Using Electronic Tools and Databases to Manage Coatings used for Corrosion Control

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ABSTRACT

This paper will explore the use of electronic tools and databases to facilitate efficient use of protective coatings for corrosion control. Electronic tools and databases are available which may impact quality assurance, condition assessment, maintenance planning, and expert systems. For various reasons, few of the tools which are developed gain widespread acceptance or use. Collecting and managing data for corrosion control coatings remains a paper-intensive activity for most owners. The paper will review the author's experience in assisting in the development of several different systems and the lessons learned in the implementation of such systems within the Department of Defense (DoD), private industry, and the bridge industry. The intent is to help future designers developing such systems.

KEY WORDS

Protective coatings, computers, database, process optimization, quality assurance

INTRODUCTION

Over the past several years there has been a substantial increase in efforts to manage protective coatings application work and extend coating life. These efforts manifest themselves in the form of enhanced quality assurance programs, condition assessment tools, maintenance planning, and expert systems. A simple Google® search of such terms will find well over 1,000,000 hits. And while many of such tools are not directly related to industrial/military painting, a substantial number do appear related and tout substantial gains in painting program efficiency, optimization of coating life, and reduced overall cost. These tools are offered by coating consultants, maintenance software developers, and paint manufacturers. And to be sure, many of these tools probably offer advantages to prospective users vs. less formal ways of managing and implementing painting projects.

Yet to a large degree, it appears that most of the industrial and military users of protective coatings do not rely on such tools to manage their painting processes or maintenance programs. It may be instructive to consider why such tools do not find more widespread use.

The authors' perspective in this regard is derived from the development and deployment of several computerized coating management systems for both the industrial and military marketplaces. These systems have included maintenance planning/optimization tools, products to streamline the collection of quality assurance data, and the development of expert, decision making tools for painting programs.

DISCUSSION

Maintenance Planning/Optimization Tools

Maintenance planning/optimization tools may be defined as software products that intend to track the condition of a large inventory of painted structures. Based on these conditions, the owner's maintenance objectives, and expected coating deterioration rates, the tools provide a recommended maintenance painting plan, usually in terms of recommended priority to minimize painting costs.

In general there appear to be three (3) different types of tools in this area:

- Complex, stand-alone database programs that seek to integrate and track comprehensive data about the condition and maintenance painting history of multiple structures.
- Generic packaged maintenance planning software where protective coatings are treated similarly to other maintenance planning, e.g., periodic facility maintenance items.
- Custom packages intended uniquely for specific facilities. These packages have been developed with varying degrees of complexity.

By their nature of tracking multiple related issues, such as structure condition, painting history, contractor selection, and predicted coating performance, the complex, stand-alone database programs would seem to offer the most comprehensive planning tool. Unfortunately the complexity of the standalone systems is also a drawback. They typically are pre-configured with limits on designation schemes for the facilities to be tracked, which may or may not agree with existing owner schemes. Similarly, their inspection schemes may not always relate to the owners inspection protocol, and, as a result, the optimization engine may not produce valuable results. Some such systems also stipulate that the owner configure the system with predicted system lifetimes. While obviously important, this data can be missing or of such generic description that it fails to truly address remaining life for existing structures. For example, while the nominal expected age to coating failure may be predictable (with a range), it becomes more difficult to establish the remaining life in a structure that has exhibited 10% of the eventual failure criteria at a given point in time.

Generic maintenance planning software, wherein coatings are treated similarly to other facility maintenance, usually do not offer a comprehensive value. Most facility maintenance items are regularly scheduled processes and the software is designed to track such efforts. Coatings, especially within complex structures or weapon systems, do not lend themselves to replacement on regular intervals—furthermore coating inspection is also often on a non-regular interval, especially detailed inspections needed to properly rate condition structure.

Custom packages would seem to offer the best solutions for most maintenance planning/optimization tools solutions. For coatings however, custom packages do not directly equate to high complexity and cost—they are simply more user friendly as they can be tailored to a complexity and work process that parallels the user's daily needs. The authors' have assisted in the development of packages based on Microsoft Excel® spreadsheets to complex Oracle® Database SQL with program costs of several thousand dollars to several hundred thousand dollars. The driver in terms of software is primarily related to the amount of data to be contained within the system, the number of users, and the Information Technology (IT) policies of the owner-organization. Higher cost does not correlate with higher performance or better predictions.

