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A Guide to Industrial Coatings and Metal Finishes

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A Guide to Industrial Coatings and Metal Finishes

This guide will take you through topics, from industrial coatings to surface preparation, to recommended coating systems for different industrial structures.

Introduction

Industrial coatings (paint)

The term “paint” is used to describe a liquid or paste which is applied to a surface through a variety of application methods.

Once applied, paint provides a protective coating against corrosion, weathering, and other forms of surficial decay.

Constituents of Paint

Pigments

provide color and opacity to the paint layer.

Additives

are various chemical products which can be added to paint in small proportions to improve the quality of the paint. They also produce special effects, speed up drying, provide tinting, and help to increase the thixotropy.*

**Thixotropy is a time-dependent phenomenon, best characterized as fluidification of the material under high shear and stiffening at rest or at low shear rates.*

Binders

are a basic ingredient in paint, allowing the paint to provide a hard protective layer after drying. Paints use binders to improve mechanical and chemical properties, and to increase the durability and hardness of the surface .

Solvents

allow for an easy application of the paint, by lowering the viscosity of the paint. Typically, paints that do not use solvents and have only a base pigment and a binder, are very thick and difficult to apply. In addition, solvents help to maintain the integrity of the paint while being stored.

Feature of paints

Paint can be classified by testing and quantifying its various characteristics of quality.

This aids the end user of the paint, to ensure the product is in good condition and meets the original manufacturer specifications.

These characteristics can be divided into two groups:

- for still wet paint
- for completely dried paint

Characteristics of paint when wet

Primary quality characteristics of paint when wet are:

- Stability
- Specific weight or density
- Fineness of grind
- Viscosity
- Pot life
- Dilution
- Application
- Drying time
- Solids content by weight or volume
- Yield

Characteristics of paint when dry

Primary quality characteristics of dry paint:

- Flexibility
- Yellowing
- Colour
- Aspect
- Scratch resistance
- Salt spray resistance
- Impact resistance
- Immersion resistance, splashing
- Hardness
- Temperature resistance
- Brightness
- Adhesion
- Resistance to exposure
- Hiding power

Durability of the coating system

The durability of a protective coating system relies on:

- the type of paint system
- the design of the structure
- conditions of the substrate before preparation
- effectiveness of the surface preparation
- standard of the application work
- conditions during application
- the exposure conditions after application

Durability can be viewed in terms of three ranges:

- Low (L) 2 to 5 years
- Medium (M) 5 to 15 years
- High (H) more than 15 years

Selecting a paint system

To obtain a good surface protection at a minimal cost, the following should be considered:

- The type of material being painted
- Shape and geometrics of the painted surface
- Condition of the surface, and amount of corrosion
- Whether the surface to be painted is indoors or out
- Weather conditions
- Aggressiveness of the environment and the effect it will have on the object
- Mechanical conditions it will encounter while in service (knocks, scratches, scrapes)
- Color and degree of gloss required
- Most practical means of cleaning the surfaces
- Available methods of application
- Consideration of time, corrosion grade and specification

Layers of Paint

Primers

These are the primary layers of paint which come into direct contact with the raw surface or substrate.

They have a high degree of pigmentation, low binder content and provide a good surface for the adhesion of the next layer of paint.

They help to avoid corrosion on metallic surfaces because of their anti-corrosive pigments.

Etching primers

Etch or self-etching primer is a paint designed to physically bond itself to the substrate to which it is applied.

This is achieved by combining an acid with the paint so that the acid microscopically etches the surface of the substrate, thus forming a physical and chemical bond between the two.

Etch primers are formulated to be applied to either ferrous or non ferrous metals, (or in some cases both).

Intermediate coats

Painted over the primer, these help to increase the total thickness of the painting. This helps to prevent the finishing coating from being applied too thick.

The pigment to binder ratio is lower in intermediate coats than in primers, but the ratio is higher than in finishing paints.

Modern processes use very thick intermediate coats, with thicknesses up to 100 - 200 microns, which saves money in the painting process.

Finishing coats

These are the last coats of paint to be applied. They can be painted on top of primers or intermediate coats.

They are made with a low pigment to binder ratio to provide water resistance and to give hardness to the surface.

They are normally glossy, though satin and matt finishes are also used.



Clear coating

Clear coats are pigment-free paints which are not used to provide opacity or color.

Clear coat is paint or resin which impart no color to the surface, but simply a layer of clear coating that is applied over colored layers. Nearly all vehicles painted today have a clear coat finish (image).

Industrial Protective Coating Standards

The SSPC

SSPC: The Society for Protective Coatings was originally founded in 1950 as the *Steel Structures Painting Council*, which was a non-profit professional society concerned with the use of coatings to protect industrial steel structures.

In 1997, the name of the association was changed to simply: *SSPC*.

SSPC

SSPC is the leading source of information on surface preparation, coating selection, coating application, environmental regulations, and health and safety issues that affect the protective coatings industry.

The SSPC's core services include:

- Creating industry standards for industrial coatings
- Providing technical publications
- Training & certification courses
- Painting contractor certification programs
- Conferences and events

ASTM standards for paint, finishes, and coatings

ASTM also provides an extensive number of publications for the standardization for paints used in industrial settings.

Per the ASTM site (<https://www.astm.org/Standards/paint-and-related-coating-standards.html>):

“ASTM’s paint and related coating standards are instrumental in specifying and evaluating the physical and chemical properties of various paints and coatings that are applied to certain bulk materials to improve their surface properties.

Guides are also provided for the proper methods of applying these coatings, which also include enamels, varnishes, electro-platings, pigments, and solvents.

These paint and related coating standards help paint manufacturers and end-users in the appropriate testing and application procedures for the coating of their concern.”

NACE (National Association of Corrosion Engineers)

This organization also offers extensive standards on corrosion and surficial protection of metals and other corrodible materials.

Per their website:

“NACE International, was established in 1943 by eleven corrosion engineers from the pipeline industry as the “National Association of Corrosion Engineers.”

Today, NACE serves nearly 36,000 members in over 130 countries and is recognized globally as the premier authority for corrosion control solutions. The organization offers technical training and certification programs, conferences, industry standards, reports, publications, technical journals, government relations activities and more.”

ISO Standards

The International Standards Organization (or ISO) also provides a number of publications on the topic of paints and varnishes. This publication is known as “ISO/TC 35, Paints and varnishes”.

Included are standards which cover the best methods for performance of paints and varnishes, as well as the main raw materials used in their manufacture.

It also includes standards on terminology and on the preparation and protection of steel substrates.

The Process of Corrosion

Corrosion

Corrosion is a natural process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulfide. Corrosion is due to the combined, decaying effects of moisture and oxygen.

Paint provides a barrier between the metal and the effects of moisture and oxygen.

The amount of resistance of a particular paint to these corrosive effects is controlled by the chemical additives in the paint formula.

Additionally, thicker paint layers tend to make it more difficult for oxygen and humidity to reach the metal, to cause corrosion.

Corrosion and rust

Corrosion refers to the *electrochemical oxidation of metal* which occurs, in reaction with an oxidant such as oxygen or sulfates.

Rust is the formation of iron oxides; this is a well-known example of the electrochemical oxidation process. This type of damage typically produces oxides or salts of the original metal, and results in a distinctive orange discoloration.

Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term "degradation" is more commonly used.

Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

Galvanic corrosion

This occurs when two different metals have physical or electrical contact with one another (image) and are immersed in a common electrolyte, or when the same metal is exposed to electrolyte with different concentrations.

