Water Efficiency Conference 2018

Thermal and flow distribution of showerheads as a method for understanding water user preferences

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Outline

- Introduction
- Methodology
- Results & Discussions
- Conclusions

Introduction

- At present, showers and showering account for 25-30% of daily per capita water use
- With a total consumption of over two billion litres per day, the shower is the highest water use function in the home
- The demand for separate shower cubicles has been increasing at ~20% per year since 1999
- An efficient shower system can therefore have significant impact on the domestic water and energy consumption.

Introduction

- **Various studies to date have looked at different aspects of shower use, including:**
  - **the use of efficient showerhead fixtures in relation to reductions in water use**
  - **shower performance in the context of awareness and habits**
  - **influence of shower monitors on water usage**
  - **comfort, lifestyles, performance or perceived needs against new efficient products.**

Introduction

- **The authors (Adeyeye & She, 2015) started a project that aimed at "Demystifying the showering experience" and sought to understand the influence of showerhead designs and physical performance characteristics on user behaviour.**
- **Initial findings (Adeyeye et al, 2017) showed the showerhead design characteristics had a clear impact on acceptability of water efficient showerheads.**

Introduction

- **In this presentation, we further explore the performance characteristics with respect to shower spray and temperature distribution and how these impact the degree of products being accepted or rejected by end users.**

Methodology

- 12x12x12 home experiment to gain user performance experience and feedback - ratings on performance of 12 different showerheads by 12 users over 12 weeks
- Controlled laboratory experiments: measurements of the physical characteristics and performance parameters of the shower-head at the point of water delivery e.g. on the human body, in addition to commonly measured parameters (pressure, flow rates etc.) at the point of supply

Methodology

Laboratory studies

Quantification of physical characteristics of showers

Surveys of end-user experience

Statistics of end-user experience

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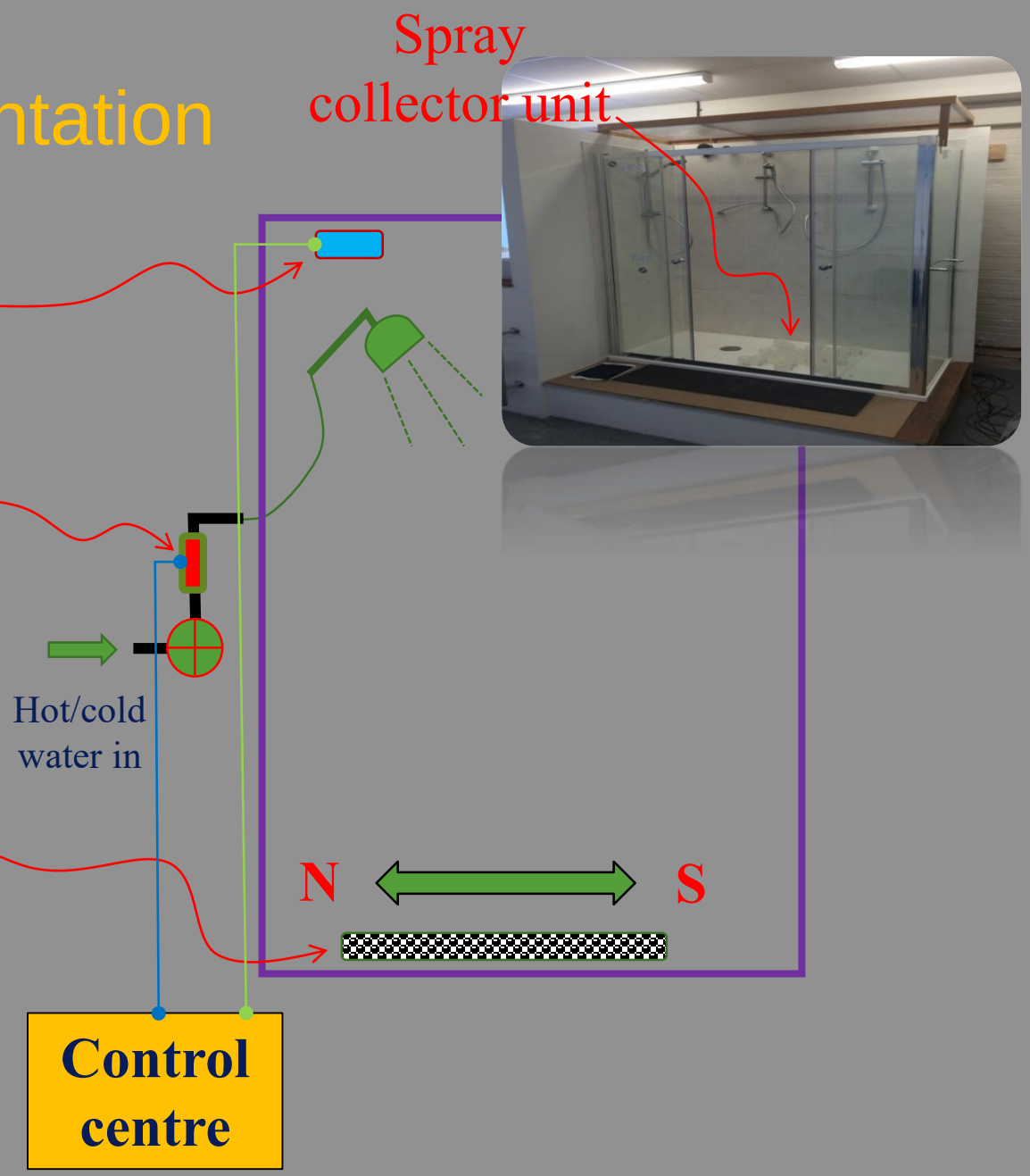
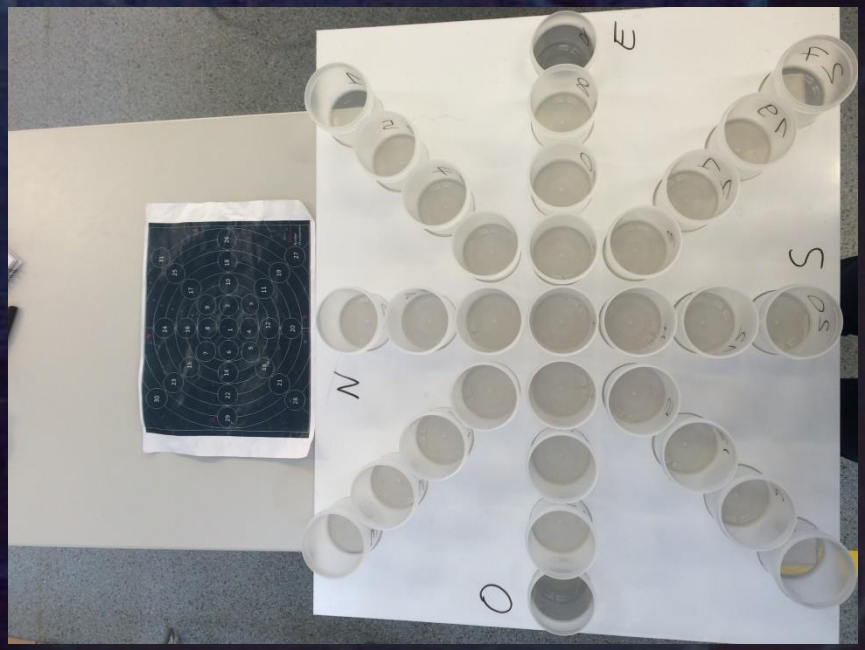
Methodology/instrumentation

