Fundamental principles and designs of aerosol actuators to cure low voc products

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Abstract
Volatile Organic compounds become a serious problem unless some thing has to be made to limit these compounds in our environment. This paper describes experiments that have been carried out to explore the effects of shaped chambers, multiple passages and throttles on the spray quality causing pressure drops, turbulence, circulation, vaporisation and consequently reducing particle sizes, this paper is related to an innovation patents WO2005005053(A1) and WO2005005055 (A1).

Introduction:

Legislation controlling VOC use is becoming increasingly strict and is already affecting the household aerosol market in California. The key performance parameters of an aerosol are the discharge rate, the particle size and the cone angle. Safety is also a key requirement (1). A spray is generated when a fluid is caused to flow through a nozzle arrangement under pressure. To achieve this effect, the nozzle arrangement is configured to cause the fluid stream passing through the nozzle to break up or “atomise” into numerous droplets, which are then ejected through an outlet of the arrangement in the form of a spray or mist.

The optimum size of the droplets required in a particular product concerned and the application for which it is intended. For example, pharmaceutical sprays that contain a drug intended to be inhaled by a patient (e.g. an asthmatic) usually requires very small droplets, which can be penetrated deep into the lungs. In contrast, a polish spray preferably comprises spray droplets with larger diameters to promote the particularly if the spray is toxic, to reduce the extent of inhalation.

The size of the aerosol droplets produced by such conventional nozzle arrangements is dictated by a number of factors, including the dimensions of the outlet orifice and the pressure with which the fluid is forced through the nozzle. However, problems can be arising if it is desired to produce a spray that comprises small droplets with narrow droplet size distributions, particularly at low pressure.

The use of low pressures for generating sprays is becoming increasingly desirable because it enables low pressures nozzle devices, such as the manually-operated pump or trigger sprays, to be used instead of more expensive pressurised containers and, in case of pressurised fluid-filled containers, it enables the quality of propellant present in the spray to be reduced, or alterative propellants which typically produce lower pressure (e.g. compressed gas) to be used.

The desire to reduce the level of propellant used in aerosol canisters is topical issue at the moment and is likely to become more important in the future due to legislation planned in certain courtiers, which proposes to impose restrictions on the amount of propellant that can be used in hand-held aerosol canisters. The reduction in the level of propellant causes a reduction in pressure available drive the fluid through the nozzle arrangement and also results in less propellant being present in the mixture to assist with the droplet break up. Therefore, there is a requirement for different types of designs of nozzle arrangement that is capable of reducing an aerosol spray composed of suitably small droplets at low pressure.

A further problem with known pressurised aerosol canisters filled with conventional nozzle arrangements is that the size of aerosol droplets generated tends to increase during the lifetime of aerosol canister, particularly towards the end of the canisters life as the pressure within the canister reduces as propellant becomes gradually depleted. This reduction in pressure causes an observable increase in the size of the aerosol droplets generated and thus, the quality of the spray is compromised.

Accordingly, it is an object of the present work and inventions to provide design of nozzles that is adapted to generally reduce the size of the droplets generated when compared with conventional nozzle devices, as well as to narrow the droplet size distributions. Also to enable small droplets of fluid to be generated at low pressures, i.e. when fluids contains reduced or depleted levels of propellant, or a relatively low-pressure propellant such as compressed gas, is used, or a low pressure systems is used, such as a pump or trigger.

The problem of providing a high spray at low pressures is further exacerbated if the fluid concerned has a high viscosity because it becomes harder to atomize the fluid into sufficiently small droplets.

Also the aim of this work is to have designs capable of generating a spray from viscous fluids at low pressures. Below one of the designs could solve low voc products.

Spray painting and coating processes are used widely in decoration and protecting substrate. This includes techniques such as electro-deposition, auto-deposition, roller or power coating. The paint and coating atomizers should be capable to produce fine drop sizes. Moreover, these atomizers must provide acceptable emissions of volatile organic compounds to

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meet the legislations to control their effects on the environment.

On household applications, there are a very wide field of so called “aerosols cans” or “packaged aerosols”. Examples of these are; aerosol cans, such as deodorants, hair-spray, anti-perspirants, air fresheners, polishes, cooking oils, cleaning spray and insecticides. This invention, (2-5) helps to develop designs of actuators which help the reduction of VOC in the cans.

Apparatus, Methodology and Procedures:

An experimental programme has used transparent actuator caps, with high-speed video recording, brass models also have been used because they last for longer.

Droplet sizing using a laser diffraction instrument (Malvern and Spray Tec.), an average of three tests had been taken for each data , flow rate was measured by weighing the can, normally average reading will be taken for three times reading, the spray time on average of five seconds. Because consistency of spraying throughout can life is important, droplet sizes and flow rate are measured for full cans, and, typically, for 75%, 50%, and 25% full.

Spray distances from the lenses are 150mm for body sprays, 200-250mm for hair spray, oil, paint and polish and 500mm for air freshener.

The actuators in the research programme have been specially machined from Perspex (Plexiglas) and Brass, a method of unit construction has been developed so that combinations of different shapes and sizes of inlets, exits, internal passages and flow control devices may be tested systematically because of variation of temperature difference between summer and winter, all tests must be done at room temperature, say 20 centigrade.

Internal features of Raj. designs, as developed for spraying air fresheners, anti-perspirant, body spray, hair spray, polish, oil and paint, key features of the devices are the inlets, pre-throttles, shaped chambers, partitions, throttle(s), straight or angled, leading to the pre-chamber and exits, exits could take different forms from a simple exit to a swirl.

