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Controlling Particle Size in Self-Pressurized Aerosol Packages

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When the actuator is pressed on an aerosol can, the valve is opened, and a stream of liquid product travels thought the valve and exits the can. (See Fig. 1) Simple, right? Consider this - as the product stream exits the terminal orifice of the actuator, an amazing feat of physics occurs. The liquid stream is instantaneously and explosively converted into tens of thousands of discrete particles every second that the valve is held open. This metamorphosis is attributed to several factors but most notably to an immediate and violent phase change. The propellant (a hydrocarbon, such as propane, butane, isobutane, or a fluorocarbon, such as FC-152, or changes from a liquid to a gas as it exits the can. The explosive nature of this change literally blows apart the liquid stream into discrete particles. Controlling the resultant particle size is the topic of this paper, and one of the factors behind a great spray finish.

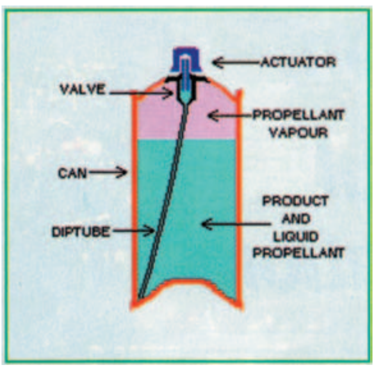

Figure 1. Aerosol can

What is the Target Particle Size?

First, let's define what we mean by the term "target particle size." In metal coating applications the optimal particle size is that which allows for a uniform coating to be applied to the target surface. The film should be smooth and uniform, and thick enough to provide full coverage yet thin enough to prevent vertical running. In addition, the particle size range should be such that these attributes are consistently delivered while keeping both "fines" and "hot spots" to a minimum. In terms of particle size, I am defining "fines" as the lower end of the particle size distribution, while "hot spots" (Fig. 2) occur when the particle size is well above the average of the distribution. Too much of either is undesirable in spray coating applications.

Figure 2. Coarse spray patterns with "hot spots."

The size of the discrete particles emitted by a self-professed package is influenced by many factors. Among these are container pressure, the type and amount of solvent present in the formula, the type and amount of propellant used, and, finally, the design of the valve system. From a practical standpoint, all of these factors can be highly customized to produce the desired effect: in this case, the preferred particle size. The control of aerosol particle size is a very complex topic. For this article I will focus on the valve systems' impact on particle size, and, more specifically, how the valve system can be adjusted to control particle size. This control is one of the keys to achieving a magnificent spray finish.

Aerosol Valve Selection

The aerosol valve system (Fig. 3) is responsible for both the quantity, and quality, of the spray produced. The quantity is controlled by the number and diameter of orifices contained within the valve system. The larger or more open the orifices are, the higher the flow rate will be, given all other variables in the system remain constant. In this article I will focus on the quality of the spray stream generated. Spray quality refers to several characteristics. A primary measurement is spray geometry. Here we are talking about the geometric shape and size of the spray. Typical shapes are stream, cone, fan, and donut. Spray rate, measured in grams per second, is also a primary measurement in defining a spray. Particle size is the third attribute of spray quality. In this article, I will specifically focus on how particle size is influenced by the valve system.

Aerosol valves are available in a surprisingly wide variety of configurations. Valve companies have, as stock components, a wide array of actuators, stems, bodies,

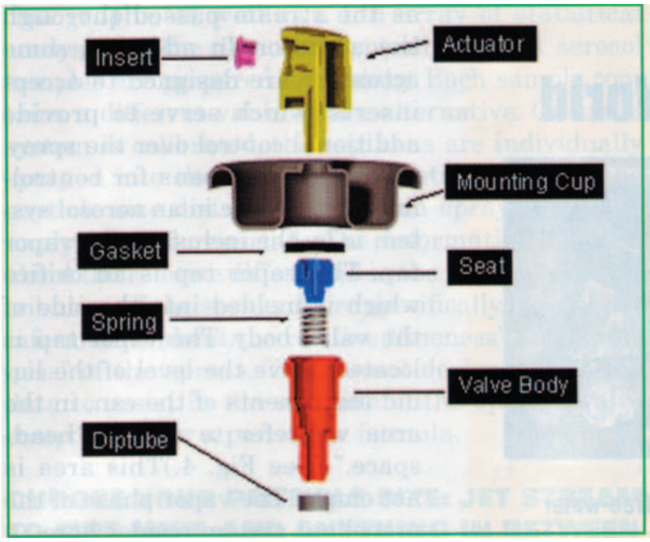

Figure 3. Aerosol valve.

mounting cups, vapor tap sizes, and dip tube orifice sizes. In fact, a former co-worker of mine estimated that there were over 200,000 possible combinations of stock components that can be combined to produce distinct aerosol valves. By the way - in case you were wondering - he didn't "cheat" by including different part colors or various diptube lengths. I will also mention that if you need a particular orifice that doesn't exist in a stock component, valve companies are able to custom mold the piece (for a price, of course).

This wide flexibility in available valve components is what makes controlling the particle size a simple job for the experienced aerosol package designer. Once the formula is established, the package designer can then utilize various orifice combinations, choose to include a vapor tap, or not, and select from a wide array of actuators and inserts to tailor the spray's particle size to suit product performance requirements.

The two primary valve components used to adjust the particle size of the spray plume are the actuator and the vapor tap. The actuator, also referred to as the "button," "spray-head," or "spray-tip," is the component representing the point of exit of the spray stream. The second component is a molded orifice located in the body of the valve and is referred to as the "vapor tap."

