and low to be less than 30 percent of dry blast.

Similar to the contractors, DOT respondents indicated highest usage for tarps and screens. Overall, they were judged to be moderately effective. The cleaning rate achieved with tarps was high to moderate. Power tool cleaning was also relatively widely used; it was rated moderate in effectiveness but low in productivity. Vacuum blasting was also rated high in effectiveness and low in productivity. Wet abrasive blasting was considered ineffective in containment and also gave low productivity. Rigid platforms were judged to be moderately effective, with moderate productivity. Barges were slightly less effective, with slightly higher productivity. Negative pressure containment and closed-cycle blasting were only used by a few agencies, but those reported the methods to be both highly effective and productive. The data are presented in Table 2.

Environmental Issues

The third part of this survey dealt with environmental regulations. The first question concerned the sources of information on various types of regulations. State and local environmental agencies were identified as the major source of information for solid waste, air quality, and groundwater quality regulations, followed by the U. S. Environmental Protection Agency. Other sources cited were other DOTs, periodicals and newspapers, FHWA, TRB, consultants and contractors, and manufacturers and suppliers. The survey also questioned how familiar the department environmental specialist was with various environmental issues. Almost one-fourth of the environmental specialists were not familiar with the TCLP Leach Test or EPA EP-TOX, and 20 percent were not familiar with the contractors' ability to meet the environmental regulations. Fifteen percent of the agencies did not know what hazardous or non-hazardous waste disposal sites were available, while 11 percent were not familiar with the requirements for sampling and disposal of waste. In general, the environmental specialists were familiar with environmental monitoring and compliance, but not with the specifics relating to lead paint disposal.

The overall attitude of the survey respondents to the extent of the lead removal problem was as follows:

- minor problem which we are handling - 15
- important problem which will have significant effects in the future - 20
- major problem that we are addressing - 21
- enormous problem with no practical solutions in sight - 3
- major problem that has been solved - 1

The numbers do not add up to the number of respondents because some agencies marked off more than one choice.

For each of the four regulatory areas, the survey asked for the degree of enforcement of regulations on bridge cleaning; responses are provided in Table 3.

The results show that enforcement is non-uniform, with air quality being the regulation least enforced and solid waste disposal enforced most frequently. Approximately one-third of the respondents do not meet regularly with environmental agencies. Another third meet with the agencies more than three times per year.

As of January 1990, about 20 percent of the highway agencies had investigated treating the spent abrasive rather than simply disposing of it as a waste. The treatments investigated include chemical or physical separation, and reuse in asphalt or concrete, or as a fill material.

COSTS OF CONTAINMENT AND DISPOSAL

Cost estimates were based on data derived from the study, data from previous publications, and from private communications and SSPC experiences.

Number of Bridges and Area Painted

From the survey of DOTs, approximately 1,200 of the 1,500 bridges painted each year contain lead. From the survey of contractors and discussions with state highway officials, it is estimated that the average number of square feet per bridge is 50,000 to 80,000 ft^2. This yields an estimate of 60 to 100 million ft^2 painted per year. These figures are consistent with those obtained

TABLE 2
CONTAINMENT EFFECTIVENESS BY DOTS

Method	Girder Urban	Girder Rural	Truss	Effectiveness* H	Effectiveness* M	Effectiveness* N	Productivity** H	Productivity** M	Productivity** L	Number of Agencies
Tarps/Screens	31	27	34	9	23	5	14	16	2	39
Barges	8	9	5	5	6	3	4	6	2	15
Rigid platform	11	7	5	9	6	1	3	8	1	15
Negative pressure containment	3	2	-	2	-	1	2	-	1	3
Close-cycle blast w/metallic abrasive	4	3	1	2	2	-	3	2	-	5
Wet abrasive blasting	7	5	3	2	1	4	1	3	4	9
Power tool cleaning	11	10	6	2	7	3	1	5	8	14
Vacuum blasting	6	3	1	4	2	1	1	-	5	6
Boom on water surface	-	-	-	-	-	1	-	-	-	1

*H (highly effective, >80%) M (moderately effective, >40%-80%) N (not effective, <40% or N/A)
**H (high, >75% of dry blast) M (moderate, >30%-70% of dry blast) L (low, <30% of dry blast)

TABLE 3
DEGREE OF REGULATORY ENFORCEMENT

	Frequent	Occasional	None
Air Quality	8	17	21
Water Quality (Streams)	13	23	11
Soil/Groundwater	12	15	20
Solid Waste Disposal	28	15	14

from a 1984 FHWA study, which estimated 100 million ft^2 of surface painted per year (*72*). That estimate was based on the percentage of bridge areas that were hand cleaned and the total amount of hand-cleaned steel.

It is also estimated that 50 to 75 percent of the surface area repainted each year is cleaned by abrasive blast cleaning. This yields a range of between 30 and 75 million ft^2 blast cleaned per year.

An estimate of the repaint cost per square foot is derived from the contractor survey which yields an average of about \$3/ft^2 and various journal and conference publications which give an average of between \$1.50 and \$2.50/ft^2 (based on 1989 data). Figures used for this synthesis are \$2.00 to \$2.50/ft^2; using these rates, the total repaint cost of the bridges to be blast cleaned is \$60 to \$188 million/yr. (Note that this amount includes the cost of containment, if required.) An overall best estimate is \$100 million/yr to repaint bridges. This figure is also consistent with that derived from a 1979 study, in which several states were asked to furnish detailed data which were then pro-rated over the total number of bridges in the U.S.(*73*).

From the contractor survey, it is estimated that in 1989 total containment was required on about 5 percent of the bridges painted, partial containment on 50 percent, and no containment on 45 percent. The added costs for total containment are estimated at 30 to 60 percent; for partial containment, at 15 to 30 percent. Thus, the overall increase in costs due to containment is obtained as a weighted average of the three alternatives and comes to 10 to 20 percent of the total bridge painting cost. Using this estimate, the total national cost for containment was \$10 to \$20 million/yr.

Cost of Disposal

Typical blast cleaning of deteriorated and rusty steel uses 6 to 10 lbs/ft^2 of abrasives. Thus, the total quantity of abrasive used on the 30 to 75 million ft^2 blast cleaned each year is estimated at 90,000 to 375,000 tons/yr. For additional computations, assume a range of 150,000 to 300,000 tons/yr.

From reports given at SSPC meetings and publications by New York State and Michigan DOTs, it is estimated that 50 percent of the spent abrasives would be classified as hazardous under the EP-TOX rule (*4,5*). Based on comparative analyses, it is further estimated that 90 percent of the spent abrasives on lead-coated bridges could be classified as hazardous under the TCLP. The disposal cost for hazardous waste in 1989 is estimated at $250/ton, based on a survey of the SSPC Committee on Lead Paint Removal. 1991 costs range from $250 to $400/ton. The same survey yielded an average disposal cost of $75/ton for non-hazardous waste. Multiplying the disposal cost per ton and the estimated hazardous and non-hazardous waste generated (based on TCLP) yields a disposal cost of $10.5 to $20.9 million/yr.

This figure is based on the total amount of abrasives used. However, most abrasives were not recovered. Using estimated recovery rates of 70 percent for total containment, 40 percent for partial containment, and 10 percent for no containment (cleanup of debris deposited on roadway, etc.), one can compute a weighted average of 28 percent recovered. The cost to dispose of all the waste (both hazardous and non-hazardous) is estimated at $37 to $75 million/yr. The cost estimates are presented in Table 4.

These data also indicate that about 70 percent of the abrasives were lost into the environment (i.e., roadways, waterways, adjacent land, etc.). This amounts to 100,000 to 200,000 tons/yr. As more regulatory and highway agencies and the public become aware of the problems created by unconfined blasting, such estimates are likely to increase along with substantially increased costs of containment.

TABLE 4
COST ESTIMATES

Number bridges painted	1,500 /yr
Bridges containing lead	1,200 /yr
Surface area painted, containing lead	50,000-80,000 ft^2/bridge
Surface area painted	60-96 million ft^2/yr
Surface area blast cleaned	50-75%; 30-72 million ft^2/yr
Repaint cost (blast clean w/ containment)	$2.00-$2.50/ft^2
Total repaint cost w/ containment	$60-$188 million/yr
Estimated total repaint cost	$100 million/yr
Increased by containment	10-20%
Estimated containment cost	$10-$20 million/yr
Abrasive used	6-10 lb/ft^2
Total abrasive used	90,000-375,000 tons/yr
Most probable amount used	150,000-300,000 tons/yr
Percent recovered	30%
Abrasive recovered	45,000-90,000 tons/yr
Percent hazardous (per EP-TOX)	50%
Disposal cost, hazardous (1989)	$250/ton
Disposal cost, non-hazardous (1989)	$75/ton
Disposal amount, hazardous	22,500-45,000 tons/yr
Disposal amount, non-hazardous	22,500-45,000 tons/yr
Disposal cost, hazardous	$5.6-$11.3 million/yr
Disposal cost, non-hazardous	$1.7-$3.4 million /yr
Total disposal cost (based on EP-TOX)	$7.3-$14.7 million/yr

CHAPTER SIX

DISCUSSION AND CONCLUSIONS

EVALUATING CONTAINMENT TECHNIQUES

Since the 1983 NCHRP report (*1*), several additional containment techniques have become available and are starting to be used. However, further development is still needed to evaluate the applicability, productivity, and other parameters of containment equipment. Manufacturers of the equipment have identified the paint removal market as very significant and have devoted considerable resources to engineering, developing, and testing new equipment.

Emphasis has been placed on equipment used for abrasive recycling and properly ventilated containment. Much of this equipment is already in use in other industries (e.g., nuclear, shipboard, fabricating shops). The major engineering challenge is to match the containment unit to the peculiarities of individual bridges. In general, this requires portability, compactness, and amenability to different configurations. Other considerations are safety, visibility, traffic control, wind, compatibility, and operator training needs.

Much of the equipment is now undergoing full-scale field evaluations. These evaluations allow suppliers, contractors, and highway agencies to determine the practicality, efficiency, productivity, cost, and environmental and public acceptance of the equipment. The suppliers can fine-tune and re-engineer components when necessary. Contractors can determine what the costs are and what their requirements are. Highway agencies must determine if the environmental protection they are receiving is worth the price that must be paid for it. Because field bridge containment is such a major project, all agencies, suppliers, and contractors are urged to conduct comprehensive evaluations of these jobs.

It is important to coordinate and communicate these findings with other DOTs, contractors, consultants, and technical and trade associations to gain the greatest benefit from the evaluations. Other agencies that have initiated research efforts in this area are PennDOT (*13, 61*) and Tennessee DOT (*74*) along with the FHWA (*15*). Such cooperation will allow much more rapid growth of knowledge and experience within the industry as a whole. The SSPC Committee on Lead Paint Removal, for example, is establishing specific guidelines for effectiveness of containment. A parallel guide will be developed on how to evaluate the effectiveness and parameters of a bridge containment job (*44*).

