How to Choose the Best Application Technology for Your Specific Coating Requirements

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Achieving the ideal finish requires not only the proper coating, but the right application method as well. Even a perfect formulation can be compromised if improperly applied. The applicator can affect droplet size, wetting, film thickness, electrostatic wrap, and other properties that can adversely impact a coatings performance and appearance. This article reviews alternative technologies for spray application and the technical trade-offs for each approach. These options include conventional air spray, airless and air-assisted airless, high volume low pressure, rotary atomizers, and other electrostatic techniques. We review the suitability of each technology with regard to atomization, transfer efficiency, cost, and suitability for various paint chemistries. The goal is to provide both formulators and end-users with a clear understanding of how a rich toolkit of application options can be utilized for industrial coating applications.

INTRODUCTION

A friend asks you to bring them a screwdriver. What kind do you choose? Even selecting the simplest tool can be confusing. You probably remember learning about flat head versus Phillips head screws? Then there are also torx and star head screws, big tips and small ones, long shafts and short ones, offset and flexible screwdrivers, magnetic and non-conductive, ratchet and power screwdrivers. There are even screwdrivers with built-in LED lights, and robotic screwdrivers used for high speed assembly.

So imagine the possibilities when it comes to asking what type of spray gun to choose. There are half a dozen technologies and a dozen variations within each of those. How do you decide on the right spray gun technology?

Using the screwdriver analogy—start with the screw. The choice of a liquid paint spray gun technology depends first and foremost on the type of paint. The paint is usually chosen early in the planning process by considering the part, the process, and the final cosmetic and performance specifications. (Although, as will be seen, the spray gun choice can influence how a part looks or performs).

There are a number of factors that influence the choice of spray gun technology and ultimately the specific make and model of spray gun that you should select. As with any other tool, the best fit depends not only on simply whether it can do the job or not, but how well designed, user friendly, safe, and durable the tool is. *Table* 1 lists a few of the most important considerations for selecting a spray gun.

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HOW A SPRAY GUN WORKS

Unlike dipping or brushing, in order to spray paint, it must first be broken up into tiny paint particles or droplets. This process of "atomization" involves forcing the paint under pressure through a small orifice, or nozzle. This breaks the paint into smaller droplets. In most cases, the liquid paint stream is further broken up when it is mixed with an air stream. Although there are many variations, including sophisticated new methods and materials, the spray gun has some basic components and structures, as illustrated in *Figure* 1, including a passageway for the paint fluid and a separate passageway for air. To start and stop the spray paint process, a tapered fluid needle attached to a trigger often acts as a valve to start and stop fluid flow to the spray gun tip. An air cap, as shown in *Figure* 2, with precisely sized and located holes allows air to interact with the paint fluid to control the atomization and the pattern of the paint droplets.

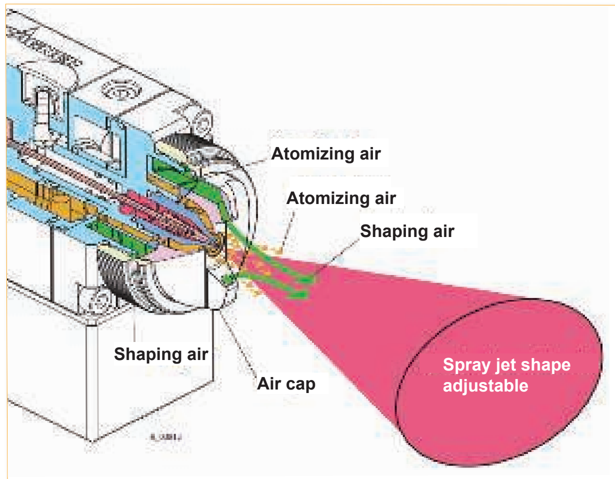

Figure 1—A spray gun is frequently designed to force paint fluid through a small orifice, mix it with air, and propel droplets to the part.

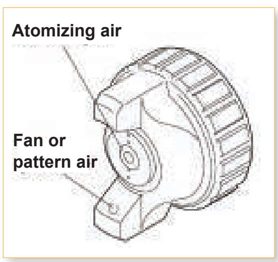

Figure 2—A typical spray gun cap design.

