Characteristics of Atomization Nozzles for Knapsack Type Mist Sprayer

By

Akira ISHIHARA

(Laboratory of Agricultural Machinery, Faculty of Agriculture, Tottori University)

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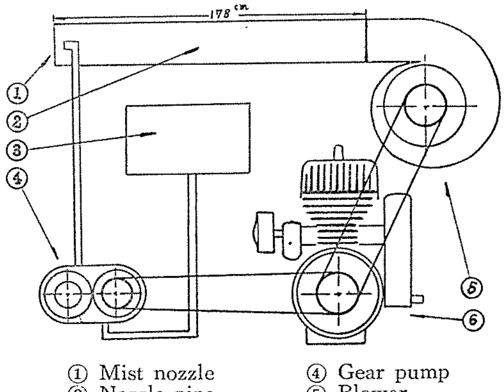
I. Introduction

In recent years, pest control machines for the application of concentrated chemicals have rapidly developed and spread.(1)(2)(10) But, although various kinds of nozzles for mist sprayers have been made, we can hardly find any analytical study of characteristics of these nozzles though these studies are very important in designing and producing the nozzles. So, the author has made a study of characteristics of atomization, arriving force, dispersion and distribution pattern of these nozzles.(6)(7)(8)(9) But in this paper, only the atomization characteristics of nozzles will be described.

An outline of characteristics of nozzles for mist sprayer is as follows : It has been generally recognized that the purpose of concentrated application was to economize consumption of chemicals, accordingly, to save time and labour, and with low volume application, application work would be rationalized and efficiency of pest control would be increased.(3)(4)(5) With mist nozzles, an atomization mechanism is required so that the size of the particles is 10—100μ in diameter. So, the mechanical structure of these nozzles is, of course, different from the nozzles of hand sprayers or power sprayers in which whirl nozzles are generally used. The sprayer nozzles are airless spray type, while on the contrary, the mist nozzles are almost blower application type. (That is, air injection spray and air blast spray type.) Therefore this atomization is mechanical dispersion and atomized small particles are applied by a blast from the blower.

II. Experimental apparatus and method

Diagram of apparatus which the author prepared is shown in Fig. 1.



① Mist nozzle ② Nozzle pipe ③ Chemical tank ④ Gear pump ⑤ Blower ⑥ Engine

Fig.1 Diagram of experimental apparatus

Engine: 50 cm^3, Two cycle single cylinder, air cooled gasoline engine. Standard revolution 3500 r.p.m, 1.6HP, Net weight 6.4kg, Fuel consumption 460 gr/HP/hr, Compression rate 6:1.

Pump: Gear pump.

Blower: Sirocco Fan, velocity of blast at outlet of nozzle pipe up to 58m/sec, air volume up to 8.7m^3/sec.

And these were driven with V-belt and this revolution ratio is as follows:

Engine : Blower : Pump = 1 : 2.057 : 0.857

All the tests were done in the experimental room of a concrete building, therefore those tests were not influenced by the wind.

The measuring method was as follows: First, the particle atomized in the nozzle were caught on the preparate glass smeared with oil. (which was made as follows: mixed mobil number 40 and caster oil and condensed until its viscocity was 89°)

The measuring position where the particle were caught is shown in Fig.2. Tested nozzles were set 44.5cm height from earth and fixed. And a microphotograph was taken of these samples caught on the preparate glass. That magnification was made seventy five times. Constant areas were set in the field of vision of these microphotographs, and the number of particles inside and these particles sizes were measured. Generally, the various mean diameter of particles are determined by the following formula: (1) Area diameter (projected area) $d_p=\sum nd/\sum n$, (2) Area length diameter $d_a=\sum nd^2/\sum nd$, (3) Volume surface diameter $d_v=\sum nd^3/\sum nd^2$, (4) Area diameter (cross-sectional area) $d_2=(\sum nd^2/\sum n)^{\frac{1}{2}}$. (5) Volume diameter $d_3=(\sum nd^3/\sum n)^{\frac{1}{3}}$.