SPECIFYING CONTAINMENT

Many contractors, with the help of consultants and equipment suppliers, have the capability of containing blast debris with reasonable effectiveness. However, there are limits to the degree of containment that can be achieved with a given technique and a given bridge configuration or environment. It is important that the highway agencies recognize these limitations and that these be reflected in the specifications.

State and other highway agencies vary considerably in the detail provided in the specifications and the detail required in the contractor's bid. There are two basic approaches for specifying containment. One approach is for the agency to give explicit instructions on the type of containment equipment (e.g., type of scaffolding, support, and screens) and the techniques to collect debris (e.g., dust containment devices, ground covers, etc.). The other extreme is to specify the end result, (i.e., the level of containment). An example of the latter would be "...85 percent dust and debris containment." This type of requirement is contingent on an accepted procedure for measuring containment efficiency.

Problems can arise with either approach used by itself. If an agency stipulates the containment materials and in effect provides a design or containment system, the contractor may not accept responsibility when the technique does not work. For example, who should be held responsible if a platform and tarp arrangement stipulated by the state is cited for generating too much dust by an environmental agency? What typically happens, of course, is that the specification also makes the contractor responsible and liable for compliance with all environmental regulations. This combination of provisions is not acceptable to many contractors.

A major difficulty that may be encountered with specifying the level of containment required is that it allows, or sometimes encourages, contractors to submit less than optimum schemes because of the need to compete in a low-bid environment. Moreover, the vast majority of agencies do not specify a precise level of containment, but rather that cleaning shall contain "all dust and debris" or other language which is impossible to attain, vague, or subject to misinterpretation (*75*). Except for total containment, very few agencies designate a level of containment that must be attained. More commonly, the agency designates one or more specific or general containment materials and structures.

An increasing number of specifications require that the contractor submit the containment plan to the engineer for approval as part of the bid package or prior to commencing the work. This practice in principle allows agencies more control over the containment. According to comments in the survey, some contractors believe that the specifications should give contractors more explicit guidance on the detail or sophistication required of their containment plans. This approach presupposes that the agency has the expertise and the manpower resources available to properly evaluate containment devices and procedures. Frequently, neither the contractor nor the engineer knows precisely how effective the containment will be under the given circumstances.

There are no sure-fire approaches to specifying containment. As noted previously, there are many uncertainties in the technology. It is important, therefore, that specifiers be aware of these uncertainties and not simply assign all the risks and responsibility to the contractor. It may not be reasonable or acceptable for an agency to stipulate that contractors shall prevent any material from contaminating the environment. If the devices and techniques are to be left to the contractor, the agency must define not only the level of containment, but how the degree of containment is defined and measured. For example, will the contractor be required to weigh or estimate the volume of abrasive debris collected and volume of abrasive consumed, and be required to monitor air for particulates or lead matter? Provisions regarding soil or water contamination should also be explicitly stated in this specification (*76*).

STRATEGIES AND COSTS OF CONTAINMENT

An important conclusion from the early estimates of containment efficiency is that it is very difficult to achieve high levels of containment efficiency (*2*). The containment costs rise dramatically as the efficiency requirement increases above 50 or 60 percent for most highway bridges.

For example, it is considered possible to specify and achieve 85 percent containment of dust for a highway overpass, but the cost may be twice as great or higher than for open blasting without containment. To achieve such a level, the agency may need to stipulate types of seams and air pressures and flow rates within the containment, and that the contractor submit the containment plan for prior review. The agency must also stipulate the type of monitoring devices and what means will be used to estimate the quantity of debris escaping.

An important corollary is the necessity to provide sufficient allocation of funds to undertake such a contract. Resources must also be allocated for an agency engineer to review the containment plan and for agency-furnished inspectors to monitor the cleaning, containment, recovery, testing, and disposal.

It is clear that such measures are extremely expensive, well beyond traditional budget allocations for maintenance painting. Thus, if agencies are to continue to conduct bridge painting within current or even moderately expanded budgets, they must adapt containment strategies.

There are several approaches or policies for dealing with the environmental containment problem. They differ in the degree of rigor and commitment and the degree to which the state formally recognizes the problem. Four general policies will be discussed:

- commitment to fully protect the environment for all structures
- commitment to protect structures in the most sensitive locations
- declared policy to protect all structures, but without commitment and resources to implement
- non-public recognition of problem

Fully Protecting Environment for All Structures

This policy would entail essentially total containment for all lead-painted structures being repainted. With any lesser measures, significant quantities of abrasive debris and dust will enter the environment. This policy would be extremely expensive to implement and would likely be limited to agencies with a small number of bridges, all of which are in populated areas. The agency would require an extremely large maintenance painting budget or be forced to greatly extend the time between paintings. Agencies most likely to adopt this policy would be those maintaining toll bridges, particularly in urban areas (e.g., port, bridge, turnpike, or tunnel authorities).

Full Protection to Structures in Environmentally Sensitive Areas

Several agencies, notably Michigan DOT (*4*) and the Ontario Ministry of Transportation (*56*), have established different levels of containment depending on the location and type of the structure. The implicit assumption here is that it is acceptable to allow appreciable quantities of abrasive to fall into non-sensitive locations. Thus, for bridges more than 200 ft from residences, Michigan DOT initially allowed contractors to open blast with tarpaulins or screens on the ground and on the sides of the bridges. Many specialists estimate that such procedures will contain 40 to 70 percent of the blast debris and very little of the dust (*77*). These agencies are therefore stressing the "nuisance" type of pollution. They want to prevent blatant displays of depositing particles in rivers, and roadways, and to avoid conditions of high wind and long transport of dust clouds.

Recognition of Problem, but Without Commitment

Containment and environmental protection issues may be given nominal recognition in the form of general pollution provisions and controls. Frequently, states have little or no enforcement of regulations. Agencies recognize that lead is a hazardous material and that waste debris should be tested; however, such agencies do not perceive the EPA, state environmental agencies, or their own upper management as providing much guidance. According to the survey, most agencies perceive their primary guidance as coming from consultants, contractors, manufacturers, and suppliers. Contractors have undertaken minimal containment, such as tarps, but have not been required to test the waste or dispose of it as required by EPA. Many states consider disposal of the debris strictly a contractor responsibility, but, as pointed out by many regulations, the owner has ultimate responsibility for the disposition of the waste generated.

Non-Recognition of Problem

This policy often represents an early stage in the agency's learning about lead problems and realizing the implications. Frequently, the agency has never been contacted or informed by regulators about potential violations caused by federal, state, or local environmental requirements. Specifiers and contractors who have been preparing and performing contracts for many years may not realize the hazards and risks involved in open blasting or the need to conduct a leach test on the spent abrasive. There probably has not been any kind of public outcry or incident to raise the awareness of the public, the press, or the top agency officials. Virtually all states now have some provisions for pollution control measures in their specifications. Most agencies' specifications still are not explicit enough about defining containment levels or requirements for testing or disposal. It is assumed that the contractor can deal with all the issues and/or that the regulators will not enforce the regulations.

Because the issue of lead paint removal and containment had been dormant for a number of years, some states have not had sufficient time to develop a comprehensive policy. Ultimately, each highway agency will need to take a comprehensive look at the problem, such as those from Michigan, Pennsylvania, New York State, Virginia, Louisiana, North Carolina and others have done. At that time, they will need to decide what their priorities and policies will be. Ignoring the problem or adopting cosmetic measures to deal with this problem may no longer be acceptable to the public or to the regulatory authorities.

ALTERNATE MAINTENANCE STRATEGIES

Consideration has been given to maintenance strategies other than blasting to remove the old paint. One such strategy is to perform spot cleaning and spot or full overcoating to extend the life of the old paint. At least one agency adopting this approach has continued the use of lead paint for touch-up recoating (*2*). The agency is convinced that lead paint is the best-performing material and will extend the time until a future repaint is needed, while adding only incremental quantities of lead to the environment. One problem with this approach is that many bridges are too far deteriorated for touch-up to be a viable option. Most of the surfaces of these bridges are covered with rust or loose paint, which would not provide a firm base for additional paint. Removing these failing paints (e.g., by hand or power tool cleaning) would still result in the need to properly contain the paint. Furthermore, if one does not remove the rust (which normally requires blast cleaning), the life of the newly applied system would be severely reduced.

Also, in many instances spot repair and touch-up painting will require substantial rigging, scaffolding, and traffic control operations which can be a major disruption to the public and also a major expense. Thus, the economics of spot painting are questioned, as it may defer repainting for only a short time (e.g., 5 yrs).

Another question raised is the responsibility for containment during spot cleaning. In almost all cases, some surface preparation will be necessary to remove the loose and degraded paint prior to applying the spot primer and topcoat. Whatever removal method is used (i.e., water jetting, hand or power tool cleaning or brush off blasting), it is likely that appreciable quantities of lead-containing paint will be removed. A strict interpretation of RCRA and CERCLA requires that this debris be contained, collected, and disposed in accordance with EPA regulations. There are few data available regarding the approaches for containing debris from spot cleaning, but DOTs specifying this approach should be prepared to give specific requirements.

Notwithstanding these considerations, planned maintenance painting can be a very valuable and economical procedure. It must be performed before the structure has become very badly deteriorated. A recent FHWA Guide to Maintenance Painting suggests that this treatment be considered for structures with 5 to 10 percent of the surface deteriorated (i.e., at least 90 to 95 percent should be sound intact paint) (*78*). Such a program requires a dedicated maintenance painting policy, based on regular inspections of coating condition and multi-year planning. Presently, very few highway agencies have such a program, but there would be many additional benefits for them to adopt one.

An alternate strategy that has been discussed is simply to not repaint the bridges at all, but rather allow them to corrode and eventually replace the structural steel. Several instances have been reported in which agencies have replaced steel members by returning them to the fabricating shop for cleaning and painting or by substituting new steel (*79*). However, this has occurred only where the deck has been removed for replacement. It is highly unlikely that this would be found to be an economical treatment with an in-place deck.

DISPOSAL AND MINIMIZATION OF WASTE

Disposal of the abrasive waste produced from blast cleaning is one of the major concerns for lead paint containment. The TCLP took effect in September, 1990; as a consequence, 90 percent or more of all blast cleaning debris from lead painted structures will very likely be classified as hazardous waste (*80*). Also in 1990, the prohibition on burying hazardous wastes (the "Land Ban") became effective. These factors will increase the pressure to reduce the amount of waste generated. Processes that treat or minimize hazardous waste will become more attractive to equipment developers, chemical process firms, contractors, and highway agencies.

The most frequently used method for minimizing waste is using recyclable metallic abrasives. This system is also amenable to total work area enclosure. The relatively small quantity of spent metallic abrasives should not present a major disposal problem, but proper protocols should be observed. Another viable approach is to reuse the spent abrasive in asphalt, paving, or other construction uses, but these are still in relatively early developmental stages. Although the prospect for surface cleaning without abrasives is favorable, the practice is somewhat farther down the road.

