Powder Coating
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Beneath the Surface: Understanding and Preventing Powder Coating Defects

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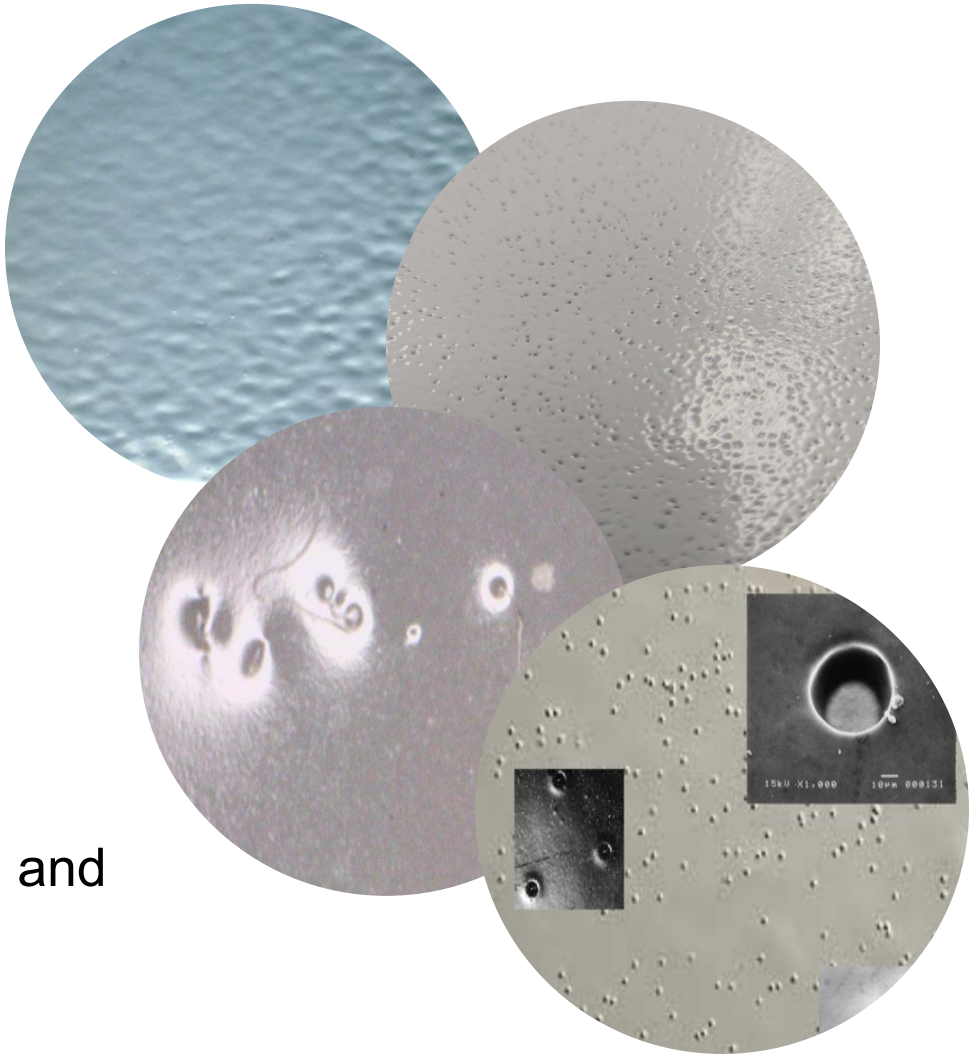
Agenda

- Introduction
- Identifying and Understanding Defects
  - Lint and bits
  - Craters and fisheyes
  - Pinholes
  - Inconsistent film build and orange peel
  - Field failures (adhesion, corrosion, color fade, and gloss reduction)
- General Practice for Avoiding Defects



Identifying and Understanding Defects

Lint and Bits: Overview

Lint and bits consist of foreign materials in the powder coating that appear as protrusions in the cured film

