微粒 撒水裝置의 特性에 關한 研究

Study on the Characteristics of A Mist System

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摘 要

本 研究에서는 効率的인 Mist System을 設計하기 爲한 하나의 規準을 얻고자 Mist Nozzle을 下向으로 設置하여 壓力變化에 따르는 Nozzle의 噴出量과 壓力, Nozzle의 設置 높이, 衝突板 거리등 3要因의 變化에 따르는 噴出粒子의 크기 및 撒水分布類型 및 여러 Nozzle을 附着시킨 pipe의 여러 地點에서의 壓力 降下 등을 測定, 計算, 比較 考察 하였다.

얻어진 結果를 要約하면 다음과 같다.

1. 供試 Nozzle에서의 물의 流量係數, C는 0.87～0.95의 範圍에 있었으며 理論式과 잘 一致하였고 每抄 噴出量은 壓力增加에 따라 增加하여 $2kg/cm^2$에서 約 6^{cc}/sec이었고 $5kg/cm^2$에서는 9^{cc}/sec이었다.
2. 噴出粒子의 크기는 Nozzle의 直下部보다 Nozzle軸에서의 거리가 增加함에 따라 增加하였고, 壓力이 增加할수록 減少했으며 $2kg/cm^2$에서는 100～300 microns, $5kg/cm^2$에서는 100～250 microns의 範圍에 있었다.
3. 撒水分布는 大體로 圓形 平面에 分布되었는데 Nozzle의 直下部는 若干 적은量의 물이 撒布되었고 Nozzle軸에서의 거리가 增加함에 따라 撒水量은 많아졌다가 다시 減少하는 傾向을 보였다. 撒水範圍는 壓力의 增加에 따라 넓어 졌으며 그 지름은 $2kg/cm^2$에서 約 120cm, $5kg/cm^2$에서는 約 160cm 이었다.
4. Nozzle의 設置 높이가 40, 120cm인때 보다 70, 100cm인때 撒水分布는 보다 均一해지는 傾向을 보였다.
5. 衝突板 距離는 1.5～4.5mm의 範圍에서 粒子의 크기나 撒水分布에 別로 影響을 미치지 않았다.
6. 內徑이 1.5cm인 pipe에 1m 間隔으로 噴口直徑 0.65mm인 Nozzle을 35個 設置해도 壓力降下나 噴出量 減少가 적었다.

I. Introduction

The total area of green houses including vinyl houses at suburban and rural area has been constantly increasing in Korea, with increasing usage, such as, cultivating flowers, vegetables, tropical fruits, and even rooting

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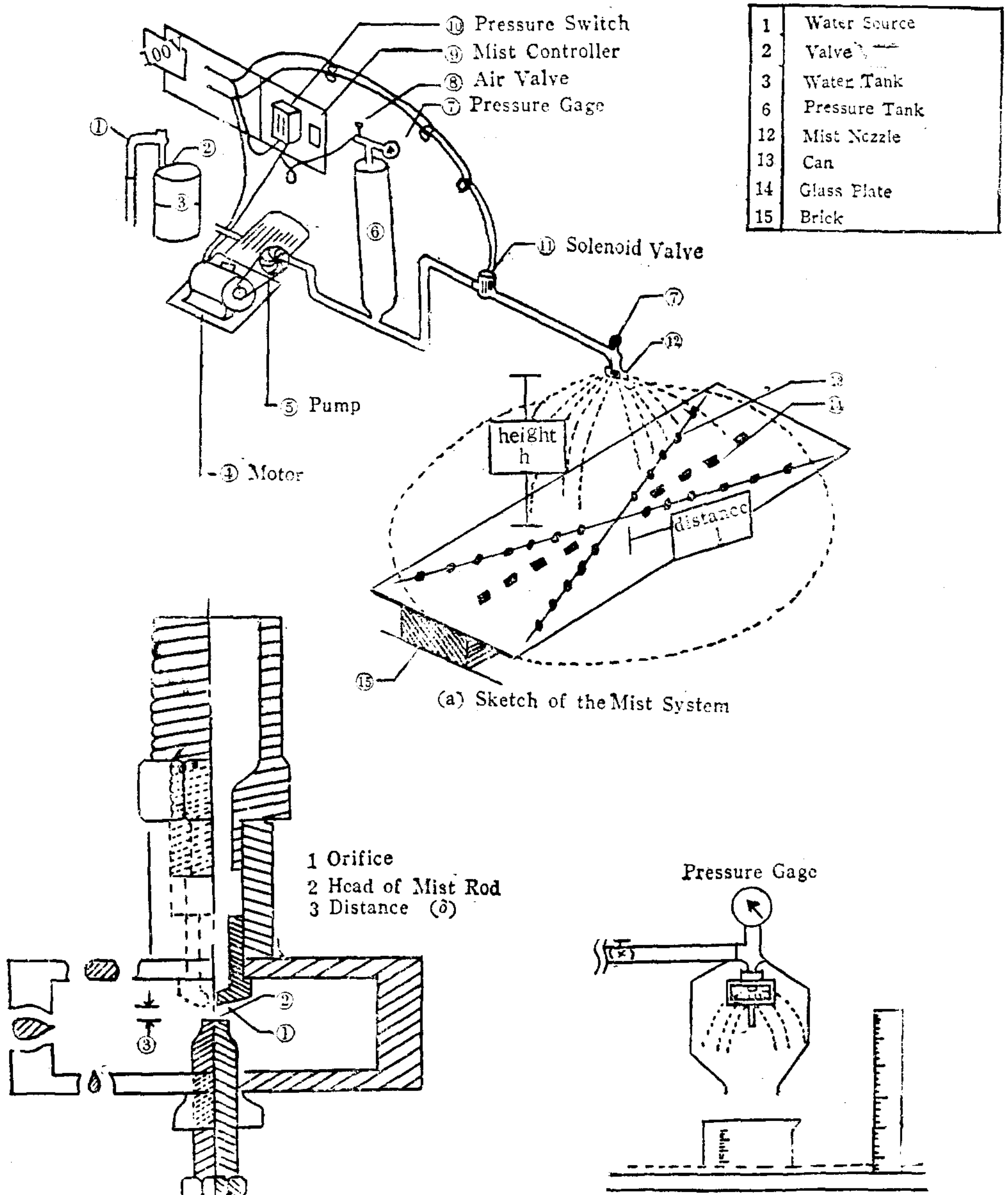
cuttings of certain valuable plannts.

