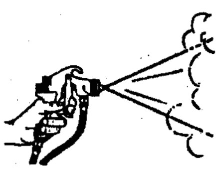
PAC²E

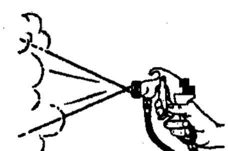
Painting and Coating Compliance Enhancement

Reference Guide



Iowa Waste Reduction Center

University of Northern Iowa



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PAC^{2}E Reference Guide Development

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LIST OF ATTACHMENTS

Section 1.0

Pretreatment Quality

Introduction to Pretreatment

The painting/coating process begins with pretreatment of the part

- **Pretreatment - the preparation of a part prior to painting or powder coating**
  - **Surface preparation is directly related to coating performance**
  - **Improves adhesion and corrosion resistance**
  - **Key components**
    - **Cleaning**
    - **Phosphatizing (chemical etching for nonferrous metals)**
    - **Rinsing**
- **Improper/inadequate pretreatment results in**
  - **Poor coating performance**
  - **Excessive rework**
    - **Inadequate surface preparation before coating is the leading cause of rejects in the finishing industry[13]**
  - **Excessive chemical and water consumption rates**
  - **Poor energy efficiency**
  - **Excessive wastewater discharges and sludge generation rates**

All of the above contribute to excessive costs and inferior coating performance

Introduction to Pretreatment

Need to consider the following factors when developing a effective pretreatment system

- ✗ **Quality requirements (e.g., degree of cleaning needed, salt spray performance requirements)**
- ✗ **Types and quantities of soils**
  - ➢ **Perform a soil audit**
- ✗ **Type and condition of substrates**
  - ➢ **Perform a substrate audit**
    - ➢ **Generally, steels do not require special consideration in regard to alkaline cleaner selection**
    - ➢ **Proper pretreatment chemical selection is more difficult for mixed metal processing, or for handling aluminum, zinc, galvanneal, galvanized or terneplated steel for good cleaning and paint bonding**
    - ➢ **Overall pretreatment performance on multiple metal lines may be limited by certain alloys**
    - ➢ **Two pretreatment lines may be the best performance option for multiple metals**
  - ➢ **A consistent quality substrate is essential for effective pretreatment**
    - ➢ **Parts must be cleanable (have compatable soils and free of corrosion)**
      - ➢ **Most pretreatment systems cannot handle rusty parts**
- ✗ **Water Supply**
  - ➢ **Need to characterize raw water to minimize sludge formation and pH adjustment for quality phosphate coating formation**
    - ➢ **Analyze water for hardness, conductivity (in micromhos) and total dissolved solids**
  - ➢ **For extremely hard waters - select alkaline cleaners or phosphate compounds with hard water stabilizers**
- ✗ **Application method and configuration of parts**
- ✗ **Process control**

Cleaning

- **The first and most critical step of the pretreatment process - *Also the most undervalued process with most companies***
  - **Subsequent pretreatment processes cannot be accomplished unless part is adequately cleaned.**
  - **Cleaner selection is based on the type and quantity of soils to be removed and the substrate of parts**
- **Variables that affect cleaning**
  - **The type and quantity of soils that must be removed[2]**
  - **The size, shape and substrate of the part**
  - **The chemistry required**
  - **The type of application method**

A cleaning solution must have a greater affinity (i.e., chemical attraction) for the substrate than the soil

Functions of Cleaners

- **Tie up minerals in the water for better rinsing and cleaning**
- **Lower the surface tension of water for improved wettability**
- **Enhance the natural solvency of water**

Cleaning
Soil Types

Soil = matter out of place

Organic Soils

- **Metalworking fluids, rust preventatives, buffing compounds, quenching oils**
  - **Oils - most common soil found on steel**
  - **Organic soils vary in degree of difficulty to remove**
    - **Easy to remove - Synthetic and semi-synthetic cutting fluids, light weight machine oils, short term rust inhibitors**
    - **Difficult to remove -buffing compounds, waxy oils, heavy duty oils and rust inhibitors, sulfurized/chlorinated lubricants**
  - **Drying, aging, welding, forming and poor storage conditions may change a soil's properties, making it more difficult to remove**
    - **e.g., varnish and rust formation on parts**

Inorganic Soils

- **Heat scale, rust, carbon, smut, particulates, tarnish, oxidation, shop dirt, abrasives**
  - **Reduces adhesion and gloss of paints**
  - **Smut - anything black or gray that can be wiped off of the surface after the cleaner has removed the oils**
    - **Includes iron oxides, carbon/graphite, shop soils, buffing compounds, etc.**
    - **An alkaline cleaner with excellent spray impingement assists in smut removal but these soils are generally acid sensitive**
      - **Cannot be cleaned entirely with an alkaline cleaner - requires an acid**
    - **Typically embedded in the pores of the metal surface - may continue to migrate to the surface even after cleaning with an acid**
    - **Alone, smut soils have a strong electrical bond to the metal and don't generally cause adhesion problems[9]**

Cleaning

Soil Types

Organic Soils

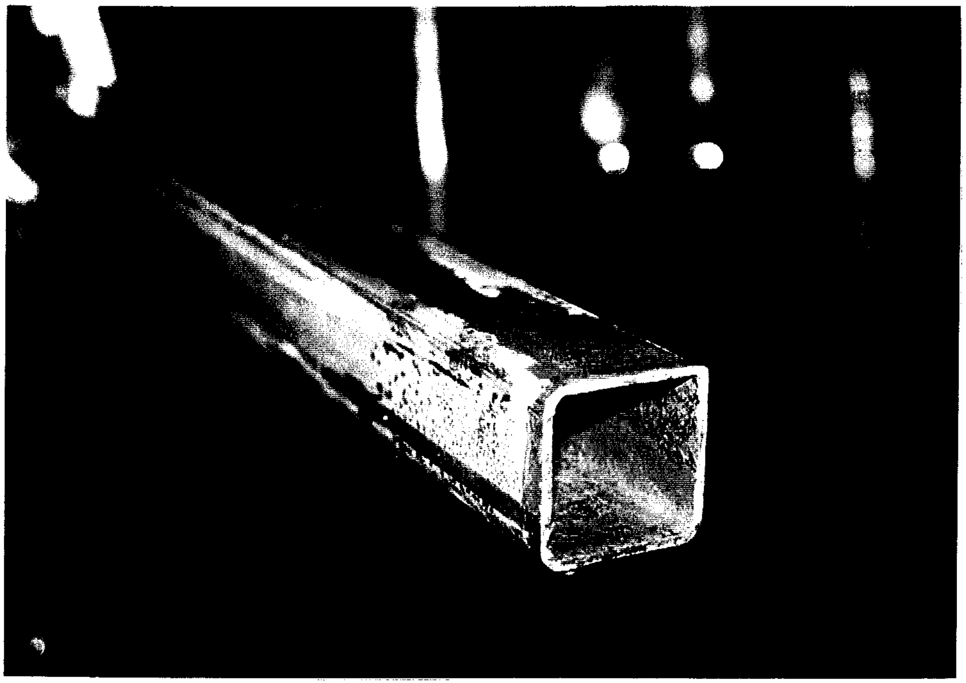
- ✗ **Alkaline cleaners remove organic soils and condition the surface to accept a conversion coating**
  - ➢ **Alkaline cleaners contain alkaline builders, wetting agents or surfactants and water softeners[9]**
    - ➢ **Modern alkaline cleaners tend to use lower alkalinity materials (i.e., borates) and little, if any, strong caustic materials (i.e., sodium hydroxide, sodium carbonate)**
    - ➢ **Wetting Agents/Surfactants - allow the cleaner to penetrate and remove soils**
    - ➢ **Water softeners - tie up minerals in the water for improved cleaning and rinsing**
- ✗ **Water break-free test - for organic soils**
  - ➢ **Surfaces free of organics will exhibit uniform sheeting of rinse water**
    - ➢ **Flush parts with fresh, uncontaminated rinse water (rinse water containing detergent additives or contaminated rinse water may mask poor cleaning because of increased wetting ability)**
  - ➢ **If water beads up, organic soils remain on part[4]**

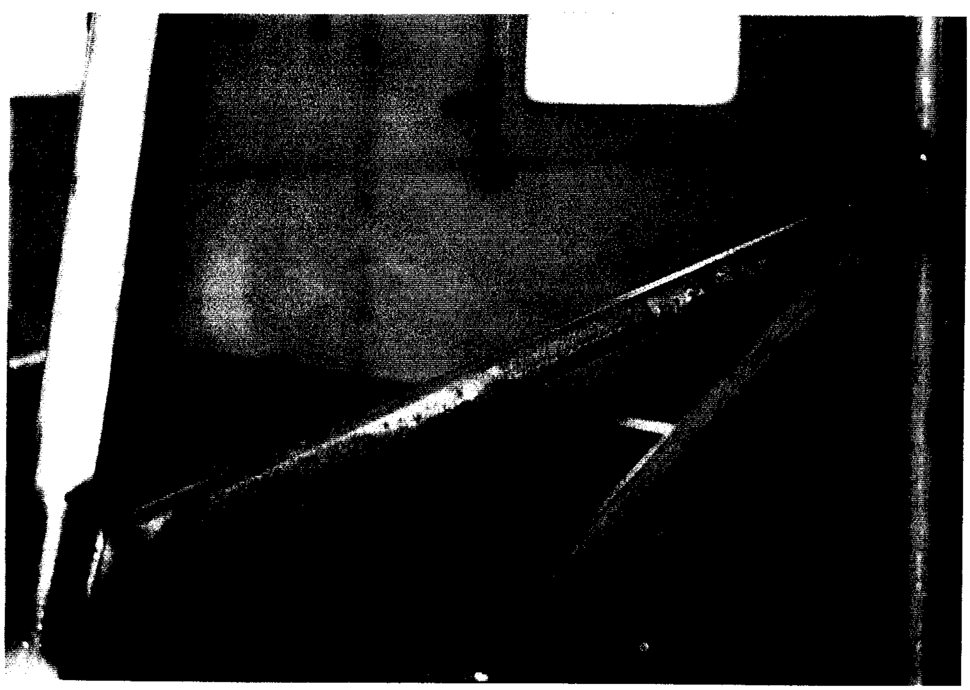
Inorganic Soils

- ✗ **Acids clean inorganic soils**
  - ➢ **Washers cannot remove heat scale or rust - requires abrasive cleaning**
  - ➢ **High amounts of inorganic soils may interfere with adhesion**
    - ➢ **Loss of adhesion = reduced salt spray/humidity performance**
- ✗ **White towel test - for inorganic soils (after dry off)**
  - ➢ **Wipe a clean white towel over a dry part surface**
    - ➢ **Check areas most likely to be shielded from direct spray impingement**
    - ➢ **A perfectly clean towel is not usually obtainable nor is it required for a quality finish**
      - ➢ **Look for relative changes in cleaning performance over time**

Cleaning

Soil Types





Need to maintain tight control over substrate quality prior to pretreatment. Most pretreatment systems cannot handle rusty parts.

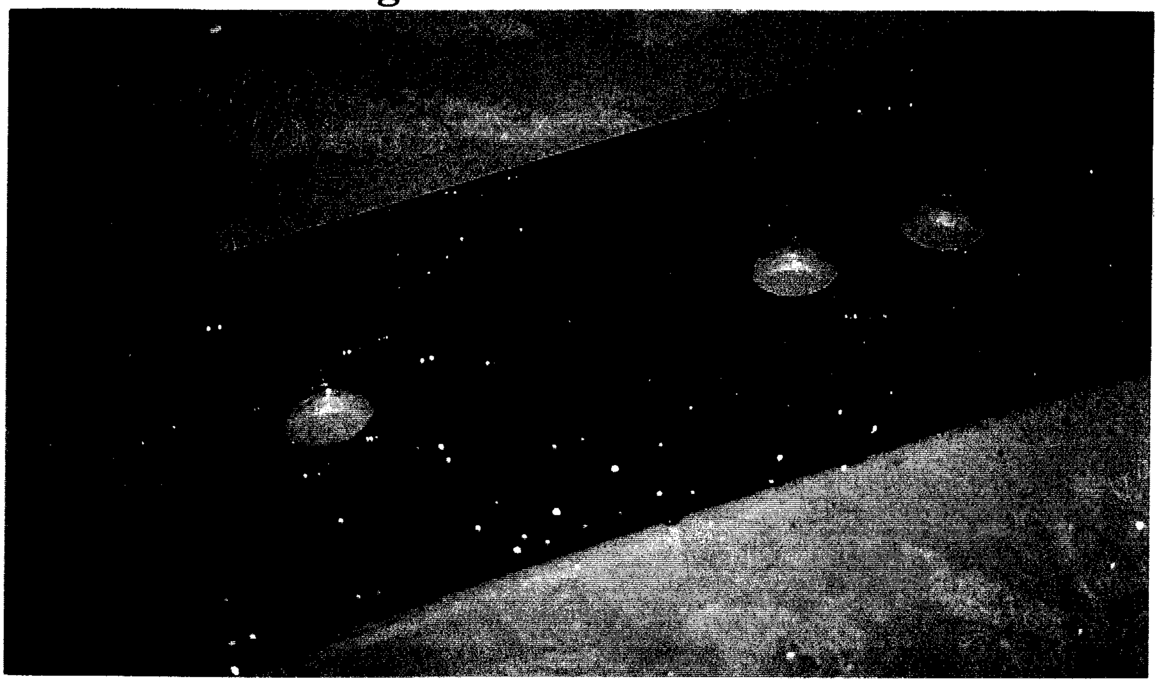
Cleaning
Substrate Types

- The composition of a part's base metal may be a limiting factor in pretreatment chemical selection
  - Chemicals must be compatible with substrate composition
  - For multiple metal cleaning - nonferrous metals are typically the limiting factor in regard to chemical selection
    - e.g., Aluminum (Al) and zinc (Zn) alloys vary considerably in their ability to withstand alkaline or acidic cleaner attack
- Must perform a substrate audit for proper pretreatment chemical selection
- Classify substrate composition as
  - Ferrous - cold-rolled steel, hot-rolled steel, stainless steel, and ferrous castings
  - Nonferrous - aluminum, zinc
  - Yellow metals - brass, copper
  - Mixed metals - combination of the above metals
  - Composites - mixtures of metals and nonmetallic parts

Cleaning

Where to Look for Poor Cleaning

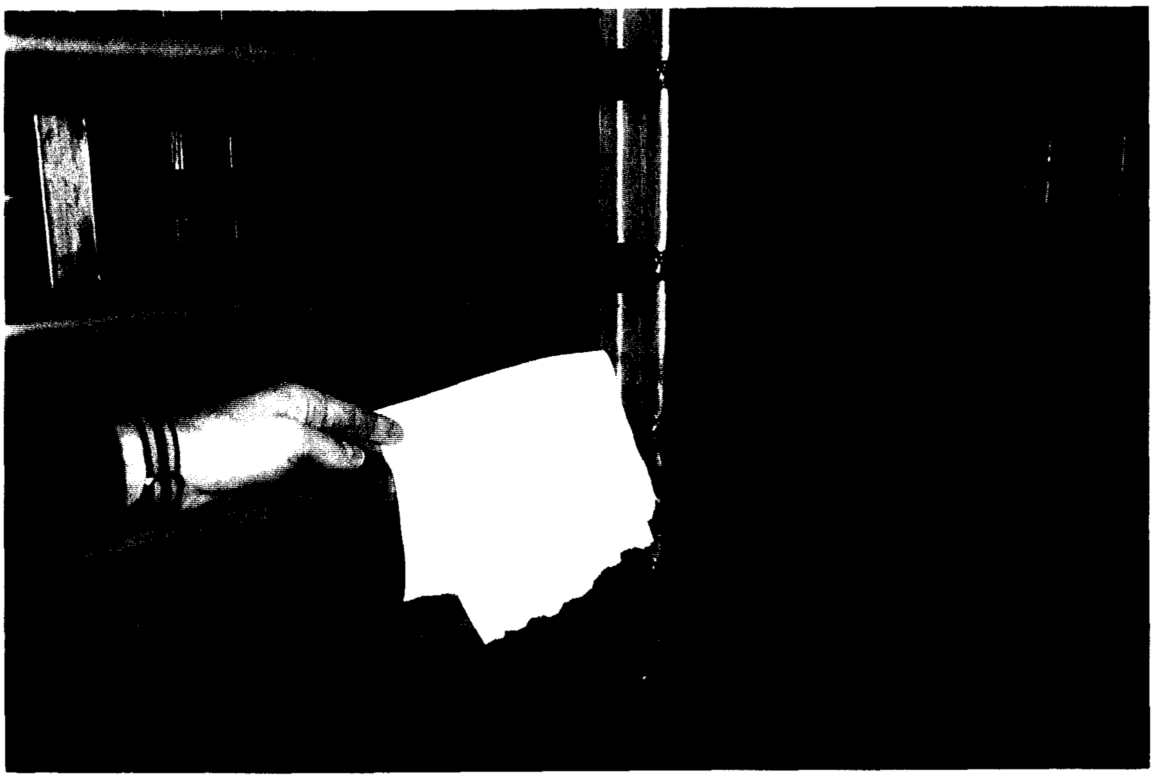
- ✗ At exit of parts washer
  - ➢ Look for water break-free
  - ➢ Poor cleaning most evident on / near weldments



Cleaning

Where to Look for Poor Cleaning

- After parts dry
  - Use white towel test
  - Parts should exhibit a clean surface with no powdering or heavy streaking
  - Smut should be removed at this point
    - Note: - it may be nearly impossible to remove all carbon, smut and soot with a conventional 3 stage washer[4]



Phosphatizing

- A conversion coating formed by the reaction of a phosphatizing chemical with a metal substrate
  - Converts a metal surface to an inert metal salt that is highly receptive to paint and powder coatings
    - Consists of a layer of phosphate crystals bonded to a metal surface
      - Produced on ferrous and non-ferrous substrates[1]
      - Phosphate coatings consist of crystalline salts of the metal which is being treated and/or crystalline salts of metal ions added to the phosphatizing solution
- Significantly improves paint adhesion and corrosion control
  - Changes the metal surface from a smooth structure to a porous, absorptive structure of metallic phosphate crystals that increases the substrate profile and improves adhesion
  - Creates a low conductivity barrier that inhibits corrosion
  - Forms a chemical bond to the metal surface that retards the spread of corrosion, preventing corrosion from undercutting the coating
- *Ferrous metals* - Produces an inert layer of iron phosphate crystals on metal surface through the combined use of acid phosphate salts, free phosphoric acid and accelerators.
  - Typically, iron phosphate coatings weighing 25-90 mg/ft^2 are acceptable for paint bonding[1]
- *Nonferrous metals (e.g., Al or Zn)* - Instead of forming an iron phosphate coating, nonferrous substrates are micro-etched
  - May also produce combination alloy phosphates in place of a typical iron phosphate coating
    - Coatings range from 40 - 70 mg/ft^2.[11]
- Most companies phosphatize prior to painting
  - Produces a higher quality, more durable product at a low cost
    - Cost of phosphatizing is minimal compared to the overall cost of manufacturing a product

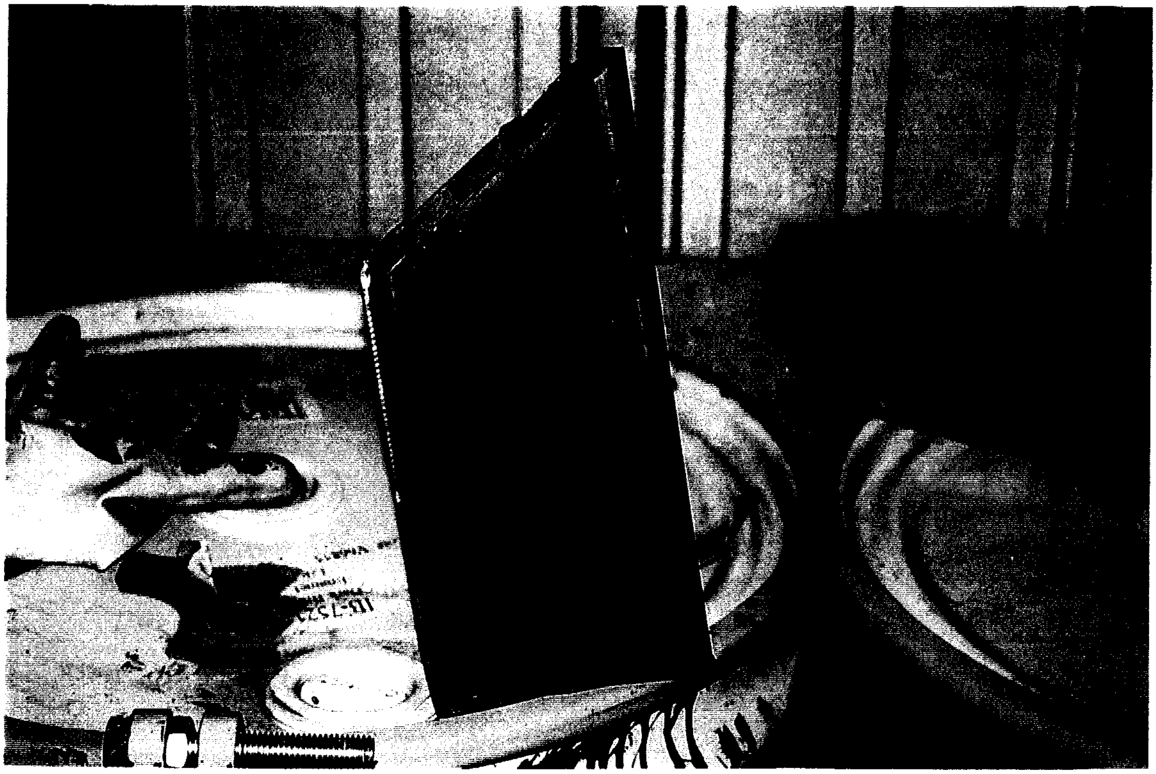
Phosphatizing

- Two major types of phosphate coatings used in prepaint systems - zinc and iron
  - Operating pH varies based on the type of phosphate compound
  - Some phosphate compounds favor a pH in the range of 3.5 to 5.0 while others favor a pH of 4.8 to 6.0
  - Zinc phosphate compounds
    - Liquid concentrate contains zinc-bearing salts and free phosphoric acid
    - Superior corrosion resistance than iron phosphate
    - Produces zinc phosphate coatings weighing 100-300 mg/ft^2
    - Generates more sludge
    - Heavy metal concentrations more of a problem
    - Typically limited to larger operations with more elaborate waste treatment capabilities
  - Iron phosphate compounds - most commonly used
    - Advantages
      - Produces a quality surface
      - Easy to control / maintain
      - Minimal or non-sludge formation characteristics
      - No heavy metal disposal problem
      - Economical to operate [1]

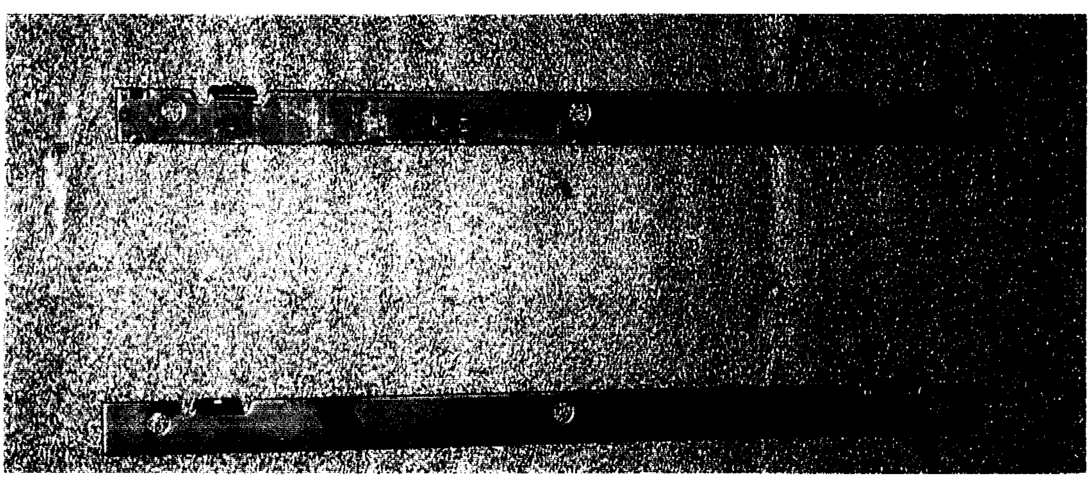
Iron Phosphatizing

- Iron phosphatizing solutions typically contain very little iron[11]
- Iron phosphate compounds include:
  - A phosphate source to form the conversion coating
  - An acid source to etch the metal surface and begin the process
  - An accelerator to help form the coating
    - An iron phosphate coating may be blue, gold, iridescent purple, green brown or gray depending on the accelerator and coating weight
    - Type of accelerator, temperature, time and operating pH dictate the final color of the phosphate coating
    - Molybdate accelerators - older technology, provide excellent adhesion and flash rust protection, limited salt spray performance and corrosion protection
    - Nonmolybdate accelerators - newer technology, provide excellent adhesion, higher phosphate coating weight, and corrosion protection, don't provide as much flash rust protection as molybdenum accelerators[9]
  - Buffering agents to control water hardness and maintain pH
  - Iron phosphate coating weight is a function of accelerator type, time, temperature, concentration, pH, spray pressure and steel type[9]
    - With regard to coating performance, the quality of the conversion coating is far more critical than the coating weight

Phosphatizing

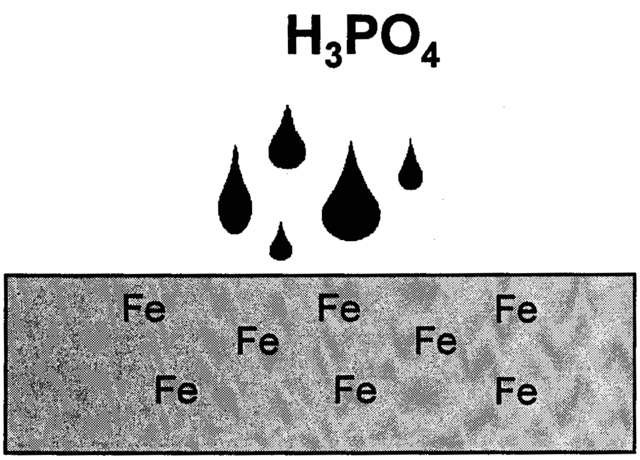


Iridescent blue phosphate coating on steel pretreated with a spray wand system.

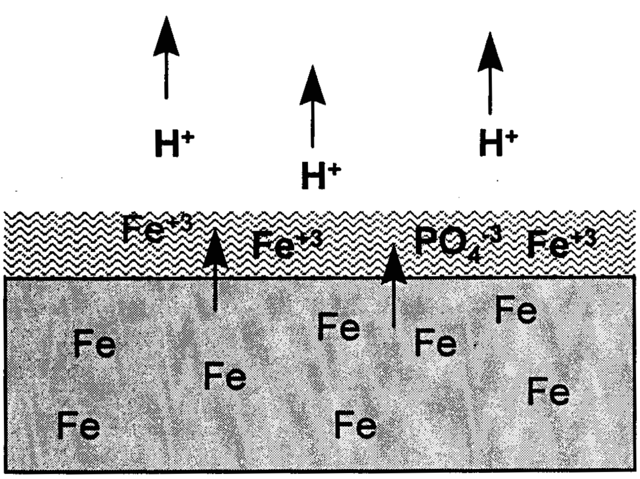


Steel parts before and after pretreatment through a spray washer. Note the oil present on the untreated surface (upper photo) and the iridescent blue color on the phosphatized part (lower photo).

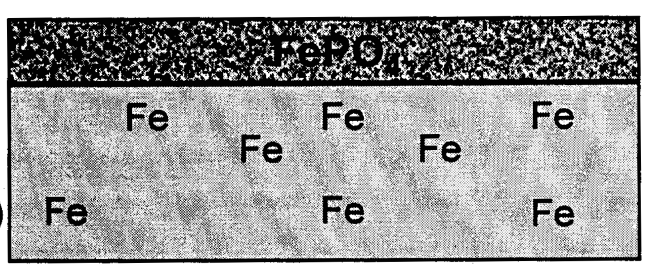
Phosphatizing Steel



- Mildly acidic phosphatizing solution comes into contact with steel
- Acid attack on the metal surface begins
  - Light pickling occurs



- As the solution attacks the metal part, iron is removed from the part's surface and reacts with the acid in the phosphating solution.
  - pH at the substrate-solution interface increases and hydrogen gas is evolved
- As pH increases, the solubility of metal phosphate is reduced and a phosphate coating forms on the etched substrate
  - Forms a relatively insoluble layer of iron phosphate
  - If the solution contains additional metal ions such as zinc or manganese, phosphate coatings of these ions will also be deposited



- Phosphate crystals continue to grow until the metal surface is covered
- Crystals then begin to grow upon themselves until an equilibrium point is reached
- Coating subsequently becomes an integral part of the metal surface

Phosphatizing

Factors Affecting Phosphate Coating Development

❶ **Cleaning - the most critical step in achieving a good phosphate coating**

- **If soils are left on the part surface, the phosphating solution cannot react with the metal substrate to produce a coating**
  - **Causes spotty, nonuniform phosphate coating**
- **Results in poor paint adhesion, blisters and under-film rust**

❷ **Chemical accelerators - phosphating compounds contain various chemical additives to accelerate phosphate coating formation**

- **Accelerators such as nitrite, nitrate, chlorate, peroxide may be added to increase the rate of coating deposition**
  - **e.g., sodium nitrite serves as a hydrogen scavenger - reacts w/ hydrogen bubbles which form as the acid attacks the steel surface. By eliminating these bubbles, the nitrite allows the phosphating solution to maintain its close contact with the metal surface, causing the reaction to occur more rapidly**

❸ **Temperature - higher temperatures result in a more aggressive acid attack on the base metal**

- **The initial acid attack takes place more quickly and the phosphate coating forms in a shorter length of time.**

❹ **Differences in steel**

❺ **pH of phosphatizing solution**

- **Too low - excessive acid attack of the metal surface**
  - **Results in a low phosphate coating**
  - **pH at metal surface does not rise sufficiently to produce a heavy phosphate coating during the conversion reaction**
  - **The phosphate coating that does form may subsequently be removed by continued attack of the free acid in the phosphating compound**
- **Too high - insufficient attack on the metal to initiate the conversion coating**
  - **It's more economical to use an acid concentrate to lower pH than to change or add phosphate compound**
- **Acceptable pH range for a typical iron phosphate process is 3.8 to 4.8**

Effective Rinsing

No part is cleaner than the quality of rinse water used

- **Degree of rinse water quality depends on the degree of quality required on finished parts**
- **Purpose of rinsing**
  - **Minimizes the transfer of processing solutions to subsequent stages**
    - **Neutralizes or dilutes remaining alkalinity after a cleaner stage**
    - **Flushes remaining soils and nonadherent phosphate coating from part**
  - **Conditions the part for subsequent stages**
  - **Maintains a wet substrate between stages**
    - **Inhibits flash rusting**
  - **Removes excess water hardness and salts before dry off**
- **Rinse water volume, application and quality must meet some minimum requirements to be effective**
- **Factors to consider**
  - **Raw water quality**
  - **Water volume**
  - **Contact to part**
    - **Application method**
    - **Part configuration or design**
    - **Solution contact time**

Effective Rinsing

- **For top performance, the final rinse must be kept clean and free of contaminants**
  - **The final rinse has a significant effect on overall performance**
  - **A poor final rinse may cause flash rust, poor adhesion and poor corrosion resistance**
- **Rinse waters should be overflowed and recharged as frequently as possible**
  - **Rinse overflow rates may range from 3 to 20 gpm**
- **pH and TDS determines how effective rinsing will be**
  - **Should monitor rinse tanks for pH and total dissolved solids (TDS) at least once per shift**
    - **General rule - keep TDS of working rinse below twice the TDS of your makeup water**
    - **The rinse tank following a conversion coating tank may be counterflowed to the rinse tank preceeding the conversion coating tank**
      - **The post conversion rinse will neutralize the alkaline salts of the cleaner rinse**
  - **Monitor with handheld meters or automated systems equipped with sensing probes**
    - **Probes sense when to increase the overflow rate (to reduce TDS) by activating a drain and refilling the rinse tank with fresh water**
      - **Probes must be maintained and cleaned to be accurate**
      - **Automatic controllers must be recalibrated**
      - **May lead to a false sense of security**
  - **Water quality is especially critical for the final rinse stage**
    - **Generally, for good performance, water with less than 100 ppm chlorides and sulfates**
    - **Consider reverse osmosis water or deionized water for the final stage if raw water quality is too poor or parts are not meeting performance requirements**

Pretreatment Application Methods

- ✗ **Application method is determined by the parts coated and quality desired**
- ✗ **Most common application methods are:**
  - ➢ **Immersion**
  - ➢ **Hand held spray wand application - 1 to 5 stages**
  - ➢ **Recirculating Spray Washers (3 and 5+ stages)**

Emphasis

Spray wand and spray washer applications

- ✗ **To select a pretreatment application method**
  - ➢ **Need to consider time, temperature, concentration and force associated with application method**
  - ➢ **Must test parts to determine if the application method will clean associated soils**

Immersion

- **Accomplished by immersing parts in a tank or a series of tanks containing pretreatment solutions**
  - **Best suited for batch cleaning or continuous production cleaning (i.e., conveyor line)**
- **May be static or agitated systems**
  - **Agitated systems accelerate soil removal**
    - **Agitation is accomplished by the use of recirculating pumps, air sparging, mixing, or by physically moving parts while immersed**

Advantages

- ***Simple maintenance because of fewer mechanical parts***
- ***Inexpensive***
- ***Prolonged contact time is possible***
- ***Foaming is not a problem - allows greater flexibility with pretreatment chemistry selection***
- ***Allows the chemical solution to completely contact multiconfigured parts***

Disadvantages

- ***Requires longer process times, higher temperatures and higher chemical concentrations than spray systems because of lower degree of application force[11]***

Spray Wand Application

- Best for large, heavy, bulky parts that cannot be cleaned on conveyor line spray systems
- High temperature/high pressure water
  - Generally operate at 4-5 gpm, 1,000 psi and 160 - 200°F
    - High heat capacity facilitates cleaning, phosphatizing and rapid drying
    - May use steam cleaning for heavily soiled small parts (melts grease)
  - Time - 5 to 15 minutes (dictated by part size, part geometry, soil types and soil quantity)
  - Concentration 0.5-1% by volume
    - High degree of application force (impingement) and high temperature of application method compensates for the lower cleaner concentration
  - Phosphate coating 20 - 40 mg/ft^2

Advantages

- *Low cost, easily installed, mobile and low labor cost*
  - *Produces excellent results at affordable prices for low to medium production facilities finishing parts of various shapes and sizes*

Disadvantages

- *Application method is operator dependent - requires a trained, conscientious employee (effective cleaner-to-surface contact is required)*
- *Systems must deliver chemical at 1,000 psi and be able to handle acidic chemicals*

Spray Wand Application

Recirculating Spray Washers

Components and Design

- Most popular application method
  - High efficiency for continuous/conveyorized production lines
  - Degree of force/impingement makes these systems efficient
- Consists of a series of stages equipped with a reservoir, transfer pump, risers and spray nozzles
  - Pumps transfer chemical solutions from the reservoir to a set of risers
  - Nozzles attached to the risers spray the solution onto parts
    - Typical spray systems operate between 10 to 30 psi of nozzle pressure
- Items to consider when selecting a spray washer
  - Nozzles - number and type per stage, placement, orientation, psi rating, construction material
  - Risers - number per stage, spacing, construction design and material, pumps
  - Tanks - capacity (dictates dumping and recharging frequencies), construction design and construction material
  - Pump motor size - dictates the number of nozzles
  - Drain vestibules - length, shielding, pitch
  - Heating - available temperature at load, type, construction
  - Access and maintenance items
    - Good lighting for maintenance
    - Catwalk design and construction material
      - Zinc plated catwalks not recommended since zinc will strip off
        - May cause wastewater disposal problems due to excessive zinc concentration

Advantages

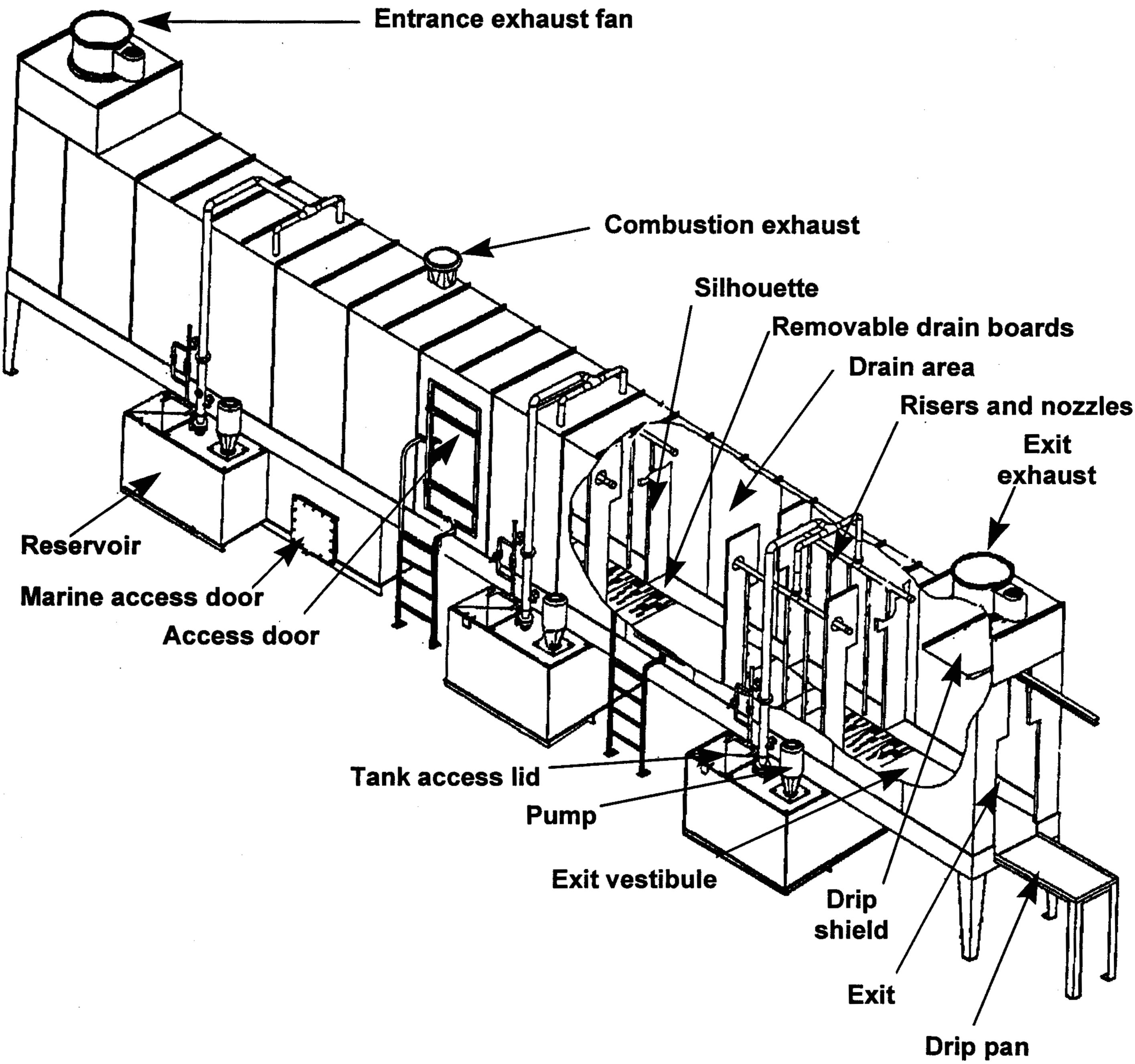
- *Spray washers reduce process times, solution temperatures and chemical concentrations resulting in energy and chemical savings*

Disadvantages

- *Higher capital cost than other methods*
- *Chemistries limited to nonfoaming varieties*
- *Require more upkeep and troubleshooting requires more expertise*

Recirculating Spray Washers

Components and Design

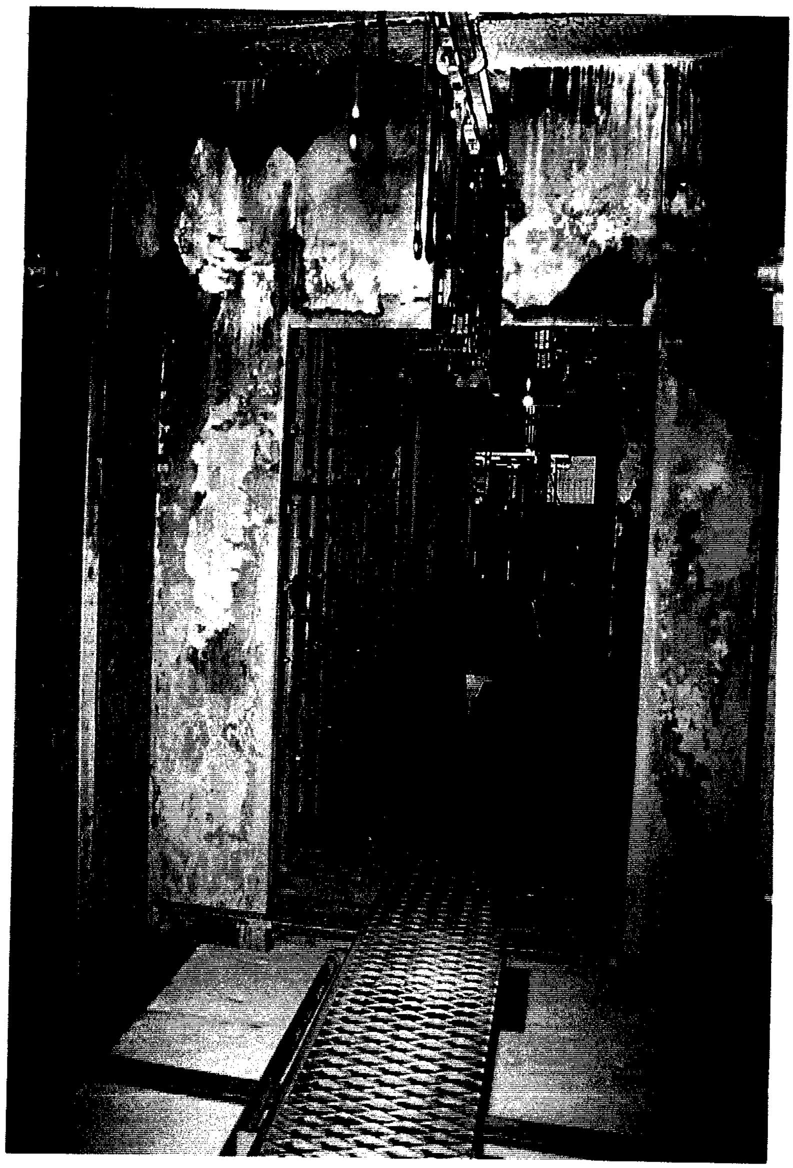


Cutaway drawing of a 3 stage recirculating spray washer

(Modified from Mueller, 1992)

Recirculating Spray Washers

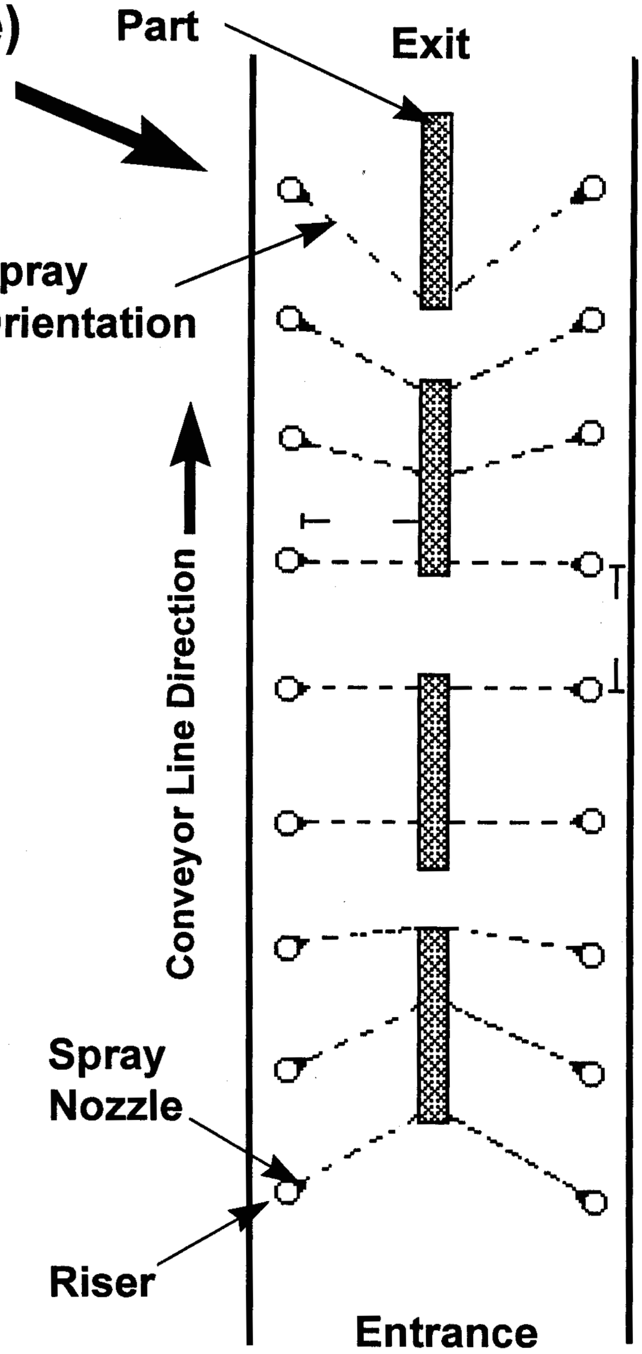
Components and Design

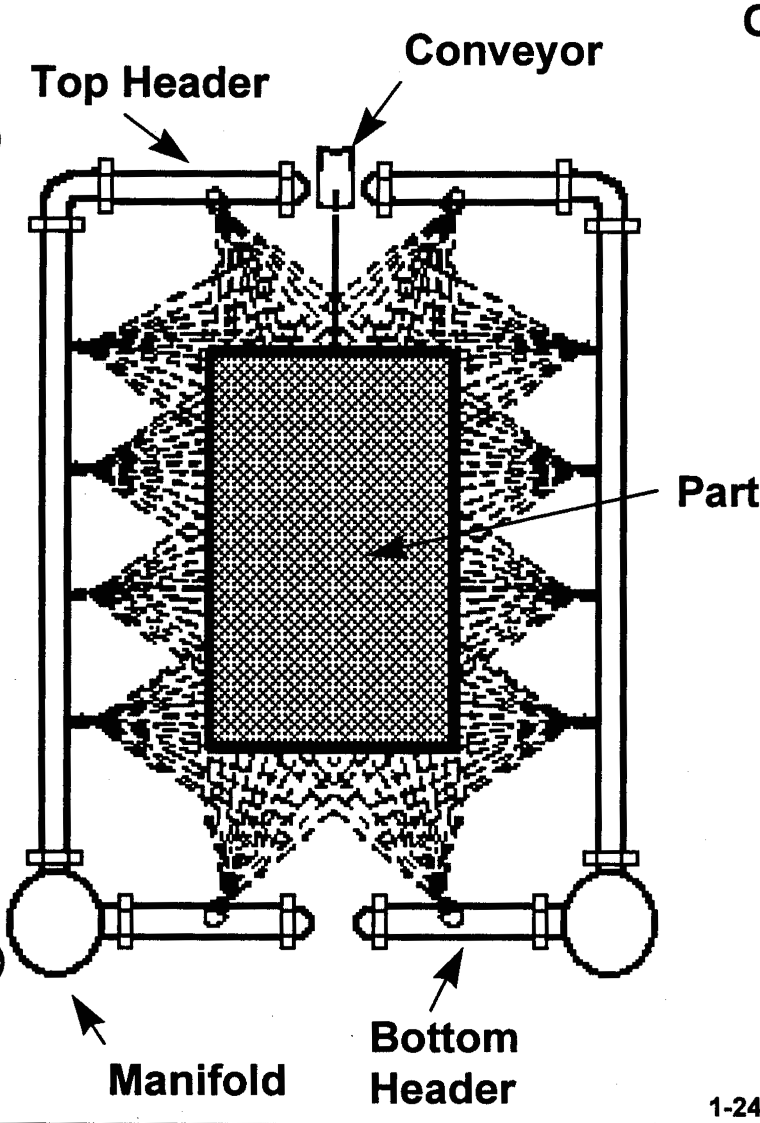


Inside components of a recirculating parts washer

Recirculating Spray Washers

Components and Design





Recirculating Spray Washers

3 Stage Spray Washers

	Stage 1	Stage 2	Stage 3
Process	Clean & Phosphatize	Rinse	Seal-Rinse
Contact Time	60 sec	30 sec	30 sec
Temperature	90-140°F	Ambient	100-160°F
Concentration	1.5-3.0% by volume (liquid) 2-4 oz/gal (powder)	N/A	N/A
pH	Acidic	Acidic-Neutral	Neutral

Note: cleaner concentration is higher than spray wand because cleaner is contained and recirculated in the washer[9]

- **Most widely used process**
- **Best for indoor products**
- **200-400 hour salt spray**
- **Spray pressures = 25 - 100psi**

Advantages

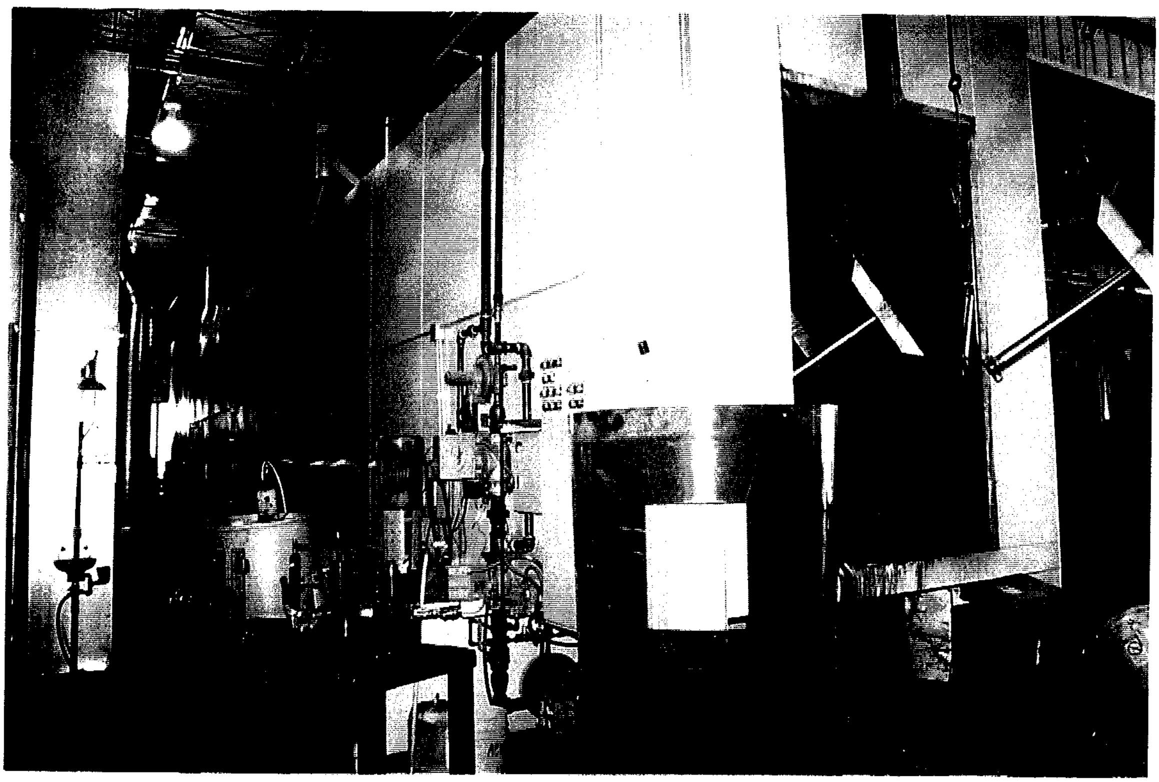
- ***goof for multi-metal preparation***
- ***Good cleaning of controlled soils***
- ***Good adhesion characteristics***

Disadvantages

- ***Acidic detergent systems are less effective than alkaline cleaning products***
  - ***Requires greater control over incoming soil types, soil loads, and washer maintenance in order to obtain good, overall cleaning efficiency***
- ***May be impossible to remove all carbon, soot and smut***
- ***Limited phosphate accelerator choices***

Recirculating Spray Washers

3 Stage Spray Washers



Recirculating Spray Washers
3 Stage Spray Washers

Stage 1 - Clean and phosphate stage

- ✗ Soil is displaced through spray impingement and wetting provided by detergent additives in acidic solution
- ✗ A phosphate coating develops as the metal is cleaned
  - ➢ Phosphate coating = 20-40 mg/ft^2
- ✗ Typical operating conditions
  - ➢ Contact time typically ~ 90 sec
  - ➢ Temperature = 90-140°F
  - ➢ Concentration = 2-3% by volume
  - ➢ pH = 3.0 to 5.5
    - ➢ pH depends on metal type and cleaning requirements
    - ➢ Lower pHs favor improved cleaning of inorganic soils
    - ➢ Nonferrous metals favor lower pH for optimum surface conditioning