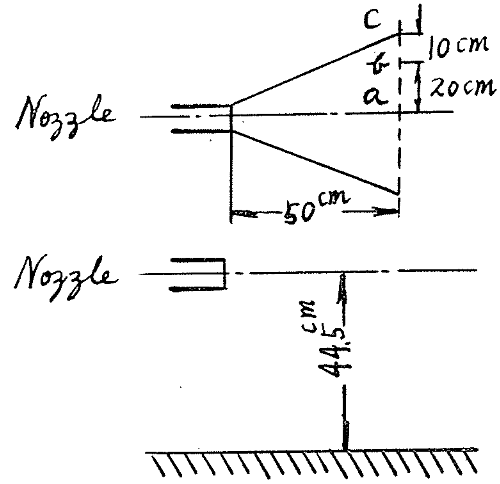


Fig. 2 Measuring Position

And, in this experiments, mean diameter of particles were calculated by the following formula:

$$d_v=\sum nd^3/\sum nd^2$$

Where d_v : mean diameter of particle

d : measured diameter of particle

n : number of particles having a diameter d

So, atomization quality was measured by atomized particle sizes and the number of paticle applied. Tested nozzles were made of brass by the author himself. And five representative type nozzles for a mist sprayer were used.

III. Experiment of air velocity and air volume from the blower

Before chemical application test, the author measured characteristics of air velocity and air volume at nozzle pipe outlet. Next, author tested air velocity of range of deposit, distribution and diffusion of air. And they were measured with a manomenter and anemometer. Those tests result are shown in Fig. 3. From these results, it was recognized that the more the number of revolution of engine increased, the more the air velocity.

As shown in Fig. 3. this velocity declined very rapidly with range of deposit. This declining curve is given in following experimental formula.

$$V=15.1x^{-0.712}$$

where V : air velocity (m/sec)

x : range of deposit (m)

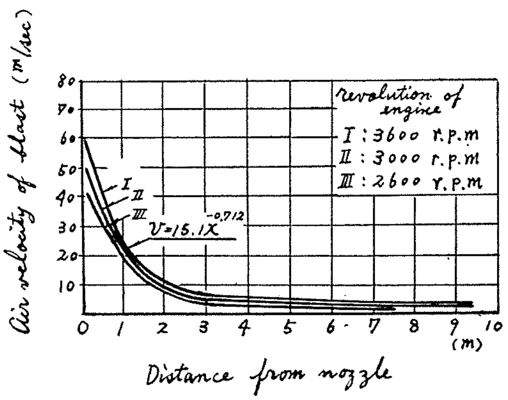


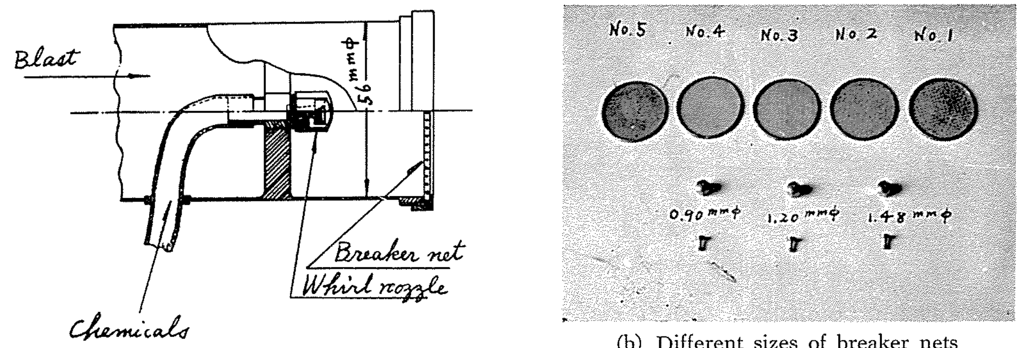
Fig. 3 Relationship between distance from nozzle and air velocity of blast

IV. Characteristics of the experiments for earch mist nozzles

(1) Whirl nozzle with breaker net type mist nozzle.

a. Structure of nozzle.

The nozzles structure is shown in Fig. 4.(a). On this type of mist nozzle, atomization



(a) Section of nozzle

(b) Different sizes of breaker nets (mesh) and whirl nozzles

Fig. 4 Structure of whirl nozzle with breaker net type mist nozzle

mechanism is explained by following principle; first, chemicals were atomized by whirl nozzle, and further atomized to smaller particles by impact on the breaker net.