Results

Several products of hair spray have been tested with different designs. All these designs and diagrams showing drop size diameter, flow rate and inhalable data are shown in figures 1 to 7.

Some of these designs feature swirl exits and others have swirls replaced by normal exits. Experience has been gained during the experimental project which has enabled the use of designs that depend less on swirls.

Figure 1b shows an average of 65µm drop size for these kinds of products, which are further reduced VOC.

Figures 2b and 3b show drop size, flow rate and inhalables; these are considered to be moderate products. Figure 2a shaped diamond chamber has been used followed by expansion chamber then a swirl. Figure 3a uses shaped and conical chamber with angled throttles hitting each other in the convergent exit. The results in Figure 3b showing an average of 40µm drop size distribution, consistent flow rate and acceptable inhalables, less than 6% microns. The advantage of a shaped exit over a swirl exit is very obvious, it produces full cone spray rather than hollow cone sprays, the throw of shaped exits goes a further distance in comparison to swirls. Other advantages of shaped exits are no blockages, easy maintenance, and cheaper to manufacture.

Figures 4b and 5b show the same product with two different designs. The first one used angled throttle hitting the pre-chamber and the other design using bigger pre-chamber, both of which were consistent in drop size distribution and inhalables.

Figure 6 use the same product with figure 6a using shaped diamond chamber, which worked better compared with figure 6b which used just a chamber. This is because the diamond shaped chamber creates more droplet break up and more circulation.

Figure 7a, b shows a design and result of one of the difficult hair sprays (further reduced VOC) on the market. The shaped chamber in the design worked extremely well to atomise this kind of complex hair spray.

Figure 8a, b shows a design working well with reduced VOC body spray, producing fine droplets with minimum inhalables and keeping the flow rate within average, again this has shown that the diamond shaped chamber are proven to be a unique and successful design.

Figure 9a, b shows a design that worked extremely well with high viscous product (polish) of the compressed air type, starting the pressure with 125psi and end at 30psi. The drop size doesn’t look bad at all when you look at the simple design which comprise of shaped chamber followed by pre-chamber and swirl.

Figure 10a, b shows a comparison between high viscous products (oil based) which used an original cap and Raj design (water based). The drop size looks identical; however Raj design shows great improvement of D90 and consistent flow rate.

Figure 11a, to 16a demonstrates performance of anti-perspirants. Figure 11a, b shows a comparison of original cap anti perspirant spray with Raj AP design 5. The inhalables of the Raj designs are far less than the inhalables of the original cap, whilst still maintaining the same flow rate.

Figure 12a and 12b shows the comparison between the original design caps with the Raj Design 35. These are the same product, but using different designs. The inhalables of Raj Design 35 are extremely low compared with the original can.

When comparing the difference in droplet sizes between figure 11 and 12, design 11a has an advantage over design 12a on maintaining droplets around 25µm.

Figure 13b shows a comparison of angled throttle designs B65 and B62, the smaller exit (B62) shows better inhalables than the larger exit (B65).

Figures 14b, 14c and 15b shows air freshener products with low VOC. Figure 14c compares the vertical design with multiple exit of 15º and multiple exits with 20º. The 20 º angled exit proved to be much better than the 15 º angled design (finer drop size). Figure 15b shows a horizontal design being compared with a vertical design; again the vertical design behaves much better than the horizontal design relating to the losses in the 90º bend and more breaks occurred as a result of shaped chamber used as vertical inlets instead of horizontal inlets. Figure 14b shows the comparison between the original designs with vertical 20º angled exit design, again the test backing the idea of a better performance when testing with vertical design 20º.

The wider angle releases the effects of co-ellesance of the individual plumes therefore allowing better droplet break up, however too wide an angle results in an overall undesirable multiple phase effect.

Figure 16b shows high viscous product (product O) with comparison to the original cap with low VOC tested by Raj design showing better results on both drop size and flow rates.

Figure 17b compares a high viscous (product O) with original cap against a Raj design which uses compressed air, here the advantage of Raj design over the original cap is clearly seen, although Raj cap is tested on compressed air product.

Figure 18b shows another type of viscous product, comparing original cans with VOC tested using an original cap and a low VOC product tested by Raj design. The graph suggests that Raj Design matches the drop size and flow rate of the original cans.

Discussion

Most of the products are reduced VOC or further reduced VOC, compress air and anti-perspirant. As shown in figures 1 to 18, model designs consists of inlets, could take different shapes, horizontal, tangential or vertical inlet, inlets also could control the flow rate. Pre-throttle works with body spray as flow control as well as create more fine droplets with no penalty to flow arte. With anti-perspirants it reduces the inhalables by increasing the drop sizes, pre-throttle sizes has to be optimised to be effective otherwise using wrong size could be counter productive, more experience needed to match such deigns with such products.

“throttle” stage, could take different forms, such as two throttles hitting each other in figure 3a and 18a, a pre chamber which create more droplet breaks or single or more angled throttles hitting the wall as shown in figure 4a, 10a and 11a convert kinetic energy into pressure energy near the wall leading to a pre-chamber, chamber shape and sizes can be determined by knowing the product and other characteristics required followed by an exit orifice stage.

It has been shown that in some designs long chambers after inlets could give better mixing to produce finer droplets as illustrated in figure 5a.

Rajab’s diamond shaped chambers such as the designs in figures 1a and 2a and 17a consist of divergence conical leading to a chamber followed by convergence conical. The chamber length of the chamber can be optimised and determined depending on several factors such as flow rate required and the type of product.

