

Novel Developments in Actuator Designs for Flashing Household Aerosols

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Abstract

With increasing legislation on volatile-organic-compounds, there is interest in either reducing the hydrocarbon content in aerosol cans or removing it completely, i.e. using inert compressed gas propellant. However both these approaches give relatively poor atomisation unless improvements in atomisation performance are made. This paper describes experiments that have been carried out to explore the effects of flow control devices on the flashing flow and the quality of the spray and which are leading to new generation of household aerosols.

Introduction

Because of the ease of atomising by using a flashing propellant, there has been remarkably little published research on how the internal geometry of the actuator affects performance, where the actuator is the cap of the can, which fits on the valve and contains the exit orifice. The exit may be a simple orifice, such as for antiperspirants, or a swirl-insert, for example for polish and paint sprays. Currently the propellants used are blends of liquefied hydrocarbon, mainly butane and these are classified as Volatile Organic Compounds (VOC's). Legislation controlling VOC use is becoming increasingly strict and is already affecting the household aerosol market in California [1]. 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].

The aims of this investigation are:

- To develop improved, aerosol actuators using a new manufacturing technology.
- To reduce VOC content of existing aerosol cans, e.g. butane reduction and ethanol replacement by water.
- To achieve spray performance at least matching the characteristics of existing aerosol air fresheners, deodorants, hair spray and body sprays.
- To gain improved understanding of internal flashing flows.

2. New Actuator Manufacturing Method

The practical utilization of more complex designs of nozzles in household aerosols is made possible by a new manufacturing procedure. Figure 1a shows a typical aerosol can where the "actuators" is that part that fits on the valve. Most actuators [2] are in two parts, the main body and the exit orifice insert. A new injection moulding technique, allows the actuator and exit orifice to be made as one part, as illustrated in Fig. 1b [3]. This is achieved by moulding a hinged cap as one unit that fold together after manufacture. Apart from the advantage of cost, it is now possible to incorporate a

wide range of flow control devices and orifice designs into a single injection moulded part.

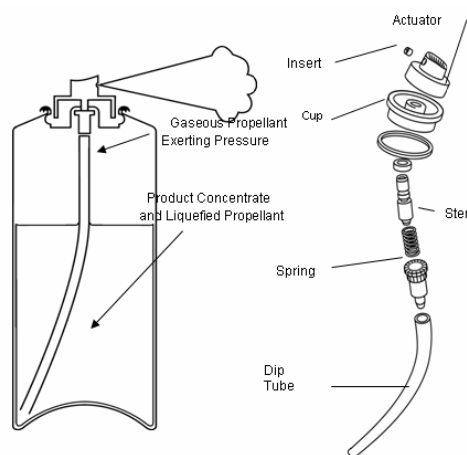


Figure 1a: Typical aerosol can and valve system (Courtesy BAMA, London)



Figure 1b: New actuator technology design [3].

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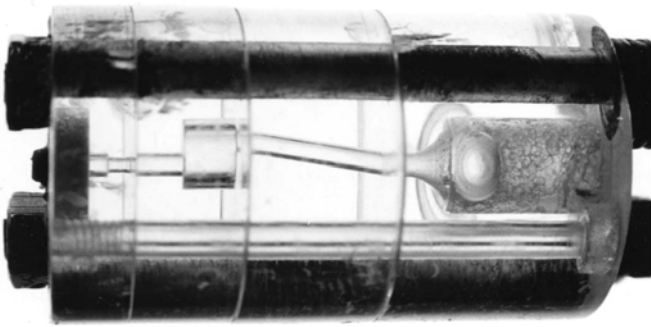


Figure 2: Top view of Raj D35 anti-perspirant atomizer

3. Apparatus and procedure

An experimental programme has used transparent actuator caps, as in Figs 2 and 3 with high-speed video recording, and droplet sizing using a laser diffraction instrument. The actuators in the research programme have been specially machined from Perspex (Plexiglas) and a method of unit construction has been developed so that combinations of different shapes and sizes of internal passages and flow control devices may be tested systematically. Figure 2 shows an example of one of the assembled units and figure 3 shows the internal features the design, as developed for spraying anti-perspirant. 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. Flow rate was measured by weighing the can. Key features of the devices are the throttle(s), leading to the pre-chamber and exit, and Fig. 4 and Table 1, illustrate some of the designs that have been used for the throttle and exit sections with codes that are referred to subsequently.