Without adequate irrigati, tohe managem-ent of a green housey malead to a failure. So the study on the method of irrigation for green houses should be accelerated.

Many Korean agricultural engineers have studied numerous aspects of irrigation for the paddy fields and few has studied the irrigation for the upland fields and for green houses.

In order to understand some characteristics of the mist system which was an automatic spray irrigation system in green house and had been introduced into Korea sevrai years ago this study was carried out. Discharge per



(a) Sketch of the Mist System

(b) Detail of Nozzle (S=1/1)

(c) Sketch of Discharge Collector

Fig. 1. The Experimental Equipments

unit time, droplet size and distribution patterns of sprayed water at different pressure, at different height of the nozzle and at different position of mist rod and pressure drop at different position along the pipe were measured and studied with necessary calculations.

From the above study, the author intended to establish a standard for designing a practical mist system.

Ⅱ. Equipments & Method of Experiment

1. The Mist System

The mist system used for this experiment is shown in Fig. 1a.

A cushion of air compresses the water as water is pumped into pressure tank from the water source. This compressed air furnishes the pressure to force the water out through the pipes.

The pressure switch starts the motor connected to the pump when tank pressure drops below the predetermined pressure. It stops the motor at predetermined high pressure. As water is discharged, the air pressure in the tank drops. When it reaches the point below predetermined the pressure switch automatically starts the motor again.

The solenoid valve that is an electrically operated valve and actuated by the mist controller which is electronically controlled by the humidity of surroundings was installed.

All pressure gages used in this experiment were bourdon tube type pressure gage, max. 14kg/cm^2, 1div. 1/10kg/cm^2 and were calibrated with a dead weight pressure gage tester before and after the experiment.

All nozzles for this experiment were installed upside down with expectation to avoid dripping of water droplets along pipe.

2. Experiment on the Mist Nozzle.

With 6 levels of pressure, 4 levels of the height of nozzle and 5 levels of the position of mist rod, 48 treatments were arranged as shown in Table 1.

Table 1. Design of Experiment on the Mist Nozzle.

Pressure (kg/cm^2)	Height of Nozzle (cm)	Mist rod Position (mm)	Discharge measured	Droplet Size measured	Distribution measured
	40	3.5			0
P 1,2	70	3.5			0
3,5	100	1.5	0	0	0
		2.5	0	0	
7,9		3.5	0	0	0
		4.5	0	0	0
		∞	0		
	120	3.5			0

Discharge of water was measured from 30 treatments with the height of nozzle fixed. Sizes of water droplets were measured from 24 treatments with fixed nozzle height. Distribution patterns of sprayed water were measured from 36 treatments. Three replications were made in measuring from each treatments.

1) Measurement of Discharge at Various Pressure and with Different Position of Mist Rod.

The discharge collector, as shown in Fig.1c, was used to collect the water from the nozzle above which a pressure gage was installed.

The solenoid valve was opened and water was allowed to run for 5 seconds while the pressure being kept fairly constant. The amount of collected water during this period was measured using a mass cylinder with 1 ml graduation.

