# Further Developments in Actuator Designs for Flashing Household Aerosols-Hair Spray

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**Abstract**

There is an 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 atomization unless improvements in atomization performance are made. Currently the propellants used are blends of liquefied hydrocarbon, mainly butane and these are classified as Volatile Organic Compounds (VOC's). This paper describes experiments that have been carried out to explore the effects of shaped chambers, partition, multiple passages and throttles on the spray quality of reduced VOC products, mainly hair spray causing pressure drops, turbulence, circulation, vaporization and consequently reducing particle sizes, 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 such as hair spray.

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. [5] The aims of this investigation are: to develop improved, aerosol actuators, 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, hair sprays, to gain improved understanding of internal flashing flows

Partitions has played a great role in having new designs working well with reduced VOC's products, non viscous products such as air fresheners, body spray and hair sprays, viscous products such as oil and polish also worked remarkably well with compress air products. The partitions create more turbulence and break up, consequently producing fine droplet. This paper is related to an innovation patents WO2005005053 (A1) and WO2005005055 (A1) and WO2007015062 (A1). [1-4]

The actuators in the research programme have been specially machined 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.

The 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. Key features of the devices are inlet, shaped chambers and inserts, throttle(s), leading to the pre-chamber and exit. 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.

Applications of Raj's designs have achieved of a major reduction in hydrocarbon content for hair spray, air-freshener, and body 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. Reduction in can VOC content is obtained without worsening the drop size distribution which is around 30 to 60 microns.

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**Introduction**

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 size of the aerosol droplets produced by 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 arise if it is desired to produce a spray that comprises small droplets with a narrow droplet size distributions, particularly at a low pressure. 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, when fluids contains in the can 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 quality spray at low pressures is further exacerbated if the fluid used has a high viscosity because it becomes harder to atomize the fluid into sufficiently small droplets. This is a new innovation which has been developed and tested to enhance the quality of spray of aerosol products with very low volatile organic compound (VOC). The partitions, shaped chamber and throttles have been used in the chamber where the flow passage of the design actuator .partitions can takes different shapes. The key design of these shapes is made to obstruct the flow in the centre of the flow.

**Materials and Methods**

Droplet size was measured using a laser diffraction instrument (Malvern and Spray Tec.), an average of three tests had been taken for each data point; flow rate was measured by weighing the can, the spray time was on average of five seconds. Spray distances from the lenses is 200-250mm for hair spray.

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 and exists can be used. 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, 20 centigrade. Internal features of Raj designs, as developed for spraying air fresheners, anti-perspirant, body spray, hair spray, polish, oil and paint were used.

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. The types of Hair Spray has been used in this programme are: Easy (slight reduce VOC) product M, Moderate ( reduced VOC ) product H, L, Hard ( further reduced VOC ) product J, K, Spray distance from lenses 200-250mm.

**Results and Discussion**

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, with 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 a 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. The advantage of a shaped exit over a swirl exit is very obvious, it produces a 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 an angled throttle hitting the pre-chamber and the other design using a bigger pre-chamber, both of which were consistent in drop size distribution and inhalables. Figure 6 use the same product with figure 6a using a 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.

Three other products of hair spray have been tested with different designs, using partitions in a chamber with different types of exits; results are shown in Fig. 8 to Fig. 13. Figure 8c shows the performances of the two designs during the life times of the hair spray aerosol. Both designs in Fig. 8a and 8b produces similar results although a swirl Was used as an exit in Fig. 8b, but because of Raj's diamond shape used in Fig.8b the performance looks the same. As illustrated in Fig. 9a, b and c using a "KS6 swirl" results in finer droplet sizes distribution than those obtained using models with "KS65 swirl", with little effect on flow rate, using diamond chamber, and two throttles hitting each other in a pre-chamber then a swirl. Fig. 10 and fig. 11 show a comparison of KS6 and KS65 design with their original cap. Fig. 12a, b demonstrates advantage of the diamond chamber design to original cap in terms of finer droplet sizes. It can be seen from Fig.13 a, b that the partition positioned in the diamond chamber; produces by the multiple exits hitting each other soon combine downstream, the partition act as turbulence generators, whilst also producing vapour release.

The model designs 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 rate. "Throttle" stage, could take different forms, such as two throttles hitting each other in figure 3a, a pre chamber which create more droplet breaks or single or more angled throttles hitting the wall as shown in figure 4a, 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 and figure 8a.