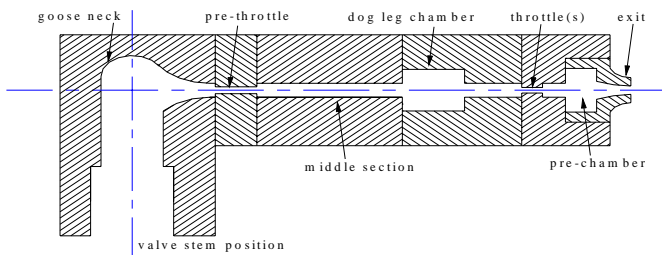


Figure 3: A typical Raj Design 35 developed for anti-perspirant sprays.

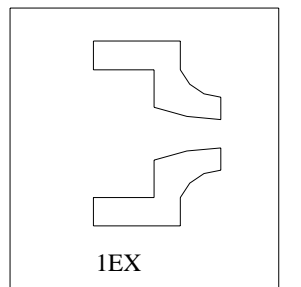
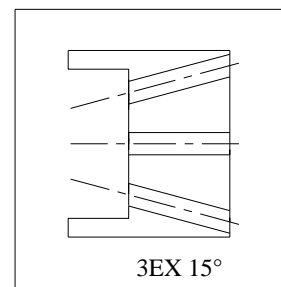
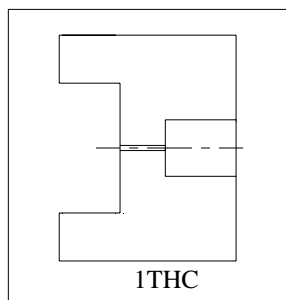
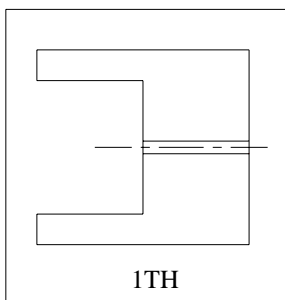
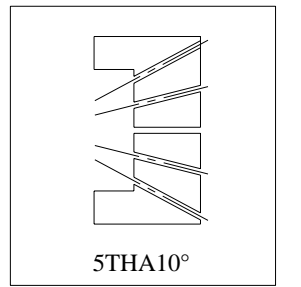
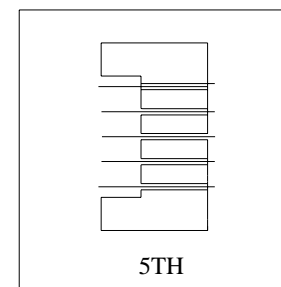
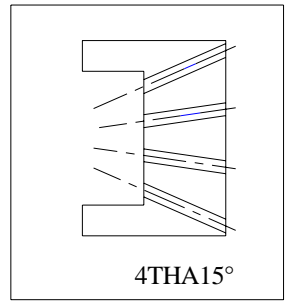
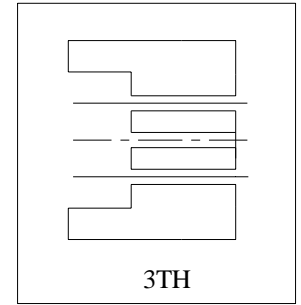
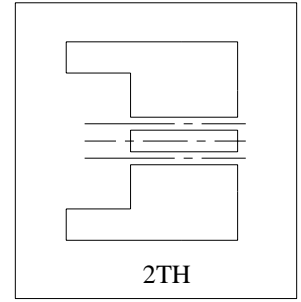
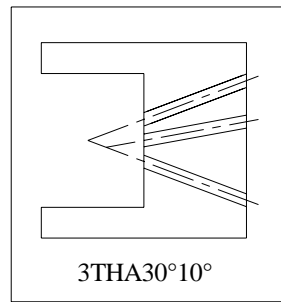
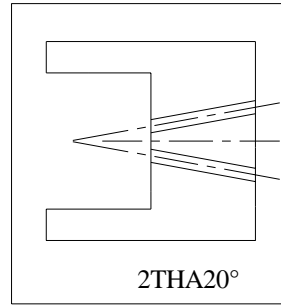
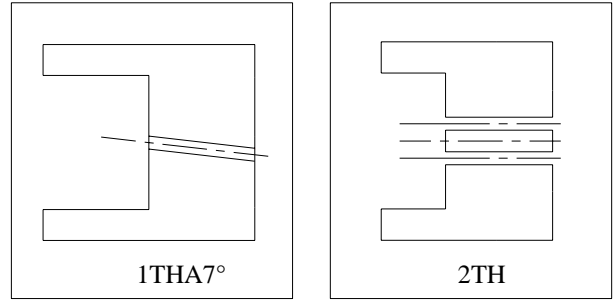