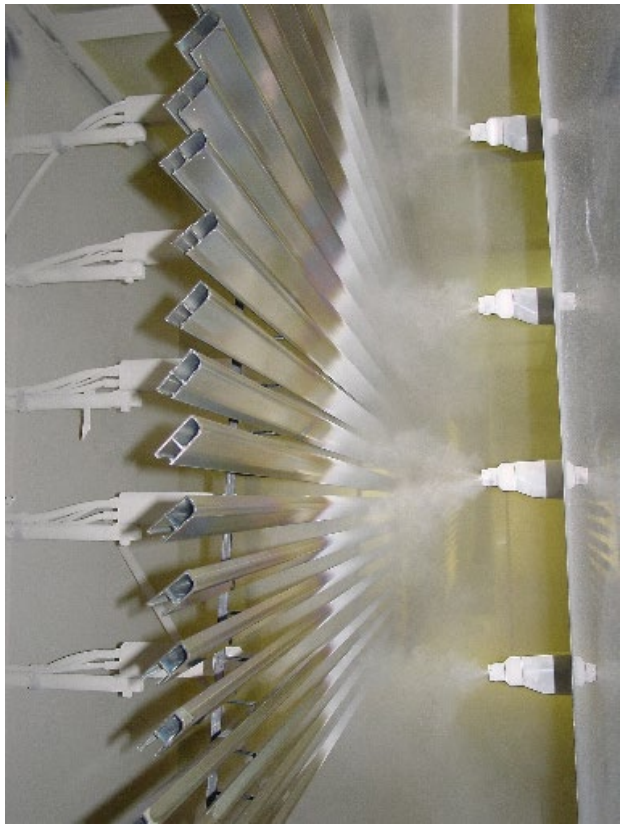
- Bits: Oversized particles or agglomerated powder
- Dirt: Foreign particles
- Lint: Fibrous contaminants
- Most often not noticed until after the powder has cured and emerged from the oven
- Parts containing lint or bits must be either scrapped or completely reprocessed; these materials cannot be removed from the cured coating

Lint and Bits: Typical Causes Related to *Raw Materials or Powder Coating Manufacturing*

- Use of sub-optimal raw materials in powder coating manufacturing
  - Resins that contain gel particles
  - Filler pigments that contain high-particle-size materials that should be “out of spec”
  - Agglomeration of particles in additives, especially flow agents
- Gel particles created as the powder coating is extruded
- Contamination from purge compound in the extruder
- Use of low-quality wiping rags, which fray or deposit fibers on equipment
- Environmental dirt due to poor housekeeping, dirty containers, or torn boxes/bags

