SPRAY BOOTH DESIGN
AND MAINTENANCE
FOR
POLLUTION PREVENTION

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Session 5-120
GOALS AND OBJECTIVES

- Protects the paint operator from inhaling toxic chemicals
- Protects the paint operator from inhaling toxic or non-toxic particulates
- To reduce the likelihood of fires

Note:
A spray booth is an abatement device for particulates but not for VOC emissions.
• Dry filter spray booths:

  Rectangular pad. Paint arrestor or other types of filter which are approximately 20 inches x 20 inches x 1 inches. (Other sizes are also commonly available).

  Roll media. Paint arrestor or other types of filter media which are supplied in long rolls, such as 40 ft long x 40 inches wide, and then cut into lengths that fit the spray booth.

  Continuous roll media on spool. These are filters which can be rolled up onto a spool as painting takes place and the filter becomes loaded. The advantage of this type is that a constant air flow through the booth can be more easily maintained.

  Cardboard baffle

  Expanded polystyrene. These filters are intended for reuse. When a filter is loaded with dry overspray, the filter is removed from the holding grid. Using a bristle brush, the overspray is brushed off, and the filter replaced for reuse. At the end of its life, it can be dissolved in a small amount of solvent, such as acetone, and disposed of as hazardous waste.

  Dry baffle. These are permanent metal baffles which collect the wet overspray. They are becoming more popular for coatings which can be collected and recycled.
• Water Wash Booths

**Low static pressure pump**

Pump is used to circulate water. Most common type of water-wash booth for general purpose use.

**High static pressure pump**

Because of the high internal static pressures, a greater amount of scrubbing takes place and the booths are considered to have higher particulate removal efficiencies. Often used in automotive plants.

**Pumpless requiring high internal static pressure**

Unlike the pump-type booths, water is drawn into the entrainment section of the booth by means of high internal static pressure. Extensive scrubbing of the particulates by water takes place. The water then falls back into the water trough.

These are high efficiency booths.

**Pumpless with low internal static pressure**

Little or no water movement takes place in the exhaust plenum. Particulates are scrubbed from the air on account of abrupt changes of direction of the exhaust air.
DIRECTION OF AIR FLOW

- **Cross Draft**

  Air movement is from behind the operator toward the vertical filter bank or water curtain. The air travels parallel to the floor.

  * This is the preferred direction when parts are suspended from racks or a conveyor and the painter applies the coating essentially in one direction.

  If both sides of the part need to be coated the part is rotated so that the paint operator continues to apply coating in the same direction.

  * Of all the spray booth types this is often the least expensive.

- **Downdraft**

  The air moves from the ceiling of the spray booth vertically downward toward the floor where the exhaust is located.

  * This is the preferred direction when the paint operator walks around the part. This is particularly popular when large machines or vehicles (which cannot be rotated) sit on a floor or grating.

  * This direction is also applicable when more than one paint operator applies coating to the part.

  * Has the potential to produce excellent paint jobs.
* Usually requires high efficiency ceiling air intake filters and an air-
make up system to push the air through the filters.

* Often more expensive than cross-draft booths as a pit is required
under the floor grating. This may require that a pit be provided
under the concrete floor of the building. Alternatively, the booth
can be elevated so that the pit can sit on top of the floor.

- **Semi-Down Draft**

  * The air moves from the ceiling at the front of the booth toward
  the floor at the back of the booth where the exhaust is located.
  Air movement is in a diagonal direction.

  * Alternatively, the air moves from the center of the ceiling down
toward one of two level exhaust plenums located along the side
walls of the booth.
Cross Draft Spray Booth

Down Draft Spray Booth
Semi Down Draft Spray Booth
Effectively removes up to 95 - 99% of particulates.

Can be used in booths of all designs, small, large, side draft, down draft, semi down draft

Ideal for low paint loading approximately 2-5 gallon coating usage per ft² of filter area. *(This is only a rule of thumb!)*

Relatively inexpensive as compared to water wash booths.

