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JOINT FIRE RESEARCH ORGANIZATION.

THE DETERMINATION OF THE DROP SIZES OF HIGH AND LOW PRESSURE WATER SPRAYS

"by

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# SUMMARY

This note describes the determination of the range of mass median drop diameters of sprays produced by impinging-jet type nozzles operating at pressures of 80 - 500 lb/in<sup>2</sup>. The drop size is shown to depend on both pressure and flow rate and to vary between 0.32 and 0.94 mm.

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## Introduction

In a previous investigation (1) the effect of high and low pressure water sprays on the extinction of fully developed room fires was studied. This note describes the determination of the range of mass-median drop diameters which were obtained in the sprays used.

# Experimental

The impinging-jet type nozzles used have been described in detail elsewhere (1) and a typical nozzle is shown in Plate 1. The nozzle for each spray examined was mounted with its axis vertical 10'0" above the floor of the laboratory. The pressure at the nozzle was adjusted to give the required water flow rate (1).

The sprays were sampled in the following manner (2).

Assmall flat dish containing castor oil was exposed to a section of the spray in a plane about 16 in. above the floor. The dish was mounted on a trolley and pulled under a slot in the lid of the box containing the apparatus (Plate 2). Samples were taken vertically below the nozzle (Plate 3) and at points up to 2 ft. from the central axis. The exposure time and number of samples taken were adjusted so that the castor oil was not overcrowded with drops, between 2000 and 4000 drops being collected from each spray. A contact photograph (Plate 4) was taken of each sample.

An enlarged image of the negative was projected on to a screen which was divided into squares to facilitate the sizing and counting of the drops. The magnified drops(x15) were measured by means of a template cut with holes of diameter ranging from 1.5 mm to 15.5 mm in steps of 1 mm. Those drops which had magnified diameters greater than 15.5 mm were measured individually.

A preliminary analysis of the drop size distribution showed that it varied across the spray, and it was therefore necessary, in the calculation of the massmedian drop size of the whole spray, to weight the measurements taken at each sampling point according to the mass distribution of the water. This was measured by setting out metal cans, 7" in diameter, over the sampling area (Plate 5) and exposing them to the spray.

#### 3. Results

The mass median drop size has been determined for nine sprays and the results, which have been weighted in accordance with the water distribution, are given in Table 1. -

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Table 1. Weighted drop diameters

Mass median drop size - mm			
Pressure Rate of p.s.i. flow g.p.m.	80	10.225 F-	500
g telig - g <b>.5</b> g	0.55	0.39	0.32
15	0.85	0.62	0.61
25	0.54	0.59	0.94

A graph of mass median drop size against pressure was plotted for the three rates of flow and is shown in Fig. 6.

Several empirical laws (3) have been derived which express the distribution of drop diameters within sprays. Other workers (4) have shown that the distribution for single pairs of impinging jets agrees with the Roser-Rammler law (5). The work described in this report also shows general agreement with this law. A convenient form of the law is -

$$R = e^{-(x/a)^n}$$

- where R = fraction by weight of the total spray composed of drops greater in diameter than x,
  - a = "absolute spray coefficient" which is equal to the value of x for which the fraction R oversize is 0.368.
  - n = homogeneity coefficient.

A typical result obtained by plotting  $\log \frac{I}{R}$  against x on logarithmic scales is shown in Fig. 7.

## 4. Discussion

The results obtained show that the sprays used give quite a wide variation in mass median drop size which ranges from 0.32 to 0.94. These results were affected considerably by using the weighting factors previously described.

Table 2 shows the weighted and unweighted results for three nozzles at a pressure of 500 p.s.i.

Table 2
Comparison of weighted and unweighted drop diameters

	Rate of flow	Mass median drop size-mm	
		Unweighted results	Weighted results
	5	0.34	0.32
	15	0.75	0.61
	25	7.58	0.94

Table 3 shows the variation of drop size across the spray from the nozzle delivering 25 g.p.m. at 500 p.s.i.

Table 3

Radial variation in drop diameter

Sampling position	Mass median drop size-mm	
Centre of spray	7.58	
1' from centre	0.35	
. 2' from centre	0.52	

The effect of pressure on the mass median drop size varies with the flow rate. At 5 g.p.m. and 15 g.p.m. the drop size is given by

$$D = \frac{k}{n^{X}}$$

where D = drop size

k = constant

p = pressure

x = 0.30 for 5 g.p.m. and 0.17 for 15 g.p.m.

This relation is similar to relations derived by other workers using pressures up to 100 p.s.i. (6). At 25 g.p.m. however a relation of this kind is not apparent. This may be due to the fact that for a given pressure the nozzle delivering 25 g.p.m. has a greater number of impinging-jets than those delivering 5 or 15 g.p.m. As the pressure increases the velocity of the water jets becomes greater and results in the formation of a wider water sheet and thus increases the chance of interference and coalescence of drops.