Rajab's diamond shaped chambers such as the designs in figures 1a and 2a and 8a to 13a consist of divergence conical leading to a chamber followed by a convergence conical. The chamber length of the chamber can be optimised. Raj's shapes "partitions" can be positions in chambers shown in figure 8a to figure 13a. These shapes can help to create more turbulence.

**Concluding Remarks:**

More complex designs of household aerosol can actuators have been made possible by using a new manufacturing technology. This has made it feasible the use of various flow control devices, throttles(s) and pre throttles, and multiple orifice actuators, partitions and 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 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, these designs 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 have been made depending on the inventions related to shape chambers, multiple passages 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**

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

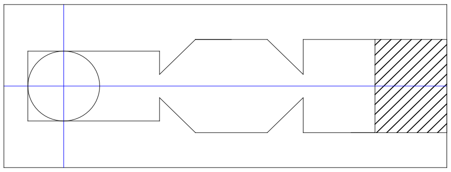

**Figure 1a:** Hair Spray - Raj 020604 2J

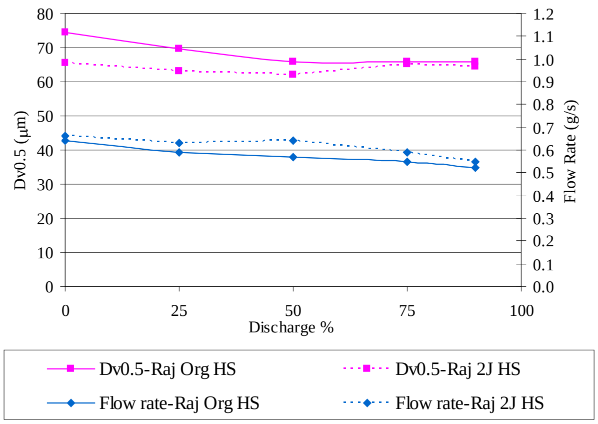


**Figure 1b:** Hair Spray, Prod J Org v Raj 020604 2J

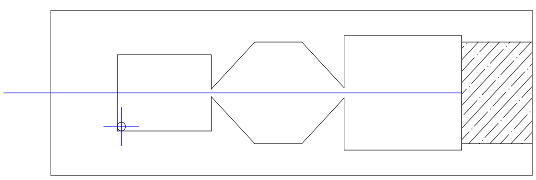

**Figure 2a:** Hair Spray - Raj 170805 D2

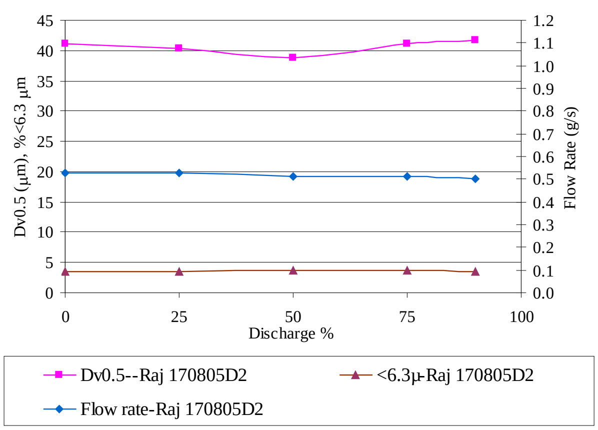


**Figure 2b:** Hair Spray, Product H Raj 170805 D2

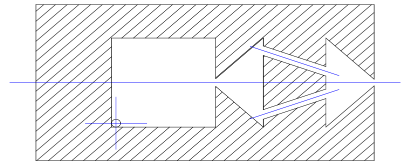

**Figure 3a:** Hair Spray - Raj 0606A

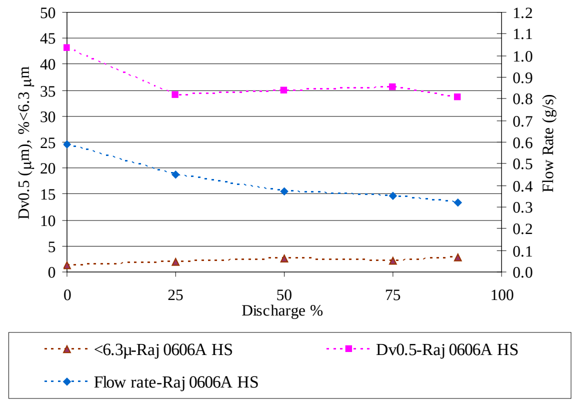


**Figure 3b:** Hair Spray, Product H v Raj 0606A

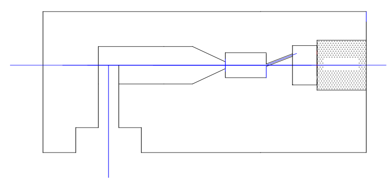

