



The Coating Inspectors Handbook

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The purpose of this manual is not to turn you into a coating inspector, but to be a resource that a trained coating inspector can use. The assumption is that you have a basic understanding of coating inspection. Because of the global nature of coating inspection, advancements in inspection equipment, new types of coating systems, changes in standards and new standards organizations, it can be difficult for a coating inspector to keep current with all the changes. This manual will try to bring together many of the current resources.

While the basics will be covered, for those that want a better understanding of the principals behind some of the tests, there will be additional details given. It is my belief that the more knowledge an inspector has, the better he or she can do their job. There are many good resources out there to help the inspector to do their job better and hopefully this manual will be one more useful tool to help you do your job better,

There is a QR code at the end of each section. Use any QR code scanner and it will take you to the page on the website that contains the tools discussed in that section

If you have any questions or comments or would like to see an additional topic added, please feel free to contact me.

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THE COATING INSPECTOR

SECTION 1

There are a lot of misconceptions out there on what a coating inspector is. Part of the confusion is many people are “trained” coating inspectors, but it is not the core part of their job. Paint Salesmen, Engineers, Consultants, Managers, Contractors, all may have coatings inspection training, but in addition to being a coating inspector, bring other perspectives to the job. Many of these individuals may get involved with the inspections of coatings during applications, but often have a different role than Quality Assurance for the painting.

Simply, a coating inspector’s role is to verify that the quality of work being performed meets the specifications and complies with any contract documents for the project. In a strict sense, judgment of the work should be based only on the documentation and no variance should be made without discussions with the owner or engineer that wrote the project documents despite what the inspector may feel is OK.

Before we discuss what a coating inspector is or isn’t, we need to understand the fundamental difference between Quality Control and Quality Assurance.

Quality Control is the role of the person doing the work. In the paints and coatings area, this is generally a contractor. The Contractor may employ a coating inspector to ensure their coatings comply with the specifications or if lacking specifications comply with general industry standards for good coating practices. Often quality control is in conflict with getting the job done and completed in the time specified or required. In the long run, it is generally better to put the priority on quality control instead of on time and money requirements, but in the real world, even the best contractors will sacrifice some quality for the sake of the bottom-line dollar. Unfortunately, some owners will often put getting their systems back online over quality and may force the contractor, sometimes over the warnings of the engineer or the inspector, to take whatever steps are necessary to complete the project on time.

If a coating Inspector is working for a contractor as their quality control, it often puts him in a difficult position. It is the quality control person’s responsibility to take measurements of the contractors work and record them as part of the quality control process. Contractors sometimes want the measurements to be more in line with what they want instead of what they are.

It is important to understand that any documentation the contractor has, may in the future, be used to determine the quality of the work should a failure occur. If the form requires a signature, and you are the one signing the form, you may be called to give a deposition or to testify in court. It doesn’t happen often, but don’t count on it. The moral and legal questions on putting incorrect numbers on inspection reports is beyond the scope of this manual, but it is a matter you should consider when working for a contractor.

Quality Assurance is typically done by someone besides the contractor. In industrial coating situations, this is often the responsibility of a third-party inspector. Quality Assurance assumes that Quality Control has already been performed and that the contractor has released the work for inspection. It is the coating inspector’s job to verify that the work complies with the project documents and specifications. If the contractor does not have a quality control person, the inspector becomes both quality control and

quality assurance. This can greatly increase the load on the inspector since if the work is not correct, the same areas may have to be inspected numerous times.

Responsibilities of a Coating Inspector

A coating inspector's responsibility is to verify that the work conforms to a set of specifications. All work must be documented. If it is not documented, it didn't happen. Inspection reports should be written so that someone that is not present during the work can recreate the project. The inspection reports can become legal documents. All reports should be complete, legible, signed and dated.

The inspector should not require the contractor to perform work that is outside the specifications even if it seems to make sense. The inspector should also avoid making judgments about the coatings that are not part of the specifications. Because someone is a coatings inspector does not make them qualified to make engineering or consulting decisions. If there are any concerns, they should be brought to the attention of the owner, the specifier, the coating supplier or other qualified person. Making suggestions or offering opinions if you are not qualified can have serious legal ramifications.

Sometimes the term "Coating Inspector" is used in a generic sense and may involve much more than just inspection verification. Depending on the qualifications of the inspector and the needs of the owner, sometimes the inspector is required to act as a project manager and have responsibilities beyond normal inspection. He may have the authority to give the contractor permission to vary from the specifications, stop the contractor from continuing work until problems are corrected or make other decisions that are beyond the scope of inspection. With increased authority comes increased responsibility and possible liabilities, including warranty issues and other legal liabilities.

If you do not carry the proper liability insurance, be careful that you are not taking on more responsibilities than you are prepared for. As an inspector, you owe it to the owner, the contractor and to yourself to not get involved in projects where you may not be qualified.

As an owner, make sure that if you are hiring an inspector, you do not require more of them than they are qualified for. Just because an inspector is NACE Certified or certified by some other training, does not make them qualified to make decisions outside verifying the work complies with the specifications. While many Consultants and Engineers are Certified Coating Inspectors, it should not be assumed that consulting, failure analysis, and knowledge to grant variances from specifications are within the skill set of a coating inspector.

Inspection Preparation Procedures

Whether you are working directly for the owner or working for an inspection company, the inspection work should begin prior to the job. You need to determine the needs of the owner, the skill level of the contractor, study the contract documents, find out the coating systems to be applied. Most of this you should be able to find out prior to showing up on the job.

Once you have the job, either the company you are working for or yourself needs to get all project documentation. The following items are useful to gather.

1. All Specifications related to the work
 - a. Make sure you have all addendums and appendices
2. All applicable codes and standards
3. Manufacturers Product Data Sheets (PDS) and Material Safety Data Sheets (MSDS)
4. Manufacturers Application Bulletins
5. Any drawings of area where work is being performed
6. Contact information for the Owner, Engineer, Contractor, Paint Salesman and Technical Service representative

Project Planning

Preconstruction Meeting and Contractor Submittals

Often coatings are part of a larger project. When beginning a large project, there is generally a preconstruction meeting where all contractors that are involved in the project are assembled to go over the project plans and specifications. At this meeting any questions pertaining to the specifications are discussed. Often, the coating contractor is left out of these meetings so the “more important” areas can be discussed. If the coating contractor is present, often coatings are treated as minor work and are not discussed in length.

A separate preconstruction meeting should be held to discuss the coatings part of the project separate from other contractors unless they will be directly affected. If a meeting is not planned, request one. Any possible problems with the specifications, conflicts between the specifications and product data sheets, safety or compliance issues need to be resolved prior to the start of the project. If the Contractor wants to change anything, this is the time. Not when the problems already exist.

Prior to the meeting, the contractor should be required to submit a written work plan or submittal. The work plan should be specific for the project and not just a generic plan. This will spell out what the contractors quality control plans are, detail any necessary safety or environmental issues, and detail any areas where the contractor is free to choose among several choices.

The advantage to having the contractor put his plan in writing has two purposes. If there is a discrepancy between his submittal and the specification or other work documents, you find out before the project begins and if the contractor says he will do it, it is much easier to avoid arguments when you can use the contractors own submittals.

Any changes agreed to during the preconstruction meeting should be put in writing. Copies should be distributed to all parties. Request that they sign the copy and return it. If arguments arise later in the project on the agreed changes, the documentation exists.

Inspection Plan

With all the project documentation as well as the contractors' submittal, you now have all the necessary information to compile an inspection plan. The inspection plan can be in two parts. A general project checklist to make sure everything is completed (Figure 1) and an inspection summary sheet to summarize all the critical parameters for the project (Figure 2).

Useful Project Checklist

PROJECT PREPARATION CHECKLIST

Job Name _____

Location _____

1. Documentation Checklist for an Inspection Project

- 1.1. Submittal Requested from Contractor
- 1.2. Submittal Signed and Returned
- 1.3. Preconstruction Meeting Agenda
- 1.4. Preconstruction meeting minutes template
- 1.5. Completed minutes
- 1.6. A copy of the specification, Product Data, and MSDS
- 1.7. Copy of all pertinent standards (ASTM, NACE, ISO) Inspection Task Summary Sheet
- 1.8. Inspector Pre-job Hazard Assessment
- 1.9. Job Information Sheet – Project Contact Sheet
- 1.10. Final report

Date _____

Inspection Summary Sheet

INSPECTION TASK SUMMARY

Specification No.	Title:	Rev. No.
Project Location/Name:		
Item(s) to be Coated:		
Project Engineer:		Phone:
Coatings Inspector:		Phone:
Coatings Inspector:		Phone:
Coatings Inspector:		Phone:
Work to be performed:		
Contractor:	Phone:	Fax or email:
Contractor:	Phone:	Fax or email:
Subcontractor:	Phone:	Fax or email:
Subcontractor:	Phone:	Fax or email:
Contact Person:	Phone:	Fax or email:
Client:	Phone:	Fax or email:

Utilities/Equipment/Material:

To be Provided By: Check (v)

Preparation

	Contractor	Owner
Power		
Water		
Scaffolding		
Lighting		
Coating		
Permits		
Storage		
Other		

Surface

	List
Abrasive Blast Cleaning	
Blast Media & Profile	
Ambient Requirements	
Other Preparation Methods	
Test Blast Area	
Containment Equipment	
Application	
Other	

Coating System

	1st Coat	2nd Coat	3rd Coat	4th Coat	5th Coat
Product					
Manufacturer					
Tech Rep					
Data Sheets					
MSDS					
Min/Max Temp.					
Ambient Requirements					
Recoat Times					
Thinner					
Pot Life					
Dry Film Thickness					
Recoat Times					
Cure Test					
Holiday Test					

Inspection Equipment/Materials Required

Test	Method	Equipment
EXAMPLE: Dry Film Thickness	SSPC PA-2	PosiTector 6000

Notes and Comments

Necessary and/or Useful reference Materials

SSPC Redbook Volume 2 or set of Surface Preparation Standards.

ASTM Volume 6.01

NACE Recommended Practices

ISO 8501:2007

SSPC Redbook Volume 1

ASTM Volume 6.02

SSPC-VIS 1 - Guide & Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

SSPC-VIS 2 - Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces

SSPC-VIS 3 - Guide & Reference Photographs for Steel Surfaces Prepared by Power & Hand-Tool Cleaning

SSPC-VIS 4/NACE VIS 7 - Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting

SSPC-VIS 5/NACE VIS 9 - Guide & Ref Photos for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning

Coating and Lining Inspection Manual – SSPC Publication #91-12

Clemco Blast OFF 2 – Your Guide to Safe and Efficient Blasting

Inspection Hold Points:

The number and type of Hold Points will vary from project to project, however, some hold points are pretty much standard for most projects. These include:

Prior to the start of work

- Inspection of steel

- Sharp Edges

- Welds and Weld Splatter

- Taping off Equipment

- Check Abrasives

- Check Air Supply

After surface Preparation

- Surface Contamination

- Visual Cleanliness

Immediately prior to application of coatings

- Climatic Conditions

- Materials Inspection

- Observation of mixing coatings

Following the application of each coat

- Dry Film Thickness

- Holiday Testing

- Recoat Time

- Coating Cure

Following the cure of the coating final inspection and sign-off

- Dry Film thickness

- Holiday Testing

Additional hold points can be added based on the requirements of the project.

Inspection Report

The best way to maintain credibility as a coating inspector is to act in a professional manner and to present your documentation in a clear and concise manner. It is alright to use a standard inspection form for most jobs but customizing the forms to match the project can increase your professionalism in the eyes of the client and at the same time make your job easier. Diagrams can prove useful in identifying areas of work and should be used when appropriate. Several examples are provided, but since many situations are unique, it may be up to the inspector to design their own report. Often the owner or the engineer can provide drawing of the equipment being coated which can be included in the report.

While it is not necessary to type reports, this can add professionalism and credibility to the reports. If reports are not typed, they should be neat and legible. A report that cannot be read is the same as not having a report.

If a deficiency is noted on a report, the correction of the deficiency should be on a subsequent report. The correction should refer back to the report where it was noted giving the date of the report and page and section if applicable.

With digital cameras being cheap and easy to use, when possible, photographic documentation should be included. When working in some area, taking photographs can be difficult or impossible due to restrictions by the owner. The inspector should use his judgment along with discussions with the owner to determine if photographs should be part of the report.

Some inspection equipment manufacturers are making it easier to generate reports by making some of the process automatic. You can incorporate notes and pictures and generate a report for the customer.

Report Distribution

Inspection reports should be provided to the Contractor and the owner on a daily basis. It is useful to get the contractor to sign the report so he cannot claim at a later time he was not aware of any problems. It is important to let the contractor know that signing the report is like signing a traffic ticket. It does not indicate that they agree with the report, only that they have received the report. The time to discuss signing the inspection reports during the preconstruction meeting so if there are any objections they can be discussed. It should be made clear that this is to protect both the contractor and the inspector.

Disagreements with the Contractor

It is inevitable at some point in a coating inspector's career that disagreements will arise between the Inspector and the contractor. Avoid arguing with the contractor. Some contractors are quick to try to argue their point. Listen to what they have to say. Make sure you understand their point of view. One way to ensure your understanding is to restate the problem as a question. "If I understand your position, you are saying that ...". Once you understand the problem let them know you understand

their viewpoint and suggest that you work together to resolve the problem. While there is no guarantee this approach will work, jumping right into an argument is not likely to resolve the problem.

If you had the preconstruction meeting, many of these problems should be avoided and can be resolved using the contractor's own submittal documents.

Dispute resolution

The simplest disagreement is when the contractor and the inspector get different measurements for the same test. As a professional, you should be able to resolve who is correct.

Step one: acknowledge the problem and let the contractor know you want to work with them to resolve the problem.

Step Two: Suggest a solution to compare the instruments they used with your equipment. Compare both instruments with the same standard or area to resolve they are reading the same.

Step Three: Observe their Quality Control person taking measurements with their equipment and allow their person to observe you. If the measurements are still different, further investigation needs to be done by the inspector to determine the cause.

Step Four: Once the difference in readings has been resolved, discuss the steps you took to resolve the problem with the contractor and the results of your investigation. Hopefully at this point you will have resolved your problems with the contractor and demonstrated that your only goal in life is not to make his life miserable. Best case scenario is you have demonstrated that you want to work with him to get the job done and the worst-case scenario is you avoided getting into an argument with the contractor.

If no resolution can be found for the problem, the next step is to get the owner involved. The contractor works for the owner. Explain the problem to the owner presenting both your argument along with appropriate documentation and why the contractor disagrees. Often the owner is not knowledgeable about coatings and is more interested in getting the job done than in having it done according to the specifications. The owner may side with you or he might side with the contractor. If he sides with the contractor, thoroughly document the problem and that the owner allowed the contractor to proceed with the work without correcting the deficiency. Since the owner approved the work to continue, a Nonconformance Report should not be issued.

Nonconformance Reports (NCR)

Nonconformance reports can be a serious issue and should not be written unless absolutely necessary. In some places Nonconformance reports can keep contractors from being eligible to bid on some government projects. When a deficiency is found, as long as the contractor corrects the deficiency, no NCR should be written up. an NCR should be issued when the contractor passes the point where the deficiency can be corrected. i.e. Surface Profile is insufficient, and the contractor has proceeded applying the prime coat without correcting the problem.

Inspection Equipment

To properly perform your duties as a Coating Inspector requires you have properly working inspection equipment. Equipment required for a specific project may vary but the below list should be sufficient for most projects.

1. Electronic Relative Humidity Temperature Meter – Note: much more accurate than a sling psychrometer.
2. Surface Temperature gauge if not included in Psychrometer – Recommend thermocouple type or Infrared Type.
3. Dry Film Thickness Gauge –
 - a. Type 1 Banana Gauge – PosiTest FM or equivalent with calibration plates
 - b. Type 2 Electronic Gauge –PosiTector 6000 or equivalent with calibration foils
4. Flashlight
5. Inspection Mirror or Boroscope
6. Magnifying Glass or digital microscope
7. Salt Testing Equipment (Conductivity or Chlorides)
8. Black light for Oil Contamination (Will not catch all oils and lubricants)
9. Blotter Paper or clean white rag for testing air supply
10. Surface Profile
 - a. Test-Ex Tape & Spring Micrometer or PosiTector RTR Probe (Replica Tape Reader)
 - b. Surface Profile Gauge – PosiTector SPG
 - c. NEW PosiTector RTRP Surface profile – Peak Density probe
11. Holiday Tester if appropriate for the project
12. VIS Standards appropriate for the project
13. Paint Thermometer
14. Optional – Blast Needle Gauge and Nozzle Orifice gauge
15. Optional – Camera if Appropriate for the project

SECTION 2: Measuring Relative Humidity and Dew Point in the Field

Many coating failures have been attributed to applying coatings when climatic conditions were not within specifications. When trying to determine Relative Humidity and Dew Point temperatures, an understanding of the wet bulb, dry bulb, relative humidity and dew point is useful in getting accurate values.

