Particle Size Control in Aerosol Packages

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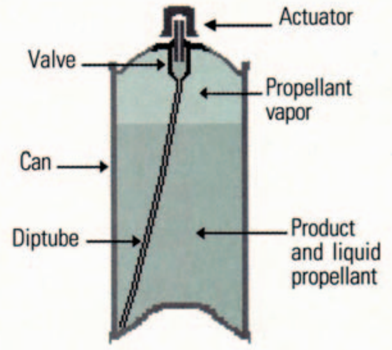
When the actuator is pressed on an aerosol product, the valve is opened, and a stream of liquid product travels through the valve and exits the can (Figure 1). Simple, right? Consider this–as the product stream exits the terminal orifice of the actuator, an amazing feat of physics occurs. The liquid stream is instantaneously 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 phase change. The liquefied propellant–a hydrocarbon, such as propane, butane, iso-butane, or, a hydrofluorocarbon, such as HFC-152, or HFC-132–changes from a liquid to a gas as it exits the can. The volatile nature of this phase change disperses the liquid stream into discrete particles. Controlling the resultant particle size is the topic of this paper, and, one of the primary factors behind aerool product performance.

Figure 1
Aerosol can



Identify the target particle size

While your customers may not relate to the term "particle size distribution," their purchase decisions certainly do. An improper particle size is the difference between a highly effective, consumer-friendly product, and, well, a sales disaster. In hair sprays, for example, controlling particle size is directly related to customer satisfaction. If the particle size is too small, the consumer chokes on the "fines", which are very small particles, typically less than 10 microns in average diameter and which "hang" in the area of the spray impact. If the particle size is too large, the dry time is much longer. Either way, the product is a failure. In aerosol spray paint, 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" (Figure 2) to a minimum. Each product category has its own set of criteria for acceptable particle size. The right particle size is determined by the end use application. Our question today is: how do we achieve and maintain the correct particle size distribution?

The size of the discrete particles emitted by a self-pressurized package is influenced by many factors. Among these are: container pressure, the type and amount of solvents 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 system's impact on particle size, and more specifically, how the valve system can be adjusted to control particle size.

Figure 2:
Course spray pattern with "hot spots"

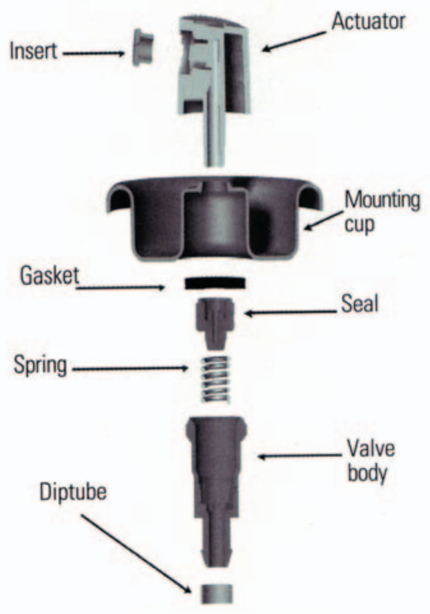
Aerosol valve selection

The aerosol valve system (Figure 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 that all other variables in the system remain constant. Spray rate, measured in grams per second, is a primary quantity measurement which defines the spray. For this article, the focus is on the quality attributes of the spray stream generated. Spray quality refers to several characteristics. A primary measurement is spray geometry, which involves the geometric shape and size of the spray. Typical shapes are: stream, cone, fan, and donut. Particle size is another attribute of spray quality, and here, 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, an array of actuators, stems, bodies, mounting cups, vapor tap sizes, and dip tube orifice sizes. In fact, a former co-worker 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 dip tube lengths. When a particular orifice is required–one that doesn’t exist in a stock component–valve companies have the ability to custom mold the piece for trial evaluations (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 then select from a wide array of actuators and inserts to tailor the spray’s particle size to suit specific product performance requirements.