In a galvanic couple, the more active metal (the anode) corrodes at an accelerated rate and the more noble metal (the cathode) corrodes at a slower rate.

When immersed separately, each metal corrodes at its own rate. What type of metal to use is determined by following the galvanic series.

For example, zinc is often used as a sacrificial anode for steel structures.





Sacrificial anodes

Zinc is often used as a sacrificial anode for steel structures. Galvanic corrosion is of major interest to the marine industry and also anywhere water (containing salts) contacts pipes or metal structures.

Factors such as relative size of anode, types of metal, and operating conditions (temperature, humidity, salinity, etc.) all have an affect on the rate of galvanic corrosion.

The surface area ratio of the anode and cathode also directly affect the corrosion rates of the materials.

The image shows a zinc sacrificial anode attached onto a ship hull.



Corrosion in alloys

Many structural alloys corrode simply from being exposed to the moisture in air, though the process can also be strongly affected by an exposure to certain substances.

Corrosion can be concentrated locally on the metallic surface, forming a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface.

Because corrosion is a diffusion-controlled process, it occurs on exposed surfaces. As a result, methods to reduce the activity of the exposed surface, such as passivation and chromate conversion, can increase a material's corrosion resistance.

However, some corrosion mechanisms are less visible and less predictable.



Substrate corrosion

Corrosion of the substrate is caused by humidity; creating an electrochemical reaction of the metal with the oxygen, producing rust blisters (image) or fading in the painted surface.

Causes of substrate corrosion:

- Untreated corrosion or poor cleaning of the substrate
- Exposure of the substrate to corrosive environments; such as salt
- Substrate exposed for too long after cleaning and before re-painting
- Poor pre-treatment of the substrate

Minimizing substrate corrosion

First, all traces of corrosion should be removed from the metal surface, and care should be taken to clean the substrate thoroughly. Avoid exposing the substrate to exterior elements without proper protection.

Minimize the time that the substrate is unprotected before priming and further treatment. Use the correct pre-treatment, depending on the type and use of substrate.

Corrosion cell

Four ingredients must be present for the electrochemical process of corrosion to occur, i.e., the corrosion cell.

All four elements must be present:

- 1) **Anode:** where oxidation (corrosion) occurs
- 2) **Cathode:** where corrosion does not form
- 3) **Metallic pathway:** Provides the flow of electrons from anode to cathode
- 4) **Electrolyte:** A liquid that contains charged particles and allows ions to flow from cathode to anode

The interaction between these four components is known as the *corrosion cell*.

Electrolytes

Three components of corrosion are already present in most metals: the anode, the cathode and the metallic pathway.

All that's missing is the electrolyte that comes from the atmosphere or chemicals. Once the electrolyte is present, electrons flow from the anode to the cathode, and ions flow from the cathode to the anode through the electrolyte, completing the electrical circuit.

The ions flowing from the cathode to the anode cause the anode to corrode and the metal to become compromised.

Electrolytic compounds

Electrolytes are typically sodium chloride and calcium compounds.

Chloride compounds are usually found in seawater, rain, mist and fog, as well as road salts and cleaning chemicals.

Not quite as common, but sulfur and nitrogen compounds can be found in fuel oil and coal.

Water tends to be the most common cause of corrosion.

Corrosion prevention by design

Corrosion is prevented by removing one of these components from the corrosion cell. As long as one of these components is missing, the electrical circuit cannot be completed, and corrosion cannot occur.

There are several methods of corrosion control. Ideally corrosion prevention is built into the design of whatever's being built.

Certain materials are immune to corrosion, such as gold and platinum.

Other alloys like stainless steel, nickel, chromium and copper resist corrosion by forming natural films that act as barriers between the metal and the environment.

Selecting materials that are inherently resistant or immune to corrosion will reduce the costs and damages associated with corrosion.

Geometric design issues

These are also a cause of corrosion.

The most common geometric design issues include:

- Areas which trap water
- Cracks or crevices
- Sharp edges
- Inaccessible areas
- Sheared edges
- Fasteners
- Stray currents

While designing for corrosion prevention is always recommended, corrosion is inevitable in any application.

Inspection and maintenance are required to prevent structural damage to buildings, vehicles and equipment that are susceptible to corrosion.

Surface Preparation and Cleaning

Preparing the surface for the coating

Proper surface preparation is vital to ending up with a good result.

A poorly prepared surface which has been painted with a top quality paint will experience worse results, than a cheaper paint which has been applied with a properly prepared surface.

The type of material, condition of the surface (presence of oxide, or previous old paint coats), size of the part and cost of the operation will be an indication of the preparation required.



Degrease the surface

Grease and oils are always found on structural materials and need to be removed completely before beginning to apply the paint.

The most common cleaning method for grease is to use a solvent based or water based degreaser.

Use of solvents for cleaning

Cleaning with a solvent or thinner is usually performed with soaked cloth. Cleaning can also be done with spray solvents and immersion in a solvent vapor.

The solvent must easily dissolve grease and possess a low level of toxicity. Cloths that are used in this operation must be replaced frequently to prevent them from becoming saturated in grease.

As a final step, the painted surface should be wiped down with a cleaning thinner.

High pressure water stream

An alternate method of cleaning involves the use of a high pressure water stream with a minimum of 750-1,000 kg/cm² and flowrates up to 4,000 liters/hr can be also used, to remove salt, rust, grease and old paint.





Manual and mechanical cleaning processes

Manual preparation can be performed by brushing, scraping, grinding or sanding the metal surface to remove corrosion and old layers of paint; however this method tend to be time-consuming.

It will not totally remove the dirt, but it can be used when access is difficult or the cost of cleaning is high. Wire brushes or steel wool (image) are often used for this purpose.

Blast (abrasive) cleaning

Blast cleaning is cleaning the surface with small particles of abrasive material. These are fired at high speed using compressed air with a spray gun through a special nozzle. The abrasive material may be small steel balls, sand or synthetic abrasives.

Blast cleaning is the best way of cleaning because it removes rust, mill scale, paint coatings, welding residues, oils, etc.

This method also gives an excellent surface for paint bonding.

Specifications for blast cleaning

Specification SIS-055900 or ISO 8501* describes the different grades of preparation that can be achieved through blast cleaning.

Blast-cleaned metal has a very active surface, very easy to rust, therefore should be immediately repainted.

**ISO 8501 was published by the International Standards Organization in 1988, after combining the content from the 1967 Swedish Standard SIS 055900 with the German DIN 55928.*

ISO 8501 is a pictorial standard showing the appearance of different rust grades at various levels of cleanliness, although it also contains text descriptions of the cleanliness levels.

ISO 8501 ranks cleanliness levels in order of increasing work required:

- Sa 1) Light Blast Cleaning
- Sa 2) Thorough Blast Cleaning
- Sa 3) Blast Cleaning to Visually Clean Steel



Levels of blast cleaning

Light

Poorly adhering mill scale, rust and paint coatings and foreign matter are removed.

Thorough

A majority of the mill scale, rust and paint coatings and foreign matter is removed. Any residual contamination shall be firmly adhering.

Very thorough

Mill scale, rust and paint coatings and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.

Intensive

Mill scale, rust, paint coatings and foreign matter are removed. The surface shall have a uniform metallic color.



Zinc phosphating

This treatment covers the surface of the steel in zinc phosphate, which provides a better resistance to corrosion, allowing the next coat of paint to stick properly.

