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INSPECTION OF COATING SYSTEMS ON CIVIL WORKS STRUCTURES: LESSONS LEARNED

by
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The U.S. Army Corps of Engineers (USACE) builds, operates, and maintains a large number of Civil Works structures such as dams and bridges. To protect these important structures against rust and corrosion, it is essential that they be coated using the proper systems and techniques. Quality assurance (QA) for Civil Works costing systems is provided through the use of paint meeting Government-approved formulas; QA during application is the USACED inspector's responsibility. To ensure proper application methods, the USACE inspector in the field must be both knowledgeable and vigilant. When a paint job is inspected at each stage, potential problems often can be identified and corrected before remedial action becomes prohibitively expensive.

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FOREWORD

This work is based on field consultation performed for U.S. Army Corps of Engineers (USACE) Civil Works Districts and Divisions on a reimbursable basis.

The work was conducted by the Engineering and Materials Division, U.S. Army Construction Engineering Research Laboratory (USACERL-EM). Dr. Robert Quattrone is Chief of USACERL-EM. Alfred Beitelman was the USACERL Principal Investigator. Dana Finney is a writer-editor in the USACERL Information Management Office.

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INSPECTION OF COATING SYSTEMS ON CIVIL WORKS STRUCTURES: LESSONS LEARNED

1 INTRODUCTION

Background

The U.S. Army Corps of Engineers (USACE) is responsible for construction, maintenance, and repair of many Civil Works structures nationwide. These structures are massive in both number and size, and include hydraulic systems (e.g., locks and dams), piers and other shoreline fixtures, barges, bridges, storage facilities such as metal tanks, and all related appurtenances. Most are constructed of steel or other metal and a large number are submerged in various types of waters. Due to the importance of these structures, the catastrophic results of a failure, and the high cost of replacement, it is critical that they receive optimal protection against damage from corrosion. The most common form of protection is some type of coating system, usually involving multiple coats of protective paint compounded to meet Government formulations and specifications. While cathodic protection is an effective corrosion deterrent in many applications, it can be expensive to operate and therefore is usually installed in conjunction with coating systems.

For these structures, most USACE painting contracts specify Government-approved paint based on specific formulations. The Government has a very strong research program in coatings and has many years of experience with a variety of products. Standard specifications for paints include chemical properties such as solids content, pigment, and viscosity, as well as performance requirements in immersion tests. In addition, contract documents contain requirements for thinning, mixing, and applying the coating under different environmental conditions.

To provide an effective coating, all requirements for the specified system must be met. In terms of formulation, a qualified laboratory normally tests each proposed paint batch to determine if it meets the specified requirements. This testing is usually done at the request of the local USACE District or Division. Quality assurance during application is the USACE inspector's responsibility; inspection must begin with surface preparation and follow every phase of the painting operation.

The U.S. Army Construction Engineering Research Laboratory (USACERL) provides USACE with testing and troubleshooting services for paint systems on Civil Works structures. The USACERL Paint Laboratory is a center of expertise for Government research and development in coating systems. The vinyl paints used on most Civil Works structures were developed at USACERL, where there is a continuing effort to revise these formulas as necessary to meet changing raw material availability or new application technologies. In addition, the guide specification used for most Civil Works contracts was drafted at USACERL. The Paint Laboratory is a member of the Steel Structures Painting Council and has established contacts with paint and equipment manufacturers as well as other professional organizations involved in paint technology.

An unfortunate trend over the years has been that USACERL is called to a site only after a serious problem develops; often it is too late to repair the defect properly without removing the entire coating system from a structure. In cases for which a job has been accepted, this type of remedial action incurs a very high cost to the Government.

Moreover, work rejected during contract enforcement often results in disputes and claims, again involving a potentially great expense to the Government for litigation. Because of this no-win situation, the corrective actions usually prescribed in these cases are less than ideal.

