

**National Shipbuilding Research Program (NSRP)
Surface Prep and Coatings (SP&C) Panel Project**

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Reducing Inspection Costs Using the Latest Digital Inspection Tools

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1 Executive Summary

The detailed information in this report can be used as the basis for process improvements in paint application and inspection for shipyards, contractors, and in NAVSEA Standard Item (NSI), specifically NSI 009-32. While it does contain specific recommendations for process improvements and changes to the NSI 009-32, the results clearly demonstrate that substantial cost savings can be achieved at every level of the Navy supply chain if these digital inspection tools are incorporated at a level appropriate to the needs of the user and the training of personnel.

The four most labor and documentation intensive areas of Navy asset paint inspection are verification of surface preparation, ambient conditions, substrate condition, and dry film thickness (DFT). Previous NSRP projects have concentrated their efforts on the first three of the aforementioned areas and their results have not only yielded significant cost savings but also supported revisions to the NSI 009-32. Current NSI 009-32 specifications for DFT inspections, however, rely heavily on outdated technology, with results manually input on paper-based documentation. For several years, other industries with similar applications have modernized their inspection and documentation protocol for DFT measurement to incorporate newer digital technologies. These industries have seen their corresponding inspection costs significantly reduced. In this study, a side-by-side comparison of four test methods (one legacy and three of the latest developments) were used to evaluate DFT in ballast tanks and other painted surfaces. These methods were evaluated for:

1. Completion Time
2. Data Accuracy
3. Data Processing

Paint and coating QA/QC Managers from BAE Systems Southeast Shipyards, HII-Newport News, HII-Ingalls, NASSCO - Earl Industries, and Elcometer all provided trained inspectors who completed DFT inspections both in the field and on laboratory prepared control panels. These inspectors performed:

- DFT inspections of painted areas according to current practice
- the same inspection using scanning probe technology, programmed to automatically calculate DFT data to the current NAVSEA standard, store results in the gauge, and export data to a paperless QA system.
- the same inspection using instruments with traditional place-and-lift probe technology, programmed to automatically calculate DFT data to the current NAVSEA standard, and exported results to a paperless QA system.
- the same inspection using a device that is factory calibrated for measuring on blast cleaned, roughened surfaces and suitable for use by untrained personnel, recording data manually according to NSI 009-32 Appendix 7.
- current practice, scanning, pre-programmed, and factory calibrated inspections on a set of laboratory prepared control panels.

2 Background

Prior to 1947 - Destructive Coating Thickness Testing

- The measurement of paint thickness over steel substrates required the use of a destructive test. It required the user to cut into the coating system with an angled cutter and measure the thickness from the top of the coating to the substrate using a microscope with calibrated reticules. This process was time consuming, subjective, and only yielded a measurement for the area that was damaged as a result of that measurement.

1947 - Non-Destructive Coating Thickness Testing

- A non-destructive test using a calibrated “horseshoe-shaped” magnet attached to a simple magnetic needle meter was invented. There were many variations of the calibrated magnet method, however, the core measuring principle remained the same until the development of the electronic gauges.

1957- Analogue Electronic Instruments

- Transistors created an analogue signal that was sent to a needle movement display.

1972 - The Introduction of the Microprocessor

- DFT instruments were developed utilizing the electromagnetic induction principle; achieving a digital coating thickness measurement with enhanced accuracy was now possible. Digital measurement greatly increased the speed at which measurements could be taken while also reducing the time needed to perform a comprehensive inspection. However, while the measurement was now digital, the corresponding data retention was not; these digital measurements were recorded manually.

1984 – Statistical Analysis & Statistical Process Control (SPC):

Data Collection and Analysis in Real Time

- Memory chips became affordable enough to fit into portable instruments and were soon incorporated into digital DFT gauges. Early adopters of this technology tended to be large scale manufacturing operations that could keep the instruments close to their mainframe and desktop computers. Having an instrument close to a data processing device allowed these manufacturers to track their measurements on the production line and make changes to their process in real time. As a result, digital statistical process control (SPC) was born.

3 Objective

3.1 Streamlining the Production Process

Unlike industrial manufacturing, industrial marine protective coating applicators cannot always control their production environments. Production areas tend to be difficult to access and can easily become congested, with numerous trades having to perform their duties almost simultaneously. Over the last 15 years, incorporating digital Statistical Analysis and SPC for DFT measurement in industrial marine protective coating environments has been established primarily in Asian and European commercial shipyards. US Military shipyards and contractor facilities have been slow to adopt these techniques for reasons which include data security, specification conformance, and the need for more portable, robust, digital data collection and analysis instruments.