- Ambient sensor unit: cubicle humidity, temperature and sound
- In-line sensor unit: water pressure, temperature & flow rate
- Spray collector unit: distribution of flow and temperature of shower spray
- PC with data logger unit connected to sensor units.



The spray collector unit



- Flow and temperature distribution is obtained by measuring volume and temperature of water in

- 70 mm cups arranged in a custom designed base template
- Thermal camera

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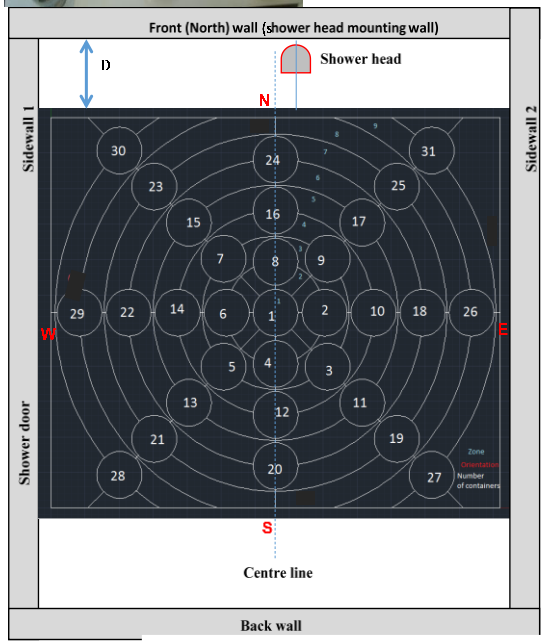
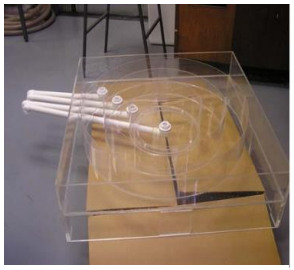
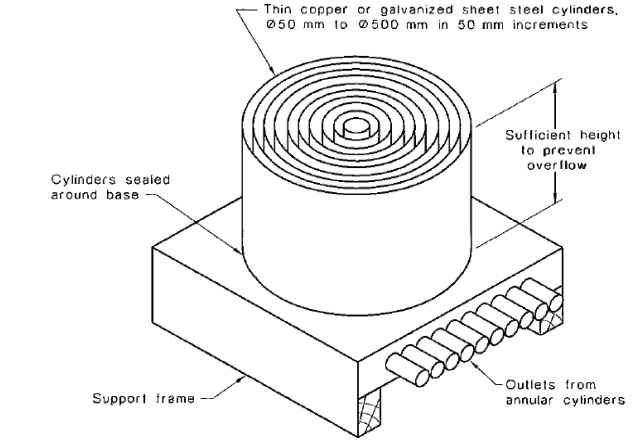
Comparison of Spray collector designs