Converged Conical chambers behaves well since create local pressure drop, converged or diverged conical chambers can also be used as exits as in Fig. 3a, 8a and 16a. It has been shown that a small around tip on the exit could narrow the drop size distributions, reduces large droplets on the sides, also can reduce liquid collection

Throughout the paper, all Raj’s designs are selections include different straight or angled throttle(s), shaped chambers, partitions, conical(s) and exit stages that have been tested for different products.

Systematic tests were undertaken, in order to reduce the drop size diameter as well as the inhalable fraction of droplets, i.e. the percentage of droplets smaller than 7 microns, with no effect to the flow rate.

Raj designs illustrate flow control devices that have been explored, including a shaped chambers, Raj diamond, Raj partitions for breaking up unsteadiness and segregation after the valve and corners, and a pre-chamber before the exit orifice, convergence and divergence conical and throttle(s) provide a local pressure drop which causes vaporisation of a proportion of the hydrocarbon

Systematic tests enabled selection of optimum combinations of exit orifice and throttle sizes, chamber shapes and partitions with the aim of producing fine sprays but with reduced inhalable fraction of droplets.

This is achieved by producing a near-homogeneous two-phase mixture in the pre-chamber which completes atomisation inside and just downstream of the exit orifice. Minimisation of liquid film on the exit orifice wall also appears to assist in reducing the width of the size distribution.

For anti-perspirants it has also been shown that the spray angle is increased by decreasing the exit size. But this will affect the drop sizes which makes it finer therefore increase the inhalable sizes percentages those less than 7 microns. In the other hand if the exit size decreased the drop sizes increased and spray angle will be narrower.

Applications of Raj’s designs is achievement of a major reduction in hydrocarbon content for air-freshener sprays, hair spray and body spray with no adverse effect on the drop size distribution.

In order to do this hydrocarbon propellant level is reduced in the can during the filling operation, and also the liquid propellant must be replaced by water. This produces problems in obtaining good atomisation for three reasons; (1) the can pressure is reduced, (2) flash vaporization is reduced, and (3) surface tension and viscosity of the liquid phase are increased.

Development work showed that to solve these problems it was considered necessary to (1) ensure significant vapour release occurred within the actuator, (2) produce a highly turbulent flow, but at length scale small compared with the flow geometry, and (3) minimise the size of the exit orifice.

Reduction in a can VOC content is obtained without worsening the drop size distribution (volume and median diameter is around 40 micron for air fresheners), 30 to 60 microns for different types of reduced VOC.