Figure 4: Throttles and exits models

Design.	Throttle/Exit
1TH	One throttle
1THC	One throttle with chamber
1TH A7 °	One throttle angled 7°
2TH	Two throttles
2TH A20 °	Two throttles angled 20°
3TH	Three throttles
3TH A30°A10 °	Three throttles angled 30° & 10°
4TH A15 °	Four throttles angled 15°
5TH	Five throttles
5TH A 10°	Five throttles angled 10°
1 EX	One exit, Simple pre-chamber
3 EX 15°	Three exits angled 15°

Table 1: Design descriptions.

As seen in Figure 3, there is a “throttle” stage leading to a pre-chamber followed by an exit orifice stage. Figure 4 shows a selection of the different throttle and exit stages that have been tested for different products.

4. Discussion

Considering first anti-perspirant sprays, these contain complex combinations of powder, silicone oil, perfumes and additives as well as the liquid hydrocarbon. Systematic tests were undertaken, in the first instance in order to attempt to reduce the inhalable fraction of droplets, i.e. the percentage of droplets smaller than 7 microns. Figures 2 and 3 illustrate flow control devices that have been explored, including a "dogs-leg", for breaking up unsteadiness and segregation after the valve and corner, and a pre-chamber before the exit orifice.

The throttle provides 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 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. Fig. 5 shows size distributions for the new actuator and a typical current commercial design, and Figure 6 shows the performances of the two designs during the life times of aerosol cans.

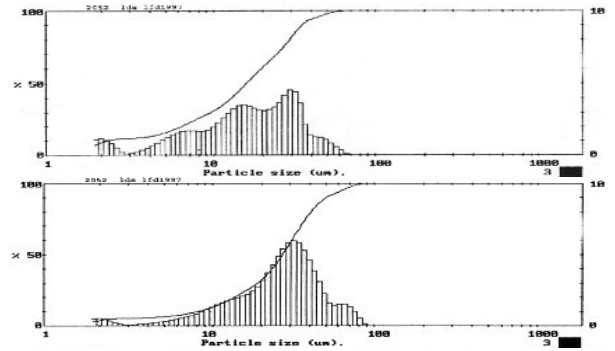


Figure 5: Anti-perspirant drop size distributions, (top) from a standard commercial actuator and (bottom), from new design.

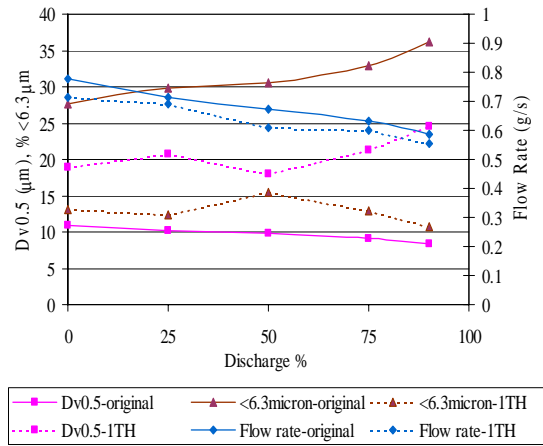


Figure 6: Performance of present and new

Figure 7, 8, 9 and 10 shows graphs for four different products, A, B, C and D using same Design 35 for anti perspirant and how the new technology design has advantage on original design, all results showing great reduction on drop sizes and inhalables.

