
Quality Control and Powder Coating

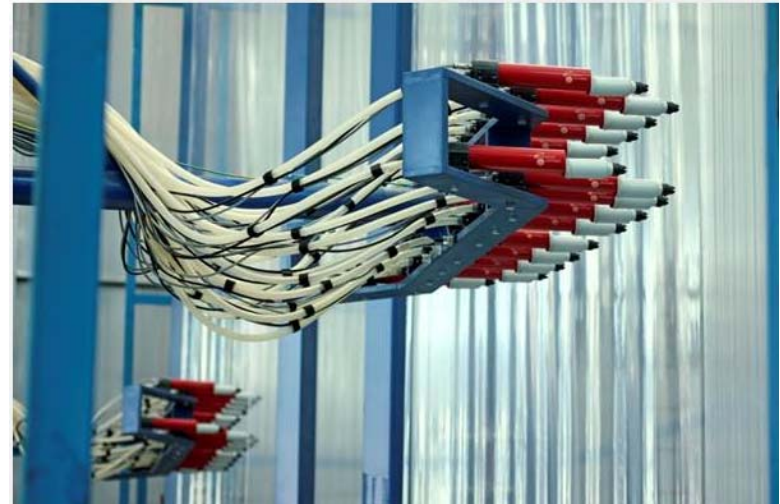
Presented by: 

David Beamish, President
DeFelsko Corporation

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Abstract

- Quality means different things to different people.
- Customers often choose suppliers that have solid quality control systems.
- With basic test instrumentation, coaters can study trends, reduce costs, and retain customers by providing them with documentation showing their ability to meet a required specification.
- Every applicator should know what equipment is available and know how to use it.



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Overview

Coating Powder Properties

particle size, specific gravity, etc.

Surface and Equipment Preparation

Surface profile and environmental measurement.

Ground testing and oven temperature profiling

Powder Coating Characteristics

smoothness, color, gloss, DOI and contrast ratio

Physical Characteristics

film thickness, impact, flexibility, adhesion, abrasion resistance

Environmental Characteristics

solvent/stain/chemical resistance, humidity, salt spray and weathering

Paperless QA

basic software for record keeping, reporting and analysis of test results



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Coating Powder Properties

| Coating Powders | | |
|--|--|------------------------------------|
| Attribute | Methods or References | Test Equipment |
| Dry Flow / Fluidization | ASTM D1895 | Funnels or Fluid Bed or Fluidmeter |
| Gel Time | PCI #6, ISO 8130-6, ASTM D3451 & D4217 | Hot Plate, Timer |
| Inclined Plate Flow | PCI #7, ASTM D3541, ISO 8130-11 | Balance, Pill Press, Oven |
| Particle Size (by sieves) | ASTM D1921, PCI Technical Brief #6 | Standard Sieves |
| Particle Size Distribution (by laser) | ASTM D1921, PCI Technical Brief #6 | Electro-mechanical devices |
| Specific Gravity, Density (by liquid displacement) | PCI #4, ASTM D5965-A, ISO 8130-3 | Volumetric Flask, Balance |
| Specific Gravity, Density (by gas displacement) | ASTM D5965-B, ISO 8130-2 | Gas Pycnometer, Balance |
| Specific Gravity, Density (by calculation) | ASTM D5965-C | Computer |
| Volatile Content, Cured Weight Loss | PCI #9, ASTM D3451 | Oven, Balance |



Coating Powder Properties

- **Dry Flow/Fluidization (a)** - ASTM D1895

- **Gel Time (b)** - ASTM D4217

Time required for a thermosetting coating powder to melt, flow, and crosslink.

- **Inclined Plate Flow** - ASTM D4242

- **Particle Size (c)** - ASTM D1921

- **Specific Gravity, Density (d)** - ASTM D5965

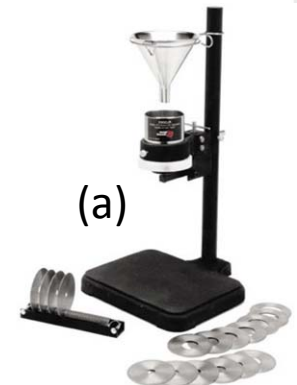
Ratio of material weight to volume.

- **Volatile Content, Cured Weight Loss (e)** - ASTM D2369

Determines weight percent volatile content of solvent-reducible and water-reducible coatings.



(b)



(a)



(c)



(d)