3.2 Streamlining the Reporting Process

To meet the requirements of the industrial marine protective coating industry, some of the latest digital coating inspection tools now have the power to process, retain (save), and export measurements using handheld instrumentation that contains processing power previously relegated to desktop computers without any of the security concerns. Statistical Analysis and SPC in the military shipyard is now possible.¹

3.3 Streamlining the Inspection Process

It is the goal of this project to provide the data necessary to justify the incorporation of the latest digital inspection tools into the Navy's paint production processes; streamlining the inspection and allowing the Navy standards to move away from obsolete inspection methods requiring colossal amounts of manually entered data and reams of paper to document inspections. Incorporating Statistical Analysis and SPC into Navy DFT specifications will bring with it the efficiencies of modern manufacturing and allow shipyards to benefit from the subsequent cost reductions and quality improvements.

¹ *Applying Statistical Process Control to Coatings Activities in Lean Production Implementation, Final report presented to NSRP/ASE Surface Preparation & Coatings Panel (SP-3) under subcontract number: 2005-360*

4 Overview

Instrument Type	Corresponding Data Collection Method (meeting the requirements of SSPC-PA2 ²)
Digital DFT Gauge	NSI 009-32, Appendix 7 (Figure 2)
Conventional Digital DFT Gauge with data collection points pre-programmed in batch and sub batch files with time- and date-stamped readings	Data download into a software program with cloud capabilities and generate inspection report (Figure 1)
Scanning Probe Gauge with data collection points pre-programmed in batch and sub batch files with time- and date-stamped readings	Data download into a software program with cloud capabilities and generate inspection report (Figure 1)
Fixed Calibration Digital DFT Gauge	NSI 009-32, Appendix 7 (Figure 2)



Figure 1 - Digital Inspection Report



Figure 2 - Manual Input, Appendix 7

²SSPC-PA 2, "Procedure for Determining Conformance to Dry Coating Thickness Requirements." (Pittsburgh, PA: SSPC, 2012).

5 Data Integrity

5.1 Laboratory Panels - 20mil Target Control

Three laboratory panels having NAVSEA approved single coat epoxy paint manually applied at a target thickness of between 20 and 30 mils (the lower and upper end of the specified range for single coat) over substrate profiles of 1 -2 mils, 2 - 3 mils, and 3 -4 mils were prepared. Each panel had variances in film thickness that can be attributed to manual application and variance of substrate profile.

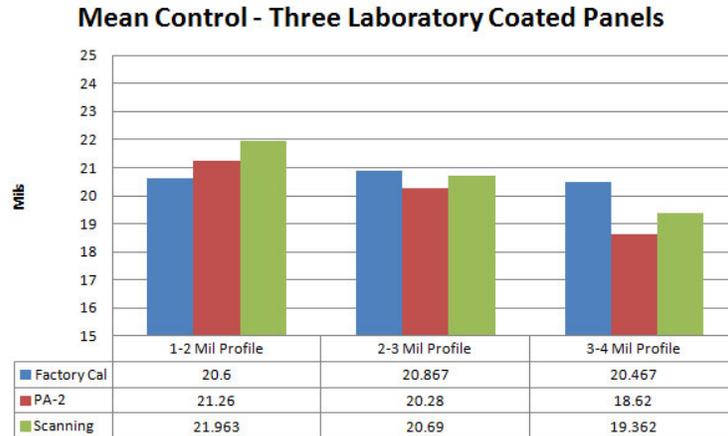


Figure 3 - 20mil Target DFT

Each instrument demonstrated a low standard deviation - with the scanning technology showing the lowest deviation overall . All of the measurements systems have a standard deviation as a result of variation in substrate profile and DFT. A lower standard deviation demonstrates greater confidence in the statistical conclusions resultant from the data for the measuring device.

