TECHNOLOGICAL ADVANCEMENTS IN OVERSPRAY COLLECTORS

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After many years of evolutionary refinements to established technology, the fragmented paint overspray collector market is being driven by a comparatively fast pace of technological advances. Industrial spray finishing processes stand to benefit as these innovations translate into improved collector performance and reduced booth operating costs.

This article discusses some of the factors driving overspray collector development. It will show how the small-company, producers/marketers who dominate this business are taking technology perfected elsewhere and adapting it to their industrial customers' evolving finishing process challenges. It concludes with tips on selecting overspray collectors for your finishing process.

INTRODUCTION

From today's vantage point, the industrial finishing industry's technical challenges of the 1960s through most of the 1980s were pretty straightforward. Conventional air spray equipment was the predominant application technology. Most finishers were spraying low-solids, solvent-based coatings. Frequently, production painting was done in waterwash spraybooths that operated for weeks, sometimes even months, with little maintenance. Over time, the booth's water tank would fill with the captured overspray solids. The water-saturated sludge cake was manually removed from the tank over a weekend and production resumed the following Monday morning without a hitch.

Intermittent or batch spray painting was generally done in dry filter spraybooths. Typically, these booths were equipped with either expanded paper (see Fig. 1), accordion-style pleated paper, or spun fiberglass paint overspray collectors. Depending on the finishing process particulars, these collectors were capable of capturing 85 to 97% of the overspray entrained in the booth's exhaust air stream. Most of the remaining overspray was deposited in the booth's backsection, on the exhaust duct's interior walls, and on the exhaust fan blades. Any residual overspray still entrained in the exhaust was emitted to the atmosphere.

HOW DO THEY WORK?

Before we address this question, let's briefly review what is known about overspray. It is the paint mist produced as a byproduct of spray application processes. As the cost of industrial coatings has increased, finishers have worked to maximize their application process transfer efficiency. They have a double incentive to minimize overspray. By definition, overspray isn't applied to substrates; therefore, it is wasted. Additional expense is incurred to capture and dispose of this wasted atomized paint. In spite of the use of higher transfer efficiency spray technologies, such as HVLP, electrostatic air spray, and automatic rotational atomizers, more than 30% of all spray-applied liquid industrial coatings end up as overspray. During 1998, U.S. industrial finishing operations produced more than 90 million gallons of liquid paint overspray.

Recent advancements in collector testing procedures have produced laboratory test data that challenge the accepted rules-of-thumb on how collectors actually capture overspray. The arresting process is more complex than previously thought. Most modern collectors utilize a combination of physical principles to capture and retain overspray from spraybooth exhaust air streams.

At the end of the 20th century almost all overspray collectors utilize one or a

Fig. 1. Expanded paper paint overspray collector.

combination of several types of mechanical filtration. Traditional air filtration technology teaches us there are three mechanical filtration processes that may be used to remove foreign particles from a moving air stream.[1]

1. Impingement—also known as impaction
2. Interception
3. Straining

Impingement is the process by which the larger (typically >10 microns) overspray particles are captured. As the overspray-laden exhaust air stream approaches the face of the arresting media, the individual air molecules begin to align themselves with the openings in collector face. The larger overspray droplets have too much forward inertia to follow the surrounding air molecules as they zig and zag through the collector's staggered openings. Figure 2 shows an overspray droplet about to be impinged on the front face of an expanded paper collector even as the air shifts laterally to pass through the openings in each ply of the media. Depending upon the process dynamics of a given spraybooth, as much as 80% of the total mass of the entrained overspray may be impinged on the collector's face. An additional 15 to 18% of the overspray is removed as the exhaust air stream passes through the successive stages or layers of the filter media. The remaining 2 to 5% (the smallest droplets) pass into the exhaust plenum to be deposited on the fan blades or the exhaust duct. Droplets making it past these impediments pass into the atmosphere.