Typically, most project requirements are a Relative Humidity below 85% and a minimum 5°F between the surface temperature and the dew point. When Relative Humidity is around 50% and the Dew Point spread is 10°F to 15°F, accuracy in the tests are not critical. However, when the Humidity is close to 85% (or whatever the requirement is) and the dew point/surface temperature spread is about 5°F, it is important that readings be accurate.

There are two basic methods of measuring Relative Humidity and Dew Point Temperatures in the field. These are addressed in ASTM E 337, Standard Method for Measuring Humidity with a Psychrometer (The measurement of Wet and Dry Bulb Temperatures). One is with a sling psychrometer and the second is with the newer electronic meters.

It is generally assumed that the most accurate method of determining Relative Humidity and Dew Point are the Sling Psychrometer. Sling psychrometers used by meteorologists are “laboratory grade” and have much greater accuracy than sling psychrometers typically used by inspectors and contractors. Even with laboratory grade sling psychrometers, the expected error is in the 5% to 7% range (ASTM E337-84) and it would be expected to see even greater errors with the psychrometers typically used on coating projects. The sling psychrometer measures two parameters, Dry Bulb (ambient temperature) and Wet Bulb.

The dry bulb temperature (DBT) or ambient temperature is the temperature of the air. This is the temperature that you would get in the shade and not the temperature in direct sun.

The wet bulb temperature (WBT) measures the temperature that results from evaporation. It is directly related relative humidity. When moisture evaporates, it cools the environment, reducing the temperature slightly. The WBT will vary with **Relative Humidity** (RH). When the relative humidity is high, evaporation is low and there is less of a cooling effect. When relative humidity is low (air is dry) evaporation increases and the cooling effect is greater. The difference between the wet bulb and dry bulb temperature therefore gives a measure of atmospheric humidity.

Relative Humidity (RH) is the measure of how much moisture is in the air divided by the amount of moisture the air can hold times 100. The amount of moisture the air can hold is dependent on the atmospheric pressure. When the air is 100% saturated, evaporation will stop, and the Dry Bulb Temperature will be equal to the Wet Bulb Temperature.

When $DBT - WBT = 0$ then $RH = 100\%$

It is strongly suggested that electronic meters be used instead of sling psychrometers for the best accuracy. If you are going to use a sling psychrometer, it is recommended that the following procedures be followed to minimize any errors.

SLING PSYCHROMETER.

- The first item is to make sure the thermometers are reading correctly.

1) Inspect the thermometers. Today, most inspectors are using the red spirit thermometers because they do not contain mercury which is considered to be a very toxic heavy metal. Make sure that the column is not separated. Often, especially when left in the heat or after shipping, the red column will separate. This will result in an inaccurate reading. Sometimes by putting the thermometer in ice water followed by hot (not boiling) water, the column can be fixed. If it cannot be fixed, replace it.

2) Calibrate the thermometers – sometimes, thermometers do not read exactly how they are marked.

a. Always field check thermometers. With the wick removed and, in the shade, both thermometers should read the same.

b. By definition, ice water (not ice) is always 32°F. Fill glass 2/3 full of ice cubes. Allow time for the ice and water to reach equilibrium. 15 minutes should be safe. Place thermometers in the water and they should read 32°F. Since the scale is linear, if it is off you can add or subtract the difference to get the thermometer to read accurately. Example: If the thermometer reads 33°F in the water it is reading 1°F high. This needs to be subtracted from each reading to get the correct value. If the temperature between thermometers is off by more than 2 °F, replace the thermometer.

- Store the Thermometers properly between uses:

If the psychrometer is stored in the sun or heat, the plastic case will become heated. When you go to take your readings, the temperature being radiated by the sling psychrometer case will affect your reading introducing an error. Keep the sling stored in the shade near the temperature you will be testing in. NOTE: Thermometers stored in a trunk or car can get hot enough to pop the top off the thermometers.

- Check the Wick:

The wick should be white, not yellow, brown or black. The wet bulb thermometer measures the rate of evaporation of water between the surface of the wick and the bulb of the thermometer. The wick should be clean and flexible. Often, when onsite, you use whatever water is available. This water often has dissolved solids and impurities that get left behind as the water evaporates. Eventually the wick becomes non-porous and while the wick may feel wet, evaporation is affected giving erroneous readings for wet bulb temperature.

When possible, use distilled water and when the wick becomes discolored or hard, cut it off and put a fresh part of the wick on the bulb. (Caution, if you continuously use hard water in the reservoir, the unused part of the wick can also become discolored and hard. It is always recommended to use distilled or demineralized water to maximize the life of the wick)

- Check the Water

When using a new wick, make sure it is soaked thoroughly. If you put a drop of water on the wick, it should not bead up. Let the wick sit for a few minutes to make sure it is saturated.

- How to Check Readings

It is important to take readings in the same area that is to be painted. Face the wind if there is any and rotate the sling psychrometer at about 2 revolutions per second for about 90

seconds. Read the wet bulb temperature first. Be careful to keep your fingers off both thermometers. Continue to rotate for 20 to 30 seconds and take a second reading. If the wet bulb has not changed you are finished. If it is decreasing, continue until you get two readings the same.

Accuracy of the method

Read the Dry Bulb Temperature before you start “Slinging” the psychrometer. Read the dry bulb at the end of the procedure. They should be the same. If they are not, the accuracy of the readings should be questioned. The accuracy of the method depends on the accuracy of the thermometers as well as the operators’ procedures. Let’s assume your reading is off by one degree in opposite directions on the wet bulb and the dry bulb.

Example:

Measured WBT = 58°F DBT = 72°F therefore Wet Bulb Depression (WBD) = 14°F

RH = 42% DB = 47°F

Actual WBT = 57°F DBT = 73°F therefore Wet Bulb Depression (WBD) = 16°F

RH = 35% DB = 44°F

A 2°F error makes a 16% difference in Relative Humidity and a 6% difference in Dew Point.

Electronic Meters:

Electronic meters come in several varieties from meters that just provide Wet Bulb and Dry Bulb Temperatures to meters such as the PosiTector DPM and TQC Dewcheck, that measure, Wet Bulb, Dry Bulb, Relative Humidity, Dew Point, Surface Temperature, Calculate the ΔT between the surface temperature and the dew point., electronic time and date stamp data and can download information to a computer.

As for all electronics, the quality of the sensors is key to how well the meter works. Some of the early meters as well as some still manufactured today, suffer from using low cost sensors that can give erroneous readings and have given electronic meters a bad reputation. Be careful that the great price you got on an electronic meter doesn’t affect the accuracy of the meter.

Electronic meters have some distinct advantages over sling psychrometers. Because there are no moving parts, you can take readings close to where you will be doing the work. Atmospheric conditions at or near the surface of steel can be considerably different inches or feet from the surfaces. Because a sling psychrometer requires room to “sling” it, you can never get readings near the surface.

Electronic meters also minimize operator error. When multiple inspectors or quality control personnel use an electronic meter, they should all get the same readings.

Some meters have calibration kits you can use to verify accuracy. Check before purchasing that this can be done in the field. In most cases, even the cheapest electronic meters will be more accurate than using a sling psychrometer.

As with the rest of industry, keeping electronic records of projects will not only become the norm, it will be required by many owners. Make sure the electronic meter has the capability of time and date stamping data as well as sending the data to a computer.

The typical costs for a sling psychrometer are \$80.00 to \$100.00 based on the model. Replacement thermometers are generally \$30.00 to \$40.00 and replacement wicks are about \$1.00 to \$2.00 each. While many sling psychrometers come with a slide rule calculator on their side, for better accuracy, it is generally recommended to use a psychrometric table which you can get for under \$10.00 or you can get the information for free at:

<https://www.weather.gov/epz/> (NOTE: While this is a government website, like all web sites the address is subject to change- working as of Oct 2019)

The cost for electronic meters varies from \$99.00 to \$800.00. The higher priced models generally have higher quality sensors, measure surface temperature, record readings and will interface to a printer or computer.

Good quality electronic meters and sling psychrometers can both supply accurate information when used properly. It is important to make sure that your readings are accurate, especially if they are going to restrain the contractor from painting. It is probably a good idea to keep both on site in case your batteries die in your meter or you break a thermometer and don't have a replacement.

Spreadsheet Formula to Calculate Relative Humidity and Dew Point.

Since most of us have computers, if you prefer to set up a spreadsheet to calculate Relative Humidity and Wet Bulb rather than using tables, the following spreadsheet will calculate them.

A	B	C
1	Dry Bulb (T)	Enter Dry Bulb Temperature Here (F)
2	Wet Bulb (Tw)	Enter Wet Bulb Temperature Here (F)
3	Convert T (F) to T(C)	=5/9*(C1-32)
4	Convert Tw (F) to Tw(C)	=5/9*(C2-32)
5	es	=6.112*EXP((17.67*C3)/(C3+243.5))
6	ew	=6.112*EXP((17.67*C4)/(C4+243.5))
7	e (Vapor Pressure)*	=C6-(1015*(C3-C4)*0.00066*(1+(0.00115*C4)))
8	RH (%)	=C7/C5*100
9	Td (C)	=(237.7*(LOG(C5*C8/611)))/(7.5-(LOG(C5*C8/611)))
10	Convert Td (C) toTd(F)	=9/5*C9+32

NOTE: Station Pressure of 1015 mb (approximately 30 inches of Hg)



SECTION 3: Surface Preparation of Metals – Profile

Surface preparation can be broken down into two main categories.

- Surface Profile
- Surface Cleanliness

Surface profile is the determination of the roughness of the surface and for painting purposes involves depth of the profile, peak density and angularity of the profile.

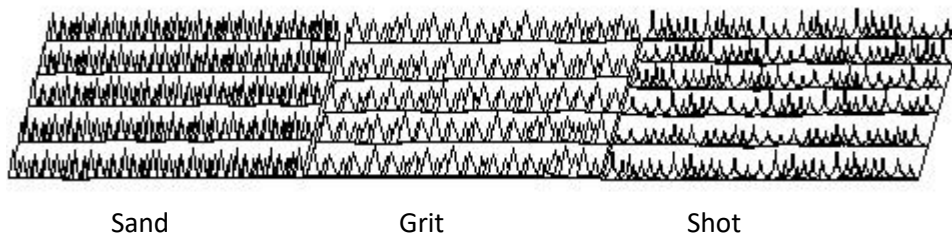
Surface Cleanliness involves determining how much of the original mill scale, rust and paint have been removed from the surface as well as how much invisible surface contamination is present usually in the form of salts. More on Surface cleanliness can be found in section 4.

Surface preparation is one of the main causes of most paint failures because more than any other factor, it affects how well the paint sticks to the surface being painted.

Most paint forms a mechanical bond with the steel and generally surfaces that have roughness will supply the best mechanical bonds. Also, when you put a profile on the surface, you increase the surface area, so the paint has more surface area to adhere to. Different paints are made for different texture surfaces from smooth to rough.

Also, remember, paint will bond to the surface being coated and if the surface is loose (rust, mill scale or old paint), when the surface breaks off, so will the paint. Some paints are formulated to coat over these surfaces with minimal surface preparation, but they should be used with caution and understanding

On Metal, is there a difference in profile due to sand, shot or grit?

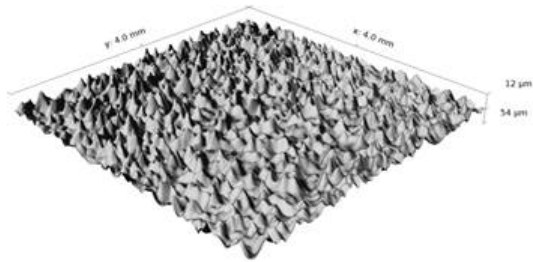


The above drawings are rough approximations of the type of profile you might get from Sand, Grit or Shot. The profile can vary due to many different factors, however, generally sand has a finer profile than grit and shot gives a rounded, “pinged” type of profile. The above drawings all have about the same profile depth but have an entirely different appearance.

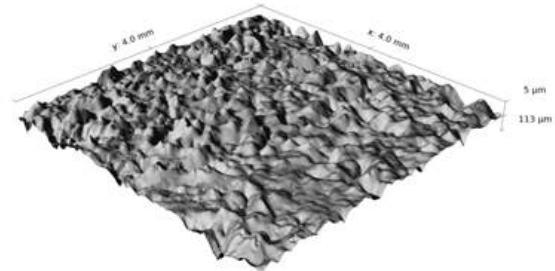
Because of the difficulty in measuring peak density, it is rarely measured for industrial coating applications, however, the peak density can be an important factor in determining the bond of the coating to the substrate. In general, sand will have the “highest” peak density and shot the “lowest”. When a specification calls for an “angular” surface profile, this is generally best done with Grit.

DeFelsko has developed a new instrument that makes measuring peak density easier and quicker, so it is worth taking a second look as this often-ignored parameter. Below are four “pictures” of surface profile taken with the new RTRP probe. Basic parameters are displayed

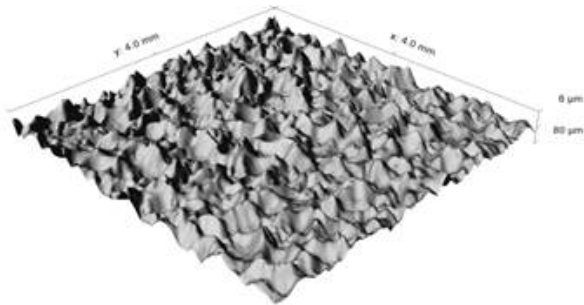
directly on the meter and other parameters can be obtained by using free or paid for third party software.



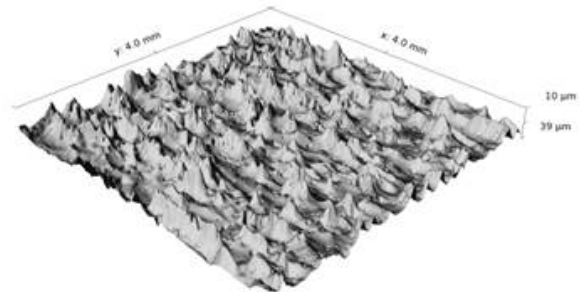
Blasted with G50



Blasted with Garnet



Blasted with S230/G40



Blasted with Bristle Blaster.

Z-axis enhanced for clarity –

The figure below is a simplified example of why BOTH *peak height* AND *peak density* are important to the understanding of coating performance. The two surfaces have different geometries, yet their height measurements are the same. To get a clearer picture of the surface available for bonding, peak count measurements must also be obtained. Furthermore, both measured values make it possible to investigate the increase in *surface area* resulting from the abrasive blasting process.

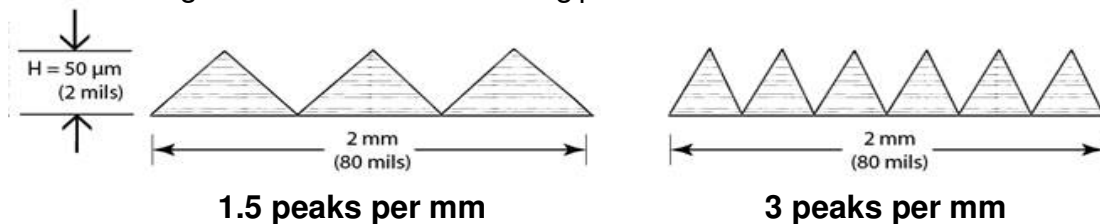


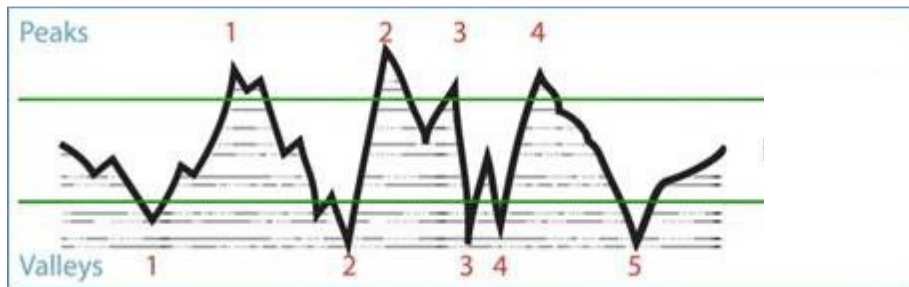
Figure 4: Both surfaces have the same measured peak-to-valley height. A second important measurable parameter, peak density, helps explain why coatings bond differently to each surface.

Pictures from “CORRELATION OF REPLICA TAPE MEASUREMENTS TO ESTABLISHED MEASUREMENT TECHNIQUES”, Dave Beamish, DeFelsko Corporation – Link to full article:

<http://www.defelsko.com/technotes/profile/surface-profile-and-adhesion.htm>

Surface Profile Depth

An “exact” profile depth cannot be determined over the surface of the substrate because the depth of the Peaks and Valleys varies greatly. Surface profile attempts to find the AVERAGE or MAXIMUM depth for the peaks and valleys over a given area based on the method used.