Therefore, on this type nozzle, effected factors of structure on atomized particle size and number seemed to be as follows:

(1) Whirl nozzles hole diameter (in Fig.4. (b.), A=0.9mmφ, B=1.2mmφ, C=1.98mmφ)

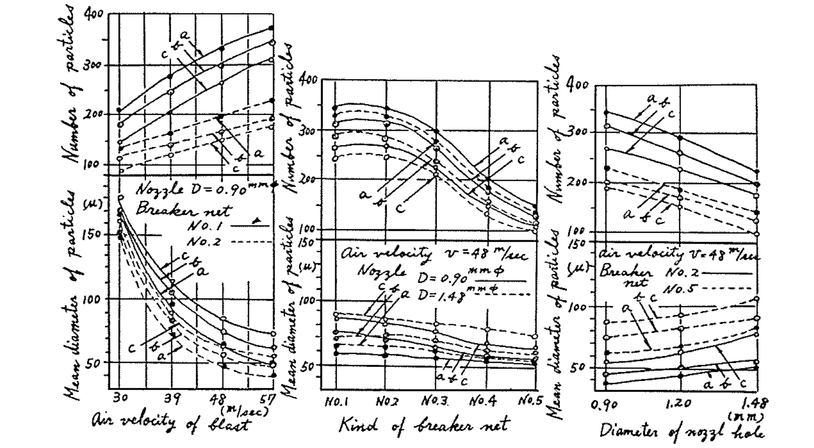
(2) Mesh size of breaker net (in Fig.4. (b), No.1=12mesh, No.2=16mesh, No.3=24mesh, No.4=32mesh, No.5=50mesh)

(3) Air velocity of a blast from blower (30, 39, 48, 57 m/sec)

Thus, experiments were done by means of variation of each of the above factors.

b. Experimental results and discussion.

The characteristical graph of the results of atomizing tests is given in Fig. 5. From these



(a) Relation of air velocity to atomization (b) Relation of kinds of breaker net to atomization (c) Relation of nozzle size to atomization

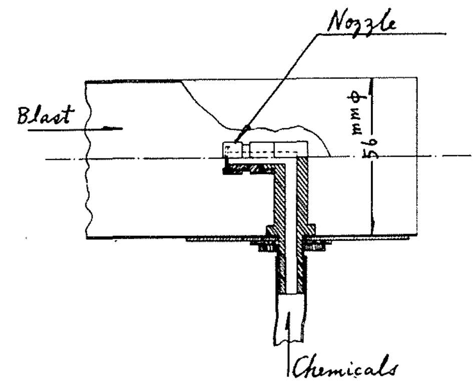
Fig. 5 Characteristics curve showing the effect of nozzle structure on whirl nozzle with breaker net type mist nozzle.

results, the effect of air velocity on particle size was the most distinctly different in comparison to the other factors. Especially, when revolution is decreased from 2600 r.p.m (39 m/sec) to 2200 r.p.m (30m/sec), particle sizes became larger from 70~100μ to 150~180μ. The effect of mesh size of breaker net was not remarkable on particle sizes, but in proportion to the smaller size mesh, the particle size became smaller. However, when the author used No.3, No.4, No 5 net, atomization was no good. From these facts it might be supposed that in these cases, mutual relation between net mesh size and whirl nozzle hole diameter was unbalanced. Atomization is not done perfectly, therefore, the volume of chemicals dropped on the breaker net is increased. So, the number of particles is decreased though particle size became smaller.

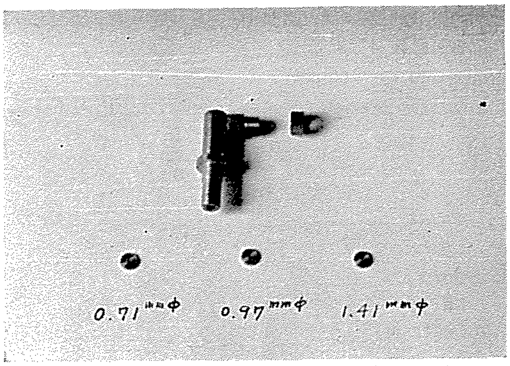
(2) Air and chemical jet impact type mist nozzle.

a. Structure of nozzle.