Discharge measurements were taken from 30 treatments-6 levels of pressure, 1, 2, 3, 5, 7, 9 kg/cm^2 and 5 levels of mist rod position, 1.5, 2.5, 3.5, 4.5, ∞ mm, with fixed, 100 cm, height of mist nozzle.

The author expected that discharge should be proportional to the square root of the pressure. He was also interested in knowing if there were any relationship between discharge and the position of mist rod.

2) Measurement of Droplet Size.

The stream from the orifice is broken up by the impact upon the head of mist rod.

The position of mist rod-the distance from the orifice to the head of mist rod-might affect the size of droplets.

Six levels of pressure as in the case of the measurement of discharge and 4 levels of mist rod position 1.5, 2.5, 3.5, 4.5, mm-were selected to establish 24 treatments.

To collect the droplets the paraffin coated glass plates of 6×6cm were used as shown in Fig. 1-a.

Shirai, K.[16], a Japanese agricultural engineer, obserbed droplets on the paraffin coated glass and derived an equation of true diameter, d, with respect to visual diameter of droplet, D, as shown in Fig. 2.

$$d = 0.81\ D \qquad (2-1)$$

In 1957, Takashi Ishihara[7] reported an equation for calculating the average diameter of droplets as follows;

$$d_o = \frac{\Sigma x^3 \Delta n}{\Sigma x^2 \Delta n} \qquad (2-2)$$

where d_o: average diameter of droplets
x: measured diameter of each droplet
Δn: total number of droplets.

The spacing of these glass plates was 10cm

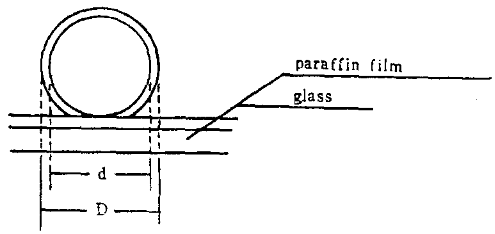


Fig. 2. Droplet on the Glass

for 1, 2, 3 kg/cm^2 and 15cm for 5, 7, 9kg/cm^2 respectively.

To measure the droplet size, 20-30 droplets were chosen randomly and were measured quickly with a microscope whose magnifying power was 50.

The average diameter was calculated by the following equation which was derived from Equation (2−1) and Equation (2−2):

$$d_O = \frac{\Sigma (0.81\ x)^3 \triangle n}{\Sigma (0.81\ x)^2 \triangle n}$$

3) Measurement of Distribution Pattern of Sprayed Water.

The distribution pattern of sprayed water is very important for deciding the interval and the height of mist nozzles. The author expected that the higher the pressure was the further droplets spread. He also expected that there should be a certain relationship between the distribution pattern and the height of mist nozzle. He tried to find out some, if any, relationship between the distribution and the position of mist rod.

With 6 levels of pressure as before, 4 levels of nozzle height (40, 70, 100, 120 cm) and 3 levels of mist rod position (1.5, 3.5, 4.5

mm), 36 treatments were established.

To receive the sprayed water, a number of cans(9.5cm in diameters and 1.5cm in heights) were arrayed 4 directions as shown in Fig. 1-a. The intervals of the cans were 10cm for 1, 2, 3 kg/cm^2 and 15cm for 5, 7, 9kg/cm^2 respectively.

The amount of water was measured with a balance whose capacity and sensibility were 200g and 0.1g respectively.

Then the sprinkling intensity, mm/h, was calculated by dividing the amount of water in mm^3, by the area of the can, mm^2, and by fraction of hour (duration).

3. Measurement of Pressure Drop Along the Pipe with 35 Nozzles.

Pressure drop along the pipe on which many mist nozzles have been installed is very important factor to be considered when one intents to design a mist system.

To measure the pressure at various nozzles along the pipe while running the water, 6 pressure gages were set up as shown in Fig. 3.

Three levels of pressure-3.5, 5.0, 7.0kg/cm^2 at tank-were selected as to form 3 treatments.

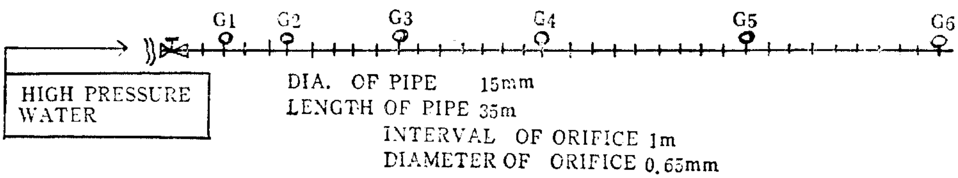


Fig. 3. Layout of Nozzles and Pressure Gages

Six obserbers stood in front of each pressure gage and the valve was opened and water was allowed to run while the obserbers took the reading of each pressure gage simultaneously.