(a) Present study



(b) Alkhaddar *et al.* 2007





NOTE: Cylinders with wall thickness in excess of 1 mm should be bevelled inwards to relevant cylinder.

Ref No.	S-01	S-02	S-03	S-04	S-05	S-06	S-07	S-08	S-09	S-10
Shape	Round	Oblong	Round	Round	Round	Round	Round	Rectangle	Curved rectangle	Round
Height	90	157	106	100	100	106	135	67	65	135
Width	90	82	106	100	100	106	135	182	120	135
Height incl. handle	215	270	239	230	230	239	246	227	219	246
Construction	ABS plastic with grey hard plastic faceplate	ABS plastic with grey soft plastic faceplate	ABS plastic with grey hard plastic faceplate	ABS plastic	ABS plastic	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with grey, hard plastic faceplate	ABS plastic with white, hard plastic faceplate
Colour	Grey and chrome	Grey and chrome	Grey and chrome	Chrome	Chrome	Grey and chrome	Grey and chrome	Grey and chrome	Grey and chrome	White and chrome
Sprout Type	recessed twin	recessed twin	recessed twin	protuding single soft rubber	protuding single soft rubber	recessed twin	recessed twin	triple central, recessed twin	recessed twin	recessed twin
Sprout Layout	3 x 3 double sprout clusters	Two long double-sprout oval rows	Two concentric double sprout circles	Central core and radial rows	Central core and radial rows	3 x 3 double sprout clusters	randon x 3 clusters	Central triple clusters, random rows	Random	random x 3 clusters
Inlet pipe connection (inch)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Working pressure (bar)	0.3 - 5.0	1.5 - 5.0	0.35 - 5.0	0.3 - 5.0	0.3 - 5.0	1.0 - 5.0	0.35 - 5.0	1.5 - 5.0	0.35 - 5.0	0.35 - 5.0
Measured Regulated flow rate @ 2 bar pressure	10.3	7.2	7.2	9.2	8.7	5.1	11.3	7.2	8.1	9.6
Regulated flow rate @ 2 bar pressure	8.7	8.7	7.9	13.2	12.9	5.1	7.6	7.4	8.3	7.6
Unregulated flow rate @ 2 bar pressure	14.5	14.5	23.9	N/A	N/A	N/A	23.3	13.8	21	23.3
Number of functions	1	4	1	3	1	1	2	2	1	2
Mode of operation	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	With Air	With Air	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets	Colliding twin jets that turn into thousands of tiny droplets
Additional comments		Supplied with 9l/min flow regulator, Includes 1x vitamin C cartridge to neutralise chlorine	Supplied with 9l/min flow regulator	Rub clean nozzles	Rub clean nozzles	Supplied with 5.7l/min flow regulator fitted	Supplied with 9l/min flow regulator, Two types of spray - Satinjet body shower or massage	Ergonomic slider function selection on handle, Supplied with 9l/min flow regulator	Supplied with 9l/min flow regulator	Supplied with 9l/min flow regulator, Two types of spray - Satinjet body shower or massage
Image										

Results – User feedbacks

- In response to a set of performance questions, the users provided a rating from 1 to 5:
  1 = strongly disagree; 3 = neutral; 5 = strongly agree
- Each showerhead is rated twice, once at start and another at the end of the week.
- A higher rating means more agreeable