Many spray guns operate on the basic principle of forcing paint out of a nozzle, and mixing air with the paint to further atomize the material. The major spray technologies differ mostly in variations such as the volume of paint that is delivered, the pressure of the atomizing air, or additional air to help shape the spray pattern. Some spray guns, like airless technology, work more like high-powered water pistols and deliver high velocity paint streams with little or no atomization, but with tremendous fluid pressure. Other spray technologies, like conventional air spray, use a small amount of paint mixed with a larger volume of atomizing air, much like a conventional aerosol spray can or spray bottle of household cleaner. They deliver more of a "fog" or mist.

By placing a charged electrode in the paint stream, an electrical charge can be added to the atomized paint. The charged paint particles seek a grounded object and will bend around complex surfaces to do so. This is the basic principle underlying electrostatic spray systems. Modern engineering, with tools such as CAD design, 3D modeling, and computational fluid dynamics has enabled better design of the spray gun chamber, size and shape of air and fluid passageways, and spray cap to vastly improve spray gun performance. Electrostatic systems have also become safer, more versatile, and more sophisticated. Yet while these refinements have continued to improve the efficiency, safety, versatility, and durability of spray guns, they have not greatly altered the fundamental designs over the last few decades.

FACTORS THAT AFFECT SPRAY GUN SELECTION

Paint Properties

The properties of each coating can often quickly help to narrow the choice of which technologies can be used and which cannot. For example, while highly viscous paints are difficult to atomize and may preclude the use of conventional air spray guns, the shear characteristics of many non-thixotropic paints may eliminate the use of airless application.

Table 1—Factors that Influence Spray Gun Choice

Paint Properties	Paint Environment	Parts and Specifications	Process Requirements	Operator Comfort/Control	Cost and Economics
Viscosity Carrier Shear Rheology	Temperature Humidity Airflow	Smoothness Uniformity Wrap Corners Recesses	Production Rate Flexibility	Ergonomics Controls	Capital Cost Maintenance Spare Parts Overspray Downtime Quality Support

Figure 3—Paint viscosity is measured by timing how long it takes for a known volume to drain through a precision orifice.

Some materials are harder to spray than others due to their viscosity (a measure of liquids resistance to flow). Some paints require higher pressure to atomize them effectively, while others spray quite well with low pressure systems. Some paints also contain abrasive particles including specialty pigments or metallic flakes that affect their ability to be effectively atomized and sprayed with a high degree of uniformity. Breaking up paints into small droplets may be harder to accomplish with various spray systems, depending on the fluid and air pressures used.

We focus on atomization, because breaking up paint into fine droplets makes it easier to apply a smooth, uniform film, but the size of the particle also affects other properties that have importance to the paint finish. For example, increasing the particle size 50% from 20 to 30 microns increases the mass of the drop 3.4 times. These heavier droplets fall twice as fast as the lighter droplets and affect the spray pattern and transfer efficiency of the process. Larger droplets also have a smaller ratio of surface area to mass; in fact, they have one third the surface area to the same volume. Solvents evaporate more quickly over a larger surface area, and this means that the droplets are drying at much different rates. Fine particles can produce a very smooth and uniform finish, but a very fine mist is also more prone to producing dry spray related problems as well. Dry spray occurs when the paint particle is nearly dry when it reaches the part surface and can no longer wet out to produce a smooth film.

Figure 4—Electrostatic spraying is well suited for metallic wire goods.

A property closely related to viscosity is the shear of a paint, which measures the frictional forces within the paint as it is being handled through mixing, flow, and spraying processes which cause shear forces in the material. Water (a so-called Newtonian fluid) has constant viscosity as it is handled, but for many ("thixotropic") paints, the viscosity increases rapidly with high shear forces introduced by handling and spraying. Some paint additives can increase a paint's sensitivity to shear as well. Thixotropic coatings are therefore poor candidates for spray guns like airless systems where shear forces can be quite high.