Before phosphating, the surface must have all of the rust, oil and dirt removed.

Preparation of the Paint

Preparation

The proper preparing and applying of industrial coatings are just as critical as selecting the correct coating system and surface preparation protocol.

Mixing and straining are important parts of the coating preparation process, while thinning is required with certain systems.

Mixing

When stored, coating pigments within the paint tend to settle at the bottom of the can.

If coatings aren't thoroughly mixed, the paint film can become uneven in color and thickness, as well as having reduced adhesion and limited corrosion or cathodic protection.

Mixing can be done manually or mechanically. Mechanical mixing is more effective and efficient (image).





Thinning the mix

Once mixed, the paint formulation might require the addition of a paint thinner to reduce the coatings viscosity. This should only be used per the manufacturer's specifications.

Using the an improper thinner may result in a defective coating, while over-thinning can create a runny coating with little to no adhesion.



Straining

Industrial paints often require straining to ensure conformity across the entire application.

Straining prevents coatings from becoming lumpy and uneven when applied.

Straining is the last step before applying, and it can be accomplished using a mesh sieve or commercial paint strainer.

Paint Application Methods



Applying the paint

Once the industrial paint is prepared, the means in which the paint will be applied should be determined.

Brushes, rollers and sprayers are the most common forms of applicators in industrial settings.

Pad applicators have also become very popular choices for applying paints (image).

Brush application

Brushing is one of the more expensive means in which to apply the paint due to the degree of labor required to properly apply the protective paint.

However, it is suitable for on-site application, requires little initial capital, doesn't rely on power and typically involves short set-up times.

Proper brushing techniques from SSPC's Good Painting Practices include:

- Shaking loose unattached fibres by spinning the brush
- Removing stray fibres with a putty knife
- Dipping the brush in paint to cover no more than one-half of the bristle length
- Removing the excess paint by tapping the brush on the end of the can
- Applying even strokes lightly
- Holding the brush at a seventy-five degree angle
- Applying paint from top to bottom, always in the same direction
- Start and finish at the natural boundaries



Rollers

Roller application is ideal for large, flat or curved surfaces.

When spray applications are prohibited or expensive, roller application is the ideal method. Roller application is also much less time intensive than brushing.

However, rollers cannot be used with quick-evaporating solvents, and they can sometimes pump air into coatings (causing voids and holidays).

Consider a spray application when dense or fast-acting solvent coatings are being used.



Sprayers

Spray application is one of the quickest industrial paint applications methods, reducing overall labor costs.

Sprayers come in two general forms:

- conventional air sprayers
- airless sprayers

Both types utilize a type of coating that's atomized into a fine powder rather than a typical liquid coating.



Conventional sprayers

Conventional spray systems are composed of a spray gun, material container, air compressor and air-controller.

These systems push compressed air and powder coating through a spray gun that controls how much is applied.

Airless sprayers

These don't use compressed air to deliver the paint. Instead, airless sprayers utilize hydraulics by combining a fluid pump, high-pressure hose and airless spray gun.





Electrostatic sprayers

Electrostatic spray systems also exist for assets that are irregularly shaped or electrically conductive.

These systems utilize a high voltage charge, in order to deliver the paint.

As the paint atomizes, each particle contains an electric charge. The particles are electrically attracted to the asset.

HVLP spray systems

High Volume, Low Pressure (HVLP) spray systems are another unique option for industrial painters.

A high volume of air pushes through the system at low pressure (10 psi or less) to avoid overspray, blow back and paint loss. HVLP systems also reduce solvent emissions to help painters abide by VOC regulations.



Industrial Coatings for Steel Structures



Steel

Steel is one of the most widely used building materials in modern construction. Steel offers a durable, affordable solution that can be used in a variety of applications.

However, different environments require different coating systems and surface preparation.

Surface preparation for steel

Abrasive blasting is the preferred surface preparation method for steel because of its affordability and efficiency.

Per the SSPC's "Good Painting Practices" publication, four factors influence the degree of abrasive blasting required:

- Type of primer
- Severity of the environment
- Desired service life
- Coating manufacturer requirements

Steel primers

Manufacturers of steel primers publish product data sheets (PDSs) that recommend the level of surface preparation required, typically using SSPC or NACE standards.

Steel primers are applied before an intermediate and topcoat are applied.

Steel surface primers must bond well with the structure, provide corrosion resistance and provide the conditions for a complementary topcoat.

There are two notable types of steel primers:

- surface-tolerant primers
- pre-construction primers

In addition, is the zinc-rich primer which acts as a sacrificial anode.

Surface-tolerant primers

Surface-tolerant primers are designed to provide corrosion protection to less thoroughly cleaned surfaces.

A topcoat is usually required in addition to the primer to provide long-lasting protection. When abrasive blasting isn't an option, surface-tolerant primers are a suitable solution.

Pre-construction primers

These need to provide strong adhesion to both the steel surface and the topcoat.

Corrosion protection, ease of application, weld-resistance and coating system compatibility are all desired properties of pre-construction primers.

While surface-tolerant primers are typically used in the field as maintenance coatings, pre-construction primers are applied before a structure is built, often in a shop environment.



Zinc-rich primers

These provide cathodic protection to a structure, increasing the steel's corrosion resistance.

The zinc coating acts as a “sacrificial anode” in the corrosion process, where the zinc, rather than the steel surface, corrodes.

This will be covered in more depth, later in the course.

Inorganic and organic primers

Inorganic primers must be applied via a sprayer, while organic primers can be applied via a brush, roller or sprayer.

Steel Coating Systems

Use similar coating type for re-painting

When using an industrial coating system to repair an existing damaged coating, it's imperative to use a coating system that's identical to the generic type of coating used previously.

So if an epoxy-based paint was initially used, be sure to use an epoxy-based or likewise coating for the new coating application.

Alkyd coating systems

Alkyds are a time-proven coating system that have been around since the early 1900s.



The primary advantage to alkyds is their ability to cure through oxidation of drying oils. They provide solid resistance to structures in mild atmospheric environments, although they are limited in their protection against corrosion in harsher environments.

These coating systems can be paired with alkyd primers, water-based acrylic paints and certain types of intumescent* (fire-rated) paints.

**Intumescent coatings, are used in buildings as a passive fire resistance measure, and can be applied to structural members as an aesthetically-pleasing fireproofing measure.*

Epoxy coating systems

There are a wide range of epoxies that can be used for various applications.

Polyamide epoxies can protect structures that are fully immersed under or in water. These epoxies can protect offshore platforms, underground pipelines and the underside of Navy ships.

Certain types of epoxies like phenolic, amine-cured and novolac epoxies are recommended when structures are exposed to damaging chemicals. They're ideal for tank linings and other harsh environments.

100% solids epoxies have little to no volatile organic compounds (VOCs). They're an environmentally friendly option that can be used as a primer, intermediate or topcoat.

Epoxy coating systems provide a lot of versatility and greater protection than alkyds, but usually come at a premium expense.

Water-based epoxies are another low-VOC option that should be considered in less demanding environments.

Polyurethane coating systems

Polyurethane coatings are usually applied as finishes, rather than primers or barrier coatings. They offer both long-term gloss and color retention, making them an appeal option when aesthetics are important.

Moisture-cured urethanes

These cure using moisture and humidity, handle higher dry service temperatures than epoxies and provide a hard, durable finish.

Acrylic polyurethanes

Have high gloss and color retention, as well as UV resistance. They're commonly used for long-term steel surface protection.