Custom packages usually afford the best possible method of capturing data from complex structures in a format that is consistent with an ongoing inspection program. This includes both the way the data is stored and the inspection data itself. This is a key, for owners are usually reticent to modify a long-term inspection protocol to fit a particular software package. For many owners the inspection protocol can be associated with a particular regulatory reporting process or as data that feeds into a larger database of system conditions. And experience suggests that common ownership of multiple structures does not guarantee similar inspection protocols at each location. The ability to customize becomes a necessity.

In developing customized inspection schemes and data collection schemes that might be used in a database, it is also important to consider ahead of time how the data will be used for optimization planning. At times, certain structures such as bridges may require detailed inspection of each and every element of a structure. However, it is highly unlikely that a painting contract would be let to paint individual elements of a structure (i.e., a single stringer in multiple, non-adjacent spans). This would be cost-prohibitive as the cost of establishing the staging to paint individual areas would be more than the cost of the actual painting. In cases where detailed data are likely to be collected, painting decisions are usually based on the composite condition of several sub-elements. If the database merely needs to hold data on the composite condition vs. the individual element condition, the database can be much less complex and much smaller.

Customization also allows tailoring of the prioritization process for recoating. There are typically three schemes employed. The first is to paint those structures (or structure areas) that are showing the most deterioration. As an alternative, study has suggested that low-cost maintenance painting occurs when touch-up painting is performed about one to three years into a structure life to repair initial damage sites, as opposed to waiting and then spending funds to repair highly deteriorated structures. The coatings on highly deteriorated structures cannot get much worse; repairing failure from original coating weak spots before the damage progresses can preserve the overall system integrity. Deferring painting on highly deteriorated structures also assumes that there is not a structural concern with the freely corroding structure. As a third choice, aesthetic issues often dominate the consideration, especially for structures exposed to the traveling or paying public (e.g., toll roads, buildings/entertainment parks). But with a customized software package, any such logic can be applied.

Developers of scalable, customized solutions, where the value is primarily in the logic engine and possible data collection/storage schemes should probably find favor in this market vs. off-the-shelf software packages.

Quality Assurance Data Collection

Quality assurance data collection tools have been developed to reduce the time and paperwork management associated with 3rd-party quality assurance of on-going painting projects. Tools include those that may simply collect data via manual entry and compile them in owner-acceptable formats, as well as advanced tools that also incorporate the capability to collect data directly from inspections tools, such as dry film thickness gauges and environmental monitoring tools.

Undoubtedly, a major advantage of such tools is a near complete elimination of the numerous pages of data and reporting that is typically required. A recent publication[1] details the results of one such application covering painting of 102 work items. In this demonstration of a computerized quality assurance tracking system, over 22,000 data points were records and 7,200 pages of paper reporting were avoided using a PC based system. This eliminated 80% of the administrative time associated with developing, tracking, approving, and filing of these contract-required reports.

Further improvements are offered in such systems that will also incorporate the ability to directly obtain the raw QA data from measurement instruments and log it into the database.

While such systems appear to offer great savings in contract deliverable requirements, one potential opportunity to further enhance the value of such tools is to utilize the electronic collection and reporting process to substantially increase the data collected and analyzed for conformance to design goals. Historically, the time to collect and report QA data has substantially limited the ability to collect a statistically representative volume of data. To be fair to the contracting community, however, there is some legitimacy to this concern. Historical manual data collection and adjudication was a slow process, suggesting that more data be collected would result in a direct increase in coating costs as the contractor must account for the stand-down time of his crew and equipment.