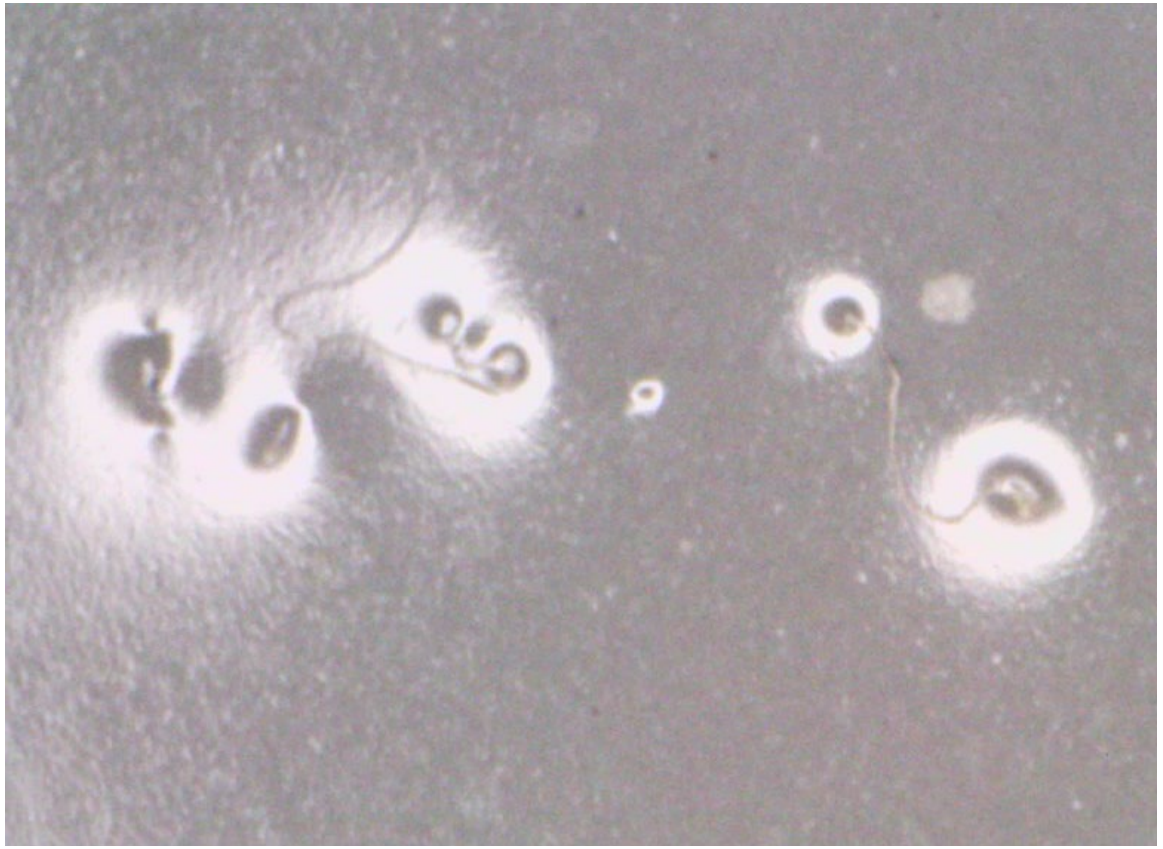
Established powder coating manufacturers have tight quality control processes and take measures to ensure oversized or foreign particles do not contaminate the finished powder.

Lint and Bits: Typical Causes Related to *Powder Coating Application Process*



- Compressed air lines: If corroding, they can send rust particles into the application air, which will be deposited in the powder coating
  - Air filters can minimize this issue, but it is best to eliminate it at the source
- Ovens, racks, and hooks: Residues that have been baked onto ovens, racks, and hooks can come loose and fall into the coating during curing
  - Ensure ovens, racks, and hooks are cleaned of residue
- Substrate: Can contain weld spatter or environmental dirt and appear as “buried” particles
  - Purchase substrate from a reputable supplier with tight quality control
  - Inspect substrates for foreign materials
  - Adhere to the appropriate pretreatment protocol and ensure rinses are clean

Lint and Bits: Particle Identification



- Observation under simple magnification to determine size, color, and shape
  - Coiled filaments are most often associated with lint from wiping rags
  - Irregular brown or dark yellow lumps are typically charred resin or binder from the powder coating
  - Lighter color nodular defects are characteristic of agglomerated particles in raw materials or large-particle-size fillers
- Suspected ferrous particles (i.e., rust) can be extracted and tested for magnetism
- If the above is unsuccessful, contracting with a third-party lab with advanced capabilities may provide answers

Craters and Fisheyes: Overview

Craters and fisheyes both appear as a dimple (crater) in the surface of the film, but fisheyes will have a visible particle at the base of the crater

- Vary in depth, from shallow to all the way down to the substrate
- Craters result from contaminants that have low surface tension and limited miscibility with the coating
- The total system will drive toward a minimum surface energy, forcing the molten powder coating to move away from the contaminant (lower surface energy) to cover areas of higher surface energy

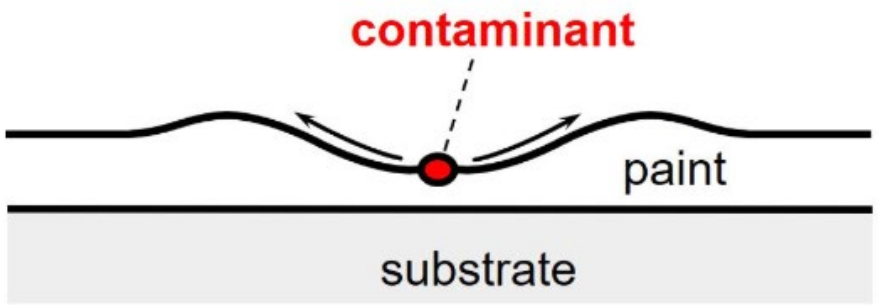


Image courtesy of: https://www.ulprospector.com/knowledge/451/pc-coating-film-defects/