Measuring Surface Profile

There are several accepted ways to find surface profile and each one has advantages and disadvantages. The First Three methods are detailed in ASTM D4417, “Standard Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel”

1. Surface Profile Visual Comparator (D4417 Method A)
2. Surface Profile Gage – Profilometer (D4417 Method B)
3. Press-o-film Testex® Tape (D4417 Method C)
4. DeFelsko RTRP Surface profile – Peak Density Gauge
5. Surface Roughness Tester Surface

Profile Visual Comparator: - Method A

There are several different visual comparators. The most common one in the US is the Kean-Tator comparators which come in sand, shot and grit. For ISO, according to ISO 8503 part 1, Surface Comparator you can use the TQC LD2040 and 2050. There is also the Rugotest (TQC LD6010) no. 3 comparison standard for blasted surfaces consisting of 6 examples of grit- blasting and 6 examples of shot-blasting.

These comparators are cast in metal to approximate surface profiles up to 4 mils. The comparators are held up to the blast profile and usually viewed with a lighted magnifier (5X or 10X) and the texture and roughness of the comparator is compared to the blasted steel. Because the profile changes based on the media used, comparators are sold as Sand, Shot, or Grit.

Comparators, when used by an experienced inspector should give accuracy to approximately ± 0.5 mils within the range of the comparator. Since not all grit gives the same profile, this is probably the most problematic comparator to use. Until the operator is experienced, it is usually best to “calibrate” their eyes using one of the other methods to confirm readings. Since the readings are subjective and there is no record with this method, I do not recommend it for field use where different abrasives may be used.

Comparators are better suited for shop use where the same abrasives and conditions are repeated. Care should be exercised when new personnel are using them and frequent checks should be made by an experienced inspector or by another method until they are properly trained.

A Surface Profile Gage – Method B

These were the original surface profile gauges. This is a gage with a wide base that sits on the peaks and has a needle that goes into the valleys. Since these gauges measure only a single point, only one peak to valley reading is made with each reading. To get a good idea of the average surface profile, several measurements must be made and averaged together. Method B requires a minimum of 10 readings per spot averaged together. The meter must be zeroed to a smooth surface, such as glass. With a dial gage, readings must be recorded as they are made. There is no permanent record.

With the emergence of electronics, the original surface profile gauges have been made easier by automating the process of averaging the readings. These gauges such as the Defelsko PosiTector SPG are digital and will record average, min and max readings and download to a computer for a permanent record. It also has wireless (Bluetooth) built in to it. To date, this is the most accurate and reliable method to determine the “accurate” surface profile. It also allows you to keep a full record of measurements. (While it does not conform to the current ASTM method, 5 readings can be taken instead of 10 with little loss in statistical integrity)

The PosiTector 6000 SPG also has a TestEx mode that simulates the same reading as you would get using TestEx tape by dropping the low readings and only recording the max reading. You can access this feature in the Advanced model using SmartBatching.

Press-o-film Testex® Tape – Method C

Testex Tape is probably the most common method used to determine surface profile. The Tape has a compressible foam layer with a 2 mil Mylar covering. A “Burnishing” tool (Most people call this a swizzle stick), is used to rub the foam into the profile. The foam takes on the shape of the profile and it is measured with a spring micrometer. Since the foam is covered with 2 mils of Mylar, this must be subtracted from the reading to get the surface profile.

It is important to understand that TestEx tape measures maximum profile and not average profile. When using Testex Tape, make sure the area is clean and representative of the area being tested. If the tape is not rubbed with sufficient pressure, the correct reading will not be achieved. As the center of the tape is rubbed, the color will change slightly. The entire surface should look the same.

If the tape is reading within 20% of the maximum or minimum reading on the Testex tape, the next higher or lower tape should be used.

The advantages to this method are:

Gives the profile over approximately 3/8-inch area.

1. Gives a permanent record of the test.
2. Easy to do.
3. No objectivity on the part of the operator.

Disadvantage.

1. Can get costly if many measurements are required
2. Improper “Burnishing” of the tape can give low results.

3. Since the micrometer reads the thickest area, it will give a number closer to the maximum value rather than the average.
4. Use of the wrong grade of tape can give the wrong answer.
5. Repeated readings can compress the tape giving wrong readings.

Testex comes in several grades.

Course E122-B - Testex Tape - 50 Tape Roll Coarse - 0.8 - 2 mils

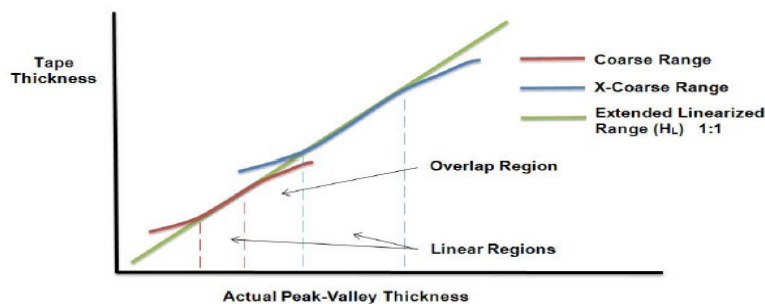
Extra Course E122-C - Testex Tape - 50 Tape Roll Extra Coarse - 1.5 - 4.5 mils

Extra Course+ E122-F - Testex Tape X-Course Plus - 1.5 to 8 mils

NOTE: There is a new optical grade for use with the Defelsko RTRP

Spring Micrometer verses DeFelsko Replica Test Reader

As previously mentioned, TestEx tape is not accurate in the upper 20% and lower 20% of its range. This is do the way the Spring Micrometer measures the tape. The New Defelsko RTR probe linearizes the Testex tape measurements so it is accurate through the full range of the tape grade Below graph was developed by DeFelsko.



What if I am on the job and I don't have a "Burnishing" Tool?

For those of us without a dictionary, Webster's Dictionary defines burnishing as; "to rub (a material) with a tool for compacting or smoothing"

To acquire the most common burnishing tool, the easiest thing is to break for lunch and go to a restaurant that serves mixed drinks. Request a Swizzle Stick and you have a burnishing tool. It should have a round end and be deburred prior to use. The ASTM method does NOT define what a burnishing tool is. The most common object used is generally the end of a disposable pen. The Press-O-Film directions say to use the edge of the container that holds the tape.

What is used as a burnishing tool is not as important as to make sure the surface is "burnished" thoroughly. Not rubbing hard enough can lead to erroneous profile readings.

We have a question on a job from several years ago and the tape was included as part of the job record. Will it still read the same?

The answer is; it should. Once the foam is compressed, it should hold the original profile indefinitely. It is possible that frequent readings or if heavy objects were placed on it, it could compress further and give low readings.

Surface Roughness Tester – Drag Stylus

This is a relatively new method and because of its complexities, generally is not used as a field test. The method involves moving a diamond stylus over the surface to be measured. The meter records max and minimum peaks and valleys, number of peaks, peak density on several other variables. The meter can be interfaced to a computer or give a direct printout. These meters start around \$1,200 to \$2,500 and are generally used in shops that have quality control departments.

The downside is that the diamond stylus may be too large to make into the valleys of the profile and may not give an accurate profile. It will, however, give an accurate peak density count.

If the blast profile measures too high or too low. What can we do?

If the profile was measured with a comparator, you could be getting a bad reading due to using the wrong comparator or even if using the correct comparator, the differences between the blast patterns on the metal may be too different to get an accurate reading. Use Method B or C to confirm.

If a profile gage was used, make sure it is zeroed properly and if you have a surface with a known profile, test it for accuracy. If it is still off after taking several readings, make sure the tip is still in good shape. While the tip is very hard, it is also brittle and dragging the tip or dropping the meter on the tip, may cause it to break.

If you used Testex tape, make sure the surface was clean before you use the tape. Dirt on the back of the tape will give erroneous readings. Make sure the tape was rubbed hard enough and with a proper burnishing tool. Your thumbnail may not provide enough pressure. Make sure the proper grade of TestEx tape was used. You can also use Method B to confirm readings.

If two different methods are used and you cannot get them to agree, testing has found the Surface Profile Gauge, when used properly, gives the best results.

If the blast profile is confirmed and it is still out of spec. Some general trouble shooting ideas may include the following:

- 1. Check Air Pressure using a needle pressure gage at the blast nozzle.*
- 2. Check Blast Nozzle Orifice size using an orifice gage.*
- 3. Are you using the proper type and size of media?*
- 4. Are you over recycling the media?*
- 5. Run a screen test to determine the actual size of the media*
- 6. Is the blast operator running the equipment properly?*
- 7. Adjust the pressure at the blast nozzle is possible.*
- 8. Change how far the operating is standing off the nozzle.*
- 9. Increase or decrease the angle of the blast on the steel.*
- 10. Are you blasting a previously blasted profile that is different than what you are trying to achieve?*

A complete discussing of Abrasive Blasting is beyond the scope of this question and a consultant should be contacted if you are having problems.

How does Surface Profile Affect Paint Usage?

The rule for paint is 1 gallon of paint applied at 1 mil will cover 1,604 sq ft. wet film thickness on a smooth surface. The effect of blast profile is important in calculating estimates of paint quantities required especially in cases in which the specification requires application of a minimum dry film thickness. Given a series of peak to valley heights of an abrasive blast cleaned surface, the greater the peak to valley height, the more paint will be required to fill the profile before a measurable thickness of paint is applied.



Figure #1



Figure #2

In the above drawings, if Figure #1 represents a 1,604 sq ft area and we needed a 2 mil coating of 100% solids paint, we would need to apply 2 gallons of paint.

It should be fairly easy to determine that Figure #2 has a greater surface area than Figure #1. If Figure #2 is the same area with a Sand or Grit blast profile, you would APPROXIMATE 3 gallons of paint to get 2 mil Dry Film Thickness (DFT). See Rule of Thumb Below.

Rule of Thumb:

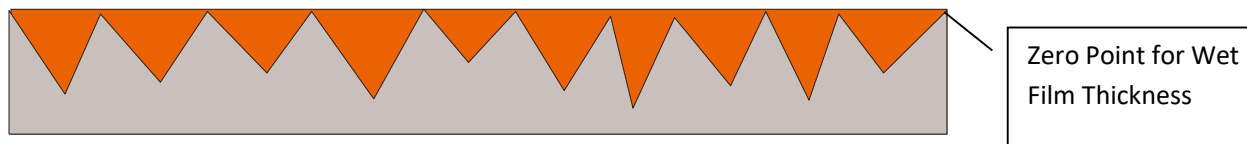
A rule of thumb for the determination of the approximate extra paint required to fill a SAND or GRIT blast profile is to multiply the peak to valley height (profile) times 0.5 and add this to the Dry Film Thickness you are trying to achieve.

For example, for a peak to valley height of 10 mils, an additional quantity of paint equal to a full coat at 5 mils dry film thickness will be required. Because a SHOT Blast Profile is smoother, the amount of paint would be slightly less, and you might want to use 0.25 times the blast profile to calculate the additional amount of paint.

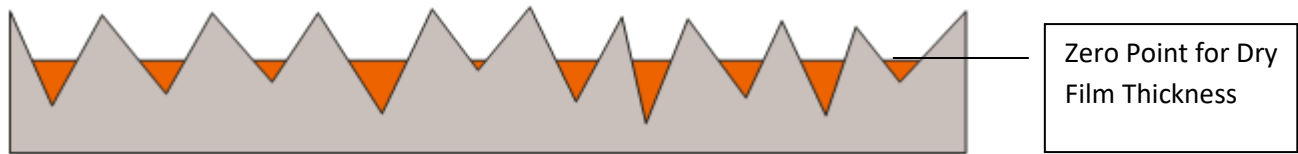
*NOTE: See next question for explanation of “before a measurable thickness of paint is applied.”

Understanding the Effect of Profile Effect on DFT Measurements?

If you calculate the Wet Film Thickness required to get a dry film thickness, if you don't allow for the profile, you will be off. When you measure a Wet Film Thickness you are measuring the amount of paint ABOVE the peaks.



When using a DFT Gage the meter must establish a zero point. When you have a surface with peaks and valleys, there is no clear line where the “Zero Point” is. There are areas in the profile that are LESS THAN THE ZERO POINT. The meter will not register any paint as being applied to the surface until it is greater than the zero point.



In the above drawing, if the DFT gage perceives the “Zero Point” to be above the orange paint, any paint below the dashed line will not be measured. This will be explained in greater detail in the section on Dry Film Thickness.

Applicable Surface Profile Standards

Standards are available from several organizations that provide direction for using various methods to obtain an anchor profile measurement. Available standards include but are not limited to the following:

ASTM D 4417: Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

ASTM D 7127: Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument

NACE RP0287: Standard Recommended Practice – Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape

SSPC PA-17: Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements - is intended for use by specifiers and contractors. It provides a method for determining whether the profile of a steel surface is in conformance with project specifications when using the instruments and procedures contained in ASTM D 4417 and D 7127

ISO 8503-1:2012: Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces

ISO 8503-2: Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel – Comparator procedure

ISO 8503-3: Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 3: Method for the calibration of ISO surface profile comparators and for the determination of surface profile – Focusing microscope procedure

ISO 8503-4z: Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile – Stylus instrument procedure

ISO 8503-5: Preparation of steel substrates before application of paints and related products -- Surface roughness characteristics of blast-cleaned steel substrates – Part 5: Replica tape method for the determination of the surface profile



SECTION 4: Surface Preparation of Metals – Visual Cleanliness –

Surface preparation is probably the main cause of most paint failures because more than any other factor, it affects how well the paint sticks to the surface being painted. Surface preparation can be broken down into two main categories.

- Surface Profile
- Surface Cleanliness

Surface profile is the determination of the roughness of the surface and for painting purposes involves depth of the profile and angularity of the profile. More on Surface cleanliness can be found in the Surface Preparation – Profile – SECTION 3

Surface Cleanliness involves determining how much of the original mill scale, rust and paint have been removed from the surface as well as how much invisible surface contamination is present usually in the form of salts. More on Surface cleanliness can be found in the Surface Preparation – Salts – SECTION 5

Visual Cleanliness

Paint will bond to the surface being coated and if the surface is loose (rust, mill scale or old paint), when the surface breaks off, so will the paint. Some paints are formulated to coat over these surfaces with minimal surface preparation, but they should be used with caution and understanding.

Because there is not specific test for Visual Cleanliness, standards have been developed to determine specific levels of cleanliness. The most common visual standards are SSPC/NACE and ISO. Since the determination is visual, guides have been established to help clarify the text in the specifications. A brief summary follows.

SSPC-SP 1 – Solvent Cleaning

This specification covers the requirements for the solvent cleaning of steel surfaces. Removal of all detrimental foreign matter such as oil, grease, dirt, soil, salts, drawing and cutting compounds, and other contaminants from steel surfaces by the use of solvents, emulsions, cleaning compounds, steam or other similar materials and methods which involve a solvent or cleaning action.

SSPC-SP 2 - Hand Tool Cleaning

This specification covers the requirements for the hand tool cleaning of steel surfaces. Removal of all rust scale, mill scale, loose rust and loose paint to the degree specified by hand wire brushing, hand sanding, hand scraping, hand chipping or other hand impact tools or by a combination of these methods. The substrate should have a faint metallic sheen and also be free of oil, grease, dust, soil, salts and other contaminants.

SSPC-SP 3- Power Tool Cleaning

Specifies the use of power assisted hand tools to obtain a steel surface free of all loose mill scale, loose rust, loose paint, and other loose detrimental foreign matter. It is not intended that adherent mill scale and rust be removed by this process. Mill scale and rust are considered adherent if they cannot be removed by lifting with a dull putty knife

SSPC-SP 5/NACE No. 1 - White Metal Blast Cleaning

This standard covers the requirements for white metal blast cleaning of steel surfaces by the use of abrasives. Removal of all mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels. A White Metal Blast Cleaned Surface Finish is defined as a surface with a gray-white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed without magnification, shall be free of all oil, grease, dirt, visible mill scale, rust, corrosion products, oxides, paint, or any other foreign matter.

SSPC-SP 6/NACE No. 3 ISO 8501 1-1: 1988(E) (SIS 05 59 00) Sa 2 - Commercial Blast Cleaning

This standard covers the requirements for commercial blast cleaning of steel surfaces by the use of abrasives. Removal of mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree specified. A commercial blast cleaned surface finish is defined as one from which all oil, grease, dirt, rust scale and foreign matter have been completely removed from the surface and all rust, mill scale and old paint have been completely removed except for slight shadows, streaks, or discolorations caused by rust stain, mill scale oxides or slight, tight residues of paint or coating that may remain; if the surface is pitted, slight residues of rust or paint may be found in the bottom of pits; at least two-thirds of each square inch of surface area shall be free of all visible residues and the remainder shall be limited to the light discoloration, slight staining or tight residues mentioned above.

SSPC-SP 7/NACE No. 4 -Brush-Off Blast Cleaning

This standard covers the requirements for brush-off blast cleaning of steel surfaces by the use of abrasives. Removal of loose mill scale, loose rust, and loose paint, to the degree hereafter specified, by the impact of abrasives propelled through nozzles or by centrifugal wheels. It is not intended that the surface shall be free of all mill scale, rust, and paint. The remaining mill scale, rust, and paint should be tight, and the surface should be sufficiently abraded to provide good adhesion and bonding of paint. A brush-off blast cleaned surface finish is defined as one from which all oil, grease, dirt, rust scale, loose mill scale, loose rust and loose paint or coatings are removed completely but tight mill scale and tightly adhered rust, paint and coatings are permitted to remain provided that all mill scale and rust have been exposed to the abrasive blast pattern sufficiently to expose numerous flecks of the underlying metal fairly uniformly distributed over the entire surface.