USACERL's experience in the field has shown that most painting failures can be traced to one or more improper procedures during application. Thus, the burden is on the USACE inspector (or contractor representing USACE) to follow a rigorous program of checking each completed step before allowing the contractor to proceed. Early detection of problems can avoid the high cost of a total system failure. By pointing out the deficiencies during a given phase of work, inspectors give their contractors fair and adequate notice that work is unacceptable and something must be done to improve it; this notice is required by the contract. Regular inspection has a hidden benefit, as well: when contractors realize their work will be checked at each step and rejected if inadequate, the motivation to produce a quality coating increases dramatically.

Purpose

The purpose of this report is to describe lessons learned during the past 15 years of consulting on Civil Works coating projects. This information is intended to provide information to assist USACE inspectors in identifying unacceptable work and determining how it can be corrected.

Approach

USACERL sends its coatings experts to an average of 12 Civil Works sites per year. In addition, many fresh and dried paint samples are sent to USACERL for testing and analysis. Results are analyzed statistically and each transaction is documented thoroughly in a Memorandum for Record (MFR). The information in this report was extracted from these MFRs and summarized by the different types of errors that have led to coating failures.

Mode of Technology Transfer

USACE has designated USACERL as the Paint Technology Center to provide a single point of expertise for field operating agencies. Each year, USACERL conducts a one-week training seminar in-house for USACE personnel involved with the specification, use, or inspection of Civil Works coating systems; in addition, instructors from the Paint Technology Center travel to several Civil Works Districts throughout the year to train personnel in specific aspects of paint inspection. The information in this report will be used to prepare a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Technical Note.

2 LESSONS LEARNED

As noted in Chapter 1, most coating defects are due to improper application techniques. However, a coating failure is often the result of two or more incorrect procedures having a combined effect. Out of some 100 field visits, defects were attributed to inadequate performance of the following steps (approximate percentages):

Cause of Defect	Percent Occurrence
Application	44
Mixing and thinning	40
Surface preparation	32
Other	24
Coating selection	12
Spot repairs	6

Problems occurring and lessons learned in each of the above steps are described below.

Improper Coating

The coating system to be applied to Civil Works structures is nearly always specified in terms of Government formulations and specifications. Civil Works Guide Specification (CW) 09940[1] is the reference cited most commonly in contracts for painting. This guide specification is tailored for each project by revising the information to suit the needs and conditions of the particular structure. The resulting document defines the surface preparation and coating to be used, application method, final dry film thickness, finished appearance, and all related factors.

The coating system to be used on a given structure is selected by engineers at the USACE District or Division that will oversee the project. The coating is specified following all applicable directives (e.g., Engineer Manual 1110-2-3400[2] and technical notes found in the guide specifications). The structural material, atmospheric conditions at the site, and intended use are all considered. For example, a steel gate to be submerged 80 percent of the time in abrasive waters would have different requirements than a service bridge or a stoplog. Another issue that must be addressed is the need to comply with local regulations on coatings. Some states prohibit shop application of paints for which field application would be permitted. In addition, District policy may dictate whether red lead paints can continue to be used for maintenance. Thus, the selection process is extremely focused.

Because of the guidance available and the care taken in choosing paints, it is rare that a coating system fails as the result of improper specification. However, such cases have been observed occasionally in the field. For example, at one site, flash rusting was unavoidable due to the high humidity and heavy dew; with the resulting surface conditions, the zinc-rich coating specified could not be applied successfully and an alternative

[1]Civil Works Guide Specification (CW) 09940, *Painting: Hydraulic Structures and Appurtenant Works* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], August 1981).
[2]Engineer Manual (EM) 1110-2-3400, *Painting: New Construction and Maintenance* (HQUSACE, 20 June 1980).

coating system had to be selected. In another case, the specified coating did not meet safety requirements because the interior space to be coated had inadequate ventilation.

Concrete structures also have been found to have poorly selected coatings. The alkalinity of concrete, especially when newly cast, can cause a chemical reaction between the surface and certain coatings such as oil-based paints. In addition, the dampness associated with concrete-lined spaces must be considered. A latex paint or cement-based sealer can be used in some cases, while in others, epoxy coatings are more desirable.