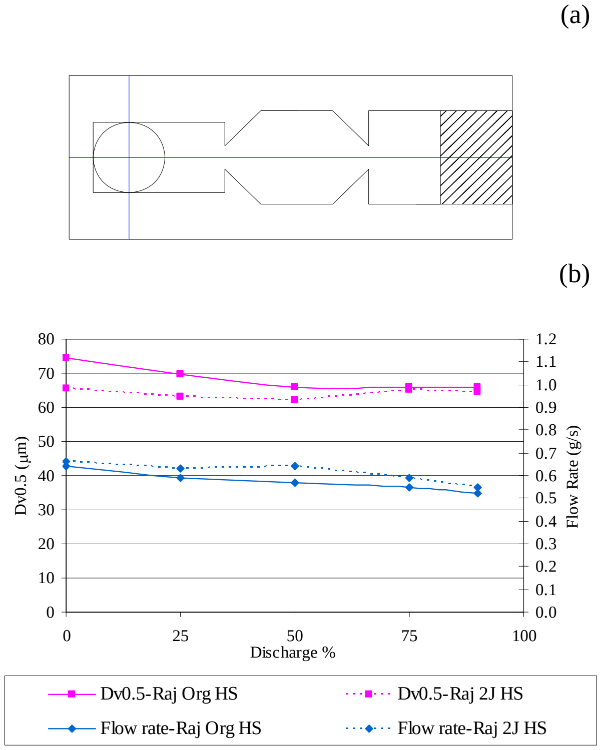


Figure 1a, b: Hair Spray, Prod J Org v Raj 020604 2J

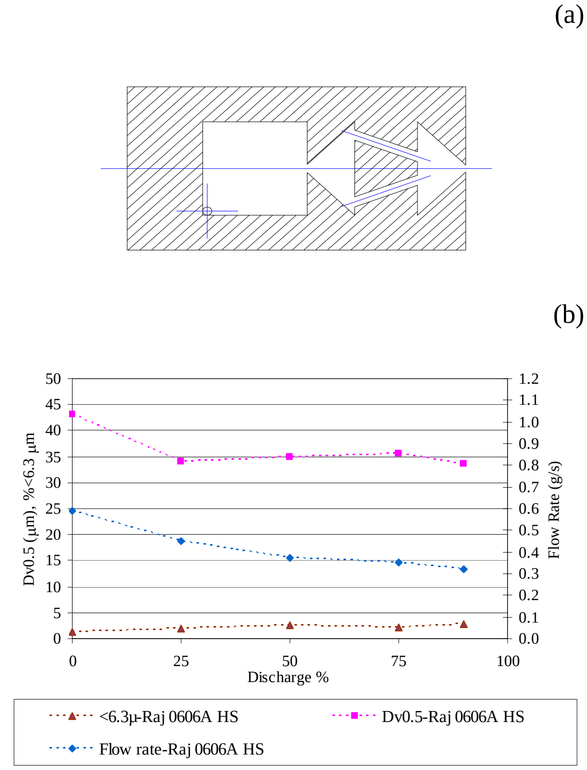


Figure 3a, b: Hair Spray, Product H Raj 0606A

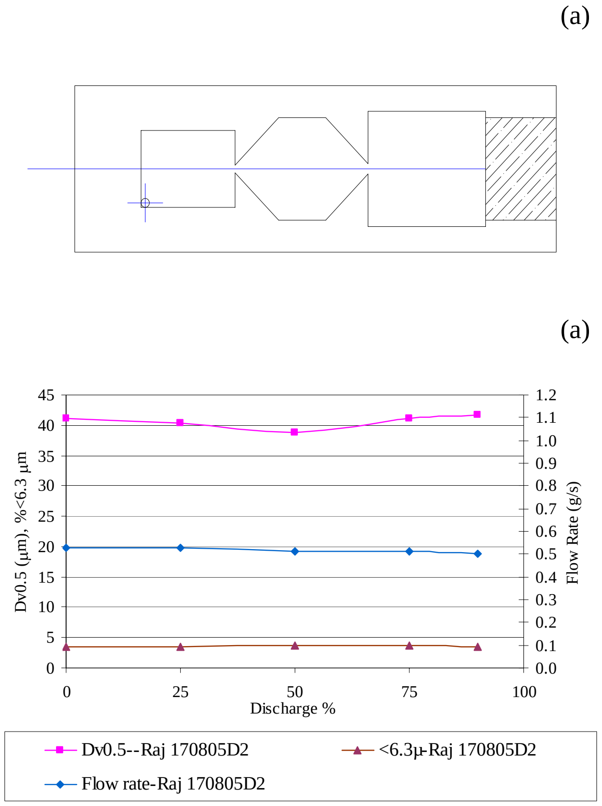


Figure 2a, b: Hair Spray, Product H Raj 170805 D2

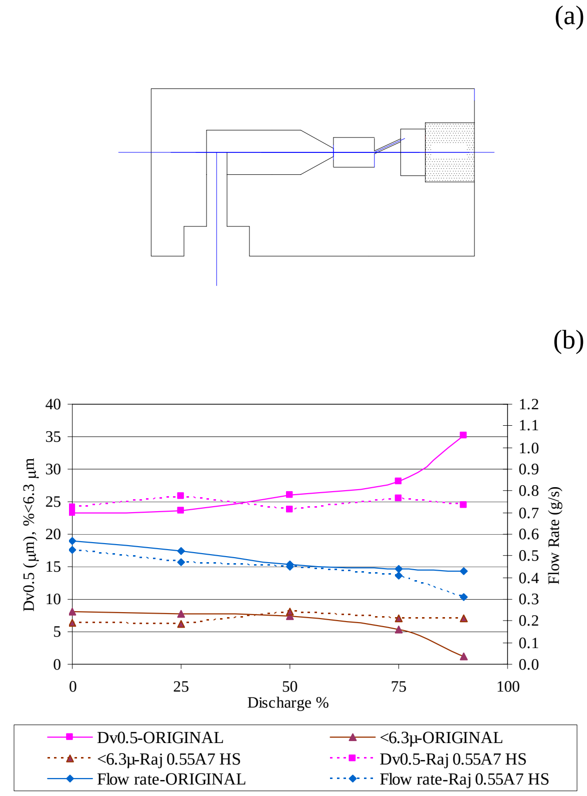


Figure 4a, b: Hair Spray, Prod. M Org v Raj 55A7

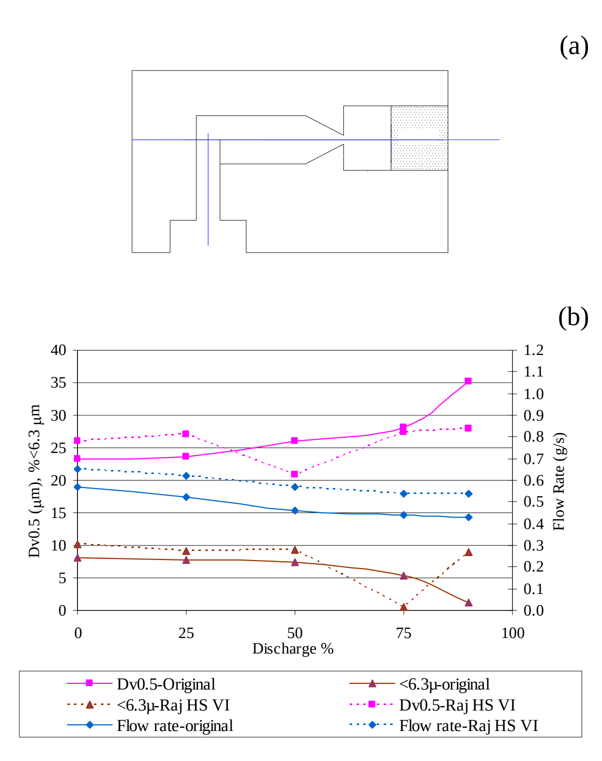


Figure 5a, b: Hair Spray, Product M Org v Raj VI

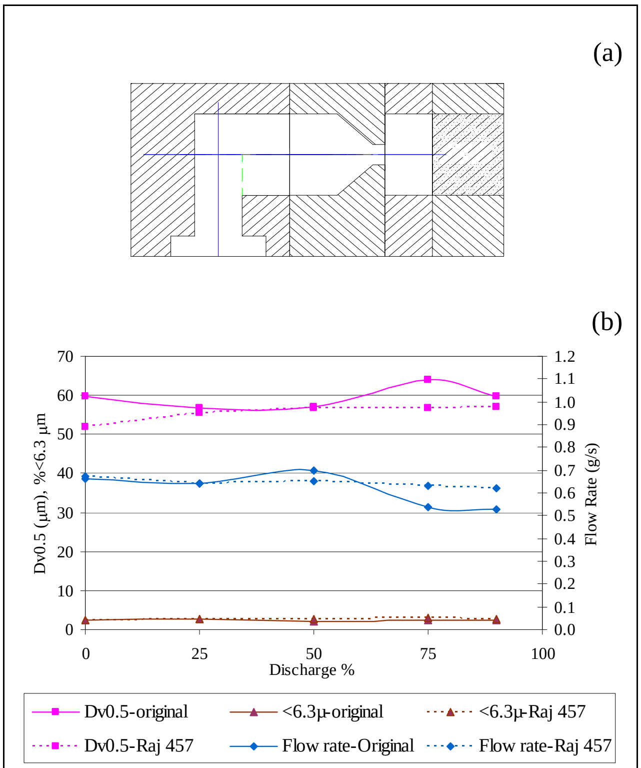


