ON THE PROPERTIES OF A WATER CURTAIN DISCHARGED FROM A DRENCHER SYSTEM

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ABSTRACT

Upon activation, a water curtain would be discharged from a drencher sprinkler system. Properties of the water curtain under various operating conditions were studied experimentally. These included the water discharge pattern, mass flux distribution, water droplet velocity and water droplet size.

1. INTRODUCTION

Drencher systems are required in all refuge floors for covering external wall openings as specified in the local codes on fire services installations [1]. A drencher system is a sprinkler that produces a water curtain [2]. It can be controlled either manually or automatically to let water flow to the drencher spray nozzles. Water discharged from the drencher heads is blocked by the metallic part and the direction of the water is changed by 90°. Because of the shape of the drencher nozzle outlet, a curtain-like spray pattern is formed and discharged to the windows concerned.

The required water discharge pressure and flow rate of the system are based on the potential hazard of the protected area. The number of drencher heads can be determined from the area to be protected. For example, if the protected area is 2.5 m (height) × 3 m (width), according to the regulations stated above, the maximum spacing between sprinklers is 2.5 m to 3 m, and one drencher head is required. Different standards [3-6] have different requirements. Four standards were reviewed, they are NFPA (13, 80A) [3,4], Australia Standard (AS2118.1, AS 2118.2) [5] and Chinese regulation [6]. A summary is given in Table 1. For example, Australia Standard (AS 2118) [5] required the flow rate to be 7.5 $m^2 \times 5$ $L/m^2/min$, or 0.625 L/s. For Chinese regulation, the flow rate should be 0.57 L/s at 3 bar with 10 mm orifice size drencher head. According to NFPA [3,4], the flow rate in each sprinkler should not be less than 56.8 L/min; i.e. 0.95 L/s.

Performance of the system depends on the physical properties of the water curtain. The physical properties of the drencher spray pattern were studied and reporting the results becomes the objective of this paper.

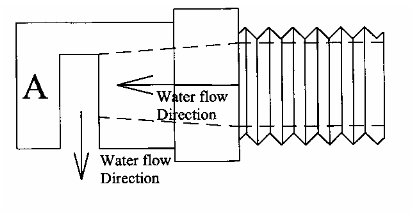
Table 1: Summary of operating conditions of drencher system under different codes

Description	Water pressure	Water flow rate
Australia Standard (AS 2118.1 & AS 2118.2 - 1995)	Not less than 70 kPa for light hazard system, 35 kPa for ordinary hazard system or 50 kPa for high hazard systems Less than 1 MPa	Not less than 5 $L/m^2/min$
NFPA (13, 80A)	Not less than 48 kPa	Not less than 56.8 L/min for each sprinkler OR 37 L/min/m for water curtain
Chinese Regulation		
- 10 mm orifice diameter drencher head	3 bar 4 bar	0.57 L/s 0.66 L/s
- 12.7 mm orifice diameter drencher head	3 bar 4 bar	0.93 L/s 1.08 L/s
- 19 mm orifice diameter drencher head	3 bar 4 bar	2.06 L/s 2.37 L/s

2. EXPERIMENTAL SETUP

Experiments were carried out in a fire chamber at the laboratory of Department of Building Services Engineering, The Hong Kong Polytechnic University. The chamber is of length 4 m, width 2.9 m and height 2.6 m as shown in Fig. 1. Pipeworks were installed inside the chamber so that the sprinkler nozzle was placed at the ceiling centre of height 2.5 m (as typical protected area is of this height) above the floor level. A fire resistant board was mounted between the drencher and ceiling. Three window type sprinkler heads as shown in Fig. 1 were used in this experiment. They were labeled as A, B and C with orifice diameter of 10 mm (k-factor = 43), 13 mm (k-factor = 84) and 19 mm (k-factor = 111) respectively. The working pressures of 2, 3 and 4 bars were listed in Table 2. Nine tests labeled as A1 to C3 in Table 2 were carried out.

The water pattern, mass flux distribution, water droplet velocity and size were measured. Photographs of exposure time 5 s were taken to study the water curtain. A 105 mm zoom lens together with specially designed optical arrangement were used. The settings were similar to those for droplet velocity measurement, but the sheet cutter was not used. The nozzle was installed at 1.4 m above finished floor level at the center of the room, and the camera was set at 1.2 m above finished floor level and 1.5 m away from the sprinkler head.