Interception is the primary process utilized in spun fiberglass collectors. It is also a secondary capturing process at work in many impingement collectors. The effectiveness of the interception process is directly proportional to the number of intercepting surfaces in the media. Arrestance by interception occurs when overspray droplets make accidental contact with a media element while entrained in the exhaust air stream passing through the media pad. Interception requires the individual overspray droplets to remain attached to the filter element for the remainder of the collector's functional life. Although many overspray droplets are relatively sticky, most interception collectors are tackified—coated with a sticky substance, usually an oil or a pressure-sensitive resin by the media manufacturer. Interception collectors are more effective in capturing larger overspray droplets than smaller ones. Experience shows that smaller fibers are more likely to retain droplets than larger ones. Additional factors having a positive impact on the performance of interception media include the air velocity—slower is better than faster, the depth of the media—thicker media increases the probability that a droplet will make contact with a fiber, and the fiber density—the closer adjacent fibers are to each other the greater the likelihood that interception will occur. Figure 3 depicts an overspray droplet making contact with a fiber element as the exhaust air carries it through the collector.

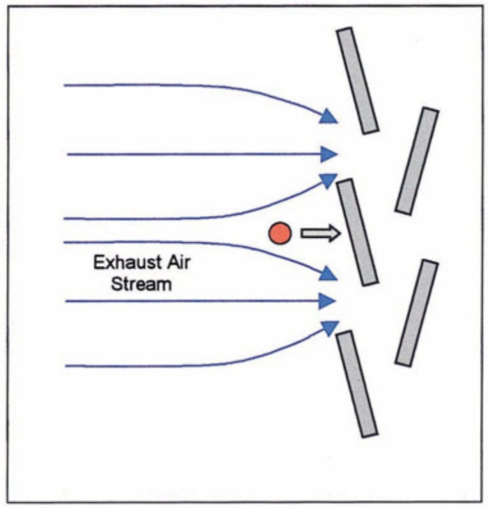

Fig. 2. Impingement.

Note, the primary distinction between impingement and interception is the physical structure of the media. Impingement media are substantially solid with a multiplicity of openings for the air stream to pass through while interception media have a network of randomly oriented fibers traversing a substantially open structure. Normally, impingement collectors have a higher resistance to air flow than interception ones under comparable air flow conditions.

Straining is the third filtration process utilized in disposable overspray collectors. It

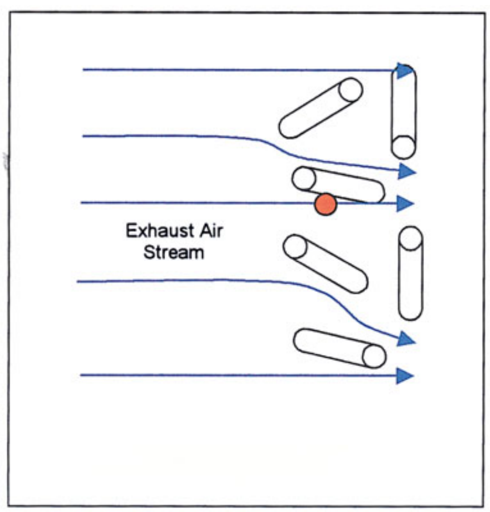

Fig. 3. Interception.

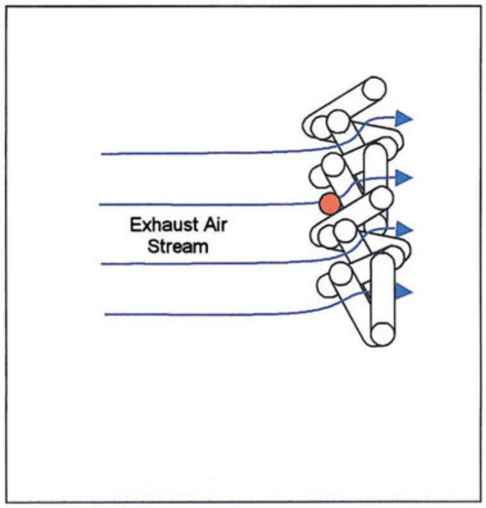

Fig. 4. Straining.

occurs when the diameter of the smallest droplet is greater than the open space between adjacent structures. Polyester and synthetic fiber collectors utilize straining. The very large number of small-diameter, randomly oriented fibers, each in very close proximity with many other fibers, enable these collectors to deliver superior performance. Typically, the midsized and larger overspray droplets are removed by straining. The smaller droplets retained by single-stage synthetic collectors are generally captured by interception. Secondary, extended surface collectors used to capture smaller diameter ($<$10 micron) droplets are straining filters. Figure 4 illustrates the straining phenomenon in a high-density, nonwoven synthetic collector. Straining collectors are constructed from smaller-diameter (denier) fibers than are typically used in an interception collector.