But with only limited data collected, it remains difficult to ascertain the “quality” of the final product as it relates to probable coating life. Consider the standard process as described by SSPC PA-2[2] for collection of dry film thickness (DFT). In this standard, a minimal number of spot readings are collected to represent the entire coating DFT. For 1,000 ft^2 a minimum of fifteen (15) spot readings are required. Each spot reading is the average of three gauge readings within a 1½-inch diameter circle. If we assume the spot readings are indicative of the area within the 1½-inch circle, we are inspecting about 0.001% of the total surface area painted. The chances of finding and identifying low DFT areas are very low. At best, the data are a broad generalization of the coating DFT.

Figure 1 shows the disparity that can exist when insufficient measurements are made in a particular area. The data show a histogram of the DFT data for a structure when data was taken by a 3rd-party QA inspector and an engineer investigating a problem in the same area. In both cases a substantially greater number of coating DFT data were taken as compared to the SSPC PA 2 standard requirements.

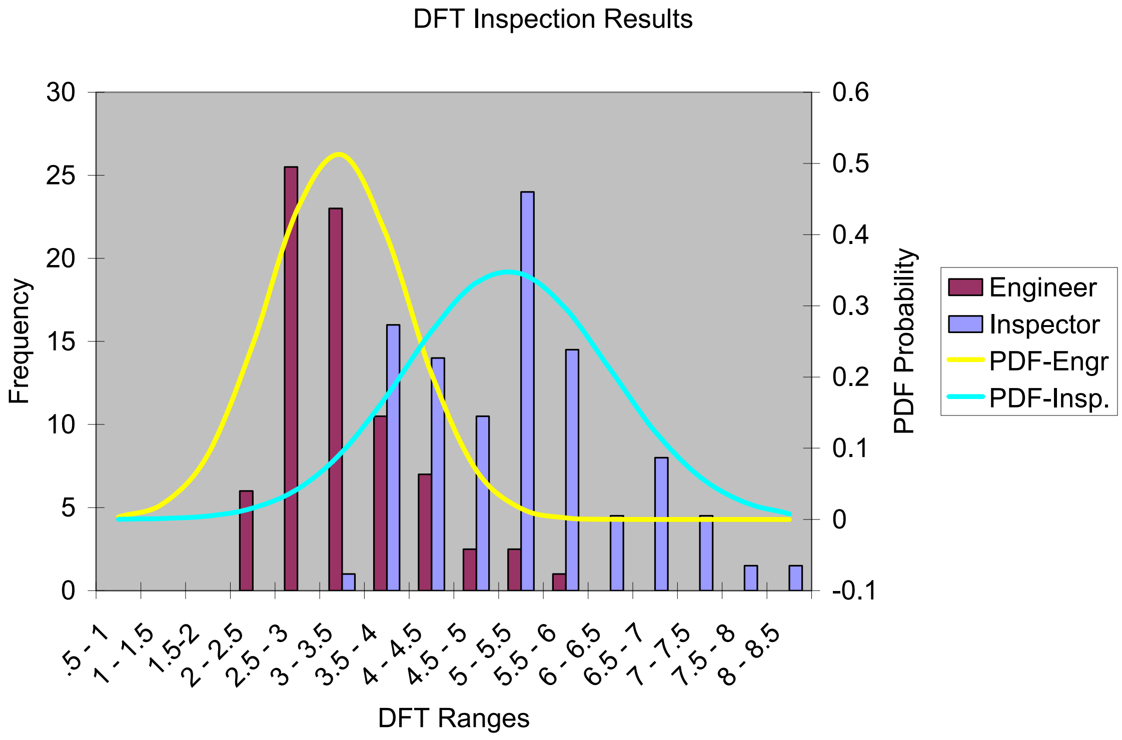


Figure 1 - Histogram of DFT Data from Two Inspectors

The first data set has a mode of about 3 to 3.5 mils DFT; the second data set has a mode of 5 to 5.5 mils—a factor of 1.6 larger. This is not to imply that either data set is “correct.” Neither probably accurately represents the data.

Other research[3] has suggested a critical minimum DFT (CMDFT) needed to ensure overall coating quality. If one cannot determine that the coating system exceeds this CMDFT, one cannot ensure a long coating life. In fact where structure coatings have been subject to extensive DFT analysis, the results suggest that as much as 1 to 5% of a tank coating can be below this CMDFT level.