As noted previously, as of 1989 many agencies were unfamiliar with some specific details regarding the RCRA regulation. From articles and reports by NCHRP, FHWA, and others, the waste disposal requirements have been well publicized to the state and local highway agencies. There has, however, been a lack of communication or directives to officials in district offices or responsible divisions or departments within agencies. This situation has continued, possibly due to lack of input or enforcement by regulatory officials. The impetus to change these practices will come either from the agencies themselves, from citations or shutdowns by regulators, or by adverse public comment and criticism.

CONTRACTOR ROLE

Obviously, the contractor is a key factor in the success of a lead paint containment program. It is useful to review the means of contractor participation and the qualifications required by contractors. There is great diversity in size, training, and expertise of contractor firms. Problems with poor quality workmanship, lack of understanding of specifications, lack of inspection, and other deficiencies by marginally qualified contractors are well documented (*81*). Awarding contracts to such contractors results either in substandard applications or contracts in default. The problems associated with poor quality contractors will be greatly magnified when containment and disposal of debris are required (*82*). Agencies cannot assume that contractors who fail to contain debris properly (e.g., allow it to fall into populated areas) or to follow proper disposal procedures will be liable for all damages. Under RCRA's "cradle-to-grave" provisions, the facility owner ultimately will be responsible for the proper disposal of the debris.

The contractor also has the major responsibility for protecting workers against health and safety hazards during paint removal operations. The most significant safety hazard is exposure to lead dusts and particulates. By requiring contractors to work in closed containment areas as a means to protect the environment, the DOTs are inadvertently increasing the lead exposure risk to the contractor. While this is, as noted, a contractor responsibility, DOT representatives must be aware of this situation. Bridge painting jobs can be shut down by OSHA or state health agencies for improper health and safety control, which could cause a major problem for the DOT. In addition, OSHA standards for working with lead in construction are expected to become increasingly stringent, which inevitably will increase costs to contractors and DOTs in undertaking lead paint removal projects (*83*).

Platforms and tarpaulins can present significant safety hazards if not installed and operated properly. Thus, agencies should take special steps to ensure that contractors are properly qualified and carefully instructed in what is required. Items to be considered for inclusion in bridge painting specifications are given earlier in this chapter.

Painting contractors should be prequalified in areas such as safety programs, quality control, technical capabilities, and management procedures. In the survey, almost all the contractors indicated support for a national contractor prequalification program. This indicates that they are interested in meeting quality requirements, but are concerned that they may be competing against underqualified firms.

Contractors surveyed also are unanimously in favor of a mandatory pre-bid meeting. Such a meeting can help to assure that each contractor is aware of the requirements of the contract, including the type of structure, type of containment required, manner in which the containment will be evaluated, type of monitoring, sampling, and testing, and the manner in which the agency's engineers and inspectors will work with the contractor.

Overall, contractors can be a major resource for the agency. Many are extremely familiar with the structures. They are becoming knowledgeable about containment, and are interested in maintaining a safe and efficient operation. With a properly planned specification and qualification program, they can achieve the most economic and efficient cleaning, painting, and containment.

CONCLUSIONS

Equipment and Containment

- Fully enclosed containment structures are considered capable of achieving 85 to 90 percent containment of abrasive and paint particles and dust for simple spans. The containment percentages are based on estimates rather than hard data. The added cost for such containment is estimated to range as high as 50 to 100 percent or more of open blasting.
- Complete containment for high trusses and other complex structures is not feasible with current bridge containment technology.
- The most commonly used containment devices include tarpaulins, windscreens, collection platforms, and barges. These are estimated to contain 40 to 75 percent of the debris.
- Equipment manufacturers and contractors have invested major resources in developing paint removal and containment devices. Considerable additional improvements are needed to make these fully effective and reliable.
- The most successful surface preparation method used within full enclosure is a steel abrasive recycling system. The breakdown rate of steel abrasives is less than 1 percent, which greatly reduces the volume of waste compared to once-through sand and slag abrasives.
- Vacuum blasting and recovery and vacuum-fitted power tools have demonstrated some success in preparing surfaces, but have some serious limitations in productivity and operator techniques.
- Key equipment components are dust collectors, abrasive recovery and transport machines, and abrasive reclaimers/separators.
- Containment structures and devices are becoming more sophisticated. Important advances have been occurring in seam construction, strength and permeability of screens, and in construction frames, rigid panels, and platforms that are rapidly assembled and disassembled and portable.
- The safety and structural integrity of containment devices is emerging as a critical issue.
- Worker health issues have emerged as another critical problem in removing lead-based paints. The environment within containment structures and industrial hygiene for all people working in or around a bridge painting job must be addressed.
- Some containment structures built to date have been based on negative pressure concepts and theoretical number of air changes. More work is needed on design and testing of containment systems based on industrial ventilation guidelines, which consider air flow.

Specifying Containment

- Several highway agencies, in conjunction with environmental agencies, have developed effective practical schemes for classifying bridges and containment requirements according to environmental sensitivity.
- According to contractor responses to the survey, some highway agencies' specifications are not sufficiently explicit regarding contractor requirements and responsibilities.
- Areas requiring definition include responsibility for hazardous waste generation, degree of containment required, methods of measuring and monitoring pollution and containment efficiency, need for submitting methods for agency approval, methods of sampling, testing, and storing waste, and responsibility for paying for hazardous waste disposal.
- Highway agencies have shown a wide range of attitudes and understanding of the lead removal problem, and differing degrees of commitment to its resolution.

Highway Maintenance Strategies

• A program of regular inspection and timely painting touch-up could greatly reduce the need to conduct abrasive blast cleaning. For most highway bridges, the deterioration has proceeded too far to allow such a strategy to be effectively implemented. In addition, the long-term cost effectiveness of touch-up painting has not been fully explored.

Disposal and Minimization of Waste

• As a result of the land disposal restrictions ("Land Ban"), effective August 1990, all land disposal of hazardous waste is prohibited.

• As a result of the TCLP test method, which became effective in September 1990, it is highly likely that almost all abrasive and paint wastes from lead-containing structures will be classified as hazardous.

• Highway agencies will be required to treat or reuse spent abrasives. Technology is available for treating heavy metals, such as lead, to render them non-hazardous. However, the logistics and economics of using these treatments on bridge blasting debris have not been evaluated. The technology for reusing abrasives is not well established or disseminated.

• A major emphasis should be placed on methods to reduce waste (e.g., abrasive recycling), eliminate abrasives (e.g., power tools) or reuse the waste (e.g., asphalt pavement).

• Under the "cradle-to-grave" philosophy, highway agencies will have ultimate responsibility for proper disposal of waste. Hence, it is important to establish procedures and properly instruct contractors and testing agencies.

• At least two states have reported initial success in reusing spent lead-containing abrasive in asphalt construction. Other agencies are starting to investigate stabilization and recovery processes.

Contractor Involvement in Lead Paint Removal

• Contractor's experience and expertise are major factors in determining the success or failure of a containment project.

• Because of damage to the environment, public safety, and community relations, highway agencies need to focus attention on assurances of competence, integrity, and responsibility of contracting firms.

• New, more stringent requirements for protection measures, training, and monitoring for working with lead are expected in the near future. This is likely to increase contract costs, but also to put a premium on contractors with a good safety and quality program.

• Many contractors have a strong interest, commitment, and incentive in working with agencies to improve and expand bridge painting activities. To take advantage of this situation, highway agencies must provide clear, unambiguous, and enforceable specifications.

• Potentially negative consequences include good contractors abandoning bridge painting because of overly high risk with insufficient benefits, and drastic reductions in bridge painting activities because of inability to comply with regulations.

GENERAL RECOMMENDATIONS

Highway agencies must recognize the extent of the lead paint removal problem and what actions may be needed to address this problem. An important aspect is the uncertainty and variability of the technology and the regulations. The development of procedures that allow agencies to review changing conditions on a continuing basis could alleviate this problem.

Recognition of and commitment to this area must be made by top agency officials, supported by the authority of legislators and the public. Highway agencies must establish procedures for coordinating the policies and programs among the various departments that are involved in bridge painting (i.e., construction, maintenance, materials, environmental, and design). It is also essential to establish communication and relations with environmental agencies, to ensure that the highway agency perspective is known to regulators. Highway agency personnel are also advised to establish and maintain contact with other highway agencies, with the Federal Highway Administration, and with industry associations and private firms.

The choices that must be made by legislators and by the public will be based on trade-offs between protecting and maintaining transportation structures and protecting the environment and the general health and welfare. The situation is complicated by competition for funds from other vital public causes, and uncertainties in cost and efficiency of containment and environmental regulations, degree of hazard, and need for enforcement.

In a recent report issued by the Federal Highway Administration on the same subject, specific recommendations are given for other groups within the industry. The report concluded that "... progress toward resolution depends on an immediate combined effort by a number of interested groups, including Federal, State, and local highway agencies, regulatory agencies, professional and trade organizations, and private industry."