Polyester polyurethanes

Are a premium product that offer abrasion-resistance while maintaining color and a glossy finish.

Painting without the primer

Formulations exist that can be applied directly to steel without a primer.

Polysiloxane (which is a type of polyurethane), acts as both a primer and a top coating, allowing for a single application (at a higher cost per application).

Combined coating systems

Industrial coatings systems can be comprised of one or more varied types of coatings. A complete coating system will address all of the requirements of the application.

For example

An application that demands cathodic protection, a barrier coat and a glossy finish could have a zinc-rich primer, followed by an epoxy barrier coat and polyurethane finish.

Concrete Coating Systems



Concrete

Concrete is a long-lasting and durable building material that's also cost-efficient. Concrete can be found in nearly any industrial and commercial environment.

It does however, require maintenance routines that should be addressed, in order to be a long-lasting material.

Concrete requires a coating to account for it's tendency to become porous and cracked. Surface preparation is the first step in properly treating concrete.

Concrete surface preparation

Unlike steel, concrete is a non-uniform mixture that's porous and tends to crack.

Moisture can also seep into concrete causing further issues.

Because of these issues, it's imperative to inspect and test before surface preparation for chemical contamination, strength, physical defects and moisture. SSPC-SP 13/NACE No. 6 can be referenced for most concrete surface preparation.

Surface prep

Surface preparation methods can include:

- Wet grinding
- Wet abrasive blasting High-pressure/low-pressure water blasting
- Abrasive blasting
- Vacuum shot blasting
- Vacuum cleaning
- Detergent washing/scrubbing
- Acid etching

Testing and inspection also need to happen after surface preparation, and the following standards should be met:

- ASTM D7234: For pull-off adhesion strength of coatings on concrete
- ASTM F1869 and ASTM F2170: For moisture content
- ICRI 310.2: For the surface profile

Concrete coatings

Concrete coatings must have the following properties to maximize value:

- Good adhesion
- Physical strength
- Moisture-resistance
- Impermeability

Concrete coatings might also need to have alkali-resistance and chemical-resistance depending on the environment.

Concrete coatings are typically divided into two categories: thin and thick films. Thin films form 1 mil layers, while thick films form 2-3 mils per layer.

Epoxies

While thin film coatings are usually acrylics or thin-film-penetrating sealers, thick film coatings for concrete may include: two-part epoxies, polyurethanes and polyaspartic applications.

These two-part coatings combine resins with a hardener for added durability. Epoxies are a great two-part option for concrete floors because they are self-leveling and fill dents and cracks.

Epoxies also be slip-resistant, abrasion-resistant and static-resistant. 100% solid formulations also exist that are durable and help businesses meet VOC regulations.



Acrylics

Water-based acrylic coatings have fast dry times, but lower performance and life-times compared to their thick film counterparts.

Solvent-based acrylics perform better and last longer than water-based acrylics but there might be environmental regulations that prevent the use of these coatings.

Polyaspartic coatings

Polyaspartic formulations are relatively new to the coatings market, but they perform well across various metrics.

Polyaspartic coatings have the following benefits:

- Quick cure times
- Can be applied in extremely cold /hot environments
- Low viscosity
- UV-resistant
- No bubbling
- High solid options
- Oil resistant
- High abrasion resistance compared to epoxies

For all their benefits, polyaspartic coatings tend to be more expensive with lower pot lives.



High Temperature Coating Systems

High temp paint

Certain environments create harsh conditions for steel due to extreme temperatures. Industries with assets like power plants, refineries, petrochemical plants and paper mills need coatings that can handle temperatures up to 650 °C.

High temperature coatings need to withstand extreme heat while also being able to protect against corrosion when temperatures drop.

Generic coating systems aren't able to handle the varying temperatures involved in these environments, which is where high temperature coatings come into play.

Silicone coatings

Silicones can withstand temperature from 370 °C to 538 °C or more.

Silicone acrylics are often marketed to withstand temperatures up to 260 °C, but they typically drop off in performance at around 204°C.

They also only provide limited film thickness, around 2-4 mils of dry film thickness (DFT).

By themselves, they're very limited in corrosion protection, which is why they work best as a cosmetic topcoat for other high temperature coatings.



Epoxy coatings

Epoxies are often used for assets in full immersion environments (e.g. underground pipelines).

Use of standard epoxies in extreme temperatures can lead to thermal degradation, cracking and ultimately premature failures.

However, epoxy coatings can be formulated in different ways that prevent these issues.

Special high-temp epoxy coatings

Fusion-bond epoxies (FBEs)

are used for underground pipelines that won't experience extreme heat conditions (around 60 °C).

Phenolic epoxies

can handle higher temperatures, around 150°C. They're also good for immersive environments and help solve corrosion under insulation issues.

Epoxy novolacs

are subset of phenolic epoxies have higher temperature and chemical resistance compared to regular epoxies, but are also less flexible and more brittle. That can be used up to 204 °C

Inorganic zinc coatings (IOZ)

IOZ coatings offer sacrificial cathodic protection to carbon steel assets and are often recommended where corrosion control is particularly important.

These coatings usually act as a primer and pair well with a top coat for additional protection.

However, moist environments can quickly destroy these coatings, resulting in corrosion under insulation (CUI) in certain scenarios.

Thermal spray coatings

Thermal spraying involves melting down different metals and spraying assets for added protection.

Metals can include aluminum, zinc, copper, stainless steel, ceramics and nickel.

These sprays are typically applied at a shop, although field sprays are also available.

Thermal spray aluminum

This is a popular thermal spray option as a high temperature barrier coating.

These types of sprays can prevent external stress corrosion cracking (ESCC) on stainless steel.

Note that thicker film overcoats are not recommended (anything above 1-2 mils) in conjunction with thermal spray aluminium.

Powder Coating Systems

Powder coatings

These consist of dry powders that have been ground into a fine dust.

Powder coatings are manufactured by mixing resins, pigments additives and curing agents, heating them up then allowing to cool, and finally grounding the material into an applicable dust consistency.

There are two primary types of powder coatings:

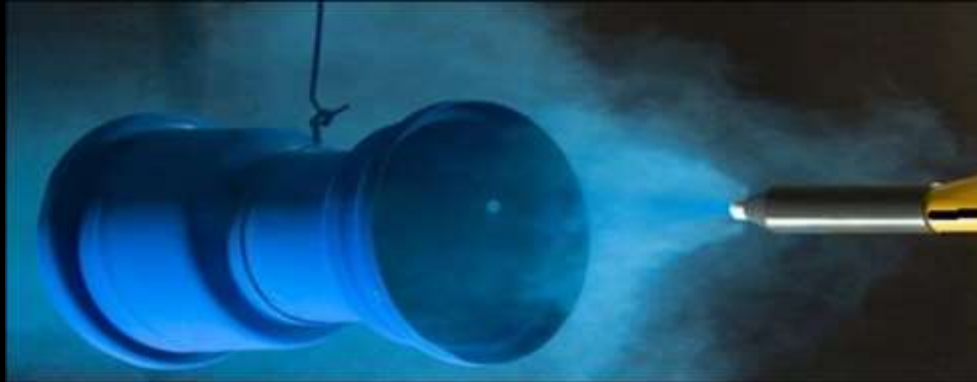
- thermoplastic
- thermoset



Thermoplastic powder coatings

These are functional coatings that provide a thick film while remaining flexible and tough. Thermoplastic coatings require no chemical curing.

These coatings can be applied using a dip, sprayer or thermal sprayer.