Liquid paints rely on some form of carrier. This could be any of a number of traditional solvents, water in a waterborne coating, or low molecular weight monomers that act as reactive diluents in 100% solids UV systems. When paint is atomized, each droplet is prone to having the carrier evaporate, leaving a dry paint particle. In finely atomized paints, the exposed surface area increases, making rapid evaporation easier. This produces a trade-off between atomization and solvent evaporation that must be anticipated. For example, while conventional air spray systems can produce highly atomized spray patterns, the fine mist is most prone to evaporation and the choice of paint carrier may be an important limitation on the spray equipment.

Spray Environment

From the previous discussion, it is apparent that, once atomized, each paint droplet is then propelled through the air towards the part surface. Each particle contains all of the paint constituents including the carrier. As the droplet is hurled towards the part, it is evaporating. The rate of evaporation depends on environmental factors such as temperature, humidity, and the airstream. A controlled environment with air conditioning provides wider latitude when it comes to paint and spray technology choice. In an uncontrolled environment, such as spraying outdoors, technologies requiring fine atomization may suffer from unexpected and uncontrolled changes in the paint environment.

Parts and Specifications

While we have suggested a "start with the screw" approach to selecting a spray gun by assuming the paint has been chosen for the proper cosmetic and performance properties, some spray technologies have limitations and advantages for certain kinds of parts and uses. For example, complex metallic parts with all sorts of nooks and crannies are well suited to electrostatic spray systems where the charged paint wraps well around convoluted grounded metal objects. Electrostatic spraying can be done on non-conductive parts made of wood or plastic, but frequently requires that a conductive primer be applied first. This introduces another step in the process which may, or may not, be justified.

Where exceptionally smooth finishes are required, such as on fine furniture or the clearcoat of an expensive automobile—systems that provide a high degree of atomization—breaking the paint into the smallest sized particles possible often yields the most highly cosmetic appearances. This can be true even if it comes at the expense of other drawbacks like lower transfer efficiency. In those cases, we see more use of air spray guns, or rotary atomizers. Some parts require selectively spraying some faces of the part but not others. Perhaps a technology like airless spraying which sometimes eliminates the need for masking can be used with this type of part.

Figure 5— Robotically mounted guns for high volume precision spray of consumer electronics.

Process Requirements

The paint, environment, and part alone go a long way to dictating what spray technology to use, but the process specifications may further define how many and what type of gun and associated paint delivery system fits best.

For instance, painting a handful of parts compared to thousands of parts per hour certainly affects spray gun choice even though the paint, part, and environment may be identical. For high speed production, automatic spray guns with remote triggering are frequently used. Often, several spray guns are required to provide enough film build in the time allowed. It is common to arrange several fixed guns in a spray station, or even to move parts between sequential spray stations to apply the required coating evenly without drips or sagging. Sometimes spray guns are mounted on simple reciprocating arms that stroke up and down or across a part to provide broader coverage than a single gun can offer. Robotically mounted guns are another popular choice for moving guns to paint large or complex part shapes. Spray guns specifically designed for robotic applications are available that are designed for the constant rotation of the air and fluid connections, and which allow the spray gun to be accurately repositioned after servicing. A little overspray may be tolerable for a handful of parts, but can amount to many thousands of lost dollars on a high speed production line. The importance of economic factors such as transfer efficiency or spray tip lifetime may suddenly become important considerations.

Another consideration in gun selection is the flexibility or versatility required on the line. For those who only need to paint a single part style, the spray gun can be set up so that it is perfectly optimized. However, many manufacturers produce a wide range of parts (and some custom coaters never paint the same part style twice). Where there is a wide range of parts, and paints that must be accommodated, a more "forgiving" spray technology should be selected. Of course, this versatility usually means sacrificing the cost efficiency that can be achieved with a line finely tuned for a specific purpose.

Operator Considerations

For manual spray painting, the proper gun choice can be as much a matter of convenience and comfort as technology. The spray gun should be ergonomically designed so that it is easy to handle and manipulate. A poorly designed gun which makes handling difficult will surely result in poorer quality and unhappy operators. The weight, size, and balance of the gun are important considerations. So is the placement of controls such as voltage potentiometers on electrostatic guns, fluid and air controls, shaping air, and other controls that permit the operator to achieve optimal results. New guns with many easily programmed recipes and digital readouts on the gun have arrived on the market.