Stage 2 - Ambient Rinse

- ✗ Contact time typically ~ 30 sec
- ✗ Flushes non-adherent soils and phosphate solution from parts
  - ➢ Should be adequately overflowed and dumped frequently to minimize chemical / soil carry-over and buildup of TDS
- ✗ Temperature 90-140°F

Stage 3 - Seal rinse

- ✗ Removes harmful residues, prevents flash rusting or re-oxidation of the metal surface, seals porosity of phosphate coating
  - ➢ Displaces unreacted phosphates to prevent powdering or corrosion[9]
  - ➢ Counters the effect of hard water by keeping hard water minerals (e.g., calcium, magnesium and iron salts) in solution, preventing them from precipitating out onto the part[9]
  - ➢ Reacts with any exposed substrate (voids in the phosphate coating), reducing the electrochemical potential for corrosion
- ✗ Keeps the metal surface in a mildly acidic state (maintains the acidic pH of the substrate, which could otherwise be raised by the pH of the rinse water)
  - ➢ Neutral to slightly alkaline pH rinse may cause paint lift or delamination
- ✗ Contact time typically ~ 30 sec

Recirculating Spray Washers
Seal Rinses

- Primary function is to seal porous areas of the phosphate coating
- Flushes any unwanted residues from conversion coating
  - Removes unreacted phosphate and other contaminant salts
- Is absorbed by phosphate coating to maximize corrosion protection and prevent flash rusting
  - Extends salt spray performance

Two Chemistry Types

- **Chromated (acidified rinse)**
  - Provides excellent corrosion protection
  - Problem with disposal - chromated rinses must be treated and sludge managed as hazardous waste
- **Non-chromated- most common**
  - Water quality for seal-rinse - important consideration
    - Use fresh, deionized (D.I.) or reverse osmosis (R.O.) water with proprietary inorganic or organic sealing polymers
  - A part is no cleaner than the quality of rinse water used[10]
  - Hard waters with low to medium water hardness and dissolved solids are commonly used
    - If water contains 150-250 ppm TDS and parts are not meeting quality requirements - consider D.I. or R.O. water rinse
      - Ideally, TDS should be <125 ppm
    - D.I. water - effective but corrosive to steel tanks unless used with seal-rinse compounds
      - Most widely used for powder coating
      - Leaves the least amount of contaminants on part, extending coating life
    - Softened water is not recommended - contains residual sodium chloride (corrosive)
- **Seal rinse should NOT be counterflowed into preceding stage**
  - Contains chemical additives
- **Maintenance is chemistry specific**
  - Seal rinses should be dumped and replenished frequently to maintain operating integrity
  - pH and conductivity monitoring and adjustment are essential
    - Conductivity dictated by raw water quality and any additional conductivity added by the seal chemicals
    - pH dictated by chemical vendor

Recirculating Spray Washers

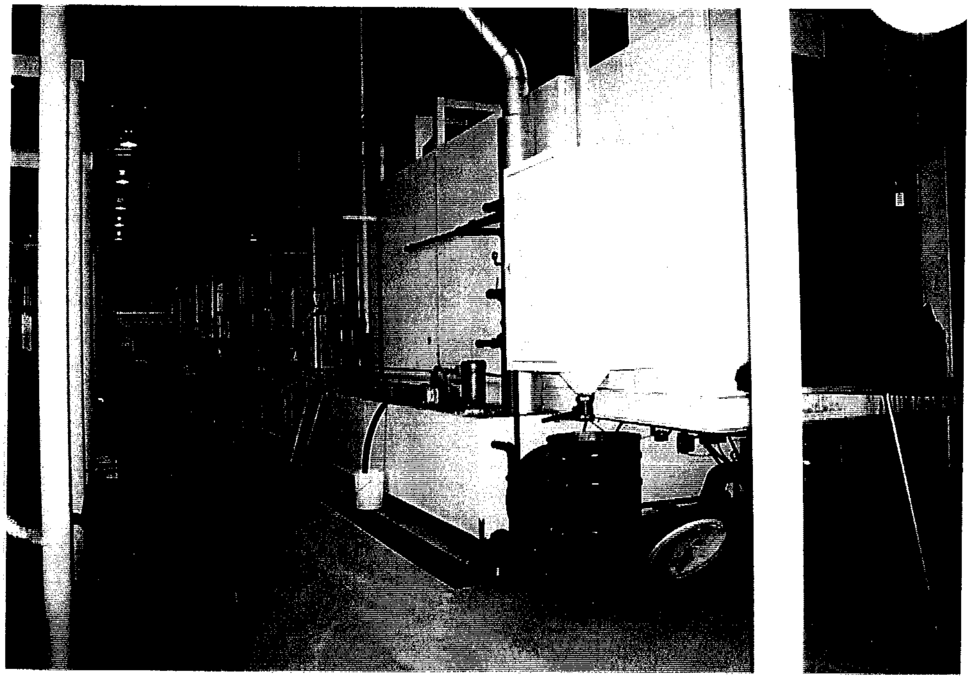
5+ Stage Spray Washers

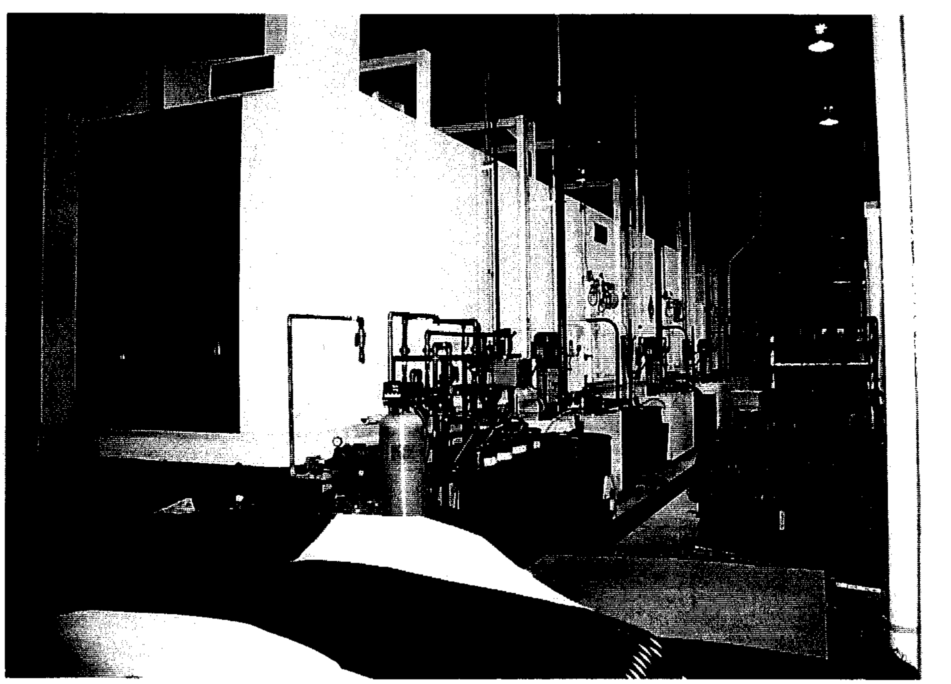
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Process	Clean	Rinse	Phosphate	Rinse	Seal Rinse
Contact Time	90 sec	30 sec	60 sec	30 sec	30 sec
Temperature	90-140°F	Ambient	90-140°F	Ambient	90-140°F
Concentration	2-4%	N/A	2-4%	N/A	0.1 - 0.25%
pH	Alkaline	Neutral	Acidic	Neutral	Acidic - Neutral

- 5 + Stage washers
  - Identical to 3 stage except the phosphate stage is proceeded by alkaline cleaner and rinse stages
  - Best for outdoor products
  - 300-500 salt spray hours
- Offers the best pretreatment flexibility and cleaning efficiency
  - Separate stages are devoted to cleaning and phosphatizing
  - 1st stage - soil displacement w/alkaline cleaner
    - More aggressive cleaner = improved cleaning
  - 3rd stage may be devoted entirely to phosphating
    - If additional cleaning is required may elect to use a cleaner-phosphate
  - Allows for broader chemical product selection and flexibility

Recirculating Spray Washers

5+ Stage Spray Washers





Entrance (upper photo) and exit (lower photo) views of a 5 stage washer with a deionized water halo rinse

Recirculating Spray Washers

5+ Stage Spray Washers

Stage 1 = Alkaline Cleaning

- Alkaline systems offer a much wider range of cleaning chemistries
  - Detergents and surfactants wet the soil
  - Alkaline builders degrade, emulsify and saponify organics
  - Water conditioners soften and control contaminants

Stage 2 = Ambient Rinse

- Flushes nonadherent soils from part
- Dilutes / neutralizes alkalinity, preventing pH contamination to Stage 3
- Must monitor and record pH and conductivity (total dissolved solids) for effective process control
  - pH and conductivity readings should maintain a slight deviation from initial raw water values
- Must ensure rinse tank is large enough to flush and neutralize or sufficient overflow capacity
- To conserve water, may counterflow into 1st stage for makeup water

Recirculating Spray Washers

5+ Stage Spray Washers

Stage 3 = Phosphating (conversion coating)

- ✗ Purpose is to convert the base metal substrate into the most receptive surface for painting/powder coating adhesion and corrosion protection
- ✗ Follow manufacturer's directions for proper concentration, pH, contact time (line speed) and temperature
- ✗ Single function allows a wide range of chemistries to be used to obtain a higher quality phosphate coating

Stage 4 = Fresh Water Rinse

- ✗ Stops phosphate development on part
- ✗ Flushes unreacted phosphate solution from part
- ✗ Prepares part for final seal rinse
- ✗ Must monitor and record pH and conductivity (total dissolved solids) for effective process control
  - ➢ pH and conductivity readings should maintain a slight deviation from initial raw water values
  - ➢ Take measurements at beginning, middle and end of each shift
- ✗ To conserve water, may counterflow into 3rd stage for makeup water

Stage 5 = Seal Rinsing

May have additional cleaning and rinsing stages beyond the 5th stage

Pretreatment

Controllable Variables

- ✗ Contact time or line speed
- ✗ Temperature
- ✗ Force of application / impingement
- ✗ Concentration
- ✗ pH
- ✗ Rinse water quality
  - ➢ Total dissolved solids / conductivity
- ✗ Degree of monitoring, maintenance and record keeping

Pretreatment

Controllable Variables

Concentration

- **Must consider substrate type, soil types and application equipment when selecting chemicals and solution strength**
  - **Certain chemicals may be designed to work within a given temperature range or for a specific application method**
    - **Operating outside the specified temperature range may lead to poor cleaning or foaming**
    - **Wrong application method may result in problems regarding the degree of reaction (cleaning or phosphating), flash rusting or foaming**
- **Control concentration by routine monitoring and adjusting**
  - **Simple titrations - measure alkalinity (total and free), acidity**
    - **Use clean glassware, a well lit area and a white background to distinguish titration endpoint**
    - **Titrate at least once per shift**
  - **Conductivity - quick approximation of solution strength**
  - **pH monitoring - quick approximation of solution strength**
    - **Extremely important for phosphatizing solution**
  - **Other - turbidity, total dissolved solids, or organic/inorganic loading ratio**
- **Alkaline cleaner life is a function of soil loading**
  - **Can assess life of cleaning solution by cleanliness tests, titrations, product consumption rates and oil splits[14]**
    - **When ratio of total alkalinity (methyl orange titration) to free alkalinity (phenolphthalein) increases by 100-200%, it is likely time to recharge**
    - **As a bath ages, product consumption rates needed to maintain the desired free alkalinity will increase markedly**
    - **Oil splits show the amount of emulsified oil in the cleaner bath**
- **Phosphatizing solution life is more difficult to predict**
  - **Monitor product consumption rates as done for the alkaline cleaner**
    - **Initially, they will be fairly uniform but will increase markedly when the solution becomes overworked**
  - **Look for streaky coatings or staining on parts**

Pretreatment

Controllable Variables

Temperature

- ✗ In general, higher temperatures increase the rate of the pretreatment chemical process
- ✗ Potential problems
  - ➢ Certain substrates and chemicals are adversely affected by elevated temperatures
  - ➢ Some foaming problems are temperature related
- ✗ Control temperature by maintaining thermostats and heating sources

Force of Application (Impingement)

- ✗ The mechanical method used to apply the chemical solution to the part
  - ➢ Includes pressure sprayers, nozzles, air lances, elbow grease and electrical or ultrasonic energy
- ✗ Extremely important for removing tough soils such as particulates and oil & grease
- ✗ Control force by:
  - ➢ Maintaining flow through spray nozzles by keeping them clear of scale and debris
  - ➢ Immersion systems or dip tanks - improve by air sparging the tank or recirculating the solution within the tank via a pump or mixer blade
  - ➢ Strategically rack parts to maximize contact in recessed areas while avoiding liquid entrapment

Contact Time

- ✗ The amount of time the part is exposed to the chemical solution
  - ➢ The longer the contact time - the more reaction there will be
  - ➢ Control is typically accomplished through equipment modification
    - ➢ Changing the line speed
    - ➢ Adding or deleting stages to the pretreatment process
    - ➢ Increasing or decreasing the number of risers within a stage
      - ➢ May adversely affect spray pressure (force of application)

Monitoring and Maintenance

- Focus more on soil control, cleaning ability and system upkeep rather than coating weights and salt-spray requirements .[11]
- Parts washers and pretreatment chemicals typically receive poor maintenance but are expected to deliver consistent cleaning and phosphating results
- Two aspects of system monitoring and maintenance
  - Mechanical performance of pretreatment equipment
  - Chemical performance of pretreatment solutions

Need to inspect washer routinely to avoid cleaning problems

- Mechanical components
  - Nozzles
  - Risers
  - Heating source
  - Filter Screens
  - Water feed system
  - Exhaust fans
  - Controllers, thermocouples, and temperature and pressure gauges
  - Pumps
  - Monorails

Monitoring and Maintenance

Nozzles

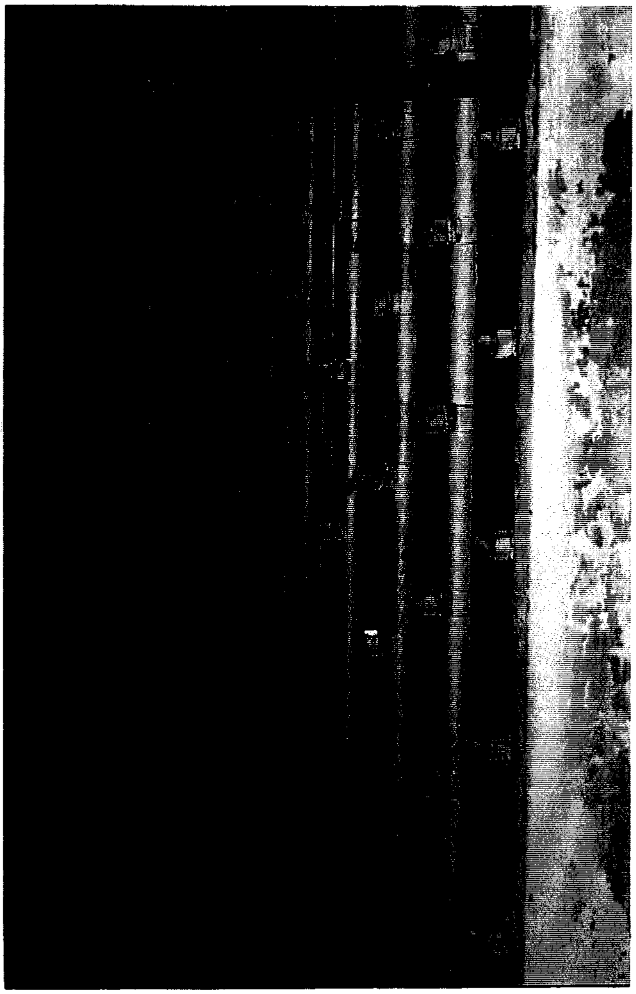
- ✗ **On any given production day, 1% to 15% of nozzles in a system are plugged, worn, damaged, missing or misaligned[5]**
  - ❒ **Should inspect daily with flashlight for debris, blockage, misalignment and excessive wear.**
    - ➢ **Clogged nozzles causes the pressure of unclogged nozzles to increase**
      - ➢ **Excessive pressure may cause spotting, produce uneven phosphate coatings, or knock parts off the racking system**
    - ➢ **Misdirected nozzles from one stage may contaminate or dilute the solution in an adjacent stage**
  - ❒ **Visually inspect spray pattern for uniformity**
  - ❒ **Replace defective/plugged nozzles**
  - ❒ **Ensure proper spray angle and flow rate for nozzles based on type of parts**
  - ❒ **Use color coded CPVC nozzles to simplify replacement**
    - ➢ **e.g.., red-tipped 65/50 nozzle - has a spray fan angle of 65° and a flow rating of 0.5 gpm**
  - ❒ **Periodically clean nozzles by disassembling, removing gross debris and placing in a descaling solution (dilute hydrochloric acid or vinegar). Afterward rinse and reassemble nozzles.**
    - ➢ **May elect to clean and service nozzles on a rotational basis by riser section to ensure efficiency.**

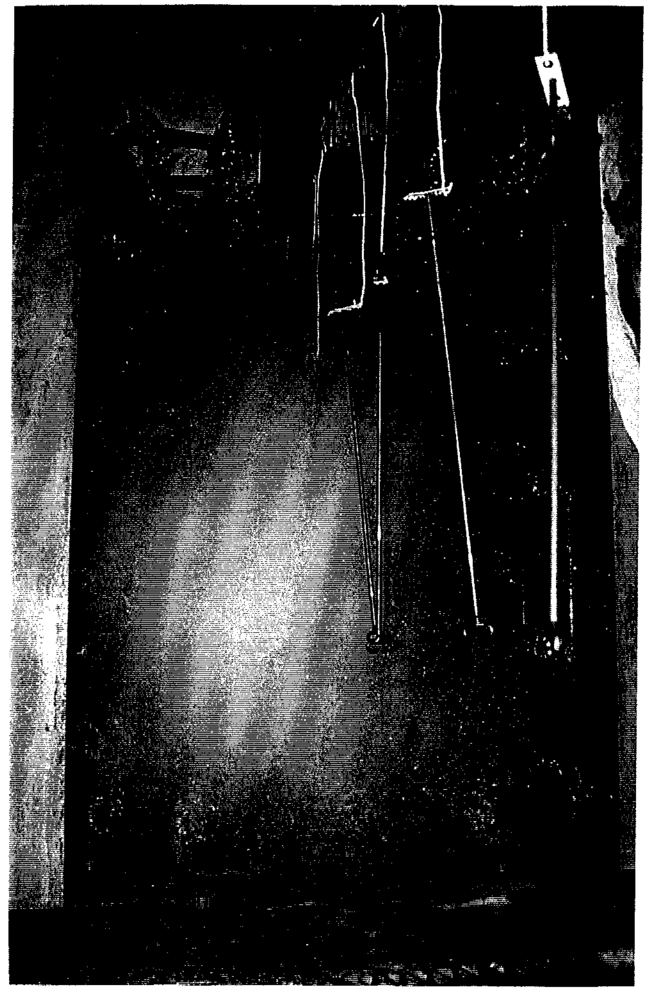
Risers

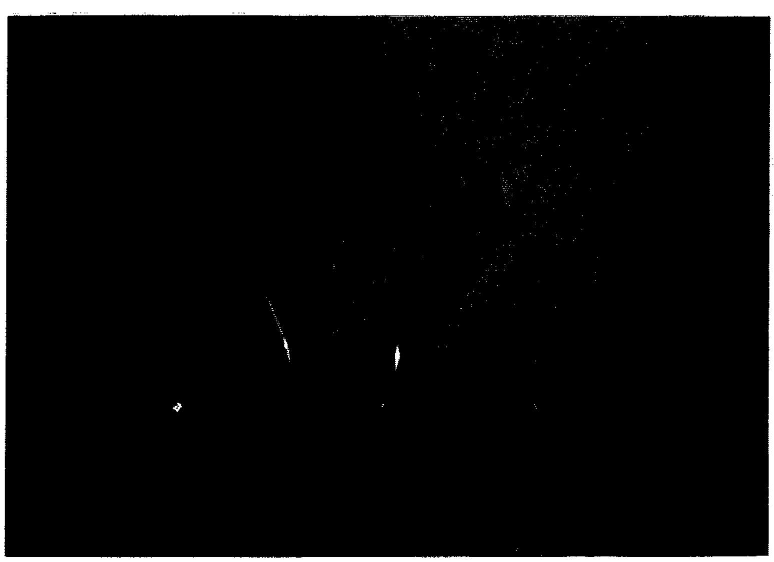
- ❒ **Inspect for scale buildup on I.D.**
- ❒ **Remove end caps to clear debris from tubes (weekly basis)**
  - ✗ **Bottom nozzles are an indicator of scale buildup - if they continually plug, the riser likely contains scale buildup**
- ❒ **Check riser spray direction for overspray and blow by**
- ❒ **Ensure riser is securely attached to the washer wall**

Monitoring and Maintenance

Nozzles and Risers







Monitoring and Maintenance

Temperature / Descaling

- Maintain heat tubes and temperature gauges
- Periodic descaling is recommended to ensure maximum cleaning and energy efficiency
  - ✓ Thoroughly clean and descale system annually or bi-annually (based on water quality)
  - ✓ Scale buildup on heat tubes acts as an insulator and drastically reduces efficiency
    - ✓ 1/32" scale buildup = 2% energy loss
- Washer manufacturer should check and adjust burners twice a year, and the filters on the combustion blower should be replaced as required.

Filter Screens

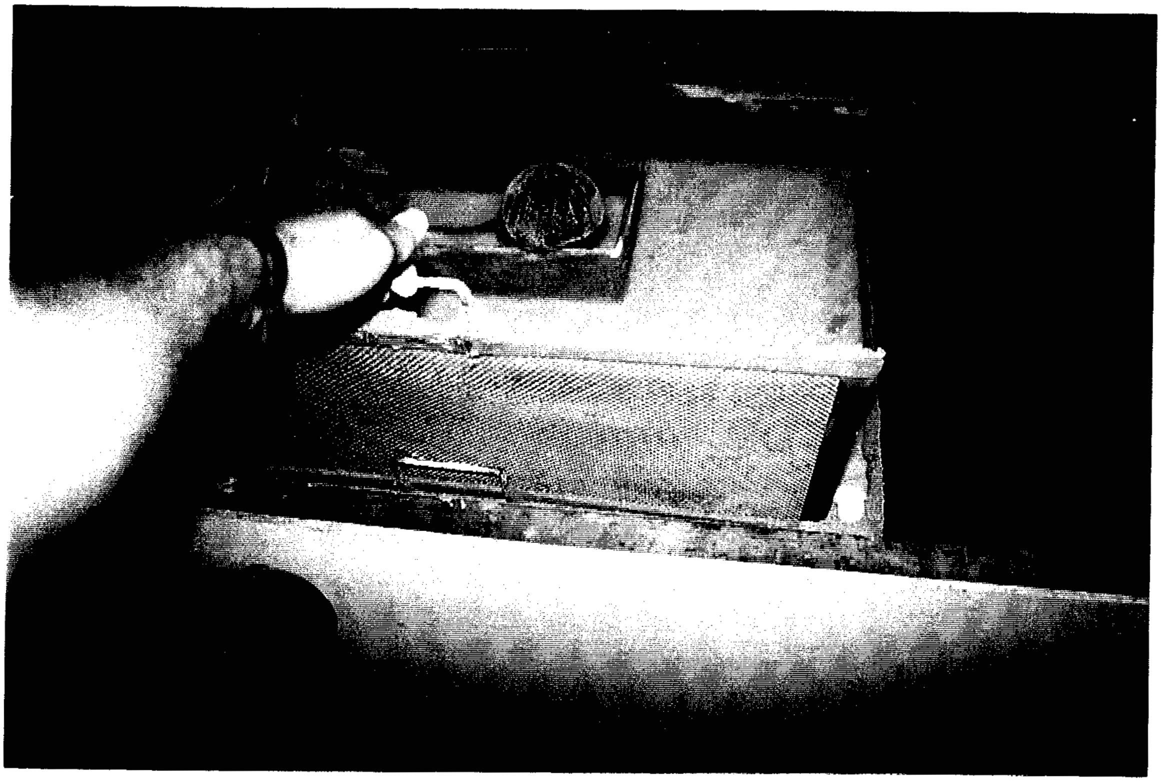
- ✗ Protect pump intakes and significantly reduce the occurrence of plugged nozzles
  - Stainless steel, double screen systems are best
  - Inspect, remove and clean screens daily (one at a time) with high pressure rinse
  - Screen mesh size should be less than the orifice size of the spray nozzles

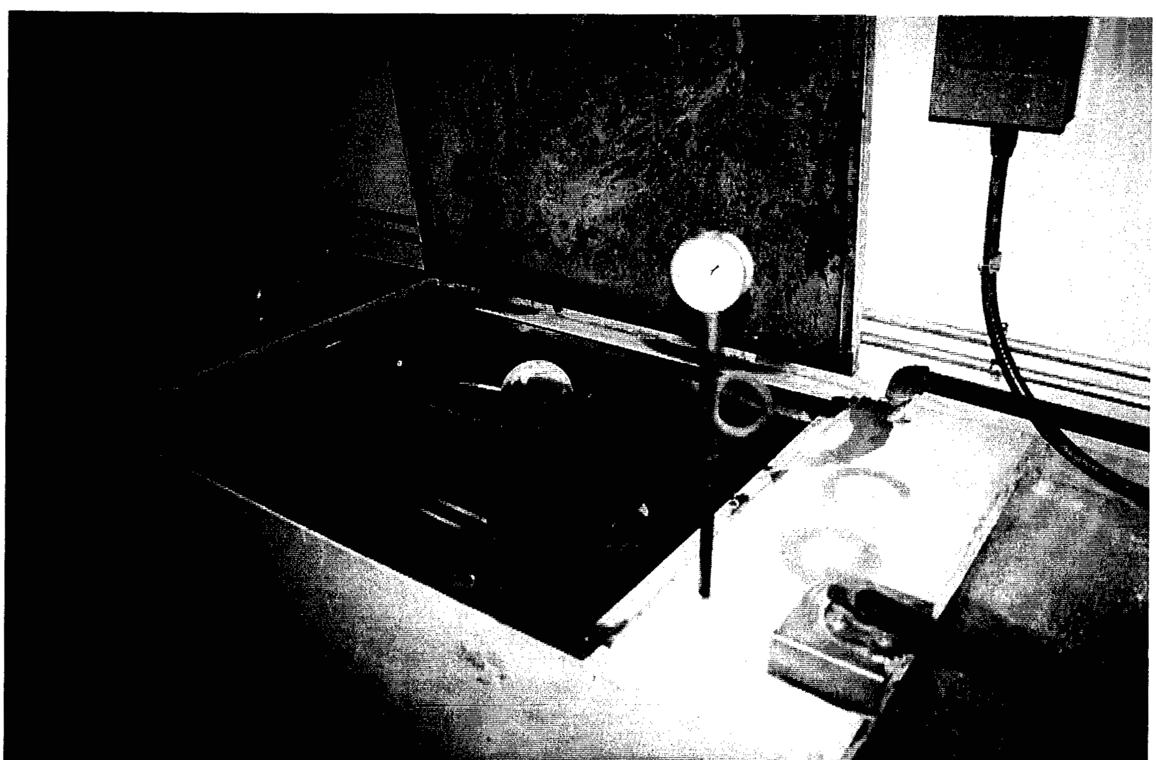
Water feed system

- Inspect daily to ensure adequate fresh water is supplied to the system and that valve mechanisms are working properly

Monitoring and Maintenance

Filter Screens and Water Feed System





Monitoring and Maintenance

Exhaust Fans

- **Designed to prevent solution mists from escaping out the ends of the washer and stage-to-stage contamination**
  - **Check exhaust fan belts for wear (monthly)**
  - **Once a system is balanced - leave as is. Do not change pulleys, dampers or belts**

Controllers, Thermocouples, and Gauges (temperature and pressure)

- **Should be checked and calibrated annually**

Pumps

- **Lubricate as recommended**
- **Inspect for excessive vibration, leakage, protective shields and overheating**

Conveyor Monorail

- **Inspect for wear and corrosion**
- **Ensure lubrication system is functioning**
  - **Contains lubricant**
  - **Dispenses lubricant in correct amount**

Monitoring and Maintenance

Record Keeping

- Pretreatment systems are dynamic with respect to temperature, chemical concentration, pH, and age of bath.
- Need to monitor and log pretreatment conditions, maintenance activities and adjustments
  - Monitor concentration, pH, temperature, operating pressures, and conductivity
  - A maintenance schedule and logbook provides a valuable reference should problems develop
    - Facilitates problem solving in a systematic fashion

Example record keeping logs and a water quality equivalents chart are provided in Appendix A

Troubleshooting

Essentials for Troubleshooting

1. **Maintenance manual - Contains maintenance procedures needed to keep pretreatment equipment operating efficiently**
   - **Contains input from chemical vendor, equipment manufacturer and facility operators**
   - **Topics may include:**
     - **Recommended nozzle size and type by stage**
     - **SOP for inspecting, replacing and cleaning nozzles**
     - **Recommended water levels and info on operating and maintaining fill mechanisms**
     - **Procedures for screen cleaning**
     - **Pressure and temperature recommendations for each stage**
     - **Dump and recharge schedules**
     - **Oil and lubrication info for pumps, motors and monorail**
     - **Information on maintaining washer exhaust systems**
     - **Maintenance log sheets**
2. **Operating manual - Provides an overview of the washer, chemicals specified for each stage and recommendations for solution quality control for each stage. May also include:**
   - **Chemical product information sheets and MSDS**
   - **Daily log sheets**
   - **Tank labels**
   - **Descaling procedures**
   - **Titration information**
   - **Safety information**
   - **Effluent neutralization procedures**
3. **Yearly audit**

Proper training and consistent use of manuals will keep pretreatment process under control, avoiding the need to troubleshoot

Troubleshooting

If process is out of control

- ✗ First Step - define the problem!
- ✗ Determine when problem started
  - ➢ Review recordkeeping
- ✗ Determine where in process problem occurs
- ✗ Determine the source of the problem

Potential Problems

Dirty parts

Foaming

Streaking

Flash rusting

Powdery residue

Coating failures related to inadequate pretreatment are rarely the result of a single, obvious cause[6]

Troubleshooting
Poor Cleaning

Potential Causes

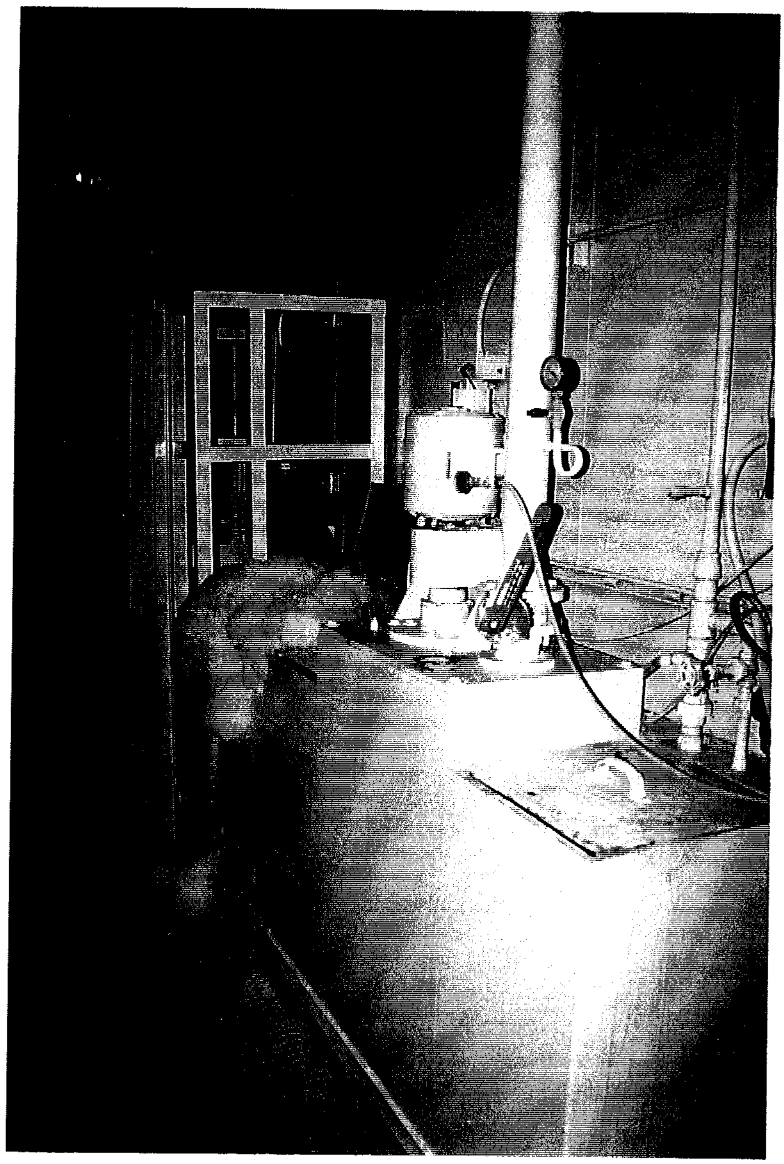
- ✗ **Improper concentration / pH**
  - ➢ Due to neglect, faulty chemical additions or increased soil load
- ✗ **Temperature too low**
  - ➢ Defective thermostat
  - ➢ Faulty or scaled heating element
- ✗ **Change in soil type / quantity or condition of parts before pretreatment**
  - ➢ Drying, aging, welding, forming and poor storage conditions may change a soil's properties, making it more difficult to remove
    - ➢ e.g., varnish and rust formation on parts
- ✗ **Spent cleaning solution**
  - ➢ Time to dump and recharge
- ✗ **Inadequate contact time or poor contact with cleaning solution**
  - ➢ Modify part orientation to improve impingement
  - ➢ Broken equipment
- ✗ **Broken equipment (risers, air lines, impeller, gauges)**
  - ➢ Improper spray pattern
  - ➢ Spray nozzles missing, blocked or misaligned
  - ➢ Blocked pump filter
  - ➢ Improper spray pressure - adjust regulator setting
- ✗ **Rinse stage contaminated by dragout/carry over/overspray**
  - ➢ Improve part drainage through racking / part modification
  - ➢ Increase overflow rate
  - ➢ Re-position spray nozzles
- ✗ **Dirty Washer**
  - ➢ Perform maintenance / complete cleanouts
- ✗ **Poor quality cleaning chemical**
  - ➢ Poor cleaners lessen the quality of the phosphate coating and may cause flash rusting, streaking or powdering

Troubleshooting
Foaming

Potential Causes

- Cleaning stage
  - Soft water
    - Add defoamer
  - Pressure too high
  - Chemical Surfactant package (cloud point) is above actual solution temperature or chemical is not formulated for low temperatures
  - Pump cavitation/sucking air
    - Low solution level, cracked pump head or defective seal
  - Temperature too low
    - Thermostat or heating element needs adjustment or repair
  - Wrong concentration - caused by neglect or faulty chemical additions
    - Monitor and adjust
  - Soils react to form soap
    - Eliminate soils containing animal fats or change cleaning chemicals
- Rinse stage
  - Cleaning solution carry over
    - Orient parts to minimize dragout, ensure parts drain back into previous stage or increase rinse overflow

Troubleshooting
Foaming



Troubleshooting
Other Problems

- *Streaking*
  - Poor cleaning
  - Normal- stress points in metal
  - Poor phosphate coating
  - Poor rinsing
  - Clogged nozzles
  - Excessive sludge
- *Water spotting*
  - Contaminated rinses
    - Dump, clean, and recharge rinse stages
    - Increase overflow
    - Check nozzle direction for stage-to-stage overspray
  - Poor raw water quality -
    - Check conductivity (TDS) of rinse tank solution
    - Dump and clean rinse tanks
    - Increase overflow rate
- *Solids drip line* - a white, chalky line at bottom of parts indicative of concentrated salts and a future corrosion site
  - Contaminated final rinse
    - Need to compare conductivity of rinse water with raw water
      - If large deviation, dump and recharge final rinse to bring conductivity (TDS) back to an acceptable level
    - Minimize solids drip line by repositioning parts to improve drainage or by using directed air blow off

Troubleshooting

Other Problems

- ***Insufficient phosphate coating***
  - Phosphate concentration too low
    - Add phosphating material to attain proper concentration
  - pH too low
    - Raise pH
  - Contact time too short
    - Raise temperature, preclean parts or use detergent additive
  - Workpiece too dirty
    - Raise temperature, preclean parts or use detergent additive
  - Temperature too low
    - Raise temperature to recommended level
- ***Mottling (streaks or spots of different color or shade)***
  - For 5 stage systems - pH too low
    - Adjust pH to recommended level
  - For 3 stage systems - more easily cleaned areas develop heavier phosphate coating or irregular spray causes mottling
    - Use alkaline precleaning
    - Control pH of cleaner-phosphate stage by increasing or decreasing operating acidity
- ***Outgassing of nonferrous casting***
  - Casting too porous
    - Check for casting change
  - Aggressive chemical attack
    - Check that chemical concentrations are at recommended levels
  - Contaminants retained in casting
    - Prebake casting or raise cleaning temperature

Troubleshooting
Other Problems

- ***Poor adhesion on nonferrous casting***
  - **Poor cleaning**
    - **Ensure part passes the water break-free test**
  - **Insufficient etch**
    - **Check for sufficient etch in cleaning and/or phosphating stage**
    - **Check nozzles for coverage and impingement**
    - **Check chemical concentrations**
  - **Change in soil composition**
    - **Check for changes in die lubricant or aging of soil**
- ***Oil bleed out***
  - **Soil entrapment - crimped or sandwiched edges trap soils**
    - **Preclean metal before fabricating/welding**
  - **Change in amount of soil load**
    - **Reduce soil amount**
  - **Change in soil composition**
    - **Change to lighter weight soil**
  - **Pretreatment variables out of control**
    - **Recheck all process variables, particularly temperature**
    - **If oil bleed out continues, prebake parts to fluidize soil**

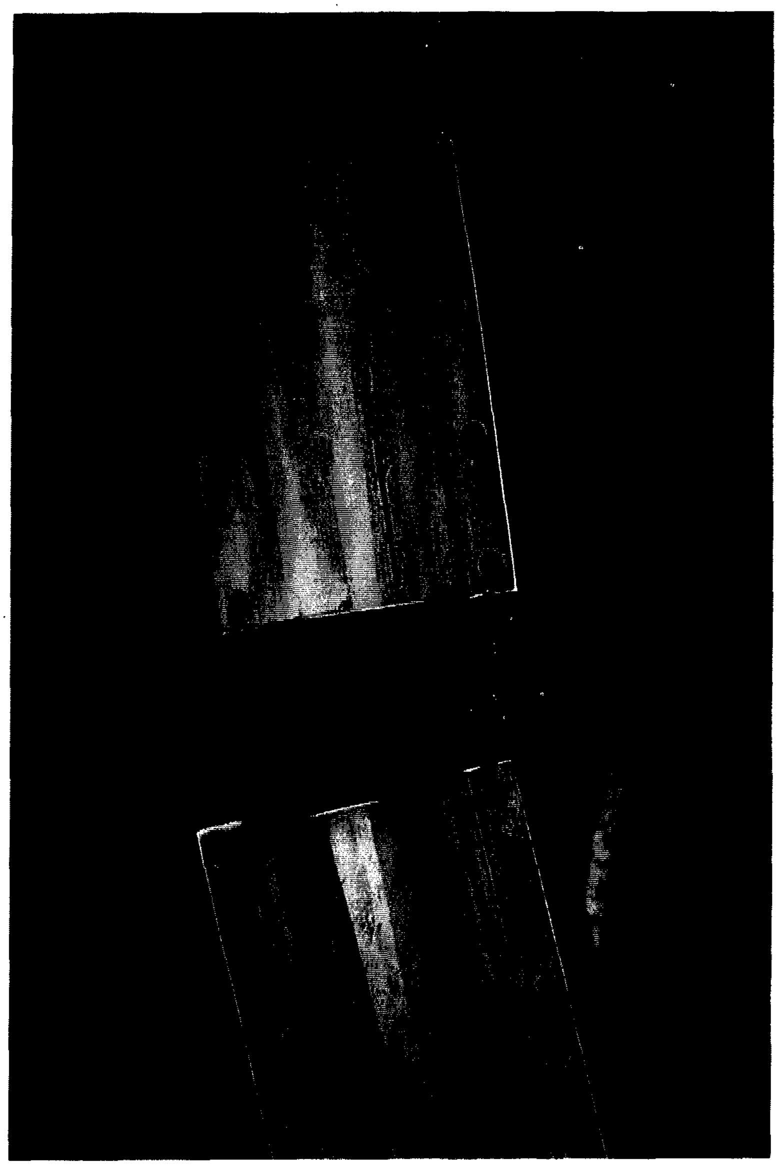
Troubleshooting

Flash Rusting

Potential Causes

- ✗ Line stoppage
  - ➢ Install misting nozzles between stages
    - ➢ Use raw water or used D.I. water at 0.25 gpm
  - ➢ Prevent line from stopping
- ✗ Good cleaning but inadequate phosphate coating
  - ➢ Part not phosphatized long enough
  - ➢ Check strength of operating solution
    - ➢ Bring phosphate solution up to recommended level
- ✗ pH too low (causes pickling of metal substrate)
  - ➢ Increase pH
- ✗ Improper rust inhibitor concentration
- ✗ Low final rinse temperature
  - ➢ Raise temperature or add rinse additive/rust proofing compounds
- ✗ Contaminated final rinse
  - ➢ Increase rinse overflow or replace rinse waters more frequently
- ✗ Time to complete dry-off too long or dry-off temperature too low
  - ➢ Reduce time needed to complete dry off by heating the final stage
  - ➢ Use fans, blowers or air knives at the washer exit to drive off water
  - ➢ Locate the dry off oven as close as possible to the washer
- ✗ Wrong product
- ✗ Water trapped on part in low, recessed areas
  - ➢ Modify part or racking to improve drainage

Troubleshooting
Flash Rusting



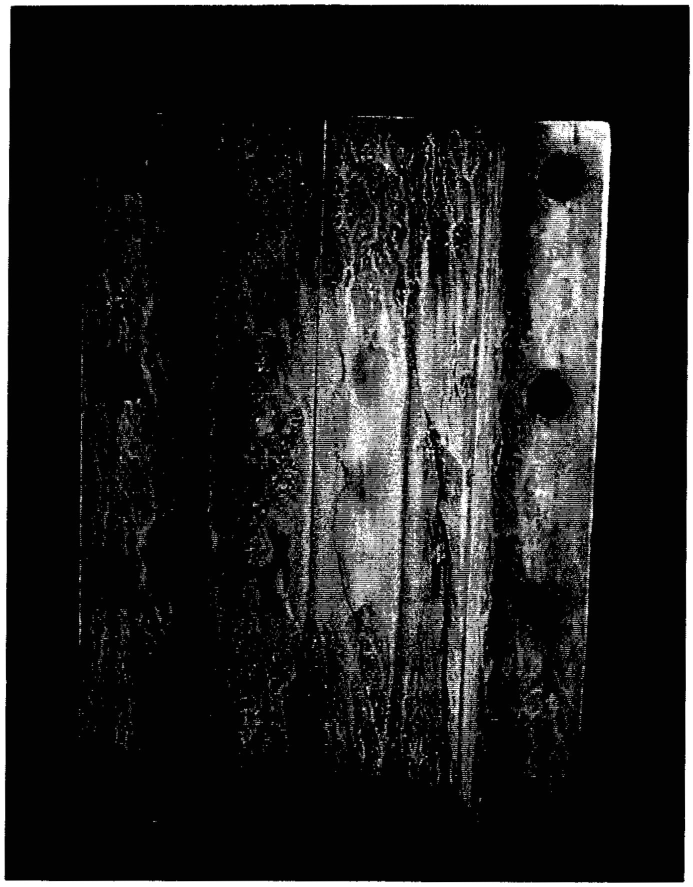
Troubleshooting

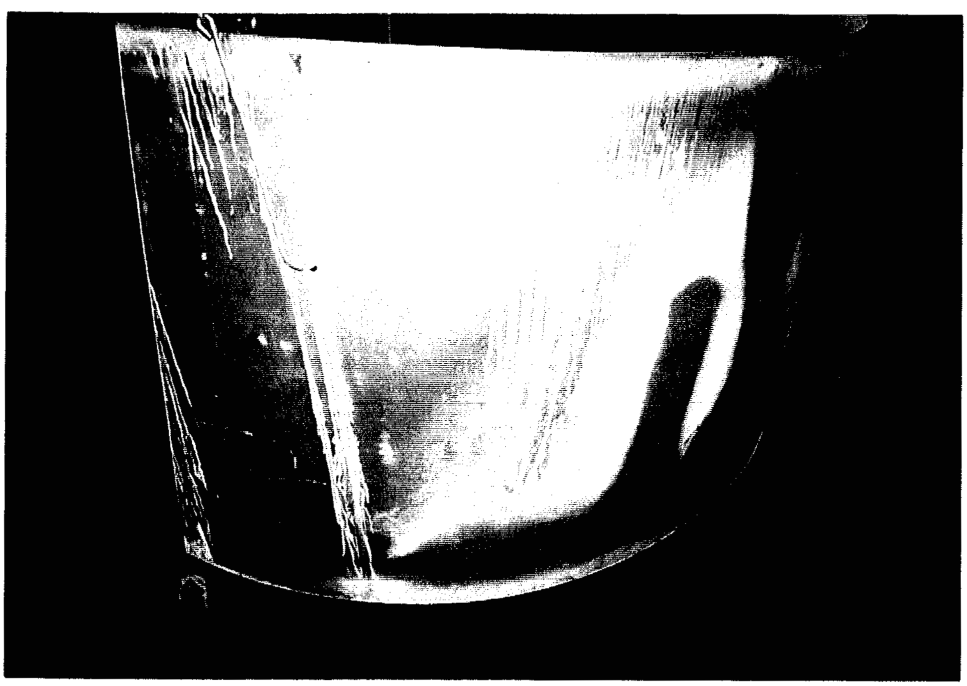
Powdery Coating

Caused by too much phosphate coating

- ✗ **Phosphate concentration too strong**
  - ➢ **Dilute to proper concentration**
- ✗ **Result of line stoppage or chemical solutions allowed to dry between stages**
  - ➢ **Install misting nozzles between stages**
    - ➢ **Use raw water or used D.I. water at 0.25 gpm**
  - ➢ **Prevent line from stopping**
- ✗ **Poor / inadequate rinsing**
  - ➢ **Rinse parts better / longer**
- ✗ **Parts washed too long**
  - ➢ **Wash parts faster**
- ✗ **Excessive contamination in rinse stages**
  - ➢ **Check conductivity (TDS) of rinses**
- ✗ **Excessively high phosphatizing solution pH**
  - ➢ **Use acid additive to bring pH to desired range**
- ✗ **Excessive sludge in phosphatizing bath**
  - ➢ **Remove sludge, renew bath or improve rinsing**
- ✗ **Particulate soils**
- ✗ **Dry-off temperature too high**
  - ➢ **Maintain dry-off temperature below 300° F**

Troubleshooting
Powdery Coating





Troubleshooting

Smut / Soot /Carbon

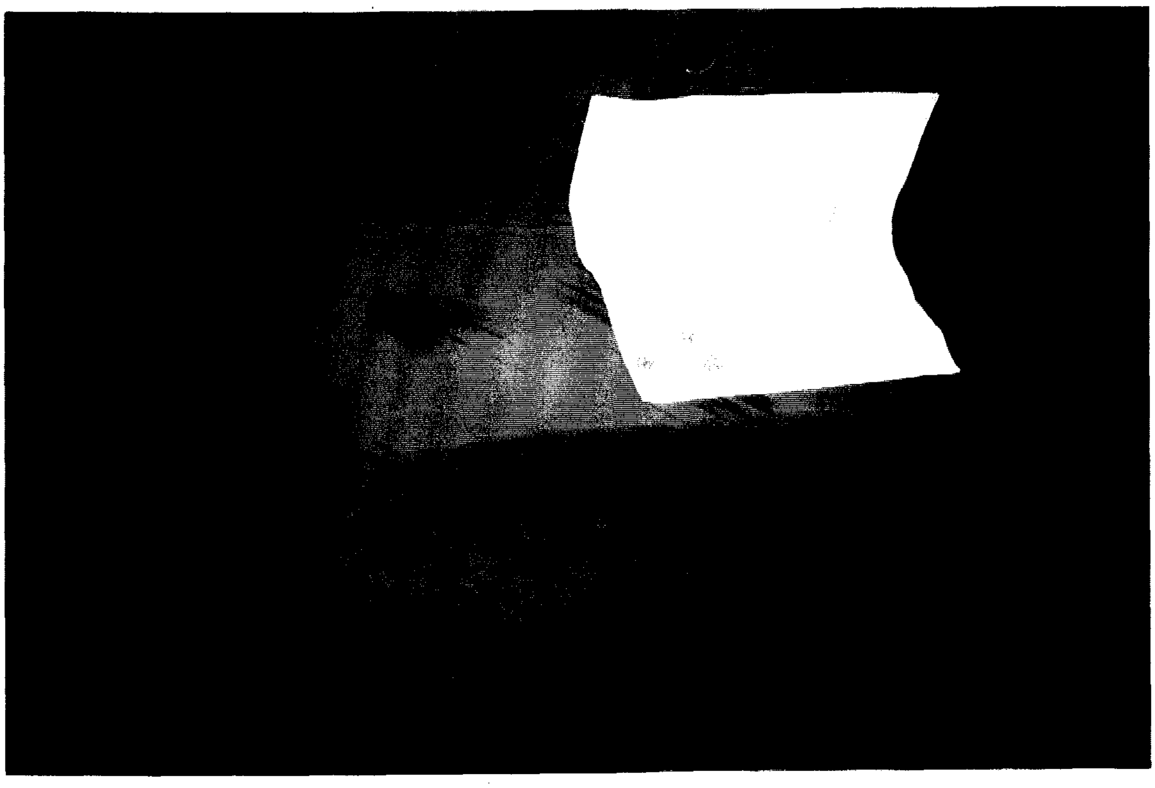
Potential Causes

- ✗ pH too high
  - ➢ **Lower pH of phosphate or cleaner-phosphate solution for more effective cleaning**
- ✗ Deficient spray pattern or impingement
  - ➢ **Check condition of washer nozzles**
  - ➢ **Ensure proper impingement**
- ✗ Poor cleaning
  - ➢ **Bring cleaner concentration up to recommended level**
- ✗ Poor quality steel or improper storage of steel
  - ➢ **Prequalify incoming steel**
  - ➢ **Store steel correctly (e.g., indoors)**
- ✗ Poorly regulated dry-off combustion leaves residue
  - ➢ **Check for proper ignition and combustion**
  - ➢ **Check air-to-fuel ratio**

Troubleshooting

Smut / Soot /Carbon

Black gritty soil commonly found on weldments, hot rolled, pickled and oiled steel



Conserving Water, Chemicals and Energy

Overuse of water increases energy and chemical usage costs

Common pretreatment mistakes that lead to the overuse of water[10]:

- ✗ **Use of high temperature chemicals**
  - ➢ **Shortens chemistry life**
  - ➢ **Increases evaporation**
  - ➢ **Higher maintenance and energy costs**
- ✗ **Use of poor quality cleaners and conversion coating chemistries**
  - ➢ **Causes frequent dumping and recharging, increased water use and places a greater burden on treatment than is necessary**
- ✗ **Water meters are not used on individual process stages**
  - ➢ **Leads to an overuse of rinse water**
- ✗ **Rinse water quality is controlled visually rather than by TDS and pH monitoring**
  - ➢ **Causes ineffective rinsing or water waste**
- ✗ **Improperly hung parts and/or the use of poorly designed hangers**
  - ➢ **Causes dragout, drainage and water cupping problems**
- ✗ **Systems have undersized tank volumes and/or improper drain vestibule lengths**
  - ➢ **Undersized rinse tanks rapidly become contaminated**
    - ➢ **Rinses are overcome by drag-in**
      - ➢ **Tanks have to be dumped and recharged more often**
      - ➢ **Increased water usage and added maintenance**
  - ➢ **Improper drain vestibules accelerate drag-in contamination rates**

Conserving Water, Chemicals and Energy

Tips

- ✗ Investigate high quality-low temperature cleaners, cleaner phosphates and phosphates to conserve energy and generate BTU cost savings - especially with spray washers
  - ➢ Cleaners should remove soils from the part and reject soils from the cleaner bath
    - ➢ Cleaners that reject oils significantly extend bath life
      - ➢ Cleaners that reject oils (nonemulsifying cleaners) result in a floating oil layer that can be removed from the system using an oil skimmer or an oil - water separator
- ✗ Install flow meters to monitor and control water usage
  - ➢ Need to know what you're using!!!
- ✗ Do NOT slug feed chemicals
  - ➢ Use chemical feed pump to keep more constant control over time
- ✗ Counterflow intermediate rinses to conserve water
  - ➢ Counterflow intermediate rinses in 3 and 5 stage washers
  - ➢ 1/3rd as much energy is needed to maintain washer when counterflowing
- ✗ Use automated raw water inflow equipment triggered at preset TDS value
- ✗ Modify parts or part racking to improve drainage
- ✗ Monitor and maintain chemical solutions and rinse water quality on a frequent basis using the appropriate equipment
- ✗ Oversize tank volumes
- ✗ Monitor and maintain rinse stages
  - ➢ Rinsing is often taken for granted
    - ➢ Must receive the same attention as chemical baths
  - ➢ Failure to maintain clean rinse tanks causes excessive chemical consumption, excessive sludging, premature bath life, nonuniform conversion coatings and potential flash rust problems

Conserving Water, Chemicals and Energy

Tips

- ✗ Rack parts so they drain back into previous stage
- ✗ Use adequate drain zone lengths
  - ➢ Typically recommend 1.5 times the length of the longest part

Drainage off part as viewed from a washer access door

Consider installing a filtration system on cleaning stage

- ➢ Filtration to remove solids (bag filters, centrifuge)
- ➢ Ultrafiltration
  - ➢ May be very effective at prolonging bath life
  - ➢ Must be careful to use a membrane compatable with the temperature and pH of the system
  - ➢ Must also ensure the membrane does not deplete the bath of its cleaning chemicals

- ✗ When the cleaning solution becomes depleted, resist the temptation to partially dump the cleaner and recharge only a portion of the system[14]
  - ➢ This practice is not cost effective
  - ➢ Use the recharge event as an opportunity to throughly clean out the stage (with a high pressure sprayer) and maintain the system

References

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4 *Pretreatment for Powder Coating*, Gruss, B.B., May 1988, Metal Finishing

5 *Pretreatment System Maintenance*, Gruss, B.B., February 1991, Powder Coating, p. 16.