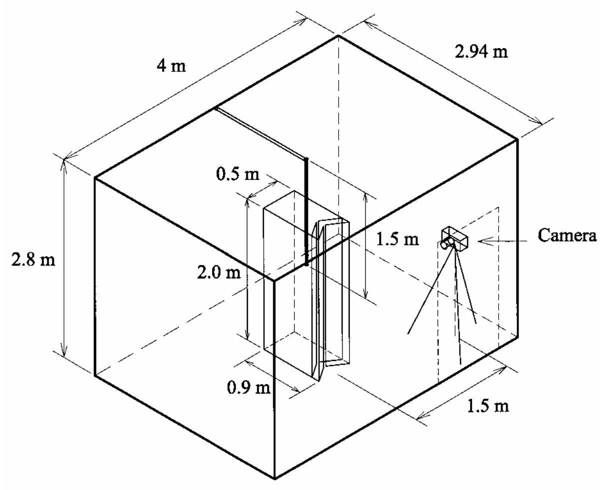


Fig. 1: Equipment setup for droplet velocity measurement

3. PHYSICAL PROPERTIES

The tested nozzle was installed at 2.5 m above finished floor level at the center of the room. Twenty-one measuring cylinders of diameter 140 mm were placed 500 mm away from each other. By measuring the collected water level h_m (in mm) and duration of water collection t_m (in mm), the mass flux density M_f (in mm/min) can be calculated.

Table 2: Summary of results

Nozzle number	Tests	Pressure (bar)	Flow rate (m^3/h)	Mean droplet size (mm)	Mean droplet velocity (m/s)	Mean mass flux density (mm/min)
A	A1	2	3.15	2.5	4.8	21.0
	A2	3	3.53	1.9	5.9	22.7
	A3	4	3.98	1.6	7.5	25.8
B	B1	2	3.60	3.6	5.9	21.5
	B2	3	4.02	3.4	6.7	29.5
	B3	4	4.37	3.3	7.9	31.2
C	C1	2	3.76	3.9	7.4	24.5
	C2	3	4.35	3.7	8.5	29.8
	C3	4	5.07	3.6	10.1	31.5

$$M_f = \frac{h_m}{t_m} \quad (1)$$

A metal water sheet 'cutter' [7] of length 0.9 m, width 0.5 m and height 1.5 m was used to give a sheet of water throwing out as shown in Fig. 1. In this way, paths of droplets can be captured. The slot of the cutter was 10 mm wide with two layers of blade edges. Water droplets passing through the first blade edge but not moving along the gaps would be blocked by the second blade. A 'scale' was placed at the area to be studied. The sprinkler head was installed at 1.4 m above the finished floor level. Images of the water droplets were captured by a camera with a macro lens installed 1.5 m away from the water curtain. Water droplets can be 'frozen' at a certain time interval by using a flash unit. It was set manually to a 'very low power' mode, taking only 1/128 of the total power output. The multi-speed flash unit was set to give five bursts at an interval of 1/100 s, i.e. the fastest setting of the flashlight. The very low power flashes occurred within a very short time interval, i.e. about 1/6000 of a second. Shutter speed was set to 1/15 s, which was longer than the five times flash, i.e. (5 × 0.01 s) or 0.05 s.

In order to reduce the vibration while taking photographs, the camera was actuated by a cable shutter release. The captured images were processed with a personal computer to measure the water droplet velocity. About 10 water droplets were counted in three randomly selected photographs taken from the same drencher, for the velocity measurement for each setting. Diameters of water droplets were measured in a similar way but with the flashlight only flashed once in taking a photograph. Water droplets were enlarged up to ten times of its original size on the screen.

The graphics software PhotoShop was used to measure the size of the droplets. An example is shown in Fig. 2. There were about 100 water droplets counted in five randomly selected photographs for the droplets size measurement for each setting. For each counted droplet a cross was marked on the screen in order to reduce duplicated measure.