This explanation simplifies the complex process of capturing and retaining individual overspray droplets as they traverse the many different types and configurations of overspray collectors in commercial use. In every case the overspray-laden spraybooth exhaust air stream is subdivided into a multiplicity of small streamlets. These small air streams twist and turn as they traverse the maze of arresting surfaces within a collector. Generally speaking, the more times a given streamlet is diverted, the higher the probability the entrained overspray droplets will be captured. Most modern collectors take full advantage of atomized paint droplets' stickiness to arrest and retain them. Collectors designed to capture overspray from rapid-drying coatings are frequently tackified to boost their arrestance efficiency.

BACKGROUND

In the early 1980s expanded paper and fiberglass pads (see Fig. 5) dominated the industrial overspray collector market. Pleated paper enjoyed a stable niche. Flat polyester media were available. The latter offered superior overspray-arrestance efficiency but wasn't a significant factor in the market. During the late 1980s, leading coating suppliers responded to the emerging environmental regulations by making significant changes in their formulations. These changes placed new performance demands on industrial spraybooths. High-production, water-wash booths had difficulty handling the new and ever-changing paint

Fig. 5. Fiberglass media.

chemistry. Industrial finishers began converting high-production wet booths to dry filters. While the first-generation higher-solids coatings challenged the collector industry, it rose to the occasion by combining two preexisting arrestor technologies—expanded paper media and polyester media. The capturing efficiency of these hybrid collectors equaled or exceeded that of water-wash booths.

IMPACT OF 1990s CLEAN AIR LEGISLATION

Title III of the Clean Air Act Amendments of 1990 is having perhaps an even greater impact on overspray management. It introduced the concept of regulating emitters based upon the proven control technology available to individual emitting sources.[2]

The EPA was required to publish a list of major source categories and subcategories emitting one or more hazardous air pollutants (HAPs). By law, the source category list has to include all categories and subcategories of major sources of the listed HAPs. In July 1992 the EPA issued an initial list of 174 industry source categories. Congress gave the EPA until November 2000 to identify and list the categories of area sources responsible for 90% or more of all area source emissions and to finalize regulations for these sources.[3] Three have been promulgated. They are:

1. 40CFR63 Subpart GG (updated 1998) National Emission Standards for Aerospace Manufacturing and Rework Facilities
2. 40CFR63 Subpart II (updated 1997) National Emission Standards for Shipbuilding and Ship Repair
3. 40CFR63 Subpart JJ (1996) National Emission Standards for Wood Furniture Manufacturing Operations.

The aerospace standard (NESHAP) is unique. In section 63.745, paragraph (g) entitled "Inorganic HAP emissions" EPA introduced its first functional performance standards for paint overspray collection systems, be they dry or wet. Repeated trials demonstrated it is feasible to mechanically remove the very small ($<10\ \mu m$) HAP particulate found in aircraft booth exhaust air streams. (Many aerospace coatings contain chromium compound HAPs.) The aerospace NESHAP promulgates different filtration efficiencies for "existing sources" and "new sources" (sources that commenced construction after October 29, 1996).

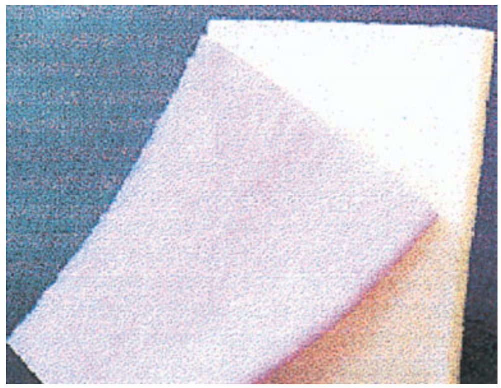

Fig. 6. Flat polyester.