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7 *Pretreatment for Powder Coating - Part I,* Gruss, B.B., September 1997, Finisher's Management, p. 24.

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10 *Reducing Pretreatment Chemicals and Water Costs Takes careful Planning,* Gruss, B.B., April 1995, Powder Coating, p. 17.

11 *How to Minimize Pretreatment Problems to Maximize Powder Performance,* Gruss, B.B., April 1994, Powder Coating, p. 37.

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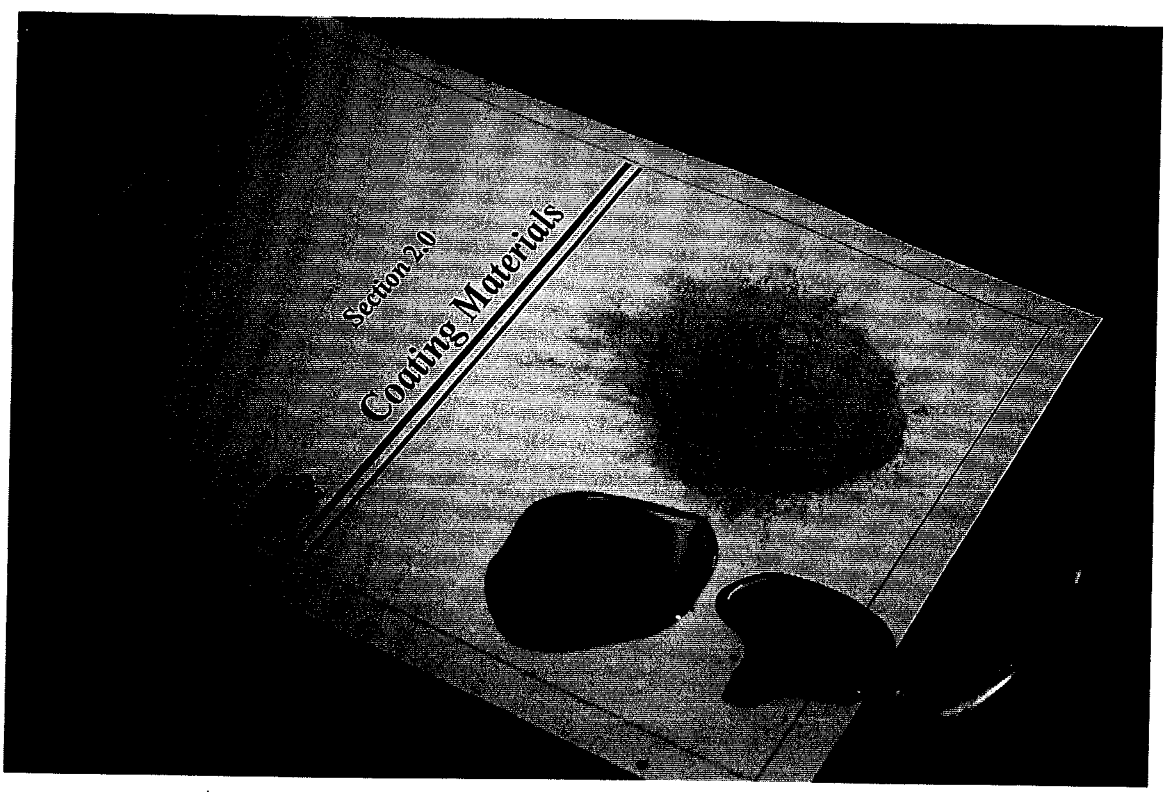
13 *Custom Coating: Powder Coating Process Control,* Cravens, M.W., March 1997, Powder Coating, p. 58.

14 *Troubleshooting Pretreatment Problems*, Gotoff, D.M., May 1997, Proceedings from the Society of Manufacturing Engineers Finishing '97 Conference, p.169.

Section 2.0

Coating Materials



Introduction to Coating Materials

2 Main Categories

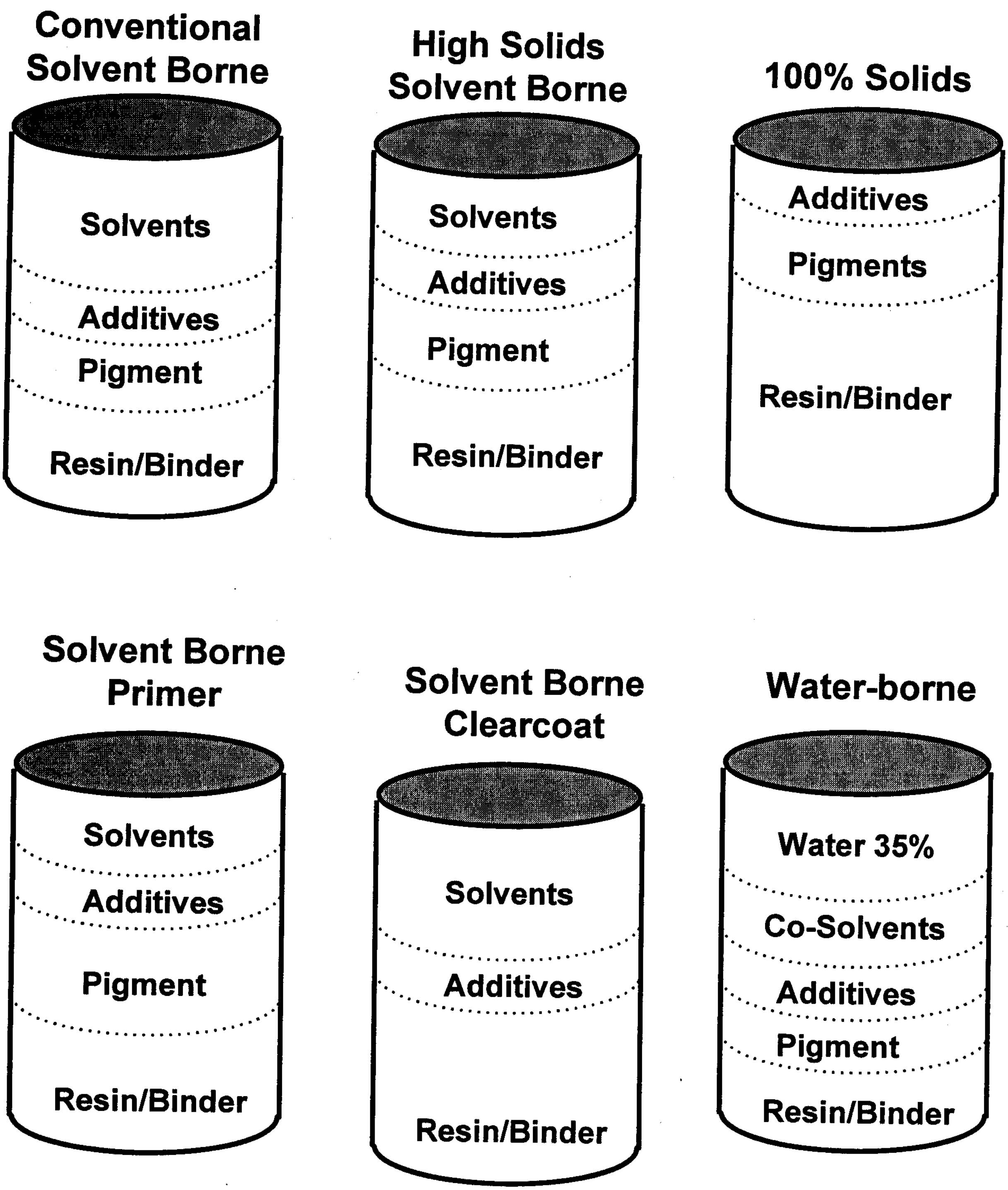
- **Paint** - A coating material applied in liquid form used to protect and/or decorate a substrate when applied in a thin film and cured
  - Solvent-borne
    - Conventional or low solids coatings
    - High solids coatings
      - Two component systems
  - Water-borne / Water Reducible
  - 100% solids
- **Powder coating** - A coating material applied in solid form used to protect and/or decorate a substrate when applied in a thin film and cured

Introduction to Coating Materials

Basic Components

- ✗ Resins (a.k.a. binders or polymers)
  - ➢ Constitutes the majority of the "film former" or solids
  - ➢ The molecules that bond to form a protective film on a substrate (or, more simply, the plastics that make up the bulk of the protective film)
    - ➢ Typical resins - polyester, alkyd, epoxy, acrylic, phenolic, silicone and vinyl
- ✗ Pigments
  - ➢ Usually the second largest contributor to a paint's solids content
  - ➢ Hide the substrate and provides decorative color
  - ➢ Typical pigments - titanium dioxide, carbon black, metallic powders, white and colored inorganic and organic pigments
  - ➢ Most expensive part of paint
  - ➢ Primers contain more pigment for greater resistance to moisture permeation and more aggressive environments
- ✗ Additives
  - ➢ Special purpose chemicals used to obtain desired properties (e.g., mar resistance, leveling, pigment wetting, anti-foaming, thixotropic, etc.)
  - ➢ Comprise a very small portion of the solids in paint
- ✗ Solvents
  - ➢ Play little to no role in final film functional performance
  - ➢ Do have a significant role in ease of application and finish quality
  - ➢ Used to dissolve resins and additives, aid with pigment dispersion and adjust the viscosity of the binder for efficient flow and application
    - ➢ May be broken down into front, middle and tail solvents (i.e., a blend of fast, medium and slow evaporating solvents)
    - ➢ Common solvents include aromatic hydrocarbons, aliphatic hydrocarbons, ketones, and alcohols

Paint
Composition Examples



Paint
Water-borne/Water Reducible

- **Water is used as the primary solvent or dispersent**
  - **Most water-borne products contain 5 to 30% organic solvent (i.e., co-solvent) to aid in fluidity, wetting, viscosity control and pigment dispersion**
    - **Typically contains 2 to 3 lbs. of VOCs per gallon**

Advantages

- ***Lower VOC and HAP emissions***
- ***For same viscosity, may contain more solids than solvent borne paint***
- ***Reduced solvent use for cleaning***
- ***Water is used for thinning - not solvents***
- ***Reduced fire hazard***
- ***Reduced waste disposal problems/costs???***
  - ***How to properly dispose of cleanup waste?***

Disadvantages

- ***Water is corrosive***
  - ***Need stainless steel or plastic fluid delivery equipment and fittings***
- ***Requires tighter controls***
  - ***Part cleaning/pretreatment is more critical***
    - ***Process is less forgiving that solvent-borne***
    - ***Water-borne is much more sensitive to dirt and oil***
    - ***5+ stage pretreatment often recommended***
  - ***Process is more susceptible to humidity and temperature***
    - ***May use dehumidified air to facilitate curing***
- ***Typically more slower drying***
  - ***Drying time characteristics are often reported at 25°C (77°F) and 50% R.H.***
    - ***Variations from these conditions has a significant effect on dry time properties***
  - ***Needs longer flash time***
  - ***More susceptible to surface defects (runs/sags and popping)***
- ***Installation of a voltage block is needed for electrostatic applications because water is highly conductive***
  - ***Isolates fluid supply line from ground***

Paint

Conventional Solvent-borne

- ✗ **Contains over 3.5 lbs of volatile organic compounds (VOCs) per gallon**
  - ➢ **Generally 50-70% solvent or 30-50% solids by volume**
  - ➢ **Typical VOC levels range from 4.5 to 5.0 lbs./gallon**
- ✗ **Rely on solvents to achieve the desired rheology and viscosity**
  - ➢ **Used to lower paint viscosity for ease of application and good atomization**
  - ➢ **Rheology - the complex flow properties of liquid materials.**
    - ➢ **Solvents play a critical role in rheological properties**
- ✗ **Paint contains a blend of fast, medium and slow evaporating solvents**
  - ➢ **Used to develop a product that will atomize, produce a smooth finish, and be free of runs, sags and solvent popping**
  - ➢ **If solvent loss is to great - will see poor flowout characteristics**
    - ➢ **May also get dry spray if too much front end solvent is used**
      - ➢ **Same effect as if using too much air pressure**
  - ➢ **If solvent loss is not high enough - will have more problems with runs and sags**

Paint Particle Dynamics

- ✗ **Paint particle characteristics constantly change from the point where atomization occurs to the time a completely cured film is formed**
  - ➢ **It is estimated that 35-45% of a paint particle's total solvent loss occurs between the gun and the target.**
    - ➢ **Front end (fast evaporating) solvents are lost**
    - ➢ **Viscosity increases as the paint particle travels to the part**
      - ➢ **"In transit" solvent loss helps prevent sagging when paint is deposited onto the part**
  - ➢ **Once the particle is deposited on the part**
    - ➢ **Middle solvents are lost during flash off time (paint loses another 30 to 40 % of its total solvent) and viscosity increases rapidly within the first few minutes on the part**
  - ➢ **Remaining tail solvents are lost during curing**
    - ➢ **Crosslinking occurs during curing**
- ✗ **Booth air flow and paint droplet size have a significant influence over solvent loss**
  - ➢ **Greater atomization = smaller paint droplets = greater exposed surface area = greater solvent loss**

Paint

Solvent-borne Two Component Coatings

- **A subset of solvent-borne - typically urethanes and epoxies**
  - **May reduce the amount of organic solvents in the coating formulation, but does not eliminate solvent use**
    - **Typically has a conventional solvent-borne VOC content**
    - **If unreduced, some coatings may reach high solids status**
- **Consists of two liquids that are mixed together prior to entering the application system**
  - **One liquid contains reactive resins while the other contains a activator or catalyst to promote polymerization of the resins**
    - **The catalyst drives the cure response in order to avoid the requirement for high levels of heat to achieve full cure**
    - **Catalysts are typically added at a predetermined ratio (typically between 3 to 5 parts of coating to 1 part of catalyst - automotive finishes may be as low as 1:1)**
  - **Once mixed, the material begins to increase in viscosity and a finite period of time exists before the mixture solidifies**
    - **This useful period is referred to as "pot life"**
    - **Once a plural component material "locks up", it is essentially impossible to resolubilize, making it necessary to throw away any application equipment in which it has solidified**

Advantages

- **Allows for low temperature processing**
  - **Saves on energy costs**

Disadvantages

- **High cost**
- **Limited pot life**
  - **May create significant amount of waste if mixed incorrectly or if wrong amount is mixed**
- **Rapid viscosity increases with time if batch mixed**
  - **May use plural component mixing systems**
- **Health concerns**
  - **Isocyanates**

Paint
High Solids

- **Contains 3.5 lbs or less of volatile organic compounds (VOCs) per gallon**
  - **Equivalent to approximately 60% solids by weight or 52.4% solids by volume**
    - **Ultrasolids - refers to high solids paint with 75% to 95% solids by volume**
      - **Typically contain 0.5 to 1.5 lbs. of VOCs per gallon**
- **Original driving force - 1973-1974 Arab oil embargo**
  - **Petroleum feedstocks used for resins and solvents were in short supply**
    - **Chemists began experimenting with formulations that required less solvent**
- **High solids industry is now driven by solvent use restrictions**
  - **Concerns over VOC and hazardous air pollutant (HAP) emissions**

Advantages

- ***Alkyd, polyester and acrylic products are readily available***
  - ***Alkyds most widely used***
- ***Significant reduction in VOC and HAP emissions***
  - ***Reduced regulatory requirements***
- ***Less paint needs to be sprayed to provide a given film build***
  - ***Same or better square foot coverage is achieved with smaller volume of paint***
  - ***Less paint must be shipped, stored, pumped and sprayed***
- ***Formulations may be less expensive to produce***
- ***Requires less energy for solvent evaporation***
- ***May be able to reduce oven air supply and exhaust flow rates because of less solvent to volatilize***

Disadvantages

- ***Higher viscosity often requires paint heating to achieve sprayability***
- ***Pretreatment is more critical than for conventional solvent borne***
  - ***Less solvent to "clean as it coats"***
- ***Difficult to clean overspray***
- ***May require some equipment modifications***
  - ***Increased line, pump and filter capacities***

Paint

100% Solids

- **Contain no solvents**
  - **In their base formulation, 100% solids materials have no solvents or other materials which volatilize at room temperature.**
    - **However, during the curing process, they will undergo a measurable loss of material**
    - **Volatiles lost during cure consist of low molecular weight portions of the resin system which volatilize prior to cross-linking of the film**
- **Initially, very low molecular weight polymers were investigated as a means of obtaining low viscosity liquid coatings with 80 -100% solids**
  - **Encountered problems with runs or sags because viscosity of material remained low once deposited on part**
  - **Resolved by using thixotropic additives**
- **100% solids technology relies on thixotropic properties to obtain the rheological properties needed to achieve a usable product and achieve good application**
  - **Thixotropy - the tendency for the viscosity of a liquid to be shear-rate dependent. More simply - when subjected to shear forces or agitation, thixotropic fluids decrease in viscosity**
    - **Specific compounds help impart a high viscosity of a liquid when at rest but allow it to become very fluid or thin when stressed during mixing or pumping**
      - **Brookfield viscosimeters take into account shear influences when measuring viscosity**
      - **Immersion cups (e.g., Zahn, Ford, Gardner, etc.,) measure at rest viscosity**
  - **Consequently, an applicator may receive paint that appears very thick when pouring or pumping but drops in viscosity when subjected to the atomization shear forces of the application equipment**
  - **Once at rest on the surface of the part, the viscosity of the paint particle rises**

Powder Coating

- Powder coating is manufactured, stored and applied as solid material
- Raw material consisting of a powder that is mixed dry, extruded and ground into a final product
  - Consist of resin, pigment, and additives (curing agents, catalysts, reinforcing filler, flow control agents)
  - Completely eliminates organic solvents from the paint formula
- Are applied dry and release negligible VOCs during cure
  - Volatiles lost during cure consist of low molecular weight portions of the resin system which volatilize prior to cross-linking of the film
- Two major powder types - thermoplastic and thermoset

Disadvantages

- Powder is less forgiving than solvent borne paints
  - Pretreatment (cleaning and phosphatizing) is more critical
- Powder usually requires higher cure temperatures than solvent borne
- Long time for color changes
  - In many cases, a company may convert a portion of their operation to powder and continue to use liquid for other colors.

Powder Coating
Thermoplastic Powders

- **Powder melts and flows when heat is applied but retains its original chemical composition once it cools and solidifies**
  - **Thermoplastics do not chemically crosslink upon application of heat**
  - **Film will remelt upon application of heat**
- **Based on thermoplastic resins of high molecular weight**
  - **Properties of these coatings are a function of the properties of the resin**
  - **Provide excellent chemical resistance, toughness and flexibility**
  - **Difficult/expensive to grind into the very fine particle sizes needed for spray application and thin film builds**
  - **Tend to be used in fluidized bed applications rather than spraying**
  - **Tend to be used as thicker functional coatings capable of extreme performance requirements**
    - **Don't tend to compete with paint finishing and thermoset powders**
- **Typical thermoplastic powders include:**
  - **Polyethylene (the first thermoplastic powder coating offered)**
    - **Excellent chemical resistance, toughness and electrical insulation properties**
    - **Provides a smooth, medium gloss finish (lab equipment coating material)**
  - **Polypropylene**
    - **Very inert, causing poor adhesion to metal and other substrates**
    - **Must chemically modify to increase adhesion**
  - **Nylon**
    - **Low coefficient of friction and excellent wear, abrasion and impact resistance**
  - **Polyvinyl chloride (PVC)**
    - **Good exterior durability / flexibility (dishwasher rack coating material)**
    - **Produces a medium soft, glossy finish**
  - **Thermoplastic polyesters**
    - **Good exterior durability/weatherability and do not typically require a primer for good adhesion to most metal surfaces**
  - **Thermoplastic polyamides**
    - **Excellent resistance to detergents, impact and high temperatures**
  - **Polyvinyledene fluorides/fluorocarbons**

Powder Coating
Thermosetting Powders

- **Based on lower molecular weight resins**
  - **When subjected to heat, these coatings melt, flow and chemically cross-link to form a high molecular weight film**
    - **The cured coating has a much different chemical structure than the basic resin**
    - **The coating is also heat stable and will not soften back to a liquid when reheated**
- **Powders of these resin systems can be ground to very fine particle sizes (e.g., average particle size is approximately 25-40 um)**
  - **Provide an excellent balance between appearance, corrosion protection and mechanical properties for many stringent applications**
  - **Suitable for spray application**
  - **Capable of producing thin, paint-like film builds in the 1 to 3 mil range**
  - **Competes with paint finishes**
- **Powders are derived from three basic resins types - epoxy, polyester and acrylic**
  - **Typical powder resin systems include epoxies, polyesters, epoxy-polyester hybrids, and acrylics**
    - **Available in clear and virtually every color, gloss level or texture**
    - **Each resin system meets different performance objectives**

Powder Coating
Thermosetting Powders

- Epoxy
  - Most common and widest range of formulations
  - Used as a thick functional coating or thin film decorative coating
    - Finishes are flexible, tough and high impact strength
    - Excellent corrosion resistance and electrical insulation
  - Poor weatherability and discolor if overbaked
    - Lack ultraviolet resistance - chalks / discolors when exposed to sunlight
      - Still maintains its mechanical and resistance properties
    - Restricted to internal uses or areas with little UV exposure
- Epoxy-polyester hybrids
  - Resin system is often 50% or more polyester, however, properties are more similar to that of epoxy
    - More resistant to chalking and over-bake yellowing than pure epoxies
      - Lower hardness and reduced solvent resistance than pure epoxies
      - Used mainly for decorative applications
  - Exhibit good electrostatic spray characteristics
    - Better T.E. and penetration into recessed areas during application
- Polyester TGIC (triglycidyl isocyanurate - curing agent)
  - Very good mechanical properties, impact strength and superior heat yellowing resistance
  - Very good weather resistance (resists chalking)
- Polyester urethane
  - Excellent thin film appearance, toughness and weathering
    - Good for outdoor applications
  - High flow, good chemical resistance and potentially very high hardness
- Acrylic urethane
  - Excellent color, gloss, hardness, weatherability, chemical resistance and thin film appearance
    - Less flexible than polyesters

Powder Coating

Typical Thermoset Properties

	Epoxy	Epoxy/polyester hybrid	Polyester TGIC	Polyester Urethane	Acrylic Urethane
Application Thickness (mils)	0.5-20	0.5-20	0.5-20	0.5-20	0.5-20
Cure Range (metal temp.. °F)	3 min@450° 30 min@250°	3 min@450° 25 min@325°	7 min@400° 20 min@310°	7 min@400° 17 min@350°	7 min@400° 25 min@360°
Weatherability	Poor	Poor	Very Good	Very Good	Excellent
Pencil Hardness	HB-5H	HB-3H	HB-2H	HB-3H	H-3H
Direct Impact Resistance (in-lb.)	60-160	60-160	80-160	60-160	20-60
Adhesion	Excellent	Excellent	Excellent	Excellent	Excellent
Chemical Resistance	Excellent	Very Good	Good	Good	Very Good

Source: Powder Coating Institute Technical Brief No. 1

Section 3.0

Liquid Spray Application Equipment

Introduction to Application Equipment

Atomization - the breaking up of paint into fine particles or droplets.

May classify application equipment based on the primary method used to atomize the paint

❶ **Air atomization - atomization is achieved using compressed air**

- **Conventional air spray**
- **High Volume Low Pressure (HVLP)**

❷ **Hydraulic atomization - atomization is achieved using hydraulic pressure**

- **Airless**
- **Air-assisted airless**

❸ **Centrifugal Force**

Each type of equipment has its advantages and limitations

Introduction to Application Equipment

Spray Gun Selection

★ Need to Consider

- Cost
- T.E. rating
- Production speeds
- Coating material
- Type of substrate (is electrostatic application possible?)
- Finish appearance requirements
- Part geometry
- Variation in part size
- Spray gun flexibility (e.g., how readily can the spray pattern size be adjusted to fit parts of various sizes?)
- Maintenance requirements
- Manufacturer/vendor support/service

★ Most Importantly

- Equipment should be compatible with support equipment, the coating to be sprayed and production rates.
- Choose equipment that will effectively atomize the coating at a low pressure setting.

Introduction to Application Equipment

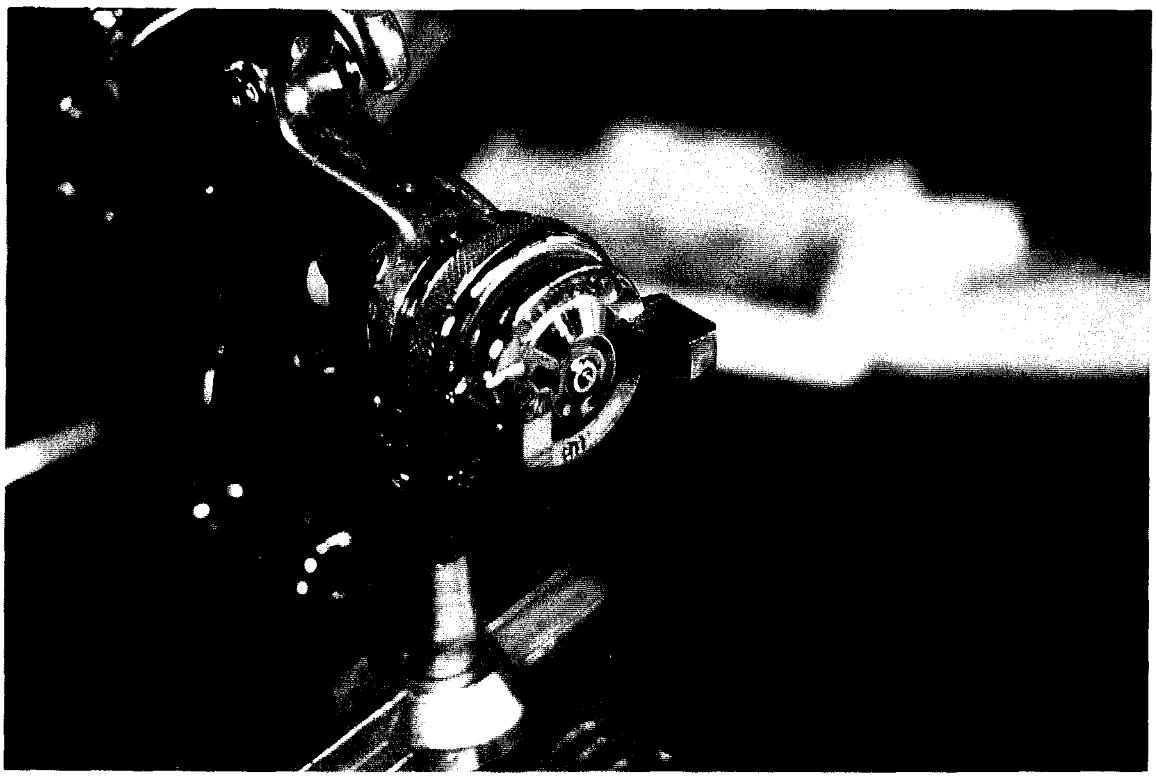
Misconceptions of Gun Efficiencies

Rated Spray Gun Efficiencies Have Limited Meaning

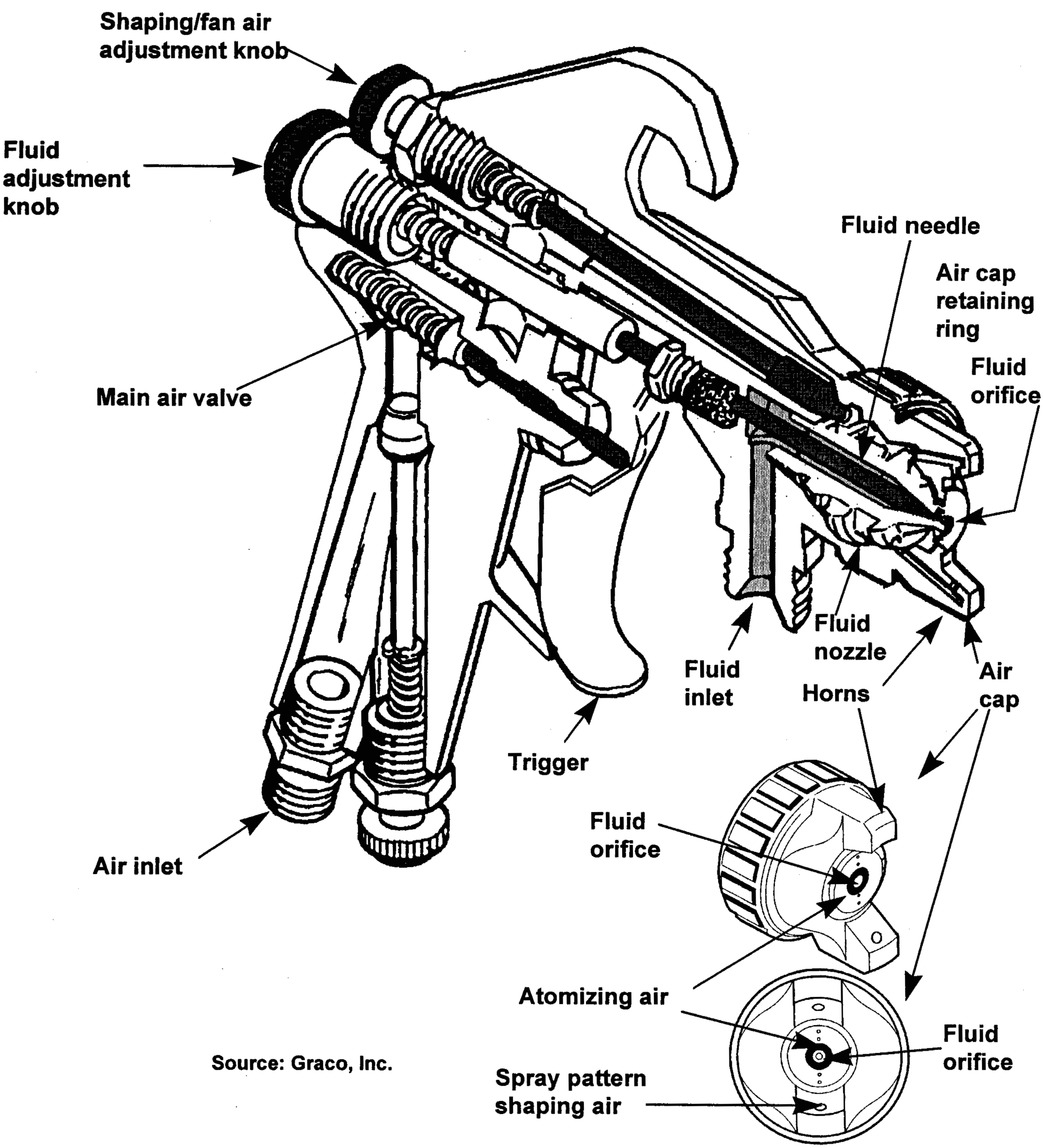
- **Equipment T.E. ratings represent ideal conditions**
  - **Technician's Skill?**
  - **Gun Settings?**
  - **Coating Type / Characteristics?**
  - **Distance?**
  - **Surface Geometry?**

Air Atomization
Spray Gun Equipment

- Uses compressed air to atomize the paint
- Includes conventional air spray guns and High Volume - Low Pressure (HVLP) spray guns
  - Conventional and HVLP are similar in appearance
- Conventional and HVLP guns are available as siphon, gravity and pressure feed systems
- Need a sufficient volume of clean, dry, oil-free air
- Properly selected air caps and fluid tips are needed for proper fluid delivery and atomization



Air Atomization
Spray Gun Components



Source: Graco, Inc.

Air Atomization

Siphon Feed Guns

a.k.a. - vacuum, suction or cup gun

- **Paint is typically supplied by a cup mounted beneath the gun**
- **Recognized by the fluid tip protruding through the air cap**
- **Air from the air cap draws paint from the cup through the fluid nozzle**
  - **Fluid flow rate is determined by air pressure setting, fluid viscosity and fluid nozzle size**
- **Best for applications that require spraying small quantities of paint, frequent color changes and low production rates**
- **Pressures of 30-60 psi are best for an efficient quality finish**
  - **Higher pressures cause more overspray**

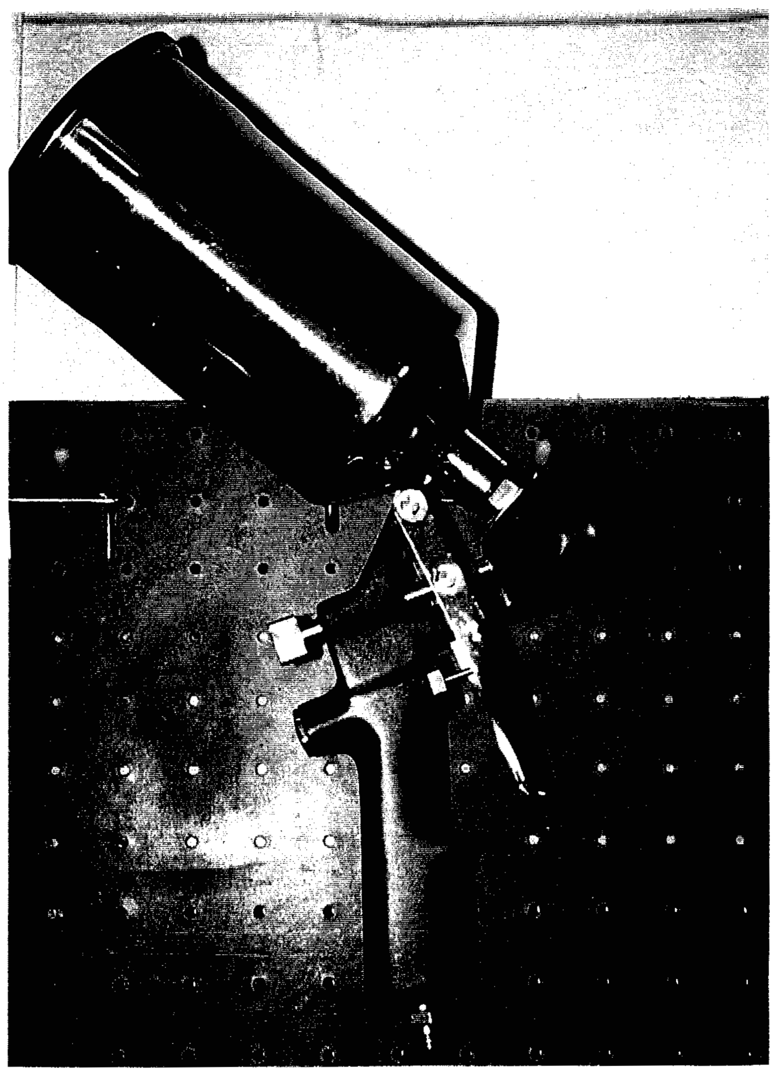
Disadvantages

- ***Limited control over fluid delivery rate***
  - ***At a given fluid adjustment valve setting, fluid delivery rate cannot be regulated independently of air pressure to gun***
    - ***At a given fluid adjustment valve setting, may increase air pressure to gun to increase fluid delivery rate. However, fluid delivery rate is not directly proportional to air pressure setting***

Air Atomization

Gravity Feed Guns

- Fluid is supplied by a cup mounted above the gun
- Fluid flows as the result of gravity
- Fluid flow rate is a function of the fluid nozzle, air pressure, fluid level in the cup and fluid viscosity
- Best suited for jobs that require smaller amounts of paint
- Are capable of handling higher viscosity fluids than siphon feed systems
- Only one adjustment on a gravity feed - air pressure



Air Atomization
Pressure Feed Guns

- ✗ Fluid pressure is provided by an external source such as an air pressurized cup, pressurized tank or pump
- ✗ Fluid delivery rate is determined by fluid pressure, fluid nozzle size, and fluid viscosity
  - ➢ Fluid pressure rarely exceeds 15 psi at the fluid nozzle
- ✗ Provide better control over fluid delivery than siphon or gravity feed systems
  - ➢ Are capable of moving large amounts of fluid without constantly refilling a paint cup
  - ➢ More suitable for industrial applications and higher production rates
  - ➢ Typically there are two areas of adjustment on pressure feed systems
    - ➢ Atomizing air pressure - controlled by air regulator
    - ➢ Fluid flow controlled by fluid regulator or regulator on pressure pot

Air Atomization

Conventional Air Spray

- Uses compressed air at high pressures to atomize the paint
  - Air pressures - 30 to 100 psi (typically 50-60 psi)
  - Air volume - 6 to 18 scfm (typically 14 to 16scfm)
- Low fluid pressures (2-50 psi)
- Flow rates = 3 to 45 ounces/minute (flow rates above 12 ounces/minute typically require pressure feed systems)

Advantages

- *Produces fine atomization and smooth finish*
- *Good operator control and penetration into recesses*
  - *Spray pattern size is adjustable*
  - *Partial triggering capabilities*
- *Rugged, requires no special equipment, low maintenance and is less costly than electrostatic systems*

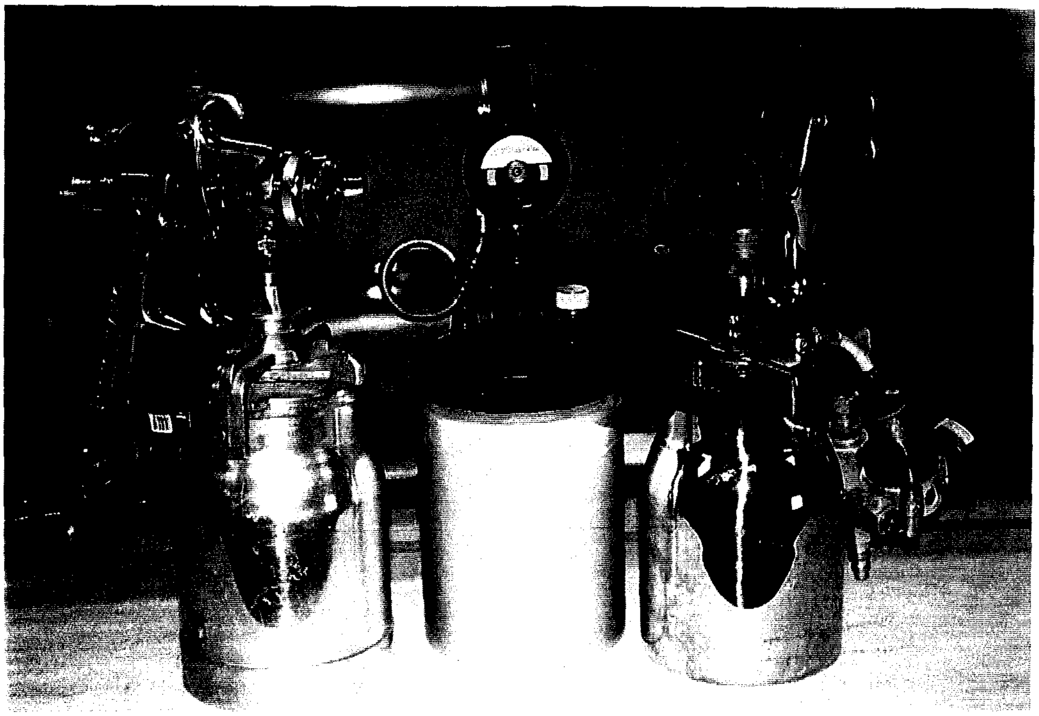
Disadvantages

- *Produces excessive overspray*
  - *Excessive air flow and air pressure cause over atomization*
    - *High pressure conventional air spray can produce paint particles of 12 microns or less SMD (Sauter Mean Diameter)*
    - *These ultra fine particles tend to miss the target and become overspray*
    - *They also tend to readily lose their vehicle and flow type solvents*
- *Low transfer efficiency - 15 to 40%*

Air Atomization

High Volume Low Pressure Air Spray

- HVLP - Resembles conventional air spray guns - HOWEVER, uses a high volume of compressed air at low pressure to atomize the paint
  - Recognized by larger sized air passages
  - 10 psi or less at air cap
    - For compressed air guns - air pressure is reduced using a precisely designed orifice inside of gun or at the air regulator at the gun inlet
    - HVLP turbine guns also available
  - 13- 30 scfm
  - Low fluid pressures (2-50 psi)
  - Flow rates = 3 - 15 oz./min
- Important to ensure adequate scfm to prevent air starvation
  - Avoid QDs and fittings that restrict air flow
  - Use 3/8" air hose minimum
- High solids / highly viscous material may be difficult to atomize



Conventional siphon feed gun (left) and HVLP pressure feed guns (middle and right)

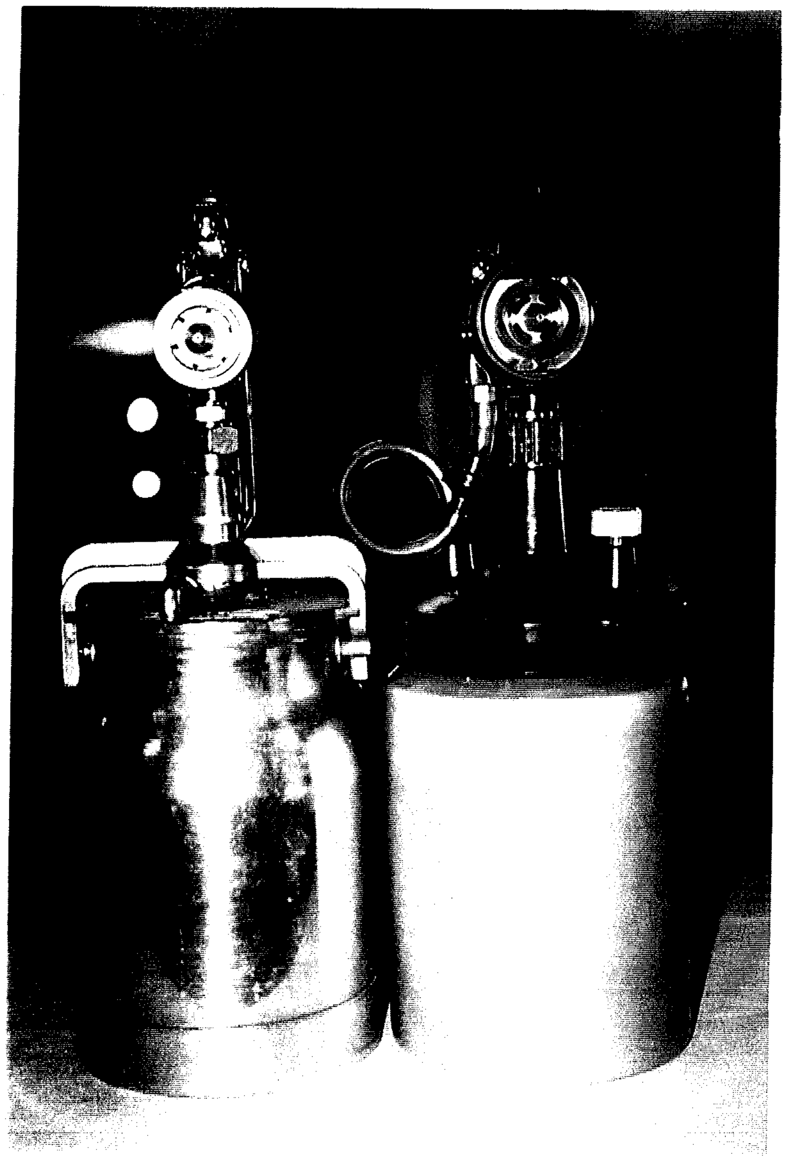
Air Atomization

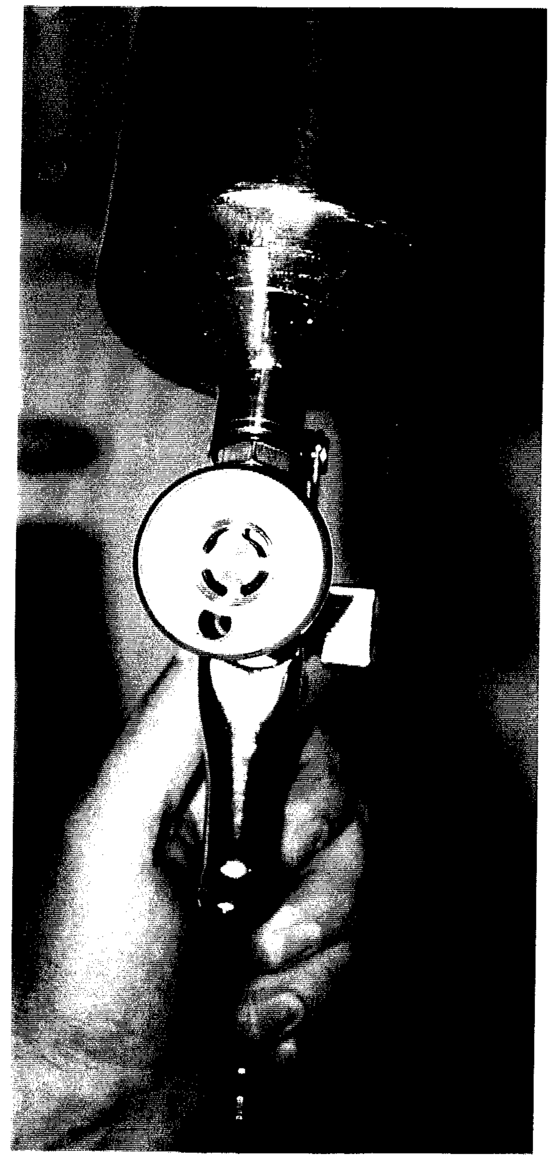
High Volume Low Pressure Air Spray

Advantages

- ***Provides a soft spray (low particle velocity) and good finish***
  - ***May need to hold gun closer to target and use slower stroke speed because of the slower forward speed of the atomized paint particles***
- ***Better transfer efficiency than conventional***
  - ***T.E. 30 to 65% (2 to 3 times more efficient than conventional)***
    - ***Reduced material consumption***
      - ***Material savings of 30 to 50% have been realized***
      - ***Increased T.E. often compensates for reduced fluid delivery rate (as compared to conventional spray guns)***
  - ***Less overspray/turbulence because of lower air pressure***
    - ***Cleaner work environment***
      - ***Less booth maintenance***
        - ***Less frequent changeout of booth arrestors***
    - ***Reduced personal protective equipment (PPE) purchases***
    - ***Reduced risk of contaminating finish***
  - ***Coarser atomization than conventional, producing a film thickness that is often greater than conventional air spray equipment***
    - ***Improved film build per spray gun pass = increased productivity***
      - ***May require fewer passes to achieve desired mil thickness (i.e., only require one coat instead of two)***
  - ***Good operator control and penetration into recesses***
    - ***Spray pattern size is adjustable***
    - ***Partial triggering capabilities***
  - ***Rugged, requires no special equipment, low maintenance and is less costly than electrostatic systems***

Air Atomization
Spray Guns





Note size of air passages of conventional gun (far left) vs. HVLP guns (middle and right spray guns)

Hydraulic Atomization

- Atomizes paint by hydraulically forcing it through a small diameter orifice.
  - Degree of atomization and fluid delivery rate are a function of the fluid tip/nozzle selected, fluid (hydraulic) pressure used and fluid viscosity
    - Change fluid tips to adjust fluid flow or atomization.
    - For a given fluid pressure and viscosity
      - smaller orifice = finer atomization and reduced fluid delivery rate
- Fluid tips are designed with specific orifice diameters and spray fan angles (designed in degrees)
  - Orifice diameters range from 0.007" to 0.036"
  - Spray fan angles range from ~ 15° to 80°
    - Controls size of spray pattern
- Manufacturers provide information on spray pattern size and fluid flow rates for a given fluid tip/nozzle
- Need to consider part geometry, coating, production speeds and required film build when selecting fluid tip
- Fluid injection hazard
- Velocity increases as fluid pressure increases through orifice
- Need to consider part geometry, coating and required film build when selecting fluid tip, air nozzle and operating pressures.