SSPC-SP 10/NACE No. 2 - Near-White Blast Cleaning - ISO 85011-1:1988 (E) (SIS 05 59 00) Sa 2 1/2

This standard covers the requirements for Near-White Metal Blast Cleaning of steel surfaces by the use of abrasives. Removal of nearly all mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree hereafter specified. A Near-White Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except for very light shadows, very slight streaks or slight discolorations caused by rust stain, mill scale oxides, or light, tight residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above.

SSPC-SP 11 - Power Tool Cleaning to Bare Metal –

Specifies the use of power tools to produce a bare metal surface and to retain or produce a surface profile. This specification is suitable where a roughened, clean, bare metal surface is required, but where abrasive blasting is not feasible or permissible. Once cleaned, the surface will be free of visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. Slight residue of rust and paint may be left in the lower portion of pits if the original surface is pitted. Surface shall have a degree of roughness (profile) of no less than 1 mil (25 microns). Although the MBX Bristle Blaster exceeds the minimum surface profile, at the current time, it falls under this standard.

SSPC-SP 12/NACE No. 5: Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

This standard provides requirements for the use of high- and ultrahigh pressure water jetting to achieve various degrees of surface cleanliness. This standard is limited in scope to the use of water only without the addition of solid particles in the stream.

SSPC-SP 13/NACE No. 6 - Surface Preparation of Concrete

This standard gives requirements for surface preparation of concrete by mechanical, chemical, or thermal methods prior to the application of bonded protective coating or lining systems. The requirements of this standard are applicable to all types of cementitious surfaces including cast-in-place concrete floors and walls, precast slabs, masonry walls and shotcrete surfaces.

An acceptable prepared concrete surface should be free of contaminants, laitance, loosely adhering concrete, and dust, and should provide a dry, sound, uniform substrate suitable for the application of protective coating or lining systems. Depending upon the desired finish and system, a block filler may be required.

SSPC-SP 14/NACE No. 8 – Industrial Blast Cleaning

This joint standard covers the use of blast cleaning abrasives to achieve a defined degree of cleaning of steel surfaces prior to the application of a protective coating or lining system. Industrial blast cleaning provides a greater degree of cleaning than brush-off blast cleaning (NACE No. 4/SSPC-SP 7), but less than commercial blast cleaning (NACE No. 3/SSPC-SP 6). Industrial blast cleaning is used when the objective is to remove most of the coating, mill scale, and rust, but when the extra effort required to remove every trace of these is determined to be unwarranted.

The difference between an industrial blast and a brush-off blast is that the objective of a brush-off blast is to allow as much of an existing coating to remain as possible, while the purpose of the industrial blast is to remove most of the coating.

A commercial blast is free of mill scale, rust, and coatings, and allows only random staining on less than 33% of the surface. The industrial blast allows defined mill scale, coating, and rust to remain on less than 10% of the surface and allows defined stains to remain on all surfaces.

SSPC-SP 15 Commercial Grade Power Tool Cleaning

This standard covers the requirements for power tool cleaning to provide a commercial grade power tool cleaned steel surface, and to retain or produce a minimum 25 micrometer (1.0 mil) surface profile. A commercial grade power tool cleaned steel surface, when viewed without

magnification shall be free of all visible oil, grease, dirt, rust, coating, oxides, mill scale, corrosion products, and other foreign matter, except as noted.

Random staining shall be limited to no more than 33 percent of each unit area of surface as defined. Staining may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating. Slight residues of rust and paint may also be left in the bottoms of pits if the original surface is pitted.

This standard differs from SSPC-SP 3, Power Tool Cleaning, in that a higher degree of surface cleanliness is required, and a minimum surface profile of 25 micrometers (1.0 mil) will be retained or produced. This standard differs from SSPC-SP 11, Power Tool Cleaning to Bare Metal, in that stains of rust, paint, or mill scale may remain on the surface.

SSPC-SP 16, Brush-off Blast Cleaning of Non-Ferrous Metals

SP 16 is intended for brush-off blast cleaning of coated or uncoated metal surfaces other than carbon steel prior to the application of a protective coating system. Surface preparation using this standard is intended to roughen and clean coated and uncoated non-ferrous metal substrates, including, but not limited to, galvanized surfaces, stainless steel, copper, aluminum, and brass. SP 16 requires the cleaned surface to be free of loose contaminants and loose coating as determined by visual inspection. A minimum surface profile of 19 micrometers (0.75 mil) on the bare metal surface is required. Intact coatings are required to be roughened to the degree specified in the project specification.

SSPC-SP 17: Thorough Abrasive Blast Cleaning of Non-Ferrous Metals

This standard contains requirements for thorough abrasive blast cleaning of coated or uncoated metal surfaces other than carbon steel prior to the application of a protective coating system. This standard is used when the objective is to remove all visible contaminants from the surface and allows random color variation on no more than 5% of each unit area of surface. Surface preparation using this standard is used to provide a greater degree of cleaning than brush-off blast cleaning of stainless steels and non-ferrous metals (SSPC-SP 16). This standard represents a degree of cleaning that is similar to that defined for carbon steel substrates in SSPC-SP10/NACE No. 2.

SSPC VISUAL STANDARDS

It is important to understand that the Guides only describes the pictorial standard and does not constitute the standard. It is to be used for comparative purposes and is not intended to have a direct relationship to a decision regarding painting requirements.

SSPC-VIS 1	Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning
SSPC-VIS 2	Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces
SSPC-VIS 3	Guide and Reference Photographs for Steel Surfaces Prepared by Power- and Hand-Tool Cleaning
SSPC-VIS 4/NACE VIS 7	Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting
SSPC-VIS 5/NACE VIS 9	Guide and Reference Photographs for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning

SSPC/NACE/ISO/Swedish Standards Chart

	Steel Structures SSPC (USA)	NACE	British Std. BS 4232	Swedish Standard SIS 05 5900 - 1967 / ISO 8501-1 : 1988	Shipbuilding Research Association of Japan-SPSS.
White Metal	SSPC - SP 5	NACE # 1	1 st Quality	SA 3	JA Sh 3 or JA Sd 3
Near White Metal	SSPC - SP 10	NACE # 2	2 nd Quality	SA 2½	JA Sh 2 or JA Sd 2
Commercial Blast	SSPC - SP 6	NACE # 3	3 rd Quality	SA 2	JA Sh 1 or JA Sd 1
Brush Off Blast	SSPC - SP 7	NACE # 4	-	SA 1	-

NOTE: In the above table, the comparisons are only approximate between Swedish/ISO standards and SSPC/NACE standards. There are significant differences and they should not be interchanged without understanding the differences.

I have a Specification that call for SSPC SP-X/NACE Y, what is my first step.

If you have a specification that requires abrasive blast, Hand tool, Power Tool or Water Jetting, make sure you have a copy of the standard specified. Unless otherwise stated in the specification, always use the most current version. If there is a VIS Guide applicable to the method being used, it is useful to have these on site. These can be purchased from the specifying organizations or from most Equipment distributors including myself.

I have a Specification that requires SSPS SP6/NACE 3, do I need to do SSPC SP1?

YES. All the surface preparation methods require removal of oil. Grease and other contaminants by SSPC-SP1 or other agreed upon method. If you do not clean the surface first, you do not meet the specification criteria.

The contractor says all the mill scale has been removed, but I think I still see some?

Mill scale usually fractures and breaks off during blasting and does not accept a profile. If there is any question, apply a couple of drops of 5% Copper Sulfate to the area in question, Steel will turn copper colored and mill scale will not.

I am arguing with the contractor over “staining” verses “rust”?

Rust is iron oxide that is attached to the surface of the steel and must be removed. If you have ever tried to get rust out of a shirt, you know that it can stain and does not come out easily. This can also happen to steel. A stain is part of the metal and can only be removed by removing the surface of the steel. Think of it like wearing a white shirt where the shirt is the metal. You spill spaghetti sauce on your shirt, it is like rust. Remove the sauce by rubbing with a wet cloth and you still have a red stain. It is OK to have the sauce stain just not the sauce.

As a last resort, you can examine the surface under magnification and determine if the stain is part of the surface or above the surface. A 10X magnifier or the 30X Pocket microscope works great for this as does the EXTECH MC108 or MC200 which also take photographs. (Note – the method states “viewed without magnification” so use caution when using magnification for what you are looking at)

I have a project that requires SSPC SP2 or SP3. Before I start, I cannot remove any rust, mill scale or paint with a Dull Putty Knife. Am I done?

NO. The dull putty knife test applies after the hand tool or power tool cleaning. Once the entire surface is clean, then check the surface with the dull putty knife.

Using Vis 1, the contractor says he has met the spec, I say he has not.

Remember, Vis 1 (and the other Vis guides) is a guide to help explain the standard. In case of disputes, the text of the method determines if the surface had met the specification. This being said, there are many factors that affect the appearance of the final blasted surface. Make sure you are using the proper starting grade for the metal in the Vis Guide.

Also, in the back of the Vis 1 Guide, it shows metal blasted to an SP5 with several different media. These all meet the criteria of an SP5 but they all have a different appearance.

My specification calls to use VIS 1 to determine surface profile. How do I do that?

You can't. Surface profile has nothing to do with surface cleanliness. Prior to doing any work, this needs to be addressed and you may want to refer them to a Consulting Service since they should not be writing specifications.

Do I really need a “white metal” blast or is “near white” OK?

In general, you need a white metal blast for immersion surfaces, metalizing, and inorganic zinc. For most other services, near white is usually OK. The coating manufacturer should have the final determination of the required cleanliness. Also, on new steel, there should not be any difference between a white metal and a near white blast because there should not be any staining.

I need to achieve an SP 11 – What is the best way?

There are many considerations to determine the best method, but in general the **Montipower MBX Bristle Blaster** easily achieves the 1 mil profile and generally 2.5 to 3.3 mils. It also gives the benefit of giving a profile that closely resembles that of a grit blasted surface.



SECTION 5: Surface Cleanliness – “Invisible Contaminants” Tips and Tricks:

While many factors can lead to coating failure, perhaps the most common reason is Inadequate Surface Preparation. It is important to understand that surface preparation has two components:

Visible

Invisible (Surface Contamination)

What are Visible and Invisible Surface Contaminants?

There is general agreement in the coating industry on the importance of visible surface preparation and that will be dealt with in the Surface Cleanliness – “Visible” Cleanliness. Invisible surface contamination is much more problematic, less understood and less agreed on by many “experts”. Remember, MOST articles on this subject have been written by people with a specific agenda in mind. I am not aware of any “definitive” article on surface contamination written from a pure “research” perspective. Make sure you separate the HYPE from the FACTS

For additional information I will refer you to the article “Myths About Salts, Chlorides, and Coatings” - This article appeared in the April Materials Performance Magazine. Much of what you know about salts may be wrong. You can get it on my website at www.m-testco.com.

Invisible surface contaminants are generally defined as any substance on the surface (or near the surface) of the substrate that cannot be viewed with the eyes. These are normally Salts. Salts primarily cause two problems:

CORROSION.

OSMOTIC BLISTERING

What are Salts?

In chemistry, salt is a general term used for ionic compounds composed of positively charged cations and negatively charged anions, that combine so that the product is neutral and without a net charge. These ions can be inorganic (Cl⁻) as well as organic (CH₃-COO⁻) and monoatomic (F⁻) as well as polyatomic ions (SO₄²⁻).

The important part is salt is composed of ions which have a negative or positive charge. When salts are DISSOLVED in water, they form a SOLUTION. The Cations and Anions are necessary for a current to flow in a liquid such as water. The dissolved salts are referred to as TOTAL DISSOLVED SOLIDS (TDS). The higher the SPECIFIC CONDUCTANCE of the ions, the better a current will flow and the easier it is to create a CORROSION CELL. In addition, the total number of ions present in the solution, (TDS) determine the OSMOTIC PRESSURE that will be exerted on a SEMIPERMIABLE MEMBRANE.

In order to understand the importance of Salts, it is important to understand some terms. These definitions may make a chemistry teacher cringe, but they are intended to explain the words in the context of this discussion.

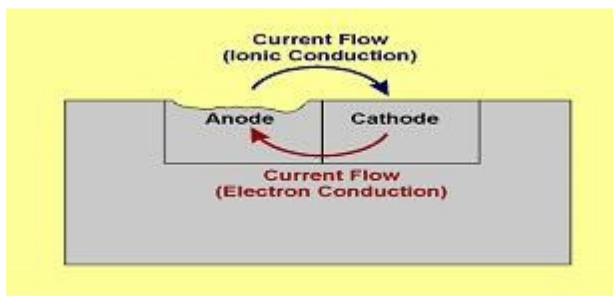
DISSOLVED: The most common salt is sodium chloride (Na^+Cl^-). When salt is put into water and stirred, it disappears. This happens because the salt breaks apart into ions, the Cation (Na^+) and the Anion (Cl^-).

SOLUTION: The dissolved salt forms a solution with the water. The ions move into the water matrix and become physically inseparable from the water.

TOTAL DISSOLVED SOLIDS: The total number of ions in a solution usually expressed in ppm.

SPECIFIC CONDUCTANCE: Different ions are more conductive than other ions. That is why sulfuric acid makes a better battery than saltwater. The higher the specific conductance of the ions in the solution, the more charge the water can carry and the more efficient corrosion cell it will generate. The conductivity of a solution is often used to estimate the Total Dissolved Solids.

CORROSION CELL: A picture is worth a 1000 words.



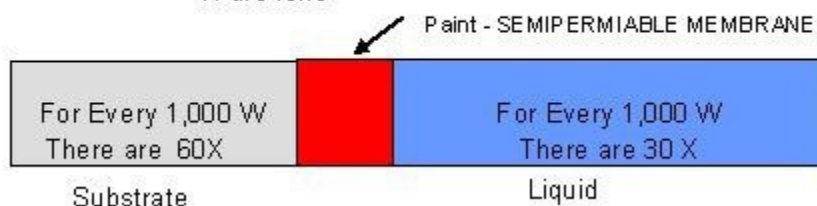
For corrosion Cell to occur requires 4 items.

1. Anode – Corrosion (metal loss) occurs at the anode.
2. Cathode – For this discussion it is sufficient to know you need a cathode.
3. **Electrolyte – Water that contains IONS (dissolved salts)**
4. Metallic Pathway – Substrate.

SO, for corrosion to occur requires Salts for the electrolyte. When a surface is painted, it physically separates the electrolyte from the metallic pathway thereby preventing corrosion cells from forming.

OSMOTIC PRESSURE (OSMOTIC CELL): Again, this is best illustrated with an illustration:

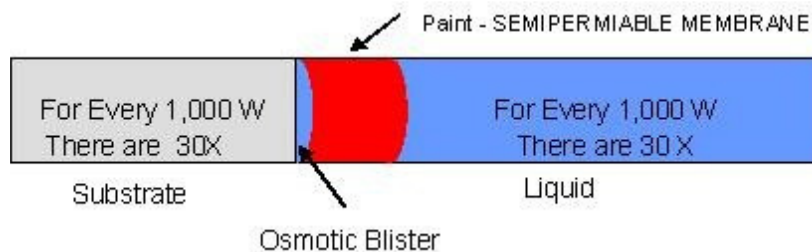
Lets Assume: W are Water Molecules
X are Ions



Nature wants everything to be in balance and will do whatever is necessary to restore that balance. There are Twice as many X's or Ions on the left side of the membrane as the right side.

To balance things out you can move 15 X's from the left side to the right side. Unfortunately, the X's or ions will not go through the membrane so it must balance it out moving the water which will go through the membrane. To balance things out, 1,000 W's must go through the membrane for every 60 X's to balance it out

Since there is not enough room for the water, it pushes up on the paint and causes a blister.



Osmosis is a property of the solution and not a property of the salt. The driving force or Osmotic Pressure is determined by the concentration of salts in the solution on the surface (substrate) and not the concentration of salts on the liquid side.

For those that want a more technically correct definition read the following. Osmosis is a relatively complex and the process is dependent on the concentration of the solute. For the salt concentrations in which we are dealing Osmosis acts like a vapor phase reaction.

While most coatings provide "barrier protection" meaning the slow the movement of water to the substrate, in reality they become saturated with water and may contain 1% to 3% moisture in the matrix. When the water molecules reach the surface of the substrate, if the surface is free of ions, the pure water will continue its journey and go back into the coating. However, if there are soluble ions on the surface, they will go into solution with the water. Since the water now has soluble ions present, the vapor pressure of the new solution is increases and the migration of the water is slowed down. Since the amount of water flowing in is constant and the amount of water flowing out is slowed, eventually the buildup of water will force the coating off the surface forming a blister. This process will continue as long as the concentration of ions below the coating is equal to the concentration of the solution above the coating at which time the water flowing in will equal the water flowing out.

Small pinholes can also lead to osmotic blistering. The water, with the salts migrates to the surface of the steel through the pinhole and insoluble contaminates then plug up the hole. At this point you have a situation like what we just discussed above.