PARTICULATE EMISSIONS

While the EPA has long concerned itself with particulate emissions, it had not previously specifically applied its particulate filtration requirements to spraybooth exhaust air streams. The aerospace NESHAP includes minimum filtration performance requirements for both liquid- and dry-phase challenges for three different sized particles. Since test protocols for measuring the fractional efficiency of overspray collectors did not exist, the EPA commissioned the development of one. The resulting procedure, commonly referred to as "Method 319," is mandated by section 63.750 (o) of the aerospace NESHAP.

Finishers spray applying aerospace coatings containing one or more listed HAPs are now required to use overspray collector systems that meet or exceed the NESHAP requirements. Manufacturers are required to certify the performance of their aerospace collectors.

Method 319 challenges overspray collectors with two paint substitutes—a liquid (oleic acid) and a dry solid (potassium chloride). One independent test lab has developed a variation of the 319 test using atomized paint as the challenge. This test, commonly referred to as a fractional penetration (FP) test, is made possible by the availability of sophisticated, computerized, laser particle counting instruments. The test can be conducted using any solvent- or water-based thermally cured, air-dried, or catalyzed coating as the challenge. Collector manufacturers, as well as some more technically astute industrial finishers, are finding that FP data reveal significant new information on overspray collector functionality.

As the finishing industry enters the 21st century there is increasing recognition that spraybooth exhaust stacks are potential sources for both VOCs and airborne PM_{10} and $PM_{2.5}$ particulate emissions. (PM_{10} is the EPA's designation for airborne particulate matter. The subscript number is the maximum dimension of particles in that category; hence, PM_{10} particles' longest dimension is 10 microns or less. While $PM_{2.5}$ particles' longest dimension would be 2.5 microns or less.) Responsible collector producers aren't waiting for the enactment of new regulations. Rather they are developing and introducing new products and systems that more efficiently capture and retain the very small overspray droplets recently reported to be penetrating some fiber-based, straining-type, media.[4] (See Fig. 6.)

ANTICIPATED METHOD 319 IMPACT

The implementation of the aerospace NESHAP raises the bar for paint overspray collector technology beyond aerospace finishing. In the foreseeable future, similar regulations will be applied to other finishing sources utilizing coatings containing HAPs. The EPA is required to apply technologies developed in one industry sector to other industry sectors with similar HAP emissions. During 1999, unofficial EPA sources indicated the Agency is considering amending the wood furniture NESHAP to require overspray collectors meet performance standards similar to those presently promulgated for the aerospace industry. Furthermore, similar changes are being considered for pending standards applicable to metal and plastic finishing operations.

The availability of collector FP test data (capturing efficiency as a function of the droplet size, using paint as the challenge) further raises the maximum available control technology. It will precipitate additional changes in EPA's regulation of finishing operations. In conclusion the aerospace NESHAP will initiate an avalanche of change in both wet and dry paint overspray control technology. In the coming decade these changes will significantly impact overspray collector design.

IMPACT OF PAINT CHEMISTRY

Twenty-first century industrial coatings are formulated from a host of different ingredients and compounds by a dozen major and literally hundreds of specialty coatings suppliers. For environmental compliance purposes industrial liquid coatings are frequently categorized by their primary diluents (i.e., water base, solvent base-high solids, solvent base-low solids, UV-cured, etc.); however, when selecting overspray collectors the primary variables are the coating's drying rate and the size spectrum of the atomized droplets produced by the coating atomizer(s).

The first is far easier to quantify than the latter. Typically, a rapid air drying coating overspray is best managed by a different collector configuration than would be recommended for use with slow-drying thermoset coatings. Droplet size data may be available from either your coating or your equipment suppliers.

COLLECTOR APPLICATION CHALLENGES

Liquid spray finishing processes have many functional advantages; however, high first-pass transfer efficiency isn't one of them. All spray application processes produce overspray. It must be managed. Each application technology produces a unique quantity and the droplet size spectrum of overspray. Experience and research have established a direct relationship between smaller coating droplet sizes and improved finish quality.[5] Hence, while quality of finish requirements causes finishers to reduce the average size of the mean droplet produced in their finishing operations, this invariably increases the performance demands placed on the overspray collection system.