Hydraulic Atomization

Airless Spray

- **Strictly uses hydraulic pressure for atomization**
  - **No compressed air**
  - **One hose to gun (fluid hose)**
  - **Highest fluid pressure - typically 1500 to 3000 psi**

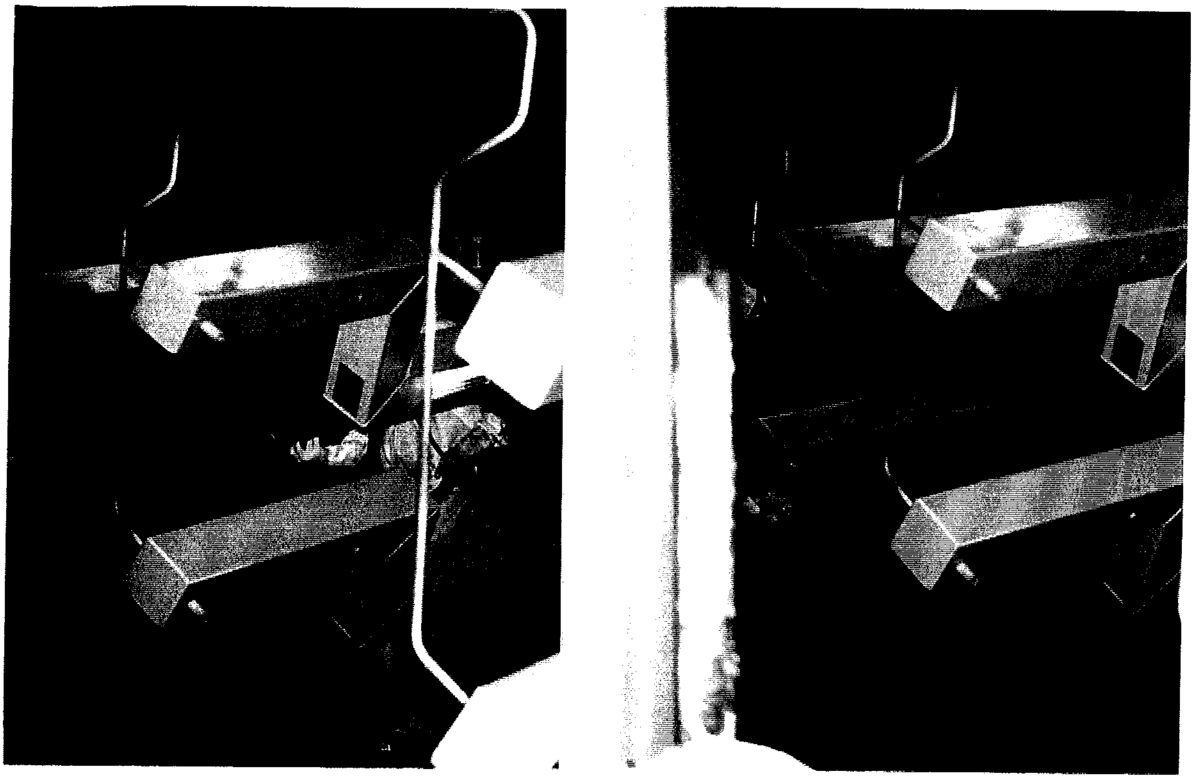
Advantages

- ***High fluid delivery rate capabilities = higher production rates***
- ***Less turbulence and overspray than conventional air spray equipment***
- ***Transfer efficiency - 20% to 50% (75% reported on flat, one-sided ware)***
- ***Good for penetration into recesses***
- ***Capable of spraying high viscosity coatings because of the high fluid pressures***

Disadvantages

- ***Not suitable for fine finishes - produces larger particles than other application equipment***
- ***Limited operator adjustments***
  - ***Tip selection and fluid pressure control size of spray pattern and fluid flow rate***
  - ***No partial triggering capability***
- ***Get "tails" with difficult coatings***
- ***Fluid tip/nozzle has a tendency to plug***
- ***Fluid injection hazard***
  - ***Fluid pressures of 700 psi and above pose a fluid injection hazard***
    - ***Wounds can occur if gun is pointed close to skin while being operated - skin contact with spray gun IS NOT necessary***
    - ***ANY injection wound, no matter the size, must receive immediate medical attention***

Hydraulic Atomization
Airless Spray



Airless gun being used to apply a primer

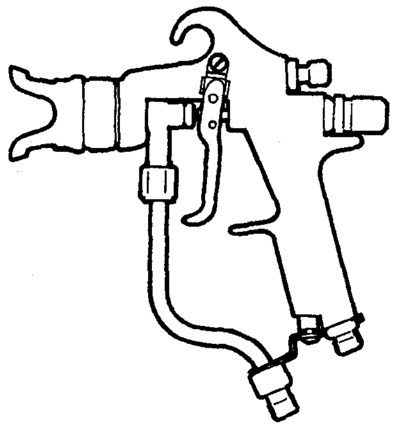
Hydraulic Atomization

Air-Assisted Airless

- **Combines features of air spray and airless spray**
  - **Combines hydraulic atomization with compressed air**
  - **Uses moderate fluid pressures (approximately 400 to 1500 PSI) to force paint through an airless tip (achieves atomization)**
  - **Also uses compressed air to shape the pattern and get rid of "tails"**
    - **5 to 30 PSI, 1 to 3 scfm**
    - **Has little effect on atomization**

Advantages

- ***Technology offers the flow rates and speed of airless while providing finer atomization than airless***
  - ***Produces a better finish than airless***
- ***Allows parts to be sprayed at lower fluid pressures***
  - ***Lower fluid pressure = lower paint particle velocity = reduced overspray***
  - ***Improved transfer efficiency over airless***
    - ***T.E. ratings ~ 35 to 60%***
  - ***Lower fluid pressure = less wear on spray gun parts***
    - ***Fluid tips wear over time***
      - ***Cost $50 to $90 per tip***
      - ***Worn tips waste paint***

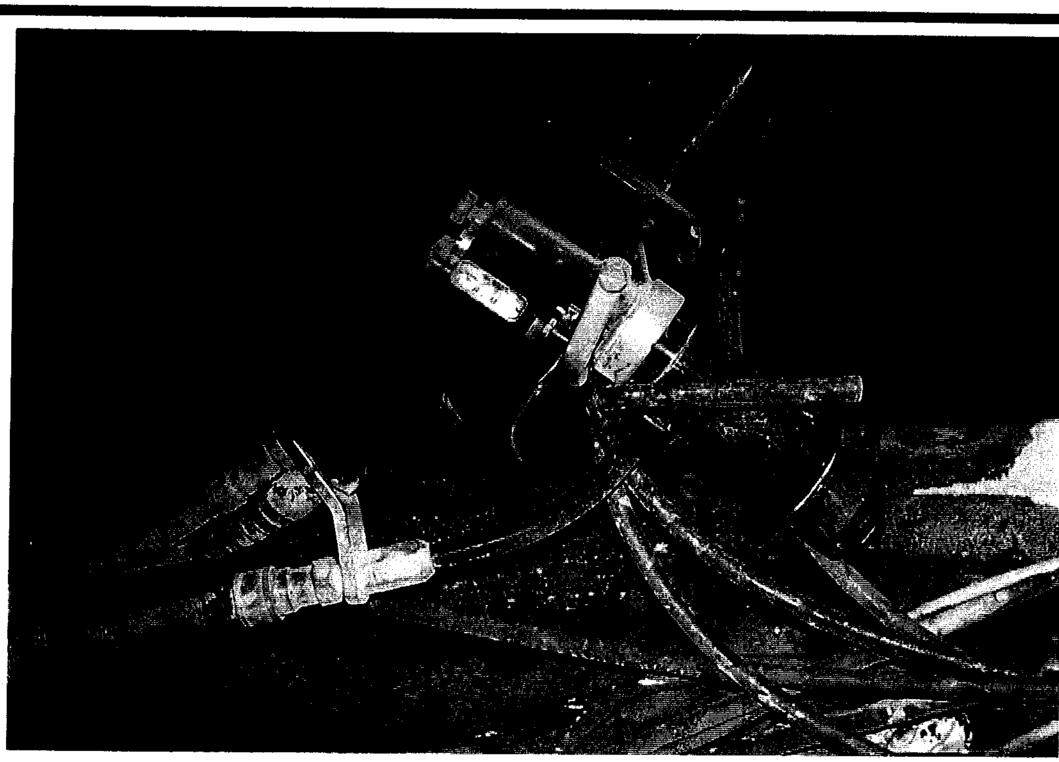


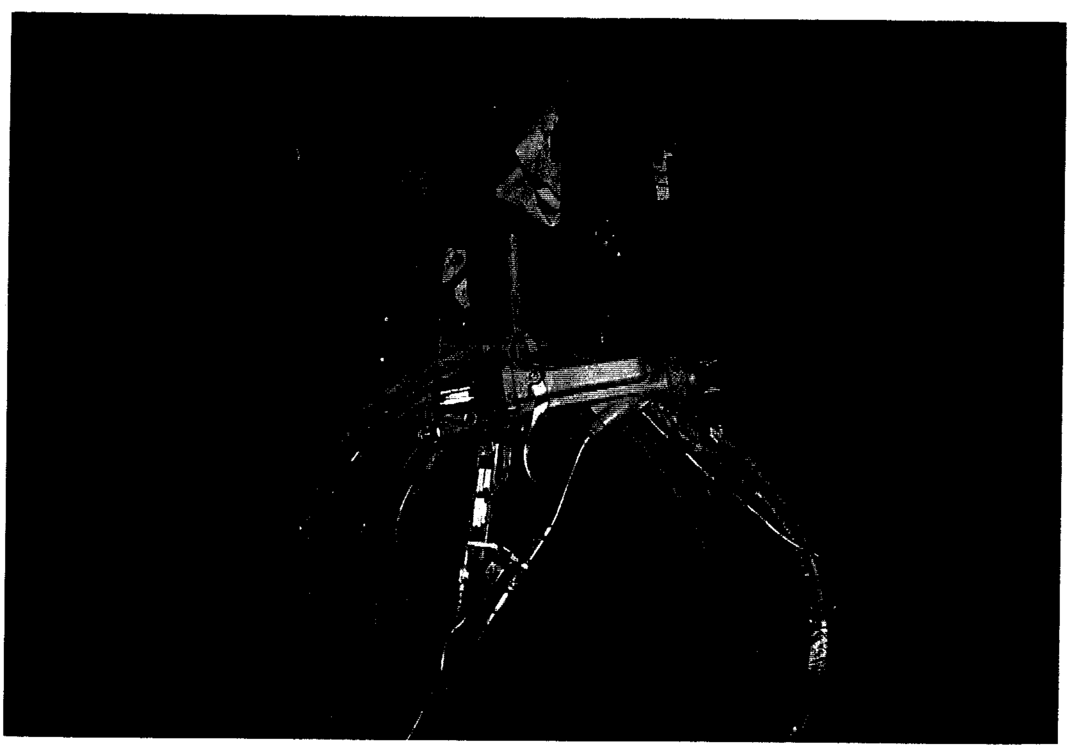
Disadvantages

- ***Limited operator adjustments***
  - ***Tip selection & fluid pressure control size of spray pattern and fluid flow rate***
  - ***No partial triggering capability***
- ***Fluid tip/nozzle has a tendency to plug***
- ***Fluid injection hazard***
- ***Requires extra hose over airless***

Hydraulic Atomization

Air-Assisted Airless





Electrostatic air-assisted airless guns

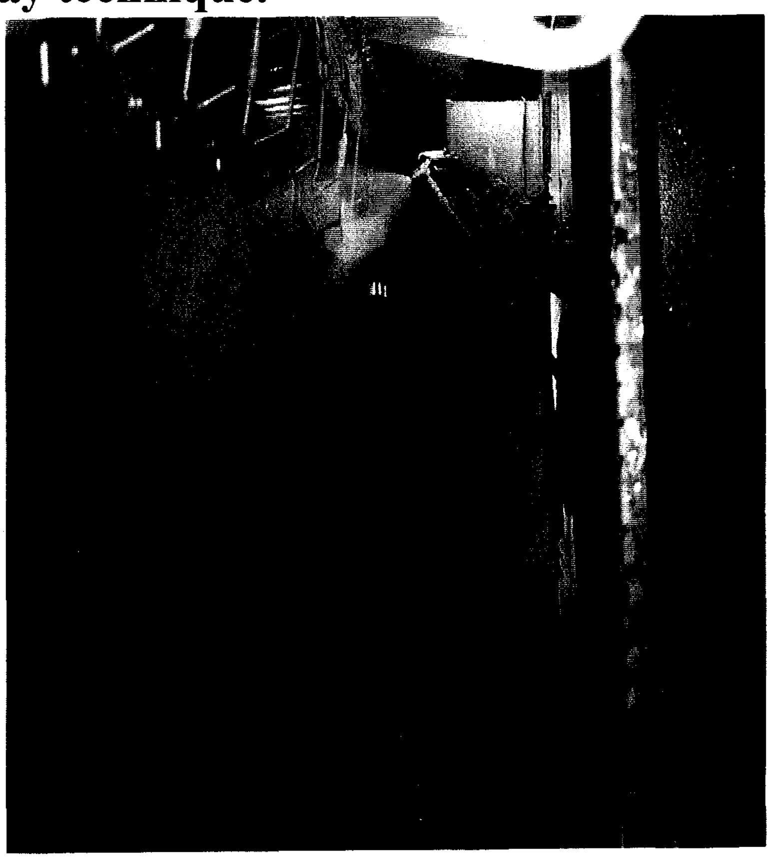
Spraying Efficiency

MORE IS NOT

NECESSARILY BETTER!!!

Key Concepts

- ✗ Always operate at the lowest fluid and air pressures that will give good atomization and the required flow rate for production.
- ✗ Select a spray pattern that best fits the part.
- ✗ Keep the spray pattern on the part.
- ✗ Use good spray technique.



Note size of spray pattern compared to part size, gun angle and part presentation to spray technician.

Gun Setup

Review owner's manual for recommended spray gun setup procedure

In General

❶ **Measure and record paint viscosity and temperature**

- ➢ **Adjust if needed**

❷ **Select an appropriate spray pattern for the parts to be sprayed**

❸ **Adjust fluid delivery rate in appropriate increments**

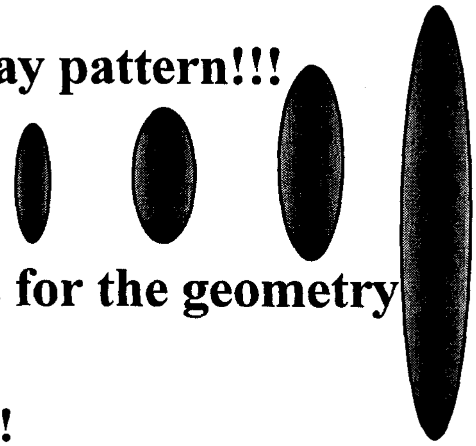
- ➢ **Fluid delivery rate = the amount of material (in ounces per minute) being emitted from the tip of the fluid nozzle.**
- ➢ **Flow rate should be as low as possible.**
  - ➢ **Only need to deliver enough paint to provide the desired finish and mil thickness in the time allotted.**

❹ **Adjust atomization in appropriate increments**

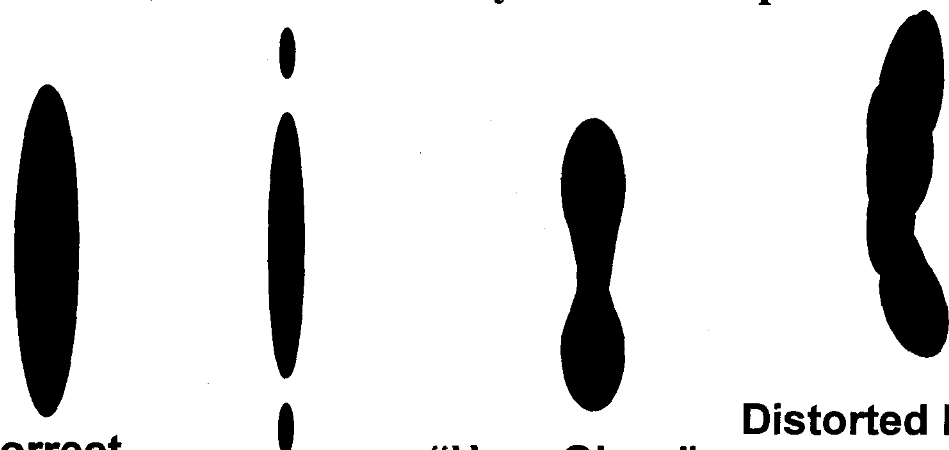
Record Optimal Settings!!

Routinely check and maintain all settings!!

Gun Setup
Spray Pattern Control



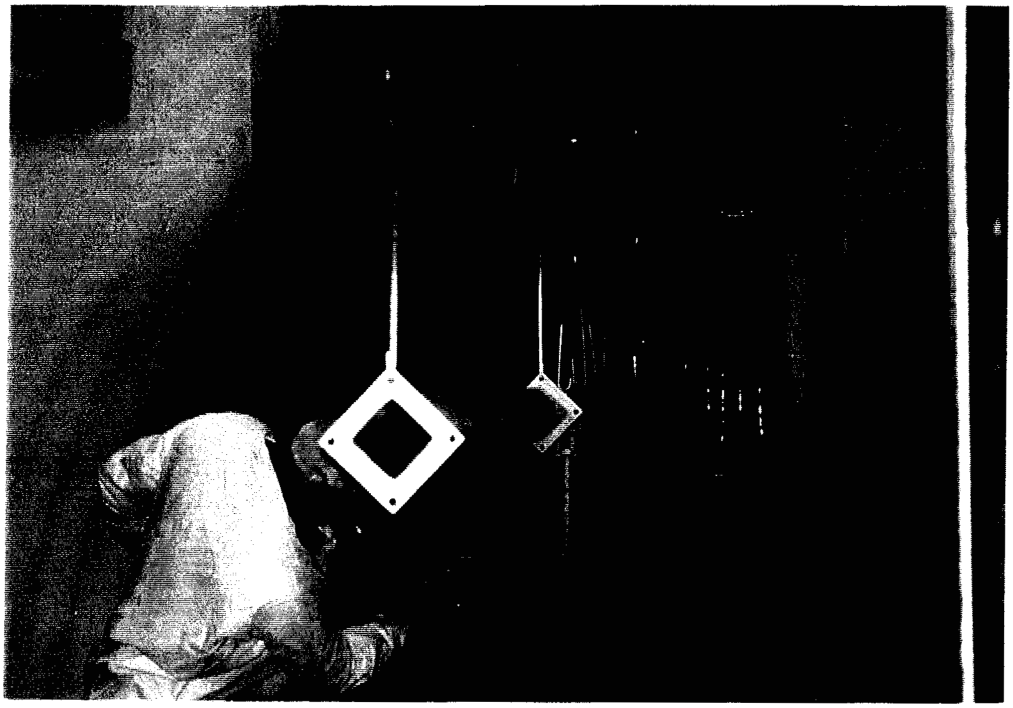
- ★ **Know the shape and size of your spray pattern!!!**
  - ➢ **Shoot test patterns**
- ✗ **Spray pattern should be appropriate for the geometry of the part being sprayed**
  - ➢ **Use a fan size that best fits the part!!!**
    - ➢ **T.E. drops dramatically if fan size for a part is too wide**
- ✗ **Check spray pattern daily!!!**
  - ➢ **Provides a visible indication of problems with atomization, fluid/air delivery and fluid tip.**

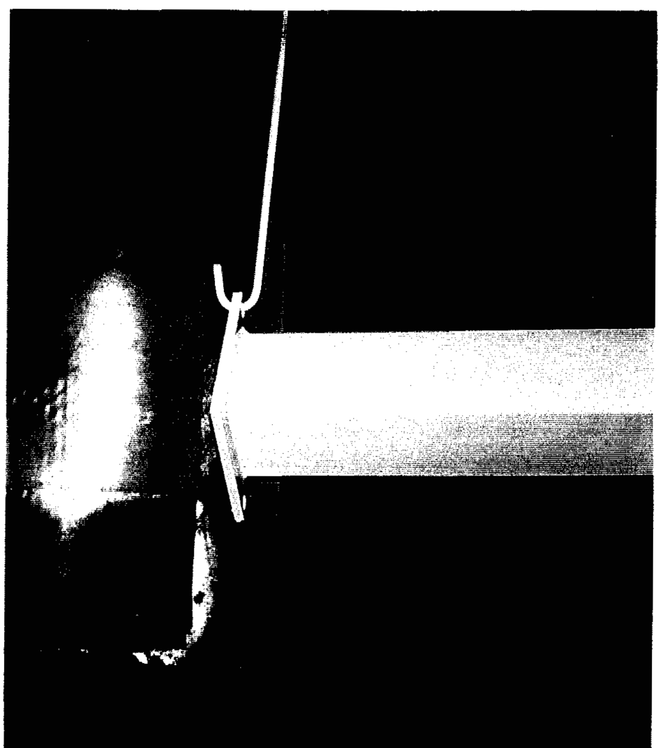


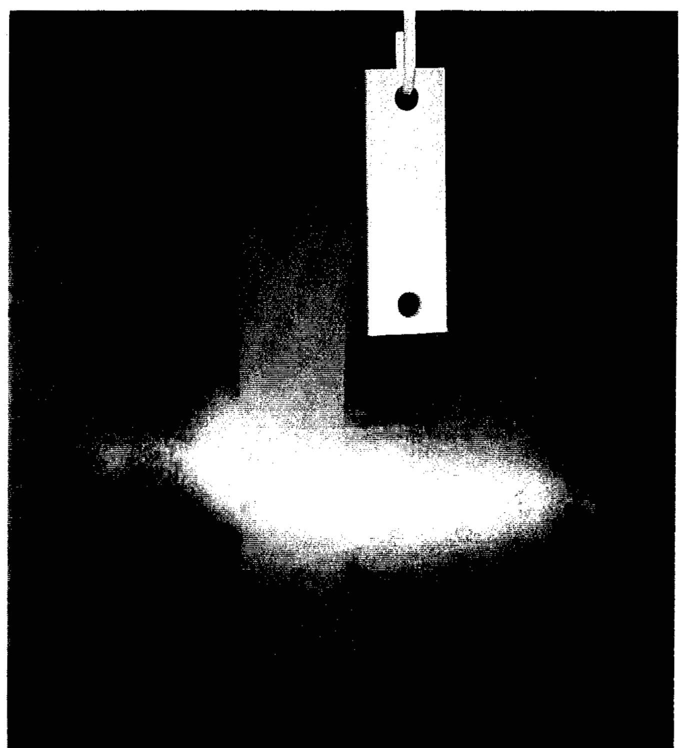
Correct Pattern **"Tails"** **"Hour Glass"** **Distorted Pattern**

Gun Setup

Spray Pattern Control



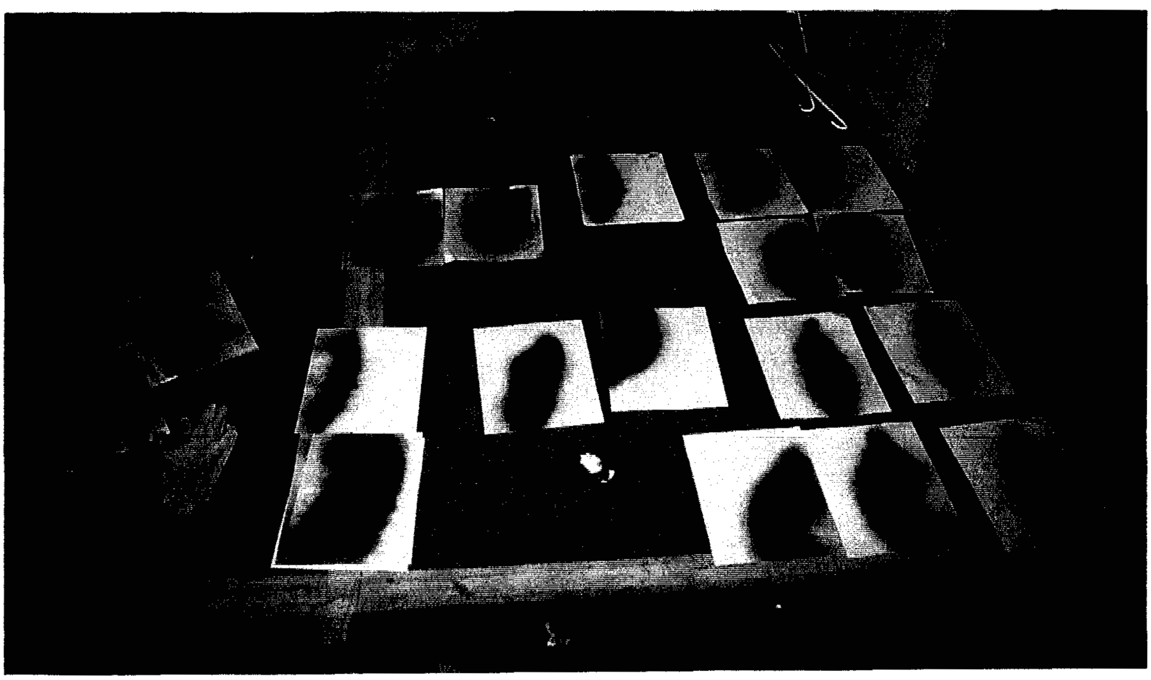




Oftentimes, the size of a spray pattern is inappropriate for the part - resulting in excessive overspray

Gun Setup
Spray Pattern Control

Test spray patterns obtained for an air-assisted airless gun. The two patterns to the left resulted from an excessive air pressure setting and a dirty air cap. The pattern on the right illustrates the distorted spray pattern once the air pressure was dropped.



Test spray patterns obtained during the proper set up of the air-assisted airless gun.

Gun Setup

Spray Pattern Control

Conventional and HVLP Air Spray

- Use partial triggering or adjust shaping air valve on gun to adjust size/shape of spray pattern

Airless and Air-Assisted Airless

- Select fluid tips based on manufacturer's spray pattern size and flow rate data
  - The fluid tip defines the spray pattern.
  - The tip orifice is very small and angled (defines the spray angle)
    - Paint is atomized as it is forced through this precision orifice and forms a fan pattern.
    - The tip is critical to achieving a full, well defined spray pattern which lets the operator apply paint fast and accurately
- May need to experiment to obtain best fluid tip orifice size and spray angle for the parts sprayed

Gun Setup

Fluid Delivery Rate

Affects atomization, film build and finish

If too high

- Runs /sags
- Solvent popping
- Mottling
- "Heavy centered" Spray pattern
- High film build
- Poor electrostatic efficiency
- Poor atomization (air atomization)
- Loss of operator control

If too low

- Dry spray
- Orange peel
- "Split" Spray patterns
- Low film build
- Poor atomization (hydraulic atomization)

Fluid delivery is affected by

- Viscosity
- Fluid pressure
- Size of fluid tip
- Adjustment of fluid control valve on gun (e.g., HVLP, Conventional)
- Triggering action of operator

Gun Setup
Fluid Delivery Rate

IN GENERAL - Keep fluid setting as low as possible while still maintaining comfortable gun speed.

Air Atomization Spray Equipment

- ✗ **REMEMBER - higher fluid settings require higher air pressure for proper atomization and transfer efficiency suffers with excessive air pressures**

Airless and Air-Assisted Airless

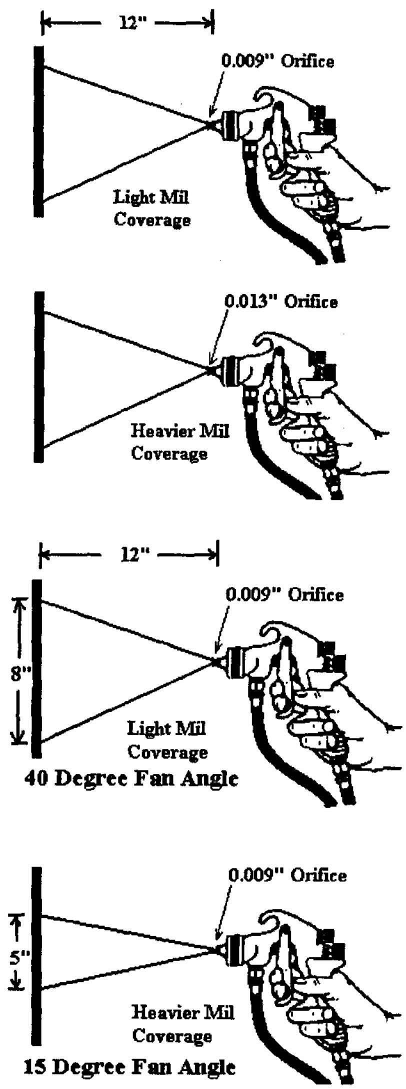
- ✗ **Adjust fluid delivery rate by tip selection and fluid pressure**
  - ➢ **NOTE: Fluid pressure SHOULD NOT be used as a primary adjustment**
  - ➢ **Although increasing fluid pressure may be used to increase flow, efficiency decreases rapidly because of increased particle velocities and additional wear on fluid tip**
    - ➢ **Instead may need to use a larger diameter fluid tip to increase fluid delivery while providing good atomization**

Gun Setup

Fluid Tip Selection

Airless and Air-Assisted Airless

- **To achieve the highest quality and efficiency with airless and air-assisted airless guns, proper fluid tip selection is critical.**
- **The tip orifice size affects the mil thickness applied to the workpiece.**
  - ➢ **Increasing the orifice size while leaving the fan size the same causes the mil thickness to increase.**
- **For a given orifice size, the fan angle will affect the mil thickness applied to the workpiece.**
  - ➢ **Keeping the orifice size the same while decreasing the fan width causes the mil thickness to increase.**
  - ➢ **Same amount of coating put out in a small size area**



Fluid delivery rate, fan pattern width and degree of atomization needed for production are the criteria used for proper Airless / Air-Assisted Airless tip selection.

Gun Setup
Atomization

- **The breaking up of paint into fine particles or droplets.**
  - **Conventional and HVLP - provide finest atomization although HVLP is coarser than conventional = <1-150 micron droplets**
  - **Air-assisted airless = 100-200 micron droplets**
  - **Airless = 100 to 500 micron droplets**

Note: Droplet sizes measured at peak efficiencies

- **In general**
  - **Finish quality improves as particle size is reduced**
    - **Finer atomization = smooth, even finish**
    - **Coarse atomization = causes an orange peel effect**
  - **Transfer efficiency decreases as particle size decreases**

Particle Size Trivia

- ★ **Maximum finish quality is achieved with 18 to 20 micron particles (Sauter Mean Diameter)**
- ★ **Smallest visible particle ~ 42 microns**
- ★ **Diameter of human hair ~ 70 microns**

Gun Setup
Atomization

Conventional and HVLP Spray Equipment

- Atomizing air
  - **Very important to material savings and quality finish**
    - **Forms droplet size - affecting paint fluidity**
    - **Shapes the spray pattern**
    - **Guides the paint to the part**
  - **A definite relationship exists between air pressure and fluid delivery.**
    - **Amount of atomization air required is determined by fluid delivery.**
    - **As fluid delivery increases, more air is needed to atomize the paint.**

USE NO MORE AIR THAN IS NECESSARY TO ATOMIZE MATERIALS SUFFICIENTLY FOR A GOOD FINISH!!

Airless and Air-Assisted Airless

- Hydraulic Atomization
  - **Adjust by selecting the best combination of fluid tip and fluid pressure**

Gun Setup
Atomization

Degree of Atomization

If too high

- Excessive overspray / fog (air atomization)
- Wasted material / excessive material consumption.
- Increased spray booth maintenance.
- Undesirable finish.
  - Blushing
  - Dry striping
- More difficult working conditions for operator.
- Poor electrostatic efficiency.

If too low

- Coarse paint droplets/particles
- Runs or sags
- Orange peel
- Solvent peel / popping
- "Heavy Centered" Spray Pattern
- Excessive film build

General Setup Procedures
Air Atomized Guns

Gravity, Siphon and Pressure Feed Cup Guns

- **Select an appropriate fluid tip and air cap size**
  - Use the manufacturer's suggested air cap/fluid tip combination for the type/viscosity of the material sprayed.
  - Larger fluid nozzles may be required for more viscous materials or higher production rates.
- **Select an initially low air pressure setting to gun**
  - Use gun manufacturers recommended starting points for inlet air setting
  - Trigger gun air to set air pressure
- **Fully open fluid adjustment valve and test spray pattern**
  - Spray test pattern on paper at recommended gun-to-target distance
    - Review atomization and pattern shape for full and partial triggering
      - Swipe the paper with the spray gun pattern to observe degree of atomization
    - Adjust spray pattern shape to fit the part using the fan adjustment knob
    - Review fluid delivery rate and uniformity of fluid delivery
- **If degree of atomization or fluid delivery rate is inadequate, increase air pressure by 5 psi increments and repeat the above steps until desired level of atomization is achieved**
  - If fluid delivery rate remains unacceptable (i.e. too high or too low) - try alternative air cap/fluid tip combination
    - May also restrict fluid flow rate with fluid adjustment knob
      - Turning the knob clockwise decreases fluid flow

Note: spraying with fluid adjustment knob less than fully open will cause premature wear on the fluid nozzle

General Setup Procedures

Air Atomized Guns

Pressure Feed Spray Guns

- **Select an appropriate fluid tip and air cap size**
  - **Use the manufacturer's suggested air cap/fluid tip combination for the type/viscosity of the material sprayed.**
  - **Larger fluid nozzles may be required for more viscous materials or higher production rates.**
- **With atomizing air off at gun - adjust fluid delivery rate**
  - **Turn fluid adjustment valve fully open**
  - **Turn off atomizing air knob at gun**
  - **Adjust fluid flow with the fluid pressure regulator**
    - **Hold gun parallel to floor and trigger gun**
    - **Adjust fluid pressure to provide a 1 to 6 inch horizontal fluid stream**
- **Adjust atomizing air inlet regulator to an initially low pressure**
  - **Open the pattern adjusting valve on gun and adjust spray pattern for the part**
  - **Spray test pattern at recommended gun-to-target distance**
    - **Review atomization and pattern shape for full and partial triggering**
      - **Swipe the paper with the spray gun pattern to observe degree of atomization**
    - **Adjust spray pattern shape to fit the part sprayed using the fan adjustment knob**
    - **Review fluid delivery rate and uniformity of fluid delivery**
- **If degree of atomization is inadequate, increase air atomizing pressure by 5 psi increments and repeat the above steps until desired atomization is achieved**
  - **If fluid delivery rate remains unacceptable (i.e. too high or too low) - try alternative air cap/fluid tip combination or adjust fluid pressure**

    Note: spraying with fluid adjustment knob less than fully open will cause premature wear on the fluid nozzle
  - **Important consideration - A larger fluid nozzle at a reduced pressure will maintain the same fluid delivery rate but slow down the velocity of the fluid stream**
    - **Advantage - allows greater contact time between the atomizing air and the fluid stream = improved atomization**

General Setup Procedures
Airless and Air-Assisted Airless Guns

- **To achieve the highest quality and efficiency with airless and air-assisted airless guns, it is important to select the proper fluid tip / fluid pressure combination**
  - ➢ **Fluid tip and fluid pressure affect**
    - ➢ **Degree of atomization**
    - ➢ **Fluid flow rate**
      - ➢ **Production rate**
    - ➢ **Size of spray pattern**

✗ **Select a fluid tip based on fluid flow requirements, geometry of parts to be sprayed and degree of atomization desired**

✗ **Beginning at an initially low fluid pressure, shoot a test pattern on a sheet of paper to review pattern shape/size and degree of atomization**
  - ➢ **Fluid pressure may be determined directly from a fluid pressure gauge or indirectly by multiplying the pump ratio and the air pressure setting to the pump**
    - ➢ **The fluid pressure provided by a 20:1 pump with an operating air pressure of 40 psi is approximately 800 psi**
  - ➢ **For Air-Assisted Airless - air to gun should be off (ignore fingers for now)**
  - ➢ **Increase fluid pressure incrementally and re-shoot test pattern**
  - ➢ **Repeat until the desired level of atomization is achieved**

✗ **For air assisted airless - once degree of atomization is obtained, turn on air to gun at an initially low air pressure**
  - ➢ **Increase air pressure incrementally until fingers disappear from spray pattern - use the lowest air pressure setting possible**

Use the lowest fluid and air pressure settings that provide the degree of atomization required!!!

General Setup Procedures
Air-Assisted Airless

Excessive overspray (fog) caused by too high of air pressure setting to air-assisted airless gun

Test spray patterns from air-assisted airless gun. Pattern to the left is well defined because of a proper air pressure setting. Pattern to the right represents an excessive air pressure setting.

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Section 4.0

Application Enhancement Equipment

Electrostatics

Paint Heaters

Electrostatics

Terminology

- ✗ **Faraday Cage Areas - Recessed areas on a part (such as inside corners or cavities) that are difficult to coat because adjacent surfaces of the part attract the electrostatic field, preventing paint/powder particles from penetrating these areas**
- ✗ **Electrostatic wrap - the tendency of paint\powder particles to coat a surface of the target that is not in direct line-of-sight with the applicator**
  - ➢ **Directly related to the electrostatic charge imparted on the particles, part grounding and the aerodynamics imparted by the gun and spray booth**
  - ➢ **Particles are deposited on the back side of the target**
- ✗ **Capacitance - the storage of electrons**
  - ➢ **Any object with surface area that does not provide a path for electrons to leave that surface will accumulate electrons**
    - ➢ **Includes ungrounded operators, equipment, containers, hoses, etc.**
  - ➢ **If electrons accumulate to a point where the object cannot hold any more, an uncontrolled release of electrons (electrical discharge) will occur**
    - ➢ **Usually an arc or felt as a shock**
    - ➢ **The greatest concern with electrostatic systems due to potential ignition**

Electrostatics

Electrostatic wrap causes paint/powder to be applied on the back side of the target. Lack of wrap indicates problems with grounding, equipment, or coating materials.

Electrostatics

Advantages

- ***Improves transfer efficiency by 20-40%***
  - ***Coating material that would otherwise be wasted as overspray is electrostatically attracted to the back side of the part (a.k.a. "Electrostatic Wrap")***
  - ***More material on part and less overspray = Material savings***
- ***May improve degree of atomization (negatively charged paint particles repel each other).***
- ***Produces more uniform film build/coverage = better finish***
  - ***May improve build efficiency***
- ***Reduces VOC emissions and booth maintenance***
- ***Good for high production speeds***

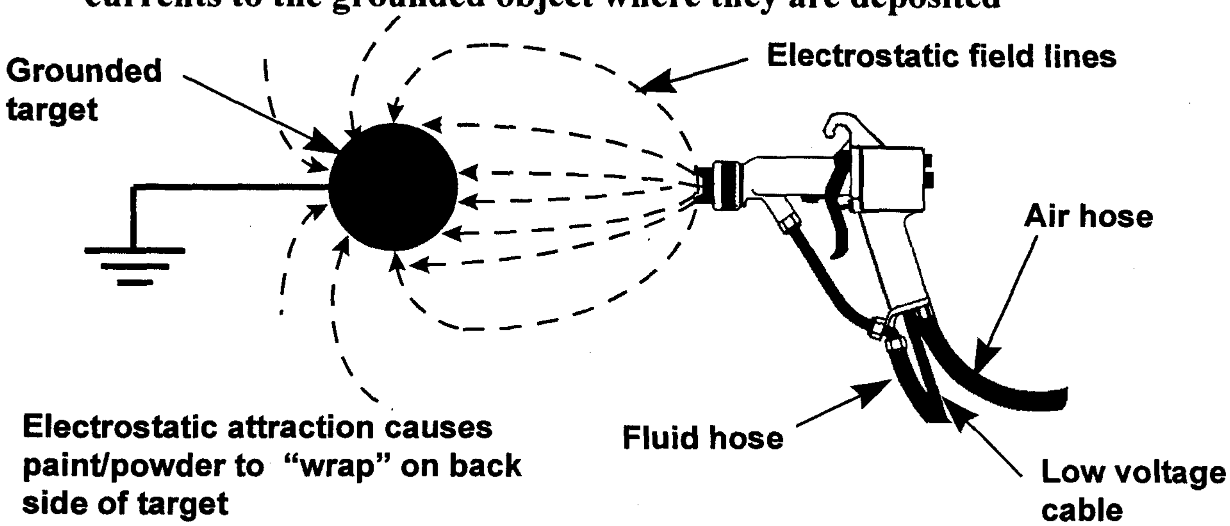
Disadvantages

- ***High equipment cost and additional maintenance***
  - ***Must ensure and maintain a good ground path***
- ***Faraday Cage effect - paint does not reach inside corners of target because paint/powder is attracted to the outer surface first.***
- ***Built-up edges or picture framing - sharp edges or protrusions of target that attract electrostatically charged paint/powder better than the rest of the target.***
- ***Wrapping back - paint particles move backwards when strongest ground is behind the spray gun.***
- ***Arcing - when electricity leaps a gap between an isolated object that has become charged (e.g., ungrounded target, operator, or object in booth) and a grounded object (e.g., spray gun)***
  - ***An uncontrolled release of electrons***
  - ***Creates a secondary ignition source***

Electrostatics

Spray Application

- **Paint/powder particles pass through an electrostatic field produced by a high voltage power source (60-100 kV)**
- **When the electrode is charged, it generates a high voltage - low amperage electrostatic field between the gun and a ground**
  - **"Field lines" depict the magnitude and direction of the electrostatic field**
  - **The electrostatic charge on the electrode is usually negative**
    - **Operators can regulate the voltage at the power source or the gun**
    - **The electrostatic field is concentrated at the electrode where it is strong enough to strip electrons from oxygen**
      - **The region around the tip of the electrode is referred to as the corona**
        - **A special type of cold plasma**
        - **The "gateway" through which the charging current flows**
      - **Electrons emitted at the corona are repelled from the electrode and collide with oxygen molecules to form negative ions**
      - **The negative ions follow the path of the electrostatic field lines**
- **Paint/powder particles passing through the electrostatic field are bombarded with ions and become negatively charged**
  - **Upon collision, electrons are transferred from the ion to to the paint/powder particle, imparting a negative charge**
  - **Paint/powder particles are then directed by the electric field lines and air currents to the grounded object where they are deposited**



Electrostatics

Factors Affecting Efficiency

- Conductivity of the target
  - Works best for parts that are electrically conductive
- Grounding of the part
- Paint/powder particle velocity
- Gun-to-target distance
- Resistivity of the solvent-borne paint / charging property of powder
- Humidity
- Part Configuration
- Racking

Electrostatics

Factors Affecting Efficiency

Grounding

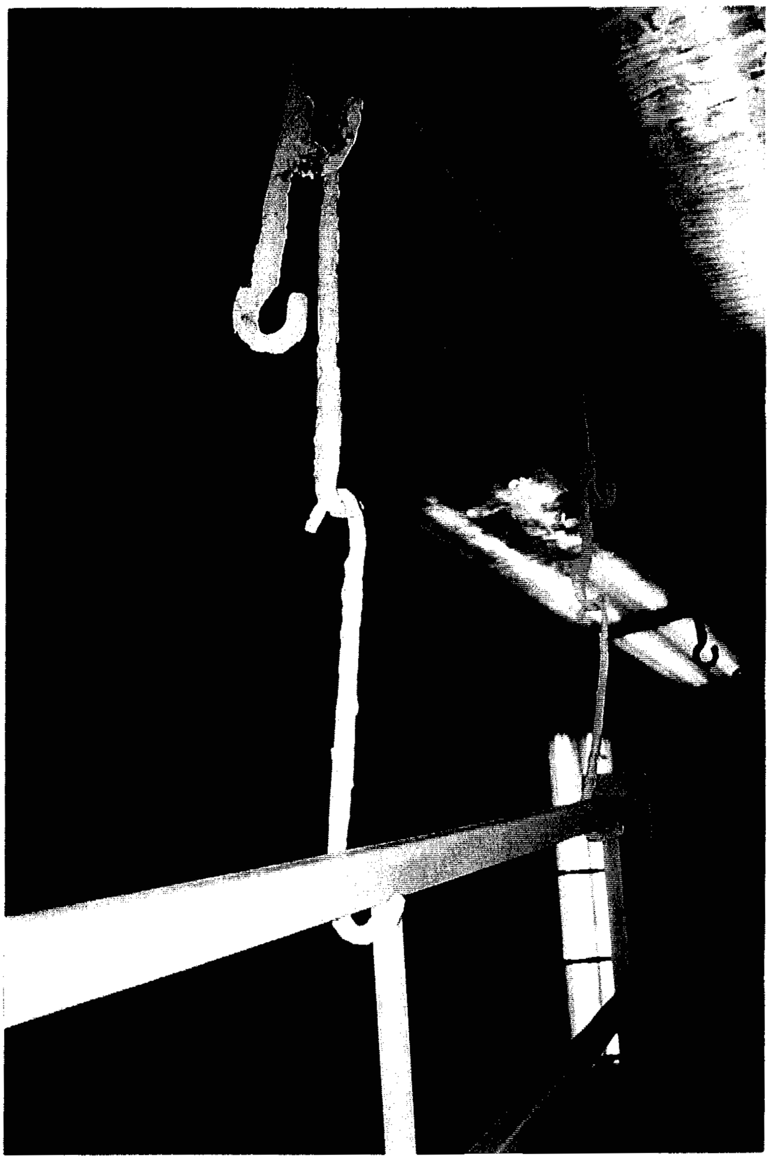
- ✗ Grounding provides the *electron drain* for the part being coated
- ✗ Lack of ground is the cause of most problems associated with electrostatic spray
  - ➢ Parts <u>MUST</u> be electrically conductive to ground!!!
    - ➢ If your part isn't grounded then you are just using very expensive, traditional spray equipment
    - ➢ Greater risk of arcing and fires
  - ➢ Poorly grounded parts may cause low film build, poor transfer efficiency and no wrap
- ✗ Determine conductivity/electrical continuity with a megohm meter or volt/ohm meter
  - ➢ Resistance from part to ground should not exceed 1 megohm (megohm meter or Megger) for safety considerations and transfer efficiency
  - ➢ Coating efficiency increases as resistance decreases
- ✗ Most importantly - clean hooks/hangers on a regular basis!!!
  - ➢ Grounding is achieved through the part's contact with the hanger - Need good, clean contact points

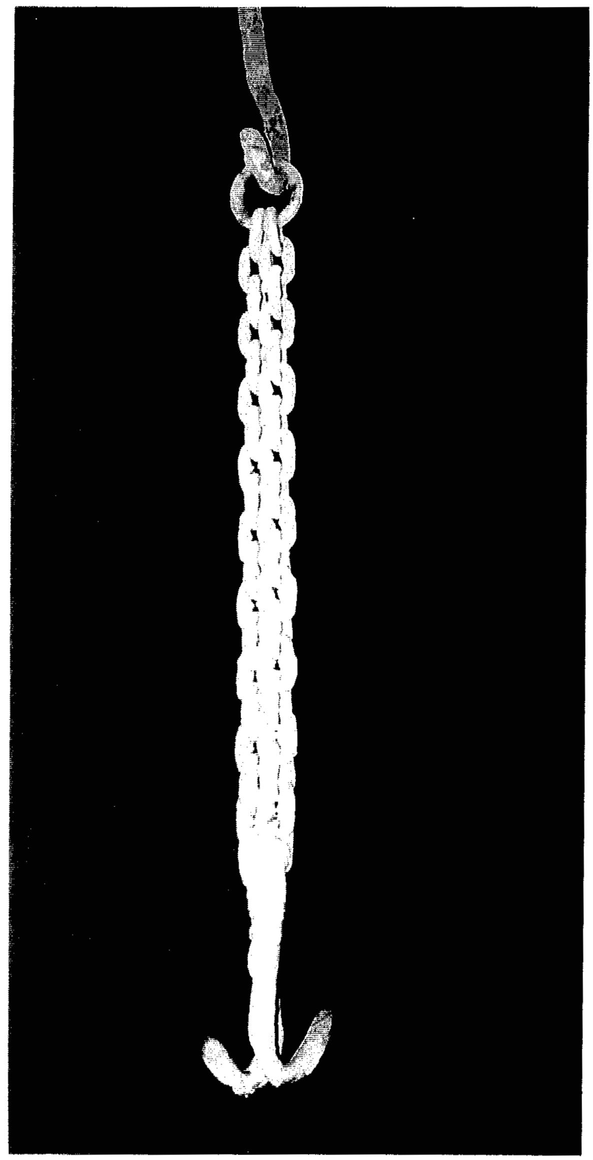
Most fires occur because of poorly grounded parts

Electrostatics

Factors Affecting Efficiency

Parts Need Continuity to Ground!!!





Examples of paint hooks in poor condition

Electrostatics

Factors Affecting Efficiency

Paint/Powder Particle Velocity

- The degree to which electrostatic forces influence the path of a paint/powder particle depends on size and velocity of paint particle
  - Large particles sprayed at high velocities have greater momentum
    - Unless deposited by direct impact, these particles will negate the electrostatic attraction and blow by the target
  - Small particles at low velocities have low momentum
    - Allows electrostatic force to attract particle to target.
    - Better "wrap", higher T.E., and reduced overspray
- Lower pressures are especially important for electrostatics
  - It is important to keep coating material flow rates (liquid and powder coating) as low as possible
    - The corona discharge can only effectively charge so much coating at a time
  - Excessively high air pressures adversely affect transfer efficiencies
    - Increases turbulence and particle velocity

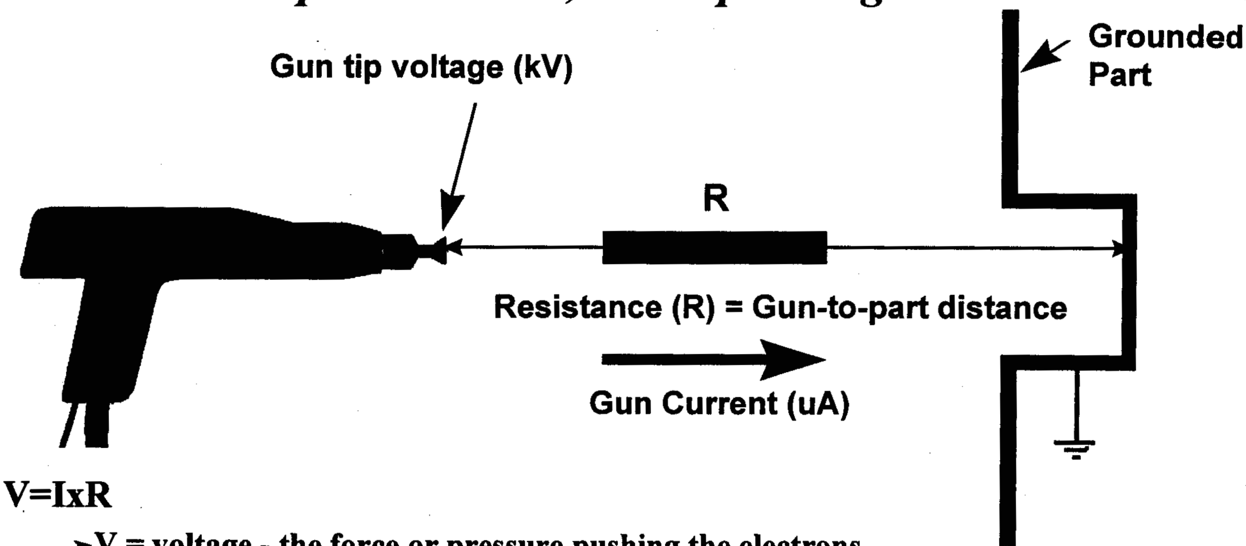
Gun-to-part Distance

- Affects
  - Particle velocity
  - Gun tip voltage
    - High tip voltage = high transfer efficiency
    - $V = I \times R$
      - Air between the gun and target represents the resistance (R) to current flow
      - As the gun-to-target distance decreases, resistance (R) and voltage decrease while current (I) increases, reducing T.E.
  - Particle charging time
    - Affects charging efficiency
      - Particles acquire a charge from the electric field while traveling from the gun to the part
  - Electrostatic field strength and shape
  - Deposition efficiency

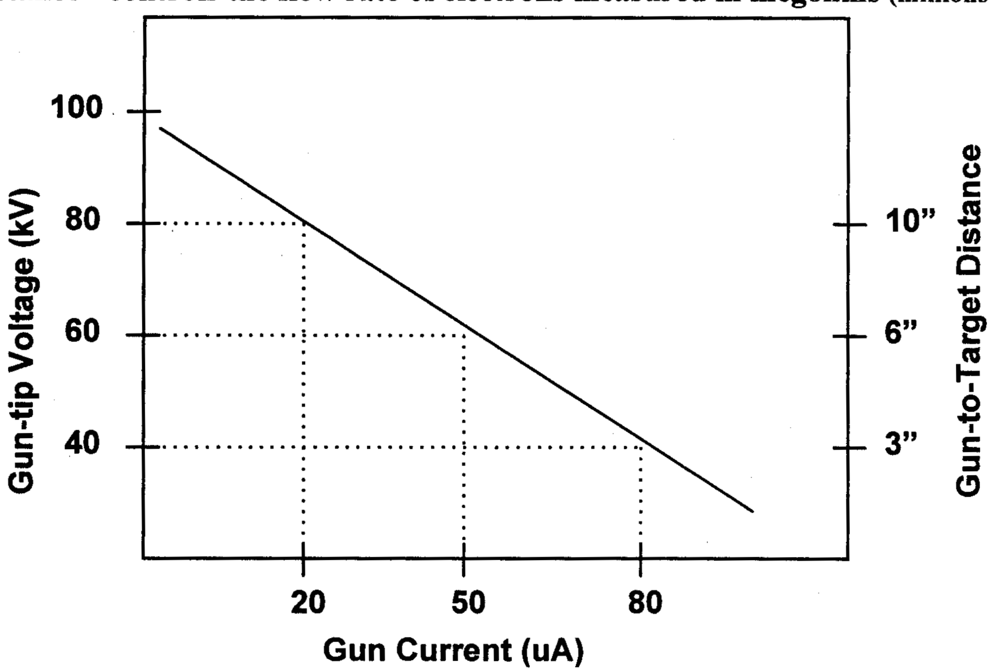
Electrostatics

Factors Affecting Efficiency

Gun-to-part Distance, Gun-tip Voltage and Gun Current



- **V=IxR**
  - **V = voltage - the force or pressure pushing the electrons**
  - **I = current = the flow of electrons**
  - **R= resistance - controls the flow rate of electrons measured in megohms (millions of ohms)**



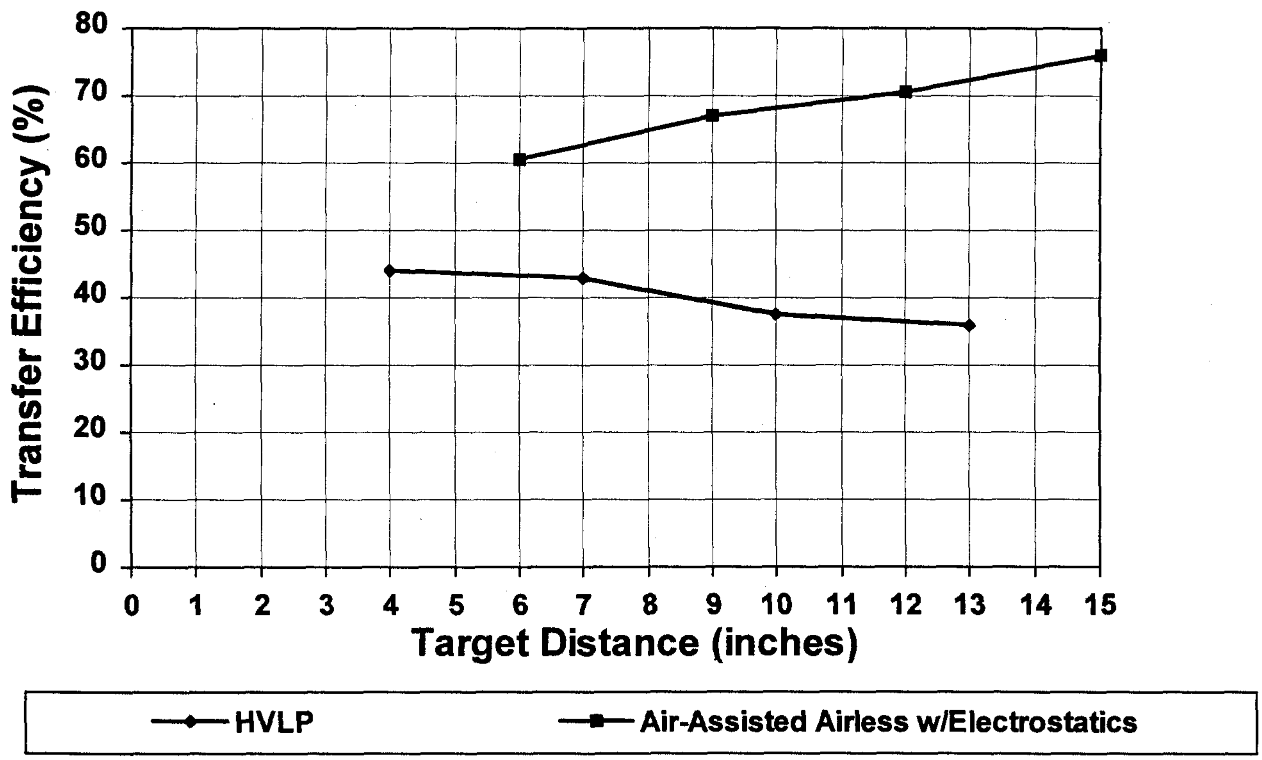
For conventional voltage control spray system, gun current will increase as the gun-to-part distance decreases. Consequently, gun manufacturers have developed systems with adjustable, current limiting features.