Survey results

	Image										
		S-1	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**
The water flow was consistent	Start of Week	4.67	4.55	4.11	4.6	4.38	4.33	4.75	4.67	4.5	4.75
	End of Week	4.56	4.67	4.38	4.7	4.55	4.44	4.75	4.83	4.6	4.58
I like the coverage of the spray	Start of Week	4.22	4.25	4	4.3	4.23	3.44	4.25	4	4.2	4.5
	End of Week	3.67	4.42	4.38	4.4	4.55	3.44	4.63	3.83	4.4	4.42
The water pressure from the shower head was consistent	Start of Week	2.33	2.18	2.44	3.2	3	3.11	3.13	3.25	2.6	2.83
	End of Week	2.22	2.42	2.5	3.3	2.82	2.89	3.29	3.5	2.4	3.08
The water pressure on the body was pleasant	Start of Week	3.44	4	3.89	3.9	3.38	3.56	3.88	3.83	4	4.33
	End of Week	3.22	3.92	3.75	3.6	3.73	3.22	3.75	3.83	3.8	4.17
The water temperature was consistent	Start of Week	4	4.27	4	4.2	4.38	3.33	4.38	4.17	4.1	4.5
	End of Week	4	4.42	4	4.2	4.36	3.44	4.13	4.08	4	4.42
This showerhead meets all my expectations	Start of Week	4	4.55	3.89	4	4.08	3.67	4.13	3.83	4.2	4.25
	End of Week	3.89	4.33	3.75	4.2	4.09	3.44	4	3.83	4.1	4.33
I will be happy to buy this showerhead	Start of Week	2.67	2.27	2.33	2.7	2.62	2.67	2.75	3	2.7	2.67
	End of Week	2.11	1.83	2.38	2.9	2.73	2.78	2.75	3.25	2.4	2.83
This showerhead was enjoyable to use	Start of Week	2.78	3.09	3	3.6	3.08	2.89	3.75	3.5	3.3	3.92
	End of Week	2.89	3.17	3	3.3	3	2.56	4.25	3.58	3	3.83
	Total (top 5 criteria)	41.22	44.95	43.2	47.9	45.25	40.65	48.45	46.49	44.2	48.83
	Average (top 5 criteria)	3.44	3.75	3.60	3.99	3.77	3.39	4.04	3.87	3.68	4.07

Highlights of user feedback

- User judgemental and experiential perceptions of the showerheads differed between start and end of the trial week, mostly about 0.1~0.2
- With the exception of showerheads 1 and 10, all the showerheads were rated higher at the end of trial week compared to the beginning of the week.

Highlights of user feedback

- Note that 7 & 10 are identical except their colours. There are small differences between their scores with an overall average difference of 0.03
- **Overall, showerheads 1 & 6 attracted the lowest scores while 7 & 10 were ranked highest followed by 4, 8, 5, 2, 9, 3, 1 and 6 in that order.**

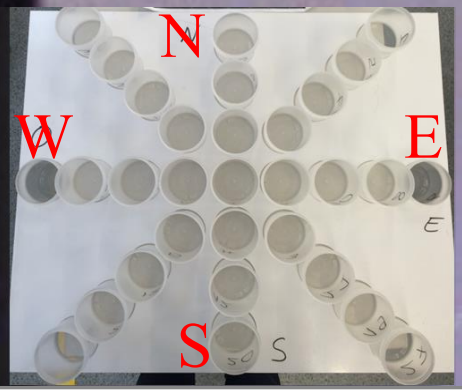
Results - Spray and temperature distributions

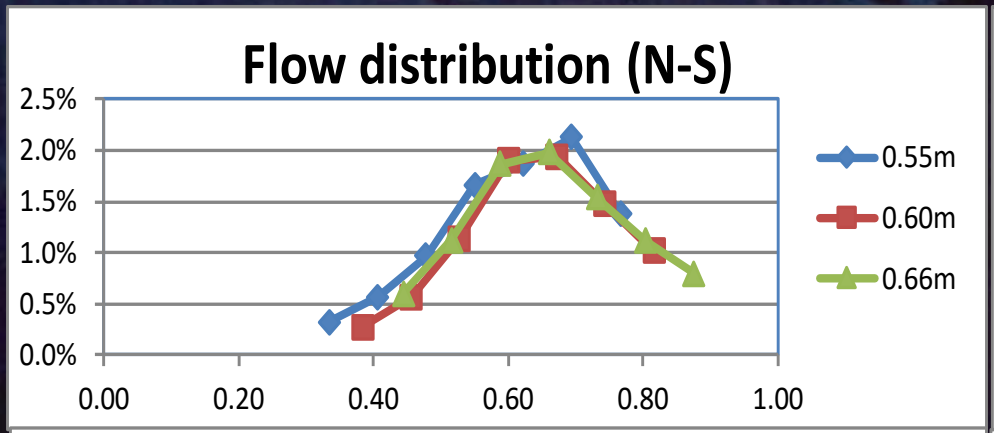
- Spray water collection was done over a fixed time of 60 seconds, with enough water being collected without overflowing the cups.
- For each showerhead, the measurement is repeated 3 times with the spray collection unit respectively placed at 0.55m, 0.60m and 0.66m from the north wall (showerhead mounting wall).
- There is good consistency between the 3 tests.