Craters and Fisheyes: Common Causes

- Craters are always caused by contaminants with lower surface tension than the powder coating
- Common culprits include:
  - Cross-contamination from other powder coatings
  - Contaminants within the powder coating
  - Contamination from liquid coatings or cleaning materials
  - Processing oils from application equipment or handling of the substrate
  - Silicone or other low-surface-tension materials used in personal care products like lotions and antiperspirants

Craters and Fisheyes: Troubleshooting

- Craters are among the most difficult issues to identify a root cause for, as this type of contamination can come from many sources
- Try to establish a pattern with the occurrence of the defects, as this may give insight into the root cause. For example:
  - Craters only appear after Powder X is run, or when Powder Y is run
  - More craters are typically observed on one portion of the substrate, such as over welds or certain vertical edges
  - Craters only occur when certain equipment is used
- Ensure parts are properly cleaned and pre-treatment is in good working order
- Systematically change out equipment, such as air filters and hoses, to determine if there is contamination in the air supply
- Clean all equipment thoroughly (very thoroughly)

Pinholes: Overview

Pinholes appear as very small holes in the surface of the coating and are typically more defined with sharper edges than craters

- If the pinholes are very small and dense, the coating may appear to be low in gloss. Observation under magnification may uncover the presence of pinholes, however
- Typically caused by degassing or a volatile material being released from the powder coating during the curing process

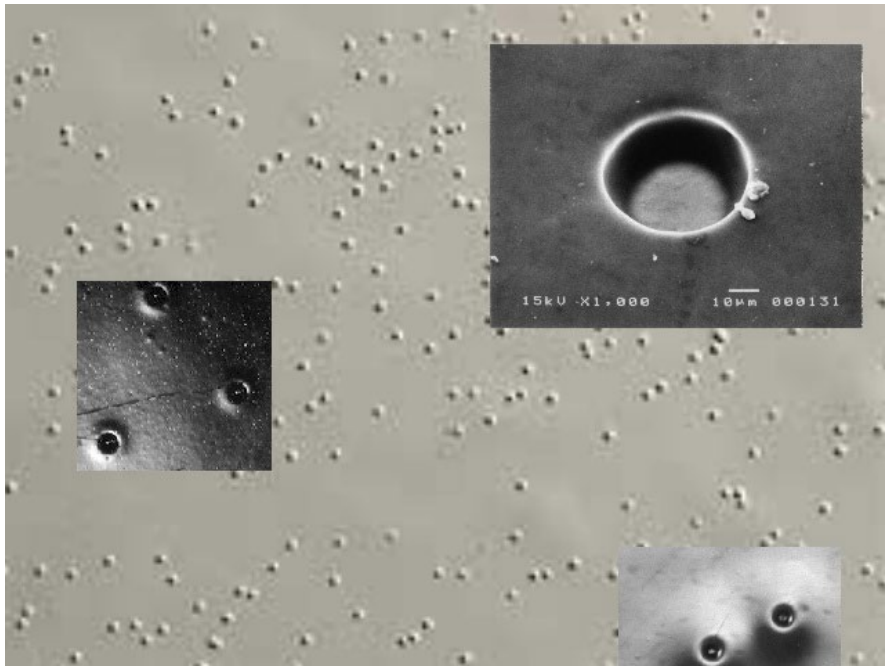
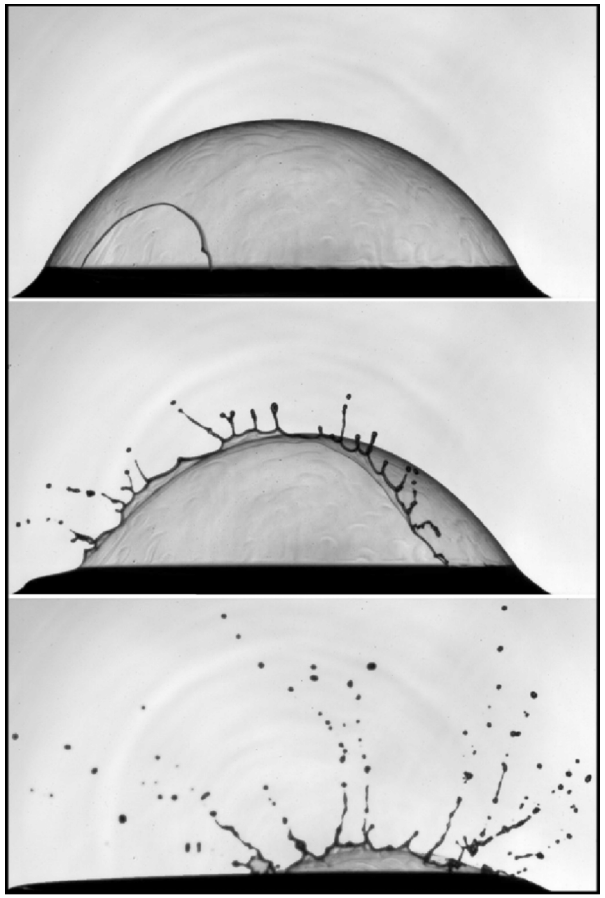