Substrate Cleaning & Pre-Treatment

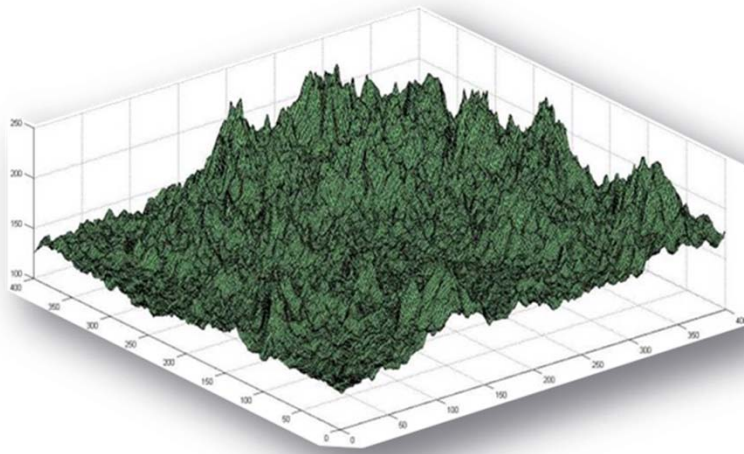
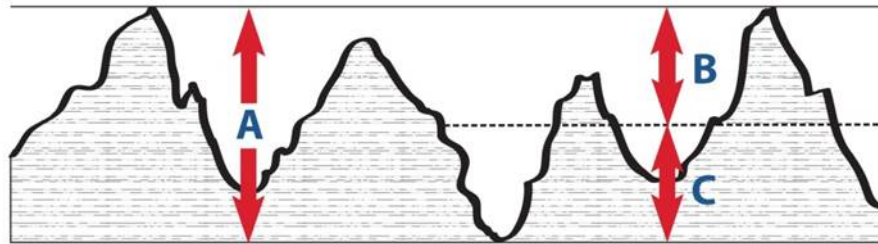
- The preparation of a part prior to coating to improve adhesion and corrosion resistance.
- Surfaces are frequently cleaned by abrasive impact, mechanical abrading or chemical cleaning.
- Roughening the surface improves coating adhesion. The resultant surface profile is comprised of a complex pattern of peaks and valleys.



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Surface Profile Measurement

- The height of the major peaks relative to the major valleys (ISO 8503-1)



A blast cleaned steel surface



Surface Profile Measurement

- Surface profile must be accurately assessed to ensure compliance with job or contract specifications.
- Instruments that can measure this profile with a high degree of precision, such as scanning electron microscopes, are suitable only for laboratory use.
- In practice, powder coaters have primarily three testing methods available to them for determining the amount of surface profile.

| | |
|-------------------|--|
| | |
| ASTM D4417 | Method B: Surface Profile Depth Micrometer |
| | Method C: Replica Tape |
| ASTM D7127 | Portable Stylus Roughness Instrument |

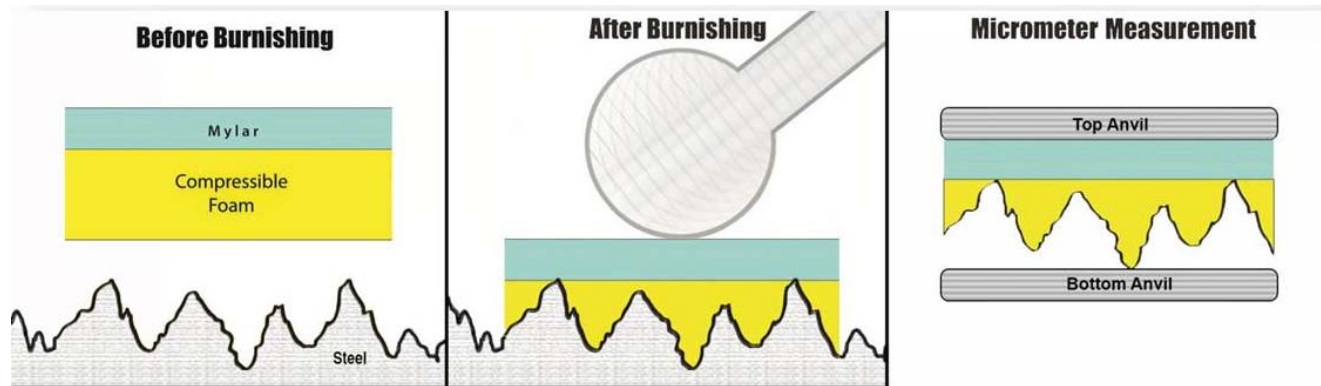


Replica Tape

- Simple, relatively inexpensive and shows good correlation with results from other methods.
- Particularly useful for measurements on curved surfaces.



Replica Tape



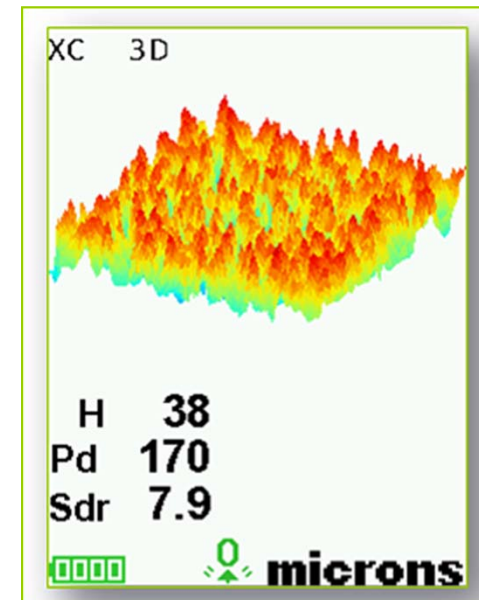
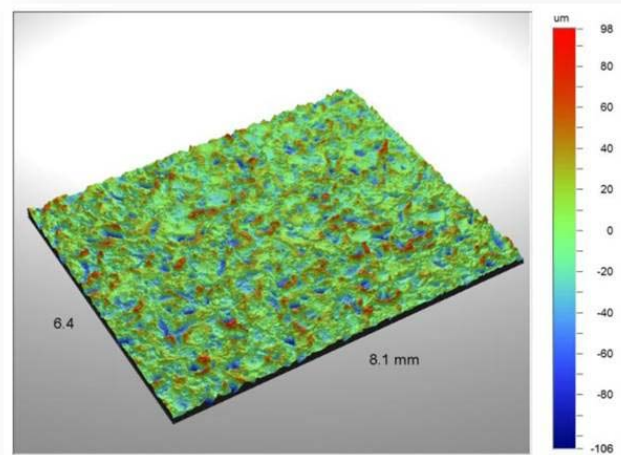
- When pressed against a roughened surface, the foam forms an impression of the surface.
- Placing the compressed tape between the anvils of a spring micrometer gives a measure of the surface profile.