The nozzles structure is shown in Fig. 6. (a). On this type nozzle, atomizing action is done



(a) Section of nozzle



(b) Different sizes of single hole nozzles

Fig. 6 Structure of air and chemicals jet impact type mist nozzle

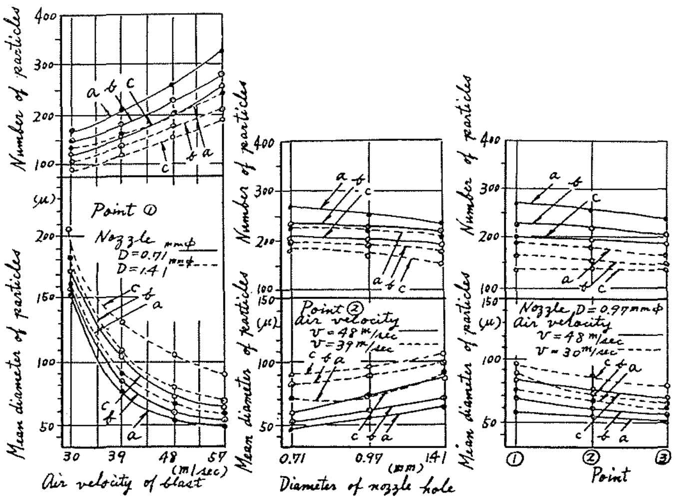
by impact reaction between air and injected chemicals. Therefore, on this type nozzle, effected factor of structure on atomized particle size and number seemed as follows, so, the author varried these factors on this test.

(1) Air velocity of blast from blower (30, 39, 48, 57m/sec)

(2) Single hole nozzles diameter (in Fig. 6. (b), A=0.71mmφ, B=0.97mmφ, C=1.41mmφ)

(3) Nozzle position from outlet of nozzle pipe (Point① =4cm, Point② =6.2cm, Point ③ =8.4cm)

Thus, experiments were done by means of changing each of the above factors.



(a) Relation of air velocity to atomization (b) Relation of nozzle size to atomization (c) Relation of nozzle hole position to atomization

Fig.7 Characteristics curve showing the effect of nozzle structure on air and chemical jet impact type mist nozzle

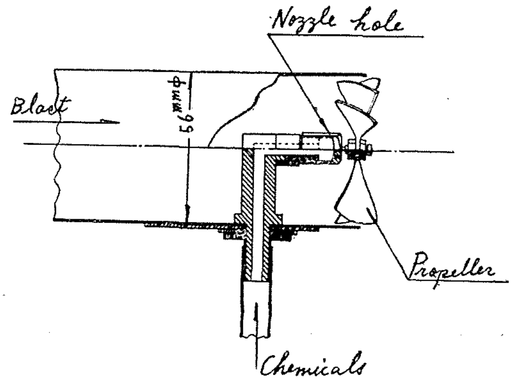
b. Experimental results and discussion.

Results obtained from the experiment were presented in Fig. 7. With this type nozzle, also, particle sizes were greatly affected by air velocity. The maximum size of particle is 210μ, therefore, it is larger than from the other type nozzles. Effects of variation of nozzle hole diameter were following that as to the larger the nozzle hole as 0.71mmϕ, 0.97mmϕ, 1.41mmϕ, the larger the particie size slightly, and the less the number of particles. But such rate of decrease is less than whirl nozzle with breaker net. As for the effect of nozzle position, when single hole nozzle was set farther in from nozzle pipe outlet, i. e., Point ③, particle size and its number were decreased as in Fig.7. This phenomenon seems to be due to dropping the chemicals on pipe wall, so, when nozzle set near outlet, i. e., point①, atomization was good.

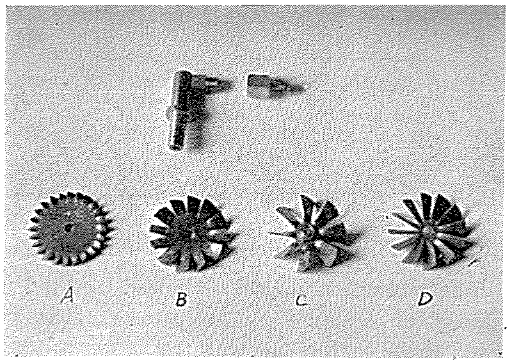
(3) Propeller type mist nozzle.

a. Structure of nozzle.

The nozzle's structure is shown in Fig.8.(a). On this type nozzle, propeller is revolved by air



(a) Section of nozzle



(b) Different shapes of propellers

Fig. 8 Structure of Propeller type mist nozzle

pressure from blower, and chemicals which were compressed are injected in six nozzle holes and its jet is impacted on propeller blades. These six nozzle holes are set on the round of propeller shaft. Therefore, on this type nozzle, effected factor of structure on atomized particle size and number seemed as follows, so author varied these factors on this tests.