Figure 7a, b: Hair Spray, Product K Org v Raj 457

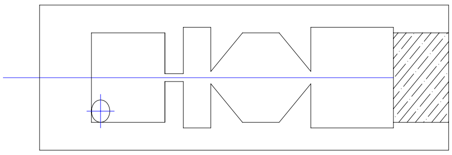


Figure 6a: Hair Spray, Raj 170805 D1

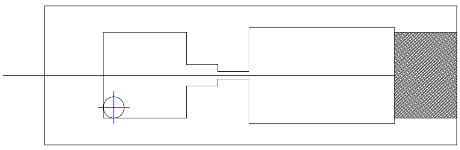


Figure 6b: Hair Spray, Raj 170805 D2

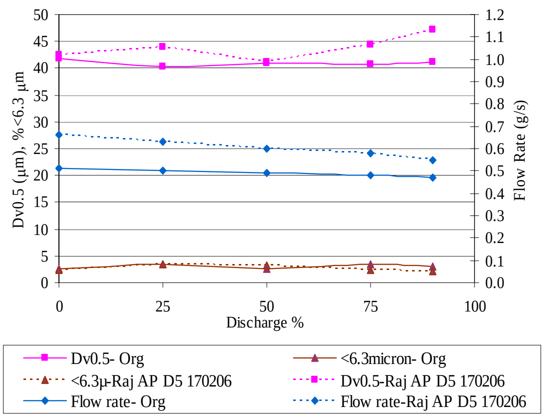


Figure 6c: Hair Spray, Prod L Raj 170805 D1 v D2

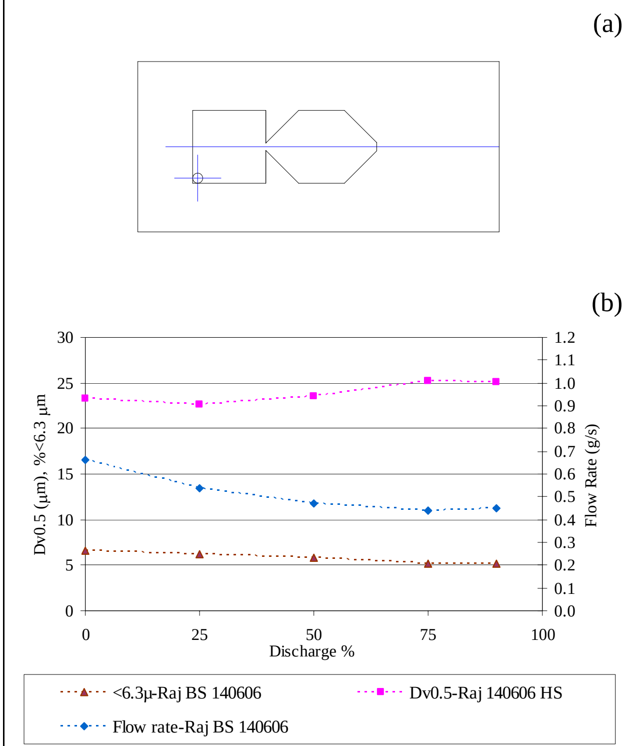


Figure 8a, b: Body Spray, Product I Raj BS 140606

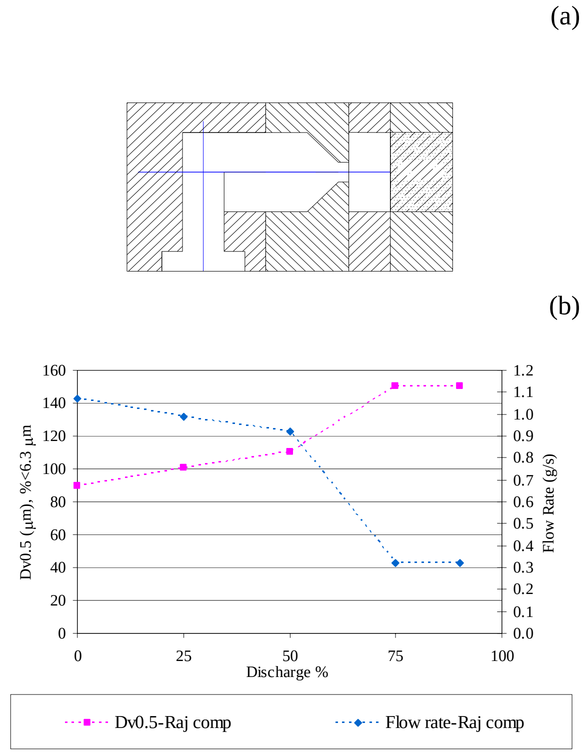


Figure 9a, b: Viscous, Product P Raj 2 8 7