Digital Replica Tape Reader

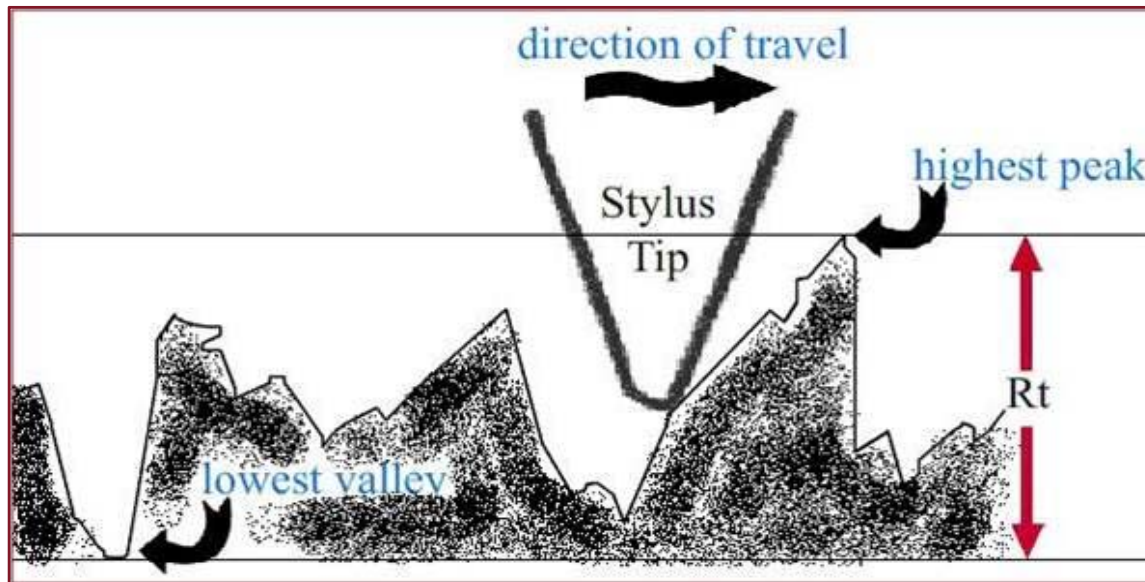


- Recent instrumentation generates significant new data through digital imaging.
- Light transmitted through the replica tape is captured to generate interesting 3-D digital images that reveal additional data such as peak density and increase in surface area.



Surface Roughness Meters

- Draws a stylus at constant speed across the surface. – ASTM D7127
- Measures the vertical distance between the highest peak and lowest valley within any given evaluation length of 0.5 inches.



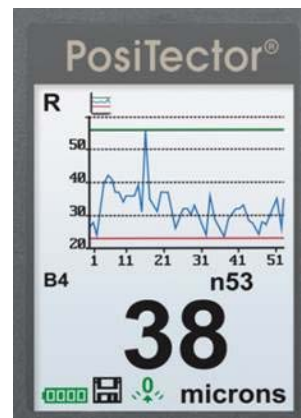
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Depth Micrometer

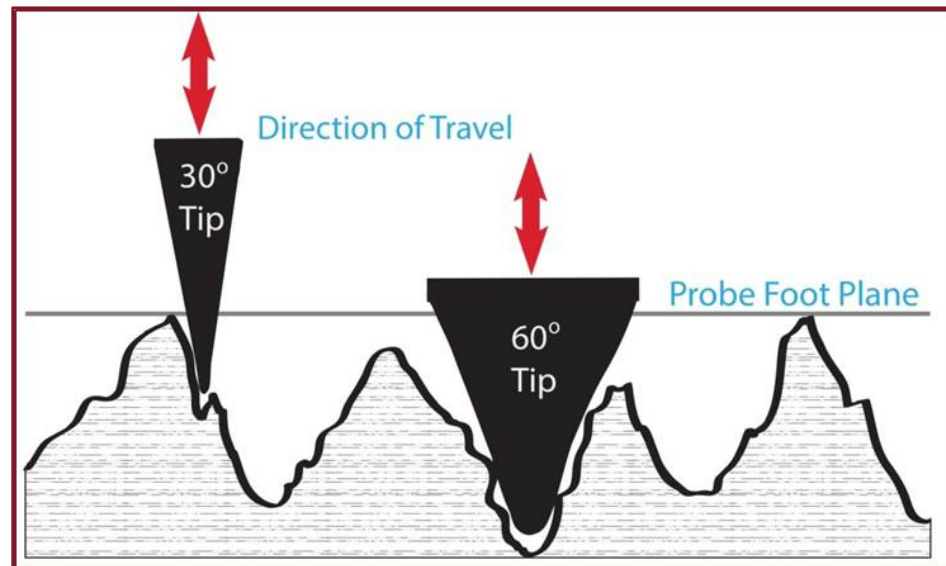
- Has a flat base which rests on the surface and a spring-loaded probe which drops into the valleys of the surface profile.