Thermoset powder coatings

are used for the majority of applications. They provide a thin layer of film that's both durable and decorative. These types of powders have a lower molecular weight than thermoplastic materials.

Thermoset materials can also crosslink with other substances and remain thermally stable. Thermoset materials can also be altered to provide specific desirable characteristics.

Powder coating advantages and disadvantages

Powder coatings are known for their high-performance protection, appealing aesthetics and relatively inexpensive costs.

They are corrosion resistant, flexible and have strong adhesion. Various textures and finishes are available on the market as well.

Pros and cons of powder coatings

Powder coatings have the following advantages:

- 100% solids (no solvent is used)
- Good edge application and retention
- Quick-curing times
- Can be applied to metal, wood or plastic
- Multiple curing options
- Minimal amount of overspray
- Good one-coat thickness with electrostatic spray
- Non-flammable

Disadvantages are:

- Difficult to coat inside surfaces
- Powder clumping
- Color changes can be time consuming and expensive
- Application usually limited to shops
- Powder suspensions in air may be explosive

Types of Metal Finishes

Metal finishing

involves treating the exterior of a metal product or component with a thin layer of augmenting material or removing material from the component's surface.

Metal finishes improve metal surfaces in a variety of ways, including:

- Improved durability
- Corrosion resistance
- Chemical resistance
- Electrical resistance
- Abrasion resistance
- Reducing friction
- Making a surface conductive
- Decorative appeal

There many different types of metal finishes that have a variety of effects on surfaces and substrates.

Electroplating

Electroplating, i.e., electrodeposition, passes an electric current through an electrolyte solution (basically a bath filled with the electrolyte or property you're trying to imbue upon the product).

Two electrodes are placed into the solution and hooked up to a battery source that connects an electrical circuit between the electrodes, electrolyte and battery.

Electricity flows through the circuit, breaking up the electrolyte which causes the metal atoms to form on one of the electrodes (which is the product you're ultimately trying to electroplate).

The electrolyte can consist of whatever type of plating the product needs. For example, a zinc plating (i.e. galvanization) will help prevent corrosion, while a gold plating provides an aesthetic appeal.

Plastics can also be electroplated on to products, and are used in a variety of applications. They're lighter, cheaper and never rust due to their inability to conduct electricity.

Rack plating and barrel plating

These are both popular forms of electroplating.

Rack plating

is most useful when a specification is complex and requires extra attention. Product components are affixed to metal racks and dipped into the solution and pulled out when complete.

Barrel plating

is most useful when looking for a low-cost, high-volume option. Barrel plating is the best option when parts are small and durable (i.e. fasteners, bolts, etc.), because parts are placed in a rotating barrel filled with the chosen electrolytic solution.

Electroless plating

This method is non-galvanic, meaning no electric current is involved in the plating process.

This process is also known as autocatalytic plating or conversion plating and no external power source is used.

Instead, the part is placed in a solution filled with nickel or copper, creating a catalytic reduction of solution that breaks up the material's ions.

Electroless plating

Electroless plating is commonly used in industries where corrosion resistance is required.

This plating method makes parts very hard and nonporous, increasing corrosion resistance.

Other benefits include:

- reduced friction
- increased strength
- uniform deposition

Thus, electroless plating is great for industries like oil & gas, food & beverage manufacturing, automotive and aerospace.

Any environment that's subject to harsh and/or corrosive environments is perfect for electroless plating.

Electrocoating

This involves the same principles as electroplating. An electric current and solution work together to coat a components substrate.

However, the solution contains electrically charged paint particulars (typically acrylics or epoxies) that create a primer over the substrate. The primer helps with adhesion when a material needs to be painted in the field or at a shop.

Cathodic epoxy e-coatings are setting the standard for corrosion resistance, although they require topcoat for UV resistance when components are exposed to sunlight.

E-coating is known for being a very low-cost-per-square-foot finishing option because of their ability to accommodate part complexity and volume.

They're also popular because of their ability to apply to almost any metal. However, other factors like equipment repair and maintenance should be considered.

Passivation

Passivation is a chemical process in which a material becomes passive, i.e., less likely to corrode. Parts are submerged in a solution of nitric or citric acid, removing corrosive particles.

Passivation reduces the amount of iron that can react with the environment (causing rust) and forms a protective shield around the metal without changing the physical appearance of the part.

Passivation can be implemented on a variety of materials including silicon, aluminum, ferrous materials, stainless steel and nickel.

Case hardening

Case hardening is the process of forming a hardened layer (or case) around a metal component that acts as a protective barrier.

Case hardening is an excellent option for components that are subject to abrasive and high pressure environments, but aren't subject to corrosive environments. Note that case hardened materials cannot be welded.

Types of case hardening

There are several types of case hardening options including:

- Carburizing
- Nitriding
- Cyaniding
- Flame hardening

Carburizing

is a process in which iron or steel absorb carbon while the metal is heated in the presence of a carbon-bearing material, such as charcoal or carbon monoxide.

Nitriding

is a process that diffuses nitrogen into the surface of a metal to create the case-hardened surface. These processes are most commonly used on low-carbon, low-alloy steels. They are also used on medium and high-carbon steels, titanium, aluminum and molybdenum.

Other types

Cyaniding

incorporates both nitrogen and carbon into the protective casing by dipping the component into a carburizing bath that contains cyanide.

Flame hardening

involves heating a material with oxyacetylene and quenching it with water.

Each process has its pros and cons, so consult an industry professional before deciding what's right for the application.

Powder coating

Most industrial coatings come in liquid form, but powder coatings are a powder-based alternative.

Powder coatings provide greater thickness than liquid coatings, and different pigments, curatives, level agents, flow modifiers and other additives can be added to the powder to provide the desired protection and aesthetic appeal.

Once the coating is selected, electrostatic spray deposition (ESD) used by coating professionals to apply the coat to the metal substrate.

A spray gun is typically used to apply the coating, and then the components enter a curing oven that heats the components, causing a chemical reaction that binds the coating and substrate.

Electropolishing

Electropolishing is the exact opposite of electroplating. Rather than depositing metal ions onto the component's surface, electropolishing remove the metal ions from the substrate.

The material is immersed in an electrolytic bath, with an electrical current being applied. The material becomes the anode, with ions flowing from it, removing defects, rust, etc.

The end result is a surface that's polished, smoothed and removed of bumps and pocks. Even at a microscopic level, peaks and valleys will be removed. This is an excellent option for materials that need to have a clean and pristine look.



Buff polishing

Buff polishing is an alternative to electropolishing that doesn't involve the electrochemical process.

Buff polishing is similar to buffing a car, where a machine equipped with a cloth wheel polishes and buffs the surface of the metal.

The result is a glossy and shiny finish that's ideal for metallic components that need a high quality look.



Brushed metal

Brushed metal is similar to buff polishing in that it effectively removes metal ions from the metallic surface.

With brush polishing, the metal is brushed in a unidirectional manner creating a specific aesthetical finish. It is often found on stainless steel, aluminum and nickel, with the end result being a distinctive, brushed polish finish with parallel lines.

Metal grinding

Again, metal grinding is a metal finish that reduces a component by grinding away metal ions.

Metal grinding involves a machine that uses abrasion and friction to smooth out a metal surface.

Handheld power tools, grindstones, grinding machines, bench grinders and wheel grinders are all options for various applications.

Metal grinding is best suited for hard materials (e.g. hardened steel) that required shallow cuts.