Within any given actuator style, there are a number of dimensions that be altered to influence the spray. One of these dimensions is the length and taper of the channel leading to the exit orifice of the actuator. The plastic leading to the exit orifice can be molded as a straight channel, or the channel can be tapered, or even reverse-tapered. Each of these configurations has a different effect on particle size. Also, within the actuator there are a variety of mechanical break-up features available to provide increasing breakup of the fluid stream as the stream passed thorough the actuator. In addition, some actuators are designed to accept inserts, which serve to provide additional control over the spray.

The second means for controlling particle size in an aerosol system is by the inclusion of a vapor tap. The vapor tap is an orifice which is molded into the side of the valve body. The vapor tap is located above the level of the liquid components of the can, in the area we refer to as the "headspace." (See Fig. 4.) This area is not empty. The vapor phase of the propellant system resides here.

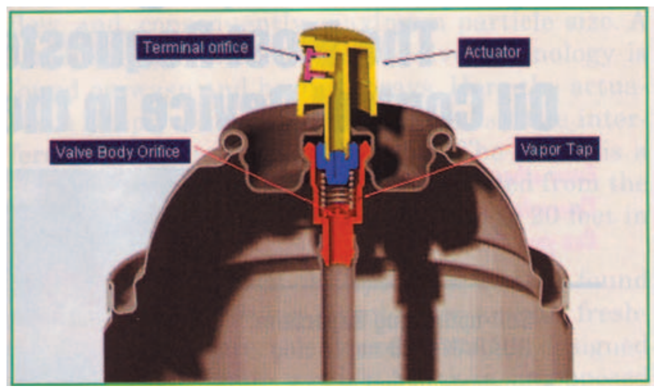

Figure 4. Aerosol valve showing vapor tap location.

The function of the vapor tap is to draw off the propellant vapor, and add it to the liquid stream, which is being drawn up the diptube when the valve is open. By mixing the propellant vapor with the spray stream, the particle size of the spray can be substantially reduced. A wider vapor tap orifice allows for a higher ratio of propellant vapor-to-liquid in the spray. The result is a smaller-than-average particle size. Obviously there is an upper limit in the size of the vapor tap. In fact, the aerosol designer must be careful to balance the size of the vapor tap orifice with the potential inability to evacuate the can due to premature pressure loss. Also, the spray can must be held in a relatively vertical position. If the can is sprayed in a vertical, or inverted orientation, the vapor tap will not function and the spray stream will rapidly degrade. The actuator and vapor tap variables described above afford the aerosol designer great flexibility in adjusting the geometry, spray rate, and particle size of the aerosol spray

Determining the actual effect of the various valve design possibilities discussed is accomplished through the use of particle sizing instrumentation. The instrument, an aerosol particle size analyzer, projects a laser beam between two optical nodes. The system's electronics rapidly measure and analyze the particle size distribution present within the light beam. The associated computer programs generate detailed reports, which include size distribution graphs, as well as a full array of statistical analyses on the data set. Typically several aerosol samples are prepared for testing. Each sample contains a different valve design alternative. Once the system is calibrated, the test cans are individually sprayed into the beam of the instrument and the particle size distribution of each spray stream is analyzed and reported. The information tells us about the relative differences in the particle size distribution of the sprays. More specifically, it provides information about the relative "fineness" or "coarseness" of the sprays. The aerosol designer uses the data to assist in the selection of the optimal valve components for a particular formula.

Choose Your Particle Size: Jet Stream to Fine Mist, and Anything in Between

The range of particle size control ranges from providing no breakup of the stream, to providing maximum breakup resulting in a very small particle size. In its simplest configuration, the actuator's internal geometry represents a simple conduit with no obstacles to impede the flow. This configuration results in minimal disruption of the product flow, and, consequently, maximum particle size. A clear example of this type of valve technology is found on wasp and hornet sprays. Here the actuator is simply a conduit which offers as little interference, and breakup, as possible. The result is a solid stream, which is forcefully projected from the can to achieve maximum distance, up to 20 feet in some cases.

At the other end of the spectrum can be found products such as flying insect killer and air freshener products. Here, the aerosol system is designed to provide maximum particle breakup, as opposed to maximum stream distance. The result is an extremely small particle size with individual particles averaging < 25 microns in size. This small particle size allows the spray to "hang" in the air longer, which enhances the performance of each product. The air freshener's fragrance is more persistent, and the small particle size enables the active ingredients in the flying insect killer to remain suspended in a room for an extended period of time thus prolonging its effectiveness against flying insects

Now that we have explored the potential range of particle size, let's refocus on spray coating applications. Obviously, we want a particle size distribution somewhere between the two extremes I outlined. To accomplish this, the aerosol product developer evaluates different actuator, insert and vapor tap combinations to find the correct balance between a spray that is too fine, and one that is too coarse for a given aerosol formula (concentrate and propellant). Note that each time the formula is altered, whether it's a "minor" solvent change or the addition of a different additive package, the particle size will vary as well. While finding the optimal spray characteristics, and particle size, can be a very time consuming process, a skilled aerosol designer can narrow down possibilities quickly by relying on their knowledge of the internal design of the various actuator and insert combinations available, as well as by selecting appropriate starting points based on previous experience.

Conclusion

The point of this paper is to highlight the levels of control aerosol designers have in adjusting the particle size of the spray. Whether you are designing new products, or upgrading current products, the particle size can be optimized through selection of the aerosol valve system. Let me quickly point out that the development of an optimized valve system is not done in a vacuum. The entire aerosol system must be taken into consideration when developing a suitable valve. The aerosol designer must consider questions such as: does the system pressure change during use, as it would when using carbon dioxide, nitrogen, air, or nitrous oxide as propellants; or, is there a change in solids which may impact clogging potential; or, is there a solvent change required for VOC considerations? These are examples of some of the questions which the aerosol designer must explore in conjunction with selecting a suitable valve system … and are topics for another day.