▶ Standard model



▶ Advanced model



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Environmental Measurement

(temperature and humidity)

Surface preparation and the application of coatings should be performed under optimal environmental conditions to help prevent failures.

Instruments measure 5 conditions :



- Air temperature
- Surface temperature
- Relative humidity (RH)
- Dew-point temperature
- The difference between the surface and dew-point temperatures



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Ground Testing

- Proper grounding of a powder coating system is absolutely essential for safe operation and quality finishing.
- Without a properly grounded surface available, a majority of the powder particles will be drawn into the powder recovery system.
- Grounding may be lost from excess build-up of coating on the hangers.
- An *Ohmmeter* measures the resistance from the hanger to the part.



Oven Temperature Profiling

- Thermoset powders requires a certain degree of temperature for a certain length of time to reach full cure. The application of energy to the product can be accomplished by convection or infrared cure ovens.
- The cure cycle is so many minutes at so many degrees of temperature.
- Oven recorders are used to measure and store the temperature profiles of both the sample and the oven during the cure process.



Powder Coating Characteristics

| Powder Coatings Films | | |
|-----------------------|-------------------------|--|
| Surface Attributes | Methods or References | Test Equipment |
| Smoothness | PCI Technical Brief #20 | PCI Smoothness Standards |
| Gloss | ASTM D523 | Glossmeter |
| Color | ASTM D2244 | Colorimeter |
| Distinctness of Image | ASTM D5767 | Visual Observation or Meter |
| Contrast Ratio | PCI #3, ASTM D2805 | Special Substrates, Reflectance Instruments |



Visual Smoothness Standards

- Smoothness is a visual property that is an important part of the coatings' decorative function.
- PCI Powder Coating Visual Smoothness Standards are a set of 10 panels showing the normal degrees of smoothness achievable with powder coatings.



- Goniophotometers



- PCI Powder Coating Visual Texture Standards are a set of 7 panels showing the normal degrees of texturing achievable with powder coatings.



Gloss & Color

■ Gloss – ASTM D523

- A subjective term describing relative amount and nature of mirror-like reflection.
- Coating reflective appearance quality is measured by a glossmeter.
- The amount of light that is reflected to a viewer's eye.
The angle of reflection is usually 20 and 60°.



■ Color - ASTM D2244

- Tested by visual inspection or computerized methods.
- Visual inspection by comparing a part to a known standard.
- For greater accuracy a color measurement device is used.
- Tristimulus values are the amount of red, green, and blue.
- PCI has a glossary of color measuring terms



Powder Coating Characteristics

Distinctness of Image (DOI) & Contrast Ratio

- **Distinctness of Image (DOI) visual check - ASTM D5767**

- Sharpness of an image reflected by a coating's surface.
- “100” has no distortion.
“0” has no image clarity.



- **Contrast Ratio - PCI #3, ASTM D2805**

- A value related to the hiding power of a coating at a specific film thickness.
- The ratio of the reflectance of a coating is measured over black and white backgrounds at the same film thickness.



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Physical Characteristics

| Powder Coatings Films | | |
|-----------------------|---------------------------|---|
| Physical Attributes | Methods or References | Test Equipment |
| Film Thickness | ASTM D1186, ASTM D1400 | Magnetic Thickness Gauge, Eddy Current Thickness Gauge |
| Impact | ASTM D2794 | Impact Tester |
| Flexibility | ASTM D522 | Conical or Cylindrical Mandrel |
| Adhesion | ASTM 2197, ASTM D3359 | Balanced-Beam Scrape- Adhesion, Cross Hatch Device and Tape |
| Hardness | ASTM D3363 | Standardized Leads or Pencils |
| Abrasion Resistance | ASTM D4060, ASTM D968 | Taber Abrader and Abrasive Wheels |
| Edge Coverage | ASTM 296 | Standard Substrate and Micrometer |
| Chip Resistance | ASTM D3170 | Gravelometer |



Why Measure Coating Thickness?

- Cured powder thickness is arguably the single most important measurement made during application and inspection.
- Powder thickness can affect the color, gloss, surface profile, adhesion, flexibility, impact resistance, and hardness of the final coating.
- Testing reduces internal reworks and customer returns.

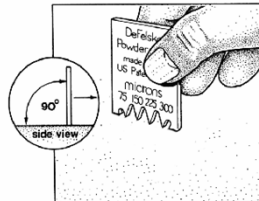


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Coating Thickness - Overview

■ Before cure:

- Powder Combs
- Magnetic gages with special powder probes
- Non-Contact Ultrasonic Instruments



■ After cure:

- Micrometers
- Magnetic, Eddy Current or Ultrasonic Instruments



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Coating Thickness - Micrometers



Advantage:

- measure almost any coating/substrate combination

Disadvantage:

- requires access to the bare substrate.