Electrostatics

Factors Affecting Efficiency

Gun-to-part Distance

- **Use distance recommended by manufacturer for best T.E.**
  - **Generally, farther distance = better transfer efficiency**
    - **Greater distance = increased residence time in electrostatic field (for better charging) and lower particle velocity**
  - **Too close**
    - **Causes high particle velocities = greater particle momentum = reduced T.E.**
    - **May negate electrostatic attraction**
    - **May be used to overcome Faraday Cage effect**
  - **Too far**
    - **Paint may wrap back onto gun or operator**



Electrostatics

Factors Affecting Efficiency

Paint Resistivity

- ✗ Solvent-borne paint formulation affects charging efficiency
  - ➢ Electrical resistivity is a characteristic of the paint's formulation
    - ➢ Solvents vary in polarity - which affects paint resistivity
      - ➢ Polar solvents readily conduct electric current
      - ➢ Non-polar solvents restrict electric current
  - ➢ Desired paint resistivity for electrostatics = 0.1 to 1.0 megohms
    - ➢ Measure with a paint resistivity meter
    - ➢ Optimal = 0.3 to 0.4 megohms
  - ➢ If too high or too low
    - ➢ Low film build
    - ➢ Poor or no wrap
    - ➢ Poor transfer efficiency

Powder Charging

- ✗ Powder composition/chemistry affects charging efficiency
  - ➢ Binders, fillers and pigments may effect charging efficiency of powder

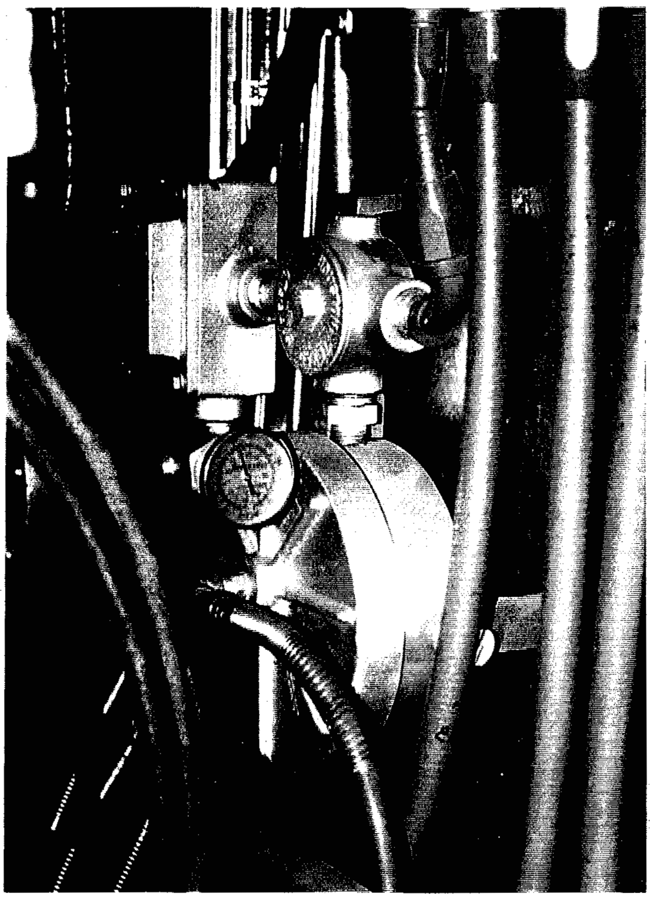
Humidity

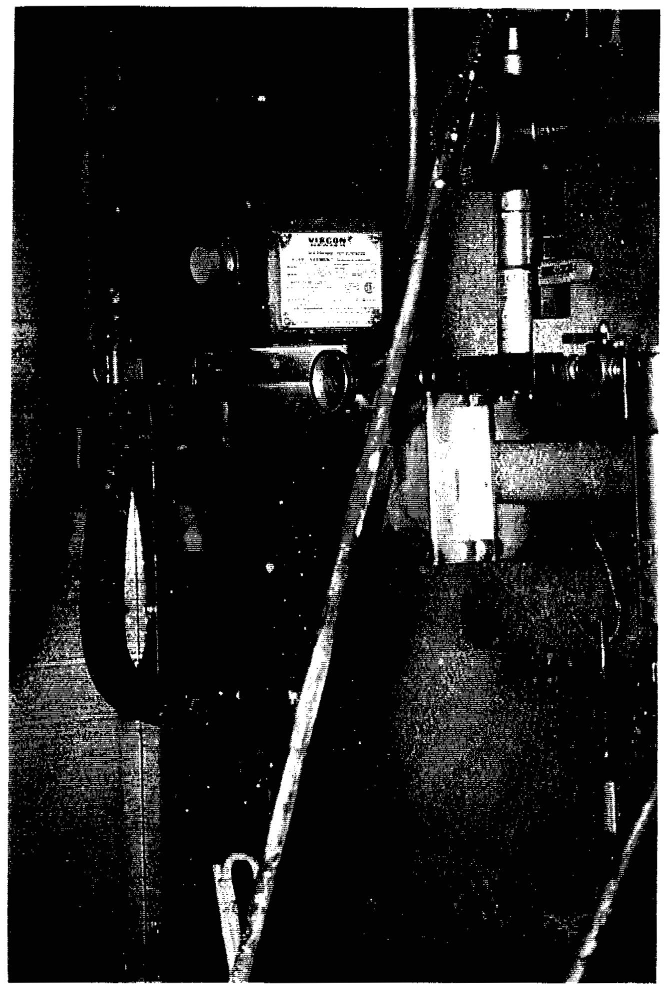
- ✗ Moisture in the air enhances electron flow
  - ➢ If humidity is high in the spray environment, the electron or current flow will increase causing voltage to drop which decreases T.E.
  - ➢ Efficiency may be better on dry days vs. wet days

Paint Heating

- ★ Used to reduce viscosity without adding solvent
  - ➢ Greatest viscosity change occurs below 120°F
  - ➢ Coating material loses certain qualities when viscosity is reduced with solvent (e.g., coverage, hiding).
  - ➢ Solvent additions may also violate air quality restrictions
- ★ Maintains the paint at a constant temperature and provides viscosity control regardless of fluctuations in ambient temperature
- ★ Allows spraying at lower fluid pressures
  - ✗ Lower pressure = lower velocity = better T.E.
- ★ Improves atomization = better quality finish
- ★ Faster flash-off time between coats
  - ➢ If faster flash-off time is needed - paint may be heated to a temperature just below the lowest boiling point of the solvents used in the paint formulation
- ★ A higher rate of film build is possible because material contains more solids and less solvent
  - ➢ Can achieve desired film build in fewer passes = increased productivity

Paint Heating





In-line paint heaters

Paint Heating
Viscosity

- A measure of a liquid's resistance to flow
  - Affected by temperature of material
  - Viscosity affects:
    - Fluid delivery
      - For same tip size and fluid pressure - fluid delivery rate will increase as viscosity decreases
    - Atomization
    - Paint fluidity
    - Pigment dispersion
- FIRST THING TO DO - Measure viscosity AND temperature of the finishing materials sprayed
  - Need to measure and record daily to avoid or solve application problems - adjust as needed
  - When several colors are being sprayed, the viscosities should be kept nearly the same
    - Allows for the uniform application of each color
    - Allows operators to use the same technique, flow and atomizing pressures for any color
- Viscosity is typically measured using the "Efflux Method"
  - A measurement of the amount of time it takes for a given quantity of paint to flow through the orifice in the bottom of a special dip cup
    - Most widely used cups are the Zahn #2 and Ford #4
      - Material should be strained and at spraying temperature
      - Gently submerge the cup into a sample of the paint to be sprayed
      - Hold the cup vertically and, with a quick, steady motion, lift the cup out of the sample material
      - Start the stopwatch when the top edge of the cup breaks the surface
      - Hold the cup no more than 6" above the level of the sample material
      - Stop the timer when the first definite break in the fluid stream at the base of the cup is observed
      - Record the time and temperature of material

A viscosity conversion chart is provided in Appendix B

Paint Heating
Viscosity

If too low

- ✗ Tendency to run and sag
- ✗ Solvent popping
- ✗ Mottling
- ✗ Excessive fog - overspray
- ✗ Low film build
- ✗ Poor hiding capacity
- ✗ Excessive material consumption
- ✗ Poor adhesion and chemical resistance
- ✗ Solvent additions may impair electrostatics
- ✗ Rework

If too high

- ✗ Orange peel
- ✗ Dry spray
- ✗ Heavy center (high fluid pressure - poor atomization)
- ✗ High film build

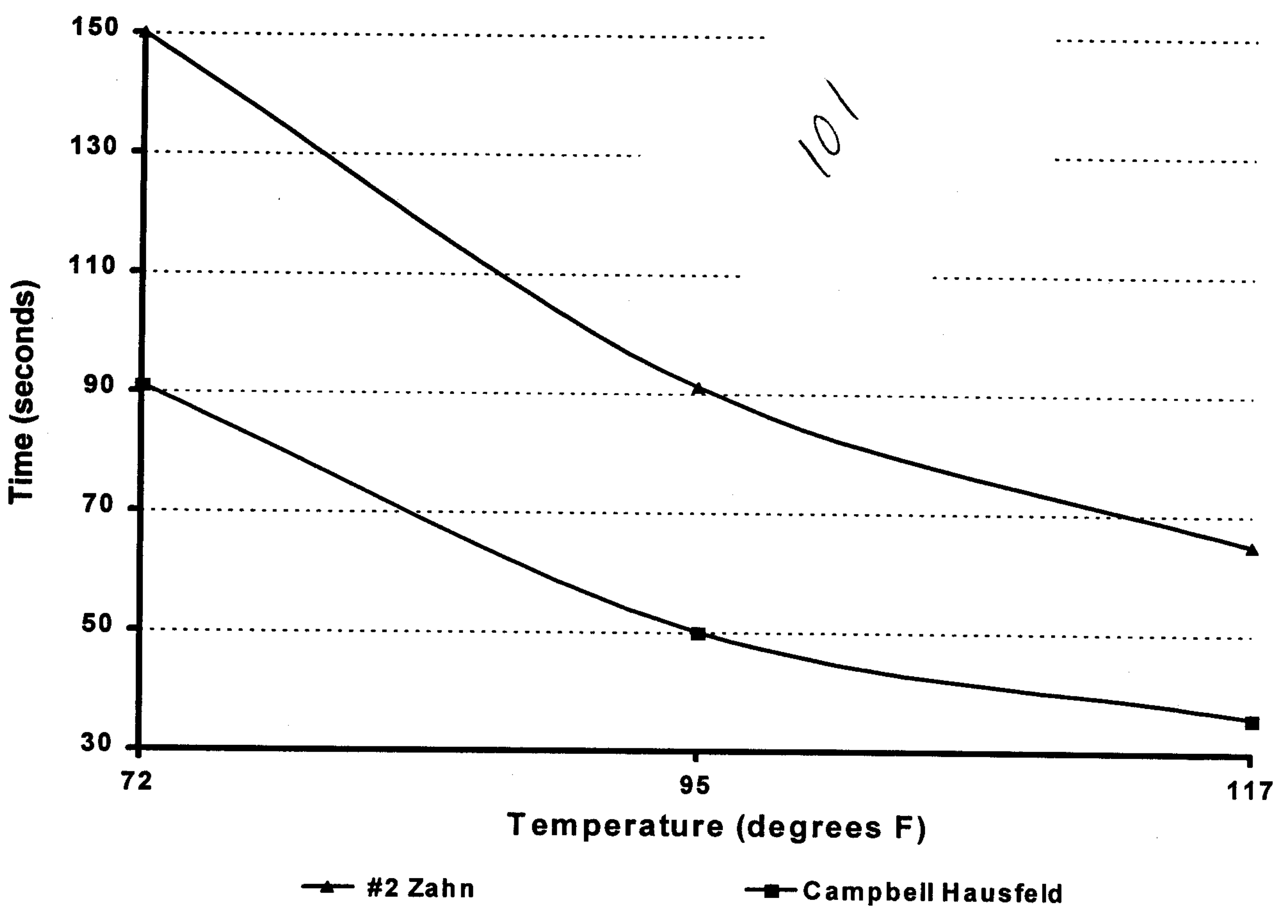
Viscosity measurement using a # 2 Zahn cup

Paint Heating

Viscosity vs. Temperature

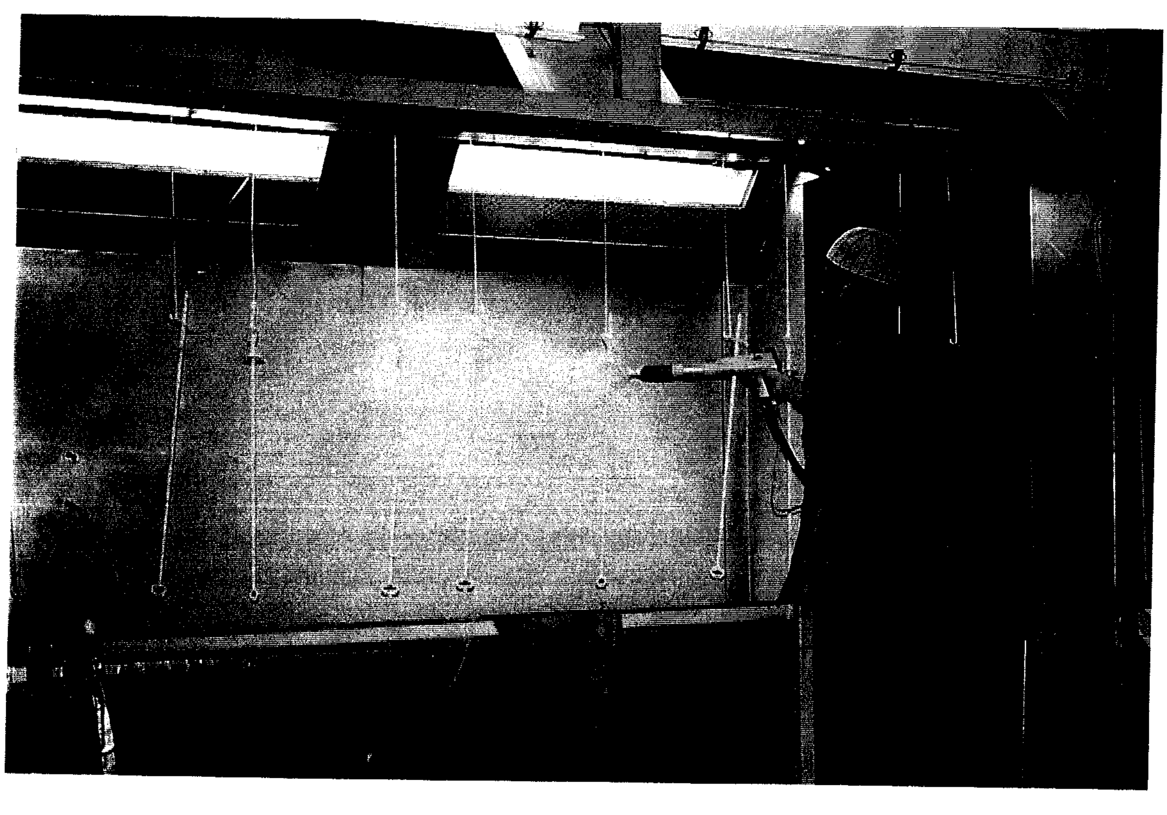
(Sherwin William's High Solids Product)

Temperature	#2 Zahn	Campbell Hausfeld
72°F	150 sec	91 sec
95°F	91 sec	50 sec
117°F	65 sec	36 sec



Section 5.0

Powder Coating



Powder Coating Advantages

Powder coating offers significant economic, environmental and performance advantages

- **One of the least expensive finishing methods available**
  - **Similar material, equipment and installation costs to liquid systems**
- **Reduced energy costs**
  - **Technology is solvent free**
  - **Air makeup to the spray booth may be recirculated to the plant**
    - **Cost of heating booth makeup air is avoided**
  - **Requires minimal amount of cure oven ventilation**
    - **Need to exhaust 1,500 SCF of air per pound of volatiles for sprayed powder vs. 10,000 SCF per gallon of solvent load for liquid coatings**
- **Reduced labor costs**
  - **Reduced cleanup times and simplified plant maintenance**
  - **Powder is ready to use upon delivery**
    - **No mixing, thinning or catalyst additions are required**
  - **Fewer operating parameters to maintain and keep balanced**
    - **No viscosity control/adjustments**
- **Safety**
  - **Safety in use and on storage**
  - **Significantly reduces the risk of fire**
    - **May reduce insurance premiums**
  - **Reduced health hazard to employees**
    - **No solvents**
    - **Cleaner working conditions**
      - **More favorable work environment**
      - **May lower employee absenteeism**

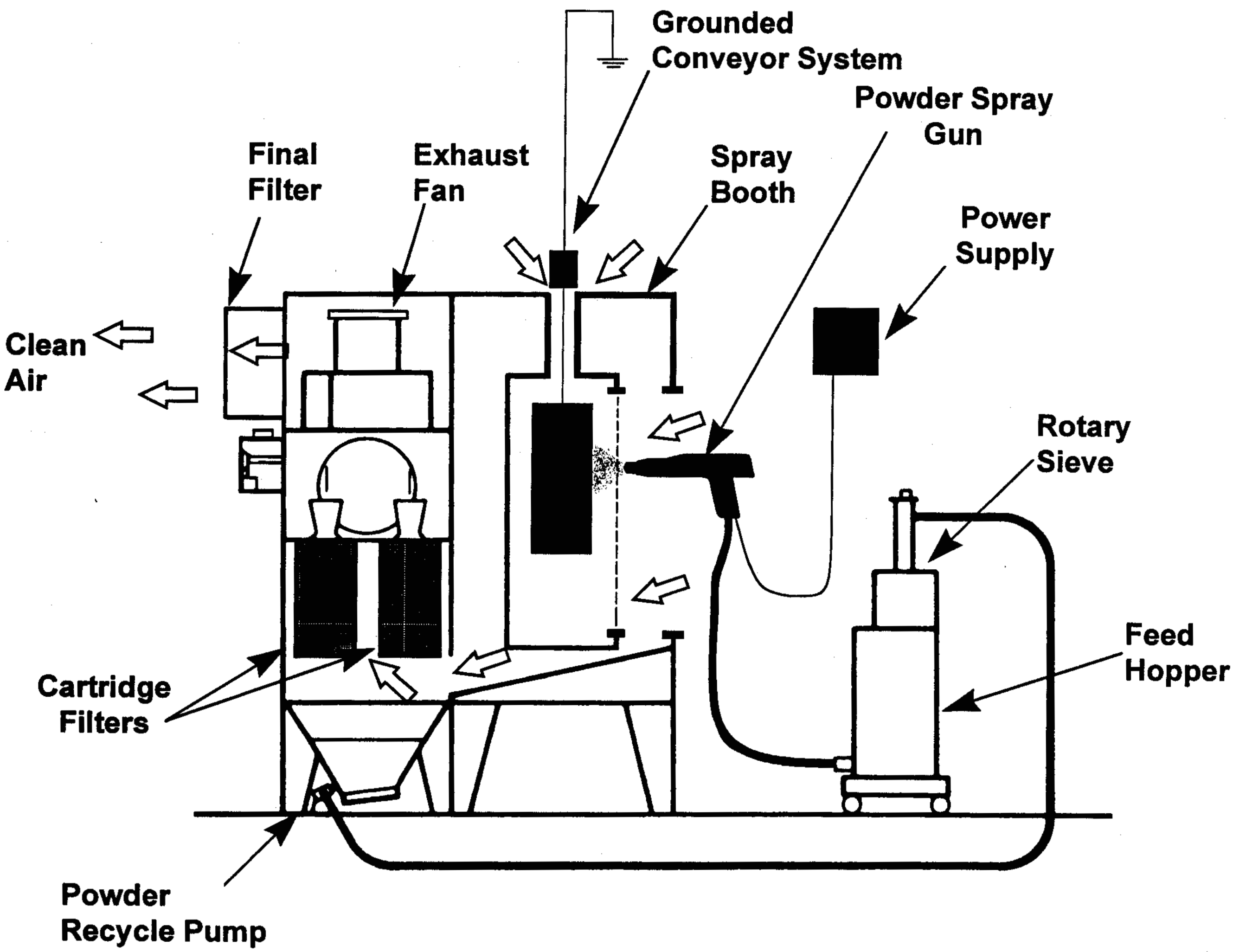
Powder Coating Advantages

- Increased productivity and efficiency
  - High material usage efficiency
    - First pass transfer efficiency of 50 to 80%
    - Overall material utilization of 95-98% can be achieved if overspray is collected and reclaimed
  - Easy to apply
  - Denser rack spacings = increased production rates
  - Lower reject rates
    - Powder coated parts develop full cure during the baking cycle and tend to be more abuse resistant than liquid coated parts upon exiting the cure oven
    - Nearly impossible to obtain runs/sags
    - Poorly coated parts may be blown clean and recoated if discovered before curing
  - May achieve film properties that are equal or superior to liquid coatings
    - May eliminate the need to prime parts
    - May eliminate the need for additional coats
  - More efficient user of plant space
    - Powder coating equipment and materials require less plant space
    - No flash-off time is required
- Reduced waste disposal costs
  - Hazardous waste generation rates are significantly reduced or eliminated
- Reduced regulatory burden
  - Little, if any, air permitting requirements
  - Hazardous waste is significantly reduced or eliminated
  - Reduced reporting

Powder Coating Equipment

- **Powder coating application methods include electrostatic spray, dipping the part in a fluidized bed or flamespray**
- **PAC^{2}E Focus ⇨ *manual electrostatic spray***
  - **Most applicable to small business**
  - **Widely used method for applying powder coating materials**
  - **Versatile and provides good control over coating thickness**
- **Five basic pieces of equipment used with manual powder coating process**
  - **Powder delivery system - supplies powder to the spray gun**
    - **Fluidized hopper, vibratory box or stirrer hopper - used to fluidize the powder for delivery to the spray gun**
    - **Venturi pump/powder pump**
    - **Powder hose**
  - **Electrostatic powder spray gun**
    - **Imparts the electrostatic charge to the powder particles**
    - **Directs the powder toward the part in the form of a diffuse cloud**
      - **Air used to transport the powder from the feeder unit to the spray gun and the electrostatic charge imparted to the powder at the gun provide the propelling force**
    - **Controls the spray pattern size, shape and density**
    - **Controls the deposition of powder on parts being sprayed through gun position and pattern shape**
  - **Control unit/power supply**
    - **Supplies and controls the electrostatic voltage supplied to the spray gun**
    - **Regulates conveying and atomizing air**
  - **Spray booth**
  - **Powder capture/recovery system**

Powder Coating Equipment



Powder Coating Equipment
Particle Charging

- The electrostatic powder spray process is dependent on effectively applying charge to the surface of powder particles
- Powder supplied to the gun is charged via one of two technologies
  - Corona (ion bombardment) charging
  - Tribo (friction) charging
- Electrons are the basic element of charge
  - A powder particle that is charged with a negative polarity ion must have an electron transferred and trapped on the surface
  - If the polarity of charge is positive, electrons must be given up by the powder particle and moved away
- The charged particle moves toward the grounded workpiece with the help of air supplied to the gun and booth air flow
- When powder approaches the part, the electrostatic attraction between the charged particles and the grounded target attracts the powder particles to the part and causes them to adhere

Powder Coating Equipment

Corona Charging

(a.k.a. External Charging Guns)

The process of inducing a static electric charge on powder particles by passing the powder through an electrostatic field generated by a high voltage device

- **Most common form of powder charging**
- **May be positive or negative corona charging**
  - **Negative charging is used for 99.9% of applications because of higher efficiencies**
    - **Powder materials have a greater affinity for a negative charge**
- **Guns are usually controlled pneumatically and electrically from a control console**
  - **A charging electrode exists at the front end of the spray gun**
  - **An electrical power source provides a high voltage (80-100kV) at low amperage (50-100uA) to the electrode**
  - **2 types of power supplies**
    - **Remote high voltage power supply - power supply is accomplished by a high voltage cable to the spray gun**
      - **Not used much anymore - cables are bulky, susceptible to damage**
    - **Integral high voltage power supply - most guns have an internal power supply**
      - **The power source delivers low voltage (10-12 V) to the spray gun where, just prior to the charging electrode, the voltage is stepped up to 80-100kV with a high voltage cascade or multiplier**
      - **Uses very low current 100-120uA**

Powder Coating Equipment

Corona Charging

(a.k.a. External Charging Guns)

- **When the electrode is charged, it generates a high voltage - low amperage electrostatic field between the gun and a ground**
  - "Field lines" depict the magnitude and direction of electrostatic field
  - The electrostatic charge on the electrode is usually negative
    - Operator can regulate the voltage at the power source
      - Typically 30 to 100 kV between the electrode and the target
    - The electrostatic field is concentrated at the electrode where it is strong enough to strip electrons from oxygen
      - The region around the tip of the electrode is referred to as the corona
        - A special type of cold plasma
        - The "gateway" through which the charging current flows
      - Electrons emitted at the corona are repelled from the electrode and collide with oxygen molecules to form negative ions
      - The negative ions follow the path of the electrostatic field lines and collide with powder particles
- **Powder particles passing through the electrostatic field are bombarded with ions and become negatively charged**
  - Upon collision, electrons are transferred from the ion to the powder particle, imparting a negative charge to the particle
    - Less than 1% of free ions are actually used to charge the powder
  - Powder particles are then directed by the electric field lines and air currents to the grounded object where they are deposited
  - Once deposited onto the target, the charge of the particle dissipates very slowly, allowing the powder to cling to the part for curing

Powder Coating Equipment

Corona Charging

(a.k.a. External Charging Guns)

Advantages

- **A full range of powder types can be applied**
- **High transfer efficiency and rapid powder film build can be achieved, resulting in high productivity rates**
- **Relatively low air volume and velocities are used, minimizing equipment wear**
- **High degree of film thickness control and is consistently reproducible**
  - **The mil thickness affected by position of the spray gun, length of spray time, level of electrostatic charge and velocity of powder flow from the gun to part, and aperture of recessed areas**
  - **Thickness of powder deposited onto part is affected by powder characteristics such as particle size, shape, type of powder material and particle size distribution**

Disadvantages

- **The "lines of force' created by the external electrostatic field can cause rejection in corners or recesses (i.e. Faraday Cage effect)**
- **Greater potential for backionization**
- **Maximum mil thickness of 5 to 7 mils**

Powder Coating Equipment

Tribo Charging

- **Tribo electricity is generated by the frictional contact between dissimilar materials**
  - **Under friction, some materials give up electrons easily (donors) while other materials readily accept electrons (acceptors)**
    - **When a donor material (e.g. nylon) is rubbed against a good acceptor material (e.g. teflon) electrons will be transferred and charging occurs**

Increasing degree of tribocharging relative to Teflon

- **Nylon (strong electron donor)**
- **Epoxy**
- **Polyurethane**
- **Polyester-copolymers**
- **Epoxy-polyester hybrid**
- **Polyester**
- **PVC (weak electron donor)**

- **Contact between the powder particle and the wall of the gun is needed for proper charging**
  - **Consequently, tribo guns have intricate internal passages designed to increase contact between donor and acceptor materials to induce frictional charging**
    - **High degree of tortuosity increases powder particle residence time in gun = better charge**
  - **Passages are typically constructed of Teflon**
    - **One of the best acceptor materials - wears well and strongly resists being coated by powder material**
- **Contact between the powder (donor material) and inside passages of gun (acceptor material) causes electrons to be stripped from the surface of the powder particles, leaving them positively charged**
  - **Gun must have an effective path to ground to continually drain off the charge stripped from powder particles**
    - **Otherwise, the acceptor material will become saturated with charge and charging will stop or build up and result in an uncontrolled discharge (arc)**

Powder Coating Equipment

Tribo Charging

Advantages

- ✗ **No remote electrical power source needed**
  - ➢ **Only compressed air is needed to transport the powder through the gun**
- ✗ **Electrostatic lines of force which cause the Faraday Cage effect are reduced**
  - ➢ **Tribo guns produce a flow of charged powder with little external electric field and no excess ion current**
    - ➢ **May be used to powder coat complex parts with many Faraday Cage areas**
  - ➢ **Absence of excess ion current allows smoother finishes, heavier film builds and more consistent finishes**
    - ➢ **Minimal backionization problems allows for higher film builds**

Disadvantages

- ✗ **Except for a ground wire, these guns are entirely mechanical assemblies**
  - ➢ **More wear components, more impact fusion problems and longer color changeover times**
    - ➢ **Excessive gun wear due to the intimate contact between the powder and the wall of the gun**
    - ➢ **Electrostatic charging can deteriorate if powder coats the inside of the gun**
- ✗ **Technology is sensitive to powder particle size, environmental conditions and powder chemistry/formulation**
  - ➢ **Different powder materials perform differently**
  - ➢ **Very sensitive to humidity and temperature**
- ✗ **Powder deposition rate on the target object is relatively slow**

Powder Coating Equipment

Powder Delivery Systems

- **Functions**
  - Allows powder to be easily transported from the hopper to the gun with a high degree of uniformity and consistency
  - Preconditions the powder by breaking up agglomerations and removing adsorbed moisture
    - Improves handling and flowability of the material
    - May screen powder into the hopper to reduce clumping, improve flowability, and ensure proper powder dispersion
- **Three basic types of powder feeder systems**
  - Fluidized Hoppers
    - Most common powder feeder system
    - The process begins with fluidizing the powder using compressed air
      - Powder is mixed with compressed air, enabling it to be pumped from the hopper to the spray gun
      - Powder delivery is accomplished with a venturi (injector) pump
  - Vibratory Box Feeders
    - Allow the powder to be pumped directly from the box it is shipped in
      - Beneficial for job shop or small batch operations
      - Plastic liner inside box may be resealed to store leftover powder for future use
    - Less uniform feed than fluidized hopper but is still of sufficient uniformity for handgun applications
  - Gravity Feed Hoppers
    - Typically conical in shape in order to funnel the powder to the pump at the base of the unit.
      - Smaller units that mount on spray guns are also available
    - Units often combine the force of gravity with vibration or mechanical agitation for uniform powder flow
    - Compressed air is not required for fluidization
    - May be best suited for powders with high specific gravities or small batch operations

Powder Coating Equipment

Fluidized Systems

- Powder is fluidized in the hopper with compressed air
  - Vibration or another form of mechanical agitation may be incorporated to assist with fluidizing heavy or hard to fluidize powders
- Fluidized hoppers used for manual application operations are usually cylindrical and constructed of stainless steel
  - Easily cleaned
    - May have dumping port for emptying leftover powder
  - May have level probes to monitor the amount of powder remaining in hopper while spraying
  - For mobility, the hopper and spray gun control module are typically cart mounted
- Floor of hopper is porous
  - Referred to as the fluidizing plate or fluidizing membrane
  - Air is introduced into the powder through the porous floor from the plenum below it
  - As compressed air moves upward through the powder, individual particles become suspended in the air stream
    - When all of the particles are in suspension, the powder is said to be fluidized
    - Once fluidized, the powder behaves like a liquid and can be pumped
    - Properly fluidized powder has a "simmering" appearance - small bubbles breaking uniformly over the entire surface of the powder
    - Poor fluidization is characterized by the formation of geysers (air escapes without fluidizing the powder)
      - Results in partial fluidization and inconsistent flow from the powder pump
  - Need a supply of clean, dry air for the hopper
    - Otherwise, fluidizing plate will plug with oil and other contaminants causing poor fluidization and, possibly, plate rupture
    - Allowing the powder to fluidize for approximately 15 minutes prior to spraying may dissipate any surface moisture on the powder particles
    - If air is moist or oily, the powder will become contaminated
      - Results in poor handling, charging and spraying properties
      - May lead to fisheyes and discoloration problems

Powder Coating Equipment

Fluidized Systems

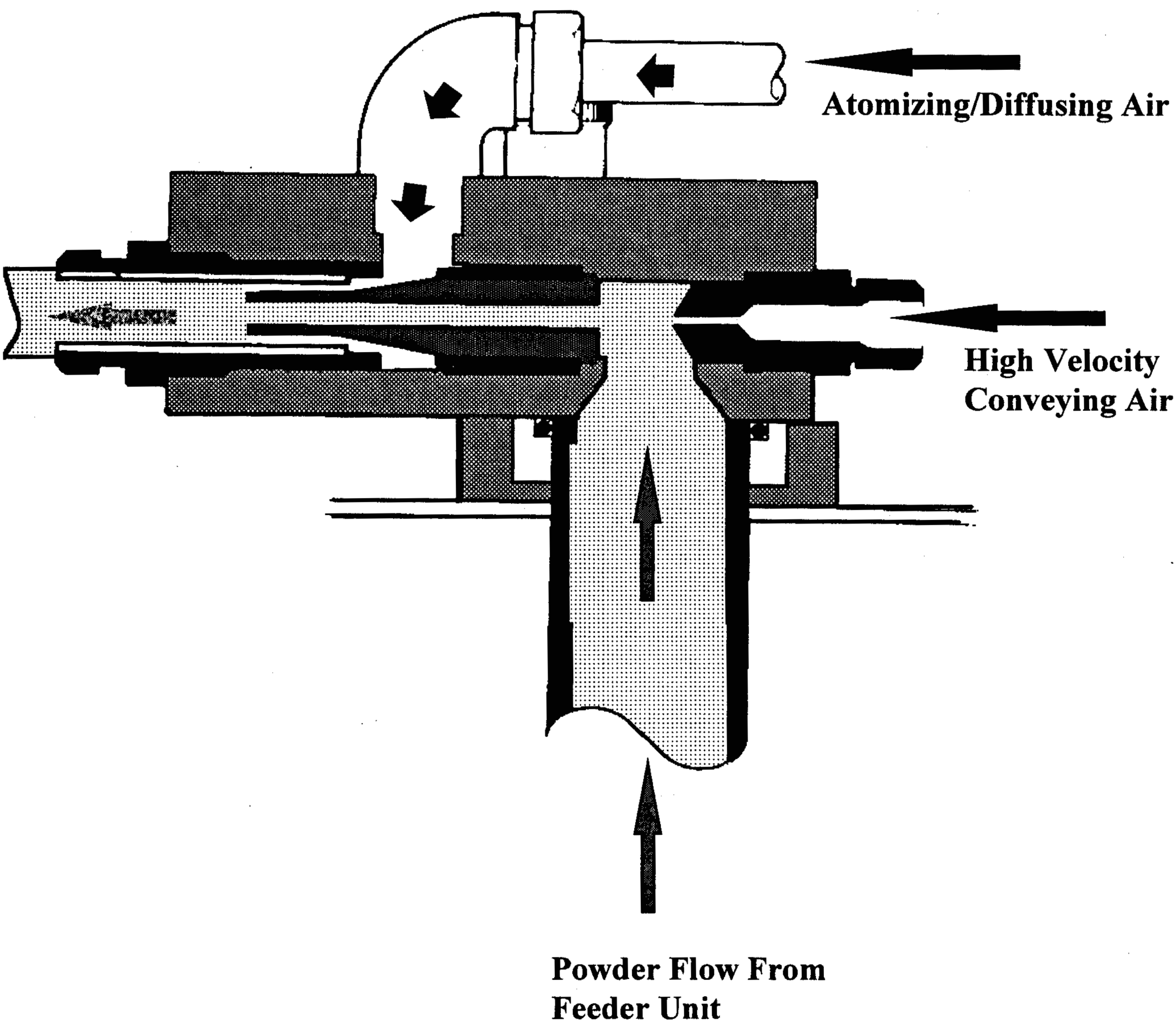
Powder Coating Equipment

Powder Pumping

- A critical component of the powder application system
  - Quality of flow affects finish quality
  - Consistent powder delivery ensures good film control and optimum charging efficiency
- Most delivery systems (fluidized hoppers and vibratory boxes) use the basic Venturi principle in their powder pump design
- Compressed air is forced through a small orifice into the Venturi pump chamber
  - This high velocity air flow is referred to as the flow, injector, conveying or delivery air
- The high velocity air passes across the top of the feeder tube connecting the pump to the powder supply
- A low pressure zone is created as the high velocity air enters the pump chamber, drawing a vacuum
- The vacuum siphons powder from the hopper into the chamber where it blends into the air flow and is conveyed through the powder hose to the spray gun
- A second air flow, referred to as atomizing or diffusing air, joins the conveying air/powder stream downstream of the feeder tube
  - Provides better control and regulates powder delivery to the applicator
  - Used to control the volume/velocity of the air flow through the powder hose
- A careful balance of conveying air and atomizing air prevents surging or spitting of powder at the applicator
  - A controlled, consistent and uniform powder flow is delivered to the applicator

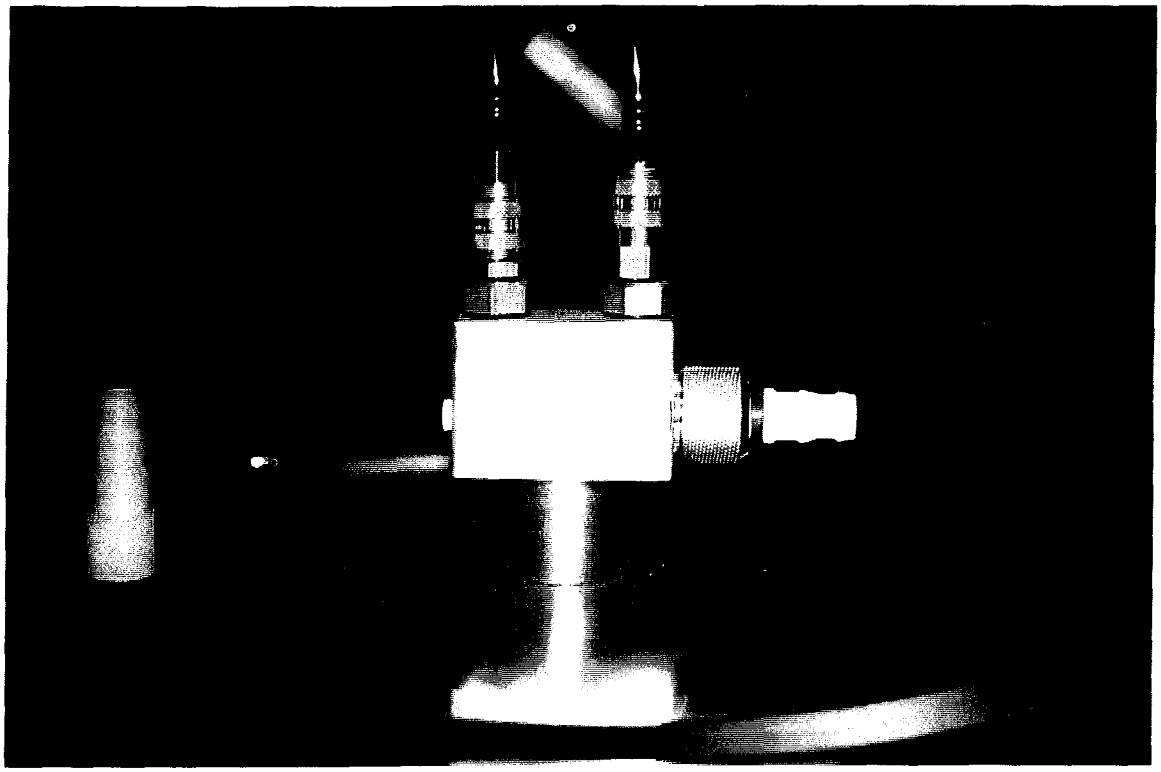
Powder Coating Equipment

Venturi Pump



Powder Coating Equipment

Venturi Pump



Powder Coating Equipment

Powder Delivery Hose

- Diameters may range from 5/16 (for specialty applications and low flow rates) to 3/4" for high flow rates and bulk powder transfer
  - Diameter of hose depends on the volume of powder to be conveyed, the distance it must travel, and the type of pump/application equipment used
  - Larger diameters are required for longer runs and higher flows
    - Prevents back pressure from building up in the hose which can inhibit powder flow
  - Need adequate air velocity through hose to transport the powder
    - Otherwise powder may settle out of suspension in the hose and cause powder surging from the gun
- Powder hoses may be constructed of a wide variety of materials
- The following factors should be considered in regard to efficiency of the powder delivery process and finish quality
  - Hose material susceptibility to impact fusion
  - Hose's ability to resist kinking
  - Will hose material chemically react with powder or generate a tribo charge?
  - Wear resistance of hose material
  - Ease of cleaning
- Hose must be installed correctly
  - Hose should be well supported
  - Keep powder hoses as short as possible and minimize sharp bends
    - Minimizes frictional resistance (meaning less heat), resulting in less impact fusion problems
      - Maintain a minimum radius of 9" at all bends
      - Impact fusion - the packing or partially melting of powder particles within application equipment
    - Long hoses and hoses with sharp bends require higher air pressure to transport powder and are more prone to impact fusion problems
  - Hose should be routed to minimize changes in elevation and number of bends
  - Keep hose clear of traffic and equipment that might damage it.

Powder Coating Equipment

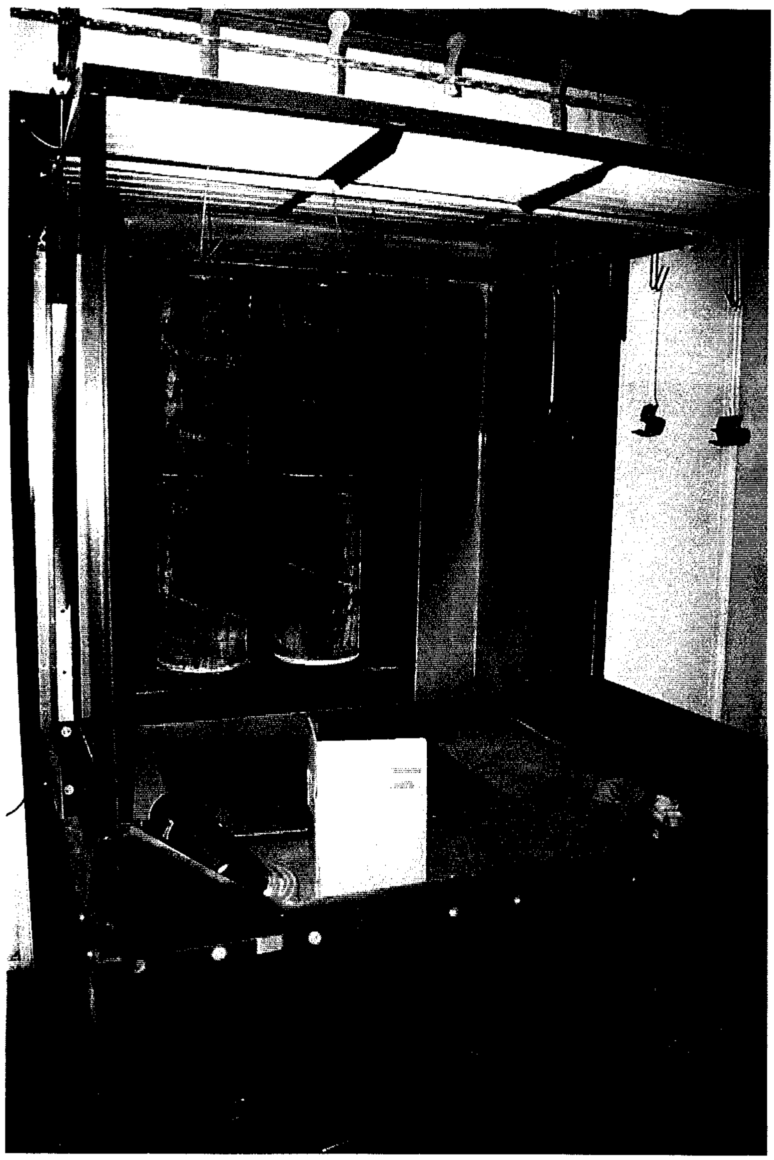
Spray Booth

- **Safely contains powder overspray within the enclosure**
  - **Conveys overspray away from operator**
  - **Air is drawn into the booth through gun openings, part entrance/exit openings and conveyor slot openings.**
    - **Drawing air at sufficient velocity through these openings prevents powder overspray from escaping the booth**
    - **Excessive air flow may draw powder away from the part**
  - **Average face air velocities through openings (stated in lineal feet per minute) is typically 100 to 120 fpm**
    - **Air flow velocities may range from 80 fpm (for small batch booths) to 150 fpm (for booths with large part openings)**
- **Important that the volume of air removed from the booth be adequate to maintain a safe ratio of the powder to air mixture**
  - **When a large amount of powder is suspended in air at a high level of concentration, it may cause an explosion if ignited in an enclosed area (e.g., duct work, closed collectors and any other structure that does not have a sufficient pressure relief opening area)**
  - **Lower explosion limit (LEL) of powder is typically around 0.03 oz/ft^3 (30oz / 1000 ft^3)**
    - **When this value is exceeded, an explosion may occur**

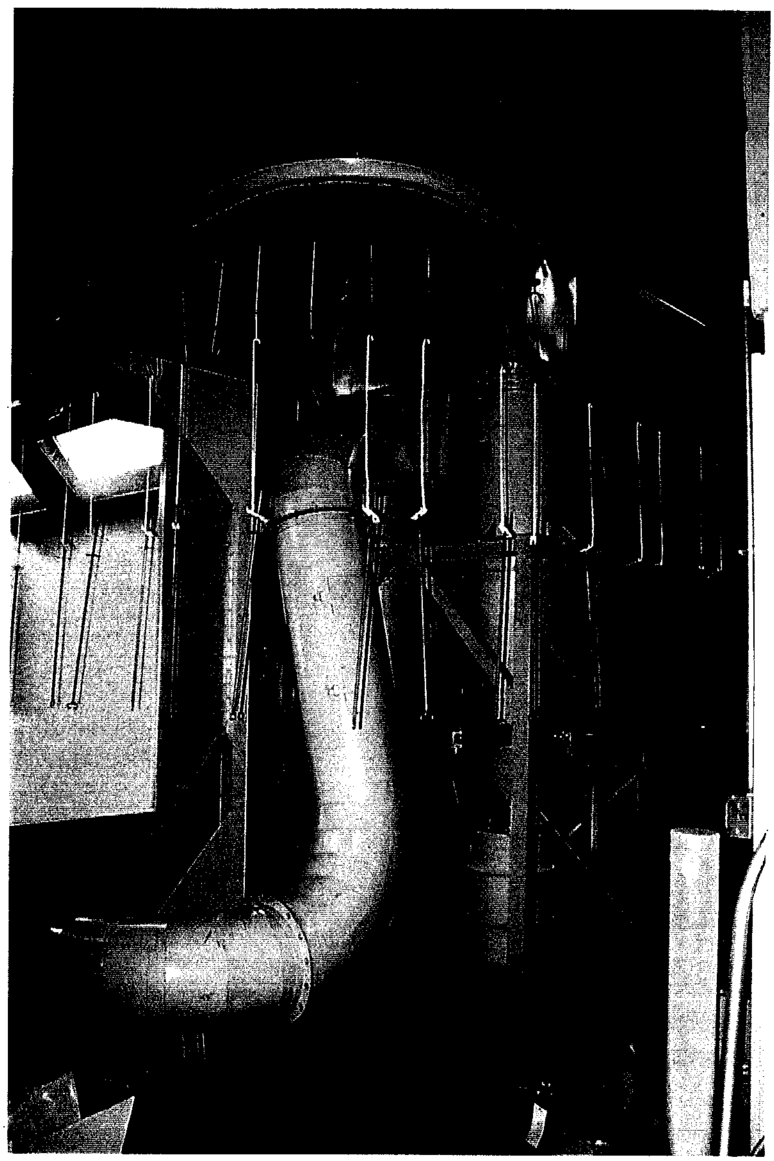
Powder Coating Equipment

Powder Recovery Systems

- Used to collect powder overspray for reuse or disposal
  - Will enhance utilization efficiency (see page 5-22) if powder is reused
    - Powder collected for reuse is sieved to remove contamination and condition the powder for re-spraying
- Minimizes the powder concentration in the spray booth
  - Typical powder combustion level = 40-60 oz per thousand cubic feet of air
- Spray-to-waste vs. recovery issue depends on
  - First pass transfer efficiency - important for both spray-to-waste and recovery/reuse operations
  - System efficiency
  - Number of colors
  - Frequency of color changes
  - Number of color changes
- Two types of recovery systems - cartridge modules and cyclones
  - Cyclone systems- one cyclone system may be used to recover a number of colors
    - Clean between color changes
  - Cartridge systems - need a dedicated module for each color to be recovered for reuse
- Cartridge module vs. cyclone
  - General rule-of-thumb
    - If greater than 5-6 colors - use cyclone
    - If < 5-6 colors - use cartridges
- Must consider recovery cost issues
  - Applied material cost, labor costs and production costs



Cartridge powder recovery system



Cyclone powder recovery system

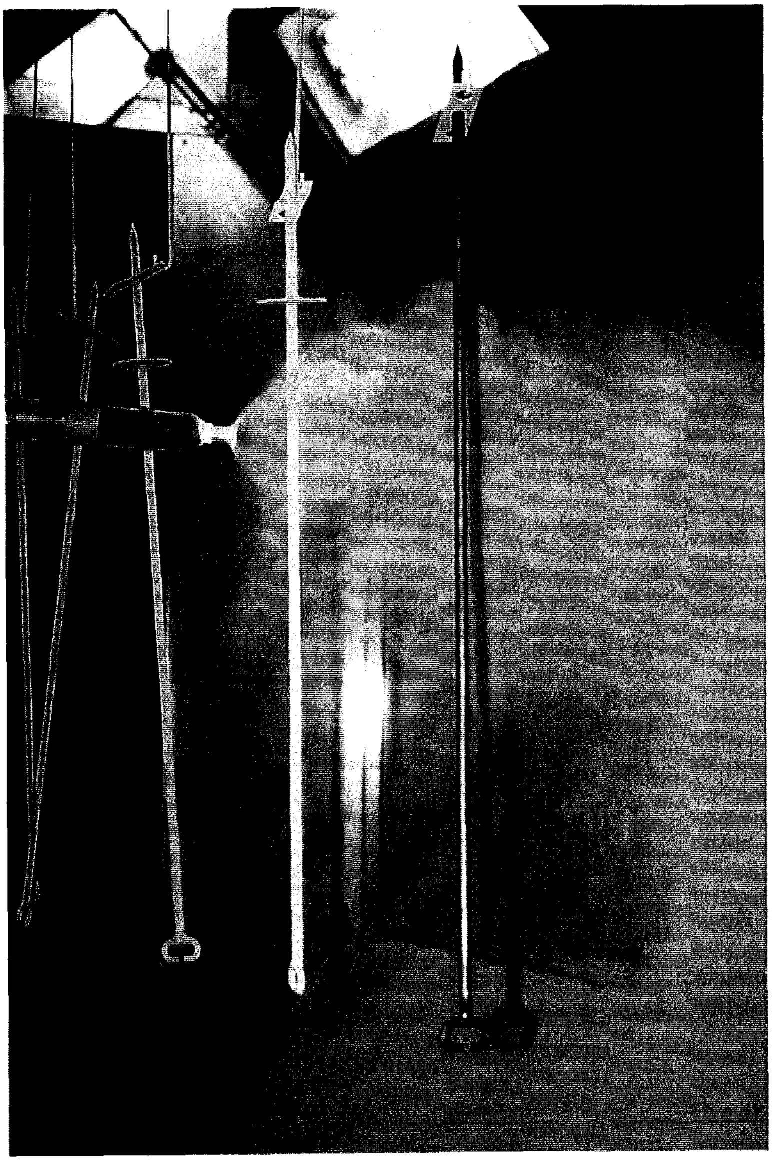
Utilization Efficiency

- Like liquid application systems, efficiency is a key consideration with powder coating
- Utilization efficiency (U.E.)
  - For spray-to-waste systems
    - $$\text{U.E.} = \%\text{T.E.} = \frac{\text{Amount of powder deposited on parts}}{\text{Amount of powder sprayed}} \times 100$$
    - First pass transfer efficiencies of 50-75% are feasible
  - For reclaim systems
    - $$\text{U.E.} = \frac{\text{T.E.}}{(1-\text{T.E.})\text{x}(1-\text{R.E.}) + \text{T.E.}}$$
    - Achievable U.E. for cartridge systems ~ 98-99%
    - Achievable U.E. for cyclone systems ~ 90-95%

T.E. = First Pass Transfer Efficiency
R.E. = Reclaim Efficiency

A Powder Coatings Coverage Chart is provided in Appendix C

Utilization Efficiency



Utilization Efficiency

Factors Affecting Transfer Efficiency

- Equipment design and setup
  - Gun electrode/nozzle configuration affects charging time, electrostatic field strength and spray pattern
  - Electrostatic parameters
    - Field strength - function of electrostatic parameters (kV and uA)
    - Gun Voltage (kV) - excessive gun voltage complicates the coating of recessed areas
    - Gun current (uA) - excessive gun current is a primary cause of back ionization
      - Nordson Corporation reports 20uA provided best T.E., coverage and finish
  - Powder flow rate/velocity
    - Generally, lower = better
    - As velocity increases, particle velocity increases and charging time decreases
    - Spray only the amount of powder needed to meet coating requirements using the minimum amount of air necessary to achieve uniform powder flow
      - First adjust "feed" air to obtain proper powder flow rate from gun
      - Then adjust atomizing air to achieve desired spray consistency and pattern shape
        - May need to slightly increase feed air pressure
- Part size and geometry
- Continuity to ground
  - Grounding is not necessary for powder particle deposition but is necessary for safety and transfer efficiency
    - Glass, plastic and wood may be powder coated
    - Ungrounded targets have a limited ability to accept charged particles
    - After an ungrounded part becomes saturated with charge, it develops a negative charge and repels subsequent particles
  - Lack of ground is the most common cause of poor transfer efficiency
    - Improperly grounded parts are less effective in attracting powder
  - Poor grounding also causes inconsistent coatings and inadequate film builds
- Racking density

Utilization Efficiency

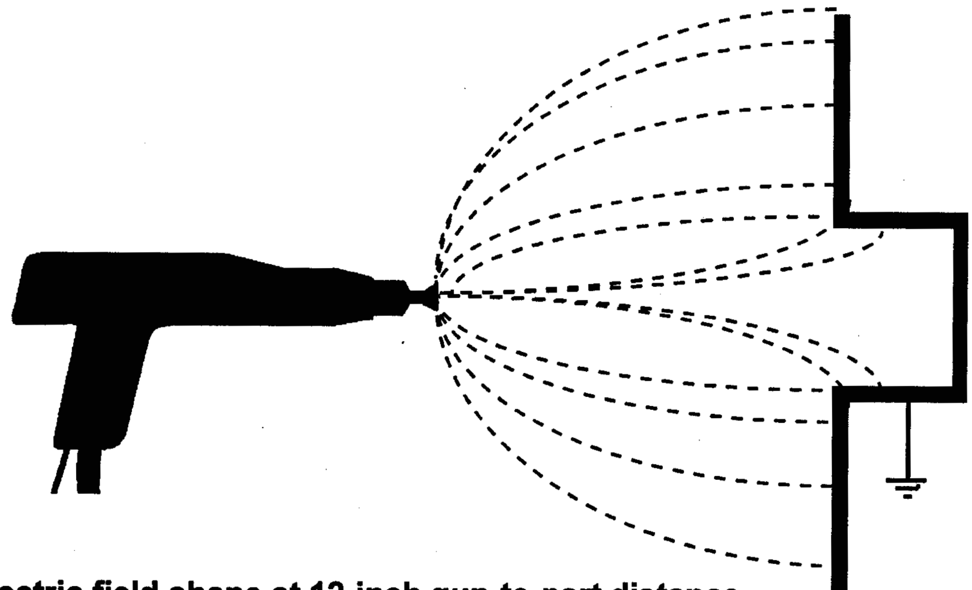
Factors Affecting Transfer Efficiency

- **Operator technique**
  - **Spray gun orientation**
  - **Pattern selection and control**
    - **Determines how powder will be distributed and directed to the target**
      - **Affects the spray pattern shape, size, velocity, orientation and distribution**
      - **Important for film thickness control and penetration into recessed areas**
    - **Use nozzles for pattern control and to reach inside recesses**
    - **A variety of nozzles exist for powder coating application equipment**
      - **Flat spray nozzles**
        - **Usually provide more penetration**
        - **Provide the powder distribution and high particle velocities needed to penetrate recessed areas but have reduced efficiency on flat surfaces**
      - **Conical deflector nozzles**
        - **Produce mushroom-shaped patterns = softer powder delivery = higher transfer efficiency**
        - **Depending on their design, patterns produced by conical deflectors may range from high velocity narrow patterns (1" diameter stream) to wide, hollow-shaped patterns (18") with very soft/well dispersed forward velocities**
        - **Provide uniform coverage on flat ware**
      - **X-cut or cross-cut nozzles**
        - **Produces two intersecting flat spray patterns**
        - **Works well as a general purpose nozzle - good penetration and transfer efficiency**
        - **Common fan patterns range from 6 to 14 inches depending on application and gun-to-part distance**
      - **Castle design nozzles**
        - **Consist of numerous slots**
  - **Gun-to-part distance**
    - **Distance affects powder charging time, electrostatic field strength and shape, and deposition efficiency**
      - **Powder particles acquire a charge while traveling from the gun to the target through the electric field of corona discharge**
    - **Generally, farther = better**
      - **Greater distance = increased residence time in electrostatic field (for better charging) and lower particle velocity**
      - **Close gun-to-part distance promotes back ionization or blows powder off part**

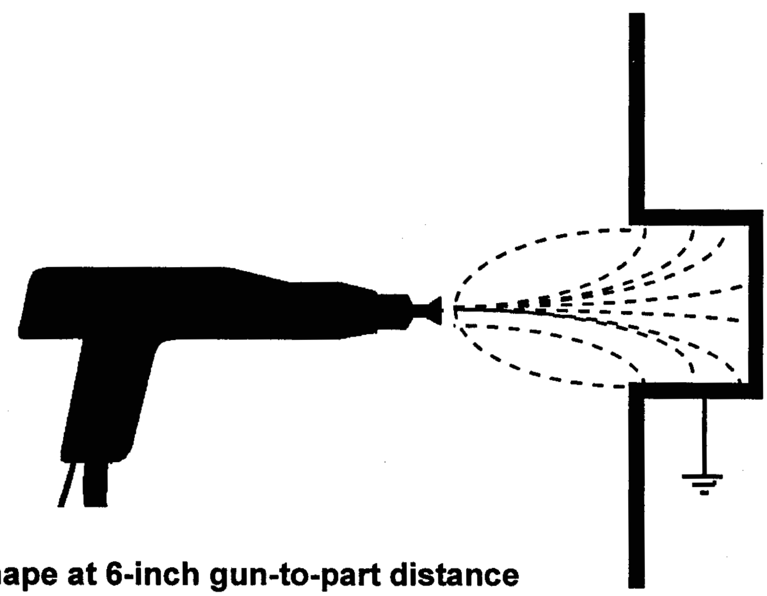
Utilization Efficiency

Factors Affecting Transfer Efficiency

Effect of Gun-to-Part Distance on Electrostatic Field



Electric field shape at 12-inch gun-to-part distance



Electric field shape at 6-inch gun-to-part distance

Utilization Efficiency

Factors Affecting Transfer Efficiency

- **Humidity**
  - Corona systems need 45-60% relative humidity or less at 65-75°F
    - Typically require environmental rooms
  - Tribo systems need bone dry conditions
    - Humidity coats the powder particle surfaces and inside of gun with a film of moisture which reduces friction
- **Booth air flow velocity and balance**
  - Excessive air velocity in spray booth decreases transfer efficiency
    - Need 100-150 ft/min air flow in powder booth
    - Minimal cross drafts in spray area
- **Booth canopy material**
  - Electrostatic field does not necessarily recognize the target as the only ground
    - Steel or stainless steel booth construction diverts a portion of the electrostatic field away from the target, lowering T.E.
  - Need to maintain 18" between top of part and ceiling/walls of booth
  - May also use a plastic canopy to increase electrostatic attraction to part
- **Powder composition/chemistry/particle size**
  - Need well charged powder for good deposition efficiency
  - Binders, fillers and pigments may effect charging efficiency of powder
  - Particle size distribution affects film thickness, texture, gloss, application efficiency (electrostatics and delivery performance), and physical/chemical characteristics
    - Average particle size ~ 30 - 40 um
    - Surface area of powder particle determines charge acceptance
    - Small particles
      - More susceptible to air currents
      - Tend to be blown by part if conveying air velocity is too excessive
      - Deposit on target first because of higher charge to mass ratio
    - Larger particles
      - Tend to penetrate recesses better
      - Deposit on top of smaller particles
      - More affected by gravity
    - A variety of particle sizes are necessary for optimum film formation

Troubleshooting

Problem - Poor T.E.