REFERENCES

1. Snyder, M.K., and D. Benderski, National Cooperative Highway Research Program *Report 265: Removal of Lead-Based Bridge Paint*, Transportation Research Board, Washington, DC (December 1983).
2. Appleman, B.R., "Lead Paint Regulations Challenge Bridge Workers," *Roads and Bridges*, (April 1989), pp. 42–44, 46–55.
3. Hower, H.E., "The Dilemma of Removing Lead-Based Paint," *Journal of Protective Coatings & Linings*, Vol. 5, No. 1, (1988), pp. 30–37.
4. Culp, J.D., "Removing Lead-Based Bridge Paint in Michigan," *Journal of Protective Coatings & Linings*, Vol. 6, No. 1, (January 1989), p. 56.
5. "New EPA Procedure Could Replace EP Toxicity Test as Early as Mid-1990," in "Regulation News," *Journal of Protective Coatings & Linings*, Vol. 7, No. 1, (1990), pp. 34–35, 1990.
6. Geoffroy, D., "New York Department of Transportation Initiates Lead-Based Paint Removal Action Plan," *Journal of Protective Coatings & Linings*, Vol. 6, No. 6, (June 1989), pp. 20–21, 218.
7. Medford, W.M., T. W. Neal, Jr., and L. M. Smith, "Bridge Cleaning Debris Containment: Field Evaluation and Cost Comparison, *The Impact of Regulations and Litigation on Protective Coatings, Proceedings*, SSPC Fifth Technical Symposium (January 21–22, 1987), New Orleans, LA, B. R. Appleman and J. Rex, editors. Report SSPC 87–01.
8. Appleman, B.R., J. A. Bruno, Jr., and R. E. F. Weaver, *Performance of Alternate Coatings in the Environment (PACE)—Part I: Ten-Year Field Data*, Report No. FHWA-RD-89-127 (also available as SSPC Report 89-01).
9. Stringos, D., "First Year's Experience with a Blasting Regulation," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium , (February 29–March 1, 1988), SSPC Report 88–01, (1988), pp. 34–49.
10. Spagnolli, D., and P. Remy, "Experience with Removal of Lead-Based Paint in Western PA," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988), pp. 203–209.
11. Thorpe, G., "Water Quality Impact: Environmental Viewpoint," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988) pp. 50–54.
12. "Report on PennDOT Environmental Controls for Surface Preparation" in "Research News," *Journal of Protective Coatings & Linings*, Vol. 6, No. 2, (February 1989), pp. 15–21.
13. Smith, L.M., "Analysis of Pollution Controls for Bridge Painting," PennDOT Research Project No. 86–223, *Final Report* (in preparation).
14. Appleman, B.R., *Removal of Lead-Based Bridge Paints*, Report on FHWA Workshop, SSPC Report 88–02.
15. "FHWA Awards Research Contract on Lead Removal," in "Regulation News," *Journal of Protective Coating & Linings*, Vol. 6 No. 12, (December 1989), pp. 86–88.
16. Sadar, A.J., and H. L. Patel, "Air Monitoring Guidance for Abrasive Blasting Operations," *Journal of Protective Coatings & Linings*, Vol. 4, No. 12, (1987), pp. 31–32, 68–70.
17. 40 CFR 302, "Designation, Reportable Quantities and Notification," *Code of Federal Regulations*, U.S. Government Printing Office, Washington, DC.
18. *Resource Conservation and Recovery Act (RCRA)*, 1976. Amendments in 1984 and 1986 (CFR 40 - Subchapter I - Solid Waste).
19. "Land Disposal Restrictions for Third Scheduled Wastes," Proposed Rules, Environmental Protection Agency: 40CFR Part 148, 261, 264, 265, 268, and 271, *Federal Register* Vol. 54, No. 224, (November 22, 1989).
20. EPA Method 1310, "Extraction Procedure (EP) Toxicity Test Method and Structual Integrity Test," from *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA Publication SW–846, 3d edition, (September 1986).
21. Friedman, D., "Toxicity Levels and Test Procedures," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (February 29–March 1, 1988), pp. 14–21.
22. EPA Method 1311, "Toxicity Characteristic Leachate Procedure (TCLP)," 40 CFR Part 261, Appendix II, as amended in *Federal Register* (March 29, 1990), pp. 11863–11876.
23. Jirka, A., et. al., "Factors Affecting EP Toxicity Metals Results," *Proceedings*, Third Annual Symposium, US EPA Symposium on Solid Waste Testing and Quality Assurance," (July 13–17, 1987).
24. "Special Report: The Effect of Land Ban on Lead Removal," *Journal of Protective Coatings & Linings*, Vol. 7, No. 7, (1990), pp. 31–71.
25. Tinklenberg, G., and L. M. Smith, "The Criticality of Sampling and Quality Control for Hazardous Waste Testing," *Journal of Protective Coatings & Linings*, Vol. 7, No. 4, (April 1990), pp. 36–45.
26. Harris, J.L., and J. T. Fleming, "Testing Lead Paint Blast Residues to Pre-Determine Waste Classification," *Lead Paint Removal from Industrial Structures* (1989), pp. 62–83.
27. "Occupational Safety and Health Standards for the Construction Industry," *Code of Federal Regulations*, 29 CFR 1926.
28. "Occupational Safety and Health Standards: Lead," *Code of Federal Regulations*, 29 CFR 1910.1025.
29. Chute, D. O., and N. L. Mostaghin, "Protecting Workers From Lead: A Review of Regulations and Practice," *Journal of Protective Coatings & Linings*, Vol. 8, No. 4, (1991), pp. 36–43.

30. Burbank, J. "Industrial Hygiene in Lead Abatement: A Contractor's Perspective," from *Lead Paint Removal: Meeting The Challenge*, Steel Structures Painting Council 91–05.
31. Rekus, J.F., "Working on Structural Steel: The Lead Hazard," *Journal of Protective Coatings & Linings*, Vol. 5, No. 1, (1988), pp. 38–44.
32. Weaver, P. E., *Industrial Maintenance Painting*, Appendix 1—"Tables of Rates and Quantities," 3rd edition, (1967) National Association of Corrosion Engineers, Houston, TX.
33. Mallory, A. W., *Guidelines for Centrifugal Blast Cleaning*, Steel Structures Painting Council, SSPC 84–03, (March 1984).
34. Claus, J., "New SSPC Specification: Power Tool Cleaning to Bare Metal," *Journal of Protective Coatings & Linings*, Vol. 4, No. 10, (October 1987) pp. 84–86.
35. Steel Structures Painting Council, *Specification SSPC SP-11*, "Power Tool Cleaning to Bare Metal," issued December 1, 1987, revised September 1, 1989.
36. Appleman, B.R., and J. A. Bruno, Jr., "Evaluation of Wet Blast Cleaning Units," *Journal of Protective Coatings & Linings*, Volume 2, No. 8, (August 1985), pp. 34–42.
37. Frenzel, L.M., M. Ginn, and G. V. Spires, "Application of High-Pressure Water Jetting in Corrosion Control," *Surface Preparation: The State of the Art, Proceedings*, SSPC 1985 Symposium, May 1985, SSPC Report 85–06.
38. Woodson, J.P., "Wet Abrasive Blasting—Problems and Solutions," *The Impact of Regulations and Litigation on Protective Coatings, Proceedings*, 1987 SSPC Symposium, January 1987, SSPC Report 87–01.
39. McPhee, W., and J. van Leeuwen, "A New Type of Vacuum Blasting Equipment for Removing Lead Paints," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (February 29–March 1, 1988), pp. 61–73.
40. Brailsford, M., "The Removal of Lead-Based Paint From Steel Structures Using a Chemical Poultice System," *Lead Paint Removal from Industrial Structures: Proceedings*, Steel Structures Painting Council Lead Paint Removal Conference, February 27–March 1, 1989. SSPC Report 89–02, (1989).
41. Armstrong, J. "A Cryogenic Cleaning System," *Lead Paint Removal from Industrial Structures, Proceedings*, Steel Structures Painting Council Symposium, (1989), pp. 99–100.
42. Private Communication, M. Portnoff, Mellon Institute, 1989.
43. Lee, R., "Water-Soluble Abrasives—A New Concept in Coating Removal," presentation at Steel Structures Painting Council National Conference, December 4–7, 1989, Houston, TX. Paper No. S–12.2.
44. "SSPC News," *Journal of Protective Coatings & Linings*, Vol. 6, No. 5, (May 1989), pp. 81, 83.
45. Calvo, R.P., and M. Seavey, "Method of Containing Dust and Debris in an Air Abrasive Blasting Operation," *Journal of Protective Coatings & Linings*, Vol. 7, No. 5, (May 1990), pp. 83–86.
46. Appleman, B.R., "Liaison With Federal Republic of Germany on Corrosion Protection of Highway Bridge Steel," *Final Report*, (November 1987), FHWA Contract DTFH61–84–C–00063.
47. Calvo, P.R., "Design and Application of Containment Screens," Presentation at Third Annual Conference on Lead Paint Removal from Industrial Structures, Long Beach, CA, March 20–21, 1990.
48. Harrison, J.F., "Removing Lead Paint From Bridges Using Recycled Steel Abrasive," *Lead Paint Removal from Industrial Structures, Proceedings*, Steel Structures Painting Council Symposium, (1989), pp. 102–107.
49. Calvo, R.P., "Enclosures on Large Structures," from *Lead Paint Removal: Meeting the Challenge*, SSPC 91–05.
50. Lyras, L.G., "Lead Containment Structure for Bridge Painting," *Lead Paint Removal from Industrial Structures, Proceedings*, Steel Structures Painting Council Symposium, (1989), pp. 52–55.
51. Hansel, D. "Vacuum Recovery Systems for Abrasives," *Surface Preparation: The State of the Art, Proceedings*, Steel Structures Painting Council Annual Symposium, May 22–23, 1985, Cincinnati, OH. Edited by B.R. Appleman and H.E. Hower, p. 19.
52. Williams, A.B., "Special Blast Cleaning Tools and Systems" and "Enclosed Blast Cleaning Facilities," in *Abrasive Blast Cleaning Handbook*, First edition, (1986).
53. Bloemke, D., "Minimizing Disposal Costs and Storage Areas by Using Portable Power Tools," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988), pp. 80–92.
54. Taylor C., and S. Lefkowitz, "Dustless Needle Guns to Remove Lead Paint from Jet Fuel Storage Tanks," presented at Third Annual Conference on Lead Paint Removal from Industrial Structures (1990), Long Beach, CA, March 20–21, 1990 (to be published in *Proceedings*).
55. "Equipment Buyers Guide," *Journal of Protective Coatings & Linings*, Vol. 8, No. 6, (1991), pp. 33–81.
56. Batten, M. "Specifications for Enclosures on Blasting Operations," *Journal of Protective Coatings & Linings*, Vol. 5, No. 7, (July 1988), pp. 29, 100–103.
57. Lunardini, J., "Current Blasting Technologies," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988), pp. 93–108.
58. McNamara, G., and K. Hooper, "Portable Ventilation for Containments," *Lead Paint Removal: Meeting the Challenge*, SSPC 91–05.
59. "Portable Dust Filter Used to Clean Exhausted Blasting Air," *Journal of Protective Coatings & Linings*, Vol. 4, No. 10, (October 1987), p. 10.
60. "Steel Grit for Field Blasting," in "Innovative Practice," *Journal of Protective Coatings & Linings*, Vol. 4, No. 9, (September 1987), pp. 3, 57.
61. Weyand, T.E., "Summary Report: Identification of Acceptable/Beneficial Re-Uses for Spent Bridge Painting Blast Debris," prepared for Pennsylvania Department of Transportation, PennDOT Project No. 89–02, (December 5, 1989).
62. Smith, L.M., G. L. Tinklenberg, and B. A. Doezma, "Stabilization of Lead-Containing Abrasive Blasting Debris," Report for FHWA Contract DTFH61–89–C–000102, April 1991 (to be published).