Through the use of electronic QA data collection and analysis tools now being introduced on the market, the authors believe that the value of such systems can be extended beyond paperwork reduction; they can be used to greatly increase the overall quality of the finished coating product with a minimal impact on the contractor. Barring major improvements inherent to application process control, enhanced QA is needed to increase the area inspected to extend coating life to a maximum.

Expert Systems

Expert system tools are intended to assist an owner in planning painting priorities. They generally differ from maintenance planning/optimization tools by going beyond the development of painting priorities on the basis of a preset algorithm. They generally allow the user to “ask questions” to discern the corrosion and coating loss risks associated with continued deferred maintenance of the particular component.

The challenges inherent to such systems are numerous. Of particular concern is the ability to properly predict the ongoing rate of coating breakdown for a particular environment. Some previous approaches in the literature have focused on “average” expected life before needed maintenance.[4] However, it is recognized that coating lives are almost always best described by a range of times to failure; in terms of reliability analysis, coatings seem to best follow Weibull distributions.[5, 6] Depending on the severity of the environment and the quality of the selected and applied coating system, this failure distribution can be quite large with life differentials exceeding a factor of two. The use a single “average” life to project recoating decisions may cause the removal of a coating prematurely.

Figure 2 shows the disparity that can occur in year to year failure rates in different tanks.[7] The data are for tanks subject to either frequent or infrequent seawater exposure. Different data on failure rates need to be developed (with appropriate error bars) for the different expected exposures. Expert systems relying on average failure rates for different exposures or assuming that the failure rates are constant with time fail to reflect actual knowledge; this tends to reduce the perceived value in such systems.