Specific conditions at a site often are difficult to anticipate when selecting paints. Any time a paint is suspected of being improper or unsafe in a particular situation, work should be delayed and the inspector should notify the Resident Engineer, who should seek assistance from qualified professionals. In addition, all new batches of paint should be subjected to analysis by a Government approved laboratory before any is applied. Some coating failures have resulted from paints that did not meet specifications. USACERL can test fresh paint samples on a reimbursable basis; the cost is $200 per sample and results are usually available within 1 week.*

Deficient Surface Preparation

Most of the coatings specified for Civil Works structures demand very meticulous surface preparation to ensure proper adherence. These surfaces usually must be cleaned to a grade approaching white metal (Steel Structures Painting Council [SSPC] Specification SP5) by sandblasting with properly sized abrasives. Conditions that suggest deficient surface preparation include:

- An obvious failure to meet the specified finish, such as mill scale, dust, rust, or old paint remaining on the metal

- A grainy texture in the coating (although this appearance can also be caused by overspray or spraying the paint with insufficient thinning as described later)

- Poor adhesion, lifting, or peeling of the coating from the substrate (Figure 1)

- Visible defects in the painted surface that indicate a previous coating has not been removed completely (or, in the case of spot repairs, discontinuities that indicate the feather edges from the previous coating have not been brushed away or removed with solvent)

- Blistering due to rust or moisture on the surface at the time of application or due to incomplete sandblasting and blowdown (Figure 2).

Contractors often conduct several phases of the painting operation at once to maximize efficiency. As a result, areas may be coated before the inspector has the opportunity to check the surface preparation. Inspectors should inform their contractors not to paint any areas until the surfaces have been accepted as meeting specifications in

*Send samples to: USACERL, ATTN: Paint Laboratory, P.O. Box 4005, Champaign, IL 61824-4005.

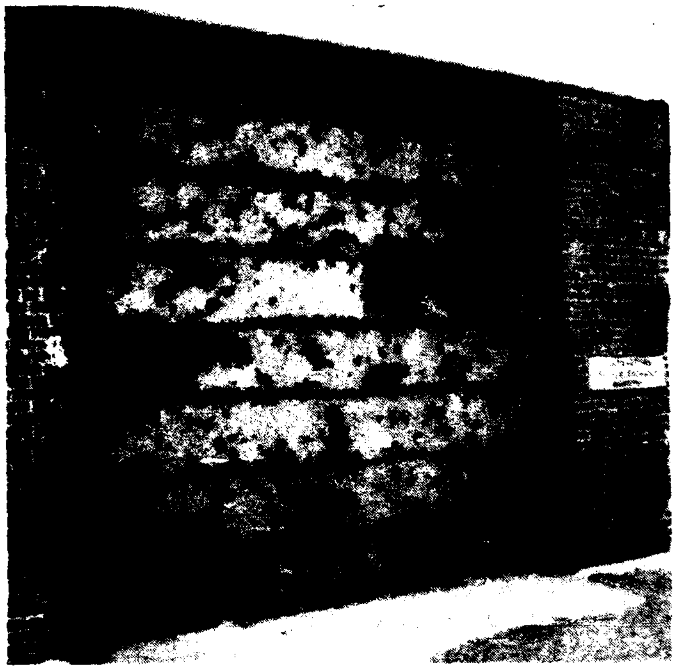

Figure 1. Peeling due to poor surface preparation.

Figure 2. Blistering on improperly prepared steel (fresh water immersion).

accordance with contract requirements. If painting has proceeded and one of the above conditions has been discovered, the entire area containing the defect must be stripped by sandblasting and recoated. Despite the number of coats a structure will receive, a poorly prepared surface will always compromise the protective value of a coating. Adhesion will be affected by dust or residual abrasive remaining on the surface, flash rusting due to moisture in sandblast lines, condensation or spray from leaking stoplogs, and salt and oils in human sweat falling on freshly blasted steel.