Take two measurements:

- one with the coating, one without. The difference (height variation) is taken to be the coating thickness.

ASTM D1005

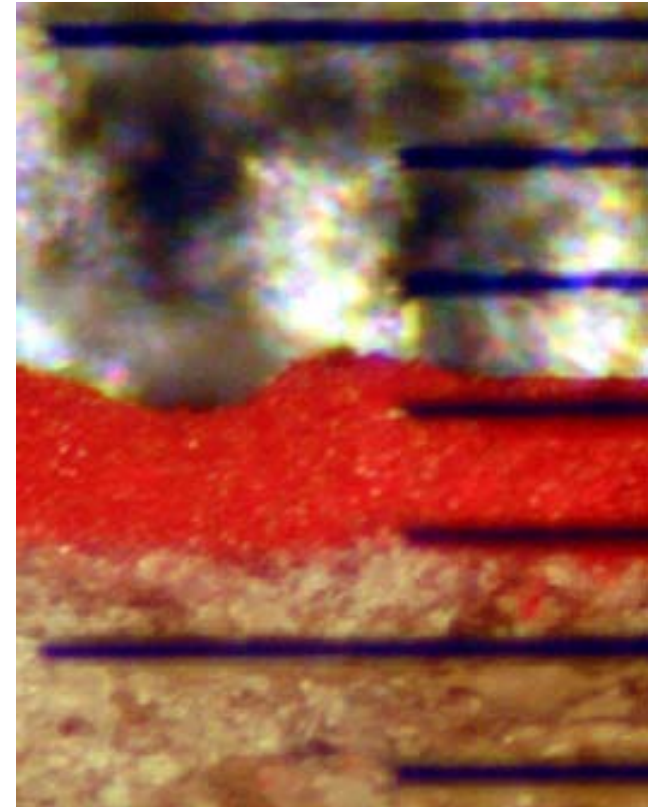


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Coating Thickness – Destructive Tests

Two common techniques:

1. cut the coated part
and view the cut microscopically



ASTM D4138



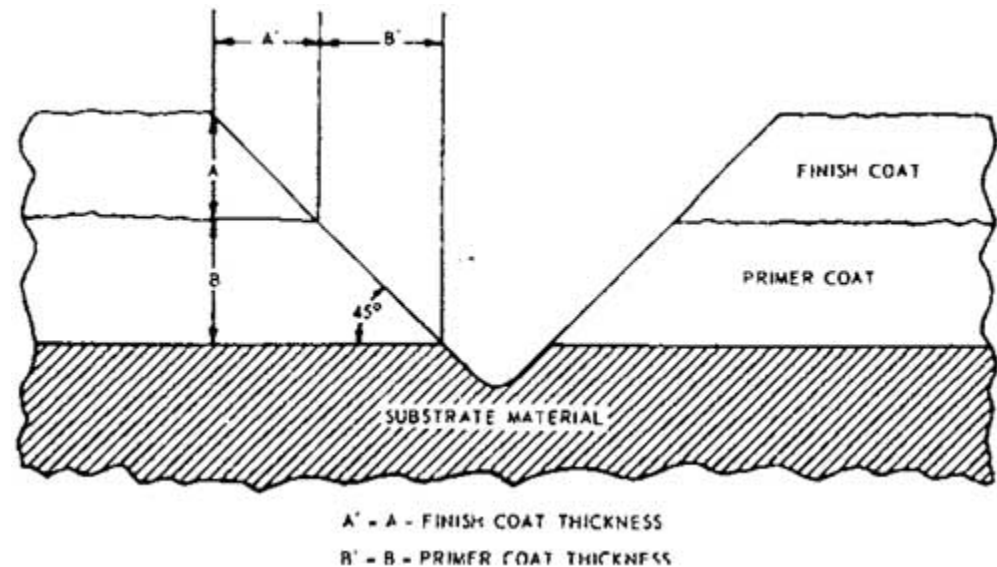
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Coating Thickness – Destructive Tests

Two common techniques:

2. Make a geometric incision through the coating and view with a scaled microscope

ASTM D4138



Coating Thickness – Non-Destructive Tests

- Thickness measurement is commonly made when the coating is cured.
- Gages are hand-held, easy to operate and relatively low cost.



Substrates:

| | |
|---------------------|-------------------------------|
| Magnetic | Ferrous metals (steel, iron) |
| Eddy Current | Non-ferrous metals (aluminum) |
| Ultrasonic | Non-metals (concrete, wood) |



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Coating Thickness Gages

Metal Substrates – Type 1, Mechanical

- Mechanical operation – no battery.
- Magnetic pull-off gages are rugged, simple, inexpensive.
- A good, low-cost alternative where quality goals require only a few readings during production.
- Also known as “pull-off” gages.