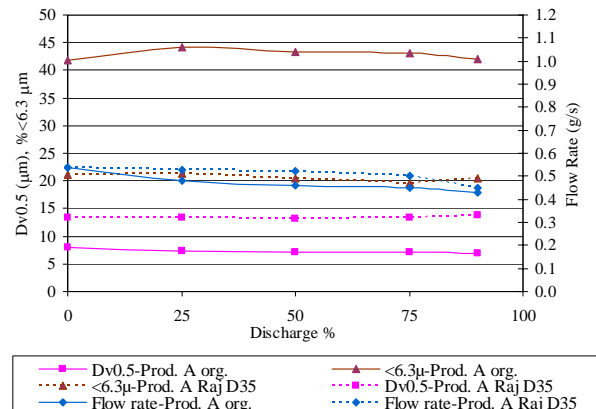


Figure 7: Anti-perspirant, product A

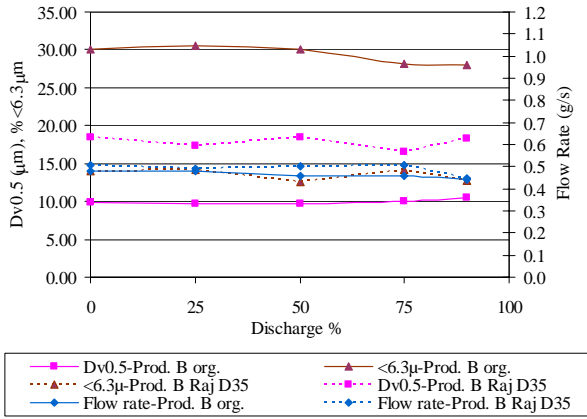


Figure 8: Anti-perspirant, product B

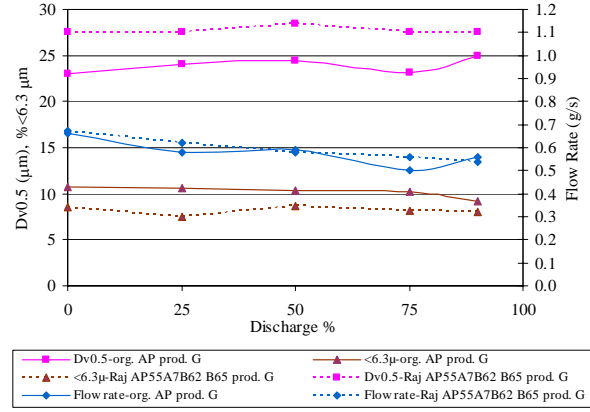


Figure 11: Anti perspirant, Product G

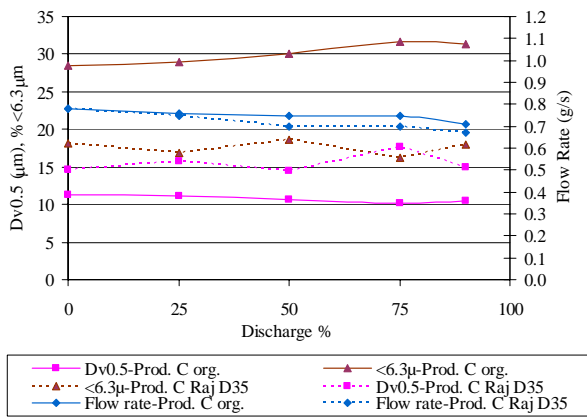


Figure 9: Anti-perspirant, product C

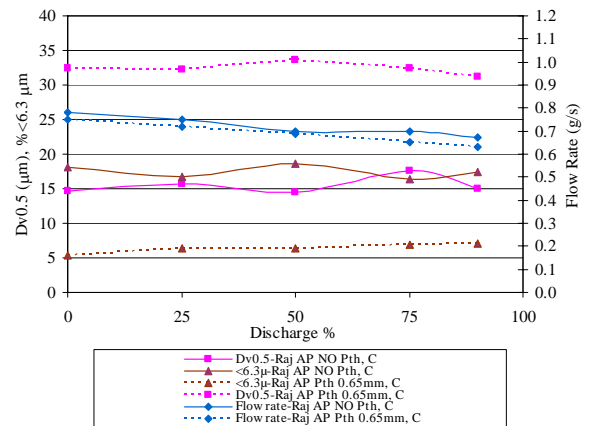


Figure 12: Anti perspirant, Product C

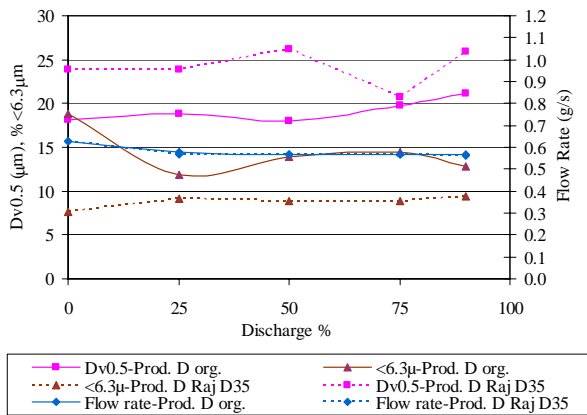


Figure 10: Anti-perspirant, product D

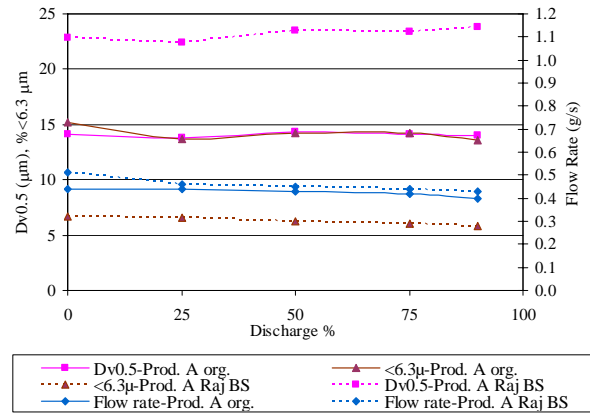


Figure 13: Body spray, Product A

Figure 11 shows the effect of pre-chamber just before the simple exit on the drop size, the shorter expansion chamber shows better effect on reduction of drop size on anti perspirant when using Raj D55A7B62.

Figure 12 demonstrates the effectiveness of the pre-throttle on inhalables on anti perspirant product A by two third when using pre-throttle compared with no pre-throttle, Raj D35. Also the pre-throttle sizes needs to be optimized.

On Figure 13, the graph shows obvious reduction in inhalables of product a body spray using Raj BS design with comparison to original caps.