**Figure 4a:** Hair Spray - Raj 55A7

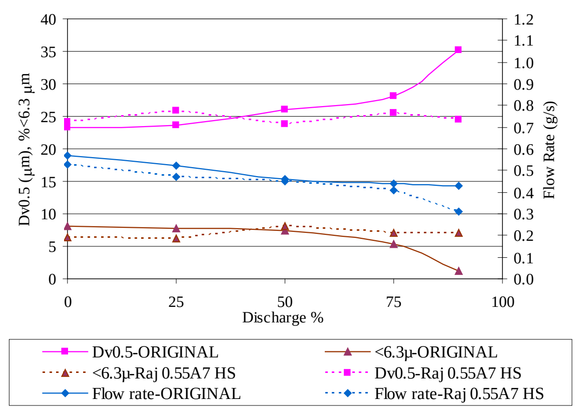


**Figure 4b:** Hair Spray - Raj 55A7

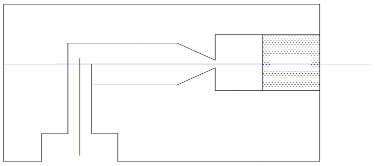

**Figure 5a:** Hair Spray - Raj VI

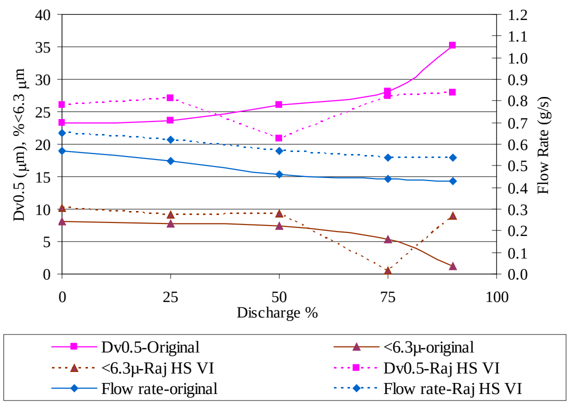


**Figure 5b:** Hair Spray - Raj VI

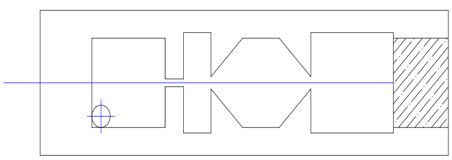

**Figure 6a:** Hair Spray, Raj 170805 D1

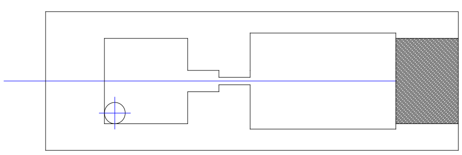

**Figure 6b:** Hair Spray, Raj 170805 D2

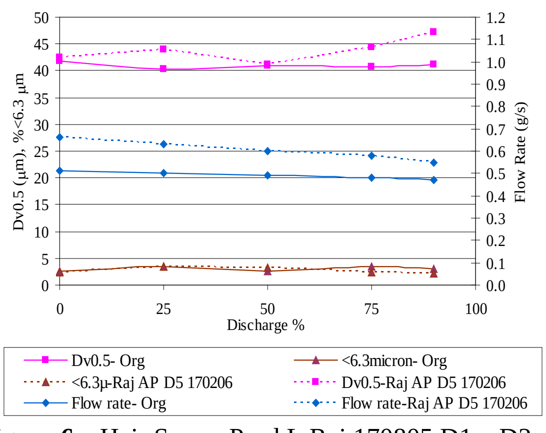


**Figure 6c**: Hair Spray, Prod L Raj 170805 D1 v D2

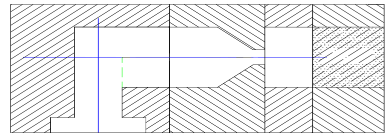

**Figure 7a:** Hair Spray - Raj 457

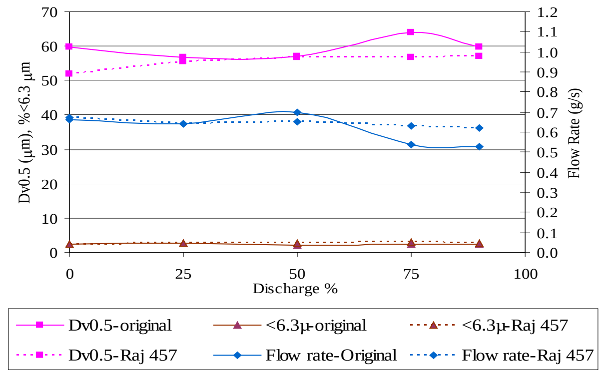


**Figure 7b:** Hair Spray - Raj 457

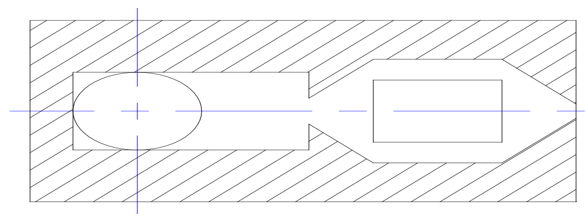

**Figure 8a** Raj 060405 HS

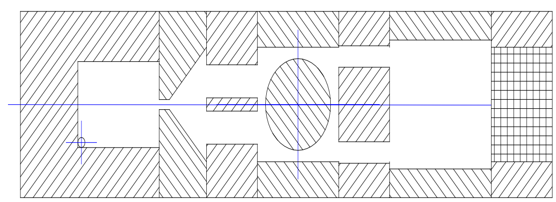