Costs

The "bottom line" is often the bottom line—with cost dictating purchase decisions. While this is often the reality, it is best to be aware of all the costs of selecting a spray gun. Of course, there is the upfront capital expenditure. But a sound financial decision should also take into account the operating and ongoing costs of the gun. Spray guns serve in a rough, abrasive environment that requires various components to be replaced frequently.

Air caps, nozzles, and packing are all wear parts whose annual cost should be calculated when comparing vendors or technologies. Those guns that are better designed, or use higher quality materials often carry a higher initial price tag, but are more cost efficient on a continuous basis.

The cost of the spray gun is directly related to the cost of an even more pricey component—paint. If half the paint goes onto the spray booth filters, the floor, and up the stack, the cost of even an expensive spray system can quickly be overcome by the expense of wasted paint. To compare the effectiveness of each spray gun system, one figure—the transfer efficiency—is frequently used. Simply stated, but not so easily measured, transfer efficiency is the ratio of the quantity of paint that goes onto the parts compared to the total amount of paint used. So, if four gallons of paint go onto parts out of a total of 10 gallons of paint consumed, the transfer efficiency is 4.0/10.0 or 40%. An important point, but one which is beyond the scope of this article, is that the paint on the parts should be fine-tuned to be an even coating of exactly the film thickness required to meet the specifications. For the purposes of this article, we will assume that the paint that goes onto the parts is all being well utilized.

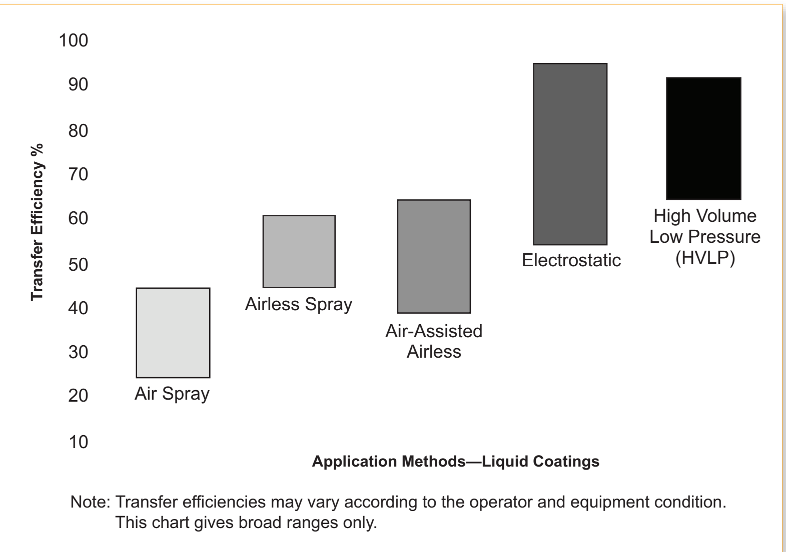

Figure 6—Comparison of application methods and transfer efficiency ranges.

Figure 6 provides a broad comparison of the typical transfer efficiency associated with various spray gun technologies. While there are differences between various makes and models of spray guns within each category, these numbers represent a range that has been validated in numerous field studies over many years and so represents a good rule of thumb for each technology.

SPRAY TECHNOLOGY ALTERNATIVES

Conventional Air Spray

Conventional air spray atomizes material at high air pressure (35 to 80 psi) and moderate air flow. The negative aspect of conventional air spray is excessive overspray and bounce-back that results from high air pressure. Conventional air spray creates excessive turbulence at the air cap, which contributes to excess overspray. Bounce-back results from the material being discharged from the nozzle, moving to the substrate at a very high velocity, and bouncing off the substrate.

The advantage of this method is ultra-fine atomization and a high rate of application. Conventional systems are used on finishing work ranging in size from small jobs to production lines. They generally are found in stationary applications.