- ✗ Lack of ground
- ✗ Poor penetration
  - ➢ Voltage too high, poor grounding, powder delivery rate too low, gun-to-target distance too great, incorrect spray pattern, or poor gun placement
    - ➢ Can increase powder velocity, decrease voltage, try alternative spray pattern nozzles or heat up part
- ✗ Powder feed surging
- ✗ Inconsistent powder delivery - improper hopper fluidization

Problem - Poor Wrap

- ✗ Poor ground
  - ➢ Clean hangers regularly
    - ➢ Chemically strip or burn off
  - ➢ Ensure part is making good contact with hanger
  - ➢ Check grounding periodically
    - ➢ Should never be greater than 1 million ohms (1 Megaohm) of resistance
- ✗ Poor charging
  - ➢ High voltage power supply not providing enough kV at charging electrode
    - ➢ Check with high voltage meter
  - ➢ Broken electrode
  - ➢ Tribo charging in hose
- ✗ Excessive powder delivery rate / atomizing air = higher particle velocity
  - ➢ Lower settings
  - ➢ Increase gun-to-part distance
- ✗ Excessive moisture in powder booth air
  - ➢ Humidity dissipates the charge applied to the powder particles
- ✗ Powder particle size distribution is too fine
  - ➢ Too much reclaim added to virgin powder
  - ➢ Virgin powder is pulverized too fine by manufacturer

Troubleshooting

Problem - Poor Penetration ***(typically caused by the phenomenon known as the Faraday Cage Effect)***

- ✗ **Excessive voltage setting increases the Faraday Cage effect**
  - ➢ **Voltage setting may be reduced to improve powder penetration**
    - ➢ **To increase penetration, a voltage setting of 50-75kV may be most effective**
- ✗ **Improper powder delivery rate - too high or too low**
  - ➢ **Higher powder delivery rate = higher air settings = higher particle velocity**
  - ➢ **If too high, air that transports the powder may blow powder off the part**
    - ➢ **Air must be able to exit recessed areas without blowing powder from part**
  - ➢ **Powder will not penetrate into recessed areas if the delivery rate is too low**
    - ➢ **Particle velocities are too low**
    - ➢ **Need to increase powder delivery air setting or use gun barrel extension**
      - ➢ **Problem - sprays more powder than what is really needed**
- ✗ **Spray pattern too wide**
  - ➢ **Shape, size, velocity, electrostatic charge, orientation and powder distribution affect penetration**
    - ➢ **Experiment with various nozzle tip designs**
  - ➢ **Use smaller deflector to better direct powder into recessed areas**
    - ➢ **Provides more forward velocity into recessed areas, allowing particles to overcome "Cage" areas**
    - ➢ **Small conical deflectors and low velocity flat spray (slotted) nozzles provide best penetration**
    - ➢ **Gun-to-target distance may need to be modified since higher forward velocities may blow powder off the part if too close**
- ✗ **Other potential causes include**
  - ➢ **Poor target grounding**
  - ➢ **Poor gun placement**
    - ➢ **May decrease gun-to-target distance to improve powder penetration into recessed areas**
    - ➢ **Gun-to-part distance affects the ability of the powder to cover the part**
      - ➢ **Greater gun-to-part distances = larger pattern for more coverage**
  - ➢ **Powder too fine**

Troubleshooting

Problem - Back Ionization *(A condition where particles do not apply to substrate due to repelling forces caused by excessive gun current or excessive mil build)*

- ✗ **Excessive gun (ion) current is the primary cause of back ionization**
  - ➢ **Can cause a reversal of electrical charge on the powder surface layer**
    - ➢ **An excessive build-up of charged powder particles limits further powder particle deposition on the substrate**
    - ➢ **Produces micro sparks in coating layer**
    - ➢ **Typically called "starring" - a very rough texture in the uncured state**
    - ➢ **Causes orange peel texture when cured**
  - ➢ **May remedy by using current limiting application equipment or free ion collectors**
    - ➢ **Controls the number of ions flowing to the part**
    - ➢ **Free ion collectors reduce the available voltage at the gun tip**
  - ➢ **May also reduce voltage setting**
    - ➢ **May lead to unacceptable penetration and/or coverage**
  - ➢ **Other potential causes**
    - ➢ **Gun positioned too close**
    - ➢ **Powder delivery rate too high**
    - ➢ **Poor ground**
    - ➢ **Powder too fine**

Problem - Powder Poorly Adheres to Part (falls from part easily)

- ✗ **Poor electrostatic charging of powder**
- ✗ **Powder output too high or air pressure settings too high**
  - ➢ **Blows powder off the target**
- ✗ **Unsuitable particle size distribution or powder type**
- ✗ **Poor ground**

Troubleshooting

Problem - Inconsistent Powder Delivery Rate / Surging

- ✗ **Insufficient/inconsistent air pressure or volume**
  - ➢ **Check air supply to ensure air pressure to powder feed does not drop when other air operated equipment is activated**
  - ➢ **Most powder systems require 60 psig or greater to operate effectively**
- ✗ **Hoses kinked, pinched, flattened or too long**
  - ➢ **Hoses should be as short and straight as possible**
- ✗ **Improper hopper fluidization**
- ✗ **Powder level in hopper is too low**
- ✗ **Hoses, venturi pump or gun is clogged with powder**
  - ➢ **Inspect equipment for impact fusion and routinely clean with compressed air**
    - ➢ **Possible causes: contaminated powder supply, humidity, powder too fine, poor powder free flowing properties**
- ✗ **Poor compressed air quality - system needs clean, dry air**
  - ➢ **Maximum oil content = 0.1 ppm**
  - ➢ **Dew point of 35°F**
  - ➢ **Particulate matter no larger than 10 um**
- ✗ **Excessive powder pump wear**
- ✗ **Powder particle size**
  - ➢ **A good blend of reclaim and virgin powder is needed to control particle size distribution**
    - ➢ **Small particle sizes (10 um or less) are more difficult to handle**
    - ➢ **When the particle size distribution becomes too fine, the ability to fluidize, transport, charge and deposit the powder on the part diminishes**
- ✗ **Temperature and humidity**
  - ➢ **Powder is hygroscopic (adsorbs moisture)**
  - ➢ **Consistent powder delivery rates are best obtained at 45%-60% relative humidity and 60-80°F**
    - ➢ **Higher humidity = higher fluidization pressures, more impact fusion problems and higher delivery pressures**
    - ➢ **Higher temperatures (above 100°F) cause poor film control**
      - ➢ **The higher the temperature, the easier it is to apply more powder**

Troubleshooting

Problem - Inadequate Powder Output

- ✗ Kinked or flattened powder hose
- ✗ Worn Venturi pump
- ✗ Air pressure settings too low
- ✗ Obstruction from contaminated powder supply
- ✗ Impact fusion blockage
  - ➢ Check equipment (guns, hoses, venturi pump) for impact fusion
    - ➢ Clean or repair as needed
- ✗ Powder level in hopper is too low
  - ➢ Less powder will be delivered to the gun at a given delivery air setting as the powder level in the hopper decreases
  - ➢ Fill hopper, adjust delivery air setting or adjust hopper fluidization air
- ✗ Powder is not fluidized properly
  - ➢ Fluidizing air pressure is too low
  - ➢ Porous membrane of hopper is blocked
  - ➢ Compressed air contains too much moisture
    - ➢ Install or repair air drying system
  - ➢ Moisture content of powder is too high
    - ➢ Review powder storage, handling and transportation practices
  - ➢ Powder has bad free flowing properties
    - ➢ Powder has passed its expiration date or has been exposed to heat

Troubleshooting

Problem - Poor Spray Pattern

- ✗ Worn equipment
  - ➢ Replace deflectors, feed tubes
- ✗ Impact fusion
  - ➢ Clean hoses, venturi pump or gun
- ✗ Delivery (feed) air too low
- ✗ Excessive fluidizing air pressure
- ✗ Powder too fine

Problem - No Air Percolating Through Powder

- ✗ Insufficient air pressure
- ✗ Plugged or obstructed porous membrane
- ✗ Compacted powder

Problem - Geysers Through Powder in Hopper (a.k.a. rat holing)

- ✗ Excessive fluidizing air pressure
- ✗ Powder level too low
- ✗ Packed or moist powder
- ✗ Membrane obstructed
- ✗ Plugged or broken membrane

Problem - Powder Stratification in Hopper

- ✗ Powder level too high
- ✗ Powder too fine

Troubleshooting
Finish Defects

- ✗ **Dirt**
  - ➢ **Dirt on parts because of inadequate pretreatment**
  - ➢ **Dirt in powder**
  - ➢ **Dirt from conveyor or hangers, operator, or booth air**
- ✗ **Orange peel or textured appearance**
  - ➢ **Coated material is warmed up too fast or too slow during curing**
  - ➢ **Powder type is too fast or particle size distribution is too coarse**
  - ➢ **Moisture contamination**
  - ➢ **Heat damaged powder**
  - ➢ **Back ionization (too much powder applied)**
- ✗ **Cratering**
  - ➢ **Contamination with other powder**
  - ➢ **Inadequate pretreatment**
    - ➢ **Organic contaminants still on substrate**
  - ➢ **Contamination from spraying area**
    - ➢ **Silicones**
- ✗ **Pinholing**
  - ➢ **High moisture content of powder**
  - ➢ **Outgassing from casting**
    - ➢ **Preheat castings and cool down before application**
  - ➢ **Gas entrapment and escaping due to chemical reaction**
    - ➢ **Keep coating thickness below 100 um**
  - ➢ **Powder has passed its expiration date or has been exposed to heat**
- ✗ **Discoloration**
  - ➢ **Improper oven exhaust**
  - ➢ **Bake time too long**
  - ➢ **Oven temperature too high**
  - ➢ **Variation in film thickness**
  - ➢ **Powder formulation**

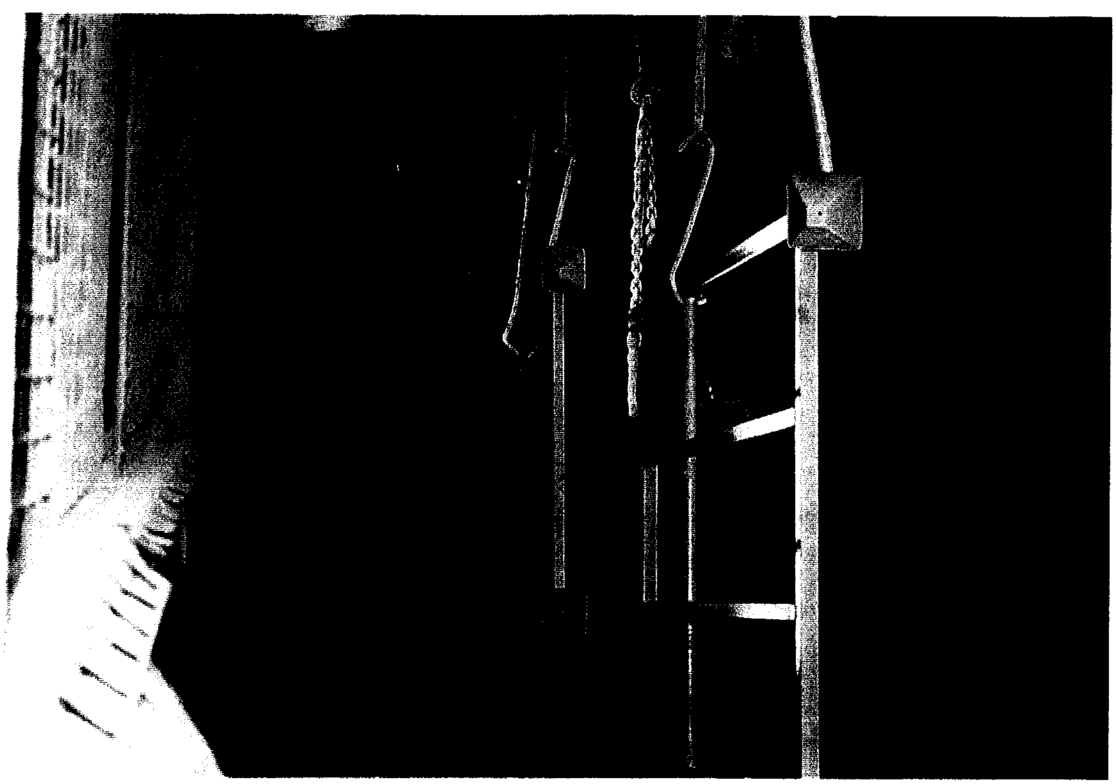
Troubleshooting
Finish Defects

- ✗ Film shrinkage leaving bare substrate
  - ➢ **Inadequate pretreatment or dry off**
- ✗ Poor chemical resistance/pencil hardness/abrasion resistance
  - ➢ **Under cured**
  - ➢ **Powder resin type or formula**
- ✗ Poor adhesion or corrosion resistance
  - ➢ **Inadequate pretreatment**
  - ➢ **Under cured coating**
  - ➢ **Powder resin type or formula**
- ✗ Poor impact resistance/flexibility
  - ➢ **Inadequate pretreatment**
  - ➢ **Under cured coating**
  - ➢ **Powder resin type or formula**
  - ➢ **Film thickness too high**
  - ➢ **Change in substrate thickness or type**
- ✗ Gloss too low
  - ➢ **Incompatible powder contamination**
  - ➢ **Micropinholing from outgassing**
  - ➢ **Powder resin type or formula**
  - ➢ **Powder has passed its expiration date or has been exposed to heat**
- ✗ Gloss too high
  - ➢ **Under cured coating**
  - ➢ **Powder formula**
- ✗ Matting of powder surface
  - ➢ **Contamination with other powder**

Section 6.0

Improving Efficiency

Techniques & Technologies

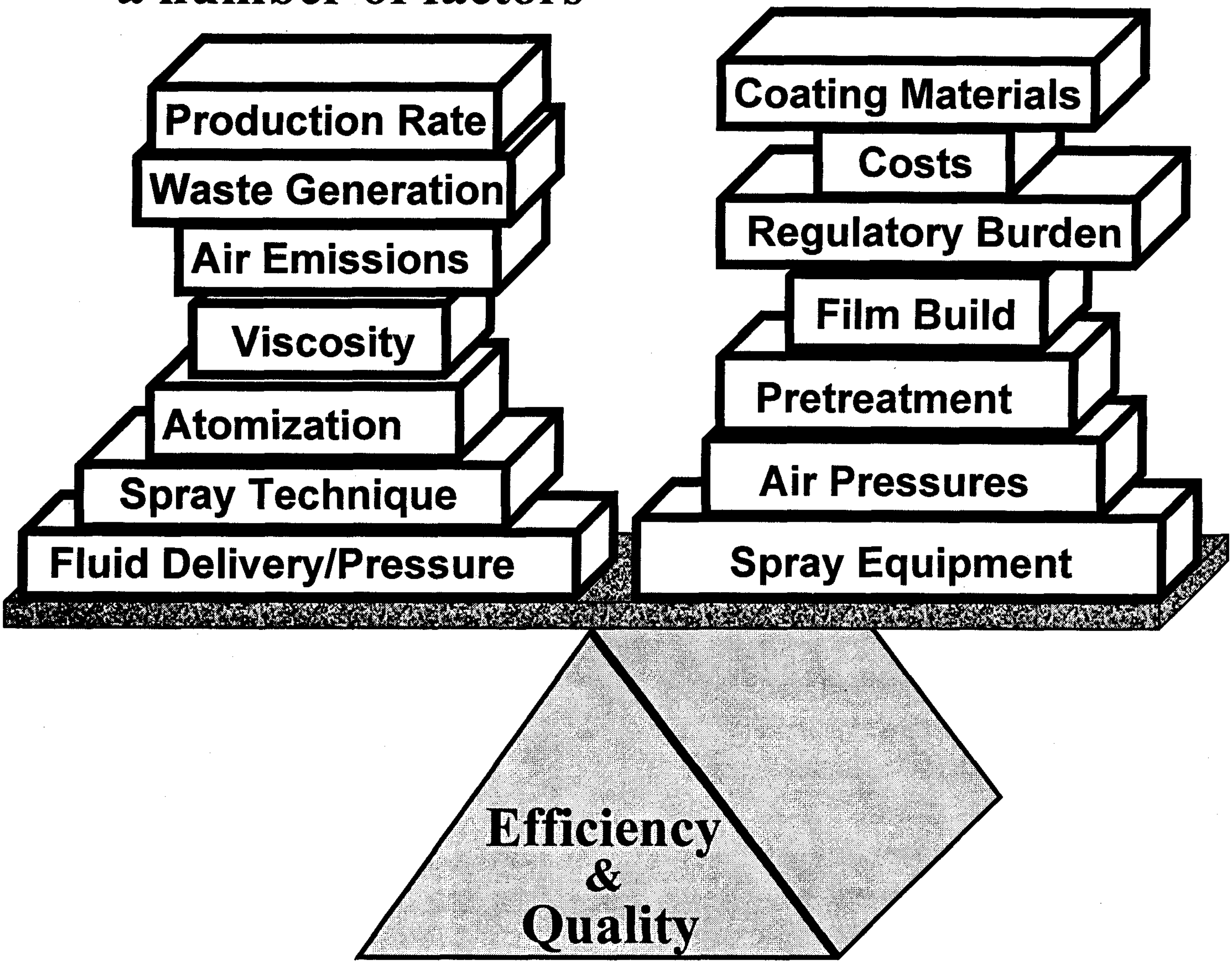


Introduction to Improving Efficiency

- Review factors that affect efficiency of painting/coating operations. Topics include:
  - Application efficiency
    - Transfer and film build efficiency
  - Operator spray technique and practices
  - Opportunities for efficiency improvement
  - Waste / cost reduction ideas, practices and technologies
- Objective - to improve efficiency and productivity without sacrificing finish quality
- Benefits associated with improving efficiency
  - Reduced waste generation rates
    - Hazardous and nonhazardous wastes
  - Reduced air emissions
    - Volatile organic compounds (VOC's) are considered air pollutants which can produce unwanted ozone.
  - Reduce costs
    - Includes waste disposal costs, product purchase costs, personal protective equipment (PPE) costs, booth maintenance costs, etc.
  - Cleaner / healthier work environment
    - Toxics (e.g., solvents and isocyanates) cause adverse health effects.
  - Reduced environmental liability / environmental impact
  - Reduced regulatory burden
    - May reduce a facility's hazardous waste generator status
    - May keep a facility out of Title V
    - Fewer environmental reporting requirements

Introduction to Improving Efficiency

- To operate efficiently and effectively, painting and coating operations must balance a number of factors



Application Efficiency

Application Efficiency measures the efficiency of the entire coating system - need to consider

- **Material**
- **Equipment**
- **Operator**
- **Environment**
- **Surface geometry of the parts painted**

To Improve Efficiency, the Entire Spray System Must Be Considered

Components of Application Efficiency

1. **Finish quality**
   - **1st priority - parts must meet a certain standard of quality**
     - **Avoids rework**
     - **All coating material is wasted on reject parts**
     - **Spray efficiency is zero or less**
2. **Transfer efficiency**
   - **Percentage of coating material deposited on part compared to the amount sprayed**
3. **Build Efficiency**
   - **Mil thickness / mil variation / uniformity**

Application Efficiency
Transfer Efficiency

The amount of paint actually applied to the part as compared to the total amount sprayed.

$$\text{Transfer Efficiency} = \frac{\text{Mass of solids deposited}}{\text{Mass of solids sprayed}}$$

OR

$$\text{Transfer Efficiency} = \frac{\text{Volume of solids deposited}}{\text{Volume of solids sprayed}}$$

Factors Affecting Transfer Efficiency

- ✗ Type of spray equipment
- ✗ Operator technique
- ✗ Equipment maintenance
  - ➢ The following adversely affect transfer efficiency: spray tip erosion; air pressure settings; air-line restrictions/plugging; air-cap cleanliness; gun electrode voltage; gun electrode position in the spray pattern; fluid pressure settings; and fluid line restrictions.
- ✗ Racking / part presentation
- ✗ Coating characteristics
- ✗ Gun setup / spray pattern
  - ➢ Fluid delivery rate
  - ➢ Atomization (particle size)
- ✗ Size and shape of part
- ✗ Booth air flow (e.g., turbulence, velocity)
  - ➢ Excessive booth air flow and imbalanced booth air flow adversely affect transfer efficiency and ability to obtain uniform coverage
- ✗ Electrostatics (e.g., ground, voltage, resistivity)

Application Efficiency

Transfer Efficiency

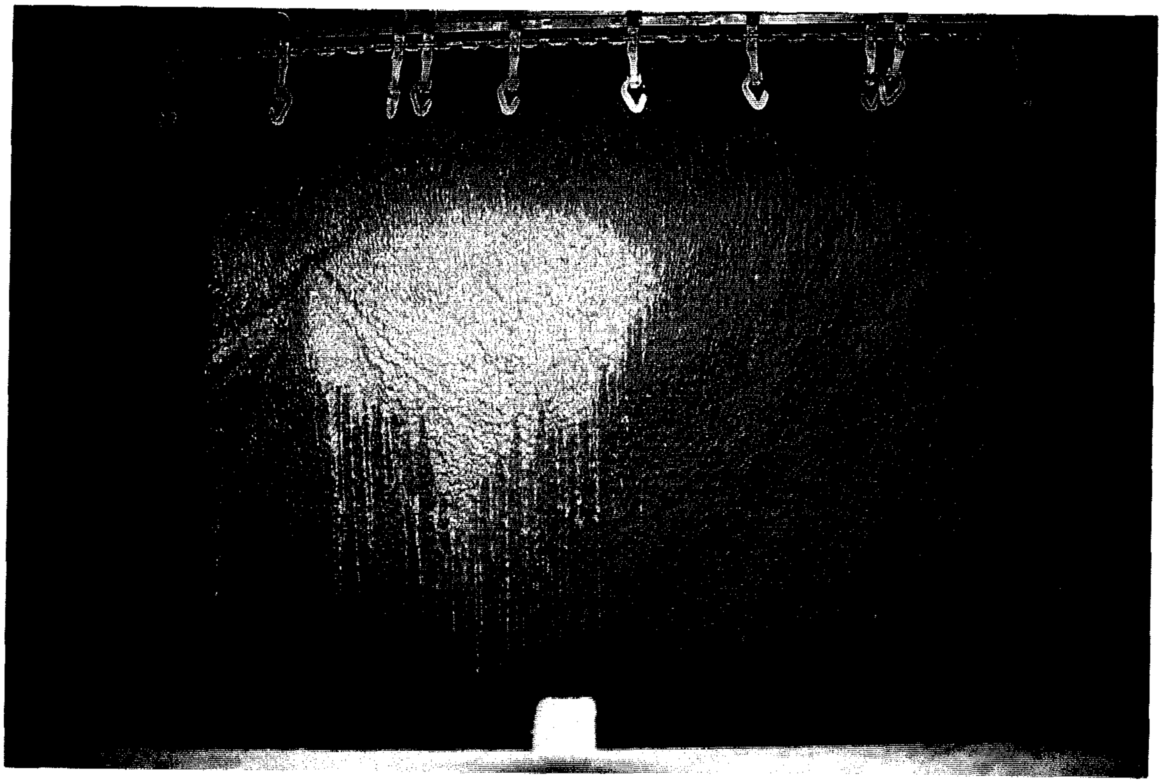
Why is Transfer Efficiency Important?

- ✗ High transfer efficiency means less paint/powder needs to be sprayed in order to coat the part
- ✗ Low T.E. causes:
  - ➢ Excessive air emissions (VOCs)
  - ➢ Excessive overspray
  - ➢ Greater booth maintenance and paint handling
  - ➢ High hazardous waste generation rates
  - ➢ High waste disposal costs
  - ➢ Excessive material consumption and higher material costs
  - ➢ Unhealthy work environment

Application Efficiency

Transfer Efficiency

Cost of Inefficiency



- ✗ At $30/gallon
  - ➢ One 55-gallon drum of material costs $1,650
- ✗ At 30% transfer efficiency
  - ✦ Approximately 39 of the 55 gallons are wasted
    - ➢ End up as overspray waste and excessive air emissions
  - ✦ $1,155 of each drum is wasted

Application Efficiency

Build Efficiency

- **A function of mil thickness and mil build variation**
  - ➢ Wet mil thickness
  - ➢ Dry film build or dry mil thickness
    - ➢ The amount of material left on the surface after the solvent has evaporated. Measured in mils.
- ✗ **Film build is affected by:**
  - ➢ Spray gun setup
    - ➢ Fluid delivery
    - ➢ Atomizing air
  - ➢ Viscosity
  - ➢ Operator spray technique
- ✗ **Film build affects**
  - ➢ Paint durability
  - ➢ Gloss retention
  - ➢ Overall performance
    - ➢ Adhesion
    - ➢ Chemical resistance

GLOSS LEVEL IS SECOND ONLY TO COLOR IN IMPORTANCE AS AN APPEARANCE CHARACTERISTIC

Application Efficiency

Build Efficiency

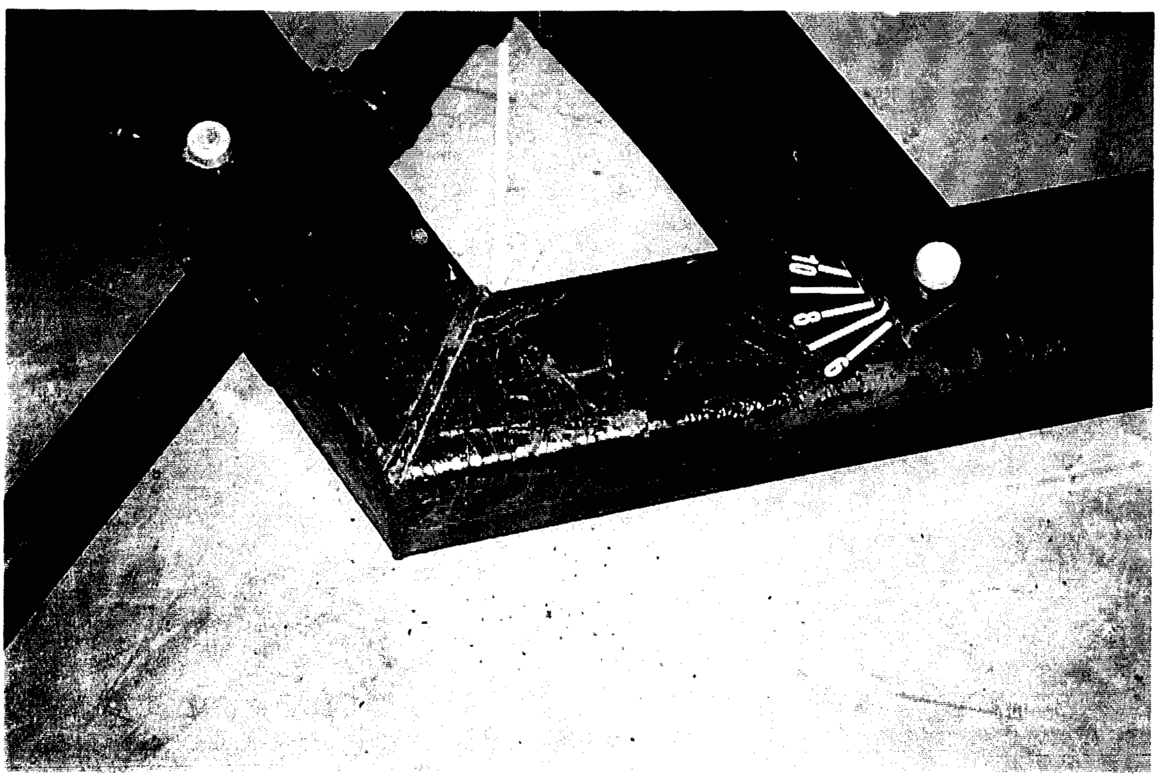
Film Build

If too high

- Blistering
- Cracking
- Line checking
- Orange Peel
- Chipping
- Solvent popping

If too low

- Chalking
- Chipping
- Fading
- Poor chemical resistance
- Poor adhesion



Application Efficiency

Build Efficiency

Cost of Excess Mil Build

- Desired mil thickness = 2.0
- Cost per gallon = $40
- 3.5 lbs VOCs per gallon

Build (mils)	Percentage of Target Build	Gallons Required	Coating Cost	VOC Emissions (lbs)
2.0	100%	50	$2,000	175
3.0	150%	75	$3,000	263
4.0	200%	100	$4,000	350
5.0	250%	125	$5,000	438
6.0	300%	150	$6,000	525

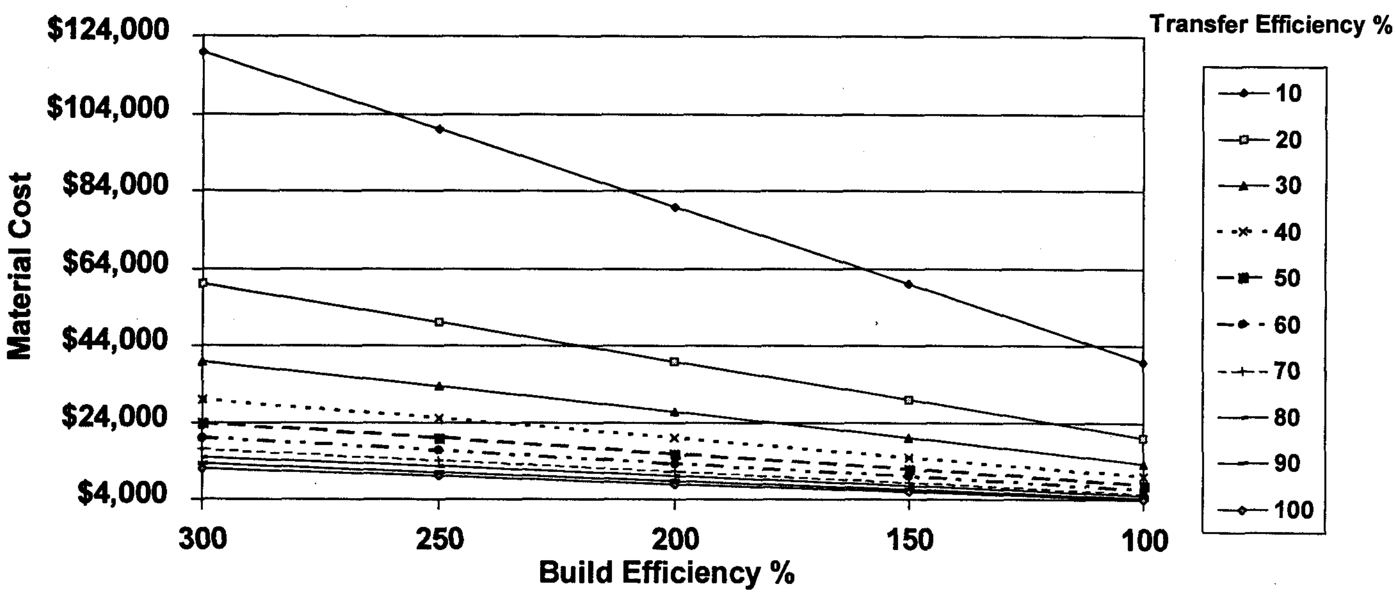
Application Efficiency

Cumulative Cost of Transfer and Build Efficiencies

- Paint consumption = 100 gallons at 100% T.E. and B.E.
- Coating cost = $40/gallon

Build Efficiency %

Transfer Efficiency %	300	250	200	150	100
10	$120,000	$100,000	$80,000	$60,000	$40,000
20	$60,000	$50,000	$40,000	$30,000	$20,000
30	$40,000	$33,333	$26,667	$20,000	$13,000
40	$30,000	$25,000	$20,000	$15,000	$10,000
50	$24,000	$20,000	$16,000	$12,000	$8,000
60	$20,000	$16,667	$13,333	$10,000	$6,667
70	$17,143	$14,286	$11,429	$8,571	$5,714
80	$15,000	$12,500	$10,000	$7,500	$5,000
90	$13,333	$11,111	$8,889	$6,667	$4,444
100	$12,000	$10,000	$8,000	$6,000	$4,000



Application Efficiency

Cumulative Cost of Transfer and Build Efficiencies

Powder Coating

- ✗ Cost of poor transfer and build efficiencies also holds true for powder coating
- ✗ The formula for estimating the cost and coverage of powder rely on knowing the specific gravity of the powder, the target dry mil thickness and transfer efficiency
- ✗

$$\text{Coverage (ft}^2\text{/lb)} = \frac{1.922 \times \text{transfer efficiency (\%)}}{\text{specific gravity (gm/cm}^3\text{)} \times \text{target mil thickness (mils)}}$$

$$\text{Cost per unit area} = \frac{\text{cost of powder (\$/lb)}}{\text{coverage (ft}^2\text{/lb)}}$$

For 100lbs of powder at $6/lb - material cost = $600

Specific gravity = 1.5 (gm/cm^3) target mil thickness = 2 mils

		Cost to cover 6400ft^2
Coverage at 100% T.E. and 100%B.E.	= 64 ft^2/lb	$ 600
Coverage at 70% T.E. and 100%B.E.	= 45 ft^2/lb	$ 853
Coverage at 50% T.E. and 100%B.E.	= 32 ft^2/lb	$1,200
Coverage at 30% T.E. and 100%B.E.	= 19 ft^2/lb	$2,021
Coverage at 100% T.E. and 200%B.E.	= 32 ft^2/lb	$1,200
Coverage at 70% T.E. and 200%B.E.	= 22.5 ft^2/lb	$1,706
Coverage at 50% T.E. and 200%B.E.	= 16 ft^2/lb	$2,400
Coverage at 30% T.E. and 200%B.E.	= 9.5 ft^2/lb	$4,042

Application Efficiency

Cumulative Cost of
Transfer and Build Efficiencies

Optimum Conditions

- ✗ **Avoid cumulative effect of poor transfer efficiency and poor build efficiency**
  - ➢ **Maintain consistent film build at desired mil thickness**
  - ➢ **Maximize transfer efficiency**
- ✗ **Achieve by:**
  - ➢ **Proper operator technique**
  - ➢ **Proper operating conditions**
  - ➢ **Proper spray equipment selection and setup**

Variables Affecting Application Efficiency

- ★ Uncontrollable variables
  - ➢ Booth conditions
    - ➢ Operating temperature, relative humidity, air flow rate/direction, operating space
  - ➢ Coating type and color
  - ➢ Size and geometry of part
  - ➢ Coating mil thickness requirements
  - ➢ Finish quality requirements
- ★ Controllable variables
  - ➢ Coating viscosity
  - ➢ Spray equipment type
  - ➢ Gun setup
  - ➢ Operator spray technique
    - ➢ Spray distance
    - ➢ Spray angle
    - ➢ Gun speed
  - ➢ Plan of attack
  - ➢ Spray equipment maintenance practices

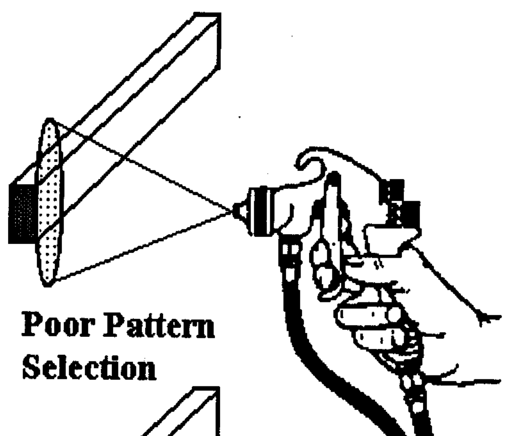
Operator Spray Technique

- Traditional focus has been on spray equipment efficiency ratings
  - This represents only one small aspect of spray efficiency
  - Spray gun efficiency ratings have limited meaning
    - Determined under ideal conditions which are likely very different from field situations.
      - Technician's skill?
      - Gun settings?
      - Coating type / characteristics?
      - Distance?
      - Surface geometry?
- Most important variable is the OPERATOR!
  - Actual gun efficiency is limited by the operator's skill / knowledge
  - Operator efficiency is a function of technique and gun setup
  - Need to consider
    - Gun-to-target distance
    - Gun position / orientation
    - Gun speed
    - Overlap
    - Targeting
    - Plan of attack

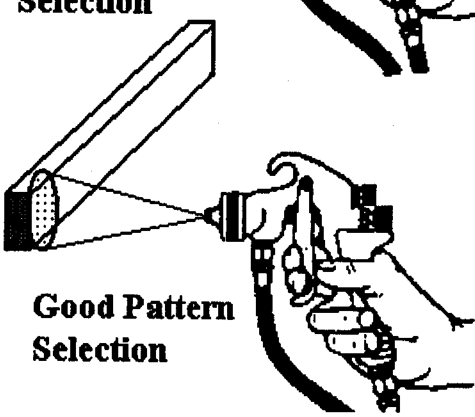
Operator Spray Technique

Key Concept

KEEP THE PATTERN ON THE PART!



Poor Pattern Selection

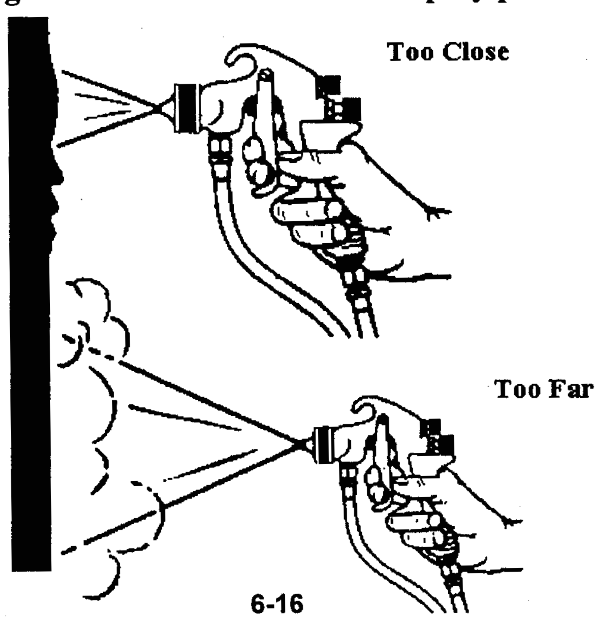


Good Pattern Selection

- ✗ Know your pattern
- ✗ Target the workpiece
- ✗ Minimize lead - lag distances
- ✗ Practice banding / edging when possible

Operator Spray Technique
Spray Distance

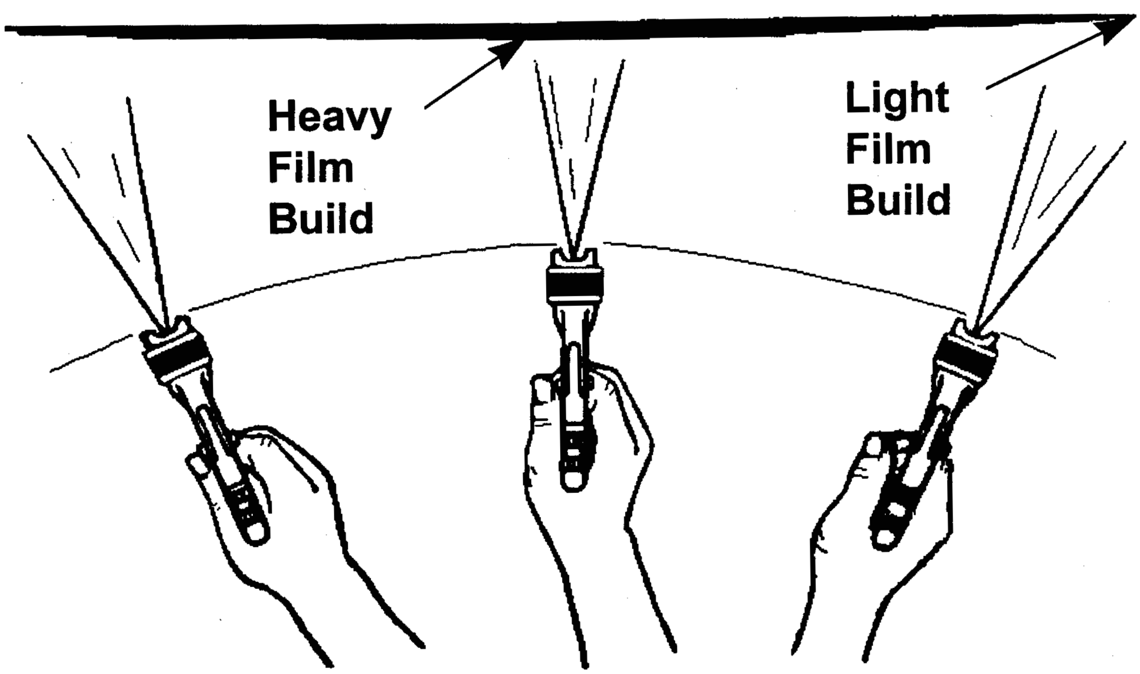
- **Keep gun-to-target distance at manufacturers recommended distance**
  - Too close - paint goes on heavy and creates runs/sags
  - Too far - causes excessive overspray (fog), dry spray, sandy finish, and low T.E.
- **Typical gun-to-target spray distances**
  - Air Atomized (conventional and HVLP) = typically 6 - 8 inches
    - Some HVLP gun manufacturers recommend 4 - 6 inches
    - Some conventional guns may be up to 10 inches
  - Airless = 12 - 14 inches
  - Air-Assisted Airless = 8 - 10 inches
    - Electrostatic air-assisted airless = 8 - 12 inches
  - Powder coating
    - Gun-to-part distances for manual applications is typically 2 - 6 inches
      - However, studies indicate higher transfer efficiencies at greater gun-to-target spray distances (e.g., 8-12")
    - Gun-to-part distances for automatic applications is 8 - 12 inches
      - May be closer than 8" for better penetration into recessed areas
      - May be greater than 12" to maximize spray pattern coverage



Operator Spray Technique

Spray Stroke

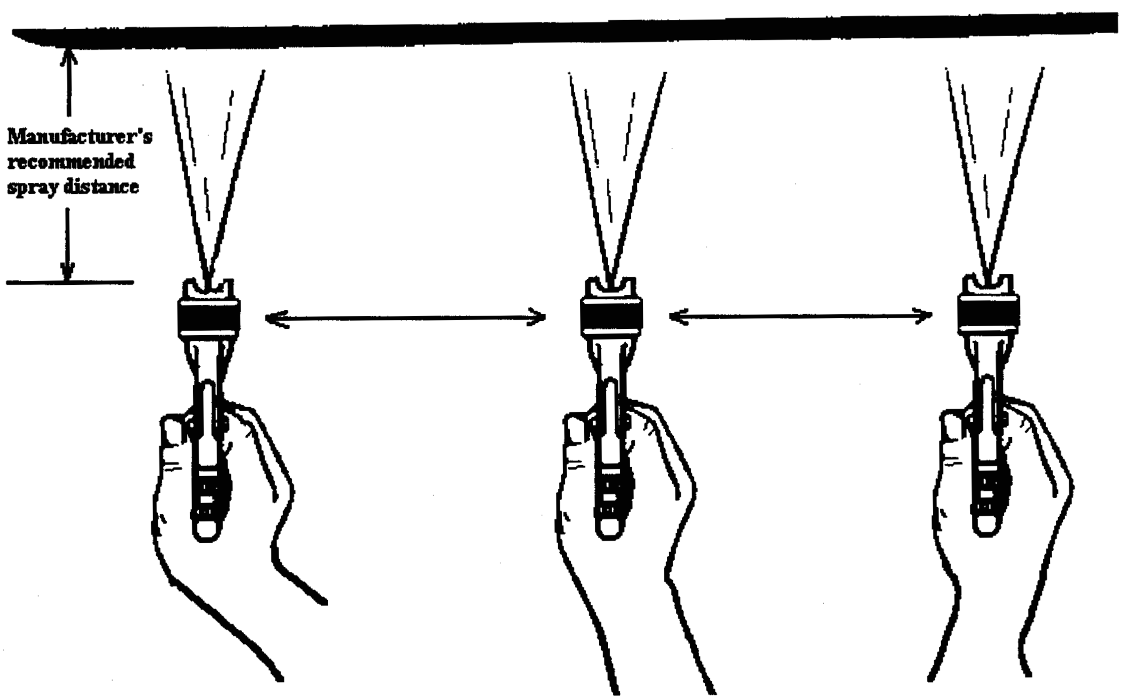
- ✗ **Do NOT arc, wave or swing the gun!!!**
- ✗ **Arcing / swinging causes**
  - ➢ **Uneven application**
  - ➢ **Excessive overspray**
- ✗ **When arced at an angle of 45° from the surface being sprayed, approximately 65% of the sprayed material is wasted**



Operator Spray Technique

Spray Stroke

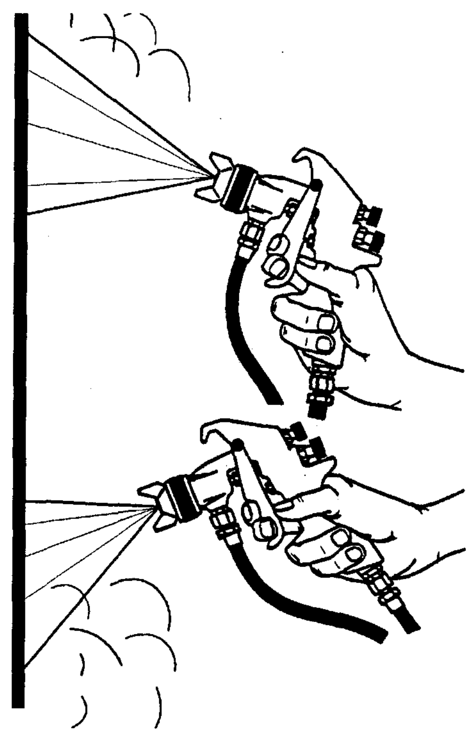
- ✗ Keep spray stroke parallel to surface at consistent distance
- ✗ Use a steady, comfortable speed
  - ➢ Uniform application
  - ➢ Quality finish
  - ➢ Maximum transfer efficiency



Operator Spray Technique

Spray Angle

- ★ Keep spray pattern perpendicular to the target surface
- ★ **Avoid tilting the gun**
  - ★ Heeling and toeing
  - ★ Pitch - wrist moves up and down
  - ★ Yaw - wrist moves left or right
  - ★ Rotation - wrist moves clockwise and counter clockwise



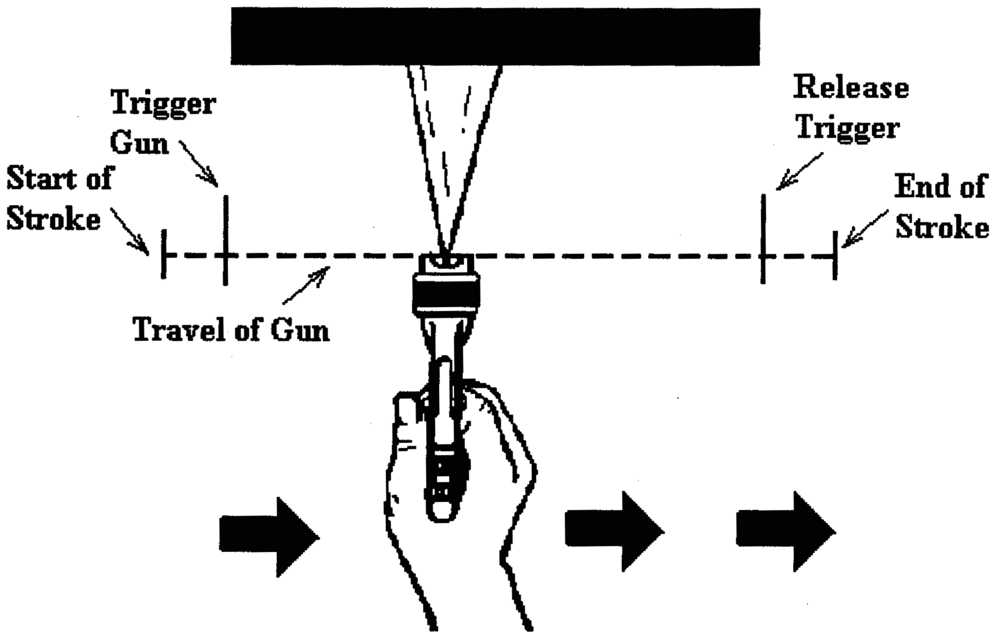
Operator Spray Technique
Overlap

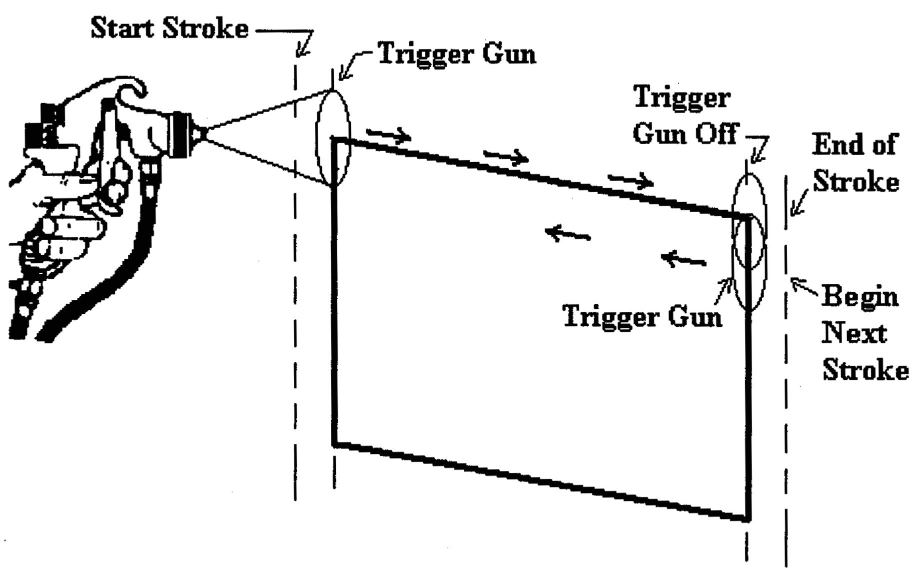
- Needed to achieve an even film build
- Amount of overlap depends on spray equipment used and the product being coated
  - 50% overlap on large flat pieces for conventional and HVLP
  - Airless and air assisted airless may require less overlap
  - Narrow pieces (e.g., stiles, rails) may not need any overlap

Operator Spray Technique
Lead and Lag

- ★ **Keep lead and lag distances to a minimum**
  - ★ **Lead - occurs at the beginning of the spray stroke. It is the distance between the point where the gun is triggered (for paint delivery) and the edge of the part.**
  - ★ **Lag - occurs at the end of the spray stroke. It is the distance fromthe edge of the part to the point where the operator releases the trigger (to stop paint delivery).**
- ✗ **Triggering - refers to the activation and deactivation of paint delivery from a spray gun during a spray stroke**
  - ➢ **Controlled by the operator**
    - ➢ **Good gun triggering technique reduces overspray, increases T.E. and reduces material consumption**
    - ➢ **Triggering the gun too soon or too late, or not triggering the gun at all (i.e. paint delivery is uninterupted) IS A WASTE OF PAINT!!!**
- ✗ **ALWAYS (except for powder coating) trigger the spray gun at the beginning and end of each stroke**
- ✗ **Always begin stroke off the part - this prevents excess paint delivery at edge of part**
- ✗ **For conventional, HVLP and air-assisted airless, air should be kept activated while spray stroke is off the part**

Operator Spray Technique
Lead and Lag





Operator Spray Technique

Plan of Attack

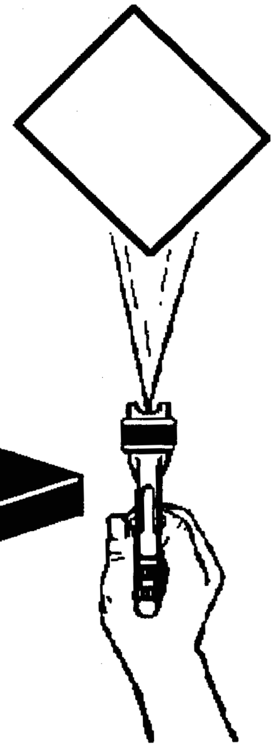
Before you spray

- ★ Study the geometry of the part
- ★ Devise a spray sequence that will allow you to paint the part without applying multiple coats to any one area during any one pass.
  - ★ Use a comfortable, continuous motion
  - ★ The sequence should be consistent throughout the coating operation.
  - ★ Use the fewest number of strokes and least amount of motion necessary to obtain the desired coverage.
  - ★ Use banding or edging techniques when appropriate.
  - ★ Always keep as much of the spray pattern on the part as possible.
  - ★ Look over coated part and adjust accordingly.

