

## EXPERIMENTS AND COMPUTER MODELLING ARE COMBINED TO IMPROVE EMERGENCY SAFETY SHOWERS SHORT PROJECT DESCRIPTION PERDAC LTD, MANCHESTER, UK, JULY 2007

### Abstract

Emergency safety showers are used to decontaminate persons who have come into contact with hazardous substances. It is therefore important that the safety shower produces a sufficient deluge of water with suitable patterning to wash off the contaminant from the person. There is a proposed EU standard for shower heads which dictates a radial and circumferential distribution to which these emergency safety showers will have to conform. From research into current shower head designs, in relation to the proposed EU standard, it has been found that a number of these designs do not meet the proposed standard with regard to radial and circumferential distribution of water. Examples of this work are outlined here and revision of designs to meet the standards are described.

### Introduction

Safety showers are used to decontaminate individuals who have come into contact with hazardous substances. Standard practice is to apply water to the individual for 15 minutes [1], [2]. There are currently three main types of safety shower heads (each with many variations of details and made by many manufacturers). Each type produces a spray in a different manner.

These design types can be referred to as:

*Rose type* which delivers the water through a number of small orifices, rather like a watering can.

*Filmer type* which uses a combination of a bowl-shaped filmer surface and a central “diffuser” or impaction plate with a number of orifices to distribute the water.

*Nozzle type* which uses a swirler plate and a single outlet orifice to produce a spray.

PERDAC has experience [3] in analyzing the design and performance of all three types of shower. Here we briefly describe how Filmer type shower head designs were investigated and patterning tests were carried out to establish the circumferential and radial distributions. From these tests a design methodology was established via which detailed control of the radial and circumferential distributions was achieved. Hence the proposed EU standard [4] patterning for emergency safety showers could be obtained even though none of the commercial showers tested met this standard.

### EU Standard

The draft EU standard for overhead emergency shower head designs, at the time of writing, states that the design should meet the following requirements [4]:

1. Constant flow of water supplied by the shower head at at least 60 l/min and at a minimum flow pressure of 1bar measured where the shower is connected to the water system. The shower head shall be capable of delivering this supply for a minimum of 15 minutes.
2. As shown in Fig. 1, at a distance 700 mm below the shower head, 50%,  $\pm 10\%$  of the volume of water delivered shall fall in a circle with a radius of 200 mm; the water level in the individual containers in this circle shall not deviate by more than 30% from the mean value.

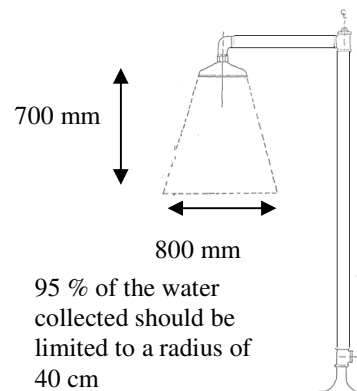


Figure 1: EU plumbed in shower standard.

3. At this measuring level, the area reached by 95% of (minimum) of the water shall be limited to a circle with a radius of 400mm.

- The water spray pattern shall be such as to ensure that it is possible for a person underneath the shower to breath normally and the velocity of the spray shall be low enough to be non-injurious to the user.

### Experimental Apparatus

The test rig was constructed from aluminum box sections which incorporated grooves that allowed the pattenator and shower head support frame to be moved vertically. Perspex sheets were attached to three sides of the test rig to contain the spray, as shown in Fig. 2. Water was supplied fom a header tank, which also incorporated a heater, which allows the temperature of the water supply to the shower head to be adjusted. A pump is used to obtain the desired flow rates of 60 l/min. A rotameter is used to set the flow rate, which is controlled by a valve. Water from the shower head is collected in a sump which discharges to the factory drain.

### Patteration Tests

Patteration test were carried out to measure the radial and circumferential distribution of the spray produced by the different shower head designs. The results of these measurements were then compared to the EU standard to see whether the shower head designs meet the required spray distribution.

The pattenator as shown in Fig. 3 consists of 17 collection sectors. The centre has a collection diameter of 200 mm and subsequent sectors are in annuli increasing in diameter by 200 mm increments up to the outer diameter of 1000 mm. Water that is collected in these sectors passes through drain holes into 10 litre measuring receptacles located under the pattenator. The height of the pattenator in relation to the shower head can be adjusted using the adjustable arms that the pattenator is mounted upon, as shown in Fig. 2. The sector was therefore kept as one with a diameter of 200 mm. This would approximately represent the area of the head

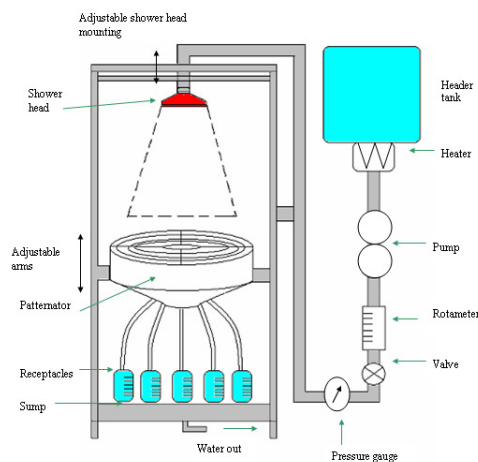


Figure 2: Schematic of the test rig.