(1) Air velocity of blast from blower (30, 39, 48, 57 m/sec)

(2) Shape of propeller (Four kinds as shown in Fig 8. (b))

(3) Pressure of chemicals (This pressure was adjusted by pressure regulator from 60lb/in^2 to 100 lb/in^2)

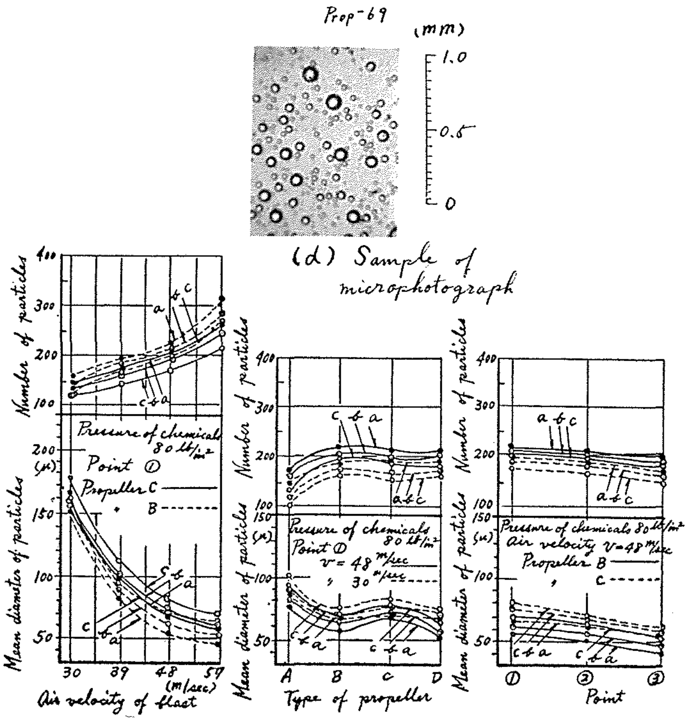
(4) Position of propeller and nozzle hole (Point ①, ②, ③, were set 4 cm, 6.2 cm, 8.4 cm from outlet of nozzle pipe)

Thus, experiments were done by means of changing each of the above described factors.

b. Experimental results and discussion.

On this experiment, nozzles and propeller shaft were made with brass, thus, propeller revolution was very smooth. But if chemicals involve many solid body or has large viscosity, shaft clearance is filled with these chemicals.

Results obtained from the experiment were presented in Fig.9. And sample of microphotograph were shown in Fig .9 (d). Effect of air velocity promoted atomization. That is the higher air velocity became, the more propeller revolution is increased, and number of particles also increased. When air velocity was 30m/sec, particle size was 150～180μ in diameter. This size is large for mist particle. When propeller revolution became high, atomization degree is very good. Effect of shape of propeller was as follows that on D-type which has 12 blades, atomizing



(a) Relation of air velocity (b) Relation of propeller shape to atomization (c) Relation of nozzle hole position to atomization

Fig. 9 Characteristics curve showing the effect of nozzle structure on propeller type mist nozzle

particle size was minimum, and its number was good as 200 at 48m/sec. Relaionship between B-type and C-type seems to be that on B-type the mean particle size is smaller than that of C-type. On A-type, particle size was largest and number was less, and so atomization was not good. From these facts it might be supposed that blade number is a very important factor for atomization. Effect of chemicals pressure was follows that although atomization is affected by air velocity and revolution of propeller, when pressure became the high as 60 lb/in^2→80 lb/in^2 →100 Ib/in^2 atomization was promoted slightly on both B-blade and C-blade.

When same nozzle hole was used, the higher the pressure, the larger the volume of delivery. But on this nozzle, atomization was more greatly affected by the impact force than the volume of chemicals. Therefore, it is believed that if higher pressure were used atomtzation would be better with smaller particles. Before test I thought that effect of nozzle position was almost negligible. But in this experiment when position set ınner, the particle mean diameter became smalle slightly, and also number was decreased. From these facts author judged that reason for this facts are due to impact on pipe wall and drop out and flow out of nozzle pipe.

(4) Breaker disc type mist nozzle.

a. Structure of nozzle.