63. "Alternate Treatment Standards for Lab Packs," *Federal Register*, Vol. 55, No. 106, (June 1, 1990), p. 22629.
64. "The Superfund Innovative Technology Evaluation Program: Technology Profiles," EPA 540/5-89/013, November 1989, Office of Solid Waste and Emergency Response, Washington, DC 20460.
65. "Project Special Provisions, Cleaning and Repainting of Existing Structures, Contract Revision, Blasting Abrasives," Project 8-184, Buncombe Co., North Carolina Department of Transportation, Raleigh, NC, 1991.
66. *Understanding the Small Quantity Generation Hazardous Waste Rules: A Handbook for Small Businesses*, EPA/530-SW-86-019. (September 1986), U.S. EPA Office of Solid Waste, Washington, DC.
67. Medford, W. M., "Containment and Beneficial Reuse of Blasting Sand in Asphalt Concrete: A Case History," *Materials and Test Unit Research Report*, North Carolina Department of Transportation, (September 1989).
68. Lodick, M., "An Overview of R.C.R.A. Regulations," *Lead Paint Removal from Industrial Structures, Proceedings*, Steel Structures Painting Council Conference (1989), SSPC-89-02, pp. 15-19.
69. Hauck, J. C., and E. S. Kline, "Pre-Qualification of Contractors: One Giant Step Toward Increasing the Service Life of Coatings," *Journal of Protective Coatings & Linings*, Vol. 3, No. 7, (July 1986), pp. 26-33.
70. Steel Structures Painting Council Surface Preparation Specification No. 10, "Near-White Metal Blasting," November 1, 1989.
71. Letter to FHWA Regions, 1987, R. Leathers.
72. Frondistou-Yannas, S., et. al., "Coatings for Non-Abrasive Cleaned Highway Steel," Report No. FHWA RD-86-053, (December 1985).
73. Frondistou-Yannas, S., "Coating and Corrosion Costs of Highway Structural Steel," Report No. FHWA-RD-79-121, (March 1980).
74. "Removal of Lead-Based Paint from Steel Bridges," Kentucky Transportation Cabinet, KY HPR 91-138, July 1, 1991 (start date).
75. Hamilos, J., "Maintenance Painting Under Present Regulations: A Contractor's Viewpoint," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988) SSPC 88-01, pp. 109-122.
76. Anderson, G., "Lead Contamination of Soil by Sandblasting of Bridges," *Lead Paint Removal from Steel Structures, Proceedings*, Steel Structures Painting Council Symposium, (1988) SSPC 88-01pp. 22-32.
77. Neyer, J. H., A. M. Batten, and L. M. Smith, "Problem Solving Forum on Containment Efficiency," *Journal of Protective Coatings & Linings*, Vol. 5, No. 10, (October 1988), pp. 11-18.
78. "FHWA Guide to Bridge Maintenance Painting," Report FHWA TS-89-14, (Federal Highway Administration, Washington DC, 1989). Also available as SSPC Report 89-04.
79. D. Spagnolli, PennDOT, private communication.
80. "Hazardous Waste Management System: Identification and Listing of Hazardous Waste Toxicity Characteristics Revisions," *Federal Register*, Vol. 55, No. 61, (March 29, 1990), pp. 11798 to 11877, 40 CFR, Parts 261, 264, 265, 268, 271 and 307.
81. Survey Responses on Conditions in the Industry, *Journal of Protective Coatings & Linings*, Vol. 2, No. 6, (June 1985), pp. 14-32.
82. Lyras, L.G., "The Cost of Lead Paint Removal: Achieving Realistic Bid Prices," *Journal of Protective Coatings & Linings*, Vol. 8, No. 7, (1991) pp. 56-62.
83. "OSHA Releases Guidelines for Working With Lead: Working With Lead in the Construction Industry," *Journal of Protective Coatings & Linings*, Vol. 8, No. 7, (1991), pp. 44-55.
84. Smith, Lloyd, "Revisions to Guide for Environmental Pollution Controls for Bridge Painting Contracts," Pennsylvania Department of Transportation Research Project No. 86-23, (July 1991).
85. Smith, Lloyd, "Analysis of Pollution Controls for Bridge Painting," *Final Report*, Pennsylvania Department of Transportation Research Project 86-23, (July 1991).

APPENDIX A

OVERVIEW OF ENVIRONMENTAL REGULATIONS

NCHRP *Report 265 (1)* provided comprehensive discussion of various regulations pertaining to lead paint removal. This appendix is intended to supplement and update those discussions, since review of regulations was not a major part of this project.

Regulations concerning waste disposal have the strongest impact on lead paint removal. Other areas of concern are water pollution, air pollution, ground and soil pollution, occupational safety and health, and soil pollution.

SOLID AND HAZARDOUS WASTE

In 1976, Congress enacted the Resource Conservation and Recovery Act (RCRA). The act was amended in 1984 by the Hazardous and Solid Waste Amendment (HSWA). RCRA and HSWA are designed to track and regulate hazardous substances/waste from manufacture to final disposal, and to assure that disposal is effective and permanent so there will be no escape of materials into the environment.

Defining Hazardous Waste

RCRA defines a hazardous waste as a solid waste that may cause or significantly contribute to serious illness or death, or that poses a substantial threat to human health or the environment when improperly handled. As required by RCRA, Section 3001, EPA has established criteria for identifying hazardous waste and has issued tests and means for classifying it. EPA has compiled a list of more than 100 substances that are designated as hazardous materials or waste. Waste is also designated as hazardous if it possesses any of the following four characteristics:

- Ignitability
- Corrosivity
- Reactivity
- Toxicity

These are known as "characteristic wastes."

Lead and other heavy metals are not listed as wastes nor are they likely to test positive for any of the first three criteria. The area of concern is toxicity. EPA has established a test for toxicity consisting of an extraction procedure to determine the amount of leachable lead or chromium in a substance. The test is known as the Extraction Procedure Toxicity Test, EPA Method 1310 (EP-TOX). If the level of leachability (solubility) exceeds 5 parts per million (ppm) the material is classified as hazardous.

A newer test procedure (Method 1311), intended to replace EP-TOX, is known as the Toxicity Characteristic Leaching Procedure (TCLP). As discussed previously, this method corrects some of the technical deficiencies of EP-TOX but will result in much higher levels of measured lead solubility.

"Cradle-to-Grave" Provisions

RCRA also required EPA to set standards for generating, transporting, and disposing of hazardous waste. This effort to identify responsibility and establish procedures for each stage is known as "cradle-to-grave" responsibility.

Section 3002 of RCRA requires standards for hazardous waste generation, including recordkeeping, labeling, and use of appropriate containers. It also requires adoption of a manifest system to ensure that the hazardous waste processing is properly documented.

Section 3003 established procedures and manifestation systems for transportation of hazardous waste. Section 3004 covers standards for storage and disposal facilities, along with treatment and disposal methods. For example, under the 1984 amendment (HSWA) the new and enlarged landfills must have double liners and groundwater monitors. The owner and operator of a disposal site must also furnish evidence of financial responsibility. Section 3005 establishes procedures for issuing permits for disposal sites.

RCRA also provides for state regulation of the hazardous waste operations. States meeting certain EPA regulations may assume responsibility for hazardous waste control. States also have the authority to establish more stringent requirements. However, if state laws are less stringent than federal, states will not be given this authority. In 1989, approximately 45 states had received such authority from EPA. Authority is not absolute, and requires participation by regional EPA offices.

The 1984 amendments to RCRA further strengthened and defined requirements for control of hazardous waste disposal. One critical aspect is in the requirement for site disposal. Others are discussed subsequently.

EPA was mandated to develop regulations to ban unsafe, untreated waste from land disposal. On May 8, 1990, EPA announced the specific provisions of the Land Disposal Restrictions or the "Land Ban," which went into effect on August 8, 1990.

The treatment standard for lead was set at 5 ppm. Thus, any waste material containing more than 5 ppm lead would require treatment prior to being landfilled.

The test method for determining if lead paint is hazardous or not is the TCLP test, which became effective in September 1990, for large-quantity generators and in March 1991, for small-quantity generators. Thus, any material that exceeds 5 ppm lead by TCLP is hazardous.

Because of a subtlety of the regulation, there are some instances in which a material that failed TCLP (greater than 5 ppm lead) can still be land-disposed. The situation arises if the waste fails TCLP but passes EP-TOX (less than or equal to 5 ppm lead). EP-TOX is still regarded as the test procedure to determine if a waste is subject to the land disposal restrictions, so the lead-containing waste could then be buried at a subtitle C (hazardous) landfill. Materials failing EP-TOX would automatically require processing. This quirk in the regulation is not expected to have much practical significance. Virtually all waste treaters are electing to treat any lead-containing waste with greater than 5 ppm lead per TCLP, so TCLP has become the de facto test for land disposal as well as for whether or not the waste is hazardous.

EPA also established requirements for treaters or processors of hazardous waste. They are subject to licensing and permitting and must present evidence of safe operation, adequate training, spill contingencies, etc. RCRA and subsequent amendments also allow for on-site treatment by the generator without a permit if done within 90 days. There are requirements for a waste analysis plan (WAP), approval by the Regional Administrator, and for the types of containers.

Other Provisions of the HSWA (1984) Amendments

EPA also was mandated to develop regulations to:

- Minimize waste
- Require that land disposal facilities are designed, constructed, and operated according to stringent standards
- Require corrective action for release of hazardous waste into the environment

Waste Reduction

The hazardous waste generator, normally the facility owner and/or the contractor, may reduce waste in several ways, including manufacturing process change, source separation, recycling, raw material substitution, and product substitution. Treatment methods include physical, chemical, and biological processes (see discussion in Chapter Four). The Land Ban provisions have thus given considerable impetus to development of more effective and economical means for treating waste.

Stringent Standards for Land Disposal Facilities

The 1984 amendments provide the following new standards and restrictions:

- Banning liquids from landfills
- Requiring more stringent structural and design conditions for landfills, including double liners and leachate collection systems and groundwater monitoring
- Requiring cleanup of leaks
- Restriction on location of disposal facilities to protect human health

Corrective Action Requirements

Under the 1984 amendments, EPA or authorized states can require a hazardous waste facility (Subtitle C) to take corrective action for any hazardous waste leak into the environment. This may require corrective action beyond the facility boundaries, and actions without regard to when the waste was placed at the facility. Operators of waste facilities must also provide financial assurance that they can complete the corrective action.

Cleanup

CERCLA (Comprehensive Environmental Response Compensation and Liability Act), also known as the "Superfund" law, was enacted in 1980. It is designed to control cleanup and designate liability for abandoned, uncontrolled, or inactive waste sites and deal with hazardous waste releases in emergencies. Any occasion or operation in which more than 1 lb of elemental lead is deposited in the environment is classified as a release or "spill" by CERCLA. Each such occurrence, known as a "reportable quantity," is a violation of the regulation and subject to enforcement and penalty. One lb of lead is the amount contained in approximately 40 ft^2 of a typical lead-containing multi-layer paint system on a bridge.

The 1986 amendment to CERCLA is the Superfund Amendment and Reauthorization Act (SARA). This act has four basic elements. First, it establishes information-gathering and analysis systems to characterize chemical dump sites and develop priorities for needed actions. Second, CERCLA establishes federal authority to clean up leaking sites and hazardous substance emergencies. It creates a hazardous substance trust fund (Superfund) to pay for removal and remedial actions. The act also makes persons responsible for hazardous substance release liable for cleanup costs. Additional details are listed in the References.