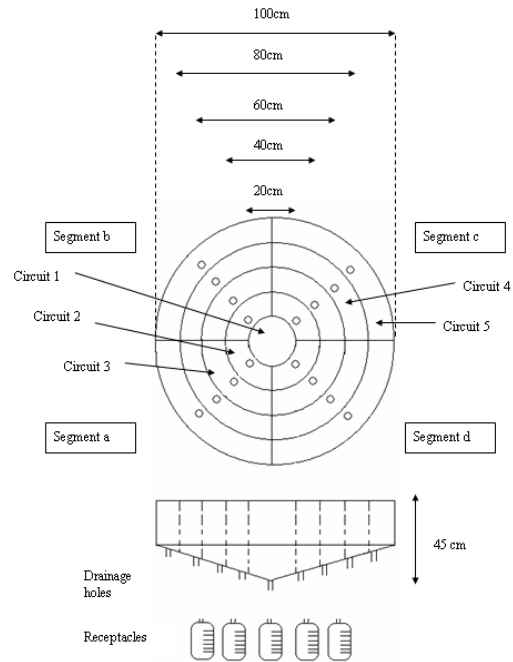


Figure 3: Pattenator.

of a person being decontaminated. An important criterion for the shower head is to deliver sufficient water into this central area, as it ensures the water will be covering the head.

As shown in Fig. 3, circuit 1 was not divided into 4 segments as the collection areas would have been too small. The circumferential distribution for the water collected within a 200 mm radius was calculated by firstly, area-weighting the water collected in circuit 1, and in the segments in circuit 2. A mean was calculated from these five values and, for satisfactory coverage in this central area, individual values had to be within 30% of this mean value.

During the post-processing the total flow rate collected in all the 5 circuits was compared with the total theoretical value of 60 l/min. During testing collected values were within  $\pm 5\%$  of the theoretical value. If this was not achieved the pattenation tests were repeated.

### Current Filmer Designs

It was found that all of the filming type of shower heads that were tested produced unsatisfactory spray patterns that failed to meet the proposed EU standards. Typical examples are shown in Fig. 4. The Filmer A and Filmer B shower heads are very similar in design, but not in performance. The design consists of an inner impact (diffuser) plate which has a number of perforated holes, producing the inner spray, and an outer

filming bowl. A proportion of the liquid escapes through a slot between the impact plate and the bowl and leaves the lip of the bowl to form an annular spray.

The current designs though similar have different problems associated with them:

Filmer A suffers from very poor circumferential distribution, as seen in Fig.5, partly due to poor filming on the bowl, as shown in Fig. 4, whilst Filmer B produces a very good film but lacks suitable radial distribution due to surface tension pulling the film inwards. This results in large amounts of water being collected in the central collection area, as shown in Fig. 6. Both designs suffer from the holes in the impact plate not discharging when full (i.e. not completely flooded) and with a number of holes not discharging water at all.

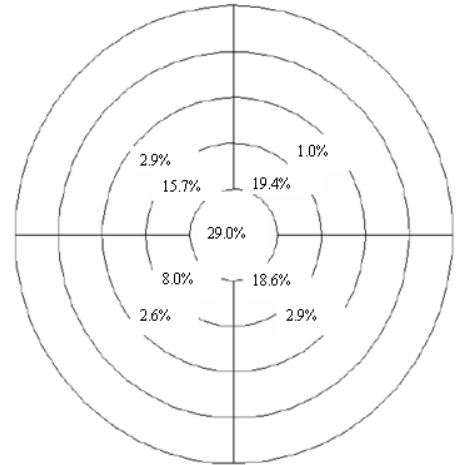


Figure 4: Filmer designs: "A" on left, "B" on right



4.5% of the water volume collected within a radius of 20cm (fails EU standards).

Figure 5: Filmer A patternation results (% water collected).



90.6% of the water volume collected within a radius of 20cm (fails EU standards).

Figure 6: Filmer B patternation results (% water collected).