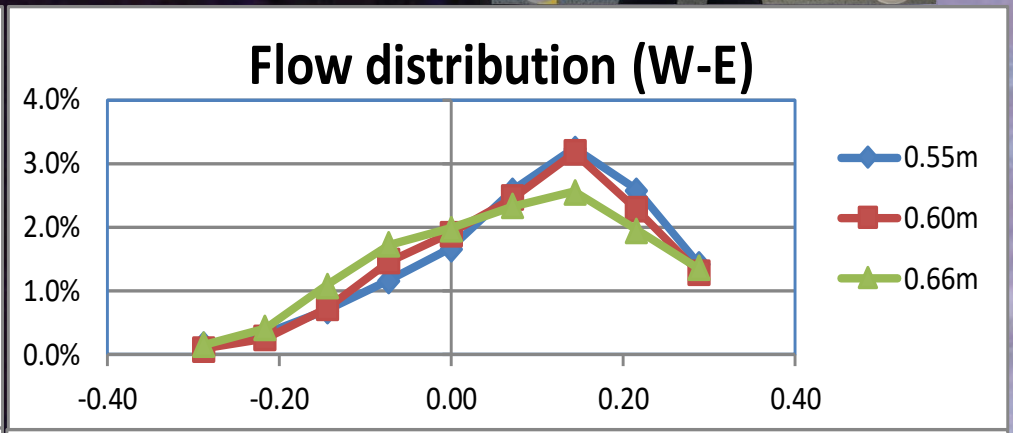
Results - Spray and temperature distributions

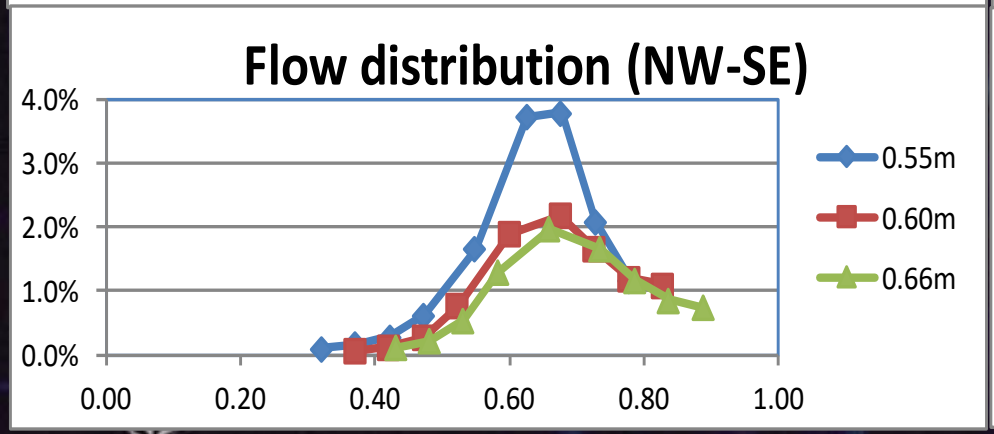
- Moving the spray collection unit ensures the whole spray area is covered.
- The measured water volumes are presented below in terms of percentages of the total.
- Up to 4% may be collected in a cup.
- The thermostat maintains a constant water temperature throughout all tests.
- The measured temperature was shown to vary from 26℃ to 36℃

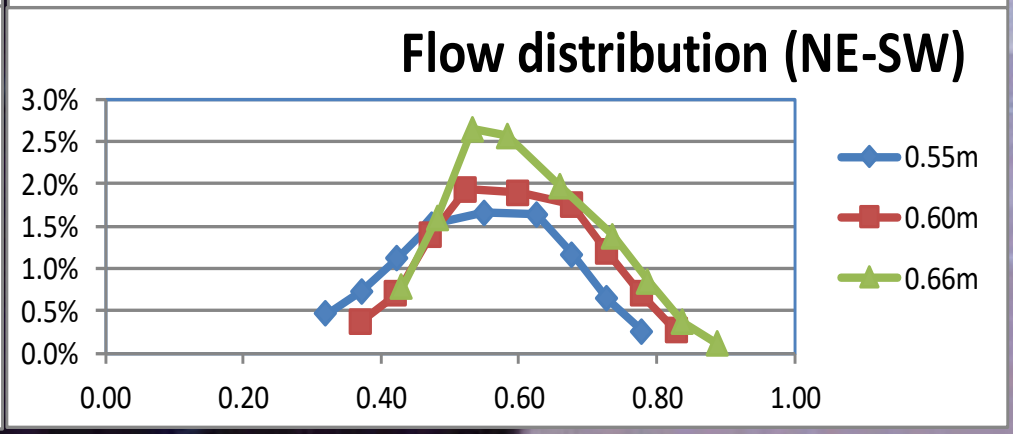
- Good consistency between measurements
- Clear asymmetry with respect to the centre of collector unit