State Laws

Almost every state has enacted regulations regarding production, storage, transport, treatment, or disposal of hazardous substances or waste. RCRA encourages states to assume some of the federal responsibilities for operating their own waste programs. CERCLA remains a federal (EPA) responsibility, but the states are not prevented from enacting their own laws to address hazardous substances or wastes, as long as they do not conflict with CERCLA and meet or exceed its requirements. In general, state laws and standards are required to be equivalent to or more stringent than federal requirements. There are some variations from state to state, and certain states such as California have enacted more stringent hazardous waste requirements. For example, California requires that heavy metals such as lead meet a maximum total concentration as well as a maximum leachable concentration.

WATER POLLUTION REGULATIONS

The original legislation known as the Water Pollution Control Authority consisted primarily of state developed ambient water quality standards applicable to interstate and navigable waterways. In 1972, the Federal Water Pollution Control Act was amended, establishing more stringent requirements including the stated goals to achieve "fishable and swimmable" waters and to eliminate pollution discharge. The 1977 amendment allowed the Federal EPA to set more stringent standards than the states.

The Federal Water Pollution Control Act required that the states and the federal government establish a permanent system to reduce effluent discharge into waters. The National Pollutant Discharge Elimination System (NPDES) regulates any discharge by point sources. According to the authors of NCHRP *Report 265 (1)*, bridge paint removal operations are considered non-point sources and the NPDES permit requirements are not applicable.

Subsequent to that report, the FWPCA (or "Clean Water Act") was amended in 1987. The amendments allowed extensions of certain provisions of the Clean Water Act, and also established different requirements for several categories of pollutants.

However, the 1987 act addresses non-point sources, which would affect bridge painting operations. States are required to establish management procedures for bodies of water where water quality standards cannot be met without control of non-point sources.

DRINKING WATER

The EPA standard for lead in drinking water has been set at 50 μg/l. However, because of health concerns from the effects of lead, particularly in children, the agency is considering reducing this limit. The proposed new limits are in the range of 10 to 15 μg/l.

A reduction in the lead in drinking water standard could also have implications for the level of leachable lead in solid waste. The current level of 5 ppm leachable lead is based on ground water transport models which assume a certain amount of leaching of the waste into the groundwater. The models provide a 100–fold dilution factor (i.e., the leachate would be expected to be diluted to 1 percent of its initial concentration by the time it reached ground water). Thus, to maintain the safety factor of 100 would require a proportionate reduction in the leachable lead standard.

AIR QUALITY REGULATIONS

The Clean Air Act, issued in 1970, directed EPA to establish standards for safe levels of potentially hazardous air contaminants. In the last 20 years, EPA has established levels for a handful of substances, including lead, ozone, carbon monoxide, nitrous oxides, sulfur oxides, hydrocarbons, and particulates. The level of lead was set at 1.5 $\mu g/m^3$ averaged over a calendar quarter. This standard was intended primarily for permanent operations such as lead smelters or battery manufacturing. This regulation has not impacted bridge painting activities significantly because of the relative lack of monitoring data and the fact that most bridge blast cleanings are completed in less than 90 days. EPA has indicated its intention to revise the standard for lead. Suggested revisions are to lower the permissible level to 0.75 $\mu g/m^3$ and shorten the period for averaging from 90 to 30 days. These changes could have a significant impact on bridge painting activities. High level emissions of lead, even for a short duration, could cause the 30–day average to exceed the allowable maximum.

EPA has also established national primary and secondary air quality standards for particulate matter less than 10 microns in diameter (PM-10). The primary standard for PM-10 is 50 $\mu g/m^3$ averaged over a year. The maximum average concentration for any 24-hr period is 150 $\mu g/m^3$. Unconfined abrasive blasting operations could exceed the 24-hr standard.

Several states and counties have their own regulations on air quality. These include California, Michigan, Allegheny County (Pennsylvania), and several jurisdictions in Texas and elsewhere (*84,85*).

ENVIRONMENTAL ACTS THAT IMPACT ON BRIDGE PAINT REMOVAL

Waste Disposal

- Resource Conservation and Recovery Act (RCRA) 1976
- Hazardous and Solid Waste Amendments (HSWA). Amendment to RCRA, 1984

Waste Cleanup

- Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 1980
- Superfund Amendment and Re-Authorization Act (SARA), amendment to CERCLA 1986

Clean Water

- Clean Water Act (CWA), 1977 amendments to Federal Water Pollution Control Act (FWPCA)

Drinking Water

- Safe Drinking Water Act (SDWA), 1974 (Amended in 1986)

Toxic Substances

- Toxic Substance Control Act (TSCA) 1976

Clean Air

- Clean Air Act of 1970 (CAA), amended in 1977, 1982, and 1990

Worker Health & Safety

- Occupational Safety and Health Act (OSHA), 1970

APPENDIX B

SURVEY OF STATE HIGHWAY AGENCIES AND TABULATION OF RESPONSES

TRB SYNTHESIS 20-5, TOPIC 20-09
"BRIDGE PAINT: REMOVAL, CONTAINMENT, AND DISPOSAL"

Questionnaire for Department of Transportation

1. Agency:______________________________

2. Coordinator of Questionnaire (name):______________________________

   (title):______________________________

   (address):______________________________

   (phone):______________

3. Date Questionnaire Received:______________ Completed:______________

This questionnaire is in three parts as follows:

I. Planning of Bridge Maintenance

   Department/Division with prime responsibility:______________

   Responsible Individual:______________________________

   Phone No.:______________

II. Bridge Contract Painting Activities

   Department/Division with prime responsibility:______________

   Responsible Individual:______________________________

   Phone No.:______________

III. Environmental Concerns of Bridge Painting

   Department/Division with prime responsibility:______________

   Responsible Individual:______________________________

   Phone No.:______________

Please Return the Completed Questionnaire by April 15, 1989 to:

Steel Structures Painting Council
4400 Fifth Avenue
Pittsburgh, PA 15213
412-268-3327

TRB SYNTHESIS PROJECT 20-05, TOPIC 20-09
"BRIDGE PAINTING: REMOVAL, CONTAINMENT, AND DISPOSAL"

I. PLANNING OF BRIDGE MAINTENANCE

Prepared by (name):______________________
(title):____________(phone)________
(address):______________________

1. For each of the following items, please identify the department and division with responsibility, the name and title of the individual responsible.

A. Authorize budget for maintenance painting.

Department/Division______________________

Individual:______________________

- At what time of year is this done?______________

B. Selecting specific bridges to be painted.

Department/Division______________________

Individual:______________________

- At what time of year is this done?______________

C. Prepare and issue painting contracts.

Department/Division______________________

Individual:______________________

D. Monitor and inspect painting contracts.

Department/Division______________________

Individual:______________________

E. Assess condition of bridges prior to painting.

Department/Division______________________

Individual:______________________

2. For the following years, please list the approximate number of steel bridges painted and the number of those known to contain lead paint. See TABLE B-1

Year	Number Painted	Contained Lead	Percent
1986	1803	1380	77
1987	1642	1333	81
1988	1315	962	73
1989 (planned)	1741	1308	75
TOTAL	6501	4983	77

TABLE B-1
HIGHWAY BRIDGES PAINTED, 1986-89

	Bridges Painted					Contained Lead				
Agency	1986	1987	1988	1989	TOTAL	1986	1987	1988	1989	TOTAL
Alaska DOT	1	2	0	1	4	0	0	0	0	0
Arkansas DOT	32	46	18	35	131	30	41	16	31	118
California DOT	14	3	16	13	46	14	3	14	12	43
Colorado DOH	1	2	1	2	6	1	2	1	2	6
Connecticut DOT	86	36	20	50	192	86	36	20		142
D.C. DPW	1	2	3	4	10	1	2	3	4	10
Delaware DOT	0	10	3	5	18	0	10	3	3	16
Del. River Authority	0	0	0	1	1	0	0	0	1	1
Florida DOT	24	25	22	10	81	0	0	0	0	0
Hawaii DOT	5	3	3	3	14	0	0	0	0	0
Idaho DOT	0	0	0	0	0	0	0	0	0	0
Illinios DOT	145	135	110	190	580	145	135	110	190	580
Indiana DOH	79	85	48	83	295	NI	NI	45	63	108
Iowa DOT	75	124	58	60	317	75	124	58	60	317
Kansas DOT	33	32	26	23	114	15	12	14	12	53
Kentucky TRC	3	15	4	27	49	3	15	4	27	49
Louisiana DOT	7	2	1	18	28	6	2	1	16	25
Maine DOT	20	20	23	20	83	20	20	22	20	82
Maryland DOT	73	14	48	114	249	73	14	48	114	249
Mass. DPW	65	41	87	25	218	65	41	87	25	218
Mass. TPK. Auth.	0	16	1	0	17	0	16	1	0	17
Miami-D Trans. Auth.	25	10	3	2	40	NI	NI	NI	NI	NI
Michigan DOT	30	50	60	90	230	27	45	54	81	207
Minnesota DOT	72	71	51	50	244	35	38	23	15	111
Missouri DOT	39	68	63	65	235	39	68	63	65	235
MS Hwy. Dept.	7	5	6	4	22	NI	NI	NI	NI	NI
Nebraska DOT	8	8	12	6	34	8	8	12	6	34
New Jersey DOT	1	11	26	42	80	1	11	26	42	80
New Mexico DOT	6	4	4	12	26	6	4	4	12	26
New York State DOT	350	350	150	300	1150	350	350	150	300	1150
ND Hwy. Dept.	3	4	3	2	12	2	1	0	0	3
NY/NJ Port. Auth.	3	3	9	4	19	3	3	9	4	19
Ohio DOT	257	186	100	192	735	129	93	0	0	222
Oklahoma DOT	7	8	0	16	31	7	8	0	16	31
Oregon Hwy. Div.	11	5	8	9	33	9	3	6	5	23
RI Tpike. & Brdg.	1	1	1	1	4	0	0	0	0	0
South Carolina DOH	10	10	0	2	22	10	10	0	2	22
South Dakota DOT	22	22	35	22	101	14	14	0	0	28
Tennessee DOT	25	25	25	25	100	25	25	25	25	100
Texas DOT	92	68	111	60	331	11	59	9	0	79
Texas Tpike. Auth.	0	0	22	0	22	0	0	0	0	0
Thou.Is.Brdg. Auth.-NY	2	2	2	2	8	2	2	2	2	8
Utah DOT	16	16	16	16	64	16	16	16	16	64
Vermont AOT	40	29	39	44	152	40	29	39	44	152
Washington DOT	29	12	26	10	77	29	12	26	10	77
Wisconsin DOT	83	61	51	81	276	83	61	51	81	276
Yearly Totals	1803	1642	1315	1741	6501	1380	1333	962	1306	4981

NOTES: Data derived from responses by 46 State Highway Agencies and 8 other bridge authorities
NI = not indicated

3. Please rate the following factors in order of their importance for selecting a bridge for painting (1 = highest priority, etc.).