To determine if surface preparation was satisfactory, scrape off a small sample of the dried paint and look at the surface side with a magnifying glass; the presence of small particles such as sand or rust is evidence that cleaning was not satisfactory. In some cases, the surface may have been blasted clean enough but the residual sand was not vacuumed or blown down. If this problem is noticed before the coating is applied, the contractor can correct it by wiping down the surfaces with a solvent-saturated cloth or blowing with clean, compressed air. The cleanup procedure should be improved for subsequent sandblasting.

The inspector should be especially attentive to dust on surfaces when the contractor is using airless spray. Painters using conventional spray can easily use the atomization from their guns to blow off residual dust or grains of abrasive. However, contractors who use airless spray do not have a compressed air supply readily available and may be tempted to paint over the contaminants.

Another important point with regard to sandblasting is the distance between the compressor and blast nozzle. At one project, the contractor was piping air and abrasive more than 1000 ft to avoid having to relocate the compressor for different areas of the structure. This arrangement allowed moisture to condense inside the hose, with subsequent deposition onto the surface. As a result, the surface flash-rusted before the paint was applied, which caused poor adhesion. Sandblasting hoses should be as short and straight as possible. In addition, an effective moisture separator should be located as close as possible to the sandblast pot.

While checking the contractor's sandblasting operation, the inspector should note if workers are attired and protected properly. Specifications usually require these workers to cover all parts of the body with clothing and to wear air-fed hoods. Besides the sandblast operator, other persons in the area (e.g., inspectors, pot tenders) should also be wearing eye and respiratory protection. The inspector should recognize the dangers to all persons in the blasting area and ensure that the necessary precautions are followed. Also, for operator safety, the abrasive hose must be equipped with a deadman control valve and it must be used as designed. Experience has shown that many contractors do not have a deadman control on their equipment or, when one is available, it has been wired or taped, thus eliminating its effectiveness.

Some coatings require less stringent cleaning (e.g., long oil primers like TT-P 86 Type I and SSPC Paint 25). For these projects, the inspector should examine the surfaces to ensure that, as a minimum, all dirt, loose rust, and loose coatings have been removed. While these coatings are capable of penetrating residual amounts of contaminants, contractors tend to provide (and inspectors tend to accept) a lower grade of surface preparation than is actually stated in the specification. This situation results more often when a low grade of surface preparation is specified than when a high grade is required. In all cases, the specification requirements should be enforced strictly.

Improper Thinning

Most of the coatings specified for Civil Works structures are designed to be thinned with a solvent before spray application. The solvent serves a dual function: it makes the paint more fluid so that it can be atomized properly and it keeps the paint wet longer so that, after it strikes the receiving surface, it can flow out properly. Paints such as vinyls V-766 and V-102, which are typically specified for structures to be submerged, must be thinned in the field as specified by the contract. Failing to thin, adding too much or too little solvent, and using the wrong type of solvent have all been identified as causes of coating failure.

Since these coatings are applied by spraying, they must be thinned a suitable amount for trouble-free equipment function. Therefore, if a contractor appears to have a problem with paint not atomizing, it is possible that the formulation has not been thinned as specified or that the nozzle is larger than recommended for the particular paint. If the coating has many runs or is not providing the specified thickness per pass, too much thinner may have been added. The vinyl paints mentioned above usually require 10 to 20 percent thinning; however, the exact amount of thinner will depend on the coating system(s) used, the type of solvent, and environmental conditions. In addition, painters will usually need to experiment at first to determine what level of thinning works best with their equipment.