Airless

Airless guns, as the name implies, do not use atomizing air, but rather atomize coatings by forcing paint through a small tip opening at very high fluid pressure. Working fluid pressures can range anywhere from 1200 to 5000 psi. An airless gun is very much like a traditional, but extremely powerful, water pistol.

Airless spray transfer efficiency is higher than conventional air spray, and offers the ability to spray the widest variety of coatings. The primary application is for high volume production work since these systems are capable of covering large areas in a short amount of time. The airless spray pattern is also very precise (much like a water-jet system), allowing airless to handle paint tasks that might ordinarily require masking. For example, 55 gallon drums are frequently striped using airless guns with no additional masking. The extreme fluid pressure of the airless system allows it to accommodate the widest range of applications.

Airless systems are typically fed by a high pressure pump often supplying up to 7,500 psi (52,000 kPa) of pressure. At the gun, different tip sizes are used to achieve the desired atomization and spray pattern size.

Advantages of airless spray are:

- The coating penetrates better into pits and crevices
- A uniform thick coating is produced, reducing the number of coats required
- A very "wet" coating is applied, ensuring good adhesion and flow-out
- A wide range of coatings can be applied since viscosity poses fewer limitations
- Often masking can be eliminated with sharp paint “cut lines”

The high stresses of airless spray painting can pose shear problems for paints that are thixotropic and so testing should be done to ensure that excessive shear of the paint will not occur.

Most coatings can be sprayed with very little thinner added, thereby reducing drying time and decreasing the release of solvent into the environment. Care must be used when operating airless spray guns since the extremely high pressure paint stream can cause serious injury, such as injection injuries leading to blood poisoning.

Air Assisted Airless

Air assisted airless equipment provides high transfer and increased application speed and is most often used with flat-line applications in high speed factory applied settings. The fluid pressure is provided by an airless pump, which allows much heavier materials to be sprayed than is possible with a conventional air spray gun. Compressed air is introduced into the spray from an airless tip (nozzle) to improve the fineness of atomization. Some electric airless sprayers are fitted with a compressor to allow the use of an air assisted airless gun in situations where portability is important.

Air-assisted airless sprayers offer fine finish capabilities combined with a medium production rate. Air-assisted technology uses a combination of airless and air spray. Fluid pressure ranges from 700 to 900 psi, with air intermixed at 15 to 30 psi. The systems typically

Figure 7— Electrostatic spraying is well suited to this complex assembly.

Figure 8—An HVLP gun provides excellent atomization and improved transfer efficiency.

are found in stationary and portable fine finish production applications. Transfer efficiency for air-assisted airless ranges from 40 to 65%.

Electrostatic Systems

Electrostatic spray systems electrically charge paint droplets at the spray gun tip. The charged particles move within the electrostatic field, which is attracted to the grounded object, forming an even coating on its entire surface. Properly designed electrostatic systems can produce very high transfer efficiency with uniform paint film thickness. A variety of electrostatic systems are available, including conventional airless and air-assisted. Since the part must be grounded to attract the charged paint particles, metal components lend themselves well to electrostatic painting. Even relatively nonconductive materials such as plastics and wood are successfully coated with electrostatic guns by first applying a conductive primer. Electrostatic painting is also ideal for parts where the "wrap" of charged paint helps with difficult geometry. For example, assemblies and wire goods are excellent candidates. Special care must be taken to design a system that is safe since sparking due to arcing could cause a fire or explosion if flammable or combustible materials are present. Electrostatics can be used with waterborne paint by incorporating well engineered voltage blocking systems. This electrically isolates the painter from dangers associated with high voltage charging of waterborne paints.

High Volume Low Pressure

High volume low pressure (HVLP) guns were originally developed to comply with tough environmental regulations passed by California's South Coast Air Quality Management District (SCAQMD). This method is similar to a conventional air spray in that a compressed air source is used to supply air, but in this case a higher volume (HV) of air is used to atomize and propel the paint at a lower air pressure (LP).