   1 Condition of existing paints on structure.

   2 Condition of critical components, e.g. joints, bearings, etc.).

   5 Visibility to public.

   3 Availability of funds within district.

   4 Criticality of bridge location (e.g., key urban intersection or river crossing).

   6 Ease of access or traffic control or locations.

4. How far in advance are bridge paintings planned? 3 mos. 1 6 mos. 14 12 mos. 22 18 mos. 5 Other: 7

5. Which of the following describes your agency's position regarding the FHWA program to participate in bridge maintenance painting?

   23 Not aware of program.

   7 Aware of program, but have not investigated it.

   7 Have investigated the possibility of participation.

   6 State is planning to participate.

   7 State has participated since ______.

   How many bridges have been painted within the program, and total dollar amount.

   /$ over 30 million dollars

<u>Please return this questionnaire to department coordinator</u>

<u>no later than April 15, 1989.</u>

Thank you for your cooperation. Any questions, call SSPC at 412/268-3326.

TRB SYNTHESIS PROJECT 20-05, TOPIC 20-09

"BRIDGE PAINTING: REMOVAL, CONTAINMENT, AND DISPOSAL"

PART II. BRIDGE MAINTENANCE PAINTING ACTIVITIES

Prepared by (name):__________

(title):__________(phone)__________

(address):__________

1. How does your agency deal with paint containment requirements (check all those that apply).

36 included in bid document
20 special guidelines, procedures
65 pre-job meetings
35 special provisions
14 pre-bid meetings
12 not addressed

2. In what year were containment requirements first incorporated into contract?__________

What is date of most recent revision? __________

(Please send copy, if availble, to SSPC at address below.)

3. Within the last 3 years, how many bridges have been painted under the following provisions?

Total Containment 159 Partial Containment 1785 No Containment 1407

4. Who is responsible for the following activities regarding bridge painting?

	Contractor	HWY. AGENCY State	Environmental Agency	Other (specify)
• Selection of containment techniques	27	23	4	FHWA
• Selection of waste sampling techniques	16	19	13	
• Leachable lead testing	19	16	11	Landfill Agreement
• Disposal of hazardous waste	35	7	4	Landfill Agreement
• Disposal of non-hazardous waste	40	3	3	
• Permits for waste disposal	34	6	5	Landfill Agreement
• Selection of abrasives	35	12		

5. Who is considered the generator of waste? 10 contractor 14 state 7 both 12 don't know

6. What types of containment have been used by contractors in your state? See TABLE 2, p. 31.

- Please rate each method for effectiveness of containment: H (highly effective, >80%), M (moderately effective >40-80%) N (not effective, <40% or N/A).
- Please rate each method for productivity in cleaning H (high >75% of dry blast), M (moderate 30-70% of dry blast), L (low <30% of dry blast).

NOTE: Open dry blast estimated at 100 sq.ft./nozzle/hour

	Girder Urban	Girder Rural	Truss	Effectiveness (H, M, or N)	Productivity (H, M, or L)
Tarps/Screens	____	____	____	____	____
Barges	____	____	____	____	____
Rigid Platform	____	____	____	____	____
Negative Pressure Containment	____	____	____	____	____
Close-Cycle Blast w/Metallic Abrasive	____	____	____	____	____
Wet Abrasive Blasting	____	____	____	____	____
Power Tool Cleaning	____	____	____	____	____
Vacuum Blasting	____	____	____	____	____
Other________	____	____	____	____	____

7. What have been the major complaints of the contractors for these jobs? ______________

____

____

8. Other special problems? (e.g., from environmental officials, residents)

______________ ______________________

____

9. What data, if any, have been developed on the costs for the following?

   Containment (i.e. costs/sq. ft. or added percentage)? ______________

   Sampling or Testing?______________________

   Disposal as hazardous waste (i.e., cost/ton)______________

   Disposal as non-hazardous waste? (i.e., cost/ton)______________

10. Additional comments or suggestions.______________________

____

____

<u>Please return this questionnaire to department coordinator no later than April 15, 1989.</u>

Thank you for your cooperation. Any questions, call SSPC at 412/268-3327.

TRB SYNTHESIS PROJECT 20-05, TOPIC 20-09
"BRIDGE PAINTING: REMOVAL, CONTAINMENT, AND DISPOSAL"

PART III: ENVIRONMENTAL CONCERNS FOR BRIDGE PAINTING

Prepared by (name):____________________

(title):__________(phone)__________

(address):____________________

1. Which department/division and individual is responsible for identifying regulations relevant to highway operations in general and for bridge painting?

   Department/Division:____________________

   Individual:____________________

2. What are the major sources of information on regulations in the following areas? List in order of importance ? (1= most important):

	Solid Waste	Air Quality	Soil & Water Quality	Groundwater Quality
Federal/Local EPA	2	2	2	2
State/Local Environmental Agency	1	1	1	1
Other DOTs	6	5	4	6
Periodicals/Newsletters	5	6	6	5
FHWA/TRB	4	4	4	4
Consultants and contractors	7	7	7	7
Manufacturers or suppliers	8	8	8	8
Other________	3	3	3	3

3. How familiar is your department's environmental specialist with the following?

	Not At All	Somewhat	Very Familiar
EPA EP Leach Test	12	24	17
Requirements for Sampling and Disposal of Waste	6	25	23
Availability of Hazardous and Non-Hazardous Waste Sites	8	24	21
Capability of Contractors to meet environmental requirements.	11	29	13
Specific local requirements	7	28	16
Environmental monitoring and compliance	4	27	20

4. How would you characterize your state's attitude to lead paint problems?

   14 Minor problem which we are handling.

   20 Important problem which will affect us significantly in the future.

   20 Major problem we are addressing.

   3 Enormous problem with no practical solutions in sight.

   1 Major problem solved.

5. Please indicate degreee of enforcement in regulations pertaining to bridge cleaning and painting.

	Frequently	Occasionally	None	Agency
Air Quality	17%	39%	43%	
Water Quality (streams)	28%	49%	23%	
Soil/Groundwater	23%	34%	43%	
Solid Waste Disposal	38%	32%	30%	

6. How many times per year do you or others in your department meet with officials from environmental agencies?

	0	1-3	More than 3
On air quality issues	13	21	15
On water quality issues	11	18	21
On solid waste issues	13	21	16
On bridge painting issues	18	20	11

11. Do you have any suggestions on how a highway agency can do a better job of learning about and complying with regulations?

12. Additional comments or suggestions.

13. Has your agency investigated treatment of spent abrasive for

- chemical/physical processing or separation? 7: CA, MA, MI, MO, OH, PA, PANY&NJ
- Re-use in asphalt? 6: CA, MN, MO NJ, NC, PA concrete? 5: CA, MO, NY NC, PA fill? 4: CA, MN, MO, PA

14. Please furnish copy of any test data on leachate testing, waste processing, or other studies relating to bridge paint containment.

Please return this questionnaire to department coordinator
no later than April 15, 1989.

Thank you for your cooperation. Any questions, call SSPC at 412/268-3326

APPENDIX C

SURVEY OF CONTRACTORS AND TABULATION OF RESPONSES

LEAD PAINT REMOVAL QUESTIONNAIRE TO CONTRACTORS
TRANSPORTATION RESEARCH BOARD/STEEL STRUCTURES PAINTING COUNCIL

1. Within the last 2 years, has your firm prepared and submitted bids requiring lead paint containment on 13 overpass bridges? 13 river crossings? 18 total contractors

2. What percentage of bridge painting contracts within the last 3 years have required: _____ total containment _____ partial containment _____ no containment See Tabulated Responses to Question #2

3. Please indicate your usage and the effectiveness of the following containment devices on bridges:

Device	Used Occasionally	Used Frequently	Effectiveness (excellent, good, fair, poor) E	G	F	P	Comments
Tarpaulins	2	13	1	8	5	0	wind, visibility problems
Windscreens	5	5	1	2	4	2	block blast
Barges	7	3	2	5	1	0	difficult, expensive
Rigid Platforms	7	2	2	3	4	0	necessary for rigging
Negative Pressure Containment	4	0	0	2	1	0	worked best, increased cost
Close Cycle Blast With Metallic Abrasives	2	0	0	1	1	0	containment very difficult
Wet Abrasive Blasting	4	1	0	1	3	1	not safe, promotes surface rust
Vacuum Blasting	4	0	0	1	2	1	slow, not cost-effective, more control
Power Tool Cleaning	4	1	0	3	1	1	for arease where can't blast, slow
Others (Describe)	1					1	high pressure water
	1					1	water curtain

4. What is approximate increase in cost for the following situations? See Tabulated Responses to Question #4
Overpass, full containment _____ partial containment _____
River Crossing: full containment _____ partial containment _____

5. Sources of Information on Regulations: For each of the following, indicate whether you use it frequently, occasionally, or not at all.

	Frequently	Occasionally	Not at All
Environmental/Regulatory Newsletter	1	6	7
EPA/DER Meetings	1	6	7
PDCA	4	4	5
SSPC	9	4	3
Other STATE DOTS	6	1	

No.	TABULATED RESPONSES TO QUESTION #2 — Percentage of bridge painting contracts within the last three years requiring the following types of containment:			TABULATED RESPONSES TO QUESTION #4 — Increase in cost for the following situations:			
				Overpass containment		River crossing containment	
	Total	Partial	None	Total	Partial	Total	Partial
1	0	50	50	60%	40%	60%	40%
2	10	10	80	150%	70%	400%	200%
3	0	0	100				
4	10	10	80	40%	20%	50%	30%
5	90	10	0	100%	50%	50%	25%
6	0	50	50			40%	20%
7	60	20	20	35%	25%	50%	40%
8	0	50	50	25%		30%	
9	0	100	0	300%	150%	400%	200%
10	0	100	0	50%	20%	100%	40%
11	10	70	20	500%	200%	800%	500%
12	40	40	20	100%	60%	120%	75%
13	15	85	15	125%	25%	200%	40%
14	50	50	0	30%-50%	30%	35%-50%	35%
15	75	25	0	$1.00/sq. ft.	$0.75/sq. ft.	$2.00/sq. ft.	$1.00/sq. ft.
16				100%	30%	200%	30%
17	HAVE NOT BID ON A BRIDGE JOB REQUIRING LEAD PAINT CONTAINMENT						
18	0	0	100	100%	85%	140%	100%
Avg.	22.5	41.9	36.6	123%	62%	179%	98%

LEAD PAINT REMOVAL QUESTIONNAIRE TO CONTRACTORS
TRANSPORTATION RESEARCH BOARD/STEEL STRUCTURES PAINTING COUNCIL

6. Who are the main persons in your company responsible for obtaining information on regulations?

Mainly listed presidents, vice-presidents

What percent of their time is spent at this activity? 1% to 15%, median = 5%

7. Improving Contracts: Please rate the following features of painting contract.

See Tabulated Responses to Question #7

Item	Favor	Oppose	Comments
Mandatory Pre-Bid Meeting	17	0	
Contractor Select Containment	12	4	
Third-Party Inspection	12	5	
Contractor Responsible for Dust Monitoring	7	8	
Contractor Responsible for Disposal of Waste	7	9	
Requiring Certified Contractor	16	1	

8. Please list other suggestions or comments you have on bridge painting contracts.

See Tabulated Responses to Question #8

9. Please list other structures or industries for which you have performed paint containment work.

See Tabulated Responses to Question #9

10. Please select one or two bridges that you have done containment on and answer the questions in the attached.

11. If you are interested in obtaining information on the results, please list your name, address, and phone number. Also, please check the box if you would be interested in providing additional information.