## 5. Conclusions

The drop size of sprays used in the extinction of fully-developed room fires has been examined. The drop size depends on both flow rate and pressure and varies between 0.32 mm. for the nozzle delivering 5 g.p.m. at 500 p.s.i. and 0.94 mm. for the nozzle delivering 25 g.p.m. at 500 p.s.i. A relation of the form  $D = \frac{k}{p^2}$  was found to hold at 5 g.p.m. and 15 g.p.m., but no consistent variation  $p^2$  of drop size with pressure was observed for 25 g.p.m. possibly due to greater interference between the water sheets.

# 6. References

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- 3. FRASER, R.P., and EISENKLAM, P. Liquid atomisation and the drop size of sprays. Trans. Instn. Chem. Engrs. Lond. 1956 34 (4) 294 319.
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- 5. ROSIN, P. and RAMMER, E. The laws governing the fineness of powdered coal. J. Inst. Fuel. 1933, 7 (31) (Oct.) 29 36.
- 6. RASBASH, D.J. The Properties of sprays produced by batteries of impinging jets. Joint Fire Research Organization. F.R. Note No.181/1955.

PLATE 1. A TYPICAL NOZZLE

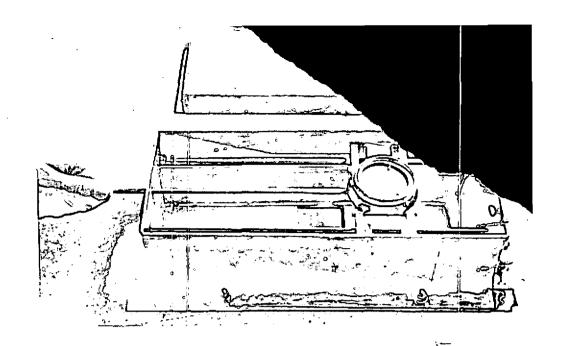


PLATE 2. DROP SAMPLING ARPARATUS

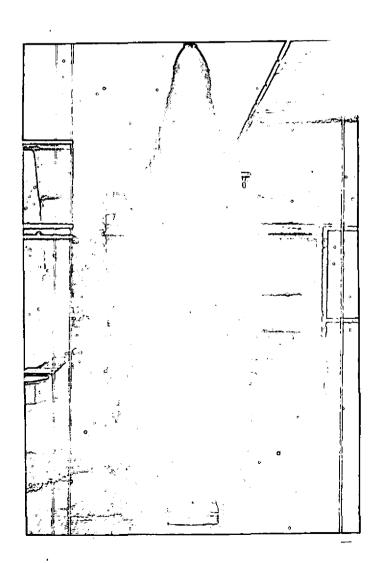


PLATE 3. DROP SAMPLING APPARATUS BENEATH A SPRAY

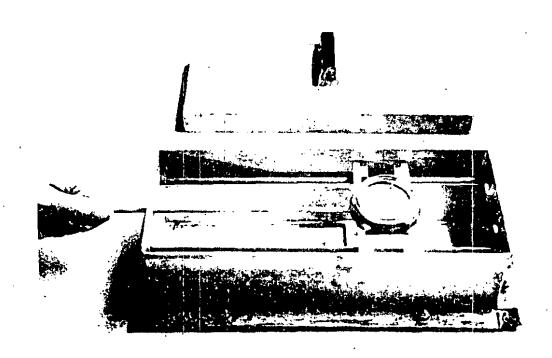
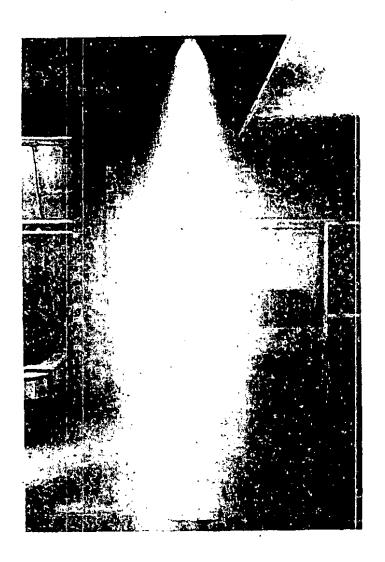