Image courtesy of: https://www.korozyonuzmani.com/en/boya-hatalari-2-pinhole-igne-deligi/

Curing Basics and Pinhole Formation



- Thermoset powder coatings contain binder consisting of a resin (polymer) and a crosslinker, which each contain reactive (functional) groups
- During the curing stage, the powder coating first becomes molten and then crosslinks, causing the molten powder to transition to a solid state
  - Crosslinking (curing) is the process of chemical bonds being formed between the resin and the crosslinker, resulting in the binder essentially becoming one molecule of infinite molecular weight
- When the powder coating is molten, volatile compounds within the coating release from the surface of the coating like air escaping from water
- Pinholes are created when volatile compounds escape from the coating, but the coating is no longer molten enough to flow. The result is a void in the surface of the coating.

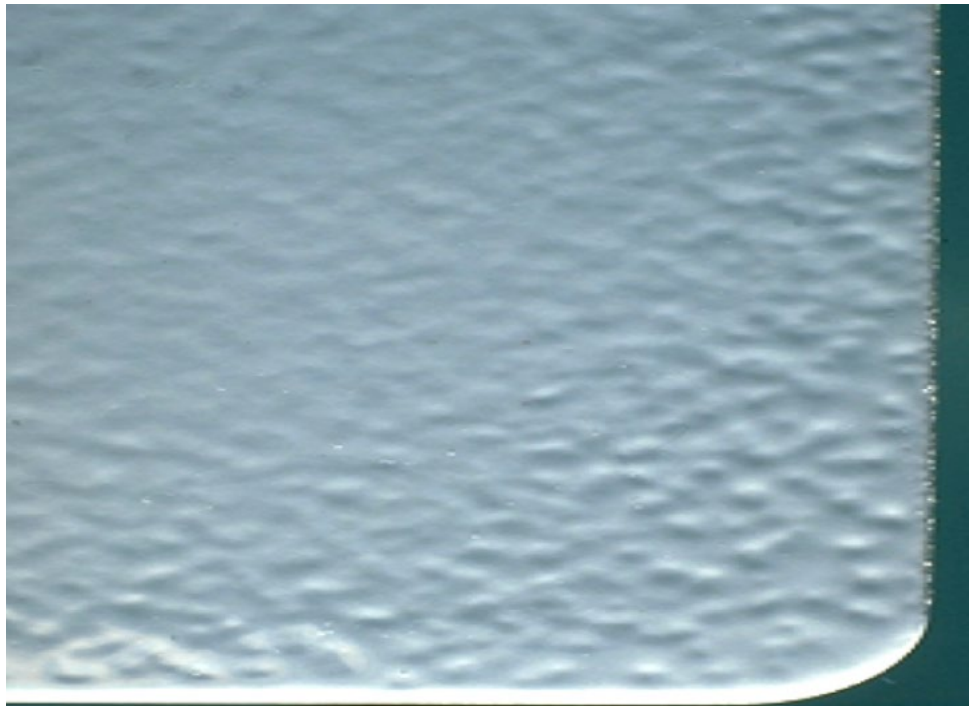
Image courtesy of:
https://www.researchgate.net/figure/Spontaneous-bursting-of-a-bubble-at-the-surface-of-a-water-bulk-Convection-cells-can-be_fig10_253723845