Coating Thickness Gages

Metal Substrates – Type 2, Electronic



- Operate on magnetic and/or eddy current principles to measure coatings over any type of metal substrate.
- The most common type of inspection instrument used in the powder coating industry



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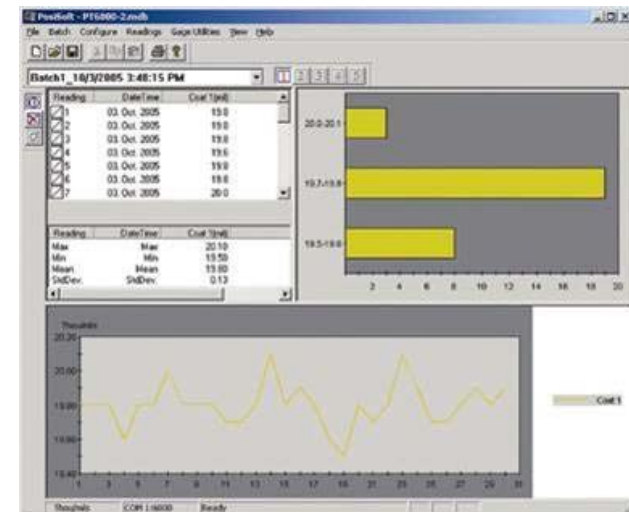
Coating Thickness Gages

Metal Substrates – Type 2, Electronic

How to Evaluate Film Thickness:

1. Take a **single** measurement.
2. Calculate the average of several measurements
3. Analyze a larger area using a statistical approach

- Optional averaging, printing, downloading, and trend analysis.



Coating Thickness Gages Interchangeable Probes



A wide selection of probes for different shapes and thickness ranges

Probe Interchangeability:

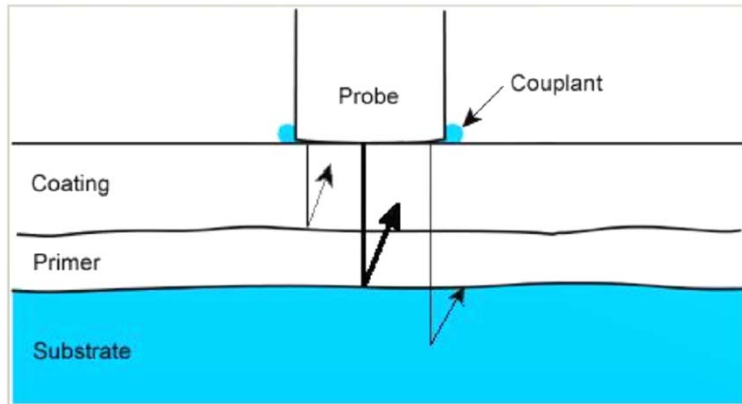
- Coating Thickness – Magnetic, Eddy Current , Ultrasonic
- Replica Tape Reader – RTR
- Surface Profile – SPG
- Environmental – DPM
- Ultrasonic Wall Thickness – UTG
- Uncured Powder Thickness - PC



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Coating Thickness Gages Non-Metal Substrates

- Coatings over plastic and wood are measured with ultrasound.



ASTM D6132 and ISO 2808



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Measuring Dry Powder (before cure)

- Making corrections after drying/curing requires costly labor, may contaminate, and may introduce problems of adhesion
- Dry Powder Thickness Gages enables the application system to be set up and fine-tuned prior to the curing process
- Helps insure correct cured film thickness
- Reduces amount of scrap and over-spray



ASTM D7378



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Dry Powder Thickness Gages

ASTM D7378 describes three procedures for measuring applied coating powders:

- A. Rigid metal notched (comb) gages
- B. Electronic coating gages with special powder probe
- C. Non-contact ultrasonic instruments

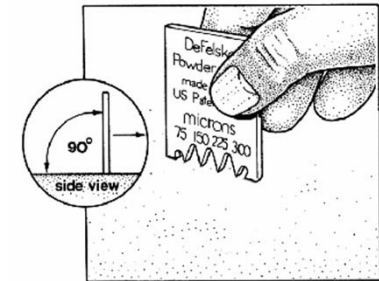


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Dry Powder Thickness Gages

■ A - Powder Comb

- Drag the gage through the powder
- Powder thickness is between the highest numbered tooth which made a mark, and the next highest tooth which left no mark



■ B - Magnetic Gage with special probe

- Micro pins penetrate the dry powder down to the substrate
- Probe is manually pressed down to the surface of the powder to effect a thickness measurement



NOTE: Both procedures result in only a height measurement of the uncured coating powder. A reduction factor must be established to confirm the cured thickness specification has been met. Measure the cured powder thickness at the same location as the height measurement.

Uncured Powder Coating Thickness Gages



- **C - Non-Contact Ultrasonic Measurement**
 - Measures powder coating by using non-contact ultrasonic technology to automatically calculate and display a predicted cured thickness.