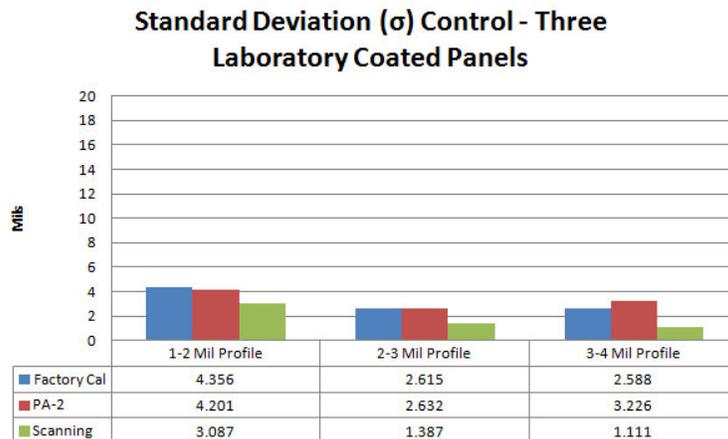


Figure 4 - 20 mil Standard Deviation

5.2 Laboratory Panels - 30mil Target Control

Three laboratory panels having NAVSEA approved single coat epoxy paint manually applied at a target thickness of between 20 and 30 mils (the lower and upper end of the specified range for single coat) over substrate profiles of 1 -2 mils, 2 - 3 mils, and 3 -4 mils were prepared. Each panel had variances in film thickness that can be attributed to manual application and variance of substrate profile.

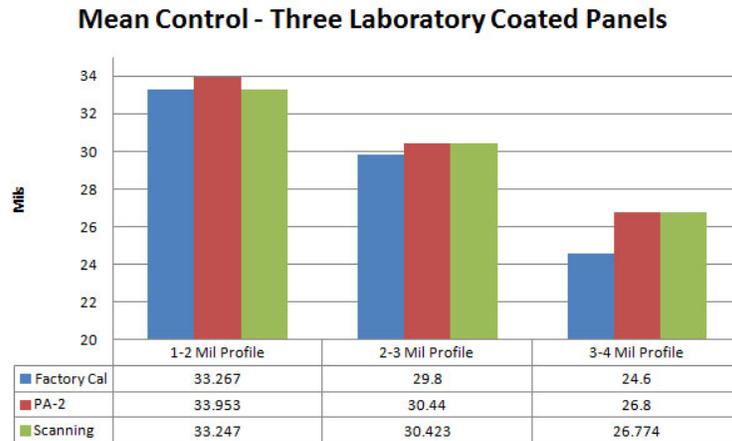


Figure 5 - 30mil Target DFT

Each instrument demonstrated a low standard deviation - with the scanning technology showing the lowest deviation overall . All of the measurements systems have a standard deviation as a result of variation in substrate profile and DFT. A lower standard deviation demonstrates greater confidence in the statistical conclusions resultant from the data for the measuring device.

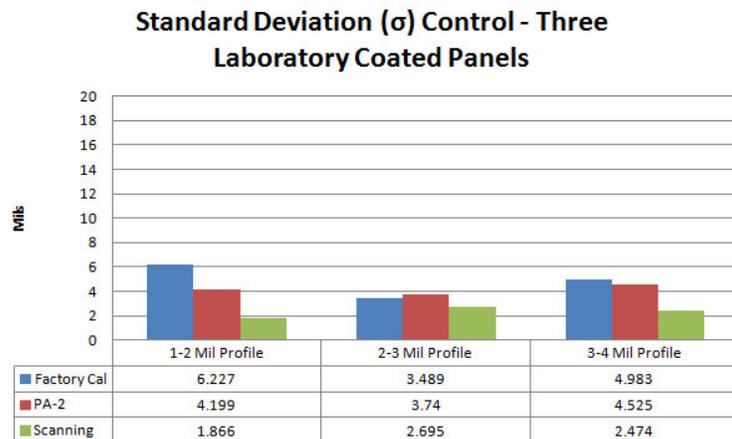


Figure 6 - 30mil Standard Deviation

6 Cost Savings

Below is a graph displaying average time requirements for each inspection tool on the multiple areas inspected. The cost savings are calculated for the most efficient inspection method.