Maintenance essentially only requires periodic replacement of filter media.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectively removes up to 95 - 99% of particulates.</td>
<td>Does not remove VOC’s.</td>
</tr>
<tr>
<td>Can be used in booths of all designs, small, large, side draft,</td>
<td>Not intended for large coating usage &gt;5 gallon per ft² of filter area. *(This</td>
</tr>
<tr>
<td>down draft, semi down draft</td>
<td>is only a rule of thumb!)*</td>
</tr>
<tr>
<td>Ideal for low paint loading approximately 2-5 gallon coating usage per</td>
<td>Air flow through the booth diminishes as the filters load up with overspray</td>
</tr>
<tr>
<td>ft² of filter area. <em>(This is only a rule of thumb!)</em></td>
<td>(unless continuous roll-up filters are used.)</td>
</tr>
<tr>
<td>Relatively inexpensive as compared to water wash booths.</td>
<td>Storage of unused filters requires space.</td>
</tr>
<tr>
<td>Maintenance essentially only requires periodic replacement of filter</td>
<td>Used filters are bulky and occupy much space, therefore increasing cost of</td>
</tr>
<tr>
<td>media.</td>
<td>disposal.</td>
</tr>
<tr>
<td></td>
<td>Potential fire hazard, particularly if dry overspray is allowed to build up.</td>
</tr>
<tr>
<td></td>
<td>Overspray of coatings, such as nitrocellulose lacquers, can cause spontaneous</td>
</tr>
<tr>
<td></td>
<td>combustion.</td>
</tr>
<tr>
<td></td>
<td>Requires installation of sprinkler system.</td>
</tr>
</tbody>
</table>
TYPICAL DRY FILTER EFFICIENCIES

(Source: How Much Do You Know About Spray Booth Exhaust", Jim Howery, Products Finishing, May 1984)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EFFICIENCY</th>
<th>HOLDING CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Solids Baking Enamel</td>
<td>Holding Capacity**</td>
</tr>
<tr>
<td>------------------------------</td>
<td></td>
<td>Ave. Efficiency Range</td>
</tr>
<tr>
<td>Standard Filter</td>
<td>96.5 - 97.5</td>
<td>2.8 lbs @ 0.10</td>
</tr>
<tr>
<td>High-Capacity Filter</td>
<td>94.0 - 96.0</td>
<td>6.5 lbs @ 0.10</td>
</tr>
<tr>
<td>High-Efficiency Filter</td>
<td>98.5 - 99.5</td>
<td>5.4 lbs @ 0.50</td>
</tr>
<tr>
<td></td>
<td>Water-Borne Bake Enamel</td>
<td>Holding Capacity**</td>
</tr>
<tr>
<td></td>
<td>Ave. Efficiency Range</td>
<td>(inches, water column)</td>
</tr>
<tr>
<td>Standard Filter</td>
<td>93.0 - 94.0</td>
<td>4.8 @ 0.50</td>
</tr>
<tr>
<td>High-Capacity Filter</td>
<td>91.5 - 92.5</td>
<td>8.7 @ 0.50</td>
</tr>
<tr>
<td>High-Efficiency Filter</td>
<td>97.0 - 98.0</td>
<td>4.0 @ 0.50</td>
</tr>
</tbody>
</table>

All performance figures were obtained using representative current industry coatings in an air-atomizing gun with two pads in tandem at a face velocity of 200 fpm.

** Test paint was very fluid and slow drying, resulting in excessive run-off on standard and high-capacity filters, with little resistance increase.
CLEAN FILTER RESISTANCE VERSUS AIR-FLOW VELOCITY

(Source: How Much Do You Know About Spray Booth Exhaust", Jim Howery, Products Finishing, May 1984)