Ⅲ. Results and Discussion

1. Relation of Discharge to pressure.

Generally the relation of discharge to pressure of water through an orifice is given in the following equation:

$$Q = C\ A\sqrt{2gH}$$

where Q = discharge, cm^3/sec.

C = coefficient of discharge

A = area of orifice, cm^2

g = acceleration of gravity, cm/sec^2

H = pressure head, cm.

The coefficient of discharge, C, is determined by the shape of the orifice, roughness of wall of the orifice, the velocity of water, etc. However in this experiment the value of coefficient of discharge, C, turned out to be within a relatively small range, 0.87-0.95, with little variation along the change in pressure-from 1 to 9kg/cm^2. This fact is clearly visualized by Fig. 4.

The position of mist rod did not affect the discharge as shown in Fig 4.

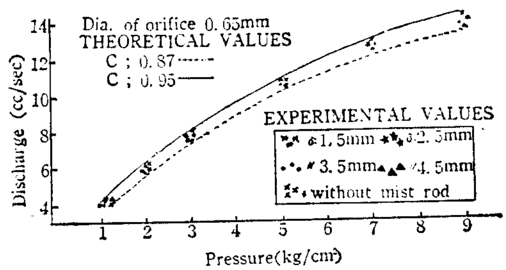


Fig. 4. Relation of Discharge to Pressure

2. Droplet Size.

Droplet size increased from the center to the exterior-100 microns to 400 microns-as shown in Fig. 5. This fact coincides with the result reported by Tate, R. W. and L. F. Janssen[19] and with that by Min[10].

Increasing the pressure affected the size of droplets to decrease. The increasing ratio of droplets size from the center to the exterior became smaller as the pressure increased. Above facts were shown in Figs. 5 & 6.