PLATE 2. DROP SAMPLING APPARATUS



DIATE 3. DROP SAMPLING APPARATUS BENEATH A SPRAY

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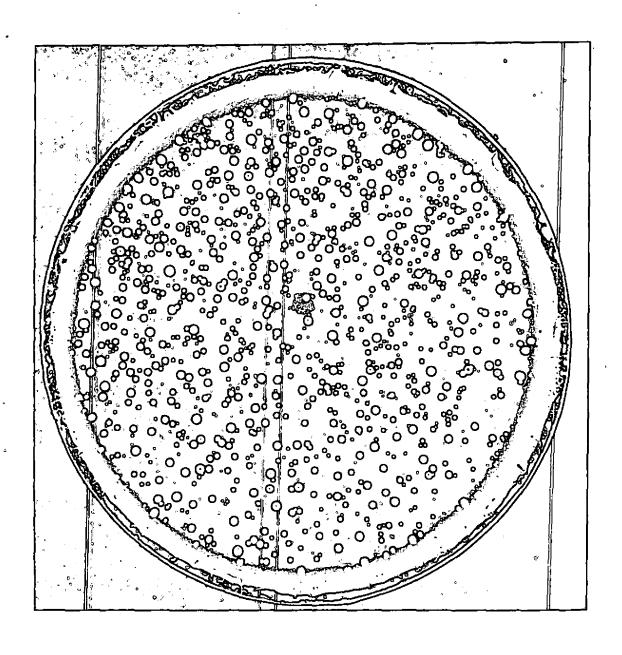


PLATE 4. PHOTOGRAPH OF DROP SAMPLE

PLATE 5. ARRANGEMENT FOR MEASURING WATER DISTRIBUTION

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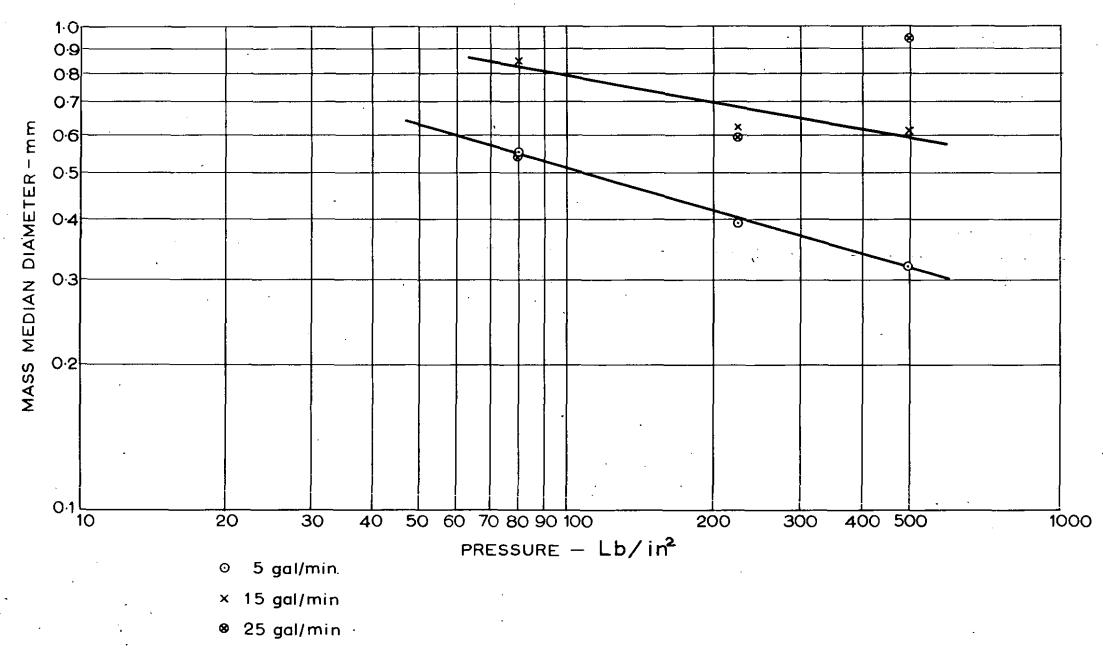
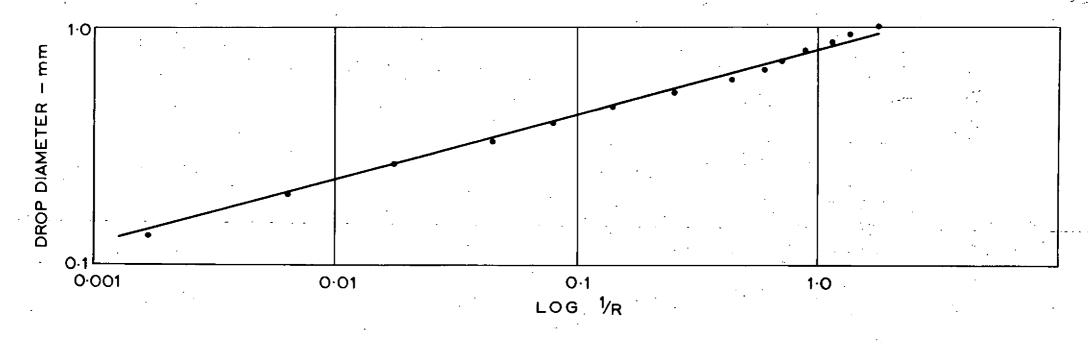


Fig. 6 THE RELATION BETWEEN DROP SIZE AND PRESSURE FOR 3 RATES OF FLOW



R=Fraction by weight of total spray

Fig. 7 DROP SIZE DISTRIBUTION (25 g.p.m. at 80 Lb/in²)