It has also been proven for anti-perspirant cans that another, upstream, "pre-throttle", see Fig. 3, has a strong effect on the flow rate. Therefore a pre-throttle can control the flow rate without necessarily having an effect on the drop size. For anti-perspirants it has also been shown that the spray angle is increased by making a countersink in the exit orifice up to 40° angle to the axis, and the drop size remain unchanged. As illustrated in Fig. 14 using a "dogleg" (Fig. 3) results in finer

droplet sizes distribution than those obtained using models with no dogleg, with little effect on flow rate using 1THA7° throttle.

Several products of hair spray have been tested with design 3TH, and using three throttles and one exit and results are shown in Table 2 and Fig. 15. Different products have different characteristics such as flow rate, drop size diameter or inhalables, all these products has been tested with their original caps, the comparisons with Raj D35 design shows an obvious improvement in terms of a reduction in drop size. Such a reduction in drop size permits reduction in the butane content of each can.

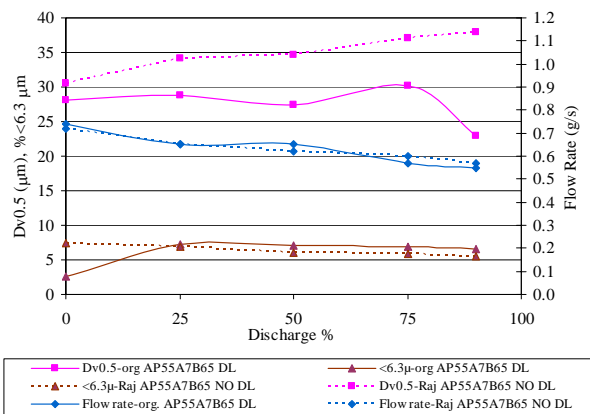


Fig 14: Effect of dog-leg on break up droplets-prod G

	Flow rate (g/s)	Dv0.5, micron	Flow rate (g/s)	Dv0.5, micron
Design 3TH232	0.82	43.0	0.80	38.0
Product 1	0.65	37.0	0.63	35.0
Product 2	0.84	32.0	0.81	28.0
Product 3	0.53	23.29	0.50	20.03
Product 4	0.72	66.92	0.70	52.05
Product 5	0.82	43.0	0.80	38.0

Table 2: Hair spray characteristics for different products.