The droplet velocity, V_d (in m/s), is obtained by dividing the distance between the droplets images, D_d (in m), measured in the photographs by the time interval between flashes, t_d (in s):

$$V_d = \frac{D_d}{t_d} \quad (2)$$

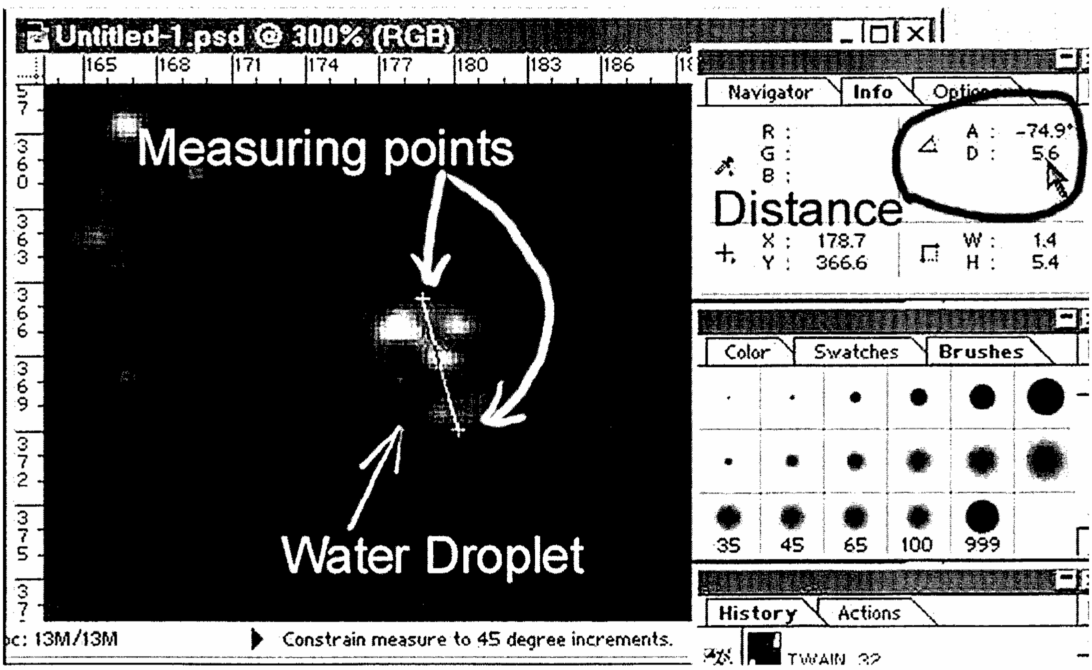


Fig. 2: Typical example of droplet capture

4. WATER CURTAIN

From the photographs taken in the experiment, a curtain-like spray pattern with an example shown in Fig. 3 (test A1) was formed after discharging water through the nozzle. This water curtain was formed by fast-moving water droplets. In fact, water was not evenly distributed in the curtain as shown in Fig. 3. Less water was found in the darker part of the water curtain. Those regions having more water would be brighter. Similar spray patterns were observed for different sprinkler heads.

As shown in Table 2, the mass flux was very high because of the nozzle design. An example for the mass flux density for test C3 is shown in Fig. 4. The line with marker in the figure represents the mass flux density along the centerline.

For tests A1 to A3, the mass flux density ranged from 21 mm/min at 2 bar up to 25.8 mm/min at 4 bar. The mass flux density increased for sprinkler heads of larger orifice diameter.

As the fire chamber was not large enough to accommodate the entire pattern, some water was deflected by the wall and dropped to the lower levels. As a result, the mass flux density was higher near the wall although it was placed far away from the sprinkler head.