Abrasive blasting

Abrasive blasting is a cost effective solution that applies to both facility exteriors and metal components. It combines surfacing cleaning and finishing into one process.

With abrasive blasting, a high-pressure stream of abrasive media (material) is blasted against a surface to remove debris, alter shape and texture and provide a smooth finish.

Abrasive blasting can also act as surface preparation for coatings and plating to increase durability.

Blasting system

A typical blasting system is made of an air compressor that adjusts pressure and volume, moisture separator to reduce humidity, water-assisted system for dust suppression, air supply line, blast machine to store media, remote controls and a hose and nozzle.

Abrasive blasting is a serious cost- and time-saving option for manufacturers and facility owners alike.

Abrasive blasting can be performed with a variety of media including sand, aluminium, plastic, glass, corn cob, steel grit, walnut shell, silicon carbide and steel shot.

Painting with Zinc-rich Primers

Zinc-rich primers

Zinc-rich primers are an excellent form of corrosion protection for facility owners and paint contractors to consider.

Zinc-rich primers are part of a group of coatings known as galvanic protection systems. Galvanic systems are also known “sacrificial” systems because the coating used corrodes instead of the integral structure or component.

Zinc is more electrically active than steel and other structural materials.

When the corrosion cell is formed (whenever the structure interacts with moisture, i.e., the electrolyte), the zinc primer acts as the sacrificial anode, protecting the structural material.

Magnesium, aluminium and zinc can all be used as galvanic coating systems because they’re all active metals.

Advantages and disadvantages of zinc-rich primers

Zinc-rich primers, and all galvanic systems, are perfect primers for steel assets in highly corrosive environments.

Zinc is particularly useful in marine, tanker and underground applications, i.e., immersive environments. Any environment exposed to constant moisture will benefit from a zinc primer.

The main drawback to the use of zinc primers is that they are consumed during the process of providing protection, thus have a short lifespan.

Types of zinc primers

Zinc primers come in two basic forms:

- Inorganic
- organic

Inorganic zinc coatings:

- Can be used without a topcoat in mild atmospheric environments
- Only use silicate as a binder, typically
- Contain more zinc and provide better galvanic protection
- Require abrasive blasting or near-white blasting to be long-lasting and effective
- Are usually applied in shops through a spraying application

Organic zinc coatings:

- Must be top-coated to provide long-lasting protection
- Use a wide variety of binders from epoxy to alkyd
- Easier to apply
- Typically applied in the field via a brush or roller

Organic zinc coatings usually act as maintenance coatings for inorganic coatings due to their relative ease of application

Industry Standards for Steel Surface Preparation

Surface Prep

Steel surfaces need to be treated to prevent corrosion over the lifetime of the structure. Surface preparation is the preliminary step to the process. When defects are removed and the surface is properly cleaned, coating adhesion and performance are improved.

Steel surface prep removes the physical defects and contaminants prior to applying the coating. For steel structures and components this process usually requires a pre-cleaning, with some form of blasting or grinding process.

Issues which require pre-cleaning

Pre-cleaning will adequately remove loose and soluble surface contaminants.

Pre-cleaning should be considered when any of the following issues are present:

- Surface is contaminated with grease or oil
- Surface is in a polluted environment
- Surface is near a high-saline environment
- Other forms of contaminants are visible on the surface

Abrasive blasting

Abrasive blasting is one of the quickest, most cost-effective means of surface preparation available for large areas of steel.

Abrasive blast cleaning is perfect for removing mill scale, rust, old paint and similar contaminants, however, it's not effective for removing oil, grease or chemicals. Be sure to remove these types of contaminants prior to pre-cleaning. If there's grease on the surface during abrasive blasting, the grease will tend to spread, rather than being removed.

Abrasive blasting considerations:

- **Abrasive particle size:** Smaller particle size results in a smaller profile
- **Abrasive velocity:** Faster velocity results in faster cleaning rates
- **Abrasive density:** Greater density is needed for thicker contaminant removal
- **Abrasive hardness:** Harder, tougher contaminants require harder abrasives

Wet abrasive blasting

Water cleaning can be used for both pre-cleaning and blasting.

- **Low-pressure** - used for pre-cleaning to handle water-soluble contaminants
- **High-pressure blasting and water jetting** - used for maintenance cleaning

Wet abrasive blasting is the preferred method when dust is a major concern.

Wet abrasive blasting is preferable, when a significant amount of coating must be removed.

However, *flash rust* can occur with wet blasting due to the water used. Applying a rust preventer can mitigate this issue.

Hand tool cleaning

Hand tool cleaning becomes necessary when areas of a job are inaccessible to power tools, such as small crevices, etc.

Wire brushes, sandpaper, scrapers, abrasive pads, chisels and chipping hammers are all hand tools that help remove contaminants.

Power tool cleaning

While hand tool cleaning is an option for steel surface preparation, power tool cleaning is more efficient when hand tools aren't required to get at the tighter spaces.

Cleaning up to near-white metal (SSPC 10) can be achieved through power tool cleaning.

There are three types of power tools used for surface cleaning:

- Impact cleaning tools
- Rotary cleaning tools
- Rotary-impact cleaning tools

Impact cleaning tools

These use an internal piston to drive a hardened edge against surfaces. These tools scrape and chip away rust and paint.

However, impact cleaning tools also run the risk of damaging the metal surface and causing more work.



Rotary cleaning tools

These consist of an abrasive material that spins on a disk at high velocity.

These tools effectively clean surface quickly, but they also leave grease and oil behind, requiring solvent pre-cleaning.



Rotary-impact cleaning tools

These utilize both impact and rotary methods of cleaning.

This includes: rotary hammers, rotary flaps (image) and cutter bundles.

Surface preparation standards

Surface preparation and cleaning can involve dirt, soil, oil, grease, chemicals, mill scale, rust paint and various other defects.

Any combination of these defects can affect the painted surface.

SSPC and NACE have developed industry standards for surface preparation that are described in the following pages.

SSPC-SP 1

Solvent Cleaning

Removal of all visible oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam.

SSPC-SP 2

Hand Tool Cleaning

Removal of loose rust, loose mill scale, and loose paint, by hand chipping, scraping, sanding, and wire brushing.

SSPC-SP 3

Power Tool Cleaning

Removal of all loose rust, loose mill scale, and loose paint, by power tool chipping, descaling, sanding, wire brushing, and grinding.

SSPC-SP 5 (or NACE #1)

White Metal Blast Cleaning

Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning by wheel or nozzle (dry or wet) using sand, grit or shot.

The is used for very corrosive atmospheres where the high cost of cleaning is warranted.

SSPC-SP 5 (WAB) (or NACE WAB1)

White Metal (Wet Abrasive Blast) Cleaning

This involves the same level of cleanliness as SSPC-SP 5/NACE #1, but is achieved by the use of wet abrasive blast cleaning.

Flash rust is a potential issue with this cleaning method. The degree of flash rust which is permissible immediately prior to the coating application must be specified.

SSPC-SP 6 (or NACE #3)

Commercial Blast Cleaning

Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning.

Staining is permitted on no more than 33% of each 9 in² (0.005 m²) area of the cleaned surface.

For conditions where a thoroughly cleaned surface is required.

SSPC-SP 6 (WAB) (or NACE WAB3)

Commercial Wet Abrasive Blast Cleaning

Same level of cleanliness as SSPC-SP 6/NACE #3, but achieved by wet abrasive blast cleaning.

The level of flash rust which is permissible immediately prior to the coating application must be specified.