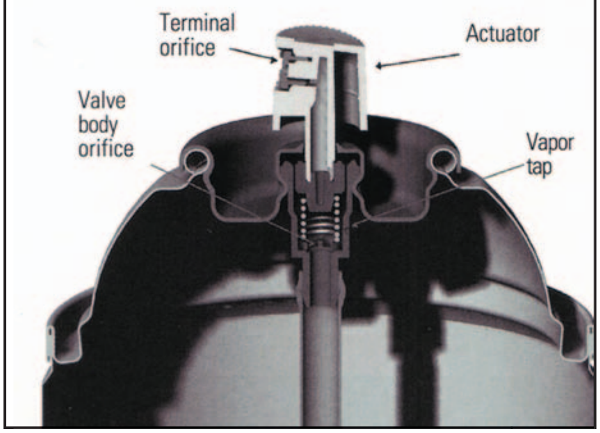
Figure 3:
Aerosol valve



The two primary valve components which are 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 which represents the point of exit of the spray stream. The second component, which has a major impact on spray quality, is a molded orifice located in the body of the valve and referred to as the “vapor tap.”

Within any given actuator style, there are a number of dimensions that may be altered to influence the spray. Two of these dimensions are 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 an effect on the resultant particle size. Also, within the actuator there are a variety of mechanical breakup features available to provide increasing breakup of the fluid stream as the stream passes thorough the actuator. Furthermore, some actuators are designed to accept inserts, which serve to provide additional control over the spray.

Figure 4:
Aerosol valve showing vapor tap location



The second method of controlling particle size in an aerosol system is by including a vapor tap, an orifice which is molded into the side of the valve body. It is located above the level of the liquid components of the can, in the area we refer to as the “headspace” (Figure 4). The headspace area is not empty–the vapor phase of the propellant system resides here.

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 dip tube when the valve is open. By mixing the propellant vapor with the spray stream, the particle size of the spray can be substantially reduced. Note that there is an inverse relationship between vapor tap diameter and particle size. A larger vapor tap orifice allows for a higher ratio of propellant vapor in the spray. The result is a smaller 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 aerosol can must be held in a relatively vertical position. If the can is sprayed in a horizontal or inverted ori entation, the vapor tap will not function, and the spray stream will rapidly degrade. The actuator and vapor tap variables described above afford the aerosol package designer great flexibility in adjusting the geometry, spray rate and particle size of the aerosol spray.

Determining the effect of the various valve design possibilities on particle size is accomplished by using an instrument called an Aerosol Particle Size Analyzer. The unit I am most familiar with is manufactured by Malvern Instruments Inc., located in Southborough, MA. This device projects a light beam between two optical nodes. The systems’ electronics rapidly measure and analyze the particle size distribution present within the beam. The as- sociated computer program generates detailed reports, which include particle 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 provides the relative differences in the particle size distribution of each of the samples. More specifically, the readouts provide information about the relative fineness or coarseness of the sprays. The aerosol designer uses the results from the particle size testing to optimize the 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 extends 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 near 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 killers and aerosol air freshener products, where the aerosol valve system is designed to provide maximum particle breakup, as opposed to maximum projected stream distance. The result is an extremely small particle size with individual particles often < 25 microns in size. This small particle size allows the spray to "hang" in the air for long periods of time, thereby enhancing the performance of these products. The air freshener's fragrance is more persistent, and a 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 efficacy against flying insects.

The particle size distribution of many aerosol products lies between these two extremes. To dial-in the desired particle size range, 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 is a "minor" solvent change, or a different additive package, the particle size may vary as well. While finding the optimal spray characteristics and particle size can be a very time-consuming process, skilled aerosol designers 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. In terms of product performance, and consumer satisfaction, it is well worth the effort.

Conclusion

There is no doubt that aerosol package designers have a range of flexibility in adjusting the particle size of the aerosol spray. Whether new products are being designed or current products are being upgraded, the particle size can be optimized through careful selection of the aerosol valve system. It is important to note, though, 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 package designer must consider questions such as-does the internal pressure of the aerosol package change during use, as it would when using carbon dioxide, nitrogen, or nitrous oxide as propellants, or, is there a change in solids which may impact the potential for clogging; or, is there a solvent change required for VOC considerations. These are just some of the questions that aerosol package designers must explore when selecting a suitable valve system, and they are topics for another day.

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