The result is a higher proportion of paint reaching the target surface with reduced overspray, materials consumption, and air pollution. In practice, a regulator is commonly used to lower the air pressure for the HVLP spray gun. In terms of transfer efficiency, the HVLP approach at around 67% is much more efficient than conventional air spray. HVLP guns typically use 8–20 cfm (13.6–34 m^3/hr), with an industrial compressor sized for this requirement.

The main advantages of HVLP spray painting are:

- High transfer efficiencies (as high as 90%)
- Excellent cosmetic quality
- Versatile system for a wide range of coatings
- Easy and safe to operate

Because of their combination of a very smooth finish along with better paint utilization, HVLP spray systems are widely used for automotive, marine, architectural coating, furniture finishing, cosmetic, and general industrial applications.

Rotary Atomizers or Electrostatic Bells

Perhaps the single greatest departure in spray paint applicators has been the development of the rotary atomizer. The rotary atomizer, also referred to as a "bell," uses the principle of centrifugal force to propel paint from a very high speed rotating paint nozzle. The nozzle, or paint cup, flings paint outward much the same way water is shed from a fast moving tire. In electrostatic models, a high voltage electrode imparts a charge to the paint particles just as in a conventional electrostatic spray gun.

Figure 9—An electrostatic bell is used for exceptional film uniformity on automotive trim components.

Table 2—Summary of Spray Technology Alternatives and Features

Technology	Main Features	Delivery System
Conventional Air Spray	Medium-Low Transfer Efficiency Medium-Low Application Speed High Versatility High Finish Quality Viscosity Limitations	Gravity Feed Pressure Pots Double Diaphragm Pumps Low Pressure Piston Pumps
HVLP	High Transfer Efficiency High Application Speeds High Versatility Limited Success with Metallic Paints	High Pressure Diaphragm Pumps High Pressure Piston Pumps
High Pressure Airless	High Transfer Efficiency High Application Speed Limitations with Metallic and Pigmented Paints No Vertical Application Except with Thixotropic Paints	High Pressure Diaphragm Pumps High Pressure Piston Pumps
Electrostatic	High Transfer Efficiency Wrap-Around Effect Homogeneous Surface Requires Proper Electrostatic Grounding / Planning	Pressure Pots Double Diaphragm Pumps Low Pressure Piston Pumps High Pressure Diaphragm Pumps High Pressure Piston Pumps
Electrostatic Bell	Highest Transfer Efficiency Wrap-Around Effect Homogeneous Surface Requires Proper Electrostatic Grounding / Planning Low Penetration	Double Diaphragm Pumps Low Pressure Piston Pumps Gear Pumps

The fine atomization produces a uniform application of paint film and so electrostatic bells are designed for high quality surface finishes, requiring a very uniform, homogeneous film thickness. A wide speed range of up to 70,000 rpm in continuous operation allows for optimal control over paint droplet size from fine to very fine. Both ball bearing and ultra low friction air bearing systems are available.

The bell provides very high application efficiency (in excess of 90%). New designs using valve blocks which have no dead spaces guarantee a thorough, precise color change. With the double valve block, a color change only takes a few seconds as the next color is already ready and waiting.

CONCLUDING REMARKS

Paint spray equipment is a highly evolved field. The industry has come a long way from the simple air spray systems of earlier decades. New materials, computer modeling, electronic controls, and precision machining driven by the demands of new coatings and tighter environmental regulations have produced a wide selection of tools.

The right spray gun depends to a large extent on the paint, but also on a number of other factors as well (such as the part, specifications, spray environment, process requirements, operator, and budgetary considerations). Like any tool, there is a wide range of makes and models from which to choose. We have endeavored to present some technical guidelines to narrow the choices and help end-users make a prudent decision. *Table* 2 summarizes some of this discussion and also provides some indication of the fluid delivery system requirements for each spray gun choice. As with many production tools, we also feel strongly that a supplier's reputation for quality and support can play an important role in how well the tool performs. We encourage all spray painters to educate themselves on the technology, and the supplier as well.

There is no doubt that as coating technology continues to emerge, those suppliers with strong commitments to R&D will continue to offer new and better ways to coat the wide range of parts the market demands. CT

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