The inspector should check on the type of thinner being used. Specifications for these paints usually require the contractor to decide which solvent to use based on ambient temperature at the site. That is, for work being done in temperatures under 50 °F, methyl ethyl ketone (MEK) would be indicated. If temperatures are between 50 and 70 °F, the choice should be methyl isobutyl ketone (MIBK); above 70 °F, methyl isoamyl ketone (MIAK) should be used. These temperatures are listed in the contract; however, they should not be considered exact cutoff points such that a 1° temperature change requires the contractor to change thinners. Both the painter and inspector should examine the applied paint as ambient temperatures approach the various plateaus. As the temperature rises, more thinner may be required to avoid overspray. As the temperature falls, less thinner will be necessary to increase film build and prevent sagging. Painters will find a point (temperature) at which switching to either a slower or faster thinner will produce better film build without overspray than will adding more of the same thinner. This point should be the criterion for changing thinners. If the weather fluctuates through these plateaus during a project, the thinner should be substituted as necessary. Like the paints, solvents must be tested and approved as meeting the required specifications.

Applying paint "too dry" is a very common cause of coating failure. This condition results when paint reaching the surface is not fluid enough to flow out into the sandblast profile and bond together for a smooth, continuous finish. Instead, the paint has dried completely or partially before striking the surface. Evidence of applying a paint too dry is described in detail under **Improper Application Methods** below; at this point, it is noted that insufficient thinning is one possible cause of dry application (i.e., the paint has not been diluted to the required "wetness" or viscosity).

All of the solvents used to thin paints are potential health hazards. Therefore, the inspector must ensure that painters wear respirators, hoods, and protective clothing, as needed, during application. Specific requirements are stated in EM 385-1-1[3] and often are included in the contract.

EM 385-1-1, *Safety and Health Requirements Manual* (HQUSACE, 1 October 1987).

Improper Application Methods

Coating deficiencies often result from a combination of factors such as too great a spray distance, poor surface preparation, and thinning with the wrong solvent. However, the single factor having greatest impact on the success of a coating is the painter's expertise. Well trained painters should be able to recognize when there is a problem with the coating or the surface and bring it to their supervisor's attention; they should be familiar enough with the equipment being used that they can make necessary adjustments in pressure and other parameters to achieve the best results.

In practice, painters are rarely this knowledgeable or experienced in paint technology. Therefore, it is critical that USACE inspectors have thorough knowledge of painting methods, causes of defects and remedies, and the requirements stated in the contract. The following conditions are evidence of improper application:

- Overspray
- Runs and sags
- Pinholes (Figure 3)
- Entrapped air bubbles
- Insufficient coating buildup or too much variation in thickness
- Bleedthrough from rust or previous coats
- Poor intercoat or coating-to-surface adhesion (delamination)
- Pinpoint rusting
- Pitting (Figure 4)
- Holidays.

Some of the more common defects are highlighted below.

Pinholes

Of the above conditions, the one seen most frequently is pinholing, which is usually discovered upon very close inspection. If a pinhole extends to the metal surface, corrosion will occur. This defect is usually caused by spraying the paint either too dry, as mentioned in the previous section, or too wet; however, factors other than thinning can contribute. For example, when the painter holds the nozzle too far away from the surface, the paint will be applied so dry that the atomized particles cannot flow together, thus leaving small voids or pinholes; or, the pressure may be set too high, the gun held too close, or the atomization is so coarse that the particles of paint cause splashing, which entraps air. As the air bubbles break, the paint is already so dry that the voids do not flow shut, leaving the pinhole. Both the equipment manufacturer and paint formulator usually list optimal paint/nozzle combinations. The painter should follow their recommendations and, if any problems are experienced, try to determine the reason and correct it.

Another common reason for pinholes is the use of airless spray or conventional internal mix equipment. Painters inexperienced with using airless equipment to apply a fast-drying lacquer coating such as vinyl often use excessive pressures and larger tips than optimal to attain a heavy film build and good production rate. This action results in poor atomization and an abundance of pinholes. A proper airless setup would include a very small tip to obtain proper atomization and additional thinner to reduce the necessary pump pressure. The contract usually states that airless equipment can be used if the "coating quality meets or exceeds that obtainable with conventional equipment." It should therefore be assumed that if a painter cannot apply a void-free coating using airless equipment, he/she should convert to conventional air atomization. It should also be noted that, for conventional spraying, the operator needs to be able to regulate the air supply at the pressure pot or transformer. Cheater valves added to the spray gun are nothing more than secondary volume controls equal to the capacity already built into the gun. They cannot duplicate the effect of a pressure control valve and should never be used for this purpose. Finally, conventional internal mix spray equipment is not designed for fine finishing and should never be used to apply vinyl coatings.