The influence of different position of mist

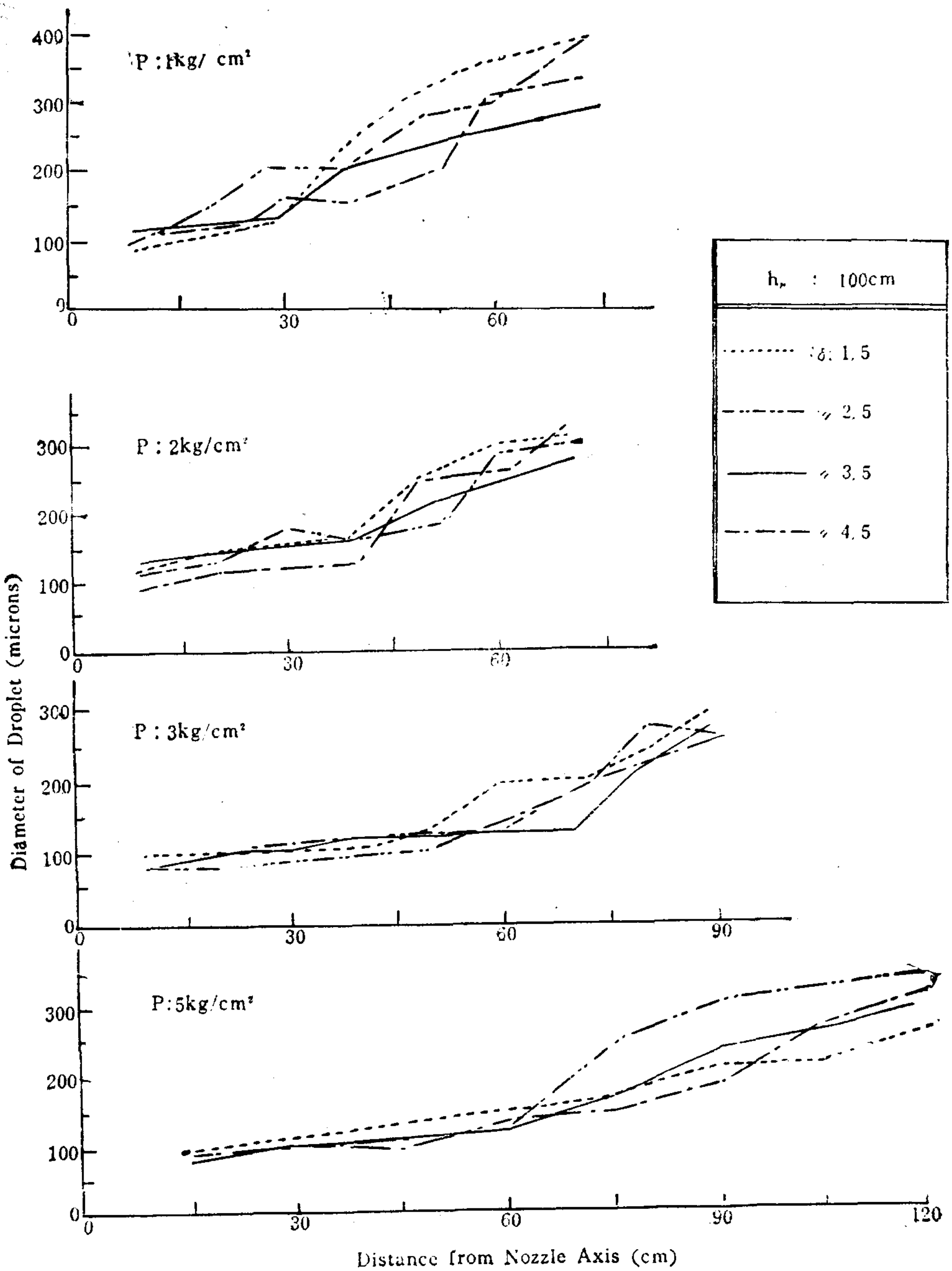


Fig. 5. Relation of Droplet Size to the Distance from Nozzle Axis for Various Position of Mist Rod (δ:mm)

rod within 1.5-4.5mm upon the size of droplets was not significant as shown in Figs 5, 6 and 7.

3. Distribution Pattern of Sprayed Water.

General distribution pattern of sprayed water

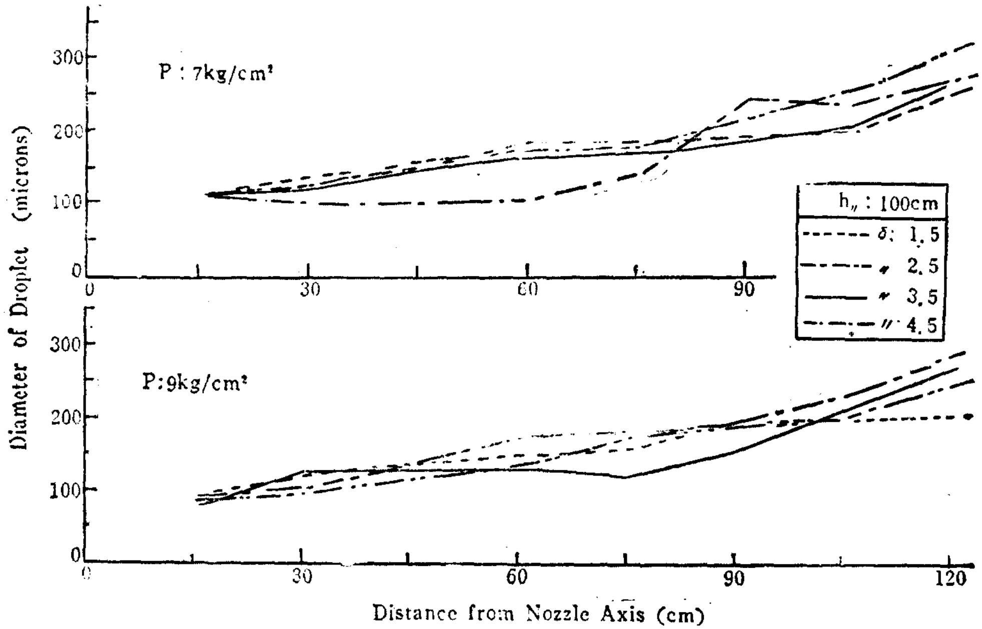


Fig. 5. Continued

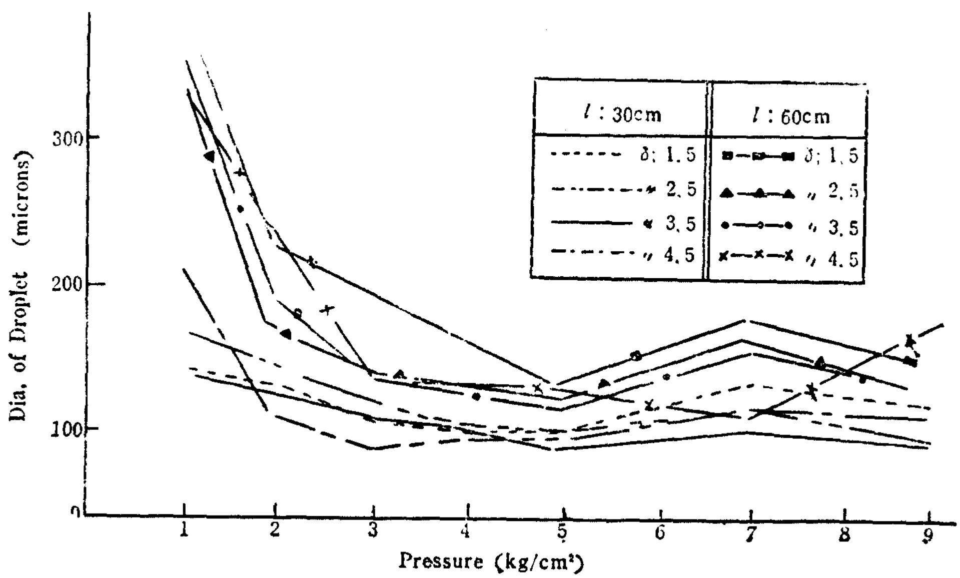


Fig. 6. Droplet Size relative to Pressure at Two Different Distance (30, 60cm) from Nozzle Axis for Different position of Mist Rod (δ:mm)