I would be interested in providing additional information.

Please return questionnaire **(by February 15, 1989)** to:

Lead Paint Removal Questionnaire
Steel Structures Painting Council
4400 Fifth Avenue
Pittsburgh, PA 15213

TABULATED RESPONSES TO QUESTION #7	
Proposed Method for Improving Contracts	Comments
Mandatory Pre-Bid Meeting	
	*Address hazards, questions, expectations
	*Prevents confusion
	*Good if all concerned parties attend
	*Inform contractors as to what to do
	*Would allow contractor to know what the
	owner expects on lead containment
Contractor Select Containment	
	*Competitive responsible bidding
	*Owner should specify
	*Allows flexibility
	*Must be approved by owner
	*Not design engineer for project
	*Contractors must be able to select containment to control costs
Third-Party Inspection	
	*Maintains Quality Control
	*Neutrality
	*Have had workability problems with
	*Very important
Contractor Responsible for Dust Monitoring	
	*Limits liability to others
	*Share responsibility
Contractor Responsible for the Disposal of Waste	
	*Controls parties involved
	*Provided specific guidelines given in advance
	*Share responsibility
	*Most contractors are presently unfamiliar with disposal
Requiring Certified Contractor	
	*Insures quality and performance
	*Dependent on type of certification or rating
	*Provided certification process is open to all

TABULATED RESPONSES TO QUESTION #8	
ORGANIZATION	COMMENTS
1	Create a workable set of regulations
2	Allow silica sand
3	
4	Coatings conforming to EPA standards; more use of acrylic-water emulsified paints to help contamination of waters
5	
6	
7	Specification uniformity
8	
9	
10	Specific procedures should be set forth in contract documents
11	Mandatory attendance of environmental regulatory organizations at pre-bid and pre-construction meetings
12	Scaffolding is a big problem and must be controlled; Inspection is very important, thus inspectors must be qualified
13	More education in the third party or state engineering group for inspection and monitoring
14	
15	Have PennDOT tell contractor what method is to be used to obtain sand, instead of having to guess as to what they want
16	
17	
18	Most prime contractors view painting contracts as a nuisance, especially under a lead-base paint containment program

TABULATED RESPONSES TO QUESTION #9	
Organization	Structures/industries for which paint containment work has been performed
1	Create a workable set of regulations
2	Tanks
3	
4	Various commercial-industrial projects requiring nonstop production and/or debris-free areas adjacent to work (by shrouds, screens, ect.)
5	
6	
7	Plant maintenance painting
8	
9	Boxcars, elevated water towers, pipelines, resevoirs
10	None
11	Water treatment, barrier walls, waste water treatment
12	Chemical industry-tanks and equipment
13	Pulp and paper industry
14	Water towers, tank linings in industrial areas
15	None
16	
17	
18	None

LEAD PAINT REMOVAL QUESTIONNAIRE TO CONTRACTORS
TRANSPORTATION RESEARCH BOARD/STEEL STRUCTURES PAINTING COUNCIL
ATTACHMENT - CASE HISTORY OF BRIDGE PAINT CONTAINMENT

1. Location: City/State ______________________ / ____________

2. Type of bridge: overpass _____ river crossing ______

3. Size: ______ tons ______ sq. ft. Proximity to homes/businesses: 50 ft. ___ 50-200 ft.___ >200 ft.______

4. Condition: paint failing ______ metal loss ______ some intact paint _____

5. Type of Paint Job: complete repaint _____ partial (touch-up) _____ Other ___________

6. Method of Cleaning: ______________________________ Surface Preparation Specification:_______________

7. Method of Containment:____

____

____

8. Paint System Applied: Generic type:__________________ Manufacturer:_________________

9. How many abrasive/paint waste samples were collected? Per Day:____________ Total:______________

10. How many samples were tested? Per Day: ______________________ Total:______________

11. Who did testing? ____

12. What were results of testing?
EP Leach Test (ppm): ___________ Hazardous?_____ Non-Hazardous?_____

13. Was any data collected on air quality (e.g., dust)? Explain. _______________________________

____

14. Who was responsible for disposing of waste? State: ______ Painting Contractor:___________

Special Waste Hauler: ________ Other:____

15. Who took care of permits and licensing? State:____________ Painting Contractor: ____________

Consultant: ________ No One/Don't Know:____________

16. Approximate time to complete job. Estimated: _______________ Actual___________________

17. Approximate bid price of contract:_____________________________ Your cost:______________

18. What were the major problems, if any?____

Additional Comments:____

TABLE C-1
TABULATION OF CONTRACTOR RESPONSES: BRIDGE CHARACTERISTICS

No.	CITY	STATE	TYPE[1]	TONS	SQ FT	DISTANCE[2]	CONDITION[3]
1	Akron	OH	RC	1000	650,000	200+	PF
2	Indiana Cnty	PA	OP		55,000	200+	PF
3	Cambria Cnty	PA	RC		80,900		PF
4	Fergusi		RC		20,000	50-200	SIP
5	Toronto	ONT	OP		28,000	200+	PF
6	Powers	MI	RC	85	15,700	50-200	PF/SIP
7	Cedarburg	WI	RC	120	21,500	<50	PF/SIP
8	Grand Rapids	MI	OP			50-200	PF
9	New Haven	CT	RC		16,000	<50	ML
10	Philadelphia	PA	7BR	952		>50	PF
11	Leominster	MA	OP		12,000	50-200	SIP
12	Groveland	CA	RC		40,000	200+	SIP(mostly)
13	Tujunga	CA	RC		30,000	200+	PF/ML
14	Toronto	ONT	RC		150,000	200+	PF/SIP
15	Flint	MI	RC		16,000	200+	
16	Durmmon	NB (Can.)	RC		250,000	200+	SIP
17	Grandfalls	NB (Can.)	RC		60,000	200+	PF
18	Bessemer	PA	RC		5,000	200+	PF
19	Buffalo	NY	RC	780		200+	PF
20	Tona	NY	OP	138		200+	SIP
			average sq ft:		90,631		

1. RC = river crossing; OP = overpass
2. Distance in ft from home or business
3. SIP = some intact paint; PF = paint failing; ML = metal loss

TABLE C-2
TABULATION OF CONTRACTOR RESPONSES: REMOVAL AND CONTAINMENT

No.	METHOD	SPEC	CONTAINMENT	PAINT	MFR	SAMPLES		TESTS	
						/DAY	TOTAL	/DAY	TOTAL
1	TARPS				SWP	0	250	0	150
2	DRY BLAST	SP-10	SEE NOTE 1	IN ZINC	PORTER	10 SH	50		1
3	DRY BLAST	SP-10	SEE NOTE 2	IN ZINC	AMERON	10 SH	20		1
4	SANDBLAST	SSPC-10	SEE NOTE 3	ZINC/VINYL	AMERON				
5	BLAST NOTE 5	SP-7/6	PARTIAL ENC	IN ZINC/VINYL	INTL PT				
6	LOW DUST	SSPC-10	RIGID PLAT/NOTE 4	ZINC EPOXY URETH	SHERWIN		3		3
7	BLAST	SP-10	FULL CONTAINMENT	ZINC/VINYL	CARBOLINE				
8	SANDBLAST	SP-10	TARPS & CABLES	ZN/EPOXY/URET.	AMERON	1	15		3
9	PT AND SB	/SP-10	TARPS, SCREENS	EPOXY AL MASTIC	SHER-WIL	1	8		
10	BLAST	SP-6	SEE NOTE 4	ALUM MASTIC	CARBOLINE		7		3
11	BLAST/STEAM	SP-5	TARPS	LEAD-BASED	CADILLAC		1		1
12	STM/SPT BLST	SP-6	RIGID PLATFORM & TARPS	WATERBORNE	KOPPERS	0	1		1
13	BLAST	SP-10	NONE	ORG ZN/VINYL	KOPPERS				
14	BLAST	SP-10	TARPS & CHUTES	ZINC/VINYL	VALSPAR				
15	BLAST	SP-5	RIGID SCAF PLATFM	3-COATS		1	2	1	2
16	BLAST	SP-6	NONE	EPOXY	DEVOE				
17	BLAST	SP-6	NONE	EPOXY	DEVOE				
18	BLAST,B.BEAUTY	SP-10	TARPS & DRUMS	IN ZN/EPOX/URET	AMERON	1	3	1	1
19	BLAST	SP-6	BARGE, SCREEN	COAL TAR EPOXY	SHER-WIL	1	48	1	15
20	SPOT BLAST		ENVIROSCREENS	ALKYD	CON-LUX	3	21		

1. Built platform under bridge, sand sucked up twice a day
2. Used tarps from handrail down 50 ft, laid tarps on ground to collect all debris, sucked up sand; in the area over the river, sand fell in
3. Superstructure: top, partial enclosure; bottom, complete enclosure
4. Platforms, sheeting, tarps, windscreens
5. Partial painting

TABLE C-3
TABULATION OF CONTRACTOR RESPONSES: TESTING

No.	TEST LAB	PPM	HAZ?[1]	AIR QUALITY DATA	DISPOSAL[2]	PERMITS
1	MESMORE		NH	NO	PC	PC
2	BROCKWAY	12.5	H	NOT REQ'D	PC	PC
3	BROCKWAY	3.2	NH	NO	PC	PC
4	NO TESTINGS			NO	PC	STATE/PC
5						
6	STATE OF MI		H	N.A.	STATE	STATE
7	NONE			NONE	PC	STATE/PC
8	MICH STATE U		H	NO	STATE	STATE
9	EPA		NH	EPA INSPECT	PC	PC
10	CITY OF PHILA		H	NO	PC	PC
11	APPROVED LAB	22.0	H	NO	PC	PC
12	PRIVATE LAB	490.0	H	NO	PC (LIC)	STATE
13						
14	MTO, ONTARIO		NH	NO	PC	DISPOSAL CO
15	MIDOT		NH	TOTAL DUST CONTAINMENT	PC/OTHER	STATE
16					PC	NO ONE
17					PC	CONSULT
18	PTL	4.8	NH	NO	GENERAL	GENERAL
19	CITY OF BUFFALO		NH	NO	PC	PC
20	NYS DOT			NO	STATE	STATE

1. H = hazardous per EP-TOX; NH = nonhazardous
2. PC = paint contractor; DC = disposal contractor

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