Specific operating challenges associated with using overspray collectors in high-production industrial finishing lines include:

- Limited overspray holding capacity resulting in frequent collector changes, sometimes more than once per shift, causing lost production and increased waste volume.
- Traditional collectors are ineffective capturers of smaller droplets allowing significant quantities of overspray to penetrate the collectors. Booth backsection, fan, and stack maintenance must be significantly increased to preclude potentially disastrous stack fires and/or premature fan drive failures.
- Premature face loading by many higher solids thermoset paints as well as by catalyzed coatings overspray often force collector change outs well before they are fully loaded.
- Excessive run-off creates messy filter grids, supporting structure, and frequently paint flows on the floor causing increased housekeeping and maintenance.
- Water-reduced coatings may attack water-soluble binders used in some fiber collectors and structurally weakened some paper media.
- Decreasing booth exhaust air flow as collector loading increases creates an additional

process variable that impacts finish quality and worker environment. Wet booth provided constant velocity exhaust, enabling finishing process technicians to tune their systems for optimum performance.

- Increased total static pressure drop, high-efficiency collector systems are often multistage. Their superior performance frequently comes at the expense of increased pressure drop. An expensive exhaust fan upgrade may be required to fully utilize a multistage overspray collection system's holding capacity.
- Collector disposal—What do you do with loaded collectors? Should they be placed in drums and watered down? Doesn't that make them hazardous waste? Are there any acceptable alternatives? Unfortunately, responsible answers to these and related questions are application specific and are impacted by the coating chemistry, the collecting technology being used, the requirements of facility's insurance underwriter, and the applicable OSHA regulations.

INDUSTRY'S RESPONSE

During the past decade the overspray collector industry responded to industrial finishers' changing needs by making numerous modifications and improvements to its overspray management products. Some of the improvements introduced in response to the challenges initiated by the clean air regulations include:

- Expanded paper collector producers reduced premature face loading by varying the length of the slits in the multiple plies in their products. Typically, slit length is longer on the entry side and smaller on the exit. Increased pad holding capacity and marginally improved arresting efficiency are additional benefits of the graduated slit length.
- Expanded paper, pleated paper, and fiberglass collector manufacturers have improved their products' average arrestance efficiency by adding a synthetic fiber secondary media to the downstream side.
- Many midline and upper-end fiberglass and synthetic fiber (usually polyester) collecting media incorporated progressive density construction. They are progressively denser, front to back. This structure decreases face loading and correspondingly increases holding capacity and lengthens the interval between collector changes.
- A synthetic fiber mat producer introduced a multiply, three-dimensional polyester collector. The manufacturer claims the unique face configuration provides holding capacity comparable to pleated paper media and arrestance efficiency competitive with traditional high-efficiency flat polyester collectors.

NEW TECHNOLOGY OPENS DOOR FOR OVERSPRAY ARRESTOR INNOVATION

The traditional ASHRAE 52.1 based Paint Arrestance Test (PAT) conducted by independent filter testing laboratories such as AFTL (Crestwood, Ky.) and LMS Technologies (Bloomington, Minn.) measure overspray collector's average efficiency and projected holding capacity. (See Fig. 7.) For many years these reports were the best performance information available to finishers. They facilitated comparing different collectors and, in more recent times, have frequently been attached to booth operating permit applications.

In recent years most PATs have been conducted using a high-solids thermoset coating as the challenge. There are several reasons for this practice. In the late 1980s compliance issues generated significant customer interest in high solids. The marketplace requested performance information on overspray collectors challenged with high-solids coatings. Once the data were widely available, finishers were able to qualitatively compare competitive collectors; however, many industrial finishers aren't applying high-solids liquid coatings. Increasingly, these folks are requesting collector performance data with coatings more representative of the ones they use.

LMS Technologies, Inc.