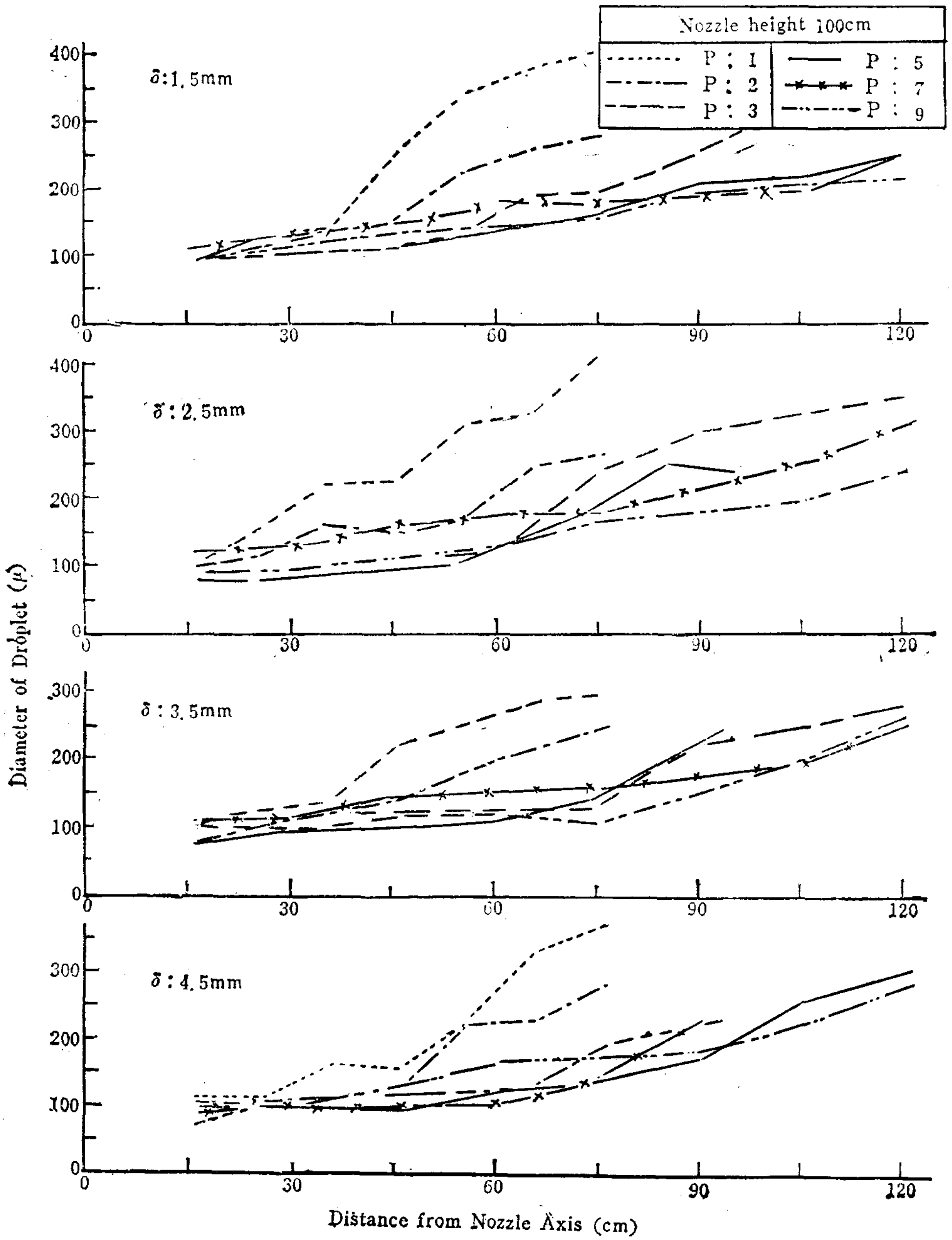


Fig. 7. Relation of Droplet Size to the Distance from Nozzle Axis for Various Pressure (P: kg/cm²)

was a kind of hollow cone, the center part of which was not truely hollow but some what lightly sprayed.

Figs. 8, 9 and 10 show the distribution pattern of sprayed water in a radial direction. As the pressure was increased the radious of sprayed area were enlarged and the maximum sprinkling intensity did not show significant change as shown in Figs. 9 and 10.