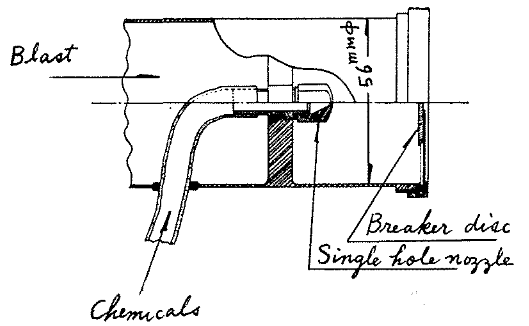
The nozzles structure is shown in Fig.10 (a). On this type nozzle, pressed chemicals which was injected in single hole nozzle is impacted on breaker disc, and these are atomized by blast from blower. The round part of the breaker disc was beveled as shown in Fig.10 (a).

Therefore, on this type nozzle, effected factors of structure on atomized particle size and number seemed as following. so, author varied these factors on this test.

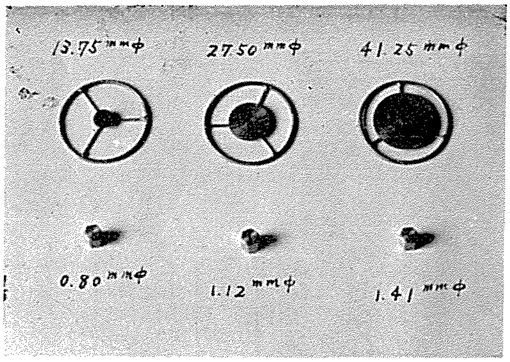
(1) Breaker disc diameter (in Fig.10 (b), D=13.75mmϕ, 27.50mmϕ, 41.25mmϕ)

(2) Air velocity of blast from blower (30, 39, 48, 57m/sec)

(3) Nozzle hole diameter (in Fig.10 (b), D=0.80mmϕ, 1.12mmϕ, 1.41mmϕ)



(a) Section of nozzle



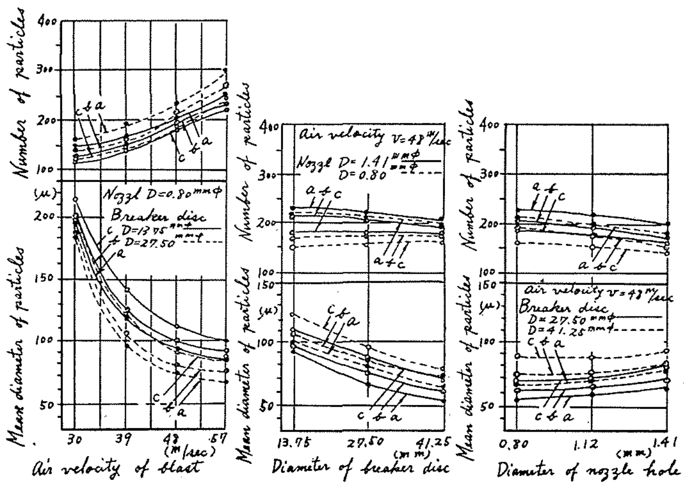
(b) Different sizes of breaker disc and single hole nozzles

Fig. 10 Structure of Breaker disc type mist nozzle

Thus, experiments were done by meaus of variation of each of the above factors.

b. Experimental results and discussion.

Experimental results presented graphically in Fig.11. This type nozzle has special characteristics. That is, atomized particle size varied with varied breaker disc size. For example, when



(a) Relation of air velocity to atomization (b) Relation of breaker disc size to atomization (c) Relation of nozzle size to atomization

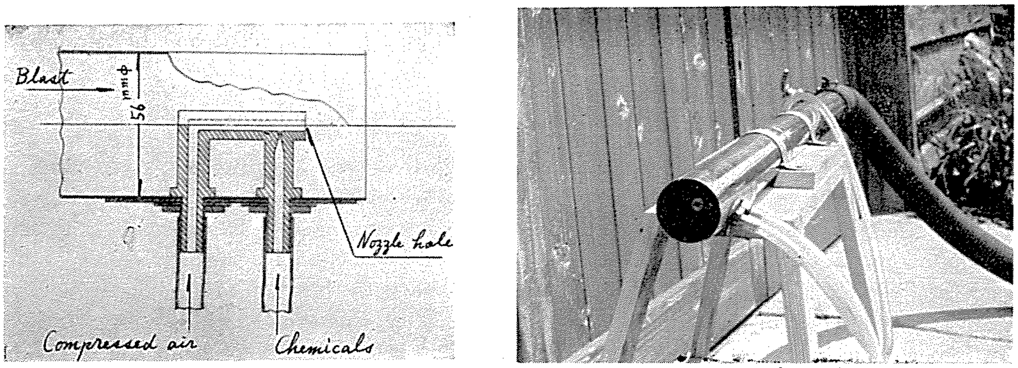
Fig. 11 Characteristics curve showing the effect of nozzle structure on breaker disc type mist nozzle