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REPORT — **PAINT ARRESTANCE FILTER TESTING** — *Report #* 003

Spray Removal Efficiency & Paint Holding Capacity — *Test #* 011

COMPANY NAME **Chemco Mfg.** — Test Requested By **Don Phillips**

Test Information

FILTER MANUFACTURER	**Chemco**
FILTER NAME	
FILTER MODEL NO.	**18WC**
FILTER DIMENSIONS (each)	**20" H x 20" W x 2" D (inches)** — H W D (cm.)
FILTER DESCRIPTION	**White spun fiberglass mat with a white polyester backing**
PAINT DESCRIPTION	**#1 High-Solids Permaclad (Sherwin Williams H67RC65 Permaclad 2400, Solvent-Based Polyester Enamel, Bon Red)**
PAINT DENSITY	1.00 grams/cc

Test Conditions

PAINT SPRAY FEED RATE	(equiv.)	5.5	Qt./40 min.	130	gr./min.	130	cc./min.
AIRFLOW RATE				150	FPM		
ROOM TEMPERATURE	(equiv.)			72	°F	22.2	°C

Test Results

INITIAL PRESSURE DROP of Clean Test Filter	**0.0409**	in. H_2O	1.04	mm H_2O
FINAL PRESSURE DROP of Loaded Test Filter	**0.50**	in. H_2O	12.7	mm H_2O
WEIGHT GAIN - TEST FILTER			**2209**	grams
WEIGHT GAIN - FINAL FILTER			14.3	grams
AVERAGE REMOVAL EFFICIENCY of TEST FILTER			***99.4%***	
PAINT HOLDING CAPACITY of TEST FILTER	***4.9***	pounds	***2209***	grams

Date	Sept. 26, 1996
Test Lab Supv.	P. Tuzinski
Approving Engineer	K.C. Kwok, Ph.D.

Fig. 7. Paint arrestance test report.

NEAR TERM BENEFITS/IMPROVEMENTS

Efforts initiated in the early 1990s to provide finishers with more useful data are beginning to pay off. Several marketers are providing FP test data for their premium collectors. This test can be conducted using any industrial coating. It provides efficiency data as a function of overspray droplet size. The FP test report in Fig. 8 shows that while the tested collector is extremely effective in capturing droplets 10 microns and larger in size, it is ineffective with those smaller than 2.5 microns. A finisher with a $PM_{2.5}$ emissions problem would not consider using it without a secondary collector to capture the smaller droplets.

Aerospace Method 319 requires the use of liquid-phase and dry-phase paint substitutes as the test challenge materials. This was done to overcome operational difficulties associated

Date :	Aug. 31, 1998	pfrac043 Test Requested by :	R. Adams
Filter ID :	Paint Pockets (PP **** series)		Paint Pockets Co.
Test Type :	Fractional Efficiency	150 FPM Filter Mfr. :	Paint Pockets Co.
Paint:	SW Permaclad High Solids SBBE	ΔP init.: 0.0732 in.	ΔP final: 0.0787 in.

Time Elapsed, min.	1 min.	2 min.	3 min.	4 min.	5 min.	6 min.	7 min.	8 min.	9 min.	10 min.	Average
	0.0732*			0.0772*				0.0787			
Size Range (μm)	Initial	Fractional Efficiency (%)									
0.2-0.3	Paint Break-Up Region - No Filtration										0.0
0.3-0.4											0.0
0.4-0.6											0.0
0.6-0.8											0.0
0.8-1.0											0.0
1.0-1.5											0.0
1.5-2.0											0.0
2.0-2.5											0.0
2.5-3.0	11.8	9.1	6.1	7.6	6.1	5.4	5.1	4.0			6.9
3-4	38.3	35.5	33.9	35.3	34.2	34.2	33.8	33.0			34.9
4-5	67.2	66.1	65.4	66.1	65.8	66.4	65.8	65.6			66.0
5-6	83.5	82.0	81.6	82.4	81.9	82.5	83.5	81.5			82.3
6-8	93.8	90.3	90.2	93.6	90.7	91.2	93.3	90.7			91.7
8-10	98.3	96.6	97.1	98.4	96.5	98.1	98.4	95.8			97.6
10-12	99.7	100.0	100.0	99.7	100.0	100.0	100.0	100.0			99.9
12-15	100% Filtration Region										100.0
15-20											100.0
20-30											100.0
30-40											100.0
40-50											100.0
50-70											100.0
70-100											100.0

$$F_{ef} = \frac{C_{up} - C_{down}}{C_{UP}} x100\%$$

F_{ef} = Fractional Efficiency of Paint Overspray
C_{up} = Particle Concentration Upstream of Filter
C_{down} =Particle Concentration Downstream of Filter