The distribution pattern was affected more by the height of mist nozzle than the position of mist rod as shown in Fig. 8.

More uniform distribution of sprayed water could be obtained at 70, 100cm, height of mist nozzle than at 40, 120cm as shown in Fig. 10.

Resonable spacing of the mist nozzle at various pressure could be given in the follwing Table 2.

Table 2. Optimum Spacing of Nozzle at Various Pressure

Pressure (kg/cm²)	1	2	3	5	7	9
optimum spacing of nozzle (cm)	100	120	140	160	190	220

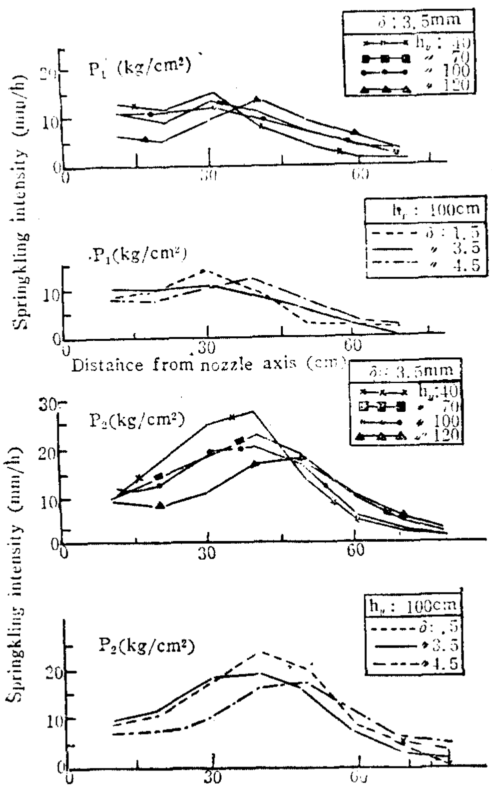


Fig. 8. Distribution Pattern of Sprayed water with Various Height of Nozzle (h_v :cm)and/or Different Position of Mist Rod (δ:mm)

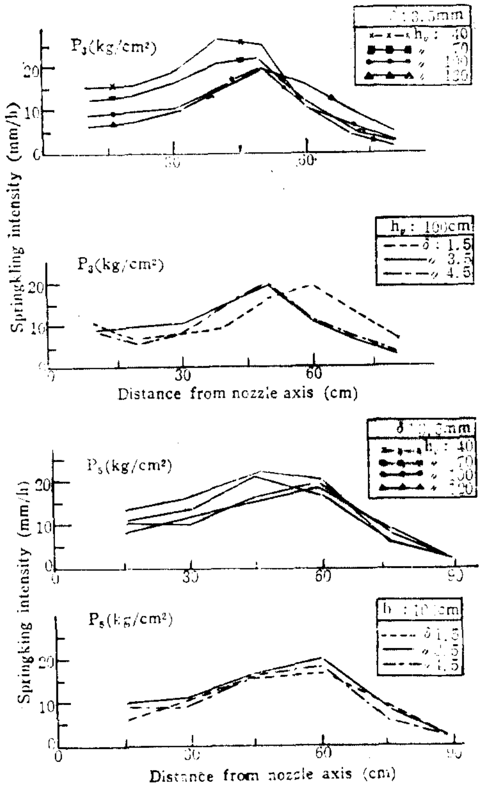


Fig.8. continued

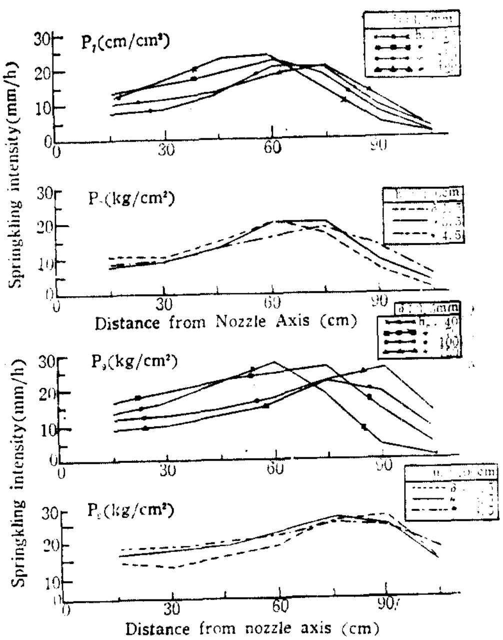


Fig. 8. continued

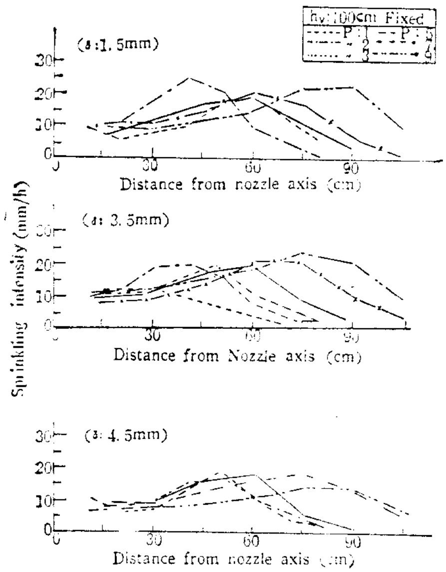


Fig. 9. Distibution Pattern of Sprayed Water with Various Position of Mist Rod (δ:mm)