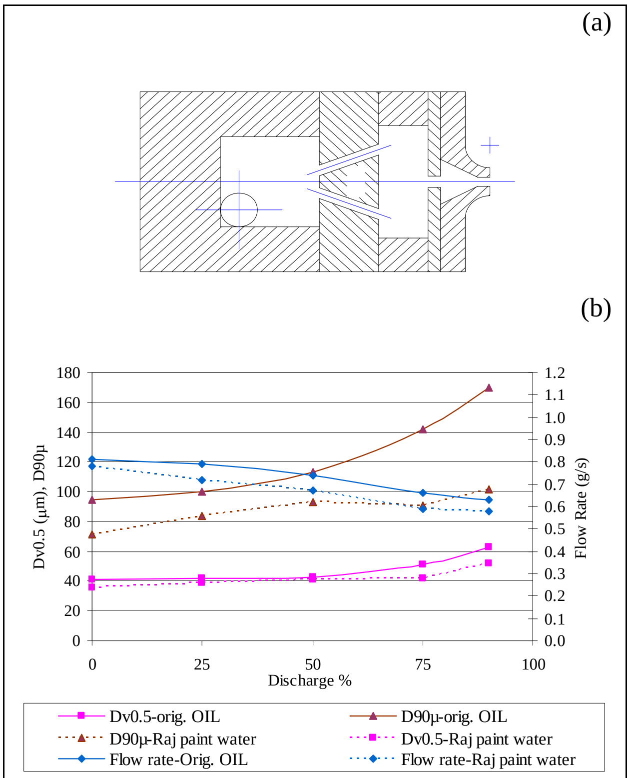


Fig 10a, b: Prod N Paint Org O v Paint Raj W D230806

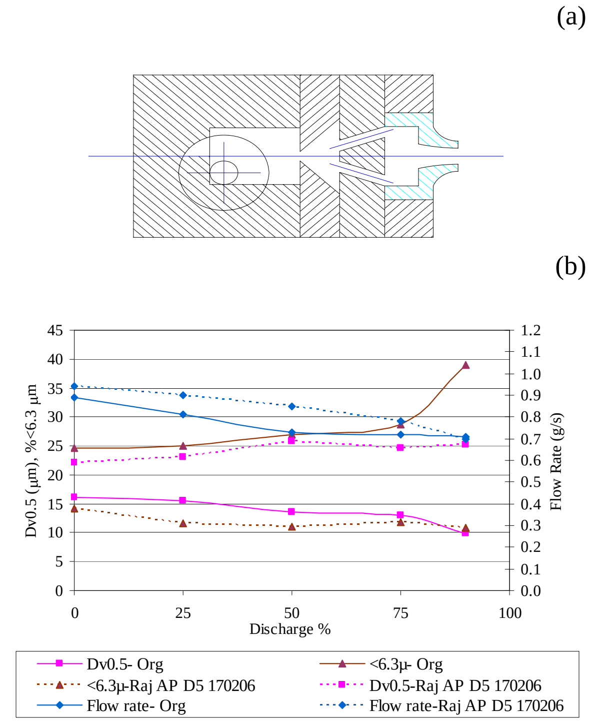


Fig 11a, b: Anti Persp, Prod C Org v Raj D5 170206

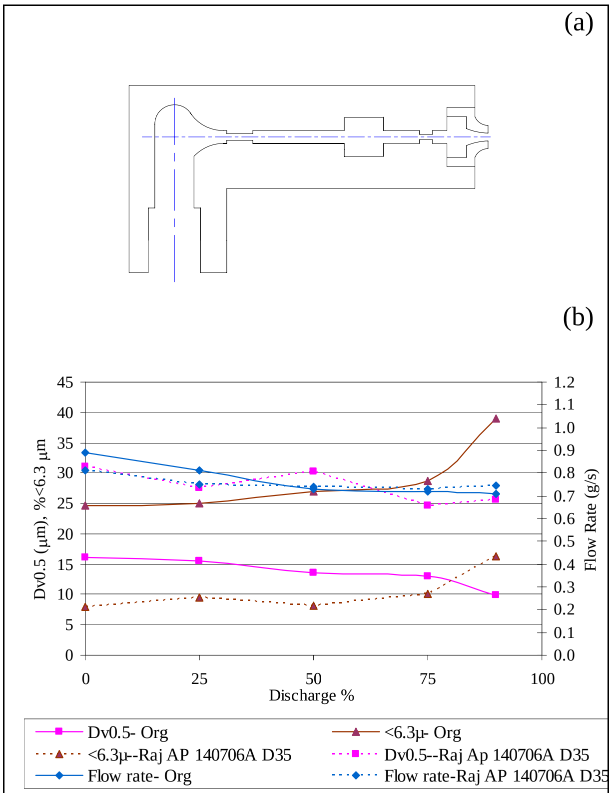


Figure 12a, b: Anti Persp, Prod C Org v Raj D35

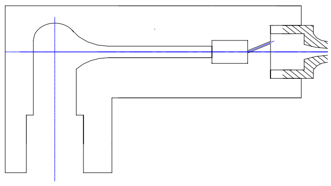


Figure 13a: Anti Perspirant Design 55A7EX3

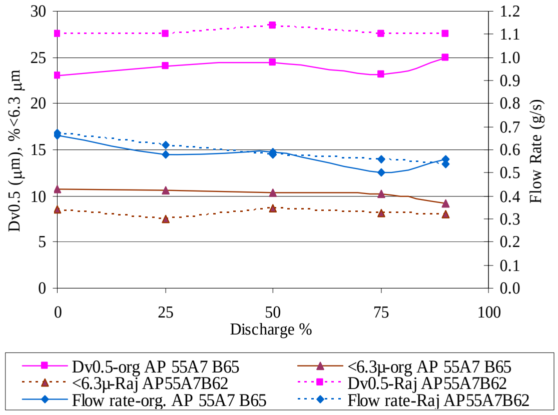


Figure 13b: Anti Perspirant, Product G