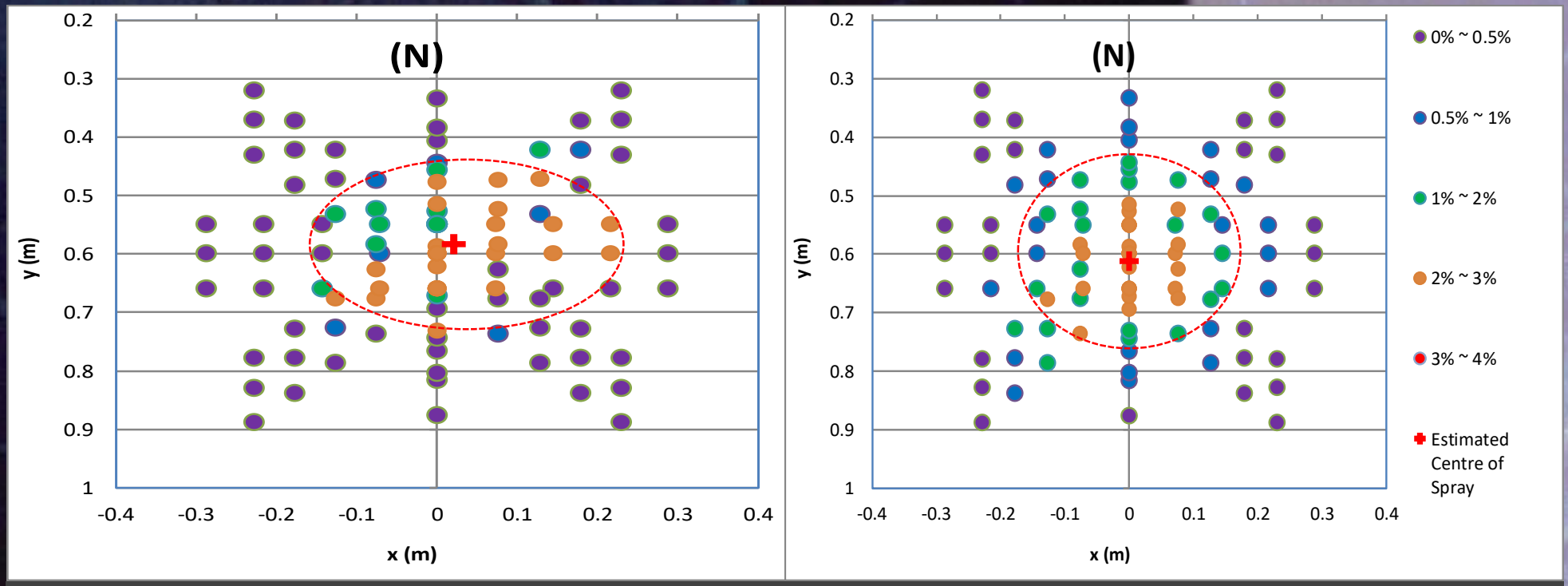






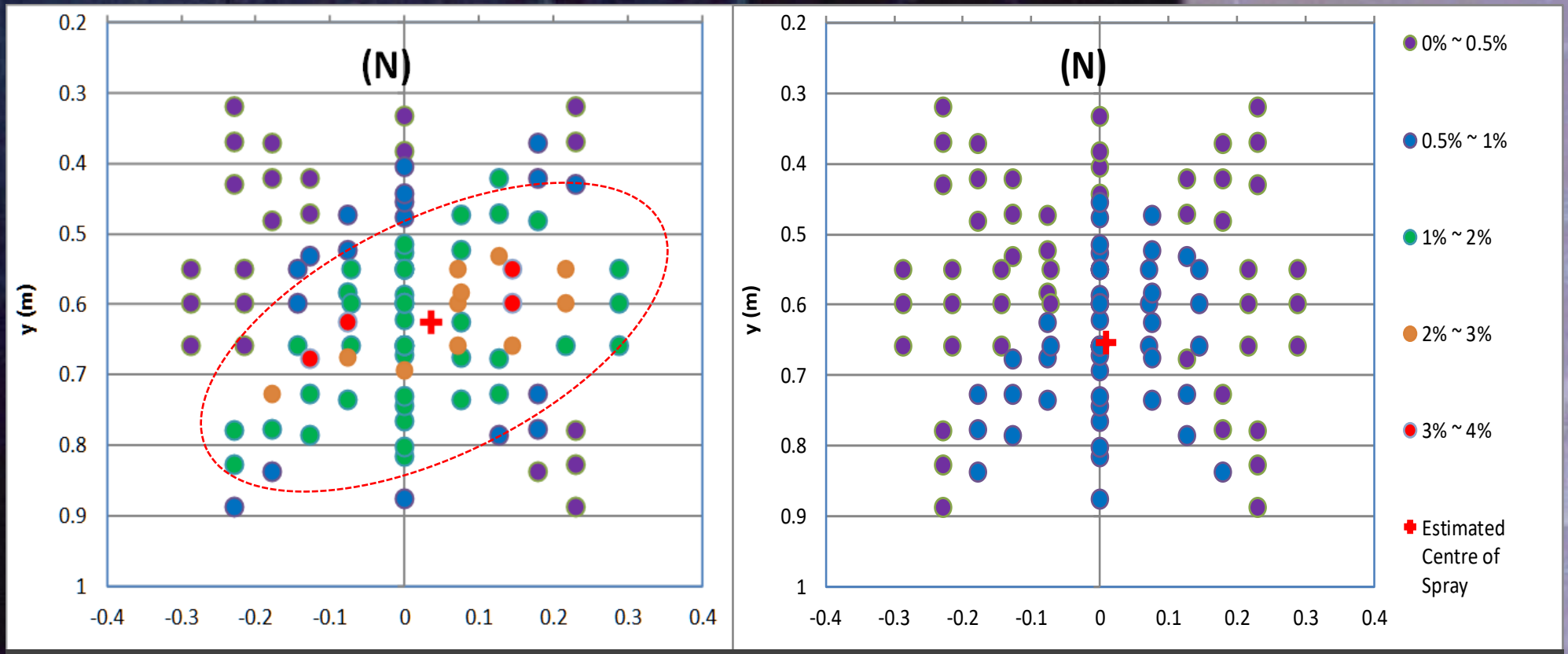


Spray water distribution over the floor area for high rating showerhead #4 (left) & #10 (right)