### Modified Filmer Design

As shown in Fig. 7, these shower heads try to combine a central sprinkler (from the impact plate) and an outer spray curtain (from the filmer bowl). A design aim should be that the two sprays combine to give even coverage at 700 mm downstream, with 50% evenly distributed within 200 mm radius and the rest within 400 mm radius. To take into account over-spray from the inner area, a 55%: 45% inner to outer split was chosen as a 'first guess' at what was

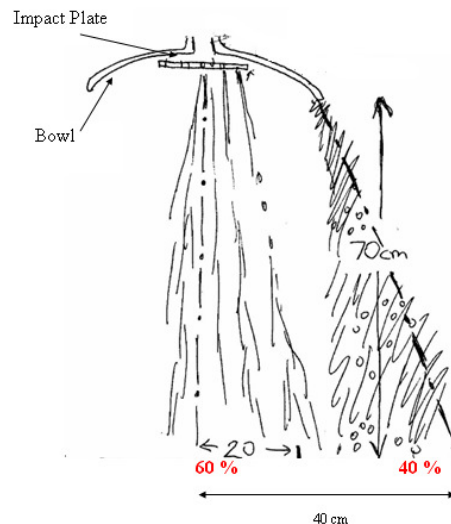


Figure 7: Desired flow split.

really required, this split being controlled by the total of the orifice areas in the impact plate, compared with the orifice area of the annular slot.

Experimental testing was combined with computational modelling in order to determine the performance of a new filmer shower head, as a function of the following parameters, as shown in Fig. 8 and these will be discussed in turn:

- Flow split
- Bowl shape
- Impact plate hole arrangement and filmer gap

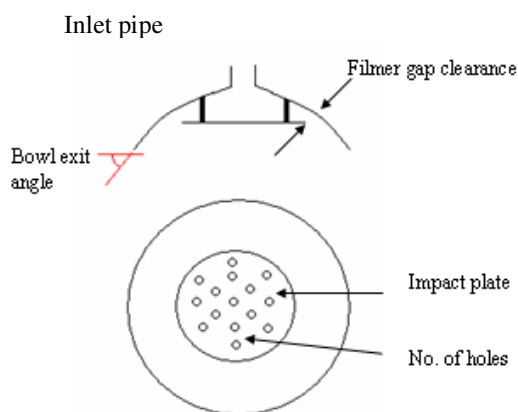


Figure 8: Main features of filmer designs.

### Flow Split

As mentioned, an approximate 55:45% flow split between the inner and outer flows was initially desired, with 55% of the water passing through the impact plate and 45% of the water passing through the filmer slot and on the bowl surface.

Inlet Pipe Area (mm <sup>2</sup> )	555	555	555
Filmer type	A	B	New
Impact plate hole area (mm <sup>2</sup> )	471	808	342
Filmer gap area (mm <sup>2</sup> )	1885	3874	471
Total discharge area (mm <sup>2</sup> )	2356	4682	813
Inner/outer flow area split (%)	20	17	42

Table 1: Hole areas.

It was shown that an important design criterion is that, to ensure the flow areas are flowing full (flooded), the total exit area (impact plate holes + filmer gap) has to be similar to the inlet area of the supply pipe. The flow split was calculated for the designs, as shown in Table 1.

It is clear from the Table that Filmer A and Filmer B have too much discharge area when compared to the total pipe inlet area. That is one of the main reasons why a number of the holes in the central impact plate were not flooded, resulting in jets of water being discharged at high ejection angles. This results in the majority of the water discharging from the holes in the impact plate spraying past a radius of 200mm, which is undesirable. In the modified design a 42% inner to outer flow split has been achieved along with a significant reduction in the total discharge area in relation to the inlet pipe area.

### Bowl Shape

The exit angle of the bowl is important in achieving the required radial water distribution beyond 200 mm radius (at 700 mm downstream). The initial bowl exit angle  $\theta$  for both filmer designs was between 10° and 15° from the vertical. This explained the limited radial water distribution with these bowl arrangements. Experimentation into cutting back the filmer bowls (and thus increasing the exit angle) has shown that a suitable radial distribution can be achieved with an exit angle around 45°.

This was confirmed, and the optimum angle was obtained, by using a droplet trajectory computational model to predict the radial distribution of the spray. The boundary conditions of the model describe the droplet position, size and velocity as it leaves the filmer lip. From this a trajectory for the droplet is calculated, as shown in Fig. 9. The trajectories shown are for the modified filmer bowl with a 45° exit angle and compared with the case for Filmer A. It has to be noted that the droplet radius and initial velocity is different in each case to reflect the reduced filmer gap in the modified filmer bowl design. As can be seen the radial distribution is increased substantially from the original filmer designs.