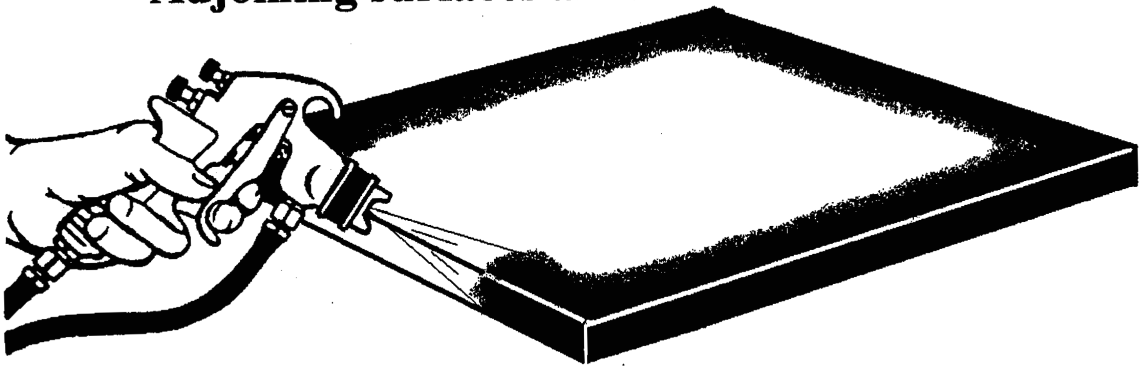
Operator Spray Technique

Plan of Attack

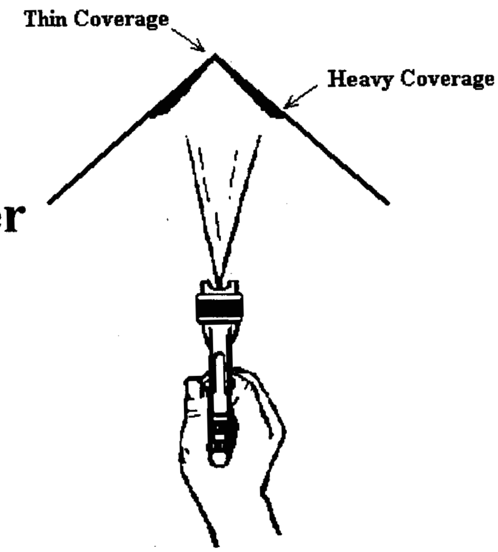
Corners



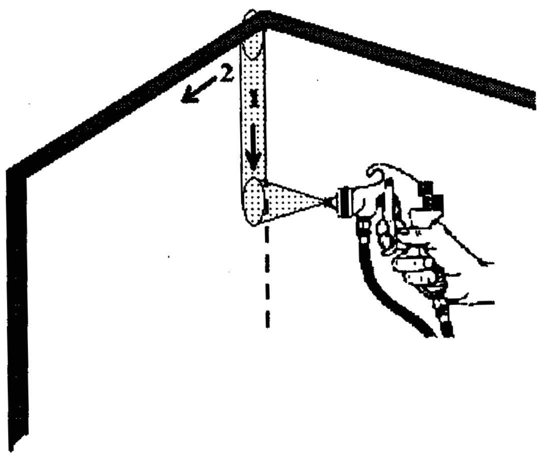
- ✗ Spray outside edges and corners first
  - ➢ Spray directly at corner with a single gun stroke
  - ➢ Adjoining surfaces are banded



- ✗ Spraying directly into inside corners produces an uneven coating



- ✗ Spraying each side of an inside corner produces an even coating



Operator Spray Technique

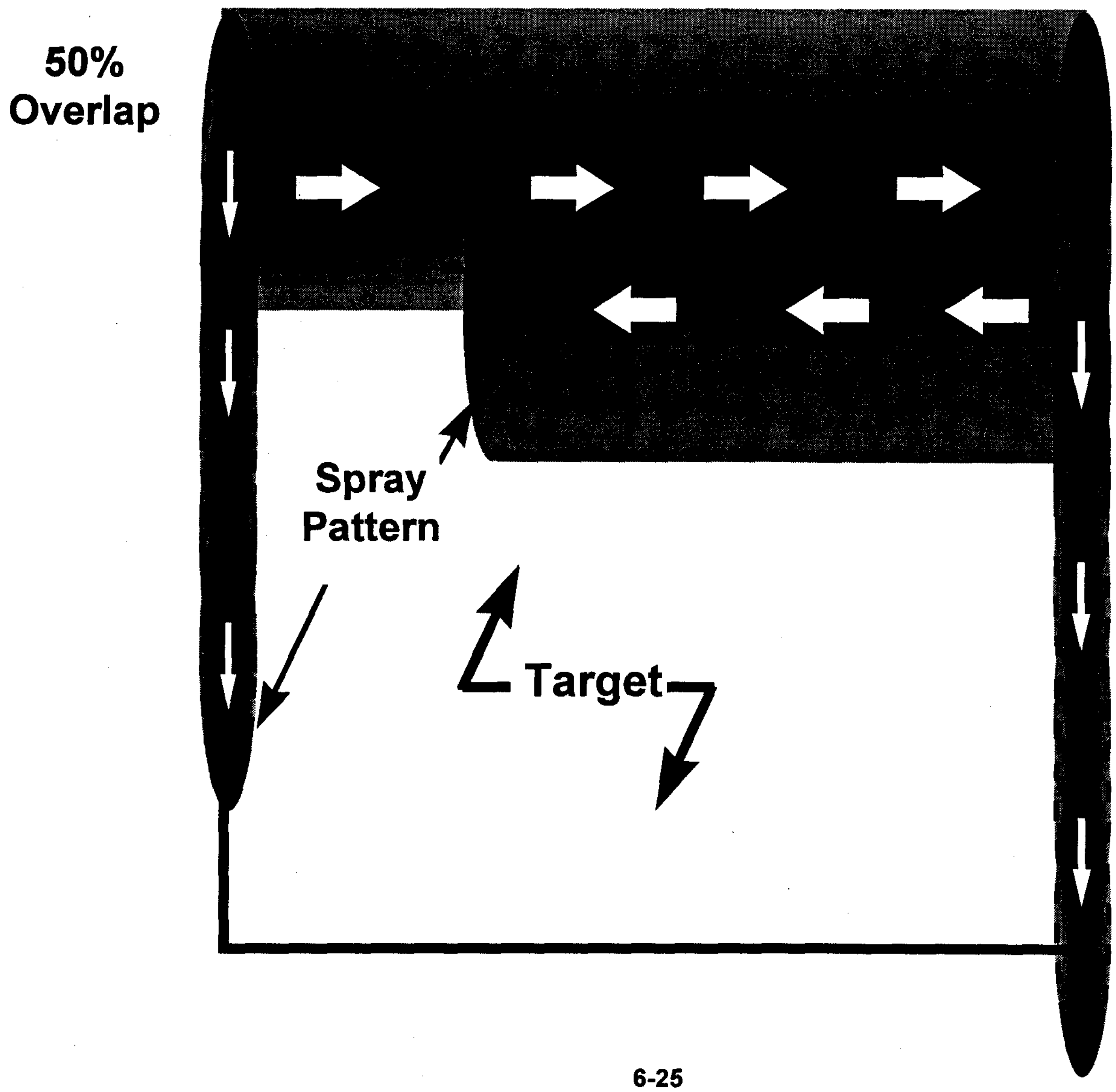
Plan of Attack

Banding / Edging

★ When possible, edge the part with the spray pattern.

★ Take full advantage of spray pattern shape.

★ The rotation of the gun may be altered to cover the edge of the target.



Opportunities for Efficiency Improvement

Common Problems Encountered With Paint Systems

- ✗ Lack of funds for paint line equipment.
- ✗ Lack of test equipment for paint line support.
- ✗ Lack of proper maintenance of paint line equipment.
- ✗ Lack of training for paint and maintenance personnel.
- ✗ Lack of or inconsistent standard operating procedures.
- ✗ Lack of adequate grounding.
- ✗ Pretreatment quality.
- ✗ Compressed air quality.
- ✗ Inadequate booth air flow or imbalance of booth.
- ✗ Low pay for paint line operators.
- ✗ High rate of operator turnover.
- ✗ Part presentation / racking.

Opportunities for Efficiency Improvement

Gathering Background Information

- ✗ **Must review materials and equipment used at facility**
  - ❑ **Obtain and review copies of equipment manuals and product literature to compare manufacturer's recommendations vs. actual use at facility**
  - ❑ **Video tape the spray operation and spray technique of the operators**
    - ➢ **Video tape from various angles to record spray technique, amount of overspray, gun-to-target distance, and degree of "wrap" (for electrostatic applications.**
- ✗ **Items to look for**
  - ❑ **Viscosity - temperature measurements (note the type of viscosimeter cup)**
  - ❑ **Type of equipment and operating conditions - compare to manufacturer's recommended operating conditions**
  - ❑ **Fluid tip sizes, air cap size**
  - ❑ **Spray pattern size / degree of atomization at manufacturers recommended gun-to-target distance**
  - ❑ **Condition of paint hooks / continuity to ground**
  - ❑ **Operator spray technique**
  - ❑ **Actual mil build thickness vs. target mil build**
  - ❑ **Air pressure settings / fluid pressure settings / pump ratios**
  - ❑ **Visual indication of transfer efficiency, overspray and finish quality**
  - ❑ **Size, geometry and type of parts painted**
  - ❑ **Production rate requirements / line speed**
  - ❑ **Part presentation / racking**
  - ❑ **Pretreatment quality**
  - ❑ **Booth lighting and air flow**
  - ❑ **Hazardous and nonhazardous waste generation rates**
  - ❑ **Finish defects**

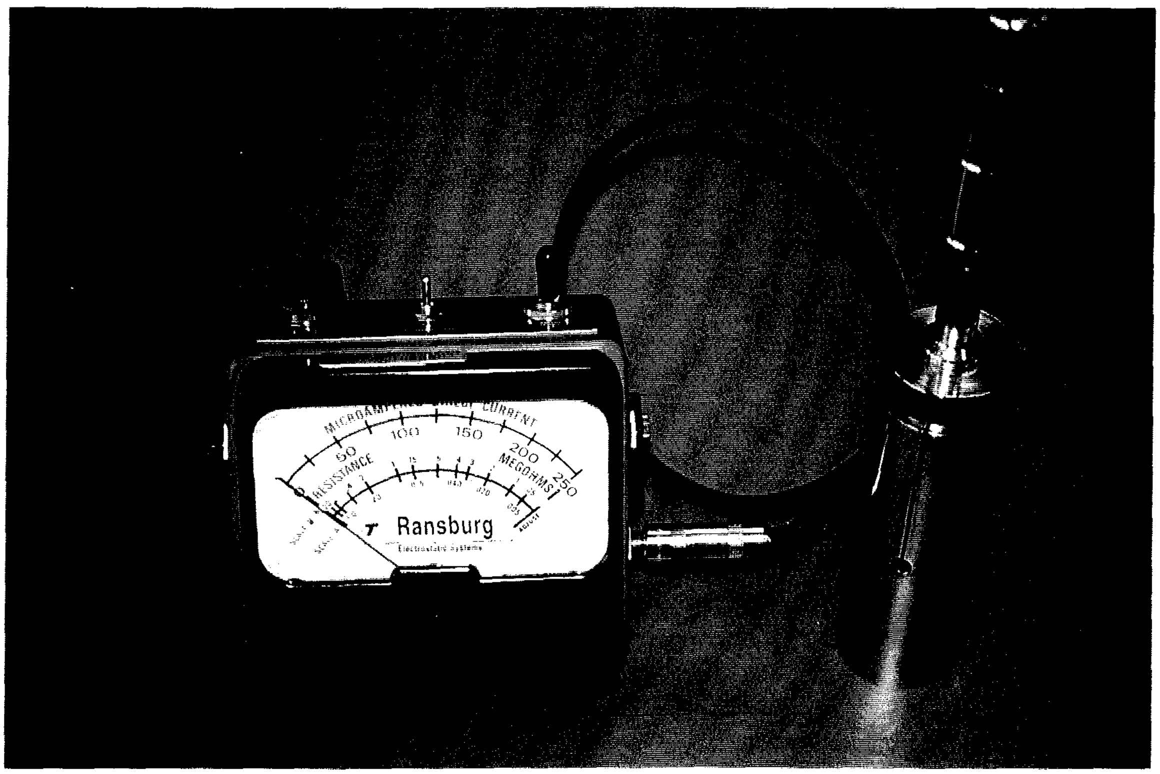
A Paint System Information Checklist is provided in Appendix D

35521 PDF

Opportunities for Efficiency Improvement

Support (Equipment)

- Dry mil thickness gauge (ferrous or ferrous-nonferrous)
- Wet mil thickness gauge
- Volt-ohm and/or Meg-ohm (megger) meter
- Video camera / camera
- Viscosity cups, stopwatch and thermometer
- Paint resistivity meter (not essential)
- Spray pattern target paper
- Conductivity/Temperature/pH meter for pretreatment monitoring



Paint resistivity meter

Waste and Cost Reduction

Waste Paint/Solvent

Solvent Reuse

- Solvent used for flushing lines and equipment may be reused to thin the next batch of paint
  - Most practical for facilities that spray a limited number of colors, a predominant color or black
  - Since the used solvent is an acceptable substitute for virgin solvent (for thinning paint), it is not considered a waste
    - The used solvent does NOT have to be included in the facility's hazardous waste inventory
      - Practice may reduce a facility's generator status
    - Reduces solvent purchase costs since it is an equivalent substitute for virgin solvent
  - Store used solvent in grounded, compatible containers labeled "Used Solvent".
    - Store in accordance with OSHA and NFPA requirements
  - Use separate containers for separate colors.

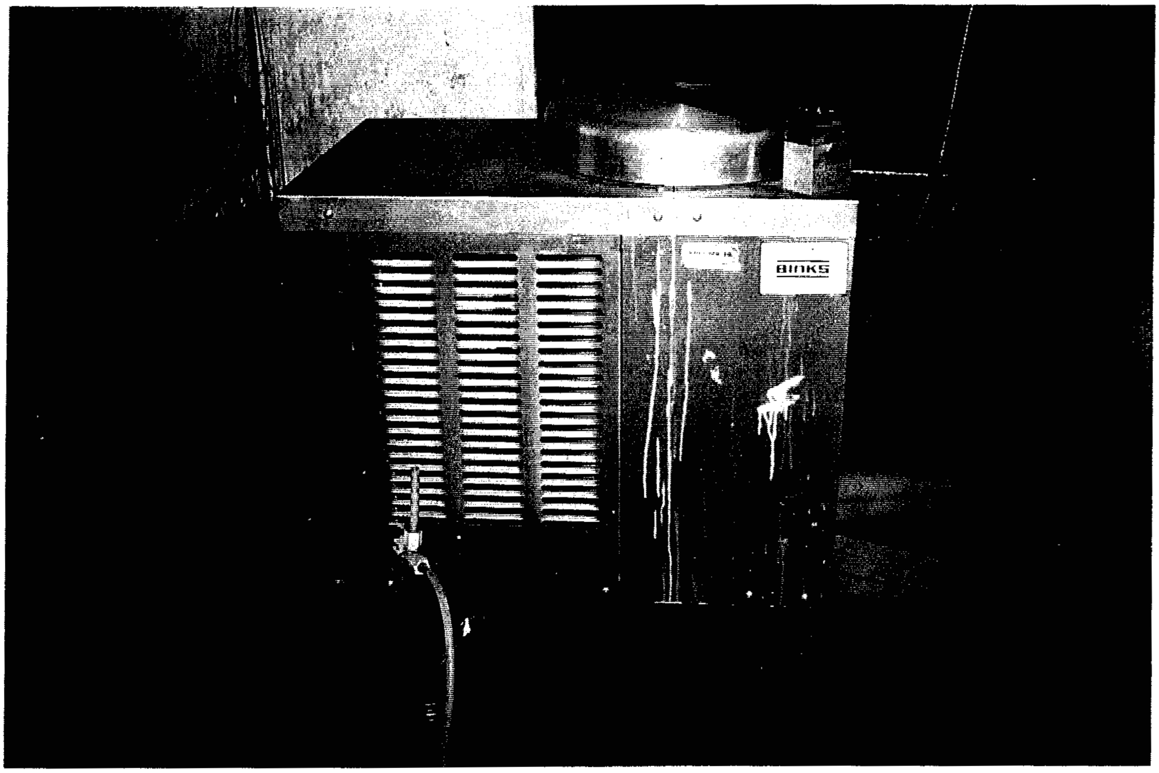
Waste and Cost Reduction

Waste Paint/Solvent

Solvent Distillation

- Allows waste solvent to be recycled for on-site use
  - Most practical for facilities generating over 10 gallons of waste solvent per week
  - Distillation units with capacities of 2.5 to over 7.5 gallons
  - Solvent distillation times vary depending on unit, type of solvent and solvent contaminants
    - 2.5 to over 7 hours
- Reduces or eliminates waste solvent disposal costs
- Reduced solvent purchase costs
- Lower hazardous waste generation rate possibilities
  - Waste solvent must be managed as hazardous waste until it is recycled. However, the amount that must be included in a facility's monthly hazardous waste inventory may be reduced significantly.
    - Note: Certain states may be more stringent than the federal regulations. For example, Kansas requires all reclaimed solvent to be included in a facility's monthly hazardous waste inventory (therefore, a facility's hazardous waste generation rate cannot be reduced through solvent reclamation).
  - Still bottoms generated by solvent distillation must be managed and disposed of as hazardous waste.
    - However, the amount of still bottoms generated is considerably less than the amount of waste solvent that would otherwise be generated.
- Solvent reclaimed with distillation may be of lower quality.
  - Quality of reclaimed solvent may not be suitable for thinning high quality paints
  - May be best suited for flushing lines and equipment cleaning

Solvent Distillation



Pneumatic Gun Wash Systems

- Similar in design to a dish washer
  - Provides a safe, quick way to effectively clean paint equipment
  - Spray gun equipment is placed inside the unit over cleaning jets
  - The lid to the unit is closed and a timer switch is used to activate the unit
    - After 1-3 minutes, the equipment may be removed
- May be used to clean conventional, HVLP, air-assisted airless and airless guns as well as other equipment
  - Note: may or may not be suitable for certain types of electrostatic equipment - check with the manufacturer
  - Certain gun wash models may also be used to clean fluid hoses

Pneumatic Gun Wash Systems

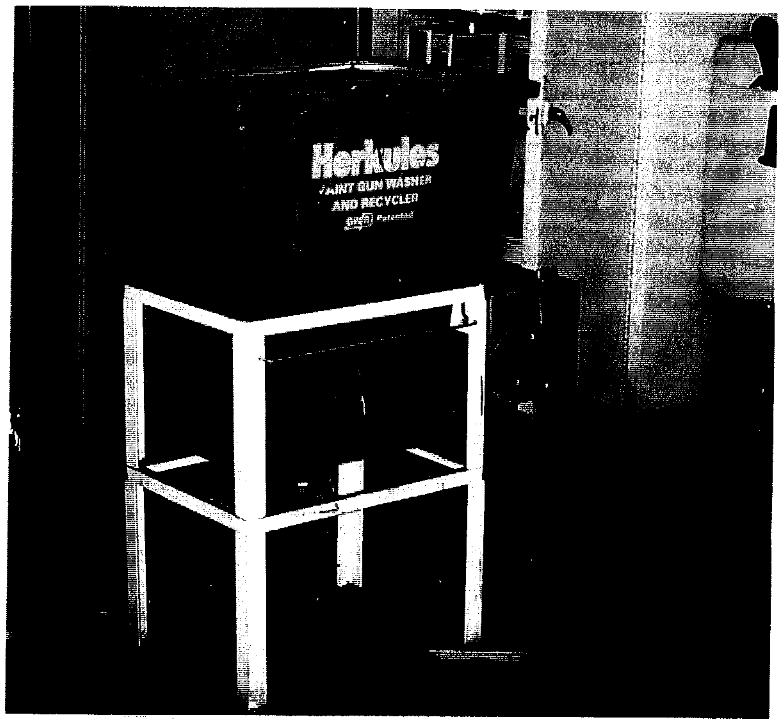
Advantages

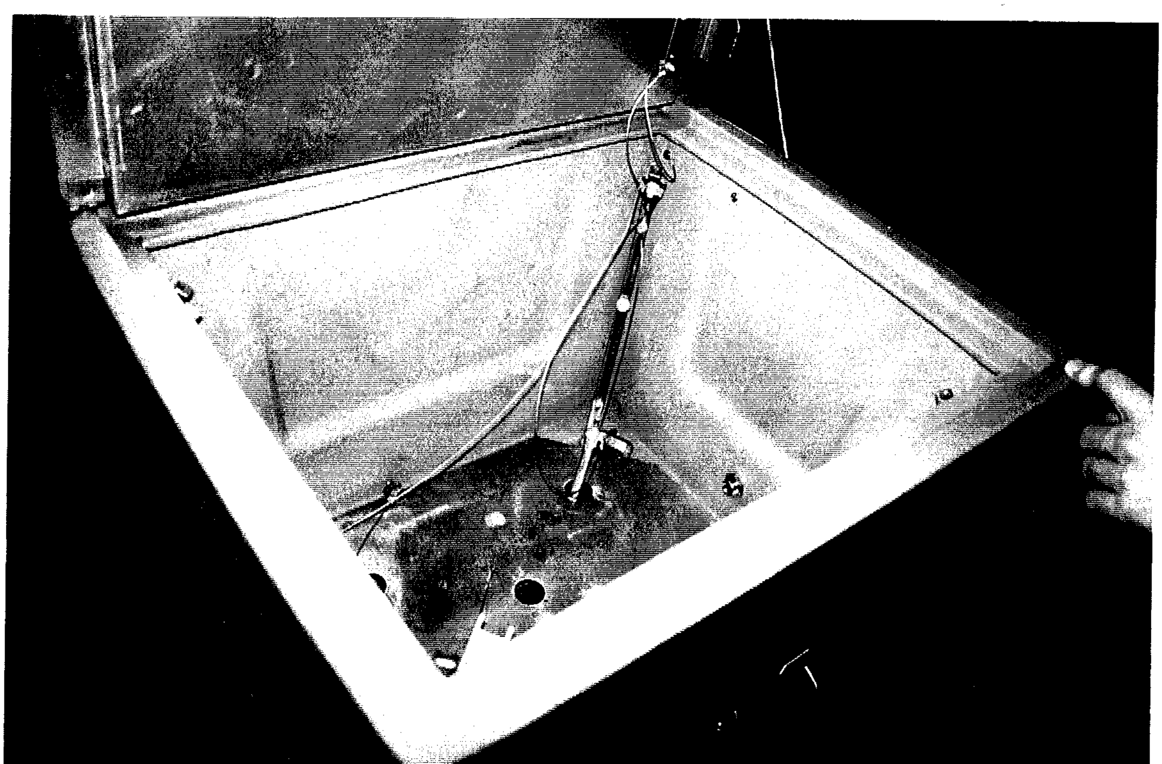
- Reduced solvent usage and waste solvent generation rates
  - With proper use and maintenance, gun wash units reduce the amount of solvent used for cleaning spray gun equipment by more than 50%
  - To maximize the life of the cleaning solvent....
    - When possible, perform gross cleaning before placing equipment in gun wash unit.
      - e.g., remove the bulk of left over paint from gun cup and supply tube and rinse the cup with a small amount of thinner
    - Some units use solvent from one reservoir to do the bulk cleaning followed by fresh solvent flush for final cleaning
    - May also use two gun wash units - one for precleaning and one for final cleaning. Once the solvent in the final cleaning unit becomes too dirty, it may be used to replace the solvent in the precleaning unit.
- Reduced solvent exposure to operators
  - The units are enclosed and the technician may leave the cleaning area during its operation.
- Increased productivity
  - Once equipment is placed in the gun wash, the operator may devote time to other tasks.
  - Reduces labor time needed for equipment cleaning by over 60%
- Reduced VOC emissions
  - Enclosed unit reduces emissions associated with equipment cleaning

Waste and Cost Reduction

Waste Paint/Solvent

Pneumatic Gun Wash Systems



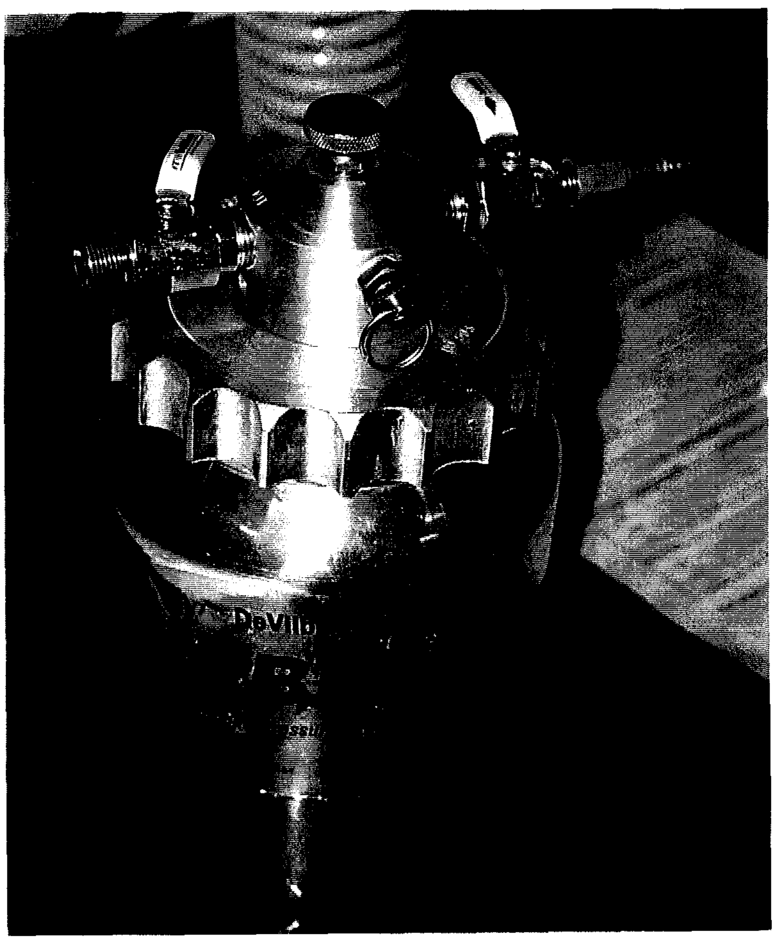


Waste and Cost Reduction

Waste Paint/Solvent

Solvent Savers

- Used for cleaning fluid lines using less solvent
- Forces a turbulent blend of solvent and compressed air through the hose
  - Get chemical and mechanical cleaning
  - Requires less solvent to clean lines because of compressed air/solvent mixture



Plural component mixing systems

- **Used to proportionally mix plural component (catalyzed) materials at the application equipment**
  - **Used for polyurethanes, polyester resins, adhesives and epoxies**
  - **Application equipment accurately meters two or more components (paint base, catalyst and possibly, the reducing solvent) and delivers them seperately to a mixing chamber where they are thoroughly mixed just prior to application**

Advantages

- ***Reduces material handling time and labor***
- ***Paint and solvent losses are kept at a minimum***
  - ***Significant amounts of paint can be wasted using manual mixing techniques if excess catalyzed paint is prepared***
  - ***With proportioning systems - you only mix what you need***
- ***Potlife (the amount of time it takes for a urethane to double in viscosity) is not such a critical factor since material is mixed as it is applied***
- ***Consistency of the mix improves the quality of finish***
  - ***Manual error in proportioning and mixing is eliminated***
  - ***A consistently proportioned and mixed coating produces a fully reacted coating which produces a high quality finish when applied***
- ***Reduced safety hazards***
  - ***System is closed so chemical exposure is reduced***
  - ***Spills are less likely***
  - ***Minimizes fire hazards***

Disadvantages

- ***High equipment cost***

Waste and Cost Reduction

Target Grounding

- ✗ Essential for safe and efficient electrostatic liquid and powder coating applications
  - ➢ *Most fires occur because of poorly grounded parts.*

Recommendations for ensuring good continuity to ground

- Paint hooks and/or hanger contact points should be cleaned on a regular basis!!!
  - ➢ Grounding is achieved through the part's contact with the hanger
  - ➢ Also need good, clean contact points between the hanger and the conveyor hang point
    - ➢ Ensure conveyor hang points are kept out of the spray booth area
- Use a minimum number of contact points when hanging parts
  - ➢ Each contact point introduces more resistance and a greater chance of interrupting continuity to ground.
    - ➢ Should use one-piece hooks and racks
    - ➢ Paint hooks attached to chains are not recommended.
- ✗ Install a grounding rod adjacent to the spray booth area
  - ➢ Ensures a good earth ground is maintained to the conveyor system at the point of coating application
  - ➢ Maximizes safety and efficiency

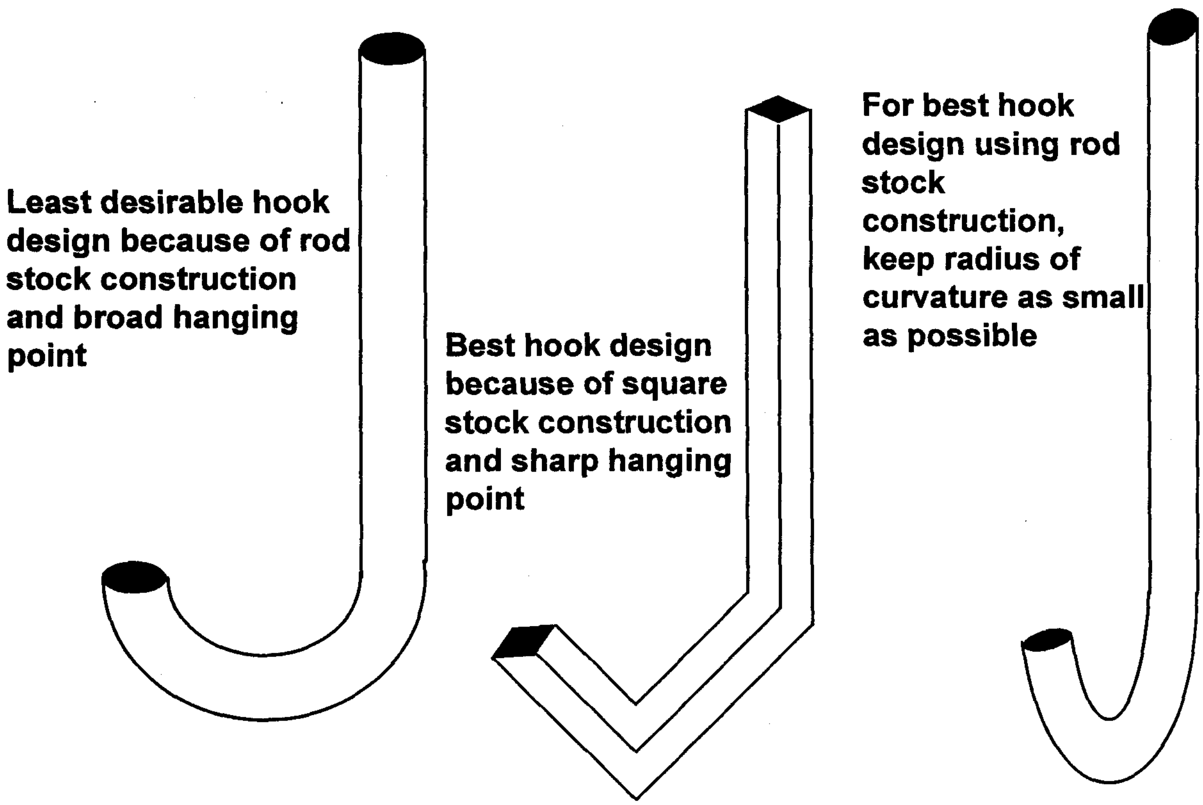
Waste and Cost Reduction

Target Grounding

- **Consider constructing paint hooks/hangers from square stock.**
  - ➢ **Paint hooks constructed from steel rod don't provide much "bite" - especially when parts are hung at points with rounded edges.**
    - ➢ **Consequently, it may take very little paint between the hook and the part to interrupt continuity to ground.**
  - ➢ **Using hooks constructed from square stock provides corners that "bite" into the part being hung, achieving good metal-to-metal contact .**
    - ➢ **Hooks are less susceptible to grounding failure and require less frequent cleaning.**

✗ **Bend in hooks should be as sharp as possible**

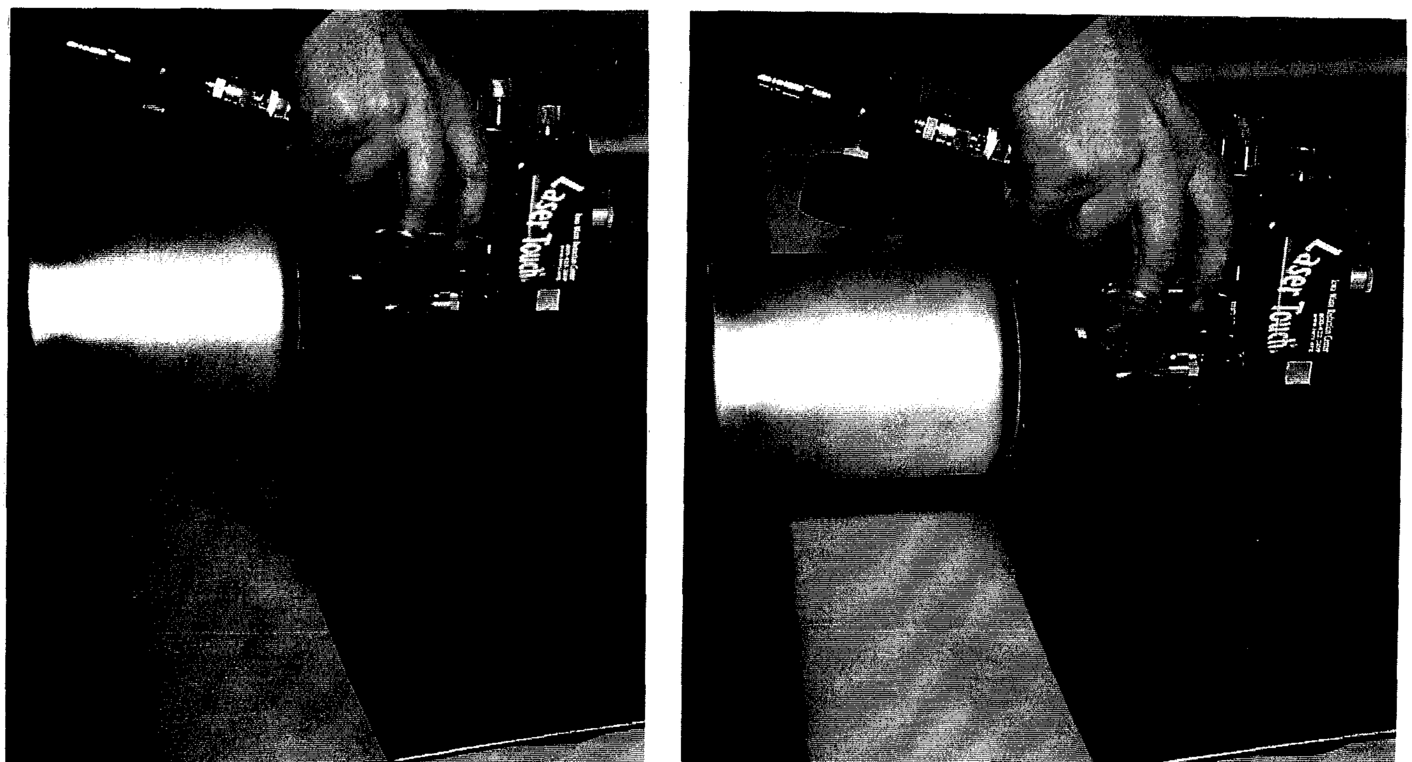
- ➢ **Consistently keeps parts at the same location on hook**
  - ➢ **Parts consistently shield contact point from coating**



Waste and Cost Reduction

Operator Technique

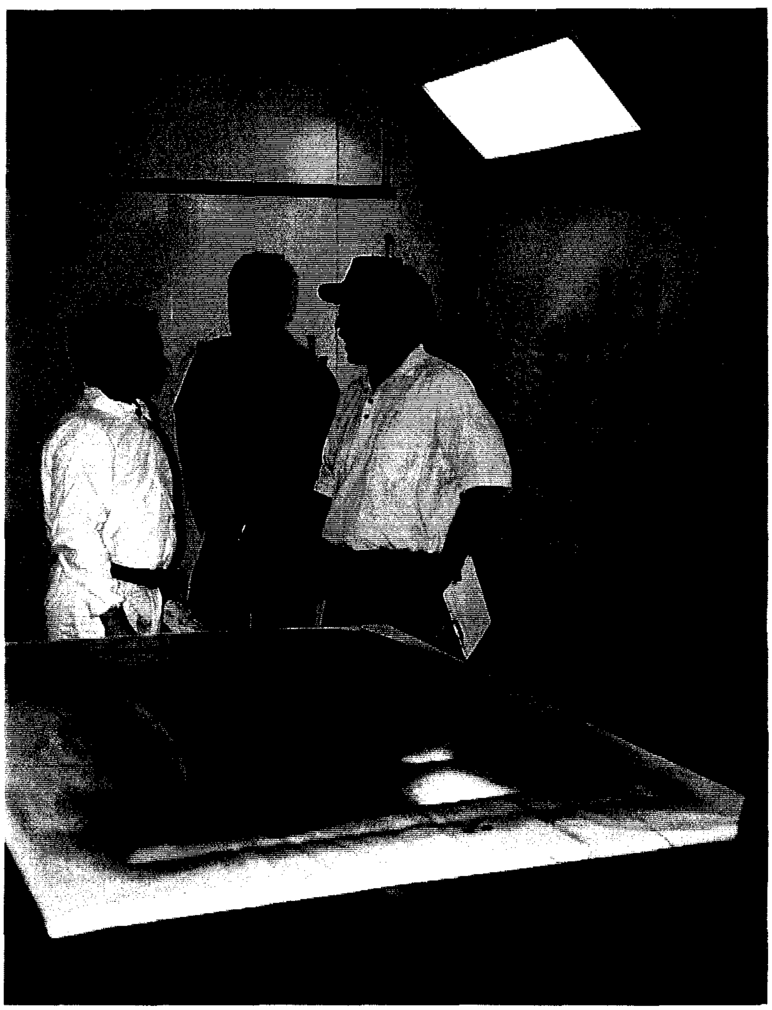
- To improve operator spray technique consider
  - Video taping operators while at work
    - Allow operators to critique themselves
  - Installing a Laser Touch™ system on spray gun equipment to provide the operator with a "real time" visual indicator of gun-to-target distance and gun angle
  - Training programs
    - IWRC's STAR program
    - Operators must be familiar with equipment manuals



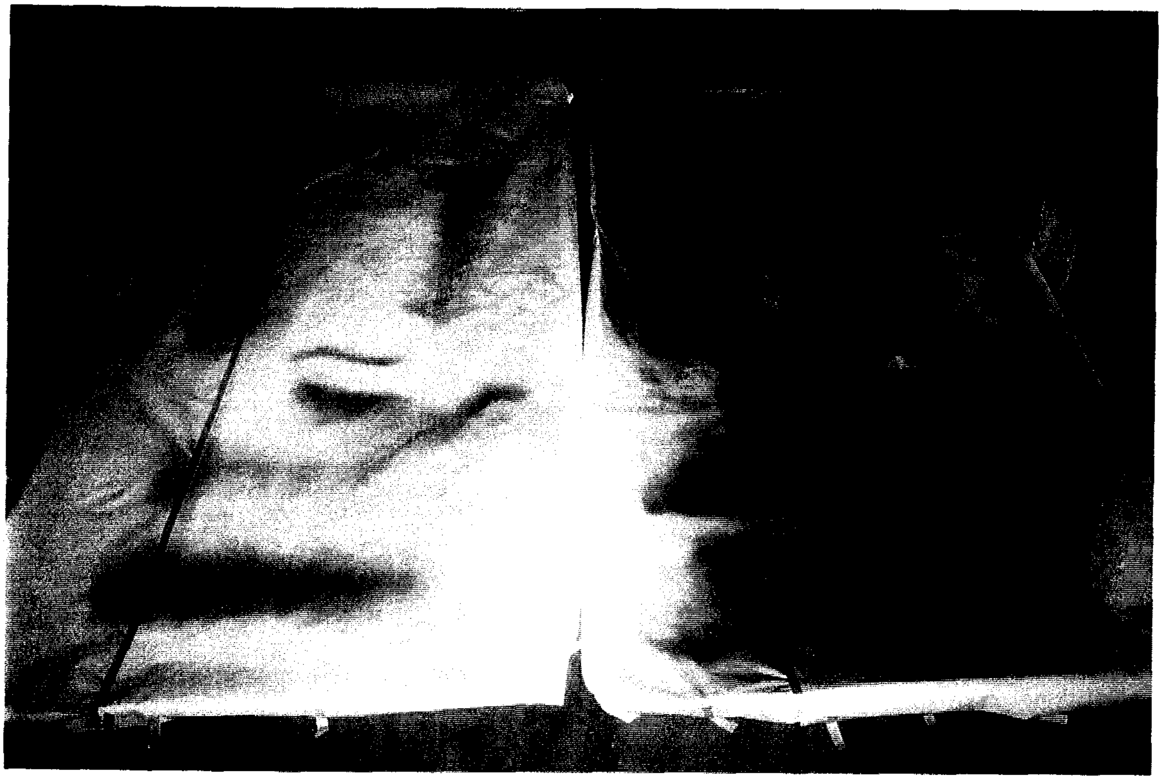
Photograph of the Laser Touch unit mounted to an HVLP spray gun. The unit projects two laser beams onto the part. When the spray pattern is oriented perpendicular to the part at the preset (optimal) gun-to-target distance, the beams converge to form one laser projection (dot) on the target. Poor gun angle or a variation from the preset gun-to-target distance produces two separate laser images (dots). Additionally, the laser dots are centered in the spray pattern to assist the operator with targeting and achieving 50% overlap.

Waste and Cost Reduction
Operator Technique

- IWRC's Spray Technique Analysis and Research (STAR) training program
  - Provides "hands-on", one-on-one spray technician training
    - Concentrates on spray technique, plan of attack and proper gun setup
    - Each participant is video taped, allowing them to self critique their spray technique
  - Measures the technician's pre- and post-training transfer efficiency
  - On the average, post-training T.E.s are 12% higher
    - Industrial painters have shown an average T.E. increase of 15%



Waste and Cost Reduction
Operator Technique



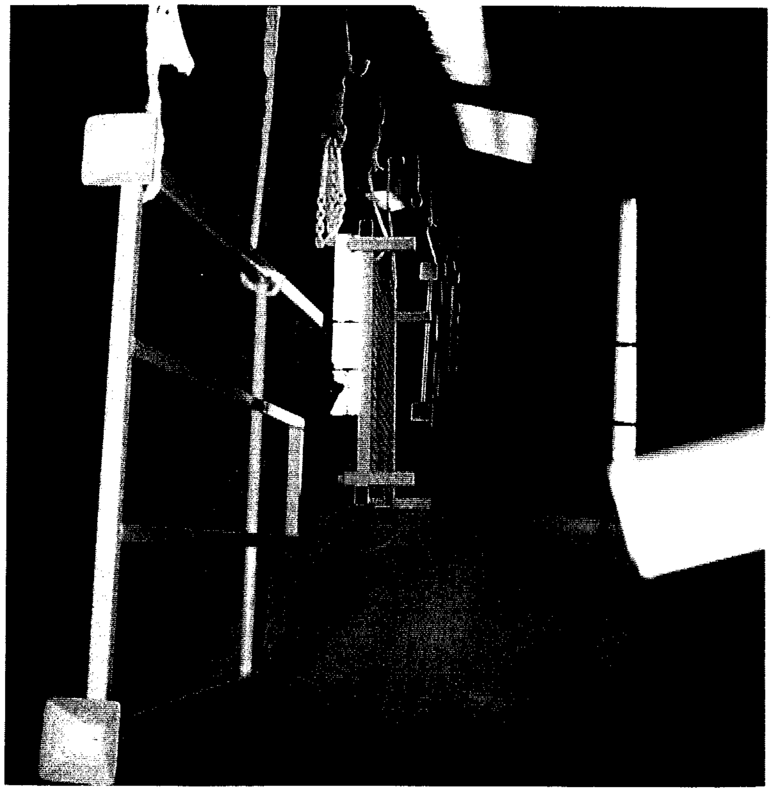
Photographs of backdrop paper used during the STAR training program. The backdrop paper on the right illustrates the amount of overspray produced before the technician is put through the STAR program (pre-training measurements) while the backdrop paper on the left represents the amount of overspray produced after completing the training program.