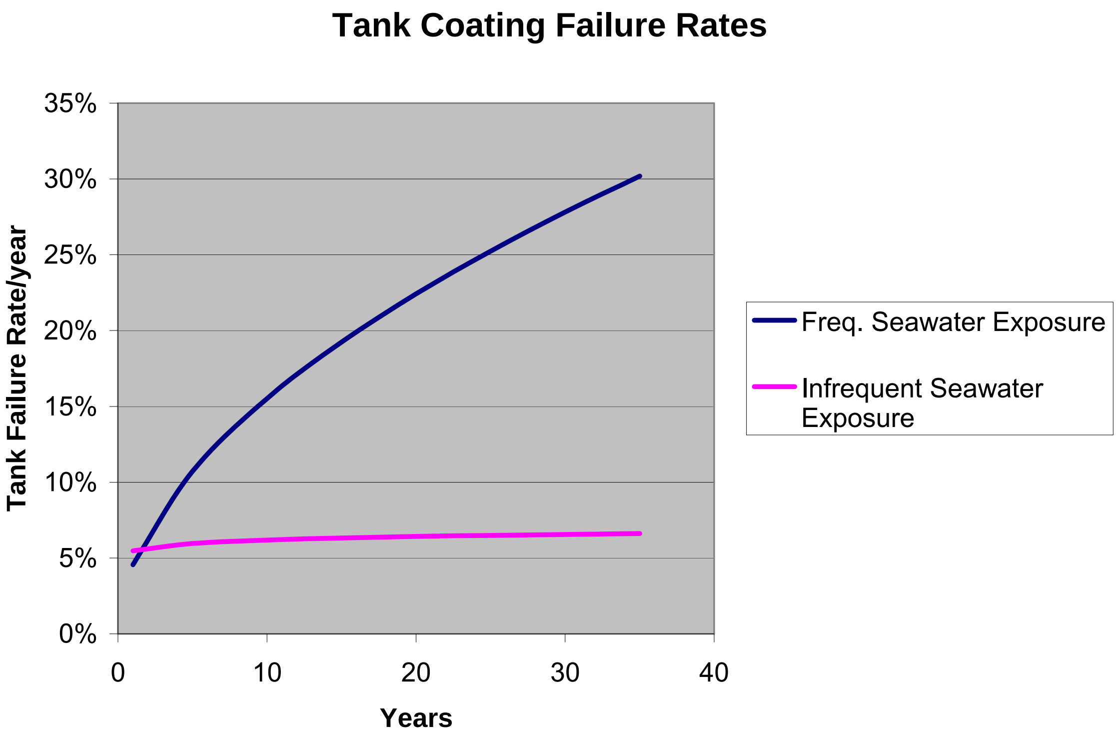


Figure 2 - Tank Coating Failure Rates

Expert systems are also challenged to understand the basis for different lifetimes or failure rates. Part of the answer probably lies in better characterizing the initial coating quality. Unfortunately, expert systems are only able to provide a response on the basis of data submitted, and this data is often minimal. The most common data submitted includes an inspection report, the operating condition, the coating system, and the initial paint-date. For the sake of speed, many inspection protocols simply reduce the coating inspection process to a single or few rating values. This rating is usually indicative of the general observed deterioration. Sometimes the time at which the coating was applied is an estimate as well, so great uncertainty exists in predicting the probable remaining coating life.

In order to better use expert systems, such systems may encourage the collection of additional data that may help explain the observed deterioration to date and the likely rate of progression. Key additional data might include selected observations as to the type of coating failure (general vs. local), associations of the observed failure with a particular cause (complex surfaces, edges, low DFT, overhead corrosion, etc.) that inspection suggests should be self-limiting, or association with enhanced QA data collection.

With additional coating characterization data, the following observations were observed between two different tanks coated using the same materials, contractors, and 3rd-party QA oversight. Figures 3 through 5 show the cumulative probability distribution of three QA data sets: surface conductivity, surface profile, and dry film thickness. Each of these graphs better illustrate the distribution of observations as a percent probability, or likelihood that a given measurement level will be observed. For example, one might conclude from Figure 3 that there is a little better than 55% probability that a surface conductivity measurement will be lower than 25 µS/cm. If it is assumed that these measurements are truly representative of the surface, it could be inferred that nearly 45% of the surface area did not have conductivities below this level. With proper failure models for coatings applied above and below 25 µS/cm, we can predict the impact of this variation on coating service life.

Similar analysis or models could be developed for the profile data or the DFT data. We have already made mention of the concept of CMDFT. In this tank the minimum target DFT was 12 mils. Tank #1 had about 5% of the surface area with a DFT below this target vs. only 1% for tank #2. This may suggest a more rapid failure rate for this tank.