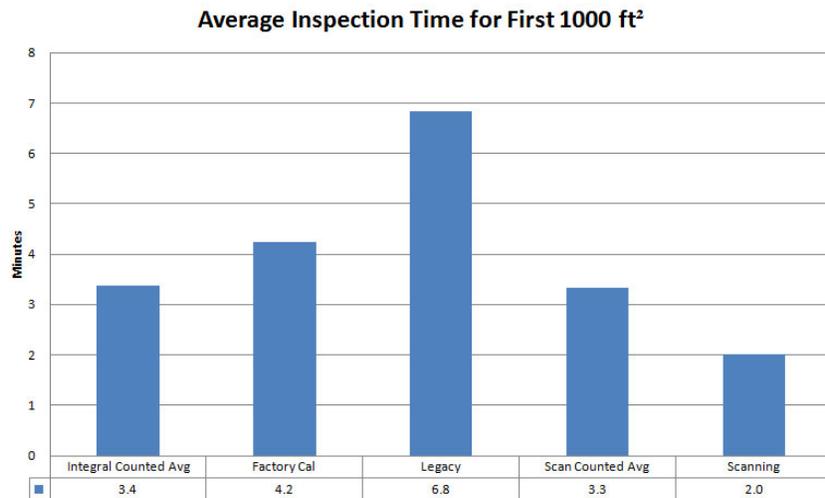


Figure 7 - Average Time Per Field Inspection

Current Practice:

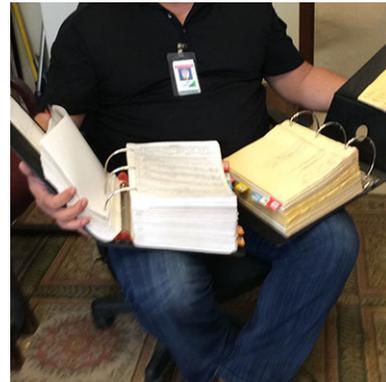
- 30 seconds x 120,000 readings = 1,000 hours
- 1,000 hours = 125, 8-hour shifts
- 3 inspectors = 8.3 weeks / 2 months

Assumptions:

- No breaks for food, etc
- No waiting time or delays
- No review of manual input data

Scanning Technology Method:

- 5 seconds x 120,000 readings = **167** hours
- **167** hours = **21**, 8 hour shifts
- 3 inspectors = **1.2** weeks
- **An 86% reduction** in data collection time



**Figure 8 - Appendix 7
Document Files**

Reduction in time and labor for digital report generation, data review, and audits leads to an exponential increase in productivity and cost savings.

6.1 Scanning Probe Technology

Determining DFT using the scanning instrument was more than three times faster than the current NAVSEA method. It can therefore be inferred that scanning technology would reduce the labor cost of an inspection by almost 70%. When the benefits of digital data output and automatic report generation are added, the labor cost savings are too significant to quantify.



Figure 9 - Scanning Technology

6.2 SSPC-PA2 Programmed DFT Gauges - Standard Probe and Scanning Technology

Digital instruments that calculate the average of three gauge readings to obtain a spot measurement and combine five spot measurements to create an area measurement, were twice as fast as the current NAVSEA method. The time savings for these instruments are almost identical and have the potential to reduce the labor cost by 50%. When the benefits of digital data output and automatic report generation are added, the labor cost savings are, again, too significant to quantify.



Figure 10 – SSPC-PA2 Programmed, Standard Probe Technology

6.3 Factory Calibration Technology

Calculating DFT using the factory calibrated instrument to complete the current paper-based data retention method performed the same inspection 33% faster than the current test method.



Figure 11 - Factory Calibrated Instrument with NSI 009-32, Appendix 7

7 Conclusions

7.1 Data Integrity

- Inspection data taken from three laboratory-prepared panels having NAVSEA approved single-coat epoxy paint applied over substrate profiles of 1-2mils, 2-3mils, and 3-4mils conclusively demonstrate that there is no loss of accuracy or repeatability using the latest digital inspection tools. The data further demonstrate that scanning technology has the lowest standard deviation of all the tested measurement methods.
- Inspection data taken from multiple inspections, working to a wide variety of coating specifications, at one new build shipyard and two maintenance/refit shipyards, conclusively demonstrate that there is no significant difference in data obtained by the currently specified inspection method and the latest digital inspection tools. The data further demonstrate that each measuring device and method has a comparable standard deviation.
- Inspection data taken from multiple field inspections, when compared to the laboratory prepared panels, conclusively demonstrate that there is no degradation of instrument performance when taken from a laboratory environment into the field.
- Data clearly demonstrate that the DFT instrument which was factory pre-calibrated to 009-32 profile specifications, saw no material difference in the accuracy of the data collected using the current SSPC-PA2 data collection method – despite taking one third of the number of readings.