<table>
<thead>
<tr>
<th>VELOCITY FPM</th>
<th>STANDARD FILTER</th>
<th>HIGH-CAPACITY FILTER</th>
<th>HIGH-EFFICIENCY FILTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.020</td>
<td>0.020</td>
<td>0.055</td>
</tr>
<tr>
<td>150</td>
<td>0.035</td>
<td>0.030</td>
<td>0.085</td>
</tr>
<tr>
<td>200</td>
<td>0.060</td>
<td>0.050</td>
<td>0.125</td>
</tr>
<tr>
<td>250</td>
<td>0.085</td>
<td>0.075</td>
<td>0.170</td>
</tr>
<tr>
<td>300</td>
<td>0.120</td>
<td>0.100</td>
<td>0.225</td>
</tr>
<tr>
<td>350</td>
<td>0.155</td>
<td>0.130</td>
<td>0.280</td>
</tr>
</tbody>
</table>
Removal Efficiency (%)

Filter Removal Efficiency
Effect of Paint Loading on

Resistance (inches of water)

Resistance to Air Flow
Effect of Paint Loading on
### TABLE OF ASSUMPTIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area to be coated</td>
<td>3,500.00 ft²/day</td>
</tr>
<tr>
<td>VOC of coating</td>
<td>3.5 lbs/gal</td>
</tr>
<tr>
<td>Density of VOC portion</td>
<td>7.36 lbs/gal</td>
</tr>
<tr>
<td>% Volume solids</td>
<td>52.45 %</td>
</tr>
<tr>
<td>Weight per gal (WPG)</td>
<td>9.8 lbs/gal</td>
</tr>
<tr>
<td>% Weight solids (Calculated)</td>
<td>64.29 %</td>
</tr>
<tr>
<td>Cost of coating</td>
<td>$20.00 /gal</td>
</tr>
<tr>
<td>Dry film thickness</td>
<td>1.5 mils</td>
</tr>
<tr>
<td>Transfer efficiency</td>
<td>5 %</td>
</tr>
<tr>
<td>Size of filters 20&quot;x20&quot;</td>
<td></td>
</tr>
<tr>
<td>No of filters across</td>
<td>4</td>
</tr>
<tr>
<td>No of filters down</td>
<td>3</td>
</tr>
<tr>
<td>Total no filters affected</td>
<td>12</td>
</tr>
<tr>
<td>Holding capacity of filters</td>
<td>3 lbs/filter</td>
</tr>
<tr>
<td>Percent of overspray going into filters</td>
<td>60 %</td>
</tr>
<tr>
<td>Cost of filters</td>
<td>$1.50 /filter</td>
</tr>
<tr>
<td>Number of filters which can be disposed in 55-gal drum</td>
<td>40 filters/drum</td>
</tr>
<tr>
<td>Cost to dispose of 55-gal drum</td>
<td>$300.00 /drum</td>
</tr>
<tr>
<td>Days of operation</td>
<td>251 days/yr</td>
</tr>
<tr>
<td>Labor required to replace filters</td>
<td>0.5 hours</td>
</tr>
<tr>
<td>Labor rate</td>
<td>$15.00 /hour</td>
</tr>
</tbody>
</table>

### CALCULATIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total liquid gallons required</td>
<td>124.82 gals/day</td>
</tr>
<tr>
<td>Total liquid coating used</td>
<td>31,329.19 gals/yr</td>
</tr>
<tr>
<td>Total solid coating used</td>
<td>16,430.80 solid gals/yr</td>
</tr>
<tr>
<td>Density of solid coating (Calculated)</td>
<td>12.01 lbs/gal</td>
</tr>
<tr>
<td>Weight of solid coating used</td>
<td>187,373.90 lbs solid/year</td>
</tr>
<tr>
<td>Weight of total solid overspray</td>
<td>187,505.20 lbs solid/year</td>
</tr>
<tr>
<td>Weight of solid overspray in filters</td>
<td>112,503.12 lbs solid/year</td>
</tr>
<tr>
<td>Number of filters to be disposed of</td>
<td>3,125.09 filters/year</td>
</tr>
<tr>
<td>Number of filter changes per year</td>
<td>937.53 drums/year</td>
</tr>
<tr>
<td>Number of 65-gallon drums to be disposed of</td>
<td></td>
</tr>
<tr>
<td>Cost of hazardous waste disposal</td>
<td>$281,257.80 /year</td>
</tr>
<tr>
<td>Cost of filters</td>
<td>$68,251.56 /year</td>
</tr>
<tr>
<td>Labor hours to change filters</td>
<td>1,562.54 hours/year</td>
</tr>
<tr>
<td>Labor cost to change filters</td>
<td>$23,438.15 /year</td>
</tr>
<tr>
<td>Number of wasted gallons</td>
<td>29,762.73 gallons/year</td>
</tr>
<tr>
<td>Cost of wasted paint</td>
<td>$595,254.61 /year</td>
</tr>
</tbody>
</table>