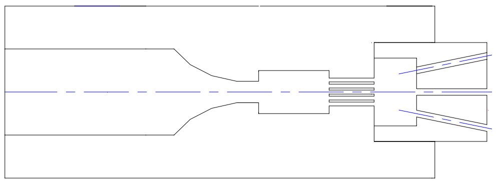


Figure 14a: Air Freshener Vertical Design, D30HV

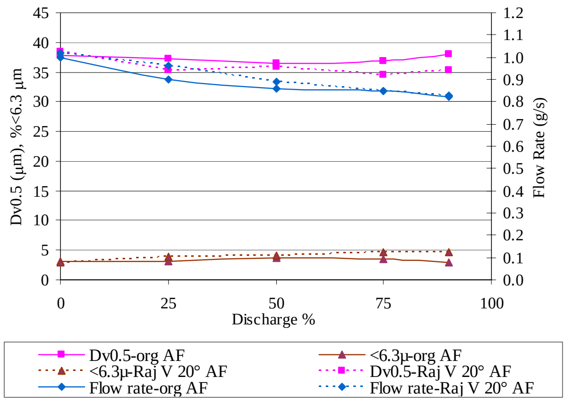


Figure 14b: Air Freshener, Original V Raj V20º

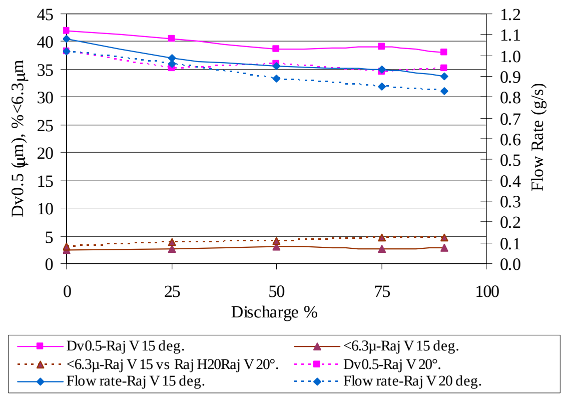


Figure 14c: Air Freshener, Raj V15º v Raj V20º

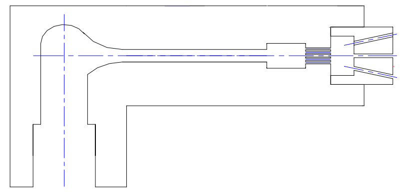


Figure 15a: Air Freshener Horizontal Design, D30H

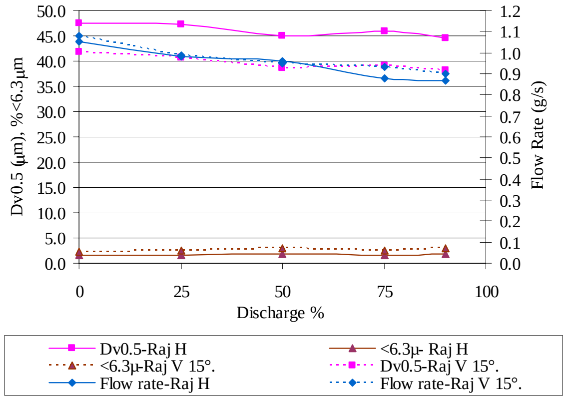
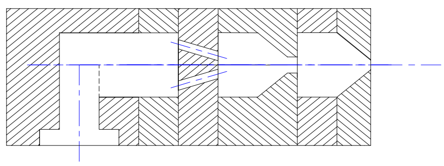


Figure 15b: Air Freshener, Raj H v Raj V15º

(a)



(b)