NOTE: Osmosis is actually far more complex than the above description and if you want a more complete description go to a good chemistry book. I would caution against going online because the explanations are also oversimplified (and sometimes wrong) for making easier to understand rather than being scientifically correct.

NOTE: Solvent Entrapment as well as other soluble organics can also cause blistering.

SEMIPERMEABLE MEMBRANE: Will allow molecules to pass through in the gas phase but will not allow liquids to pass through. In coating applications, Paint can act as a semi-permeable membrane. How permeable the paint is depends on various properties of the paint including type, hardness, porosity, and thickness.

How much Salt is too Much?

My Rule of Thumb: The less salts the better. Some salts on the surface of the substrate to be coated are generally not critical on surfaces that will have atmospheric exposure unless water may pool on the surface or the surface is exposed to consistent condensation. (Remember: Condensation and precipitation are close to pure water) The definition of "some" can be debated. For surfaces that will be in immersion environments, it is important that the "conductivity" of the contaminants on the surface to be coated, be an order of magnitude or less than the "conductivity" of the liquid on the surface of the coating.

Some Specs require testing for chlorides and some for salts, are they the same?

Yes and No. The primary salt present on most surfaces is sodium chloride. Na^+Cl^- . The chloride ion is one half of the sodium chloride molecule. When running a "chloride" test, the test looks specifically for the chloride ion. Much of the time, this is sufficient to determine invisible contamination on the surface, but it does not give total salts.

The only practical way to measure total salts is by use of conductivity. This is a backdoor approach to measuring salts because it measures the results of the salts and is not specific to any particular salt. As salts dissolve in a liquid, they break down into their ionic states. The ions increase the conductivity of the liquid so the greater the measure of conductivity, the greater the salt level. This can be used to estimate the Total Dissolved Solids (TDS)

A conductivity sensor measures how much electricity is being conducted through a centimeter of water. Specific conductivity is expressed as mhos per centimeter (M/cm), sometimes called siemens per centimeter (S/cm). Because a mho (or siemen) is a very large unit, the micromho (microsiemen) or millimho (millisiemen) typically is used (mS/cm).

The conversion factor depends on the chemical composition of the TDS and can vary between 0.54 – 0.96. A value of 0.67 is commonly used as an approximation if the actual factor is not known

$$\text{TDS (ppm)} = \text{Conductivity (mS/cm)} \times 0.67$$

For values in the range sensed by most TDS meters, a rough conversion is that 1 ppm NaCl = 2.2 mS/cm.

Which is more important, Salts or Chlorides?

For most applications, total salts are more important than looking specifically for chloride. Chloride ions have gotten a bad reputation because it is believed they are more aggressive to steel than many other ions. For chloride (or any other ion) to be aggressive, however, there must be a corrosion cell present and if the surface is painted properly, a corrosion cell does not exist. The main purpose for removing salts is to prevent osmotic blistering. Osmotic pressure depends on the number of ions in solution and is independent of the type of ions present. Again, Osmosis will only occur in IMMERSION environments and when the CONCENTRATION of IONS on the surface of the steel is Greater than the Concentration of Ions in the liquid on the exterior of the coating.

It is important to note that surfaces that are in atmospheric service that are subject to pooling rain or persistent condensation can have some of the same problems experienced in immersion services. Rainwater and condensation are relatively pure which can cause osmotic cells and blistering if surfaces under the coatings are contaminated. IN GENERAL, when properly painted, "some" salt or chloride contamination on a substrate is NOT A PROBLEM for atmospheric service.

What Units are used to measure salts?

In the US the most common unit of measure for Surface Concentration is Micrograms per square centimeter ($\mu\text{g}/\text{cm}^2$)

In Europe the most common measure is Milligrams per square meter (mg/m^2)

This is mass per unit area conversion is: ($1 \mu\text{g}/\text{cm}^2 = 10\text{mg}/\text{m}^2$)

The concentration of the salts in solution may be referred to as $1 \mu\text{g}/\text{mL} = 1 \mu\text{g}/\text{g}$ (of water) = 1 PPM.

Where do Salt Limit Numbers Come from in Specifications?

Every coating is different. The coating manufacturer should be able to tell you how much surface contamination the coating can withstand. Unfortunately, very few manufacturers have a clue so they resort to playing it safe. Most specs, that have salt or chloride limits use one of the following limits.

No Measurable Chlorides (Salts) (SSPC SC-1)

Less than $3 \mu\text{g} / \text{sq cm}$ (Mil Spec)

Less than $5 \mu\text{g} / \text{sq cm}$

Less than $7 \mu\text{g} / \text{sq cm}$ (SSPC SC-2)

Less than $20 \mu\text{g} / \text{sq cm}$

Less than $50 \mu\text{g} / \text{sq cm}$ (SSPC SC-3)

REMEMBER: Since most test methods only extract, at best, 50% to 80% of the non-visible contamination, the amount of surface contamination is actually at least twice as high as the amount measured. i.e. If you measure 10 µg / sq cm you probably have about 20 µg / sq cm on the surface being measured.

When dealing with salts on metal to be painted, less is always better. Generally, if specifications require less than 20 µg / sq cm for non-immersion surfaces, the specifier is being cautious unless extenuating circumstances are present. That doesn't mean he is wrong in setting the salt limit so low, just that he is being cautious.

When dealing with immersion surfaces, it is important that the ionic strength of the liquid on the outside of the coating be used to determine the amount of salts that can be tolerated on the substrate. When dealing with Demineralized or pure water, less than measurable salts should be present on the substrate. When dealing with potable water, most commonly 7 µg/sq cm is used.

Also, the thicker, and less permeable the coating, the more salts can be tolerated on the substrate.

My specs say salt or chloride levels shall be less than X ppm. What does this mean?

It means the person who wrote the specs doesn't know what they are doing. Contact the owner or spec writer prior to starting the project to determine the proper limit. To get from ppm to µg/sq cm you need to know:

1. The amount of surface area used to collect the sample.
2. The amount of water used to collect the samples.

$$\text{Equation: } \frac{\mu\text{gm}}{\text{cm}^2} = \frac{(\text{ml Water})(\text{ppm Salt})}{(\text{Surface Area (cm}^2\text{)})}$$

What is the best way to test for chlorides or salts?

There are various methods of testing for salts. The first thing that needs to be determined is do you need to test for total salt or chlorides. If the test method uses conductivity, you are testing for Salts, not chlorides. If the test uses "chemistry", (Quantabs, titration, drops or Kitagawa tubes), you are testing for chlorides.

Salt tests include the:

Bresel Test with the Conductivity Meter
DeFelsko SST Test with SST probe or conductivity meter
Surface Contamination Test (SCAT) with a Conductivity Meter
Potassium Ferricyanide Test
Parks Salt Meter

Chloride Tests include

*Chlor*Test OR NEW Mtest Chloride Test
Bressel Test with Quantabs or Kitagawa Tubes
Scat Test with Quantabs. or Kitagawa Tubes
SST Test with Quantabs or Kitagawa Tubes*

NOTE: The Chlor-Sleeves can be used with a conductivity meter but do NOT use the solution that comes with the test. The solution has conductivity and will not give an accurate reading for salts. If you use the solution you need to subtract out the conductivity of the solution from your reading

There is also a CSN (Chloride/Sulfate/Nitrate) Test. While this is billed as a "Total Salts Test" it is not since there are many other salts. It does test for the most common salt Anions – Chloride and Sulfates. Unless you are in an agricultural area – nitrates are generally not a problem. It does not tell you what the cation attached to the anion is.

What is the least expensive way to run salt or chloride tests?

The least expensive test is the Scat Test. It involves drawing a 6 in x 6 in (10 cm x 10 cm) square and swabbing it with DI water and a cotton ball. This is also the least accurate.

Bresle Test: Initial Cost (by conductivity) \$450.00 and about \$4.00er test

SST Test – As low as \$0.50 per test (by conductivity)

*Chlor*Test: \$20.00 per test*

MTest Chloride Test - &15.00 per test

CSN Test: \$40.00 per test

Potassium Ferricyanide Test - \$0.25 to \$0.50 per test

How long do the tests take?

The SCAT Test, Chlor*Test, MTest Chloride test and Bresle & SST Test take about 10 minutes per test. The complete CSN test takes 15 to 20 minutes per test.

Potassium ferricyanide take about 30 seconds per test. It measures F⁺⁺ (Free ferric ions) which will not exist without an anion. This is a yes/no test and it semi-quantitative. More blue on the paper indicates higher levels of salt but it is relative and not quantitative.

The Parks salt meter takes about 5 to 10 minutes per test.

Which test is most Accurate?

Accuracy comes into play in the effectiveness of removing the salts to be measured from the surface as well as the method of measurement. It is generally accepted that the SCAT Test removes about 25% of the salts from the surface and at best the other methods remove 40% to 60% of the salts from the surface so the number you get is probably half of the amount of actual salts on the surface being tested. Independent testing of the Elcometer SCM shows random extraction amounts. I have not seen any test data from the manufacturer. The amount of water in the paper at the time of measurement can affect the test results and there is not a good way to control it, especially in hot, dry environments.

When they are run properly, Potassium Ferricyanide test papers are sufficient if just looking for the presence of salts. It needs to be run within minutes after the blasting of the steel. Since it is actually measuring the amount of FE^{++} , it is not appropriate for other substrates. MTEST is one of the few companies selling the papers.

The Bresle test is currently the only test that has its own standard, ISO 8503-6 and ISO 8503-9. When running a Bresle test, the accuracy ranges from 40% to 80% extraction based on how long you massage the patch. When running a Bresle test, it is generally advisable to run a blank and subtract any "built in contamination" from your results. If you follow the extraction directions in ISO 8502-6, you should be able to achieve 80% to 90% extraction. Based on watching operators run this test, the general extraction rate is probably about 40%.

It has been reported that some Bresle patches may contain high conductivity. These patches are generally imitations made in Asia and if you are not sure of the manufacture, a blank should be run to test for conductivity contributed from the patch.

While I have not seen it, I have also been told of positive tests for nitrites using the CSN kit due to contamination of the test sleeve so if you encounter a problem with nitrates – run a blank before proceeding.

What about determining if oil is present on the surface of the steel:

ASTM A-380 Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems contains specific details on use of black light for surface inspection: 7.3.2 "Black Light Inspection is a test suitable for the detection of certain oil films and other transparent films that are not detectable under white light. In an area that is blacked out to white light, inspect all visible accessible surfaces with the aid of a new, flood-type, ultraviolet lamp." However, ASTM A-380 also states that "The test will not detect straight-chain hydrocarbons such as mineral oils." Use of Black Light for inspection of surface preparation is a useful tool and can be a required step for certain industries.

When using this method, it works best in low ambient lighting so do it at night or turn out the lights. Black light and UV light are sometimes considered the same, but they are different. I find that UV lighting at 365 nm works the best. Black light is in the 400 – 450 nm range. UV from 300 to 400 nm. MTest had the X80UV designed especially for this purpose. It contains both spot and Flood UV at 365 nm as well as 10,000 Lumens white light.

Some people like putting a drop of water on the surface. When Oil is present the water tends to ball up verses spreading out on clean steel. This test can be subjective and is only reliable for highly contaminated surfaces. It also works better on smooth surfaces rated than abrasive blasted surfaces.

NOTE: For additional information on SALT TESTING see SSPC GUIDE 15.



SECTION 6: Nondestructive Dry Film Thickness (WFT)

Many contractors wait until after the paint dries before determining its thickness. While it is not generally the inspector's responsibility to monitor the Wet Film Thickness, it is generally a good idea to check it when possible. This should be the responsibility of the contractor as part of their quality control program but is sometimes overlooked. If you determine the wet film thickness is high or low prior to coating a large area, adjustments can be made to correct the application. It is much easier to correct the film thickness prior to letting it cure. It is relatively simple to calculate the wet film thickness that should be applied to get the proper dry film thickness.

Theoretical Coverage

1 mil of 100% Solids Coating covers 1604 ft²/WFT

Practical Coverage

Theoretical Coverage x % Loss

Dry Film Thickness = DFT in mils

Wet Film Thickness = WFT in mils

All % are by volume and expressed as a decimal i.e. 60% = .60

DFT = WFT x (% Solids)

$$DFT = WFT \left(\frac{\%Solids}{1 + \%Thinner} \right)$$

DFT	WFT	%S	DFT	WFT	%S
7	8	90%	5	8	60%
6.5	8	80%	4	8	50%
6	8	70%	3	8	40%

$$WFT = \frac{DFT}{\%Solids}$$

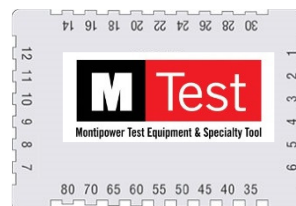
$$WFT = \left(\frac{DFT}{\frac{\%Solids}{100\% + Thinner}} \right)$$

Using A Wet Film Gage

1. Dip WFG into wet paint
2. Paint Wet Film Thickness is between 4 to 6 mils in the above example.



The comb gauge pictured is the most common one in use. They may be made of stainless steel and if properly maintained should last for many years. Less expensive ones are made of aluminum and are good for a few uses and some are made of plastic and are used once and thrown away.



MTest had TQC Build a Wet Film Come for us called the TQC-SP4085. It covers the range of 0,5 to 30 mils. It also has teeth at 12, 13, 14, 15 and 16 mils on one side.



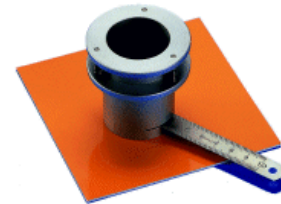
There are other types which are more commonly used in other industries. The wet film wheel consists of three circles. The central circle is of smaller diameter and is eccentric of the two outer circles. By rolling the gauge through a wet coating, the center disc eventually touches the film. This point on the scale indicates the thickness.



Various measurement ranges are available from 0 to 25 μ m to 0 to 3000 μ m (0 to 1mil - 0 to 40mils) are available

- Continuous Scale results in $\pm 5\%$ measurement accuracy
- Suitable for flat and curved surfaces
- Stainless steel giving a hard-wearing instrument which can be cleaned with solvents for reuse

The Pfund Thickness Gauge consists of two concentric cylinders, one sliding inside the other. A spherical glass lens is fitted to the end of the central cylinder and when pressed into the wet film it leaves a trace. The diameter of this mark varies depending on the thickness of the coating, which can easily be assessed from the conversion table supplied with the instrument.



- Ideal for measuring the thickness of translucent products (varnish, oils etc.)
- Measurement range of 2.25 - 360 μ m (0.09 - 14.17mils)



SECTION 6A: Mixing and Thinning

After surface preparation, mixing and thinning is probably the area that causes the most failures. Improper thinning, the wrong thinner, the wrong mixture, incorrect induction time or exceeding the pot life can all cause paint failures or a shorter life than the coating was designed for.

To prevent errors in mixing coatings, it is important to read and understand the product data sheet (PDS) for the coatings being used. If you do not have access to the PDS, then contact the coating manufacturer. Do not assume you know the proper mixing procedure and thinner.

Prior to doing any mixing, the batch number should be recorded, and the date should be checked to make sure it is in date. While it does not happen often, sometimes paint failures are the result manufacturing errors.

If part of the coating fails and the failed coating is a different batch number than the good coating, this is an indication it could be a manufacturing problem rather than an application problem. Manufacturers retain batches and can recheck the coating to determine if the failure was due to a problem with the coating.

SOLVENT EVAPORATION RATE (in minutes)

Solvent	Evaporation Rate	Uses in Paint Industry
Denatured Alcohol	3	Not Used for Paints
VM & P Naphtha	4	can be used for cleaning up certain residues like masking tape or stickered labels
Lacquer Thinner	2	It is also used in some epoxy and automotive finishes. Can be used as a clean-up solvent for "oil-based" products and is a good brush cleaner.
Paint Thinner or Mineral Spirits	60	a general-purpose solvent used in the manufacture of most oil-based trade sales paints. It is excellent for thinning oil-based paints
Toluene	3.5	Thinner for polyesters, industrial paints and finishes. Cleaner and degreaser. A fast evaporating solvent and thinner.
Xylene	12	Similar to Toluene, is also strong and fast acting but evaporates at a much slower rate than Toluene. Many oil/alkyd resins are made with Xylene. it is too fast for most brush applications. Consequently, its use is really limited to paints applied by spray gun and as a clean-up solvent.
Acetone	1	Ketones are often used in maintenance paints like vinyls, phenolics, acrylates and chlorinated rubber coatings. Acetone is a strong, fast acting solvent, cleaner and remover for inks, resins, adhesives and contact cement. It can be used as a clean-up after fiberglass projects.
M.E.K.	2	It is a strong, fast acting solvent, cleaner and remover for inks, resins, adhesives and contact cement.
Turpentine	40 5	It has a narrow range of solvency and possesses a strong odor. Its use in coatings is very limited.
Kerosene	325	Has extremely low solvency and slow evaporation are desired. Possible uses might include paste wood fillers and putties

The thinner that is used can greatly affect the cure of the coating. Different solvents evaporate at different rates and the thinners used for a particular coating system are chosen so that they evaporate out faster than the cure. If the coating cures prior to the solvents evaporating, solvent entrapment can occur which can lead to coating delamination, blistering or improper curing. If they evaporate too fast, the coating may skin over and wrinkle or a haze may form.