### SUMMARY

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of waste + filters + labor</td>
<td>$360,947.51 /year</td>
</tr>
<tr>
<td>Cost of wasted paint</td>
<td>$595,254.61 /year</td>
</tr>
<tr>
<td>Total cost of waste</td>
<td>$956,202.12 /year</td>
</tr>
</tbody>
</table>
TOTAL COST OF WASTE AS AFFECTED BY TRANSFER EFFICIENCY

Dollars/year

$1,000,000.00
$900,000.00
$800,000.00
$700,000.00
$600,000.00
$500,000.00
$400,000.00
$300,000.00
$200,000.00
$100,000.00
$0.00

Transfer Efficiency

5 10 15 20 30 40 50 60 70 80 90 100

6-150-2A.XLC
COST OF FILTER DISPOSAL BASED ON HOLDING CAPACITY

Dollars/year

$0

$10,000

$20,000

$30,000

$40,000

$50,000

$60,000

$70,000

Filter Holding Capacity (lbs/filter)

2

3

4

5

6

Transfer Efficiency = 30%

Transfer Efficiency = 65%

$1.00 per filter

$1.50 per filter

$2.00 per filter

$3.50 per filter

$5.00 per filter
SELECTING DRY FILTERS BASED ON PERFORMANCE

- **Efficiency** is the ability of the filter to remove particulates before they can enter the exhaust stack. Select a filter with high efficiency.
  
  * This will lower particulate emissions into the ambient air
  
  * Reduce loading of overspray on surfaces inside the spray booth exhaust duct, and particularly on the fan impeller.
  
  * Reduce energy load if fan impeller is covered with overspray.
  
  * Lower cost and frequency of maintaining booth.

- **Resistance** of a filter to air flow passing through. Select a filter with low air flow resistance.
  
  * Lower energy requirements.

- **Holding Capacity** is the amount of overspray which a filter can hold or retain during the service life of the product. Select a filter with high loading capacity
  
  * Reduce frequency of replacing filters.
  
  * Reduce volume waste to be disposed of.
SELECTING DRY FILTERS BASED ON PERFORMANCE (Cont)

- **Can they be incinerated?** Check whether the filters can be incinerated and that they meet all incinerator standards.

- **Are they biodegradable?** It may be advantageous to use filters that are biodegradable.

- **Do they meet landfill standards?** Check that the filters meet all landfill standards.

- **Are they flammable?** Check that the filters meet the requirements of the National Fire Protection Bulletin #33 and are approved as a Class 2 Filter by Underwriter’s Laboratories.

- **Can you use the filter for water-borne coatings?** Some filters, particularly if made of paper, may not be suitable for water-borne coatings.
# WATER WASH SPRAY BOOTHs

## ADVANTAGES

- Ideal where large quantities of coatings are used.
- Air velocity through booth remains constant, provided water trough is properly maintained.
- Essentially low fire risk (compared with dry filter booth).
- Effectively removes particulates with very high particulate removal efficiencies, >99.0% possible.
- Chemicals (deflocculants) can be chosen to sink, float or disperse the paint overspray.
- Can be used in any type of booth design (small, large, open, closed, side draft, down draft).