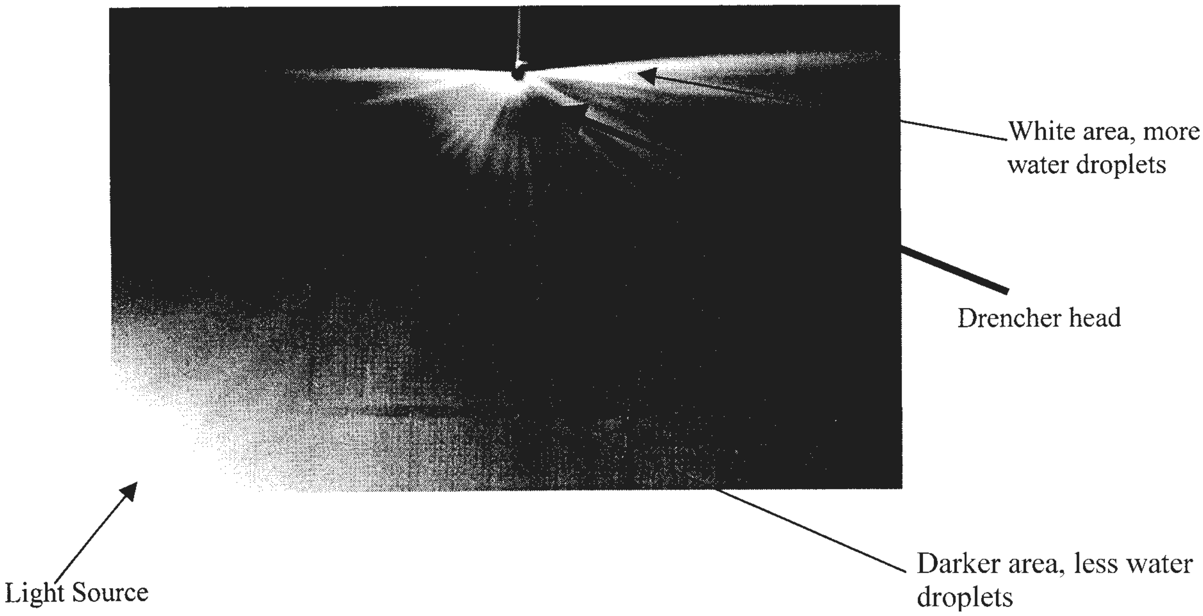


Fig. 3: Water curtain

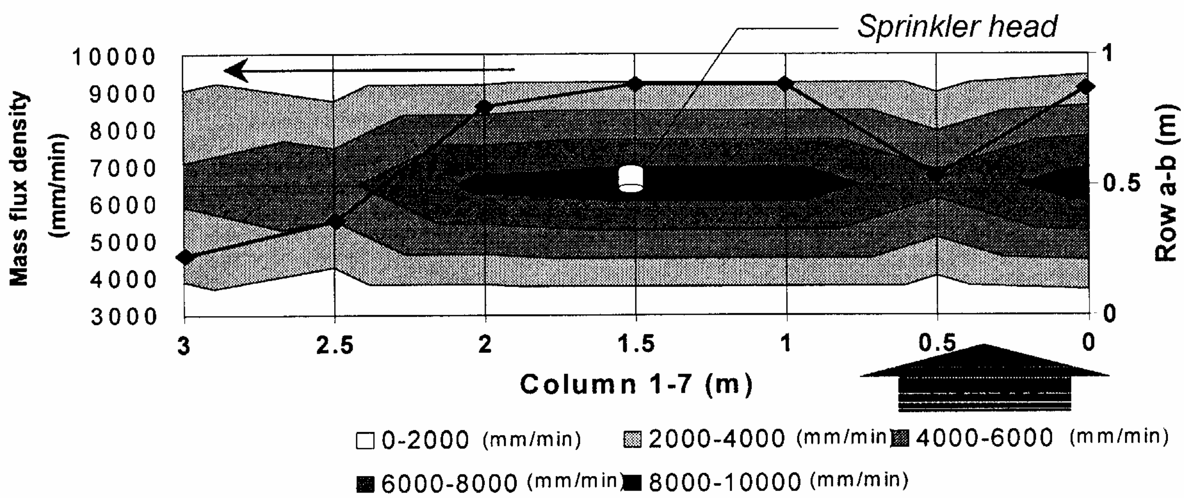


Fig. 4: Mass flux distribution for test C3

5. CONCLUSION

A water curtain would be formed when discharging water from a drencher system. There are water droplets inside the curtain with non-uniform distribution. From the photographs taken, areas with less water droplets appeared darker. The mass flux density of the water spray at the floor level increased when the water supply flow rate and pressure increased. The mass flux density was higher along the centerline in a direction parallel to the linear nozzle.

This paper on preliminary study of water curtain is only the first of a series of reports. Further studies must be carried out to assess the performance of the system.

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