7.2 Inspection Time

- When inspection completion time was analyzed, digital instruments were observed to be between two to three times faster than the current NAVSEA specified data collection method.
- Scanning technology demonstrated the most significant time savings despite recording ten to twenty times the number of individual measurements.
- The factory calibrated DFT instrument completed identical inspections in nearly half the time of the current paper based data retention method.

7.3 Data Output and Report Generation

- Time savings for report generation between manual report generation and digital methods were so significant that the benefits of digital reporting are incalculable. In one instance, a shipyard showed NSI 009-32 Appendix 7 reports for a single ship that took almost 2,000 man hours to complete, review, and audit. The reports were stored in 12" ring binders(Figure 8). Those same reports could have been generated digitally in under one minute.

8 Recommendations

8.1 Approve Scanning Technology

- Approve the use of scanning technology and the digital reports generated from the use of this technology as an equivalent to the current specified SSPC-PA2 procedure in NSI 009-32.
- Approve, for inspection and audit compliance, the upper and lower boundaries as specified in the Product Data Sheet of the coating. Boundaries established in generated reports allow for easy pass/fail inspection during the audit process.

8.2 Approve Programmable DFT Instrument Technology

- Approve the use of both programmable place-and-lift and scanning technology DFT instruments. Also approve the digital reports generated from their use.
- Approve, for inspection and audit compliance, the upper and lower boundaries as specified in the Product Data Sheet of the coating. Boundaries established in generated reports allow for easy pass/fail inspection during the audit process.

8.3 Approve Factory Calibrated DFT Instrument Technology

- Approve for use factory calibrated DFT instruments designed to work with the specifications of NSI 009-32 both as a reference instrument and as an equivalent measuring tool for obtaining the average of three spot readings in Appendix 7 of NSI 009-32.
- Approve for use a factory calibrated DFT gauge with scanning technology and the digital reports generated from the use of this technology as an equivalent to the current specified SSPC-PA2 procedure in NSI 009-32. Approving such an instrument would give NAVSEA the benefits of pre-calibrated instrument while incorporating the efficiency of scanning technology.

8.4 Approve Data from Digital DFT Instruments for Paperless QA Documentation

- Approve DFT data obtained by the use of scanning, programmable, and factory calibrated DFT instruments for direct input into approved NAVSEA Paperless QA/QC documentation systems.

8.5 Incorporate Scanning and Pre-Calibration Technologies into Edge Measurement

- Study the benefits of using scanning and pre-calibration technologies to document edge DFT measurements on beams and stiffeners.

9 Inspector Feedback

At the conclusion of each shipyard visit, inspectors were asked a series of questions regarding the use of the latest digital inspection tools and the current practice. Here are some of their responses:

9.1 Q: What are your Impressions of the factory calibrated gauge?

A: Very basic, easy to use. The gauge doesn't record data which would be an issue and a hassle. It would be good for foreman or painter to check job before calling for an inspection.

A: Great, I would love to use

A: Time consuming

A: It wasn't as fast as the others

9.2 Q: What are your Impressions of scanning gauge?

A: Easy to use and read DFT's at a fast, real time pace.

A: It gave a better scope of the total DFT of an area and made mapping out areas that are out of spec easier and more accurate.

A: Saves time

A: Saves 15 - 20 minutes per checkpoint

A: I really liked the scan. Much faster and can put readings right to appendix

9.3 Q: Did you prefer the counted average in the integral gauge or on the scan probe?

A: Scan probe

A: Scan

A: I preferred the scan probe. It gave me a way better overall feel for the tank.

A: It would depend on the size and arrangement of the area being inspected. For open areas with simple geometry, I would prefer the scan probe. In tighter areas with complex geometry, would prefer the counted average gauge.

9.4 Q: What is your biggest challenge when inspecting DFT's according to 009-32?

A: Mapping out large tanks and the time it takes

A: Inspecting, writing, and only having two hands

A: The amount of time it takes to do all the paperwork

9.5 Q: If you could make three changes in the way you take and record DFT's, what would those changes be?

A: Cut back on readings per sq. ft.

A: Taking out appendices on deck plate

A: I would have calibration memory spots

A: Less paper work

A: Utilizing the scan method

A: Uploading reading

A: Not utilizing a shim for underwater hull

10 Results from Individual Inspections