### Impact (Diffuser) Plate

#### Hole size

The impact plate hole area is calculated based upon an inner to outer flow split of 45% of the total inlet area and maximising the number of holes consistent with avoiding atomization that is too good (giving fine droplets that do not perform the required flushing process). Our investigations, both computational and experimental, have shown that it is desirable that the holes are located as close to the centre line of the shower head as possible. The reason for this is due to the ejection angle of the jets of water from the holes. Even with the holes discharging

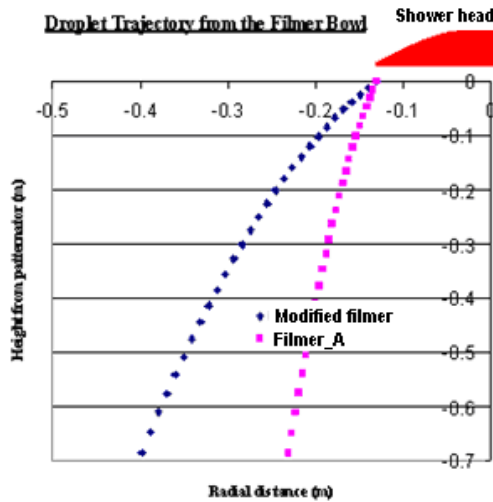


Figure 9: Droplet trajectory

in the “flooded” condition, the ejection angle can be between 10 and 20° from the vertical, which is enough to put the inner spray beyond a radius of 200 mm. This ejection angle tends to increase if the holes do not discharge “flooded”. The reason for the non-vertical jet angles is that the water streamlines approach the holes, inside the water approaching the diffuser plate, in a naturally diverging pattern.

The hole sizes for the impact plate was calculated from the inner flow area in order to have sufficient number of holes to ensure good circumferential patterning, and for the holes to be contained within a radius of 50 mm to prevent too much over spray (beyond 200 mm radius).

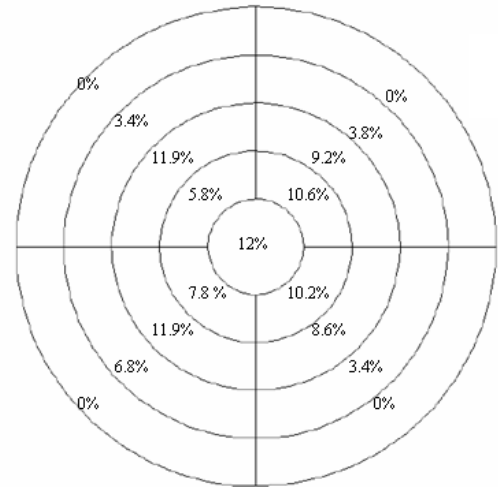
A flow straightener was added inside the pipe immediately upstream of the shower head, this significantly improve the symmetry and regularity of the shower.

Filmer Gap

The filmer gap clearance between the bowl and the impact plate is critical. If the gap is too large, the outer flow will take more of the inlet water due to having a greater area. If this gap is increased further the bowl will not film and water will just run off the topside of the impact plate. There is also a danger of not achieving a uniform film with a very small gap size, which would result in poor circumferential distribution.

**Modified Design Results and Discussion**

As a result of carrying out the aforementioned design changes, the modified filmer design produced the patterning results as shown in Fig. 10, with 46.7% of the water being collected within a radius of 200 mm (EU requirement, 50% ±10%). The circumferential water distribution is also within ±30% of the mean total water collected in circuits 1 and 2 for each individual segment within circuits 1 and 2. As shown in Figs. 10 and 11 the radial distribution is also greatly improved over the original designs, with the modified design achieving coverage out to a radius of 400 mm. The design therefore meets the proposed EU standard for emergency shower heads.



• 46.7% of water collected EU 60 l/min.

Figure 10: Modified filmer design to conform with EU standards (% water collected).



Figure 11: Modified filmer design (60 l/min)..

**Concluding Remarks**

In this investigation design procedures were developed to permit the filming type of shower head to be modified to meet the proposed EU standard for emergency safety showers.

The filming performance, and radial and circumferential water distribution have been substantially improved due to a number of design changes:

- Reducing the combined flow areas of the filmer plate slot and impact plate holes. This ensures the holes in the impact plate discharge flooded and

reduces the ejection angle so more water is concentrated within a radius of 200 mm.

- Splitting the inner and outer flow % more evenly
- Adding a flow straightener
- Reducing the exit angle of the filmer bowl.

A Conference Paper based on this work has been prepared [5] and complementary work evaluating shower efficacy, drop sizes, and shower momentum distribution has also been described [6].

#### **Acknowledgement**

Hughes Safety Showers Ltd (Stockport, UK) financed the study described here and we thank HSS for permission to present this information, particularly the Managing Director Mr Tony Hughes, and for the provision of facilities for the experimental work. HSS have IPR on aspects of the improved safety showers.

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