ASTM D7378



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Physical Characteristics

Impact – ASTM D2794

- Impact resistance of a powder coating is an indicator of its ability to withstand sudden physical stress
- Test measures a coating's ability to withstand a force; expressed in inch-pounds
- Impact tests can be performed as direct impact or reverse impact. Both tests use a Variable Height Impact Tester.
- The panel is placed on a surface under a tube. A cylinder of a precise weight is dropped down a tube onto the panel surface from different heights



Physical Characteristics

Flexibility – ASTM D522

- Measures a coating's bend capability over a given shape
- Coatings attached to substrates are elongated when the substrates are bent during the manufacture of articles or when the articles are abused in service
- Coating flexibility can be important if the field use of the part will cause it to be stressed by thermal changes or handling. A conical mandrel bend test is used to test the coating for flexibility and adhesion.



Physical Characteristics

Adhesion

- The ability of a coating to adhere to the substrate or to a previous coating.
- Many ways to evaluate degree of bonding. But there is no single test to accurately and quantitatively determine adhesion.
- Many factors should be taken into account.
Conservative evaluations are recommended.



Physical Characteristics

Knife Adhesion Test – ASTM 6677

- 2 cuts forming an “X” are made into the coating.
The point of the knife is used to attempt to lift up the coating.
- Performance is based on both the degree of difficulty to remove the coating and the size of removed coating.
- Adhesion is evaluated qualitatively on a 0 to 10 scale.
- Highly subjective.

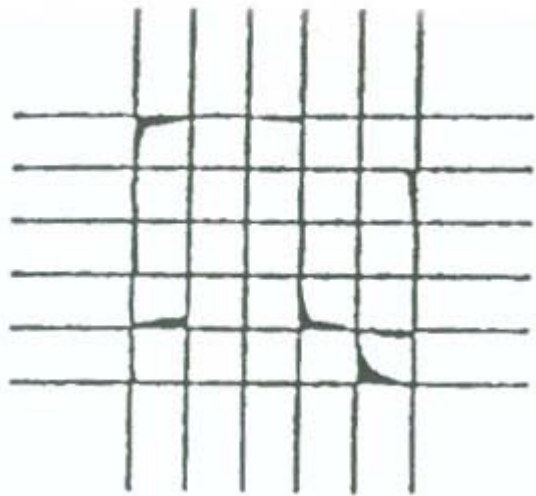
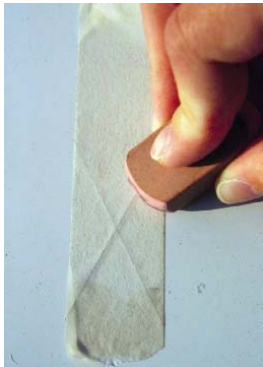


Physical Characteristics

Cross Hatch & Tape Adhesion Test – ASTM 3359

Two variants:

1. Tape is placed over an “X” cut and removed rapidly. Adhesion is assessed qualitatively on a scale of 0 to 5.
2. Tape is placed over multiple parallel incisions made in a cross-hatch pattern.



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Physical Characteristics

Pull-Off Adhesion Test – ASTM 4541

- A loading fixture (stub) is glued to a coating, then pulled by a portable pull-off adhesion tester.
- Determines greatest tensile force that a surface area can bear before material is detached, or whether the surface remains intact at a prescribed force (pass/fail).



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Physical Characteristics

Pull-Off Adhesion Test – ASTM 4541



Hydraulic Tester

- Mechanical (twist by hand), hydraulic (oil), or pneumatic (air) pressure.
- Widely used by coatings manufacturers, specifiers, inspectors, coating specialists.
- For use on rigid substrates only.



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Physical Characteristics

(Pencil) Hardness – ASTM D3363



- Relative rating of a coating's ability to resist scratching
- The test method covers a procedure for drawing pencil leads of known hardness over the coating
- Hardness is defined by a numerical value equal to the hardest pencil that will not break the surface.



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Physical Characteristics

Abrasion Resistance, Edge Coverage & Chip Resistance

- **Abrasion Resistance – ASTM D4060**

- Determines how much physical abuse the coating will take
- Taber Abraser or Falling Sand Abrasion methods



Model 5135

- **Edge Coverage – ASTM D2967**

- Measures the degree to which different coating powder materials cover sharp corners

- **Chip Resistance – ASTM D3170**

- A coating's ability to resist breaking and chipping when an object hits the coating
- Gravel propelled by high pressure to impact a cold coating is a typical test



Environmental Characteristics

| Powder Coatings Films | | |
|--------------------------|--|---|
| Environmental Durability | Methods or References | Test Equipment |
| Solvent Resistance | PCI #8 | Swab and MEK or other solvent |
| Stain Resistance | ASTM D1308 | Standard Reagents |
| Chemical Resistance | | Immersion or Spot Tests |
| Humidity | ASTM D1735, ASTM D2447 | Standard Water Fog Chamber, Test Chamber, 100% RH @ 100°F |
| Salt Spray | ASTM B117 | Salt Fog Chamber |
| Weathering: | | |
| Natural | ASTM D1014 | Panel Racks, |
| Accelerated Natural | ASTM D4141 | Special Racks with Reflectors |
| Artificial | ASTM D5031, D822, D4587, D3361, G23, G26, G53 | Weatherometer, QUV and other Equipment |