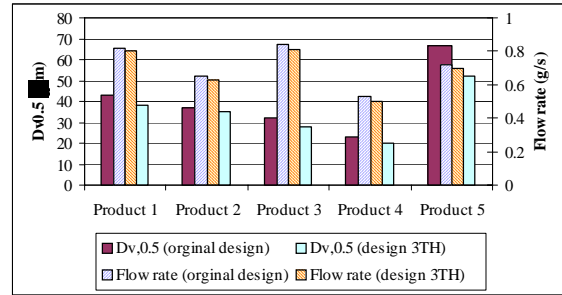
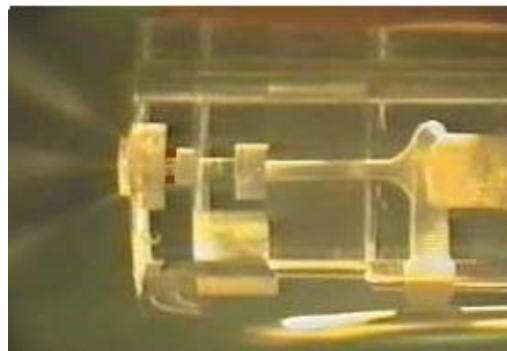


Figure 15: Performance of design 3TH, with hair spray products using multi throttles with a single exit.

Another example of application of the new actuator technology is the achievement of a major reduction in hydrocarbon content for air-freshener sprays, 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. Figure 16 shows a design which provides a very significant reduction below the typical current level of around 30% VOC. Reduction in can VOC content is obtained without worsening the drop size distribution (volume and median diameter is around 40 micron for air fresheners). It can be seen from Fig. 17, that the multiple sprays, produces by the multiple small exit orifices soon combine downstream. The multiple throttles act as turbulence generators, whilst also producing vapour release.



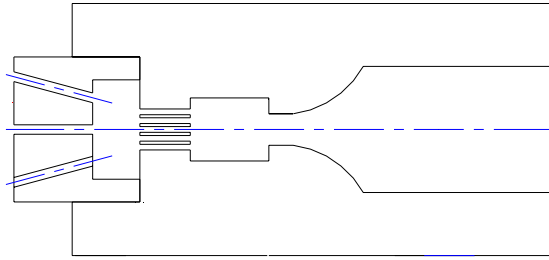
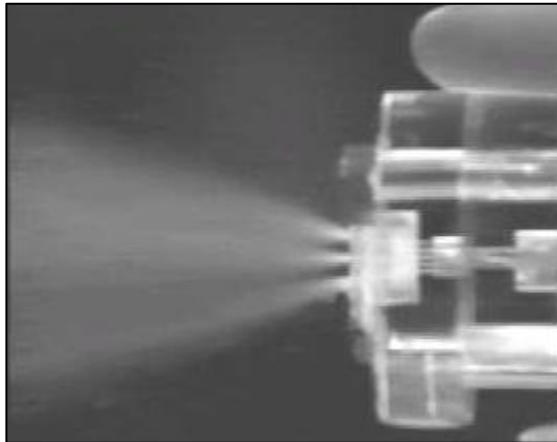
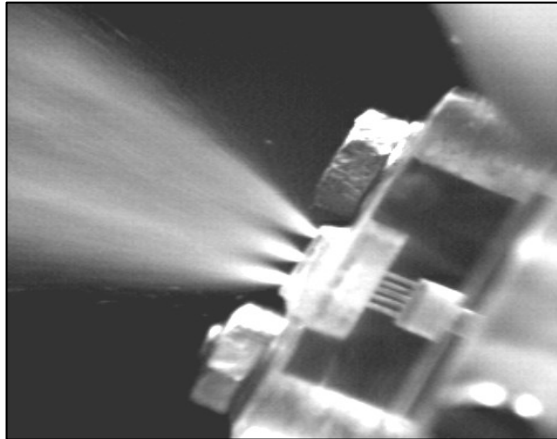


Figure 16: Designs for reduced VOC products.



Figure 17: Multi exits and multi throttle models for air fresheners with reduced VOC.



5. 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 and multiple orifice actuators, 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, anti-perspirant, hair spray and air-freshener. 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 Design 35 on several products, 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.

References

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