using nozzle D=0.80mmφ at D=13.75mmφ breaker disc, shown mean particle diameter 95μ at center of application. And when D=41.25mmφ breaker disc, particle size became smaller as 60μ. On the other hand, the smaller the particle size, the greater the number of parlicles became, and application pattern is good. But when using nozzle D =0.80mmφ, the larger the breaker disc diameter as D=13.75mmφ→27.50mmφ→61 25mmφ, the smaller the particle size and also the number was decreased. Especially at m.p. a and b which is nozzle center, these facts are presented very distinctly. From these facts I thought that this phenomenon is due to as following reason : in spite of breaker disc diameter becoming larger (i.e., atomizing reaction part is large), jet volume is less, too. Therefore designer can increase jet volume more in this case. For these reasone, on this type nozzle it is most important that mutual relationship between breaker disc size and nozzle size is selected in optimum. Effect of nozzle diameter was as follows, that when using the same breaker disc, the smaller the nozzle size, the smaller the particle size and the number increased. And also, the higher the air valocity, the smaller the particle size aud number increased, too. But generally speaking, on this type nozzle particle size is larger than the other type nozzle. For example, when using nozzle D=0.80mmφ, breaker disc D=13.75mmφ at Point a, 30m/sec, particle mean diameter of 200μ occoured.

(5) Pneumatic type mist nozzle.

a Structure of nozzle.

The nozzles structure is shown in Fig.12.(a) (b). In this test, the author using air compressor



(a) Section of nozzle (b) View of nozzle

Fig.12 Structure of Pneumatic type mist nozzle

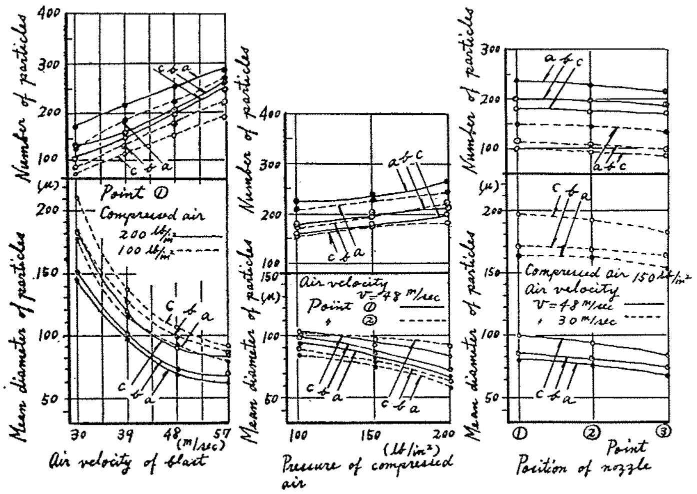
to obtain compressed air. Therefore, this type nozzle needs excessive apparatus for atomization On this type nozzle, effected factor of structure on atomized particle size and number seemed as follows, so, the author varied these factors on this test.

(1) Pressure of compressed air (100, 150, 200 lb/in²)
(2) Position of nozzle (Point ①, ②, ③)
(3) Air velocity of blast from blower (30, 39, 48, 57 m/sec)

Thus, experiments were done by means of changing each of the above factors.

b. Experimental results and discussion.

Results obtained from the experiment were preseuted in Fig.13. On this type nozzle, mutual.