SECTION 7: Nondestructive Dry Film Thickness (DFT)

Which Dry Film Thickness Gage is Best for Me?

There are two types of nondestructive DFT generally referred to as Type 1 or “Banana Gages” or Type 2. Electronic gages. Advantages and disadvantages of both types are listed below.

Type 1

Advantages

No Batteries
Relatively Durable
Intrinsically Safe
No Electronics

Disadvantages

Not as easy to calibrate
5% Accuracy
Generally not zeroed to base metal
Easier affected by operator procedures
Less accurate than \pm electronic gages
Cannot store readings or do statistics
More difficult to read
Works only on Magnetic Substrates

Type 2

Advantages

Easy to Calibrate
Can Calibrate to Base Metal
Faster Readings
Menu Driven
 $\pm 1\%$ to $\pm 3\%$ Accuracy
Statistics and Memory Capabilities
Downloadable to a computer
Will work with Ferrous and Nonferrous
Metallic Substrates

Disadvantages

Requires Batteries
Not as Durable as Type 1 Gages

NOTE: Type 1 Gages also include “Pencil Pull-off gages” which are good for quick field checks but generally not used for Quality Control Purposes. They are generally rated at $\pm 10\%$ to $\pm 15\%$ accuracy when used properly.

Are There any Guidelines for Using These Meters?

The most commonly used Guideline is SSPC-PA2, “Measurement of Dry Film Coating Thickness with Magnetic Gages”.

IMPORTANT: There are significant differences between the Original PA2 (1982/91) and the Newer Version (1997, 2004, 2012). Make sure you know which version you are working from.

Other Standards that may be applicable are the following ASTM Methods:

ASTM B 499, "Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals."

ASTM D 1186, "Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base."

ASTM D 1400, "Nondestructive Measurement of DFT of Nonconductive Coatings Applied to a Nonferrous Metal Base."

ASTM E 376, "Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods."

ASTM G 12, "Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel."

European Specifications generally refer to EN ISO 19840, "Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces".

Understanding PA-2

PA 2 helps determine the number of DFT readings required on a project.

- *For Structures not exceeding 300 sq ft, take 5 spot readings per 100 sq ft.*
- *For Structures not exceeding 1000 sq ft, Select 3 random 100 sq ft areas to test.*
- *For Structures exceeding 1000 sq ft, Select 3 random 100 sq ft areas to test in the first 1000 sq ft and for each additional 1000 sq ft test one random 100 sq ft area.*
- *If any area is not in compliance, the non compliant area should be determined*

How do I determine the minimum number of tests required?

To determine the number of tests required if the surface area is greater than 1,000 sq ft, use the following formula to determine the minimum number of areas to test:

$3 + [(SFC\ AREA) - 1000] / 1,000 = \text{Number of Test Areas}$
 $\text{Number of Test Areas} \times 5 = \text{Number of Spot Readings}$
 $\text{Number of Spot Readings} \times 3 = \text{Number of Gage readings}$

Example: 27,500 square feet to be coated to 12 – 15 mils of paint.

Round to 28,000

$3 + [(28,000 - 1,000) / 1,000] = 30$ areas to test

3 areas in the first 1000 sq ft and one area in the remaining 27 – 1000 foot areas
30 X 5 = 150 Spot Readings
150 X 3 = 450 Gage Readings

All Spot readings must be $\pm 20\%$ of range.

For a spot reading use roughly a 1-inch diameter circle. Within this, the probe is placed 3 times in random positions (Gage Reading). The average of these 3 gage readings is called the 'spot reading'

Example:

The previous example calls for a DFT range of 12 to 15 mils, the area meets SSCP PA-2 if:

The Average of all the Spot readings must fall within the 12 -15 mil range

and

- All spot readings are greater than 80% of the Specified DFT ($0.8 \times 12 = 9.6$ mils)

and

- All spot readings are less than 120% of the Specified DFT ($1.2 \times 15 = 18$ mils)

Therefore, the PA2 Range = 9.6 to 18.0 mils for individual spot readings. Individual Gage readings do not have a range.

In the current PA2, it requires mapping out of areas that are out of compliance and only requires correcting those areas. Determine the spot DFT at 5-ft (1.5-m) intervals in eight equally spaced directions radiating outward from the nonconforming 100 ft² (~10-m²) area as shown in the Figure Below

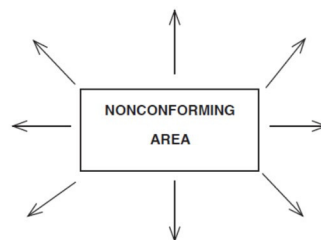


FIGURE 1
RADIATING SPOT MEASUREMENTS TO DETERMINE
EXTENT OF NONCONFORMING AREA

The old method requires mapping out the entire project. Also, the square footage can be in any shape, not just squares.

Standardization bodies, such as ASTM, BS, CEN and DIN, hold the copyright to all their publications. Everyone wanting a Standard must therefore pay for it via the standard body's websites.

Level of Restriction

An important addition to PA-2 is the thickness conformance restrictions. There are 5 different levels of conformance that can be specified within PA-2. If a level of restriction is not specified, then it defaults to Level 3.

COATING THICKNESS RESTRICTION LEVELS

Thickness	Gage Reading	Spot Measurement	Area Measurement
Level 1			
Minimum	Unrestricted	As specified	As specified
Maximum	Unrestricted	As specified	As specified
Level 2			
Minimum	Unrestricted	As specified	As specified
Maximum	Unrestricted	120% of maximum	As specified
Level 3			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	120% of maximum	As specified
Level 4			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	150% of maximum	As specified
Level 5			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	Unrestricted	Unrestricted

What if ISO is specified?

EN ISO 19840, "Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces". This standard method has special calibration techniques, (See Procedure).

Readings of the thickness of the paint film should be taken according to a sampling plan. The number of readings depends on the size of the inspection area and they are taken at random points (see table).

SAMPLING PLAN

INSPECTION AREA	MINIMUM NUMBER OF MEASUREMENTS
Less than 1m ²	5
1 - 3m ²	10
3 - 10m ²	15
10 - 30m ²	20
30 - 100m ²	30
Above 100 m ²	Add 10 per 100m ²

Most of the readings should be above the Nominal Dry Film Thickness (N) so the average (\bar{x}) will be equal to or greater than N.

- Dry Film Thickness (N) so the average (\bar{x}) will be equal to or greater than N.

- No more than 20% of the readings in an area can be thinner than the Nominal (N) but not thinner than 80% of nominal (0.8N).
- All readings should be less than the maximum thickness (Max).

ALTERNATIVE PLAN

Annex B of EN ISO 19840 is a variation of the above procedure, subject to agreement by interested parties. Say 5 thickness readings are taken in a 30mm circle and the average is calculated. The location of these little groups is according to the Sampling Plan above. The thickness of the coating is classed as acceptable when the averages are analyzed, and they fit within the graph

I need an electronic Type 2 meter, what should I get?

For most people the Defelsko Positest 6000 is the best choice. It is designed primarily for field usage, is light, compact and easy to use. It can be ordered with an “integral” probe or with a separate detached probe. If you are only going to measure large pieces a fixed probe is a good choice. If you later need a separate probe, no problem, change it out.

If you get involved with many different types of projects, need to get into small areas get involved with coating thickness from thin to thick films, the DeFelsko probe provides the flexibility to change with the job by just changing out the probe.

The meter comes with a ferrous (F), nonferrous (NF) or a dual FN probe. There is now a Duplex probe that measures zinc and the coating at the same time. (FND). The same meter will accept all the probes, so if your needs change, you only need to order a new probe.

The last decision is memory or no memory.

*Standard 250 Readings in One Batch
Advanced 100,000 Readings in 1,000
Batches*

For basic applications, the Standard Model will store 250 readings and download them to your computer or the Posisoft.net website. For large projects, where batching is needed, the Advanced model can save hours of work and provide you with professional, computer generated reports. PosiSoft Desktop Version 4 has just been released.

The Advanced PosiTector has Memory as well as Bluetooth and WiFi capabilities or you can download either version via a USB cable

For the more adventurous, DeFelsko has released the PosiTector SmartLink which works with most of the standard probes. This allows a lower cost alternative to the advanced body that uses your Iphone or Android Phone to collect and display the data. The downside is it only works with the core probed,

- . If you want to use scanning mode – you need the advanced or SmartLink.

How often should I calibrate the meter?

Type 1 meters should be **verified** each time they are used. The BMR should be subtracted from each gage reading to get the proper coating thickness. PA2 specifies that the Type 1 meter should be verified using “Calibration Plates” not shims or foils.

Type 2 meters should be **calibrated** each time they are used, according to PA2 before and after each shift. In situations where many readings are being taken throughout the day, I recommend frequent verification of the calibration. If you take 500 readings over the course of the day and the verification at the end of the day is off, since there is no way of knowing when it went wrong, you have to backtrack all the readings until you find the point. It is much simpler to verify the accuracy of the meter throughout the day.

Type two meters can be calibrated with foils (shims) or calibration plates. When using foils, calibrate with the shim on the prepared substrate. DFT is the actual reading taken. If the meter is calibrated to plates, then the actual DFT is the Reading MINUS the magnetic base reading (BMR).

When using a type 2 meter on **nonferrous metals**, it is essential to calibrate the meter to the base metal being tested. Calibrating the ferrous part of an F/NF meter does NOT calibrate the nonferrous probe.

What is a Base Metal Reading (BMR)?

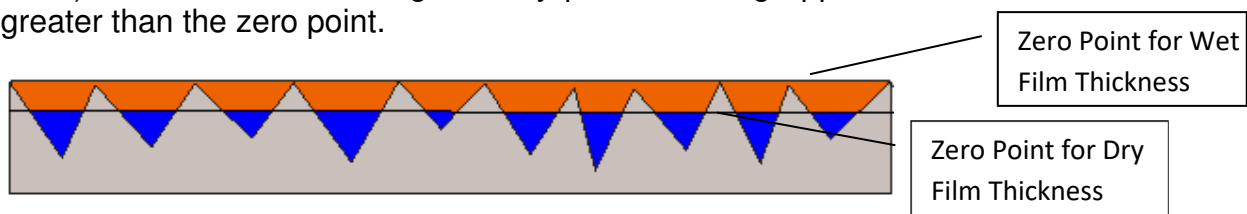
This is probably one of the most misunderstood concepts in Coating Thickness Testing. There are two separate properties that effect the BMR.

1. The magnetic properties of the steel
2. The surface profile of the steel

Generally, the BMR is 30% of the surface profile measurement

All meters are zeroed to steel with a certain magnetic property. Since many factors can affect the magnetic properties of steel during its manufacture, each metal will have its own “zero point”.

When you have a surface with peaks and valleys, there is no clear line where the “Zero Point” is. There are areas in the profile that are LESS THAN THE ZERO POINT (Blue Paint). The meter will not register any paint as being applied to the surface until it is greater than the zero point.



In the above drawing, if the DFT gage perceives the “Zero Point” to be the top of the blue paint, any paint in this area will not be measured.

When you calibrate a DFT Gage to a flat plate, the BMR simply adjusts the Dry Film Thickness to the Zero Point.

Let's look at the effect of BMR on a Type 1 & Type 2 meter with a 2 mil surface profile.

- with a **Type 2 gage** properly calibrated to the blasted substrate, if you measured every possible point from peak to valley, the average DFT reading would 2.0 mils because the meter was "zeroed" to the BMR.
- With a **Type 1 gage** properly calibrated to a calibration plate, if you measured every possible point from peak to valley, the average DFT would be greater than 2.0 mils. If the BMR was 0.75, the average measurement would be 2.75 mils, Since the BMR is 0.75 mils this must be subtracted from all readings to get the actual DFT.

The BMR is most important when measuring thin coats or prime coats. As coating thickness increases, not accounting for the BMR becomes less important.

Why is DFT Important?

The most obvious reason is if a contractor bids a job to give you 12 to 15 mils and you end up with 8-10 mils, you did not get what you paid for.

Since many coatings are for corrosion protection, the main way most of these coatings protect is by "Barrier Protection". The thicker the barrier, the better the protection. There are other important reasons you do not want a coating too thin or too thick.

Many coatings today cure by catalyzation. While there is some room for error built into the coatings, some coatings require a minimum thickness to get enough catalyst to cure properly but if the coating is too thick the reaction may occur too quickly causing other problems including solvent entrapment and blistering..

What do I do if my DFT is out of Spec?

When discussing concerns on DFT, the coating manufacturers Technical Representative, should be contacted. (Nothing personnel to you sales guys out there, but unless you have confidence in your salesperson, talk to the Technical Rep. and GET IT IN WRITING). Arguments over tenths of a mil above or below spec generally should be avoided as variations in the MBR, measurement errors, where readings were taken or not taken can all have a greater effect then this.

Remember PA2 allows for variation of individual points to 20% below the minimum and 20% above the maximum specified range.

Type 1 meters are generally $\pm 5\%$ so at 10 mils there is a possible error of 0.5 mils. Type

2 meters are generally $\pm 1\%-3\%$ so at 10 mils there is a possible error of 0.3 mils.

While many electronic meters read to hundredths (0.01) of a mil at low DFT's, it is generally best to round to the nearest tenth (0.1) since most meter are at best ± 0.1 mil.

Once you get above 2 to 3 mils, to be perfectly honest, do not worry about numbers after the decimal point. Round to the nearest .5 mil and that is more than sufficient for most applications.

SECTION 7A: Measuring Coatings On Concrete (and other nonmetallic substrates)

A question I often get asked is can I measure the Dry Film Thickness of coatings applied to concrete and other nonmetallic substrates. The answer is a definite maybe. Using Ultrasonics, DeFelsko has developed a means of determining the thickness of many coatings on nonmetallic substrates, as long as there is no aggregate in the coatings

The Defelsko PosiTector 200 Non-destructively measures a wide variety of applications using proven ultrasound technology. It can usually measure coating thickness over wood, concrete, plastics, composites and more. Advanced models measure up to 3 individual layer thicknesses in a multi-layer system and features a graphic readout for detailed analysis of the coating system. Proven non-destructive ultrasonic technique conforms to ASTM D6132 and ISO 2808 and SSPC PA9. Limitations are coatings cannot contain aggregate, Coating thickness is limited to 300 mils or with some Polyureas about 200 when using the “D” – 0 to 300 mil probe due to the sound attenuating properties of the Polyurea.

I am using a PosiTector 200 and the readings don't make sense.

Unlike a traditional DFT meter, the ultrasonic meters require some additional setting to get them to read properly, the meters look for the first change in speed and report this as the coating thickness, Often this reading is much too low. There are two adjustable ranges on these meters – LOW and HIGH. Set the Low range about one half of the expected coating thickness and the HIGH range about twice the coating thickness. This will generally filter out false readings, but several should be taken to confirm the reading and don't forget to use the gel.

Also, take into account the evenness of the substrate. If you are trying to measure a 30 mil coating on an uneven concrete coating, the unevenness may be greater than the thickness of the coating you are trying to measure. Take a minimum of 10 readings in a small area and average them to get a good film thickness,

If readings still do not make sense, there may be something in the coating preventing proper measurements.



SECTION 8: Holiday Testing (or as the Brits say Porosity Testing):

Simply, holiday or porosity testing is looking for voids in the coating or coating system that go to the substrate. For holiday testing to work requires two conditions:

1. The coating system must be nonconductive.
2. The substrate must be conductive.

Holiday testing works best on conductive metallic substrates but will also work with concrete but is not as straight forward as metallic substrates due to variations in concrete that affect its conductivity.

NOTE: There is a new method to holiday test coatings that uses UV. I will discuss it at the end of the article.

Which Holiday Tester do I need?

A good rule of thumb is when testing nonconductive coatings on metal, coatings up to 20 mils should be tested using a low voltage (sponge) tester (DeFelsko LPD or Tinker-Rasor M1/2). Coatings over 20 mils should be tested using a high voltage tester. Lacking guidance from the specifications, coating manufacturer or product data sheets, the high voltage tester should be set at 100 volts per mil of coating.

IMPORTANT: High Voltage testing can DAMAGE the coating being testing so make sure you know what you are doing.

Holiday testing on concrete must be done using a high voltage tester. Generally, a coating on concrete will require a higher voltage than the same coating on metal. Holiday testing concrete is as much an art as a science and if you are not experienced, seek help to avoid problems.

I have a coating on metal less than 20 mils, what do I do?

The standards that address low voltage holiday testing are

ASTM D5162-01.

NACE RP0188.

ISO 8289A

ASTM require 67.5 volts for testing these coatings.

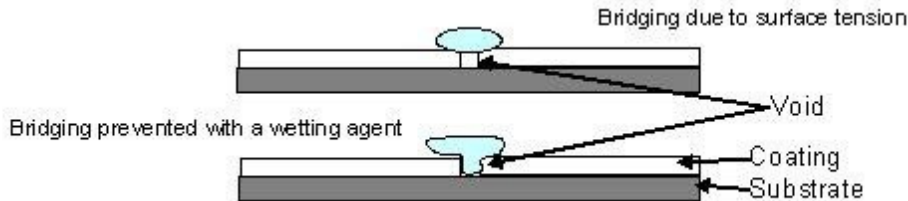
ISO requires 9 volts for coatings to 12 mils and 90 volts for coatings to 20 mils.