**Figure 8b:** Raj 170805 D1 HS

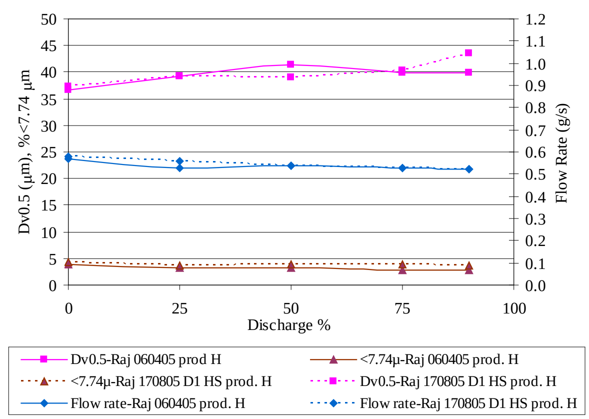


**Figure 8c:** Raj 060405 vs 170805 D1 HS Prod. H

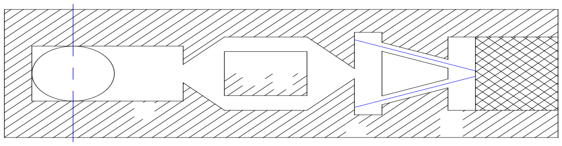

**Figure 9a:** : Raj 060605 HS

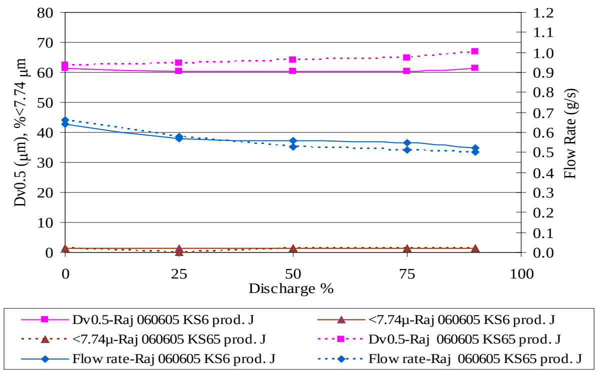


**Figure 9b:** : Raj 060605 KS6 vs 060605 KS65

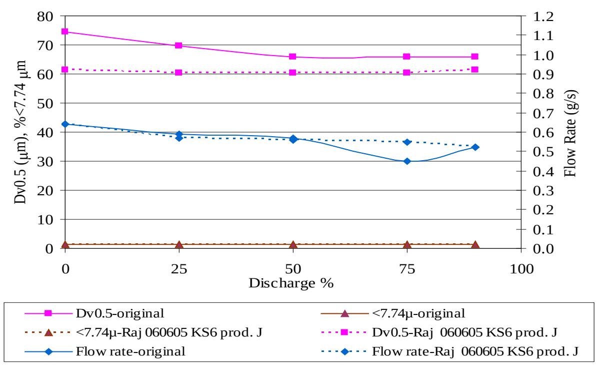


**Figure 10**: Original vs 060605 KS6 product J

(a)

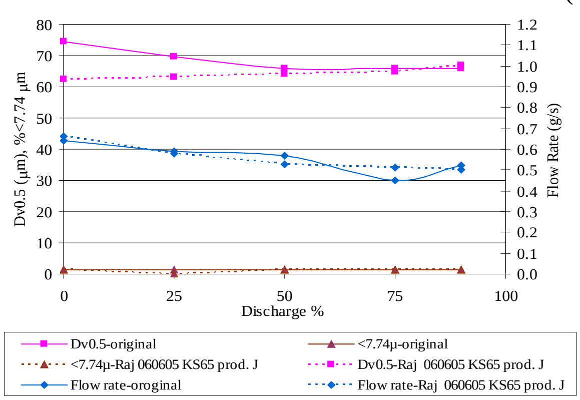


**Figure 11:** Original vs 060605 KS65 product J

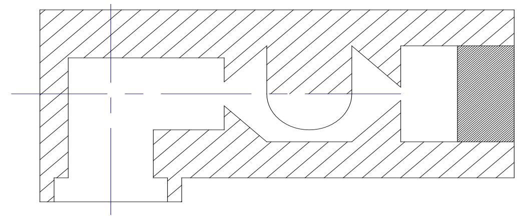

**Figure 12a**: Raj 060605(option3)

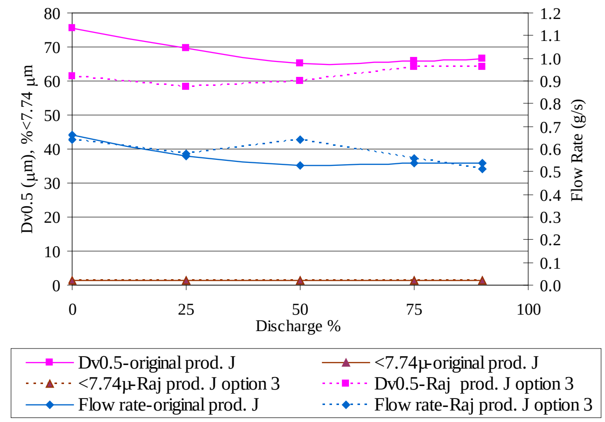


**Figure 12b**:Original vs Raj 060605(option3) prod. J

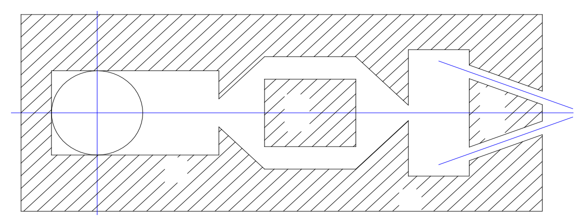

**Figure 13a:** Raj 40463 080605 HS

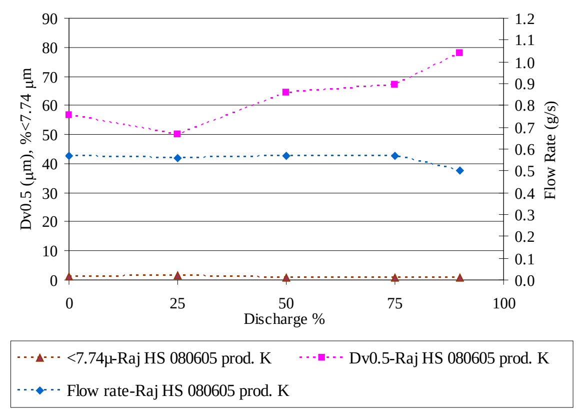


**Figure 13b:** Raj 40463 080605 HS vs product K