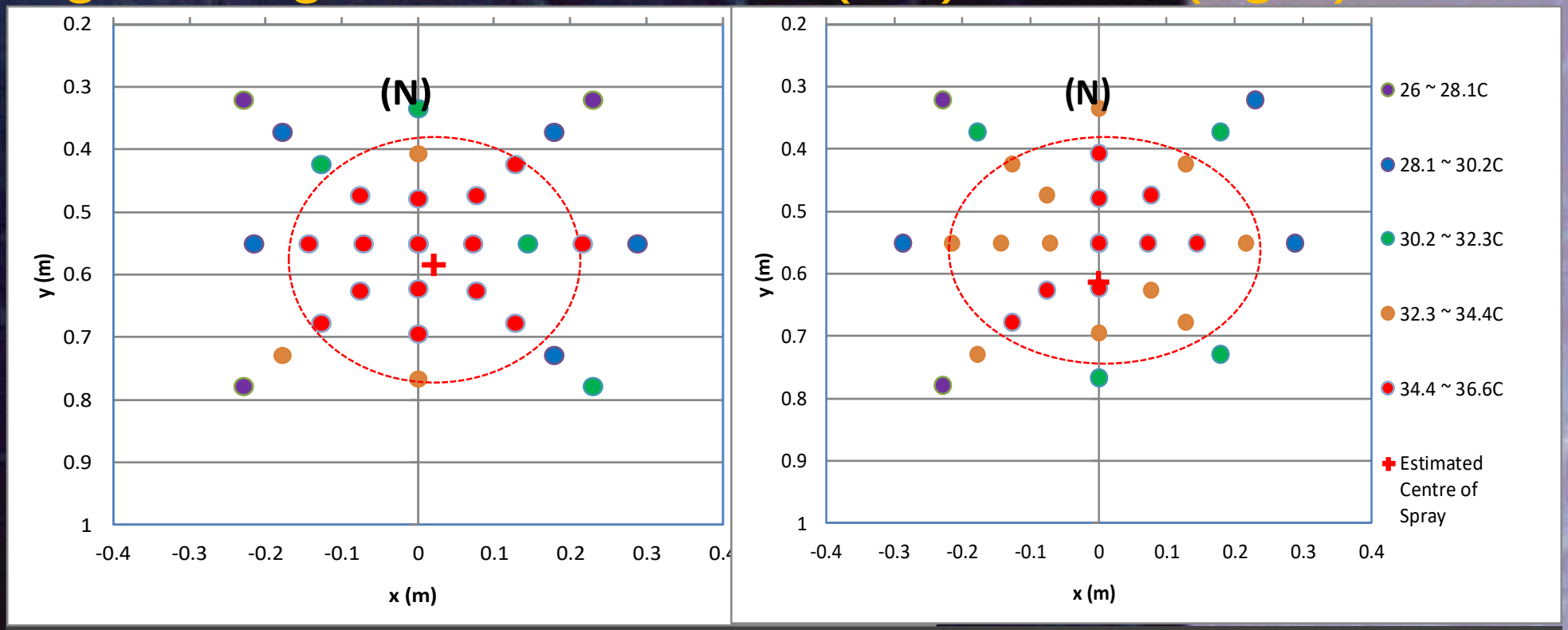
- High intensity spray is focused on a well defined central area, symmetrical with respect the spray centre.
- Less than 20% of the spray does outside this area.