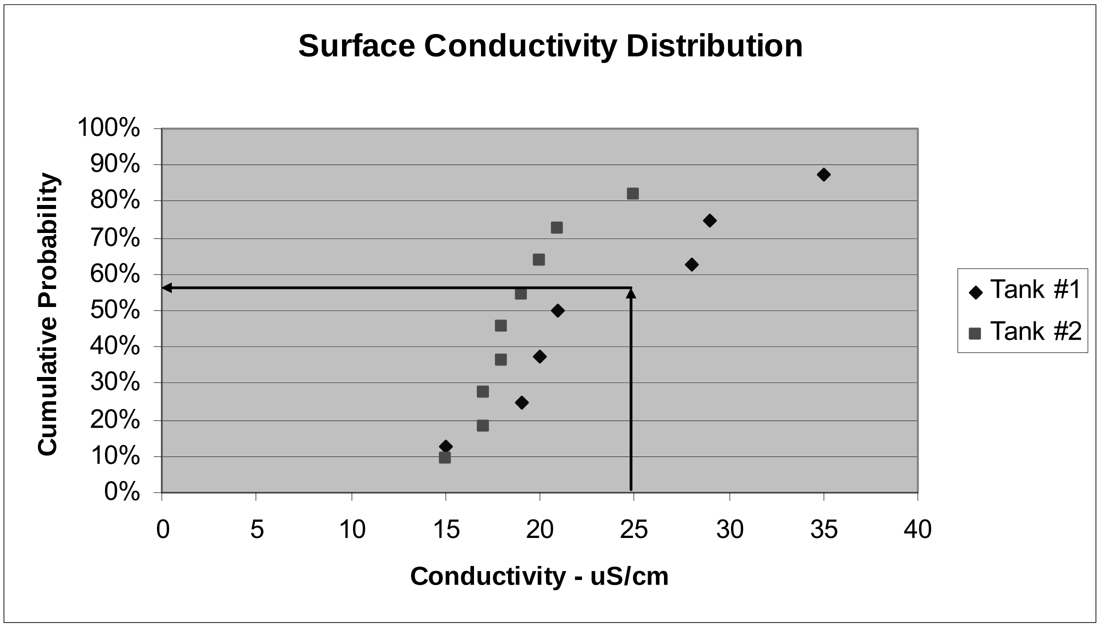


Figure 3 – Surface Conductivity Distribution for Two Similar Tanks

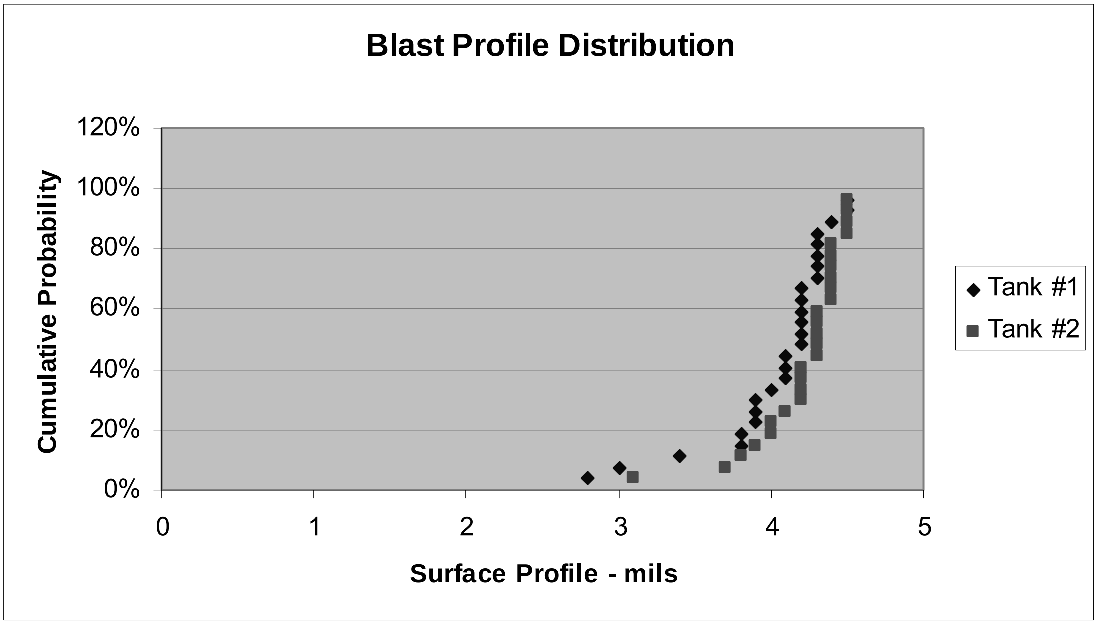


Figure 4 – Blast Profile Distribution for Two Similar Tanks

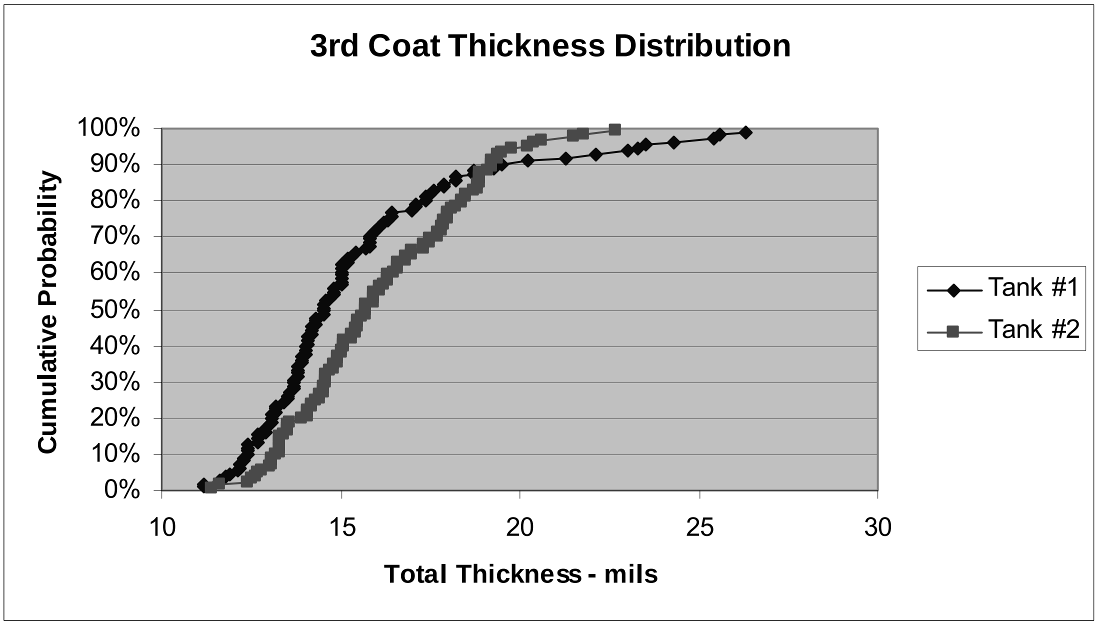
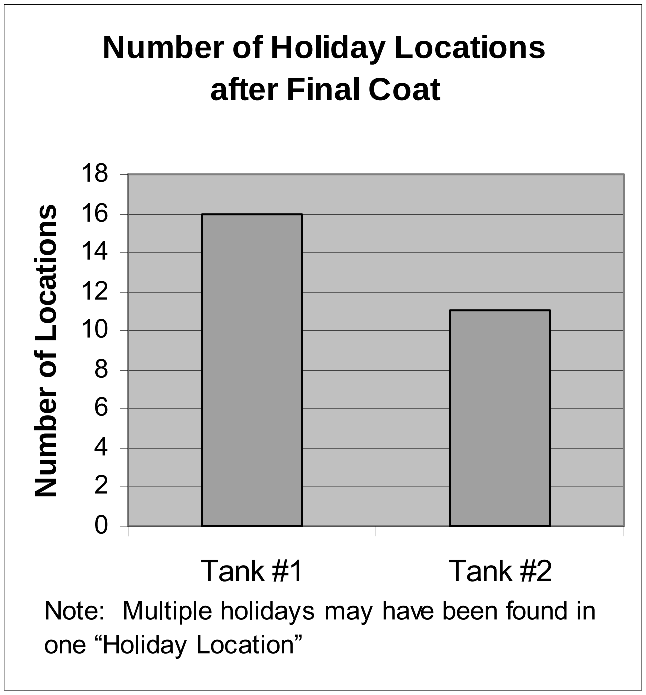


Figure 5 – Dry Film Thickness Distribution for Two Similar Tanks

Figure 6 shows the number of holidays noted for repair after the final coat. While all of these holidays were properly repaired, it is possible that the repair area has a different probability of failure than the surfaces which were properly coated to begin with. Noting that tank #1 had more holidays for repair, one might conclude that this tank will fail somewhat sooner than Tank #2.



Note: Multiple holidays may have been found in one “Holiday Location”

Figure 6 – Number of Holidays Observed on Two Similar Tanks

Tracking of such data over time as well as the ultimate performance of these coatings may begin to show the value of other data in helping develop expert systems in predicting coating life.

RECOMMENDATIONS

The authors’ experience suggests that the use of electronic tools and databases to manage coating used for corrosion control would be enhanced with:

1. The development of scalable easily customized maintenance planning tools, where the product-focus is primarily in the logic engine and flexible data collection and data storage schemes. Such systems should probably find favor in the maintenance planning market vs. off-the-shelf software packages.

2. The value of QA collection tools in reducing paperwork and administrative time appears to be well documented in recent trials. However, a major advance in achieving true coating quality and life extension may be achieved by expanding the use of electronic data collection devices that will acquire and rapidly analyze substantially more coating data than is currently required by standard inspection protocols.

3. Expert systems for predicting coating life need to be capable of using a wider range of data to assist in coating decisions. Owners need to support such systems by adjusting inspection schemes appropriately to gain some additional data.

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