These days, with the diversity of companies doing business in the US, it is possible to be working on specifications that reference ASTM or ISO. A low voltage sponge tester that will handle all three voltages is the DeFelsko PosiTector LPD, TQC-LD8105 or the Tinker-Rasor M1 or M2. It is easily adjustable among all three voltages; they are light and easy to use. The PosiTector LPD and TQC unit has an optional accessory kit that has everything you need to make the holiday inspection easier (DeFelsko-LPDACCPK; TQC-LD8155)

What is a wetting agent and do I need one?

Many people like to use a wetting agent to reduce the surface tension of the water. If you have a fairly thick coating near the upper end of the 20 mil range, due to the surface tension of water, the water may bridge the void and therefore not find the holiday.

Bridging due to surface tension



If the surface is to be recoated, it is generally not advisable to use a soap as the wetting agent because it may leave a film. The most common wetting agent is Photo-flo.

NOTE! While it does not comply with the standards, I have sued sponge testers side by side with high voltage testers on coatings up to about 50 mils and found all the same holidays. I would feel very comfortable in using a sponge tester up to at least 30 mils.

Neat Little Trick.

When trying to test in a tight spot (Sponge test only), grab the sponge in one hand and with a wet finger, feel around for holidays. Sometimes the sponge is too big to determine the location of the pinhole. On most units it will beep, and you will not feel anything. On some units such as the Tinker and Razor M-1, you will get a jolt similar to a static shock, but your inspector, so man (or woman)- up and take it.

Can I use a High Voltage testing on coatings less than 20 mils?

Yes, but the thinner the coating, the more likely the coating may be damaged by using the improper voltage. Suggested voltages in NACE RP0188 are:

Mils	V
8 to 11	1,500
12 to 15	2,000
16 to 20	2,500
21 to 40	3,000
56 to 80	6,000
81 to 125	10,000
126 to 185	15,000

How do I do high voltage testing on nonconductive coatings on metallic substrates?

High Voltage Holiday Testing is addressed in the following standards:

ANSI/AWWA C 214-89	BS 1344-11
ANSI/AWWA C 214-91	ISO 2746
AS 3894.1	ISO 2746
ASTM D 4787	JIS G-3491
ASTM G 6	NACE RP0274
ASTM D 5162	NACE RP0490-2001
ASTM G62-B	NACE RP0188-88

The first step is to make sure you know the dry film thickness of the coating. This is the first step in determining the voltage setting. Ideally, assuming the DFT is in spec, the specification should tell you what voltage setting to use. If it does not, some product data sheets or application bulletins will provide the information. Lastly, ask the coating manufacturer. If none of this works, use the above table or use 100 volts per 1 mil of coating thickness.

An alternative to setting test voltages in the field is to use the formula developed by the National Association of Corrosion Engineers International (NACE) and incorporated into several Standards. The formula for thin film coatings applied to 30 mils (.76 mm) thickness is $V=525$ times the square root of "T" where "T" is the coating thickness in mils. Example: a coating 25 mils (.64 mm) thick would work out to an inspection voltage of 2600 volts. For thicker applied coating the Constant changes to 1250. Example: a coating 125 mils (3.175 mm) thick would work out to an inspection voltage of 14,000 volts.

Which is best – a Direct DC High Voltage Tester or a PULSE Tester?

There are two types of High Voltage Holiday testers – Direct DC and Pulse Types. Direct DC is generally less expensive and works well on dry coatings. Because they put out a constant current, as they go over the surface of the coating, they can impart a current into the coating that will back-feed to wand causing a "false" holiday. There is a sensitivity knob on these meters that adjusts the milliamp setting that will trigger a "beep" from the meter. For most coatings the default setting will generally work, however if you are getting "beeps" (or Jeeps) from the meter without a spark, you may need to change the setting.

Pulse Type Meters are more versatile in that they can be used in damp environments with moisture condensation on the coatings. The electrical pulses are generated between 20 cps. and 60 cps. Each electrical pulse is "on" for a time period between 20 microseconds and 200 microseconds. They do not require the sensitivity knob.

While the pulse type meter has the advantage of being able to work in damp conditions, both types of meters will work under most circumstances with proper training.

How do I do high voltage testing on nonconductive coatings on concrete substrates?

This can get complicated and there is no easy answer. I do not have any experience in very dry, desert like areas, but generally there is enough moisture and salts present in concrete to make it conductive. When testing pipelines, sometimes the ground cable is just dug along on the ground so soil and concrete both conduct electricity.

I generally recommend the following steps:

1. If available, ground the meter to rebar in the concrete.
2. If rebar is not available, often steel is bolted directly to the concrete. You can ground the meter to the BARE steel.
3. If testing a slab with no steel, drive a piece of rebar into the ground at least the depth of the slab and immediately next to the slab. It helps if you make sure the soil is wet. Use this as your ground.
4. An alternative grounding method to a concrete structure is to place a 2' X 2' piece of ordinary metallic window screen wire flat upon the concrete surface. Place wet sandbags over the entire metallic surface and connect the ground wire to the screen wire. The wet sandbags placed upon the screen wire assures intimate contact of the screen wire against the concrete surface. This grounding method is usually sufficient for either the low voltage "wet sponge" or high voltage "spark type" holiday detectors. Check the electrical circuit of the detector by touching the exploratory electrode to the bare concrete substrate and observe the audible signal. No audible signal means inadequate grounding and a better ground must be obtained or the signal sensitivity increased.
5. As with metal, first follow the specs, next go to product data and application bulletins and then go to the coating manufacturer.
6. If you still do not have a voltage setting, do not use the settings recommended for steel. The best way is to find several areas representative of the coating to be tested at varying distances from the ground. Create a holiday and determine the voltage necessary to create a spark. If the voltage increases as you move from the ground, you need to increase the test voltage or move the ground point.

Several coating manufacturers that make concrete coatings are now making conductive primers. By using one of these primers, you can follow the procedures for holiday testing metallic substrates.

Are Holiday Testers dangerous working with such high voltages?

All holiday tester output currents in the range of anywhere from 0 volts up to over 40,000 volts. The good news is the output is in DC volts which means you cannot electrocute yourself if you get zapped, and if you do it often enough, you will get zapped. The danger is not from the current but that the current can make you jump. If your feet are planted firmly on the ground, this is generally the worse damage, but if you are on a ladder or scaffold, jumping can be dangerous. The voltage will not hurt you, but the fall can.

What is with all the brushes or probes?

There are four basic types of probes:

1. *Wire Brush Probe -Wire Brush probes work best on textured surfaces where the brush can follow the contour of the surface. It comes in various sizes up to 40 inches and works well on large surfaces. For small surfaces, the band brush that come with the 236 works well*
2. *Rubber Brush Probe - The Rubber Brush is a conductive rubber strip that works well on large, smooth flat surfaces.*
3. *Internal Pipe Probe - Come in diameters from 1.5 inches to 12 inches for testing internal pipe coatings.*
4. *External Pipe Probe -Comes in sizes from 2 inches to 36 inches for testing 360° of external coating with one pass. Springs can be connected together for larger diameters.*

I have a DC High Voltage Tester but do not understand the sensitivity knob.

In most cases leaving the sensitivity knob centered in its range will work for the setting. This knob only controls the audible alarm setting and has no effect on the meter sparking or the visual LED in the wand. On some coatings, as you run the holiday tests, the coating can become charged and discharge back to the wand causing a false holiday indication. The sensitivity knob is designed to tune down the audible alarm to avoid false alarms. If you are getting audible alarms when the meter is not producing a spark, turn the knob counterclockwise if you are getting sparks with no audible alarm, turn the knob clockwise. Adjust knob as required to find the best setting so the alarm beeps only when there is a spark.

If the knob is set full clockwise the meter will beep almost continually even when no holidays are present.

If the knob is set fully counterclockwise, you will still get a spark, but the alarm will not sound.

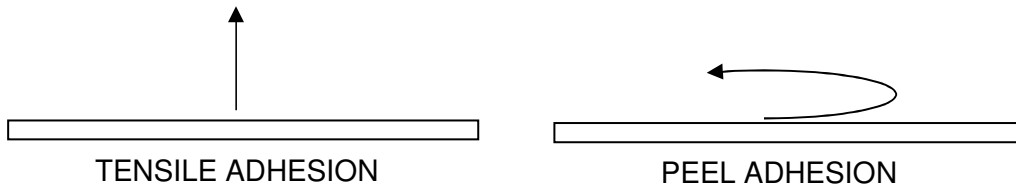
How do I do a holiday test with a UV light?

A couple of coating Manufacturers have developed coatings that incorporates a UV pigment. When you shine the UV light on the coating with the pigment. holidays show up as a black spot. When you coat over the primer hand shine the light on the coating, if you see bright spots, you have a holiday to the primer. A black (or purple) light at 400 to 450 nanometers is used to detect holidays. You can also use UV down to 365 nm. Since manufacturers are continually coming up with different products, make sure you know the correct frequency range to test.



SECTION 9: Tape (Peel) Adhesion:

There are two basic types of adhesion tests, Peel and Tensile.



The Tape (Peel) Adhesion Test will determine if the bond strength of a coating on a substrate is “**Generally Adequate**” and was designed specifically for use on **steel substrates**. Use on other substrates may not be consistent. It is not intended to determine high levels of adhesion.

Adhesion tests are DESTRUCTIVE and generally should only be conducted if a problem is suspected.

Tape Adhesion is addressed in ASTM D 3359, “Standard Test Methods for Measuring Adhesion by Tape Test” and ISO 2409, “Paints and varnishes - cross-cut test”.

There are two types of Tape Adhesion tests, Method A – X Cut and Method B- Cross Cut. ASTM D 3359 provides the following guidelines:

Coating Thickness	Type Test	Spacing
1-2 mils	Method B	1 mil
2-5 mils	Method B	2 mils
>5 mils	Method A	X Cut

Under ISO 2409 for coatings 5-10 mils it allows for Method B with a 3 mil spacing.

WHEN IS ADHESION TESTING APPROPRIATE?

There are several good reasons for testing adhesion.

- There are questions about surface preparation, intercoat cleanliness or overcoat window times.
- When you want to overcoat an existing coating
- When there is a premature coatings failure and you want to determine the cause.

What Tape Should I USE?

When D3359 was developed, Permacel 99 tape was the specified tape. Permacel is no longer made. There are several other tapes that are close to Permacel specifications including the CrossHatch Tape on our web site.

Any tape agreeable to all parties involved is acceptable but keep in mind Permacel 99 tape was closer to drafting tape than duct tape.

When performing the ASTM test we recommend and sell part number D3359TAPE. When performing the ISO test, the method requires ISO Tape be used (Our Part Number TQC-SP3007).

How Accurate is this test?

There are many things that can affect the accuracy of the test and for that reason grading is done on a 0 to 5 scale to avoid the appearance of greater accuracy. Some of the items that can affect the accuracy of the test are:

- Type of Tape Used
- Is the coating the thickness it is supposed to be?
- How well the tape adheres to the coating
- How well the tape is applied to the coating
- Angle of pull of the tape
- Rate of Pull of the tape
- Squareness of knife to the surface when scoring
 - NOTE: Flexible panels need to be well supported
- Sharpness of the blade
- Accuracy of the spacing
- Pressure applied during the cut
- Age of the tape
- Temperature and humidity during the test

When run properly and consistently, generally repeatable results can be achieved within one to two units.

What do the numbers mean?

Rating	Area Removed
5	0%
4	<5%
3	5-15%
2	15-35%
1	35-65%
0	>65%

Now that you ran the tests and got numbers, what do you do with them. Part of the answer goes back to the reason the test was run in the first place. NOTE: FOR ISO - NUMBERS ARE REVERSED

Make sure you know what the coating thickness IS not just what it is SUPPOSED TO BE. If you use a 2 mm spacing on a coating reported to be 4 to 5 mils and it turns out to be 11 to 12 mils, it will probably fail the test.

Reason 1: We suspected a problem with the application:

There is no way to give an exact answer, but for a new coating system I would expect a 4 or 5 with 0, 1 or 2 indicating a possible problem. A 3 is a little more "iffy" to judge. Was it closer to a 4 or to a 2. Is the DFT in the proper range for the test. Is the break between coats or at the substrate?

This test is not a substitute for inspection or experience but is only one tool to be used in the evaluation of the application.

Reason 2: We need to overcoat an existing coating; will we have a problem?

Adhesion testing is only one of the criteria used to determine if a coating can be overcoated. As new coatings cure, they exert forces on the existing coatings. The greater the adhesiveness of the existing coating, the more curing stresses they can adsorb without failing. Generally, with proper surface preparation, if all other factors, (condition of substrate, number of coats, current DFT) are within reason, **then after running a test patch**, conditions 3, 4 and 5 are probably OK to overcoat. If you are not sure, consult your coating supplier or a independent third party.

What is best – Single or Multi-blade?

For an X Cut you need a single blade and a straight edge. It is best if you have one that keeps the blade perpendicular to the score line. We also now have the MTEST X-CUT Template.

You can also use a single blade for the crosshatch test, however, to do it accurately requires use of a cross-hatch template (SP3000) or the MTest XCUT Template. The advantage of this method is box cutters are inexpensive and blades are readily available.

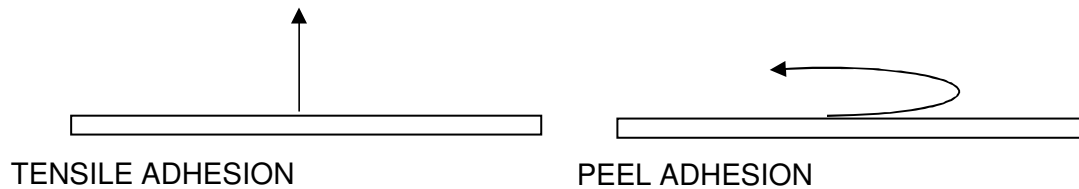
Multiple cut blades (TQC CC1000, 2000 or 3000) ensure proper spacing and are much easier to use. They must be used on nonflexible, smooth surfaces to get a good cut with all blades. If all the blades are not cutting evenly, use a piece of smoked glass, (use a candle or match to blacken glass with soot) and lightly score through the smoke with the blade. All blades should touch the surface or the blade should be replaced. If the blade is good, check the item being tested for flexibility, flatness or smoothness.

Test Tips:

- Tape should be pulled at a 180° Angle.
- Make sure blades are sharp (preferably new).
- Keep blades square to the surface.
- Cut in an as even a motion as possible.
- Make sure tape is new or has been stored properly.
- Make sure surface is clean and dry before applying tape.
- Rub tape onto surface using pencil eraser.
- Pull tape within 1 to 2 minutes; remember the bond strength generally increases with time.
- Run two more confirming test in same area.
- Keep the tape as a record of the test
- It is often easier to read the tape than the panel.
- For X-cut tests use a ruler to measure failure
- For X-Cut use a straight edge or the MRest X-Cut Template.
- Report Number of Tests, Mean, Range, where failure occurred, type of test used, environmental conditions, location of tests
- Keep a copy of ASTM D 3359 (or ISO 2409) available



SECTION 10: Tensile Adhesion



A Tensile Adhesion Tester will determine the bond of a coating on a substrate, or cohesion of the coating or cohesion of the substrate. Adhesion tests are **DESTRUCTIVE** and generally should only be conducted if a problem is suspected.

NOT ALL TESTERS ARE EQUAL

The measured pull is highly dependent on the tester used. I.e. The psi reading taken with an Elcometer 106 will not equal the psi reading taken with an P.A.T.T.I.. There is **NO** valid way to compare psi readings taken with different model testers. It is even difficult to compare readings between different operators

Adhesion testing is addressed in ASTM D4541, "Standard Method for Pull-Off Strength of Coatings using Portable Adhesion Testers". It identifies 5 types of portable adhesion testers.

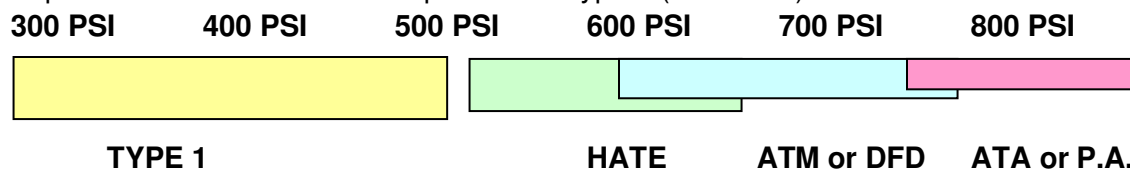
When choosing an Adhesion Tester, in general, the Tensile Adhesion Strength between the different models is:

Lowest Pull: TYPE 2 (Method B) - Elcometer 106
 TYPE 3 (Method C)- HATE or Elcometer 108 TYPE
 6 (Method F) - DFD 1910, 1920, 1930, 1940
 TYPE 5 (Method E)-, DeFelsko AT
 Highest Pull: TYPE 4 (Method D)- P.A.T.T.I.