Spray water distribution over the floor area for low rating showerhead #1 (left) & #6 (right)



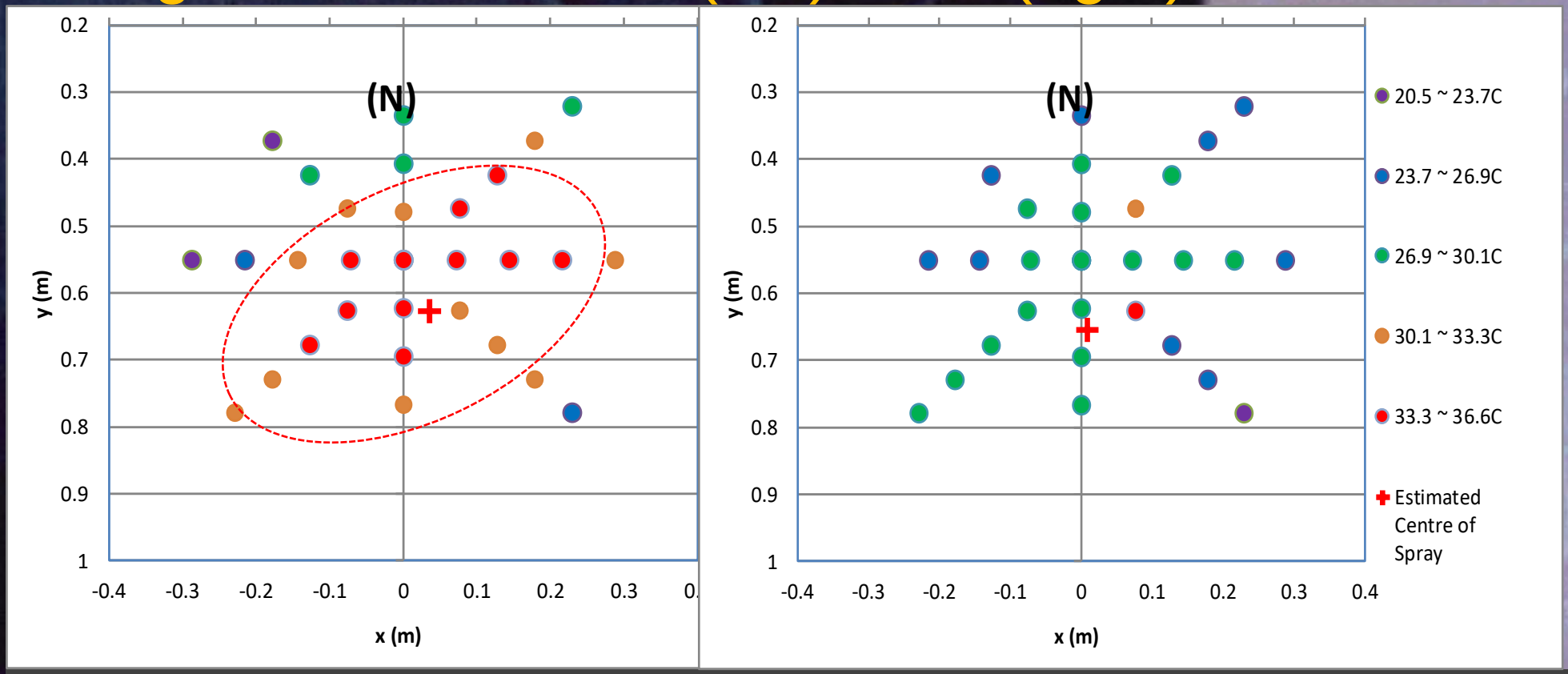
- Lower intensity spray over a larger & asymmetrical area.
- Showerhead 6 shows extremely spray intensity.

Temperature distribution over the floor area for high rating showerhead #4 (left) & #10 (right)



- Temperature distribution follows the spray distribution pattern.
- Higher temperature overlaps the high intensity spray area.

Temperature distribution over the floor area for low rating showerhead #1 (left) & #6 (right)



- Similar to spray volume, temperature shows clear asymmetry.
- Showerhead 6 shows significant heat transfer from spray to air.

Conclusions

Laboratory studies

Quantification of physical characteristics of showers

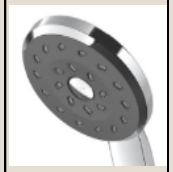
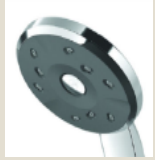
Surveys of end-user experience

Statistics of end-user experience

Related?

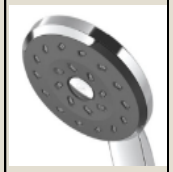
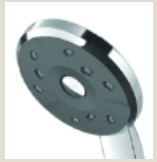
Yes, there is a correlation between the two; but the relationship is complex.

Conclusions

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Image										

- Showerhead 4 & 10 received highest overall score, followed by #8. #1 & 6 received the lowest score.
- 4 & 10 produce a well-defined area of high flow intensity and temperature.
- In contrast, 1 & 6 have an asymmetrical spray area or low flow intensity and large heat loss.

Conclusions

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
Image										

- Although the physical appearance (colour and shape) and the number of spray functions have an influence on user preference of showerheads, ultimately the user experience and preference are to a greater extent affected by the produced spray pattern, intensity and its capacity to maintain water temperature.

Further and on-going work

- To explore other physical parameters such as flow rate, spray velocity, heat transfer rate, spray pressure etc;
- To establish potential correlation between these parameters and user experience and preferences.

Thank you for you attention

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