SSPC-SP 7 (or NACE #4)

Brush-Off Blast Cleaning

This involves the removal of all loose contaminants while uniformly roughening the surface. (A tightly-adhered residue consisting of mill scale, rust, and coatings may tend to remain after the cleaning is completed.)

SSPC-SP 7 (WAB) (or NACEWAB 4)

Brush-Off Wet Abrasive Blast Cleaning

Same level of cleanliness as SSPC-SP 7/NACE No.4, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.

SSPC-SP 8

Pickling

This standard involves the complete removal of rust and mill scale by use of acid pickling, duplex pickling, or electrolytic pickling methods.

SSPC-SP 10 (or NACE #2)

Near-White Blast Cleaning

Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning. Staining is permitted on no more than 5% of each 9 in² (0.005 m²) area of the cleaned surface.

This method is used for high humidity, chemical atmosphere, marine, or other corrosive environments.

SSPC-SP 10 (WAB) (or NACE WAB2)

Near-White Metal Wet Abrasive Blast Cleaning

Same level of cleanliness as SSPC-SP 10 or NACE #2, but achieved by wet abrasive blast cleaning.

The level of flash rust permissible immediately prior to the coating application must be specified.

SSPC-SP 11

Power Tool Cleaning to Bare Metal

Complete removal of all visible oil, grease, coatings, rust, corrosion products mill scale, and other foreign matter by power tools, with resultant minimum surface profile of 1 mil (25.4 μm).

Trace amounts of coating and corrosion products may remain in the bottom of pits if the substrate was pitted prior to cleaning.

SSPC-SP 14 (or NACE #8)

Industrial Blast Cleaning

Between SP 7 (brush-off) and SP 6 (commercial). The intent is to remove as much coating as possible.

Tightly adhering contaminants can remain on no more than 10% of each 9 in² (0.005 m²) area of the cleaned surface.

SSPC-SP 14 (WAB) (or NACE WAB8)

Industrial Wet Abrasive Blast Cleaning

Same level of cleanliness as SSPC-SP 14/NACE No. 8, but achieved by wet abrasive blast cleaning.

Level of flash rust permissible immediately prior to coating application must be specified.

SSPC-SP 15

Commercial Grade Power Tool Cleaning

Between SP 3 and SP 11. This method involves the complete removal of all visible oil, grease, dirt, rust, coating, mill scale, corrosion products and other foreign matter by power tools, with resultant minimum surface profile of 1 mil.

Random staining is limited to no more than 33 percent of each 9 in² (0.005 m²) of surface.

Trace amounts of coating and corrosion products may remain in the bottom of pits if the substrate was pitted prior to cleaning

SSPC-SP 16

Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals

Requirements for removing loose contaminants and coating from coated and uncoated galvanized steel, stainless steels, and non-ferrous metals.

Cleaned surface is free of all visible oil, grease, dirt, dust, metal oxides (corrosion products), and other foreign matter Requires a minimum 0.75 -mil (19- μ m) profile on bare metal substrate.

SSPC-SP WJ-1 (or NACE WJ-1)

Waterjet Cleaning of Metals–Clean to Bare Substrate

When viewed without magnification, the metal surface shall have a matte (dull, mottled) finish and shall be free of all visible oil, grease, dirt, rust and other corrosion products, previous coatings, mill scale, and foreign matter

SSPC-SP WJ-2 (or NACE WJ-2)

Waterjet Cleaning of Metals—Very Thorough Cleaning

When viewed without magnification, the metal surface shall have a matte (dull, mottled) finish and shall be free of all visible oil, grease, dirt, rust, and other corrosion products except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter.

The staining or tightly adherent matter shall be limited to no more than 5 percent of each 9 in² (0.005 m²) area of the cleaned surface.

SSPC-SP WJ-3 (or NACE WJ-3)

Waterjet Cleaning of Metals—Through Cleaning

When viewed without magnification, the metal surface shall have a matte (dull, mottled) finish and shall be free of all visible oil, grease, dirt, rust, and other corrosion products except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter.

The staining or tightly adherent matter shall be limited to no more than 5 percent of each 9 in² (0.005 m²) area of the cleaned surface.

SSPC-SP WJ-4 (or NACE WJ-4)

Waterjet Cleaning of Metals–Light Cleaning

When viewed without magnification, the metal surface shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating.

Any residual material shall be tightly adhered to the metal substrate and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter.

SSPC-PA 17

Conformance to Profile/Surface Roughness/Peak Count Requirements

A procedure suitable for shop or field use for determining compliance with specified profile ranges on a steel substrate.

Surface prep as important as the coating system used

Surface preparation is just as important as the coating system selected to protect the painted surfaces.

Finding the right surface preparation protocol is critical to establishing a long-lasting, and effective coating system for the coated structure.

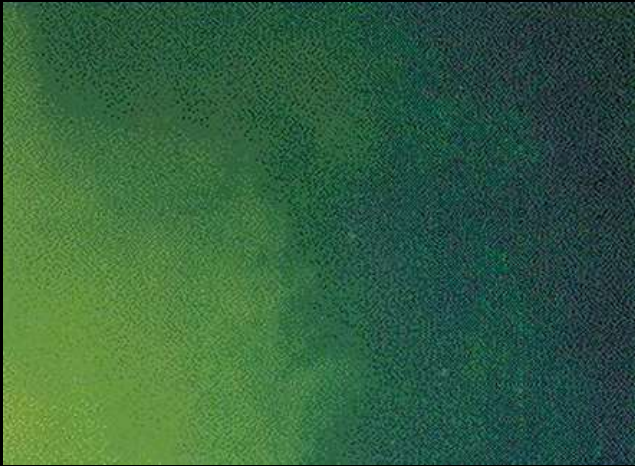
Types of Paint Application Defects



Bleaching

This is the migrating of pigment caused by the solvent in the new topcoat dissolving soluble dyes or pigments in the original finish, allowing them to seep into and discolor the newly applied topcoat. Show up as a red or yellow discoloration on the topcoat.

This is caused by: spot repairs being made with polyester putties (such as in automobile repairs), too much Peroxide in the preparation of polyester putties, reactions with the subsequent layers of paint, migration of pigment from previous layers caused by the solvent of the final layer.



Blooming

Lack of gloss, dullness caused by the quick evaporation of the thinner. This lowers the substrate temperature below the dew point, causing moisture in the air to condense in or on the paint film.

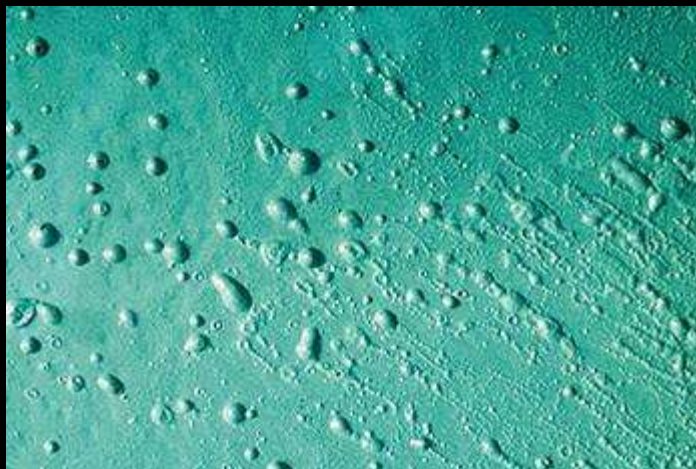
This is caused by: relative humidity being too high, inadequate solvents (not moisture repellent) or solvents evaporating too quickly, a lack of air circulating during the drying process at room temperature, incorrect preparation of the paint or defective ingredients, too thick of an applied layer.