Unless otherwise stated, published PSI ratings for adhesion are often done using the P.A.T.T.I.[®] Meter because it gives the **BEST** adhesion results. Recent test I have run indicate the DeFelsko AT-A tester give results close to, but not quite as high the P.A.T.T.I.

My Rule of Thumb for the Adhesion Testers based on MY personnel experiences with the different testers:

Expected Pull Rate for 400 PSI pull with a Type 2 (Method B) with the different meters



NOTE: Many factors can affect the PSI obtained especially operator technique. The above chart is not a hard and fast rule but only intended to be a guideline. By understanding the different testers, you can optimize results.

MATERIALS

Coating must be on a firm substrate, such as on metal, on concrete or on stiff wood products. Flexible or soft substrates will distort when under load and this may interfere with the bond, reducing the adhesion. The tester needs to be supported by the sample to deliver the reactive force. This means the choice of tester is limited by the size of the sample it can stand upon.

Small diameter pipes can be a problem due to using flat dollies on a curved surface. The HATE and Elcometer 108 provides concave and convex dollies for pipe diameters about 8 inches to 75 inches. On smaller diameter pipes, below about 16 inches, adhesion will be compromised by using a flat dolly on a curved surface. As the pipe diameter increases, the effect of the curvature becomes less. It should be noted that using curved dollies introduces shear forces into the pull so it is not purely a Tensile Test.

If Adhesion tests are a specification requirement, consider coating test panels in lieu of testing the equipment. This solves the problems of testing a curved surface, prevents repairs and is usually acceptable to the owner when it is explained to them.

Adhesion Testers

ASTM Type 2 Method B – 106, ASTM
Type 3 Method C - HATE, 108 ASTM
Type 4 Method D – P.A.T.T.I.
ASTM Type 5 Method E – DeFelsko AT
ASTM Type 6 Method F - DFD

Type 2, 4, 6 and 6 Testers pull on the test stub (dolly) from the outside.

Type 3 Tester pulls the dolly and delivers the reaction through a hole in the center of the dolly along its axis and pushes the dolly off.

PULLING

There are three factors that come into play in pulling dollies”

- Manual or automatic
- Rate and Evenness of pull
- Squareness of pull

Method of pull (applying force) is applied in 3 ways.

Elcometer 106 : A wheel or wrench turned by hand (Manual)

P.A.T.T.I.: by gas pressure. (Automatic)

DeFelsko ATM, HATE or Elcometer 108, DFD 1910 1930 1940 1941: by hydraulic pressure by hand or pump. (Manual)

DeFelsko ATAb by hydraulic pressure (Automatic)

Manual vs. Automatic

The rate and smoothness of the pull can affect the final tensile adhesion measured. Some testers ensure the increase of force is at a slow uniform rate. Operators sometimes increase it in quick steps. For manual testers, those that allow for a continuous pull rate will normally give the highest results. **Automatic testers will in general give higher more consistent rates than manual testers.**

Rate and Evenness of pull

An important aspect of pulling is to provide a direct axial (perpendicular) force. There must be no attempt to twist the dolly off the surface, nor to lever it off. The straighter the pull, the closer the test is to the 'tensile' required rather than to the easier 'peel'. Testers where the pull head is separated from the crank or knob, minimize twisting and levering during the pull

Squareness of Pull

To Be A "Tensile Pull", the test fixture must be pulled perpendicular to the surface. While some testers use ball bearings to adjust for misalignment, this does not ensure a perpendicular pull. The only self-aligning testers to date, are the DFD 1910, 1920, 1930 and the 1940.

The DFD PAT 'legs' adjust to be square to the dolly before doing any work. Other testers stay perpendicular to the surface, so some leverage is possible. But even when the incline is less than 5 degrees (<1% reduction in force), some tests show a break that is off-centre, as if a crack moved along the diameter of the dolly.

The HATE Tester avoids this problem by concentrating the force and reaction within the area of the dolly.

RATING THE TEST

It is not enough to record the maximum stress (tensile adhesion). Standard methods require some analysis of the material remaining on the dolly. Often the nature of the break is more important than the pressure that it pulled.

There could be a break between layers of a coating system. One layer may be split, indicating the cohesion is less than the adhesion. The system may break from the substrate. The cause of this may be inadequate preparation or even dust. It is quite possible for the glue to break between the dolly and the surface of the coating; this does not constitute an adhesion value.

Usually, most dollies have "multiple" mode failures. Record per cent adhesive, cohesive and glue failure

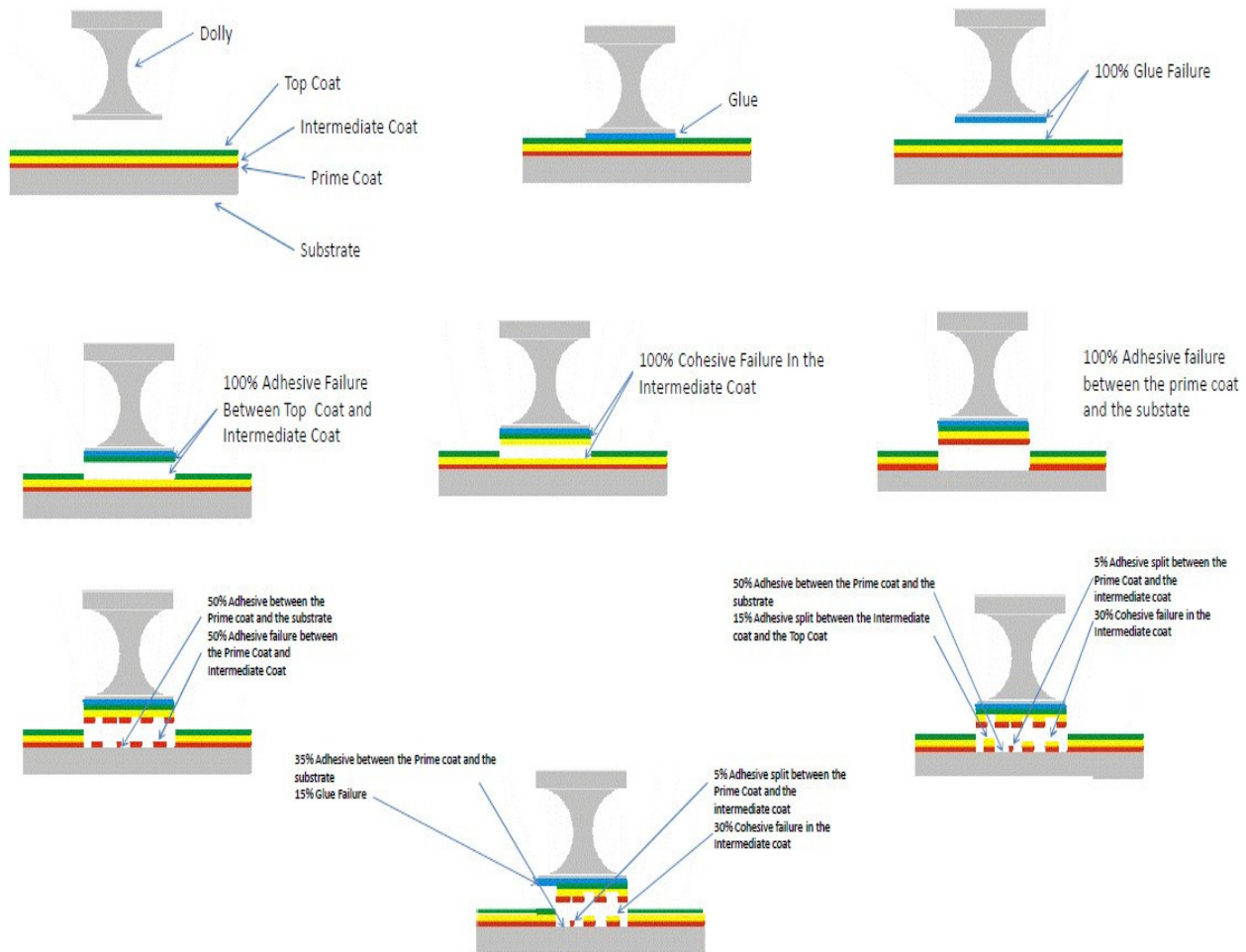
Example: Text fixture failed at 750 psi.
 30% adhesive failure to substrate
 40% cohesive failure in intermediate layer
 30% adhesive failure between topcoat and glue.

Definitions

Adhesion Failure – defined as a failure between layers of paint or between the substrate and the paint

Cohesive Failure – defined as a failure or break within one coat of paint.

Glue Failure – Break occurs between the glue and the paint or the glue and the dolly. This is not an adhesion failure.



TO SCORE OR NOT TO SCORE

The specification should say whether or not to score around the dolly. ASTM D-4541 leaves it open to the owner and the person doing the test. It cautions scoring can cause micro-cracking that can cause lower adhesion but also acknowledges that not scoring can lead to higher pull rates due to the influence of the adjacent coating

The ISO 4624 and BS EN 24624 standards require a tensile test over the area of the dolly. This means the surface must be separated from that adjacent, so a circular cutter is used around the dolly before testing.

Generally, I recommend not to score unless the coating is elastomeric, very thick or a solid surface glued to the substrate. If the specifications do not tell you what to do, discuss with all parties involved with the test.

WHICH METER IS BEST FOR ME?

If you are working to specifications, the specification should give both the pull rate expected and the type of meter the test is to be done with

If cost and range are considerations, the following Table will help:

Cost	Range (psi)	Meter
\$995 - \$1,200	0 – 3,200	Elcometer 106
\$1,800 to \$2,600 but less expensive)	0 – 10,000	Hate or Elcometer 108 (Same as the 108
\$1,800 to \$2,600	0 – 14,000	DeFelko PosiTest AT or ATM
\$1,000 - \$5,700	0 – 17,400	PATTI, 1910, 1940
\$5,000 - \$5,200	0 – 11,600	DFD 1941
\$11,000 - \$16,000	0 – 23,200	DFD 1920, 1930

NOTE: In the above table, some meters come in multiple ranges. Range can be modified by switching the dolly size being used (or piston size on the {PATTI}).

A common meter in use today is the Elcometer 106, not because of its accuracy or its repeatability, but because of its low cost, portability, and ease of use. It does require recalibration on a regular basis to ensure some accuracy. Best accuracy is in 20% to 80% of scale reading. Reported accuracy in ASTM D4541 is about ± 40%. **NOTE: This is the least accurate and lowest pulling tester on the market.**

The P.A.T.T.I. generally gives the best pull but this meter is better suited to laboratory use, although I have used it successfully in the field. The pistons require a large footprint and a flat area. The cost is \$1,000 to \$5,700 and can be ordered with piston to 10,000 psi. There is only one size pull stub. To change pull range, you change out the piston size. They have come out with a lower cost field unit.

The HATE tester is commonly specified by companies based in Europe. It is a good choice if you require better accuracy than given by the Elcometer 106 and is less expensive than some of the other options costing \$1,700 to \$2,200 and measures up to 2,600 psi. There is only one size dolly but you can order convex or concave dollies for testing pipe.

My new favorite is the DeFelsko Positest ATAutomatic Adhesion tester and at \$2,595 is an excellent choice offering good cost, excellent pull rates and ease of use in the field. Testing shows pull rates almost equivalent to the P.A.T.T.I. meter and if you are doing multiple tests, it is easy on the hands. The manual meter works well, but it is worth upgrading to the Automatic to get the easier pulls and more consistent results.

My old favorite is the DFD Pat Handy. While it is a Lot more expensive, at \$4,524, it is light and easy to use in the field, gives repeatable readings and comes with a self-aligning head that is separate from the crank. It works with a variety of dolly sizes and goes to over 14,000 psi. The company is in Europe and repairs can be expensive and very slow (months). Other DFD models are priced much too high to recommend except for C633 testing. The rig will cost around \$10,000 but is one of the few commercially available. Specified for TSA on pipe.

WHAT GLUE SHOULD I USE?

Instant gratification or 24 hours is one of the decisions to be made when choosing glue. Generally, the most acceptable method is using a 2-part epoxy glue and allowing 24 hours of cure time of at least 50°F for the to cure to a maximum adhesion.

There is no one glue recommended and each manufacturer, and many labs, have their favorites.

I have had good success with Ardilite 2011 Epoxy is usually used because it is compatible with most surfaces and generally, (when mixed properly) give pull strengths in excess of 3,000 psi. It has become difficult to find in small quantities, but I still sell it.

DeFelsko, after much testing, recommends ResinLab EP11HT 2-Part Epoxy.

Loctite 907 was tested by at least one adhesion tester manufacturer and has been found to give very good results.

Testing by Shell's coating lab found 3M DP420 to work well for them.

TxDot likes using 3M DP 8005 and DP 8010

Sometimes it is necessary to get results the same day. It is possible to use "Superglue" (Cyanoacrylate) on many coating types. If available, use a high viscosity glue such as 3M Pronto CA-100. Superglue should NOT be used on porous coatings because it will penetrate the coating and can glue the dolly to the substrate. Also, Cyanoacrylates are not compatible with some coatings such as Fluoropolymers and can dissolve, penetrate or soften coatings. For maximum pull, generally it is best to let Cyanoacrylate cure for a minimum of 3 hours.

If you need a pull of over 3,000 psi, your best option is a heat cured epoxy. These can provide pulls in excess of 10,000 psi without adhesive failure. Lastly for high PSI pulls, you may want to use the coating being tested as the adhesive by putting the dolly in the coating prior to pulling.

Remember, there is no difference between putting on a topcoat or gluing on a dolly. If you would expect low adhesion such as top-coating a polyurethane with an epoxy, then the adhesion of the epoxy glue will be effected by the same properties. If you have exceeded the overcoat time of the coating being tested, it may be necessary to slightly abrade the surface tested to improve adhesion. In addition, glue will not sick to oil, grease or dust any more than paint would stick to it, so make sure the surface is clean.

CAN I AVOID DAMAGING THE SURFACE IF ADHESION TESTING IS REQUIRED?

The answer is a definite maybe. If the specification requires the coating must reach a specific psi rating, there is no reason to pull to failure. At this point you can leave the dolly in place which may be acceptable for some applications. (The 106 dollies are aluminum and can easily be cut off at the neck to reduce their profile on the surface) If the dolly needs to be removed, often a hit on the side of the dolly with a hammer will remove the dolly without pulling off the coating. There is no guarantee this will work but the Peel force required to remove the dolly is usually less than the tensile force.

Heat can often be used to soften the glue to make the dolly easier to remove.

Always assume the test will be destructive, and if you can remove the dolly without destroying the surface you are one step ahead of the game.

WHAT DOES ADHESION TELL ME ABOUT THE COATING?

This is a good question without any good answers. There are many factors that affect the longevity of coatings and Adhesion can be one of them. Adhesion tests work best to help determine a mode of failure rather than determining how long a coating will last. Adhesion is often more of a MARKETING TOOL than then a true indicator of how good a coating system is.

One manufacture's product data sheet may state the Adhesion of their coating is minimum 1000 psi while another coating manufacturer states their coating system is a minimum of 500 psi. Will the 1000 psi coating outperform the 500 psi coating? Maybe.

If the 500 psi reading was taken with a 106 and the 1000 psi reading was taken with a P.A.T.T.I., then the readings may actually be about the same.

If they were both taken with the same type tester, there is still no guarantee that the 1000 psi system will outperform the 500 psi system. Adhesion is only one of many factors that may affect a coatings longevity and is probably not a good test to use as a predictor.

HOW DO I TEST CURVED SURFACES?

There are two methods to test curved dollies. The first is to use curved dollies such as the HATE tester uses. You can also have a machine shop put a curve on the dollies being used. It should be noted that cured dollies only give a true tensile pull only where the dolly is perpendicular to the curvature of the pipe. The rest of the curved surface is subject to sheer forces, so it is not a true tensile pull.

The second way is to reduce the size of the dolly to minimize the effect on the pull. Some of the testers have multiple sizes for dollies. For flat or large curvatures, the 20 mm dolly, standard to

most testers work fine. Manufacturers such as DeFelsko have various size dollies and the suggested dolly size is provided below:

Adhesion Strength	Dolly Size	Max Pull-Off Pressure		Min Curvature with Minimal effect on pull
	10 mm	14000 psi	70 MPa	Down to 2 inches (50 mm)
	14 mm	7000 psi	40 MPa	Down to 6 inches (150 mm)
	20 mm*	3500 psi	20 MPa	Down to 8 inches (200 mm)
	50 mm**	560 psi	3.5 MPa	Used mainly on Concrete

*supplied with PosiTest AT

**requires 50mm kit

WHEN IS ADHESION TESTING APPROPRIATE?

There are several good reasons for testing adhesion.

- There are questions about surface preparation, intercoat cleanliness or overcoat window times.
- When you want to overcoat an existing coating
- When there is a premature coatings failure and you want to determine the cause.





DISTRIBUTORS FOR:

COATINGS TESTING

DeFelsko
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ElektroPhysik
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Fischer

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TestEx

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DeFelsko
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