Besides being a common defect, pinholes are especially troublesome because there is usually no "quick fix." If pinholes appear in one coat, they will most likely appear in all succeeding coats. If the problem is noticed early enough and does not cover an extensive area, the painter can attempt to seal the holes by brushing a thick layer of paint into the surface, forcing it into the pinholes, or by physically melting the holes closed using solvents. However, for structures where a large percentage of the coating has pinholes or where rust has formed in the pinholes, the only acceptable remedy is to remove the entire coating by sandblasting to the original specification requirements and repainting. The prohibitive cost of such a repair underscores the inspector's responsibility in checking each phase of the painting. It is much less devastating to remove one or two coats of paint than to lose five to 10 coats; moreover, early discovery of a problem will allow the contractor to make adjustments before too large an area is affected.

Figure 3. Pinholes with pinpoint rusting.

Figure 4. Pitting.

Insufficient Coating Buildup

The painting contract will specify a dry film thickness (DFT) for the coating to be achieved in each pass and a final DFT. The inspector should perform a random check on the painted surfaces after each coat to determine if the proper thickness has been attained (average of several measurements). The best tool for taking these measurements in the field is a magnetic dry film thickness gage, costing from $300 to $900 (1989 dollars). No special skills are required to use these instruments. Every paint inspector should have one which has been calibrated for use on the profile of the sandblasted steel (not bare, smooth surface). Calibrating the gage as specified in the contract will ensure accurate measurements in the range of the calibration.

If surface measurements show that the required thickness has not been achieved, the contractor should investigate the reasons. It is possible that the paint has been thinned too much. If the DFT varies a great deal from one area to another, the painter's technique should be assessed. Effective spray painting requires the operator to hold the spray gun perpendicular to the surface at approximately 8 to 12 in.* away. Under normal conditions, painters should maintain this spray distance at all times. If the distance must be reduced due to the confines of the structure or high wind velocity, the spray gun should be adjusted appropriately. The spray distance should never exceed 12 in. Passes should be smooth and overlapping about 50 percent. Painters showing erratic performance should be instructed in the correct procedures.

Two defects related to excessive coating buildup are runs and sags. In an attempt to save time and labor, contractors may apply coatings thicker than specified; the effect of this heavy application can be both unsightly and counterproductive. A heavy coat of paint may not dry or cure properly before the next coat is applied. In addition to runs

*1 in. = 2.54 cm.

and sags, this condition can produce poor adhesion between the coating and surface and/or between successive coats, wrinkling of oil-based paints, and solvent entrapment with subsequent poor performance in other coatings. It should be noted that a thick coating may not be intentional; it can be due to the pressure setting on the equipment or to paint that has not been thinned properly. The problem should be diagnosed and adjustments made to ensure that all succeeding coats are within the specified requirements.

Although it is always possible to prevent runs and sags, even on complex structures and in the areas around bolts and welds, the inspector must sometimes overlook these defects in the interest of providing good protection on irregular surfaces. The overriding criterion must be the protective qualities of the paint system. Runs and sags containing voids detract from the protection offered by the paint and therefore must be removed. However, such defects not containing bubbles, pinholes, or other voids often should be accepted instead of requiring the contractor to repair them due to the time, cost, and potential for new damage that could be inflicted to the surface during this repair effort.