## DISADVANTAGES

- Does not remove VOC’s, except for a small concentration which is dissolved in the water.
- Requires regular monitoring for:
  - level of water in trough
  - Concentration of chemicals to de-tackify paint
  - foaming
  - rancidity
- More expensive to install and operate than dry filter booths.
- Requires slightly more space.
- Requires installation of sprinkler system.
- Paint sludge must be removed from water and disposed of.
- Water will need to be replaced and disposed of.
CHEMICALS DEFLOCCULANTS FOR WATER-WASH SPRAY BOOTHs

- Chemicals are available which sink, float or disperse paint sludge.
- Chemicals are designed to remove tackiness (stickiness) quickly.
- Failure to de-tackify coatings causes blockages in water pump, nozzles above water curtain, etc.
- Some chemicals are available as solids or liquids.
- More expensive chemicals dewater the paint sludge and hence reduce volume of sludge to be disposed of.
- Chemicals used to prevent foaming and to prevent bacterial growth in water.
- A chemical which is effective for one type of coating resin may not be effective for another. Chemicals must be selected based on type of coatings being spray-applied.
Filter efficiency measures the effectiveness by which the spray booth removes particulates.

Efficiency is expressed as a percentage.

Efficiency = \( \frac{W_{pa} \times 100}{W_{pa} + W_{a}} \)

Where \( W_{pa} \) = Weight increase of test module (filter to be tested)

\( W_{a} \) = Weight increase of the absolute filter

Test Method:

The test module comprises the regular dry filter to be tested, plus an absolute filter that traps any particulates which pass through the test filter. The absolute filter is located behind the regular filter.

A spray gun is positioned six feet from the filter bank, and a commonly used coating is used for the test.

Fluid flow rate is set at 2-3 fluid ounces per minute.

Air flow rate remains constant throughout the test.

Air velocity through booth is 200 ft/min.

Test continues until pressure drop across booth is 0.5 inches of water.

Typical efficiencies for dry filter spray booths are 97-99%
What is Grain Count
How can we use it?

- Grain Count is expressed in Grains/1000 ft$^3$

- Grains/ft$^3$

  \[ \text{Grains/ft}^3 = \text{Coating Wt. Solids} \times \text{Transfer Ineff.} \times \text{Collection Ineff.} \times 7000 \]
  \[ \text{60 minutes/hr} \times \text{ft}^3/\text{min} \]

  \[ = \text{Coating Wt. Solids} \times (1 \times \text{Transfer Eff.}) \times (1 \times \text{Collection Eff.}) \times 7000 \]
  \[ \text{60 minutes/hr} \times \text{ft}^3/\text{min} \]

Where:

  - coating weight is in lbs/hr
  - 7000 = grains/lb

- Typical allowable emission rate = 0.003 grain/ft$^3$

  or, Count = 3 grains/1000 ft$^3$
Example of Calculation to Determine Particulate Compliance

Problem:

Assume filter efficiency = 97.5%
Side draft spray booth dimensions = 20 ft W x 8 ft Deep x 8 ft H.
Air velocity through booth = 135 ft/min
Percent wt. solids of coating = 42%
Weight/gallon of coating = 9.4 lbs/gal
Coating usage = 4 gals/hr
Transfer efficiency of spray gun = 67%

Calculate grains/ft\(^3\) passing the filter

Is this in compliance with the allowable limit of 0.003 grains/ft\(^3\)?

Calculate the permissible emission rate (lbs/hr)

Calculate the actual emission rate (lbs/hr)
Solution to Problem:

- **Calculate air flow rate (cfm):**
  
  Area of filter bank = 20 ft x 8 ft
  
  = 160 ft²

  Air flow rate (ft/min) = Area of filter bank x air velocity
  
  = 160 ft² x 135 ft/min
  
  = 21,600 cfm

- **Calculate weight of solid coating spray-applied:**
  
  Weight of coating used = 4 gals/hr x 0.42 x 9.4 lbs/gal
  
  = 15.79 lbs/hr solid coating

- **Calculate Grains/ft³:**
  
  = Coating Wt. Solids x (1-Transfer Eff) x (1 - Collection Eff) x 7000
  
  60 minutes/hr x cfm
  
  = 15.79 lbs/hr x (1 - 0.67) x (1 - 0.975) x 7,000 grains/lb
  
  60 min/hr x 21,600 ft³/min
  
  = 0.00070

  This is in compliance with the limit of 0.003 grains/ft³

- **Calculate permissible emission rate (lbs/hr):**
  
  Permissible emission rate = 0.003 grains/ft³
  
  = 0.003 grains/ft³
  
  7,000 grains/lb
  
  = 0.43 x 10⁻⁶ lbs/ft³

- **Calculate total permissible particulate coating weight in spray booth exhaust:**
  
  = 0.43 x 10⁻⁶ lbs/ft³ x 21,600 ft³/min x 60 min/hr
  
  = 0.557 lbs/hr
Calculate actual particulate coating weight in spray booth exhaust:

\[= \text{Coating usage (lbs/hr)} \times \text{Transfer Inefficiency} \times \text{Capture Inefficiency}\]

\[= 15.79 \text{ lbs/hr} \times (1-0.67) \times (1-0.025)\]

\[= 0.130 \text{ lbs/hr}\]
What Factors Affect
Total Emission of Particulates into Air

- **Percent weight solids of coating:**
  The higher the weight solids of the coating, the lower the particulate emissions.

- **Transfer Efficiency:**
  The higher the transfer efficiency of the coating application, the lower the particulate emissions.

- **Filter Efficiency:**
  The higher the filter efficiency, the lower the particulate emissions.

- **Air Velocity:**
  The lower the air velocity through the booth increases the allowable emission rate.

**Example:**

In the previous example, what would the allowable particulate emissions rate be if the air velocity through the booth were increased from 135 ft/min to 150 ft/min?
Solution to Problem:

Calculate concentration of allowable particulates:

\[ \frac{0.003 \text{ grains/ft}^3}{7,000 \text{ grains/lb}} = 0.43 \times 10^{-6} \text{ lbs/ft}^3 \]

Calculate allowable emission rate:

\[ 0.43 \text{ lbs/ft}^3 \times \text{Face velocity of air through booth (ft/min)} \times \text{Surface area of face of booth} \]

\[ = 0.43 \times 10^{-6} \text{ lbs/ft}^3 \times 150 \text{ ft/min} \times 160 \text{ ft}^2 \times 60 \text{ min/hr} \]

\[ = 0.6192 \text{ lbs/hr} \]

The permissible emission rate at 135 ft/min air velocity was 0.557 lbs/hr.
## AIR MAKE-UP

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provides clean air into the booth.</td>
<td>Can be relatively expensive.</td>
</tr>
<tr>
<td>Provides warm air, particularly in winter months.</td>
<td>Requires additional space, usually on roof of building.</td>
</tr>
<tr>
<td>Enhances viscosity management programs.</td>
<td>Filters must be replaced periodically.</td>
</tr>
<tr>
<td>Allows for controlled air velocity through the booths and, with well balanced system, can reduce air turbulence.</td>
<td>High efficiency intake filters are required to filter out airborne dust</td>
</tr>
<tr>
<td>A must for facilities which require coating finishes free of dust contamination.</td>
<td></td>
</tr>
</tbody>
</table>
METHODS FOR REDUCING POLLUTION
FROM SPRAY BOOTHs.

• Select dry filters which have high particulate capture efficiency.

• Select dry filters which allow a high loading before needing to be replaced.

• Select chemicals for water-wash booths which will quickly remove tackiness.

• Select chemicals which will **dewater** the paint sludge.

• Consider installing equipment to continually remove sludge from water.

• Install good lighting to minimize need for rework.

• Apply strippable latex type coatings onto booth walls and ceiling. Remove coating frequently to prevent build-up of overspray from contaminating freshly painted jobs. This will lower reject and rework rate.

• Keep unnecessary papers, tapes, rags, cans outside of booth. These only serve to contaminate freshly painted surfaces, and increase reject and rework rates.
Bibliography


Various product literature