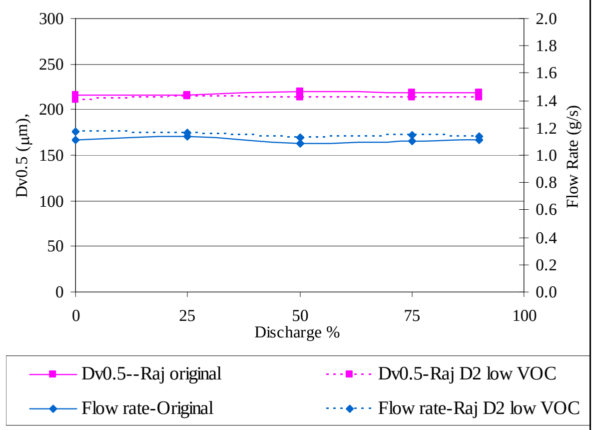


Figure 16a, b: Org v Raj Visc G Low VOC Prod O

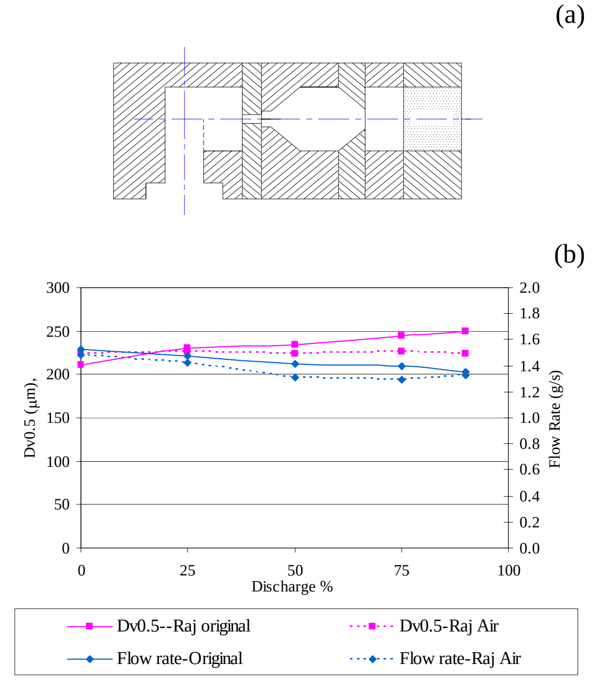


Figure 17a, b: Org v Raj Viscous G air Prod O

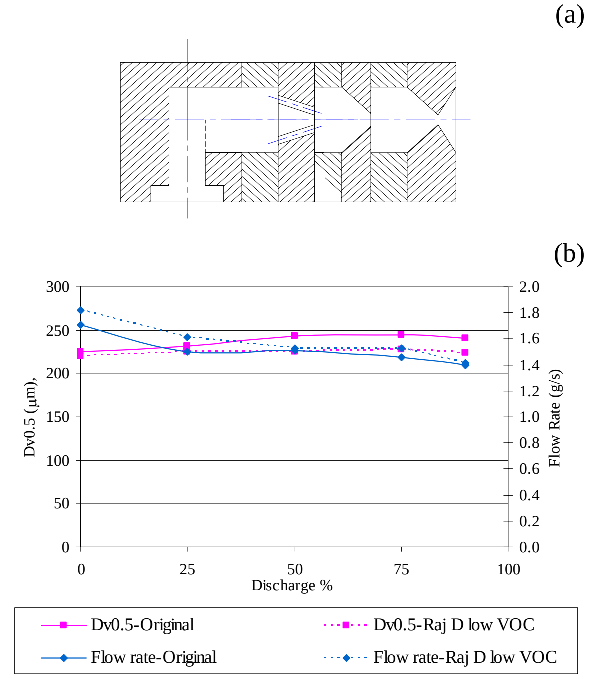


Fig 18a, b: Org v Raj Viscous B (Org), Product O

Concluding Remarks:

More complex designs of household aerosol can actuators have been made possible by using a new manufacturing technology.

This has made feasible the use of various flow control devices, throttles(s) and pre throttles, and multiple orifice actuators, shaped chambers with no cost penalty.

An experimental research programme has systematically applied these flow control devices in specially made actuator models for the cases of spraying those very different types of products, non viscous, anti-perspirant, hair spray, body spray, air-freshener and viscous products, polish, oil and paint.

The experiments have shown that these flow control devices permit control of droplet size, control of flow rate, spray pattern manipulation, the production of narrower droplet size distributions, and reduction of can VOC content.

From the experiments carried out by Raj designs on reduced VOC hair spray, body spray and oil. These designs improved the inhalables on anti-perspirants. It has proven that great improvements on reduction of drop sizes and crucial reduction on inhalables by keeping the flow rate the same with comparison to the original cap

More advanced designs of actuators has been made depending on the inventions related to shape chambers, multiple passage of flow and throttles. It is now possible to manufacture household can aerosols such as air fresheners, body sprays and hair sprays with massive reduction in hydrocarbons or volatile organic compounds (VOC).

Also some of these designs can help to atomise viscous fluids such as oil, polish and paint. Also these designs can work with compress gas can products. From the experiments carried out it is obvious that these designs helped several products which was rather difficult not a long time ago. It is also helped to reduce the inhalable of these cans especially with the anti perspirant, oil and paint.

References

1. BAMA, "Scoping study: the futures of aerosols". British Aerosol Manufacturing Association, London, Nov. 2001.

2. An atomizing Nozzle and An aerosol canister comprising an atomizing Nozzle, UK patent publication No. WO2007015062 (A1), World Intellectual Property organization application No. W02006GB02745 20060720(2007-02-08), inventor, Rajab Sharief.

3. Shaped Chamber, Nozzle arrangement, UK patent Publication No. WO2005005053 (A1), World Intellectual Property organization application No. W02004GB02848 20040702 (2005-01-20), inventors Keith Laidler, Rajab Sharief and Hassan Abduljailil.

4. Multiple Passages, Nozzle arrangement, UK patent publication No. WO2005005055 (A1), world intellectual property organization Application No. W02004GB02898 20040702 (2005-01-20), inventors Keith Laidler, Rajab Sharief and Hassan Abduljailil.

5. Flap Arrangement, Nozzle arrangement, UK patent publication No. WO2005005054 (A1), world intellectual Property Organisation Application No.W02004GB02851 20040702(2005-01-20), inventors Keith Laidler, Rajab Sharief and Hassan Abduljailil.