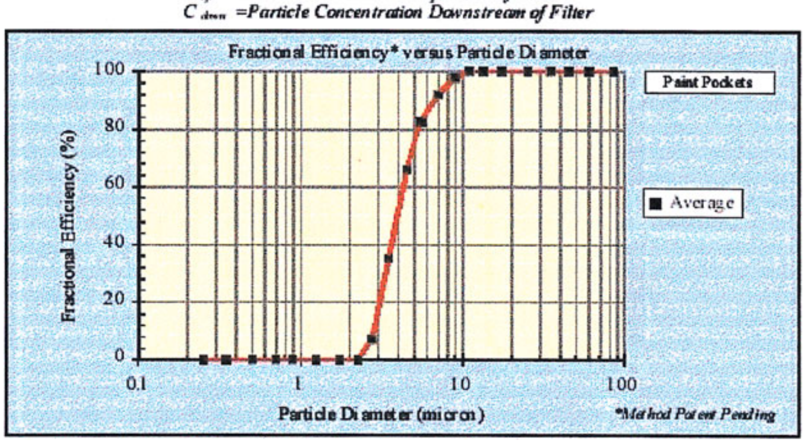

Fig. 8. Fractional penetration.

with the use of paint in the testing process. Unfortunately, recent advancements have shown there is, at best, a tenuous correlation between a given media's performance with the specified substitutes and with commercial coatings. The appropriate federal and industry parties are discussing revisions to Method 319.

Today, most higher-efficiency, single-stage, overspray collectors boast arrestance efficiencies greater than 99%. This leads many industrial finishers to falsely assume there is little difference between them. To facilitate more accurate product comparisons, several collector suppliers are providing “penetration” information expressed as a percentage of the total overspray challenging the test collector. Smaller penetration numbers translate to longer intervals between stack, fan, and booth backsection maintenance.

The FP test is producing evidence of a previously unknown phenomenon associated with overspray collectors. The data available at this writing indicate some collectors have a negative efficiency in the 0.2- to 2.0-micron droplet size range. In laboratory tests more droplets in this size range have been detected downstream of collectors than are present in the upstream challenge. This phenomenon has been termed “shedding” and is the subject of investigation by both the manufacturers and the testing laboratory. Should shedding prove to be more than a byproduct of the test procedure, finishers can anticipate the introduction of a series of overspray collector improvements that address the problem.

The collector industry’s current technical challenges are significant. The evolving environmental regulations are a moving target. The advent of sophisticated, computerized test equipment is unleashing a flood of new information on collector functionality. Since most producers are small businesses their resources are limited; nevertheless, the industry is responding. Often it is finding technology in other disciplines, some far removed from finishing, and is using it to respond to its customers needs.

COMING BENEFITS

The first decade of the 21st century will be a dynamic period for the industrial overspray collector market. Developmental work already well along is expected to produce significant benefits for industrial finishers. Among them are:

- Increased overspray holding capacity—reducing the frequency of change outs and all of the expenses associated with changing and disposing of loaded collectors.
- Dramatic increase in single-stage collector efficiency, particularly with smaller droplets—increasing the interval between booth backsection, fan, duct, and other downstream equipment maintenance.
- Reduced paint runoff from saturated collectors—reducing daily paint spraybooth housekeeping and maintenance.
- Significant improvements in dry spraybooth ventilation—providing much more stable air flow over the functional life of the collection media. Stable ventilation will provide an improved environment for finishing operations; and reducing process variability supporting better control of the finishing processes (SPC, ISO 9000, etc.).

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