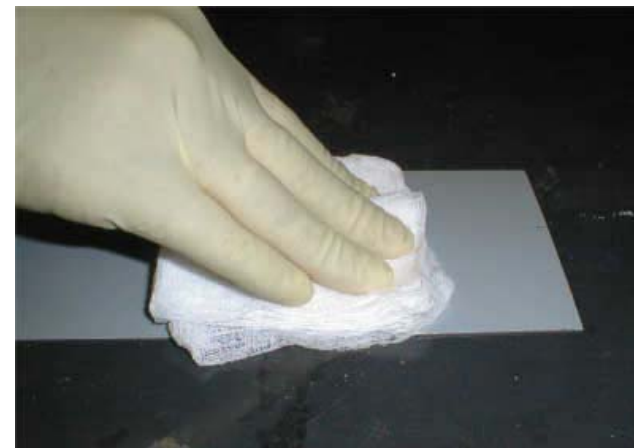
Environmental Characteristics

Solvent, Stain & Chemical Resistance

A powder coating should resist the staining effects of various substances and chemicals.

- **Solvent Resistance (PCI#8)**

- Test involves rubbing the baked film with cheesecloth soaked with MEK until failure or breakthrough of the film occurs



- **Stain and Chemical Resistance (ASTM D1308)**

- performed by exposing a sample to a solvent or reagent for a specified amount of time. Stained sample is then subjected to cleanability tests and rated.

| SOLUTION | 1 MONTH | 3 MONTHS | 6 MONTHS | 12 MONTHS |
|-----------------------------------|----------------------------------|---|--|---|
| 0.1% Chlorine | No Effect | No Effect | No Effect | No Effect |
| Anti-Freeze (50% Ethylene Glycol) | No Effect | No Effect | No Effect | No Effect |
| 87 Octane Unleaded Gasoline | No Effect | Dulls, Softens | Dulls, Softens | Dulls, Softens |
| 15% Hydrochloric Acid | No Effect | No Effect | *No Effect Dulls Textures | *No Effect Discolors, Dulls Textures |
| 40% Hydrochloric Acid | No Effect | *No Effect Discolors, Dulls Textures | *No Effect Discolors, Dulls Textures | *No Effect Discolors, Dulls Textures |
| 15% Sulfuric Acid | *No Effect Oxidizes Metallica | *No Effect Oxidizes Metallica | *No Effect Test Terminated on Metallica | No Effect |
| 40% Sulfuric Acid | *No Effect Oxidizes Metallica | *No Effect Oxidizes Metallica | *No Effect Test Terminated on Metallica | No Effect |
| Isopropyl Alcohol | No Effect | Dulls, Softens | Dulls, Softens | Dulls, Softens |
| Acetone | Dulls, Softens - 1 hour | | Test Terminated - 1 hour | |
| Methyl Ethyl Ketone | Dulls, Softens - 1 hour | | Test Terminated - 1 hour | |
| Brake Fluid D.O.T. Type 3 | Dulls, Softens - 1 hour | | Test Terminated - 1 week to 1 month | |
| Dow Oven Cleaner | Dulls, Swells | | Test Terminated - 1 to 3 months | |



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Environmental Characteristics

Humidity & Corrosion Testing (Salt Spray)



- **Humidity Resistance** - ASTM D1735 (Water Fog Humidity)
ASTM D2247 (100% Humidity)
 - Measures a coating's ability to withstand exposure to 100% relative humidity at various temperatures.

- **Salt Spray Resistance** – ASTM B117
 - Scribed or unscribed panels are placed in a cabinet and examined periodically for deterioration.
- **Accelerated Weathering (QUV)** – ASTM D1014, D4141, D5031, D822, D4587, D3361, G23, G26, G53
 - Measures the changes in appearance that occur when products are exposed to various types of exterior conditions.



Quality Control

- ▶ In today's competitive environment, customers often choose finishing companies that have solid quality control systems.
- ▶ Invest in a simple system that records and analyzes measurement results.
- ▶ Study trends, reduce costs, and retain customers by providing them with documentation showing your ability to meet a required specification.
- ▶ Simple analysis of this data requires software to export information to a quality control or SPC system for ISO- or QS-9000 record keeping.



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Paperless QA

Old Way

- Write it down
- Calculate an average
- Type a report



New Way

- Gage memory
- On-screen statistics
- Software



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Paperless QA



Charts



Annotations



Reports

Software Solutions



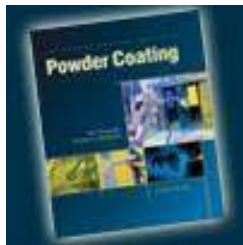
- **Desktop Software** - for downloading, viewing and printing measurement data locally.
- **Cloud** - Web-based applications offer secure centralized management of readings accessible from any web-connected device.
- **USB Drive** - Connect to a PC/Mac using USB cable to access and print stored readings, graphs, photos, notes and screen captures. No software or internet connection required.
- **Mobile** - access readings, graphs, capture photos and update annotations through WiFi enabled devices, such as tablets, smart phones and computers.



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- Provides visibility into your business
- Estimates operational costs

Additional Reading



Powder Coating: The Complete Finisher's Handbook - 4th Edition

www.powdercoating.org



PCI Technical Briefs - 28 documents detailing coating materials, the application process and health issues.



ASTM – A source of Standards and Test Methods

www.astm.org

Quality Control and Powder Coating

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