Pinholes: Common Causes

- Film thickness is too high: This creates a longer path for the volatile material to escape the film before curing occurs
  - Reducing film build will resolve this issue
  - Common issue with “TGIC-Free” (HAA) formulas
- Powder coating moisture content is too high: Water requires more time at a given temperature than most volatile materials
  - Follow proper storage recommendations for the powder coating
  - Ensure the air dryer is working properly to reduce water content
- Outgassing of the substrate materials: Some substrates, such as blasted, cast, or galvanized parts, contain materials that will evaporate when heated
  - Determine if the substrates being used must be pre-baked prior to applying the powder coating

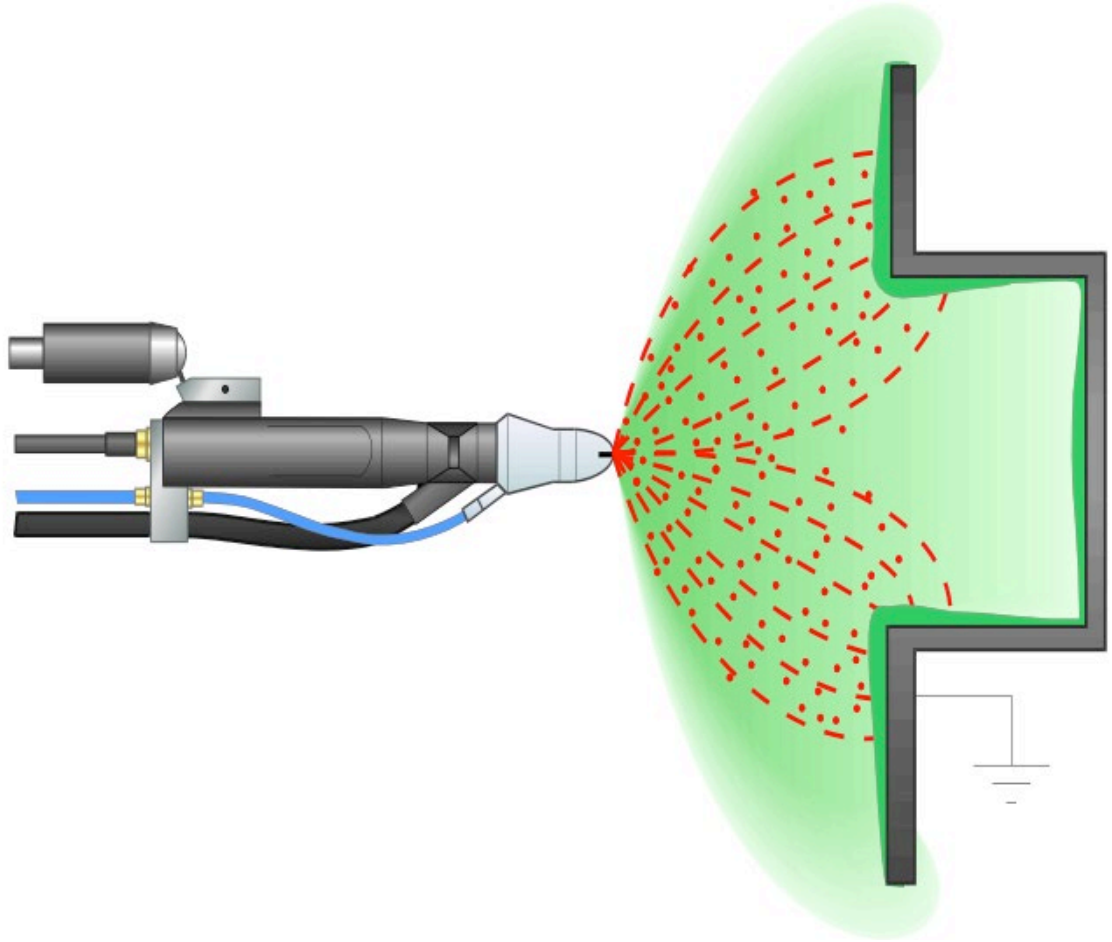
Inconsistent Film Build and Orange Peel: Overview