Pinholes (solvent bubbles)

Small surface spots produced by the breaking through and deformation of the paint surface.

This is caused by the evaporation of the solvent trapped after the outside layer of paint is dry. Additional causes are: solvents evaporating too quickly, high ambient temperatures during application, the coat applied too heavily.



Blisters and air bubbles

Small blisters are caused by the deformation of the painted surface. This is due to trapped moist air escaping after the outside layer of paint has dried.

This can be also be caused by the paint being shaken too much prior to application, or due to water or condensation on the surface to be painted due to temperature changes.

Water in the compressed air or incorrect regulation of the spray equipment will cause this as well..



Sagging

Sagging or running of the paint occurs when applied to vertical surfaces.

It can be caused by too low of a viscosity due to an excess of solvent, or due to too thick of a layer being applied, especially when brushing.

Additional causes are: the use of heavy solvents, low ambient temperature, low air pressure in the spray equipment, flowrate set too high or spraying an incorrect distance from the surface, or evaporation time between coats too short.



Crazing

This is a folding of the painted surface, caused during the spraying or drying process.

It is caused by: a reaction due to incompatibility between the base coats, insufficient drying or hardening of the previous coats, the use of an incorrect solvent, or the topcoat being applied too heavy or too wet.



Overspray

Paint particles that reach dry the painted surface resembling a fine dust finish.

This is caused by: too fast drying solvents, high ambient temperatures, high application pressure, low flowrate of paint, distance too far from the spray gun to the substrate, high viscosity of application, inadequate adjustment of spray equipment.

Over-extended drying time

With this condition, the paint film is soft to the touch, and will fingerprint or water spot within hours/days following the application.

This is caused by: low ambient temperature or a high relative humidity, the use of solvents which are slow to evaporate, too heavy of a coat. Use of a paint which is old. incorrect mixing ratio in the hardener.



Lack of adhesion

A loss of adhesion or separation of the paint film from the substrate.

This is caused by: incorrect preparation of the surface leaving grease or moisture, previous layers in bad conditions, inappropriate sanding, wrong choice in the paint system.



Water marks

Circles with raised edges or whitish spots resembling the various shapes of water droplets appear on the surface of the paint film.

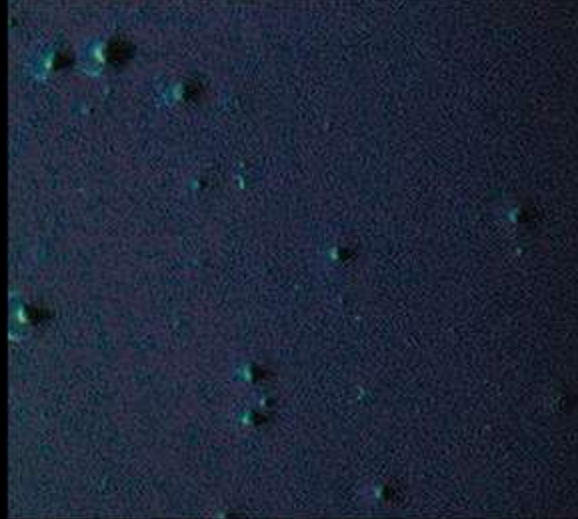
This is caused by: allowing water to come into contact with a finish that has not thoroughly dried or cured, exposure of the painted surface to a humid atmosphere, water splashes or drops of rain on the painted surface.



Sanding marks

These are visible lines or marks in the paint film, that follow the direction of the sanding process.

This is caused by: insufficient dry/cure of undercoats before sanding and top coating, incorrect selection of the sanding orbit, inappropriate choice of grit sandpaper, paint layer too thin to cover and fill the sanding marks, inadequate preparation of previous layers of paint.



Dust and dirt

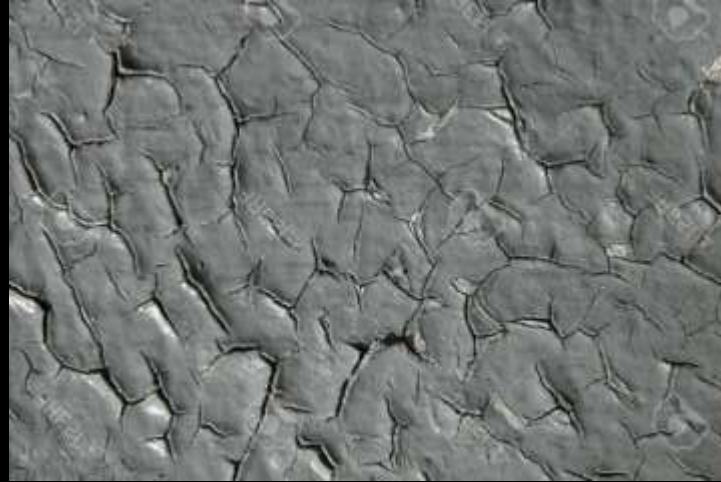
This occurs when foreign particles become embedded in the paint film.

This is caused by: inadequate cleaning of the surface to be painted, dirty spraying environment, paint becoming contaminated with particles of dust and dirt, compressed air contaminated or dirty spray equipment, airborne particulate matter in the painting environment.

Opacity

This is when the original finish or undercoat is visible through the topcoat.

It is caused by: insufficient thickness or number of color coats applied, substrate not uniform in color, color over-thinned or over-reduced, use of pigments with poor hiding power.



Cracking

This is when there is a total cracking of the painted surface during the application or when drying.

Causes of this condition are: incorrect preparation of the paint, previous layers that are not dry enough, excessive film thickness layer, paint being applied too heavily.



Craters or silicones

Small circular, crater-like openings that appear during or shortly after the spray application. Caused by a lack of wetness of the surface, normally contaminated with oil, wax, silicone, grease, etc...

This occurs when there is: a poor cleaning of the surfaces, environmental contamination (mainly by silicones), water or oil present in the compressed air, dirty spray guns or equipment.



Orange peeling or unevenness

With this defect, the surface shows an uneven texture due to lack of stretching or levelling, that resembles the skin of an orange.

This occurs due to: too high of a viscosity of application, incorrect adjustment of the spray gun, excessive flowrate of the paint and low atomization pressure, solvents evaporating too quickly, base layers insufficiently dry, excessive paint used when spraying or incorrect position when applying the paint, (too close), insufficient preparation or sanding of the previous coats.

Pigment separation

Separation of the pigments causing stains, stretch marks and creating different layers of uneven color tones within the coat.

This occurs due to: incorrect solvent being used for the type of paint, excessive dilution or poor mixing of the paint, a paint coat thickness being applied too heavily.



Sinkage

These are defects caused when the repaired area, normally with polyester putty, becomes visible within hours, days or weeks after the repair is completed.

This is caused by: incorrect preparation and use of the polyester putty, poor coverage of the repaired area due to incorrectly adjusted spray equipment or poor preparation of substrate, poor preparation of the patch edges or the area to be repaired.

Bibliography

- 1) SSPC: The Society for Protective Coatings
- 2) Wikipedia
- 3) www.bernardoecenarro.com
- 4) www.basf.com

This concludes our course on “A Guide to Industrial Coatings and Metal Finishes”.
You may now proceed to the final exam.

Thank you for taking this Flashcard course!

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