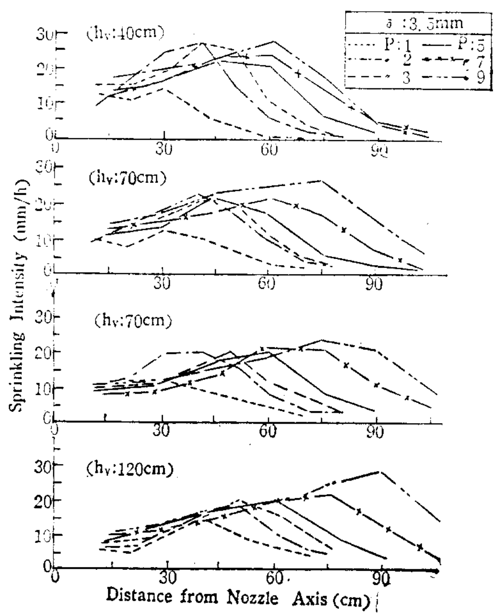


Fig. 10. Distribution pattern of Sprayed Water with Various Height of Mist Nozzle (h_V:cm)

4. Pressure Drop at Various Orifices.

Pressure distribution along the pipe which has 35 mist nozzles is shown in Fig. 11.

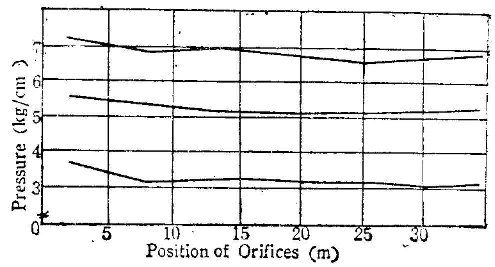


Fig. 11. Pressure Drop at Various Orifices along the pipe

The pressure drop at the end ef 35m pipe was slight despite the levels of pressure. Generally pressure drop depends upon the loss in velocity head $\frac{v^2}{2g}$ and friction loss of head $-C\frac{v^2}{2g}$.

Since the diameter of nozzle is only 0.65mm and that of pipe is 15 mm, velocity of water in the pipe is very small even when all nozzles are discharging water. Therefore the pressure drop which might be proportional to the square of the velocity of the water should be small.

This pipe, 35m in length, 15mm in inside diameter, installed with 35 mist nozzles, having orifice of 0.65mm in diameter, shonld not encounter any difficulty by pressurre drop in the range of 3.5-7.0kg/cm².

The result of this experiment is remarkable when compared with the report of Kadota and Mizumachi[3] in which they have used entirely different perforated pipe.

Ⅳ. Summary and Conclusion

This study was carried out in order to establish a standard reference for designing a practical mist system.

Setting the nozzles upside down, discharge, droplet size and distribution pattern of sprayed water depending upon pressure, height of mist nozzle and mist rod position and pressure drop at various orifices were measured and studied with necessary calculations.

The results of this study can be summarized as follows:

A. Coefficient of discharge, C, for the mist nozzle was in the range of 0.87-0.95. Discharge increased with increasing pressure, i.e., 6cc/sec at 2kg/cm² and 9cc/sec at 5kg/cm². There were no many differences between theoretical values and experimental values.

B. Droplet size was increased from the center to the exterior and was decreased by increasing pressure, i. e., 100 microns to 300 microns at 2kg cm² and 100 microns to 250 microns at 5kg cm².

C. The distribution of sprayed water was a kind of hollow cone. The sprinkling intensity was moderate in the center zone and increased toward outside and then decreased after reaching the peak. The diameter of sprayed area increased with increasing pressure, i. e., 120 cm at 2kg/cm² and 160cm at 5kg/cm².

D. More uniform distribution of sprayed water was obtained at 70cm and 100cm than at 40cm and 120cm of the heiget of mist nozzle.

E. Both the droplet size and distribution pattern of sprayed water were not affected by the different mist rod position, within the range of 1.5-4.5mm.

F. Along the pipe, 15mm in inside daimeters, installed with 35 mist nozzles at 1m intervals, whose diameter was 0.65mm, there were little pressure drop.

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