- Inconsistent film build can be identified using a thickness gauge or often through simple observation:
  - More (and tighter) orange peel in the finished coating, often on certain areas of the coated part
  - Insufficient hiding
- Inconsistent film build and orange peel are often related, with lower film build typically exhibiting a higher amount of orange peel



Causes of Inconsistent Film Build and Orange Peel

- Improper spray gun settings or technique
- Faraday cage effect
- Poor grounding
- Back ionization
- Surging and/or spitting
- Impact fusion



Field Issues: Overview

Field issues are among the most frustrating to deal with, since they are almost always noticed by an end user (customer) well after the application process is complete

- It is essential to keep good records of the application process to determine the root causes of field failures
- The three most common field failures include:
  - Adhesion/chipping failure
  - Premature corrosion failure
  - Color fading and/or gloss loss

Avoiding Adhesion/Chipping Failures

- Ensure batch-to-batch substrate consistency
  - Inspect for oils, corrosion, and other contaminants
  - Request that vendors certify the quality of substrates

- Ensure pretreatment chemicals are suitable for the substrates; mixed-metal parts can be especially difficult
- Ensure pretreatment system is in-spec for temperature, concentration, pH, TDS (total dissolved solids), exposure time, etc
- Ensure pretreatment rinses are clean
- Confirm coatings are adequately cured, check ovens, and conduct random solvent tests
- Avoid excessively thick coatings
- Recoat can cause issues; confirm recoat adhesion in an inconspicuous spot

Avoiding Premature Corrosion

- Properly manage substrate quality and pretreatment (see previous slide)
- Apply powder to sufficient film build; must be at or above minimum thickness recommended on product's Technical Data Sheet (TDS)
  - Edge coverage can be especially difficult but is critical to achieving expected corrosion resistance
- Ensure the powder coating being used is suitable for the required performance in the field
  - Understand the requirements in the field and consult with powder coating suppliers
  - Extreme environments may require the use of a primer and topcoat
- Confirm coatings are adequately cured, check ovens, and conduct random solvent tests

Avoiding Color Fading and/or Gloss Loss

- Color fading and gloss loss over time in the field are caused by UV degradation and other environmental factors
- All coatings will eventually fade and lose gloss when exposed to the sun. The key is to understand the end-use requirement and use the correct powder coating
  - Discuss the end-use requirements with the customer
  - Consult with powder coating suppliers to select the correct coating for the job
  - Manage expectations with the customer
- Under-cured powder coating can also cause premature fading or gloss loss
  - Confirm coatings are adequately cured, check ovens, and conduct random solvent tests

General Practice for Avoiding Defects

General Practice to Avoid Defects

The best method for avoiding defects is to take a proactive approach to your finishing operation

- Establish relevant and comprehensive specifications
  - Customer requirements
  - Substrates
  - Powder coatings
  - Cleaning and pretreatment process
  - Application and curing equipment
- Maintain a controlled process
  - Environmental
  - Powder coating storage
  - Pretreatment
  - Application and curing
- Continuous improvement: Keep good documentation and address systemic issues
- Hiring and training: Hire good people and train them well and regularly

Thank you! Questions?

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Thank you!

Additional Questions?

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