Other Types of Coating Failures

USACERL has observed some unusual cases of coating failure that were not caused by any of the shortfalls described above. One example is a coating that was lifting and corroding underneath as the result of a potential difference between dissimilar metals. This condition could be corrected using cathodic protection. Other failures have been caused by an improperly maintained cathodic protection system causing the coating to blister. Excessive buildup of previous oil-based paint systems frequently leads to failures on older structures. Damage due to welding on the back side of a painted surface also has caused some unusual failures. Moisture migration through wood and concrete substrates often causes paint peeling. In one case, it was documented that Mayflies, common insects along many waterways, ate holes in an applied proprietary coating, thus causing its failure.

"Spot" Repairs

Even the most diligent inspector may discover flawed or damaged coatings at some advanced stage in the life of the paint system. In general, "spot" repairs of such work are not effective; it is too difficult to ensure that the surrounding paint is feathered back properly such that all edges are sealed to the surface. However, *area* repairs are permissible. The contractor should repair an area encompassing the defect(s) where there are defined edges on the structure (e.g., the downstream face of a gate or the area from the water line down). The entire area should then be sandblasted to specifications and repainted. In cases for which a very large section of the structure has random defects such as pinholes or rust-through, the area should be completely reworked. As usual, the reason for the defect should be identified so that the contractor can make adjustments that will result in an acceptable coating.

3 SUMMARY

USACERL's experience has shown that most coating failures on Civil Works structures result from improper or inadequate surface preparation, thinning and mixing, equipment selection and setting, and coating technique. The resulting defects could be prevented through regular inspection by a qualified inspector.

A common complaint in the field is that personnel shortages preclude an active inspection program and that funds are not available to support new hires. However, it may be possible to contract inspection to an outside party at a lower cost than hiring in-house personnel because of extra training costs. Moreover, the situation must be viewed in a broader economic sense. While hiring qualified inspectors will incur a cost, proper inspection will ensure an effective coating with maximum service life. The cost of inspection must be weighed against the expenses involved when a coating fails:

1. If a defect goes unnoticed until final inspection, the contractor will not be amenable to complete replacement because he/she stands to lose money--perhaps forfeiting the entire profit margin or even forcing bankruptcy. Therefore, the contractor may sue USACE for the extra work. Whether USACE wins or loses, litigation is extremely costly and can delay further work on a project.

2. If the failure occurs several months or years after the work is done, USACE will bear the cost of replacement. For large structures, this cost can be in the hundreds of thousands of dollars.

3. Without timely replacement of a failed coating, the Civil Works structure can sustain major damage, requiring expensive repairs or perhaps new construction--incurring an even greater cost to USACE.

The huge cost associated with a coating failure clearly justifies the investment for qualified inspectors--either in-house or contract. By identifying problems before they become major defects, inspectors give the contractor an opportunity to correct the procedures being used. In addition, the mere presence of a knowledgeable inspector can improve contractor performance: when contractors understand that quality work is expected and that the inspector will reject anything less, they tend to give a job their best effort.

An inspector does not have to be a chemist to become qualified. The results of USACERL's research and development in paint technology are presented in a 1-week seminar each year designed for USACE inspectors. This program is offered through the Huntsville Division training branch. In addition, onsite training can be arranged on a case-by-case basis under a reimbursable order.

The inspector's role in preventing coating failures cannot be overstressed. Civil Works Districts and Divisions are urged to provide at least one knowledgeable inspector for the duration of a coating project. Whether this inspector is in-house or contracted is a District/Division decision.

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ATTN: Canadian Liaison Officer 65473
ATTN: German Liaison Staff 65473
ATTN: French Liaison Officer 65473
ATTN: Water Resources Center 22060

US Army Engineer Districts
ATTN: Library (41)

US Army Engr Divisions
ATTN: Library (14)

NAVFAC
ATTN: Division Offices (11)
ATTN: Facilities Engr Cmd (9)
ATTN: Naval Public Works Ctr (9)
ATTN: Naval Civil Engr Lab (3)
ATTN: Naval Constr Battalion Ctr

Burea of Reclamation (Dept of Interior)
Denver, CO 80225

Tennessee Valley Authority
Knoxville, TN 37902

Defense Technical Info. Center 22314
ATTN: DDA (2)

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