Waste and Cost Reduction
Booth Lighting

- Poor lighting
  - May cause a technician to spray more than what is needed to ensure complete coverage
  - May lead to rework because of inadequate coverage, excess mil build, or paint failure
- Spray technicians are often expected to coat parts that are difficult to see because of inadequate lighting, poor booth maintenance and impaired vision caused by PPE
- Solutions
  - Replace fluorescent bulbs - fluorescent bulbs lose intensity over time and should be replaced twice a year
  - Install additional lighting - Spray booth lighting inserts are available
  - Use a clear liquid masking product to improve lighting and decrease booth maintenance time
  - Allow time for booth maintenance
  - Paint inside of booth with a white, strippable booth coating
    - Improves brightness of work area
    - Facilitates booth maintenance and cleaning

Waste and Cost Reduction

Booth Lighting



Waste and Cost Reduction

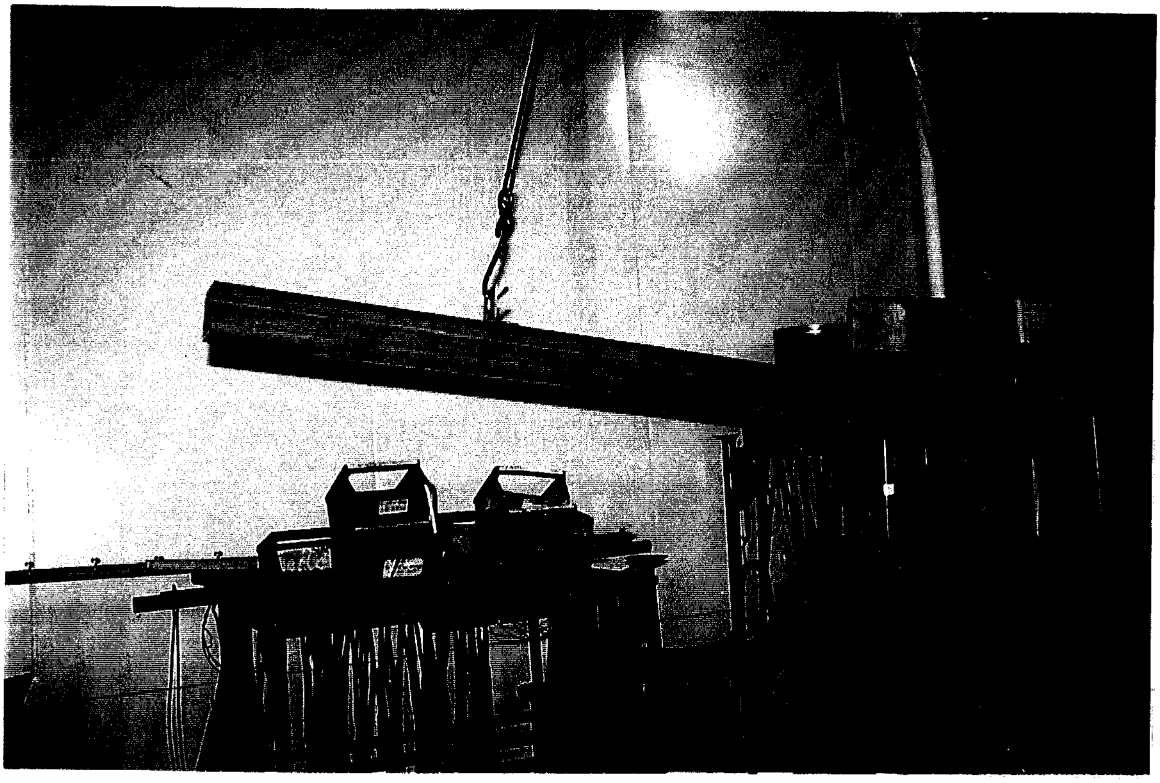
Part Presentation / Racking

Present parts in a manner favorable to pretreatment, efficiency/productivity and the spray technician

- **Pretreatment considerations**
  - **Parts should be racked to provide good impingement**
    - **Solutions must effectively reach the part to clean, phosphatize and rinse**
  - **Parts should be racked to provide good drainage**
    - **Parts with pockets, holes or shelves should be positioned to achieve proper drainage.**
      - **Eliminates cupping**
    - **Part design may also be modified to improve drainage (e.g., weep holes may be drilled to improve drainage).**
  - **Long parts passed through a multi-stage pretreatment process should be racked so drainage is directed back into the previous stage**
    - **The lead end of the part should be tilted up**
- **Spray technician considerations**
  - **Present parts in an ergonomically favorable manner**
    - **Technicians should not have to struggle to coat the part's surfaces**
      - **Causes poor technique and fatigue**
      - **Contributes to waste, excessive material usage and greater emissions**
  - **"Class A" surfaces of a part should be presented to the spray technician as squarely as possible**
- **Review racking density and racking patterns - especially if using electrostatic equipment**
  - **May increase productivity and transfer efficiency**
  - **Ensure racking method does not adversely affect continuity to ground with electrostatic systems**

Waste and Cost Reduction

Part Presentation / Racking



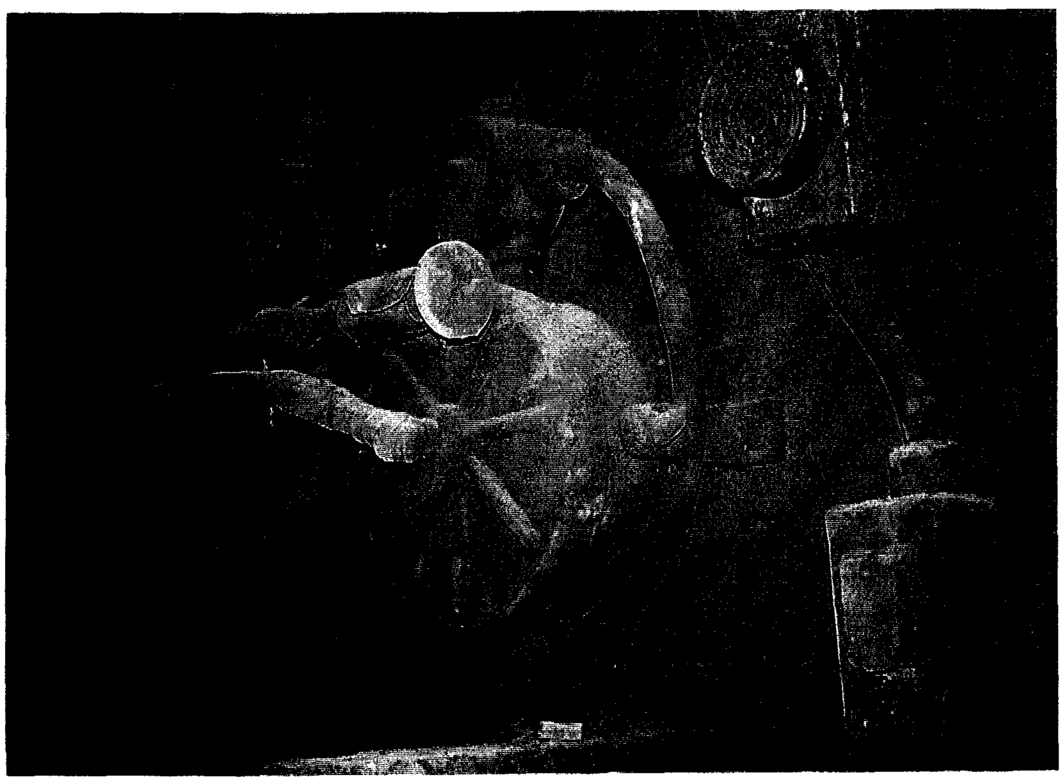
Waste and Cost Reduction

Monitoring and Maintenance Practices

- ✗ Eliminate inconsistencies and variables in equipment operation, adjustments, and spray techniques
  - ➢ Determine and record optimal operating settings
- ✗ Finishing materials must be carefully controlled with respect to storage, mixing, straining, viscosity, temperature, etc.
- ✗ One or two people should be responsible for managing all the above factors.
  - ➢ Eliminates inconsistencies
  - ➢ Facilitates problem solving in a systematic fashion
- ★ **Inspect, clean and maintain application equipment regularly to ensure optimum performance**
  - ➢ Includes hoses, pumps, spray application equipment, paint hooks/hangers, conveyor line systems and spray booth
    - ➢ Clean and service according to manufacturers specifications
    - ➢ Develop a routine service schedule for equipment and devote time to perform maintenance
    - ➢ Guns should be disassembled, inspected for wear and serviced regularly as specified by the manufacturer
      - ➢ Unkept guns may leak, form distorted spray patterns or atomize poorly
    - ➢ Replace/repair defective pressure gauges/air regulators
      - ➢ Need to know operating settings
    - ➢ Routinely inspect and clean all fluid supply filters on liquid application systems
      - ➢ Filters at gun, pump, paint heater, or in-line filters
      - ➢ Filter cleaning - very important to reduce tip plugging
    - ➢ Drain air filtration equipment daily
      - ➢ Drain oil & water extractors, coalescers and dryers

Waste and Cost Reduction
Monitoring and Maintenance Practices

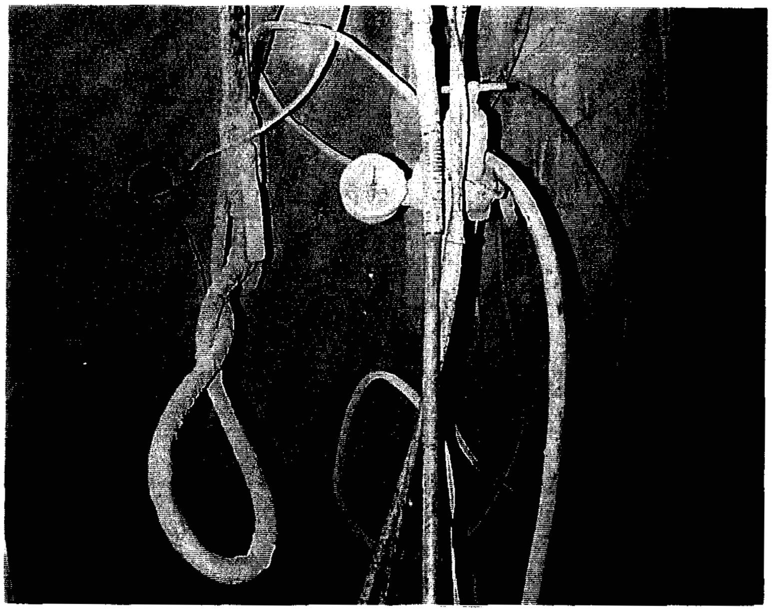
Appearance of fluid filter from gun before and after cleaning

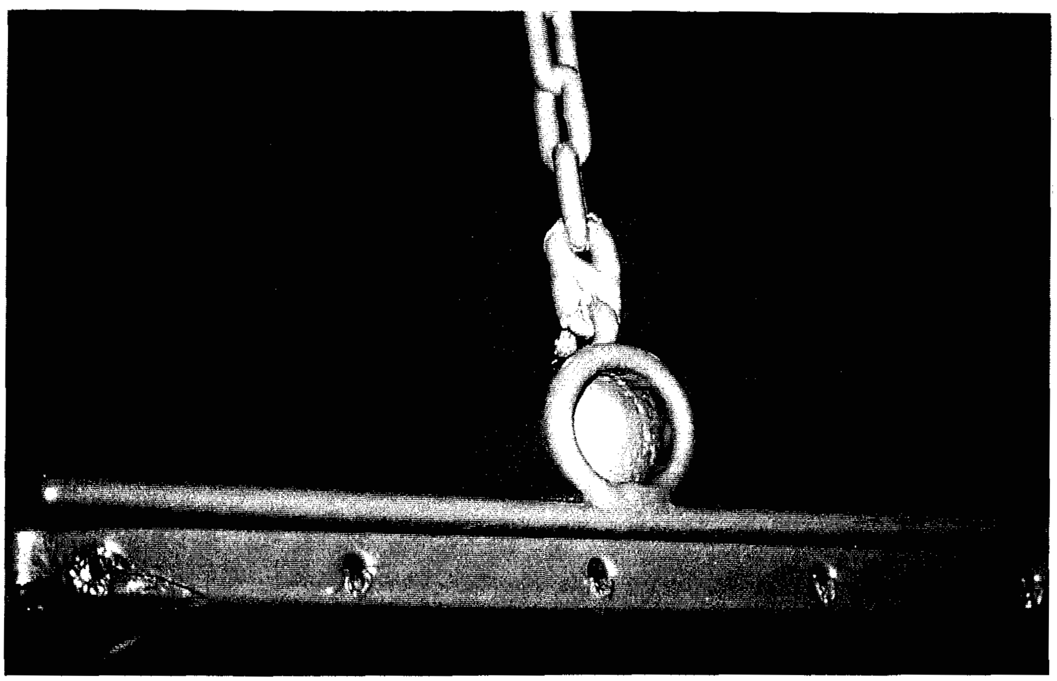


Equipment must be cleaned and maintained to achieve optimum performance.

Waste and Cost Reduction

Monitoring and Maintenance Practices





"Caked on" hangers, hangers with multiple contact points, and inoperative/unreadable pressure gauges are common problems encountered at painting and coating facilities.

Waste and Cost Reduction
Other Ideas

- ✗ Use of supplied air systems rather than respirators
  - ➢ Cartridge replacement not necessary
    - ➢ Typically $9-$16/pair
  - ➢ No medical monitoring/training requirements
- ✗ Recondition powder coating filter cartridges rather than disposal
  - ➢ Prolongs filter life
  - ➢ May save up to 50% on new filter purchase costs
- ✗ Collect and provide spray-to-waste powder to a user for coating "unseen" parts
  - ➢ Contact state waste exchange programs for assistance in locating a reuse market
- ✗ Reusable paint strainers

Case Study

Projected Savings from Improved Transfer Efficiency

Background Information

- Agricultural equipment manufacturer
- Annual paint purchase cost = $73,554
- Paint consumption = 2,553 gallons
- Average cost per gallon = $28.81
- Equipment / materials used
  - High solids enamel
  - In-line paint heaters
  - Air-assisted airless and electrostatic air-assisted airless guns
- Average T.E. of spray operators (before training) = 52.4%

Post Training Results

- Average T.E. of spray operators = 68%
  - Average increase in T.E. = 15.6%
- Projected paint consumption reduced by ~`400 gallons/yr
- Projected savings = $11,474/yr
- Reduce VOC emissions by 1,400 lbs.

Note - Projected savings based on paint consumption and costs from previous year. Future production rates are expected to increase.

Section 7.0

Environmental Regulatory Review

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Topics

Environmental Regulations Affecting Painting & Powder Coating Facilities

- **Solid Waste**
  - **Hazardous Waste**
    - **Resource Conservation and Recovery Act (RCRA)**
  - **Nonhazardous Waste**
- **Wastewater**
- **Used Oil**
- **Storm Water**
- **SARA (Superfund Amendments and Reauthorization Act) Title III**
- **Air Quality**
  - **Title V Permits**
  - **State permitting considerations**
  - **NESHAPS**
- **112(R) Accidental Release**
- **CERCLA and EPCRA Continuous Release Reporting**

Hazardous Waste Regulations

The 1976 Resource Conservation and Recovery Act (RCRA) directed the U.S. EPA to develop and implement a program to protect human health and the environment from improper hazardous waste management practices

- **RCRA program is designed to control the management of hazardous waste from its generation to its ultimate disposal**

What is hazardous waste???

Two types - "Listed" and "Characteristic"

"LISTED" Hazardous Waste

- **Over 400 wastes are specifically identified (listed) by EPA as being hazardous - includes**
  - **Manufacturing wastes**
    - **Spent halogenated and nonhalogenated solvents such as xylene, toluene, TCE, PCE, methylene chloride, acetone, MEK and MIBK**
    - **Still bottoms**
      - **EPA hazardous waste numbers F001 through F005**
    - **Sludges from electroplating operations, water from wood preservation, petroleum refining wastes**
  - **Certain discarded commercial products**

"CHARACTERISTIC" Hazardous Waste

- **Exhibit one or more of the following characteristics:**
  - ☑ **Ignitability**
    - **Liquids having a flashpoint < 140° F**
      - **Examples - naptha, mineral spirits**
      - **EPA hazardous waste number D001**
    - **Solids capable of causing fire through friction, absorption of moisture or spontaneous chemical changes at standard temperature and pressure**
      - **Spray booth filters??**
  - ☑ **Corrosivity - pH ≤ 2 or ≥ 12.5**
    - **EPA hazardous waste number D002**
  - ☑ **Reactivity - Waste is unstable under normal conditions**
    - ☑ **React violently with air or water; Are capable of detonation or explosive reaction; or generate toxic gases, vapors or fumes when mixed with water or air**
    - ☑ **EPA hazardous waste number D003**
  - ☑ **Toxicity - Wastes that meet or exceed regulatory levels established for any one of 40 regulated contaminants**
    - **EPA hazardous waste numbers D004 through D043**

Hazardous Waste

Toxicity

- ✗ **Wastes that are potentially hazardous because of toxicity must be characterized by laboratory analysis or by "thorough knowledge" of the waste and the process generating the waste**
  - ➢ **"Thorough knowledge" requires documentation to support the waste's nonhazardous determination**
    - ➢ **Documentation may include MSDSs and specific certification from the manufacturer indicating the product is nonhazardous**
    - ➢ **Ultimately, the regulatory agency determines whether thorough knowledge may be used in place of laboratory testing**
- ✗ **Laboratory analysis - Toxicity Characteristic Leaching Procedure (TCLP)**
  - ➢ **List of 40 TCLP parameters includes**
    - ➢ **8 heavy metals**
    - ➢ **8 pesticides**
    - ➢ **10 volatile organic compounds**
    - ➢ **14 semi-volatile organic compounds**
- ✗ **Potential characteristic hazardous wastes generated at facilities that perform painting and powder coating**
  - ➢ **Spray booth filters**
  - ➢ **Overspray**
  - ➢ **Masking**
  - ➢ **Waste powder**
  - ➢ **Paint strainers**
  - ➢ **Parts washer sludge**

Hazardous Waste
Toxicity

TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP) PARAMETERS

Parameter	Regulatory Level	EPA Hazardous Waste Number
Arsenic	5.0 mg/l	D004
Barium	100.0 mg/l	D005
Benzene	0.5 mg/l	D018
Cadmium	1.0 mg/l	D006
Carbon tetrachloride	0.5 mg/l	D019
Chlordane	0.03 mg/l	D020
Chlorobenzene	100.0 mg/l	D021
Chloroform	6.0 mg/l	D022
Chromium	5.0 mg/l	D007
m-Cresol	200.0 mg/l	D024
o-Cresol	200.0 mg/l	D023
p-Cresol	200.0 mg/l	D025
Cresols (total)	200.0 mg/l	D026
1,4-Dichlorobenzene	7.5 mg/l	D027
1,2-Dichloroethane	0.5 mg/l	D028
1,1-Dichloroethylene	0.7 mg/l	D029
2,4-Dinitrotoluene	0.13 mg/l	D030
Endrin	0.02 m/l	D012
Heptachlor	0.008 mg/l	D031
Hexachlorobenzene	0.13 mg/l	D032
Hexachloro-1,3-butadiene	0.5 mg/l	D033
Hexachloroethane	3.0 mg/l	D034
Lead	5.0 mg/l	D008
Lindane	0.4 mg/l	D013
Mercury	0.2 mg/l	D009
Methoxychlor	10.0 mg/l	D014
Methyl ethyl ketone	200.0 mg/l	D035
Nitrobenzene	2.0 mg/l	D036
Pentachlorophenol	100.0 mg/l	D037
Pyridine	5.0 mg/l	D038
Selenium	1.0 mg/l	D010
Silver	5.0 mg/l	D011
Tetrachloroethylene	0.7 mg/l	D039
Toxaphene	0.5 mg/l	D015
Trichloroethylene	0.5 mg/l	D040
Vinyl chloride	0.2 mg/l	D043
2,4,-D	10.0 mg/l	D016
2,4,5-TP	1.0 mg/l	D017
2,4,5-Trichlorophenol	400.0 mg/l	D041
2,4,6-Trichlorophenol	2.0 mg/l	D042

Note: 1 mg/l is equivalent to 1 part-per-million (ppm).
TCLP metals are in bold type.

Hazardous Waste
Generator Categories

- 3 Hazardous waste generator categories exist with varying degrees of regulation
  1. Conditionally Exempt Small Quantity Generators
  2. Small Quantity Generators
  3. Large Quantity Generators
- Each category is defined by:
  1. Monthly hazardous waste generation rates; AND
  2. Weight of hazardous waste stored at the facility at any given time

Hazardous Waste
Generator Categories

Conditionally Exempt Small Quantity Generators (CESQGs)

- ✗ Generate ≤ 220 lbs of hazardous waste each month; AND
- ✗ Never accumulate/store more than 2,200 lbs of hazardous waste on site
- ✗ Least restrictive category with regard to applicable regulations

CESQG Regulatory Requirement Overview

Hazardous waste containers.....

- ✗ Must be kept sealed except during transfer operations
  - ➢ Closeable funnels are inadequate
- ✗ Must be compatable with the waste stored
- ✗ Must be labeled with a description of their contents
  - ➢ i.e., "Hazardous Waste - Waste paint/solvent"

No storage time limits apply provided....

- ✗ The facility never exceeds the 2,200 lb hazardous waste storage limit
  - ➢ Once the amount of hazardous waste stored on site exceeds 2,200 lbs the facility becomes a Small Quantity generator and more stringent regulations apply

Hazardous waste must be delivered to an EPA permitted Treatment/storage/disposal facility

CESQG's are not required to have an EPA I.D. number but one is usually needed for off-site transport and disposal

Hazardous Waste
Generator Categories

Small Quantity Generators (SQGs)

- ✗ Generate between 220 and 2,200 lbs of hazardous waste per calendar month on a regular or intermittent basis; AND
- ✗ Never accumulate/store more than 13,200 lbs of hazardous waste on site

SQG Regulatory Summary

- ✗ SQGs must have an EPA generator I.D. number
- ✗ Hazardous waste containers must be...
  - ➢ Kept sealed except during transfer operations
  - ➢ Compatable with the waste stored, in good condition and not leaking
  - ➢ Labeled "Hazardous Waste" and marked with the date hazardous waste was first placed into the container unlee the container is being managed as "Satellite Accumulation"
    - ➢ Satellite accumulation allows up to 55 gallons of hazardous waste to be accumulated at one or several generation points
    - ➢ Containers must be kept closed and marked to identify contents (e.g., "Hazardous Waste - waste solvent")
    - ➢ When satellite accumulation containers become full, they must be dated and moved to the facility's designated hazardous waste storage area within three days
- ✗ Hazardous waste cannot be stored for longer than 180 days before it is shipped to a TSD facility (or 270 days if transported > 200 miles)
- ✗ Other requirements
  - ➢ Hazardous waste storage area must be inspected weekly
    - ➢ Inspection records must be maintained on file (weekly inspection sheets are provided in Appendix E)
  - ➢ Preparedness and prevention requirements
  - ➢ Employee training in waste handling and emergency response
  - ➢ Posting of emergency information at phone nearest the storage area
- ✗ Hazardous waste manifests must accompany off-site shipments of hazardous waste
  - ➢ Manifests must be maintained for at least 3 years
  - ➢ Treatment Standard Notification forms must be maintained for 5 years

Hazardous Waste
Generator Categories

Large Quantity Generators (LQGs)

- **Most restrictive category with regard to applicable regulations**
- **LQGs**
  - **Generate >2,200 lbs of hazardous waste per calendar month on a regular or intermittent basis; OR**
  - **Accumulate/store more than 13,200 lbs of hazardous waste on site**

Regulatory Requirement Summary

- **Must meet and exceed SQG requirements**
  - **Hazardous waste cannot be stored for longer than 90 days before it is shipped to a TSD facility**
  - **Biennial reporting**

GENERATOR RESPONSIBILITIES

- **First - Perform a hazardous waste inventory**
  - **Identify characteristic and listed hazardous wastes generated at your facility**
    - **Determine if wastes are hazardous or nonhazardous by**
      - **Reviewing lists of listed hazardous wastes**
      - **Reviewing MSDSs for information on flashpoint, reactivity and corrosivity**
      - **TCLP laboratory analyses**
      - **"Thorough knowledge"**
  - **Businesses are often cited for "Failure to make a hazardous waste determination" on wastes that are potentially hazardous because of toxicity**
    - **Documentation must be maintained to support a wastes nonhazardous classification**
      - **TCLP laboratory analytical reports or specific product manufacturer documentation**

- **Second - Determine which set of generator regulations apply based on...**
  - **The weight of hazardous waste generated per month AND**
  - **The total weight of hazardous waste stored on site at any one time**

- **Third - Comply with the appropriate set of hazardous waste generator regulations**
  - **Regulatory summaries for CESQGs, SQGs and LQGs are provided in Appendix E**
  - **Perform an in-house audit to ensure compliance with the appropriate set of regulations**

Wastewater Regulations

- A facility is subject to the Metal Finishing category of the federal Pretreatment Standards (40CFR, Part 433) if wastewater from one or more of the following operations is discharged to a publicly owned treatment works (POTW)
  - Electroplating
  - Electroless plating
  - Anodizing
  - *Coating, including phosphatizing or chromating metal parts before application of a finish coating*
  - Chemical etching and milling
  - Printed circuit board manufacturing
- Facilities subject to the Metal Finishing standards are required to meet certain monitoring and reporting requirements
  - Baseline Monitoring Report
  - Compliance Reports
  - Monitoring requirements

Wastewater
Baseline Monitoring Report

- Provides information on a plant's current operations, its wastewater characteristics and its compliance status with the applicable pretreatment standard
- Includes
  - The name and address of the facility and its owners
  - A description of facility operations
    - Average production rates
    - Standard Industrial Classification (SIC) code
    - Schematic diagram of the processes that discharge to the POTW
  - Wastewater flow measurements from regulated discharges
  - Identification of the Pretreatment Standards applicable to each regulated process and pollutant concentration-mass data for regulated parameters
  - A statement certifying whether the facility is in or out of compliance with applicable pretreatment standards
  - A description and schedule of actions that will be carried out to achieve compliance if the plant is noncompliant
- Must be submitted to the facility's control authority
  - Control authority may be the POTW, the state or an EPA regional office
  - Was due in February 1984 for facilities in operation at that time
  - Facilities with regulated processes beginning after February 1984 are to submit a BMR 90 days prior to starting operation

Wastewater Compliance Reporting

- **Facilities must submit a report on compliance (a.k.a. 90 day Compliance Report) to the control authority within 90 days of the final compliance date of the standards or of the date of discharge of a regulated wastewater in a new facility.**
  - Report indicates whether the Metal Finishing Pretreatment Standards are consistently being met
  - Includes information on
    - The concentration of all regulated pollutants
    - Average and maximum daily flow rates
    - If noncompliant, the additional practices to be carried out to achieve compliance
- **Periodic reports of continued compliance**
  - Must be submitted to the control authority semi-annually
    - Regulations indicate the reports must be submitted in June and December, however, the control authority may adjust these reporting deadlines to meet specific needs.
  - Contains information on....
    - The concentration of regulated pollutants discharged to the POTW
    - Average and maximum daily flow rates
    - Sampling and analytical methodology
    - A certification statement indicating that the methodology conforms with the regulations
- **Notice of Slug Loading**
  - Facilities must immediately notify the POTW of any pollutants released to the POTW at a flow rate or concentration that will interfere with the normal operation of the POTW
- **Recordkeeping**
  - All records and monitoring activity data must be maintained on site and available for inspection for a minimum of 3 years

Wastewater Monitoring

- Wastewater discharges from facilities in operation prior to August 1982 must meet Pretreatment Standards for Existing Sources (PSES)

Pollutant or Pollutant property	PSES Single-day Maximum (mg/L)	PSES Monthly Average Maximum (mg/L)
Total cadmium	0.69	0.26
Total chromium	2.77	1.71
Total copper	3.38	2.07
Total lead	0.69	0.43
Total nickel	3.98	2.38
Total silver	0.43	0.24
Total zinc	2.61	1.48
Total cyanide	1.20	0.65
Total toxic organics	2.13	

Note: Additional restrictions on wastewater pH , oil & grease and total suspended solids levels allowed in the discharge will likely be imposed by the POTW

- Plants beginning operation after August 1982 are subject to pretreatment standards for new sources (PSNS)
  - With the exception of cadmium, PSNS discharge limits are the same as idenfified above for PSES facilities
    - PSNS cadmium discharge limits are reduced to 0.11 mg/L for the single day maximum and 0.07 mg/L for the monthly average maximum
- Total toxic organics (TTO) category includes approximately 110 compounds
  - Including benzene, toluene, tetrachloroethene, trichloroethene and PCBs
  - The BMR must include initial monitoring results for TTO parameters that would reasonably be expected to be present in the waste stream
  - The control authority may exclude subsequent TTO monitoring if the facility
    - Demonstrates TTO compliance in the BMR;
    - Submits a solvent management plan to the control authority; and
    - Provides a statement in each periodic report certifying the facility is implementing the toxic management plan submitted to the control authority and no dumping of concentrated toxic organics has occurred at the facility

Wastewater Regulations

Other Potential Discharge Points

- Direct discharges to a surface water body require a National Pollution Discharge Elimination System (NPDES) permit
- Discharges to septic systems/drain tiles
  - ✓ Are considered Class V injection wells
  - ✓ May be prohibited by state and local regulations
    - e.g., IDNR prohits the discharge of industrial wastewaters to a septic system

Used Oil

Any oil that has been refined from crude oil or any synthetic oil that has been used and as a result of such use is contaminated by physical or chemical impurities

- **Includes lubricating, hydraulic, tramp oil, and metalworking fluid**

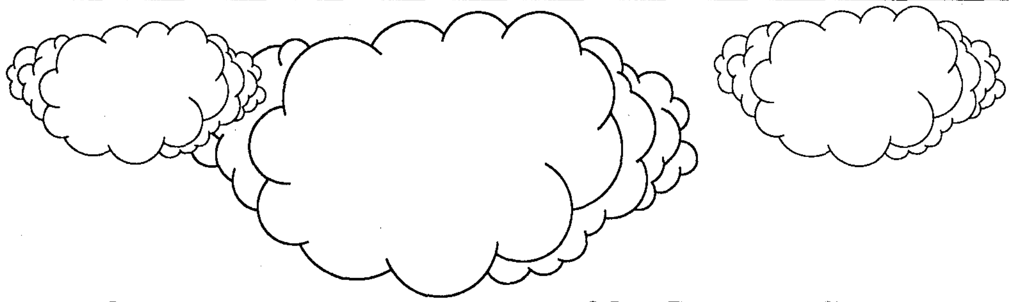
Used Oil Regulations

- **Used oil is exempt from federal hazardous waste regulations if it is recycled or burned for energy recovery**
  - **Separate regulations exist for generators, marketers and burners of used oil**
    - **Certain states are more restrictive and classify used oil as a hazardous waste**

Federal Used Oil Generator Requirements

- **All containers storing used oil including drums, piping, and tanks must be clearly labeled "Used Oil"**
- **Hazardous waste can not be mixed with used oil**
- **Used oil should be provided to an EPA-recognized used oil marketer for recycling or burning**
- **Use of used oil for dust suppression on roads is banned**
- **Used oil generators may burn used oil on site in an oil-fired space heater**
  - **Can only burn used oil generated on site or received from "do-it-yourselfers"**
  - **Must be burned in an oil-fired space heater with a capacity less than 0.5 million BTU's**
  - **Heater must be vented to outside**
- **Can only self transport less than 55 gallons**

Storm Water Regulations



- ✗ Originated from amendments to the 1987 Federal Clean Water Act
- ✗ Regulations require businesses engaged in certain types of industrial activity to get a National Pollutant Discharge Elimination System (NPDES) permit for storm water discharges originating from their facility
  - ➢ Intent - improve surface water quality by reducing or eliminating contaminants transported by storm water runoff from areas of industrial activity
- ✗ Standard industrial classification (SIC) codes and the potential to contribute to storm-water pollution determine whether a facility is subject to storm water permitting
  - ➢ SIC code is a four digit number assigned to a facility based on the type of economic activity in which it's primarily engaged
  - ➢ Must compare the facility's SIC code with the SIC codes of businesses regulated under the storm water NPDES program
- ✗ Most facilities that perform painting and powder coating will likely fall within a conditional permitting category (a category 11 facility)
  - ➢ Category 11 facilities include manufacturers with the following SIC prefixes and codes
    - ➢ 20, 21, 22, 23, 2434, 25, 265, 267, 27, 283, 285, 30, 31 (except 311), 323, 34 (except 3441), 35, 36, 37 (except 373), 38, 39, and 4221-4225

Storm Water Regulations

- Category 11 facilities are subject to storm water permitting requirements only if they have certain materials or activities exposed to storm water
  - Permits are required if material handling equipment and activities, raw materials, intermediate products, final products, waste materials, by-products, or industrial machinery located within the following areas are exposed to storm water
    - Sites used for storage and maintenance of materials handling equipment
    - Materials handling sites
    - Storage areas for raw materials, and intermediate and finished products
    - Shipping and receiving areas
    - By-product or waste material storage areas
    - Manufacturing buildings
    - Areas where industrial activity has taken place in the past and significant materials remain exposed to storm water
  - Category 11 facilities may avoid storm water permitting requirements by removing potential pollution sources from storm water exposure - a practice encouraged by regulatory agencies and technical assistance providers
    - Materials and operations may be moved indoors, placed under roof, or eliminated altogether
- Facilities that fall within one of the other regulated categories must obtain a storm water permit regardless of the actual exposure of these same materials or activities to storm water

Storm Water Regulations

- **Permitting Requirements**
  - **Facilities subject to storm-water permitting must get a storm water discharge permit from the regulatory agency authorized to administer the NPDES program**
    - **May be an EPA regional office or a state agency**
  - **In many cases, the NPDES permitting authority will issue a *general* permit**
    - **A simplified permitting process that covers storm water discharges from most industrial activities**
  - **General permit coverage typically requires the facility to file a Notice of Intent (NOI) application to the regulating agency**
    - **Submittal of an NOI indicates the discharger agrees to the terms and conditions of the general permit, which may or may not require collection of storm water samples for laboratory analyses**
    - **Some states may also impose public notification requirements and/or charge a permit fee**
- **Other permit types that may be issued to a facility include *Individual* and *Multisector General* permits**

Storm Water Pollution Prevention Plans

- **Most facilities issued a storm water permit must also develop and implement a storm water pollution prevention plan (SWPPP)**
- **Purpose of a SWPPP is to**
  - **Identify potential storm water pollution sources**
  - **Describe practices that will be implemented to reduce or prevent storm water pollution**
- **SWPPPs are NOT submitted to the regulatory agency**
  - **However, they must be kept on file and available for review at the request of regulatory personnel**

SARA Title III

- a.k.a. Emergency Planning and Community Right to Know Act (EPCRA)
- Consists of four major sections dealing with:
  - Emergency release notification;
  - Community right-to-know reporting;
  - Toxic chemical release inventory reporting; and
  - Emergency planning.
- Emergency planning - Section 301-303
  - Defines the roles of Local Emergency Planning Committees (LEPC) and State Emergency Response Commission (SERC)
- Emergency Notification - Section 304
  - Outlines the requirements and means to report a hazardous chemical / waste spill or release to applicable state and local response agencies.
  - If a spill or release occurs:
    - Stop the source of the release. Make appropriate internal and external notifications.
    - Contain the spill to minimize its environmental impact.
    - Repair the cause of the spill.
    - Determine appropriate disposal method for clean up materials. If release is to groundwater or subsurface soil, determine the impact on affected area and initiate a recovery program.

SARA Title III

- **To determine if the spill/release must be reported to the regulatory authority under Section 304:**
  - **Use information at hand (e.g., MSDSs, laboratory data, etc.) to determine the composition of the material released.**
  - **Determine if any of the ingredients are listed under the Section 304 EHS - RQ or CERCLA - RQ headings in the Consolidated Chemical List (CCL). (Appendix F contains the CCL - also available at http://www.epa.gov/swercepp/)**
    - **The CCl was prepared to help firms determine whether they need to submit reports under sections 302, 304, or 313 of SARA Title III**
    - **Chemicals are listed by Chemical Abstract Service (CAS) registry number in front of the list. (They are also listed alphabetically in the middle. Wastes are listed in the back.)**
  - **Determine the amount of each listed chemical involved in the release. (The weight of the material released multiplied by the percentage of the listed chemical present in the material.)**
  - **If the amount of listed chemical in the release exceeds its reportable quantity (RQ) as found in the CCL, report the following to the SERC and LEPC:**
    - **Chemical name, whether it is an EHS or CERCLA chemical, and the quantity released.**
    - **Time and duration of release.**
    - **Whether it was released into the air, water and/or land**
    - **Health effects and advice regarding medical attention for exposed individuals**
    - **Precautions such as evacuation and cleanup actions taken**
    - **Name and number of contact person.**
  - **Written notification, including an updated summary of the information included in the initial telephone report, must be provided to the SERC and LEPC as soon as practical after the release.**

SARA Title III

✗ Community Right-to-Know - Sections 311-312

- **Section 311 - mandates a one time submission, with periodic updates, of chemcial hazard information to local and state response agencies for chemicals stored on site in quantities that exceed established thresholds.**
  - **Facilities must submit copies of MSDSs or a list of hazardous chemicals to the SERC, LEPC and local fire department for:**
    - **Any Extremely Hazardous Substance (EHS) listed under the column heading "Sec. 302 (EHS)-TPQ" in the CCL if ever present at the facility in quantities greater than 500 pounds or the Threshold Planning Quantity (TPQ), whichever is lower. AND**
    - **All other hazardous chemicals present in quantities greater than 10,000 pounds.**
  - **Hazardous chemicals are those materials for which OSHA requires Material Safety Data Sheets (MSDS) to be maintained in the workplace**
  - **Five exemptions from reporting requirements exist including:**
    - **Any food additive regulated by the Food and Drug Administration (FDA)**
    - **A solid (such as steel) that does not present a hazard under normal conditions. The solid is included if it is used in a manner that creates exposure hazards such as cutting, welding, grinding, etc.**
    - **A substance used for personal, family or household purposes. Also, a material used by business that is in the same form (i.e., packaged for home use) and concentration as a material sold to the general public is exempt.**
    - **Substances used in research labs, hospitals, or medical facilities under the direct supervision of a technically qualified individual**
  - **If a list of chemicals is submitted, each reportable chemical must be placed in one of the following categories:**
    - **Immediate (acute) health hazard (i.e. toxic or irritant)**
    - **Delayed (chronic) health hazard (i.e. carcinogenic)**
    - **Fire hazard**
    - **Pressure hazard**
    - **Reactive hazard**
  - **An MSDS or revised list must be provided to all three agencies when new hazardous chemicals become present at the facility in quantities greater than the thresholds listed above. Also, revised MSDS must be submitted to update originals if significant new information is discovered about the hazardous chemical.**

SARA Title III

- Section 312 requires annual chemical hazard reporting under the same criteria as Section 311
  - Facilities must submit annual "Tier II" hazardous chemical inventory forms to the SERC, LEPC and local fire department by March 1 for Extremely Hazardous Substances (EHS) and other hazardous chemicals reportable under Section 311 criteria and present at the facility at any given time during the preceding year.
    - The purpose of the Tier II form is to provide state and local officials and the public with specific information on hazardous chemicals present at your facility during the past year.
- Section 313 - Toxic Release Inventory
  - Requires annual submission of Form R to the EPCRA Reporting Center and the SERC by July 1 for the preceding year if the facility:
    - Employs the equivalent of 10 or more full time employees;
    - Has a Standard Industrial Classification (SIC) code in the range of 20xx - 39xx; AND
    - Has manufactured or processed any of the chemicals listed in the Section 313 column of the CCL in quantities greater than 25,000 pounds or otherwise used any of these listed chemicals in quantities greater than 10,000 pounds during the preceding year.
  - Information on the Form R includes:
    - Name, location and type of business
    - Off-site location to which the facility transfers toxic chemicals for waste recycling, energy recovery, or treatment and disposal.
    - Whether the chemical is manufactured, processed, or otherwise used and the general categories of use
    - The amounts of reportable chemicals manufactured, processed or otherwise used at the facility
    - The quantity of chemicals released from the facility via air, land, water or other transfer
    - Waste treatment/disposal methods and efficiency of methods for each waste stream
    - Source reduction and recycling activities.

Air Quality Regulations
Definitions

- **Fugitive Emissions**
  - **Emissions which could not reasonably pass through a stack, chimney, vent or other functionally equivalent opening. Fugitive emissions eventually get out of the building through doors, windows or roof vents. Leaks from equipment or vents, solvent cleaning without a vent, and welding fumes are likely examples of fugitive emissions.**
- **Air Pollutants**
  - **Two groups of air pollutants are involved - *criteria air pollutants* and *hazardous air pollutants* (HAPs)**
    - **Criteria pollutants include sulfur oxides (SOX), nitrogen oxides (NOX), total suspended particulates (TSP), particulate matter (PM10), carbon monoxide (CO), volatile organic compounds (VOCs), and lead**
    - **HAPs, of which there are 188, are also known as air toxics.**
- **Emission Points or Source**
  - **Any equipment or process that emits regulated air contaminants**
    - **Examples include spray booths, bake ovens, sand blasting operations or welding hoods**
- **Control Equipment**
  - **Any equipment that prevents or reduces emissions of one or more air pollutants to the atmosphere from an emission point**
    - **Example - spray booth filters**

Air Quality Regulations
Definitions

- **Actual and Potential Emissions**
  - **Actual Emissions - the amount of emissions emitted based on the actual operating hours, operating capacity of the equipment/process, and material consumption**
    - **Air pollution control equipment should be taken into account while estimating the actual emissions**
  - **Potential Emissions -the amount of emissions that could be emitted if the equipment or process were operated continuously at maximum capacity for one year (8760 hours); not how much it actually does emit**
    - **Potential emissions should be calculated taking into account any air pollution control equipment that might be used in the process**
    - **Potential emissions have nothing to do with actual emissions or frequency of equipment use**
- **Emission Inventory**
  - **An estimate of emissions from all sources of air pollutants within the facility. An emission inventory must indicate actual and potential emissions from the facility, as well as, the individual emission sources**
  - **The emission inventory should also show, separately, emissions of criteria pollutants and each individual air toxic, if applicable**

Title V Operating Permit

- Under the 1990 Clean Air Act Amendments (CAAA), all "major" sources of air pollutants are required to apply for an operating permit
  - Businesses must complete an emissions inventory to determine whether as source is "major" or not as defined in Title V of the CAAA
  - An emission inventory is used to determine if the facility is a "major" source, and what permitting options are available
  - "Major" source thresholds are
    - Potential emissions of 100 tons per year of a criteria pollutant;
    - 25 tons per year of a combination of hazardous air pollutants (toxics) and 10 tons per year of a single toxic

Air Permitting in Iowa

- Air Quality Construction Permits
  - The Iowa Department of Natural Resources (IDNR) administers the air emissions permitting for new or existing sources of air pollutants
  - The IDNR's permit to install or alter equipment or control equipment for new stationary sources and modifications of existing stationary sources is also known as a "construction permit"
    - This permit is required for each air emissions source to the outside atmosphere regardless of equipment size, facility size, and frequency of operations
    - Equipment installed prior to September 23, 1970, provided no major modifications have been completed, is exempt.
    - Facilities should apply for a construction permit before installing or constructing an air emission source. Existing sources use the same application form
    - A approved construction permit is good forever unless the source is modified or there is an process change affecting air emissions
    - There is currently no fee associated with the construction permit application
    - General permit requirements include unrestricted vertical discharge at a reasonable height above the building roof line.
    - Depending on emission level, geographic location, and stack dimensions, some sources may be asked to meet additional requirements like computer modeling, increased stack height, greater air flow, or stack testing

Air Permitting in Iowa

Permit-by-Rule for Spray Surface Coating Operations

- Surface coating operations meeting the following criteria are covered under a "permit-by-rule"
- There are two options
  - Consumption of less than one gallon of sprayable material (including paint, thinner, hardener etc.) per day requires:
    - One time notification of the IDNR
    - Maintaining 18 month rolling records to show the sprayable material consumption never exceeds one gallon
  - Consumption of more than one gallon and less than three gallons of sprayable material (including paint, thinner, hardener etc.) per day requires:
    - One time notification of the IDNR
    - Maintaining 18 month rolling records to show the sprayable material consumption never exceeds three gallons
    - A stack at a height of 22 feet above grade

National Emission Standards For Hazardous Air Pollutants

- **National Emissions Standards for Hazardous Air Pollutants - known as NESHAP**
  - **Apply to certain pollutants and the process they originate from**
  - **Under the 1990 Clean Air Act Amendments (CAAA), NESHAPs will be established for 174 specific source categories in the next 10 years.**
    - **Example - a NESHAP for halogenated solvent users was finalized in September, 1995**
  - **NESHAP requirements vary from one source category to another, but general requirements (e.g., initial notification and record keeping) will apply to all source categories**
- **NESHAP eligibility also affects Title V applicability determinations**
  - **Example - sources subject to NESHAP must include fugitive emissions in Title V applicability determinations**

Wood Furniture Manufacturing NESHAP

- **Wood Furniture Manufacturing**
  - The finishing, gluing, cleaning , and washoff operations associated with the production of wood furniture or wood furniture components
- **NESHAP applicability**
  - Applies to each facility that is engaged (in part or in whole) in the manufacture of wood components and is located at a plant site that is a major source for Hazardous Air Pollutants (HAPs)
    - Major Source - those that emit or have the potential to emit 10 tons/year or more of a single listed pollutant, or 25 tons/year or more of a combination of HAPs
- **The EPA final rule is based on emission limits and work practice standards**
  - A choice of four different compliance options is offered
  - The final rule limits the amount of HAPs that can be contained in the coatings used for finishing, gluing, and cleaning operations. The emissions limits can be met through using a variety of coatings that contain lower quantities of HAPs
- **The intent of the work practice standards is to reduce waste and HAP emissions**
  - Good housekeeping measures (such as keeping containers of materials closed), periodic training of operators who use solvent and/or coatings, and performing periodic inspections to locate and repair leaking equipment are required by the work practice provisions.
  - The rule also requires the use of spray equipment which is believed to be more efficient in applying coatings

Wood Furniture Manufacturing NESHAP

- A new source is one from which construction commenced on or after December 7, 1994
- An existing source began construction before December 7, 1994
- Emissions Limits are different for new and existing sources
- Compliance dates
  - Existing source emits <50 tons/yr in 1996
    - December 7, 1998
  - Existing source emits >50 tons/yr in 1996
    - November 21, 1997
  - New Source
    - Immediately upon startup or December 7, 1995, whichever is later
    - Reconstructed sources are subject to new source requirements
  - An area source which becomes major for HAP must comply with the standard
    - Existing source - one year after becoming major
    - New source - immediately upon becoming major

Reinforced Plastics and Boat Manufacturing NESHAP

- Subcategories currently being considered
  - Open molding (i.e, spray up, hand layup, flow coating, filament winding, gel coating,
  - Closed molding (i.e., compression molding, injection molding, resin transfer molding)
  - Polymer casting
  - Pultrusion
  - Continuous lamination/casting
  - SMC manufacturing
  - Equipment cleaning/mixing of HAP - containing materials (including BMC manufacturing)
  - Storage of HAPs - containing materials
- NESHAP is due in the year 2000

112(R) Accidental Release

- CAAA regulations finalized in June 1996 require development and implementation of a Risk Management Program (RMP) at facilities that manufacture, process, use, store, or otherwise handle regulated substances in quantities that exceed a specified threshold
- A list of regulated substances and separate thresholds have been established
  - The list contains approximately 77 toxic substances (vapor pressure greater than 10 mm Hg), and 63 flammable substances (flash point below 73°F and boiling point below 100°F)
  - Threshold quantities vary from 500 to 20,000 pounds for toxic substances, and 10,000 pounds for flammable substances

CERCLA and EPCRA Continuous Release Reporting

- ✗ A release occurs when a hazardous substance enters the environment via air, water, or land (above or below ground)
  - ➢ May include a spill, discharges to wastewater, and routine fugitive and point source air emissions (i.e., continuous releases)
- ✗ If a company releases more than an established RQ of a CERCLA regulated chemical or an extremely hazardous substance (as defined by EPCRA) within a 24 hour period, the facility must:
  - ➢ Contact the federally managed National Response Center (800/424-8802);
  - ➢ The state spill response coordinator;
  - ➢ The state emergency response commission; and
  - ➢ The local emergency planning commision response
  - ➢ A written report detailing the release and cleanup actions also must be submitted within 30 days
- ✗ Regulated chemicals include all CERCLA regulated chemicals plus an additional 222 substances designated extremely hazardous
  - ➢ The 356 regulated substances are included in the Consolidated Chemical List

Examples

Chemical	Reportable Quantity
Xylene, mixed isomers	100 lbs
Methyl isobutyl ketone	5,000 lbs
Toluene	1,000 lbs

CERCLA and EPCRA Continuous Release Reporting

- Continuous Releases - operations that emit hazardous substances as part of normal operations (e.g., xylene from spray painting operations)
  - Must be reported if the chemical(s) released exceed established RQ thresholds
  - Facilities with continuous releases must contact the National Response Center and prepare a written report within 30 days

  Example - an industrial painting facility could exceed the 100 pound RQ for mixed isomers of xylene by spraying 35 gallons of paint in one 24-hour period if the paint contains 35 percent mixed isomer xylene
- Annual reporting is required if the release continues at levels above the RQ (i.e., a stable continuous release)
  - A special form is available for stable continuous releases
  - Allows annual reporting
  - May obtain the Reporting Requirements for Continuous Releases of Hazardous Substances form by calling (913/551-7970) and request EPA document No. 540-R-97-047

3 Stage Pretreatment
Daily Log Sheet

Date ________

Raw Water TDS/Conductivity ________

Baseline Operating Conditions

Stage	Function	Time (sec)	Product	Tank Capacity (gal)	Acceptable Concentration Range	Acceptable pH Range	Acceptable TDS or conductivity	Operating Temperature	Last Dumped
1	Clean and Phosphatize								
2	Rinse								
3	Seal Rinse								

Daily Monitoring Results

Date/time	Stage	Concentration	pH	Chemical Additions	Temperature	TDS/ Conductivity	Pressure (psi)	Remarks/Initials
	1							
	2							
	3							
	1							
	2							
	3							
	1							
	2							
	3							
	1							
	2							
	3							
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	3							
	1							
	2							
	3							
	1							
	2							
	3							
	1							
	2							
	3							

5+ Stage Pretreatment
Daily Log Sheet

Date ________
Raw Water TDS/Conductivity ________

Baseline Operating Conditions

Stage	Function	Time (sec)	Product	Tank Capacity (gal)	Acceptable Concentration Range	Acceptable pH Range	Acceptable TDS or Conductivity	Operating Temperature	Last Dumped
1									
2									
3									
4									
5									
6									

Daily Monitoring Results

Date/time	Stage	Concentration	pH	Chemical Additions	Temperature	TDS/ Conductivity	Pressure (psi)	Remarks/Initials
	1							
	2							
	3							
	4							
	5							
	6							
	1							
	2							
	3							
	4							
	5							
	6							
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	1							
	2							
	3							
	4							
	5							
	6							
	1							
	2							
	3							
	4							
	5							
	6							

Water Quality Equivalents Chart

Conductivity (uS)	Total Dissolved Solids (Parts per Million $CaCO_3$)	Specific Resistance (ohm/cm)[a]	Grains per Gallon (as $CaCO_3$)
0.056	0.028	18,000,000	0.002
0.071	0.036	14,000,000	0.002
0.100	0.050	10,000,000	0.003
0.167	0.083	6,000,000	0.005
0.500	0.250	2,000,000	0.015
1.000	0.500	1,000,000	0.029
1.667	0.833	600,000	0.049
2.5	1.250	400,000	0.073
10	5	100,000	0.292
20	10	50,000	0.585
40	20	25,000	1.170
80	40	12,500	2.340
312.5	156.25	3,200	9.137
625	312.5	1,600	18.273
2,500	1,250	400	73.990

[a] Indicates at 25°C

Note: 1uS (microsiemens) = 1umho (micromho)

Viscosity Conversion Chart

Poise	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0	5.0
Centipoise	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	250	300	350	400	500
Zahn #1	30	37	44	52	60	68														
Zahn #2	16	18	20	22	24	27	30	34	37	41	49	58	66	74	82					
Zahn #3									10	12	14	16	18	20	23	25	34	40	46	57
Zahn #4										10	11	13	14	16	17	21	24	27	30	37
Zahn #5															10	13	15	18	20	25
Ford #3		12	19	25	29	33	36	41	45	50	58	66								
Ford #4	5	10	14	18	22	25	28	31	32	34	41	45	50	54	58	67	74			
Fisher #1	20	30	39	50																
Fisher #2		15	18	21	24	29	33	39	44	50	62									
Sears Craftsman Cup				19	20	21	23	24	26	27	31	34	38	40	44					

For reference

Water = 1.0 centipoise
Kerosene = 10 centipoise
#10 SAE weight motor oil = 100 centipoise

Powder Coatings Coverage Chart

Typical powder coating coverage (in ft^2/lb.) for a film thickness of 1.0 mil

	Utilization Efficiency									
Specific Gravity (g/cm^3)	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
1.0	19.2	38.4	57.7	76.9	96.1	115.3	134.5	153.8	173.0	192.2
1.1	17.5	34.9	52.4	69.9	87.4	104.8	122.3	139.8	157.2	174.7
1.2	16.0	32.0	48.1	64.1	80.1	96.1	112.1	128.2	144.2	160.2
1.3	14.8	29.6	44.3	59.1	73.9	88.7	103.5	118.2	133.0	147.8
1.4	13.7	27.5	41.2	54.9	68.7	82.4	96.1	109.8	123.6	137.3
1.5	12.8	25.6	38.4	51.2	64.1	76.9	89.7	102.5	115.3	128.1
1.6	12.0	24.0	36.0	48.0	60.1	72.1	84.1	96.1	108.1	120.1
1.7	11.3	22.6	33.9	45.2	56.6	67.9	79.2	90.5	101.8	113.1
1.8	10.7	21.4	32.0	42.7	53.4	64.1	74.8	85.4	96.1	106.8
1.9	10.1	20.2	30.4	40.5	50.6	60.7	70.8	81.0	91.1	101.2
2.0	9.6	19.2	28.8	38.4	48.1	57.7	67.3	76.9	86.5	96.1

Note: To determine powder coating coverage at a film thickness other than 1.0 mil, simply divide the coverage obtained from the above chart by the desired film thickness. For example, at 50% utilization efficiency, a powder with a specific gravity of 1.6 g/cm^3 will cover approximately 60.1 ft^2 per pound at 1 mil film thickness. If a film thickness of 2.0 is desired, simply divide 60.1 ft^2 by 2 to get 30.1 ft^2 per pound.

PAINT SYSTEM INFORMATION CHECKLIST

Spray Gun

- ❒ **Make/Model** ______________________________
- ❒ **Type of Application Equipment (HVLP, Electrostatic, Airless)** ______________
- ❒ **Wall Air Pressure (psi)** ________ **Inlet Air Pressure (psi)** ______________
- ❒ **Pump Ratio** __________ **Air Pressure to Pump (psi)** ___________-___________
- ❒ **Fluid Pressure (psi)** ______________________________
- ❒ **Applicator Flow Rate (oz/min or cc/min)** ______________________
- ❒ **Air Cap** ______________________________
- ❒ **Fluid Tip Size** ______________________________
- ❒ **Spray Pattern Size = _____ - inches @ _____ - inch gun-to-target distance**
- ❒ **Copies of Spray Gun Specifications**
- ❒ **Fluid Hose I.D. and Length** ______________________
- ❒ **Air Hose I.D. and Length/Restrictions** ______________________
- ❒ **Air Compressor Size/Condition/Air Dryer** ______________________
- ❒ **Condition of Air Gauges** ______________________

Coating Characteristics

- ❒ **Description** ______________________________

  ____
- ❒ **Viscosity = ______ seconds in a ___________ cup Temperature __________**
- ❒ **Temperature of Storage Area __________ Controlled? Yes / No**
- ❒ **Resistivity** ______________________________
- ❒ **Percent Solids** ______________________________
- ❒ **Consumption Rates** ______________________________

  ____

  ____
- ❒ **Paint Heaters in use? Yes / No If so, what temperature?** ___________
- ❒ **Desired Dry Mil / Wet Mil Thickness** ____________/______________
- ❒ **MSDS Obtained? Yes / No**
- ❒ **Coating Manufacturers Specifications Obtained? Yes / No**

Spray Booth/Conveyor

- ❒ **Air Flow (cfm)** ______________________________
- ❒ **Manometer Readings** ______________________________
- ❒ **Conveyor Speed** ______________________________
- ❒ **Booth Lighting Conditions** ______________________________
- ❒ **Grounding** ______________________________

Target Description (size, configuration and composition)

____

____

____

- ❒ **Target Pathway to Ground** ______________________________
- ❒ **Condition of Hangers** ______________________________

Wastes Generated/Rates

- ❒ **Waste Paint/Solvent** ______________ **gallons/month**
- ❒ **Spray Booth Arrestor Changeout Frequency** ______________
- ❒ **Overspray Waste** ______________________ **lbs/month**
- ❒ **Hazardous Waste Generator Category? LQG / SQG / CESQG**
- ❒ **Used Oil** ______________ **gallons/month**
- ❒ **Title V Facility? YES / NO**

Standard Operating Procedure

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Problem Areas and Recommendations

Painter's Input/comments/Concerns