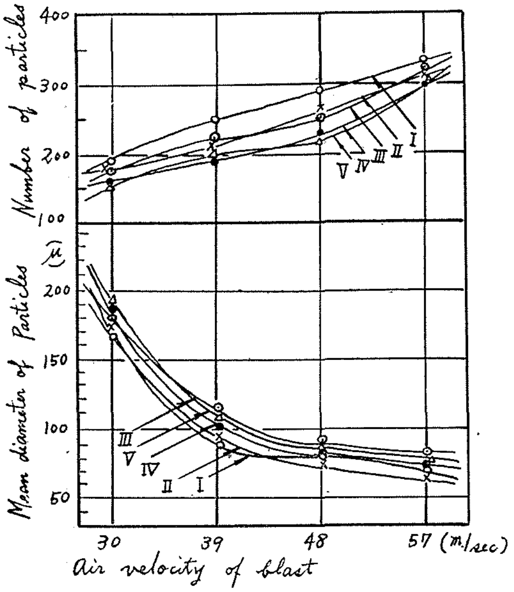
(a) Relation of air velocity to atomization (b) Relation of air pressnre to atomization (c) Relation of nozzle position to atomization

Fig. 13 Characteristics curve showing the effect of nozzle structure on Pneumatic type mist nozzle relationship between chemicals pressure and compressed airs pressure greatly affected particle size and number. For example, under the constant chemicals pressure 80 lb/in², atomized particle size was 105μ on air pressure 100lb/in², and particle size was 90μ on air pressure 150 lb/in², and particle size was 75μ on air pressure 200 lb/in². Thus, from these facts, it was clear that as to the atomized particle, the higher the air pressure, the smaller the particle size, and number is increased, i.e., 230 on 100 lb/in², 235 on 150 lb/in², 270 on 200 lb/in². Effect of air velocity was as follows, that the higher the air velocity, the less the particle size and number was increased. These facts were clear on both 200 lb/in² air pressure and 100 lb/in². But on this type nozzle, particle distribution density was different from measuring position, i.e., a, b and c, especially. That is, on nozzle center particle was a mass, and on the side particle distribution was rough.

V. Mutuality of five nozzles for use on mist sprayer

As discribed above, on each nozzle for representative five type mist nozzle, the author has studied experimentally the characteristics of atomization. And in these cases the author investigated the effect of some constructural factors for each type nozzles. The next, author has made experiments for mutuality among these five nozzle characteristics. Experimental conditions for each nozzle were selected as follows : Whirl nozzle with breaker net type nozzle—nozzle diameter D=0.90mmϕ, breker net No.4 (32mesh), chemicals pressure 80 lb/in². Air and chemical jet impact type nozzle —— Point ①, nozzle diameter D=1.4mmϕ. Propeller type nozzle —— chemicals pressure 80 lb/in², propeller blade B-type. Breaker disc type nozzle —— chemicals pressure 80 lb/in², nozzle diameter D=0.80-mmϕ, breaker disc diameter D=13.75 mmϕ. Pneumatic type nozzle —— Point ①, compressed air 200lb/in², chemicals pressure 80 lb/in². There are more effective conditions on each nozzle, therefore, the above condition is not the maximum condition of structure. But, in general, atomization, disperition, is contradictory to each other. So, the author selected one factor in many variable factors for experiment. This one factor is air velocity of blast from blower.

Results obtained from these experiment were presented in Fig.14. From this mean particle size curve, it was shown that particle size is smallest on whirl nozzle with breaker net type nozzle, and also propeller type nozzle coresponds very closely. Above two type nozzles has two step atomization reaction. And propeller type nozzle is almost equal to breaker disc type nozzle in regard to atomizing reaction. That is, their atmization is done with centrifugal force. And second, on pneumatic type nozzle particle size was small on 30 m/sec air velocity, but on 39 m/sec, 48m/sec, 57 m/sec, it was large. From these facts it seems that action is not affected by air velocity on this type nozzle. And next, air and



I : Whirl nozzle with breaker net type mist nozzle nozzle D=0.90mmϕ, breaker net No.4.
II : Propeller type mist nozzle Pressure of chemicals 80lb/in², propeller B
III : Pneumatic type mist nozzle compressed air 200lb/in², Point①
IV : Air and chemical jet impact type mist nozzle Point①, nozzle D=1.41mmϕ
V : Breaker disc type mist nozzle. nozzle D=0.80 mmϕ, breaker Disc D=13.75mmϕ

Fig. 14 Relationship between air velocity of blast and mean diameter and number of particles on each type nozzles chemicals jet impact type nozzle follows, and breaker disc type nozzle was largest (note: in this experiment, on breaker disc type nozzle small disc was used, that is arriving type nozzle.). In regard to particle number curve, nozzle with breaker net type nozzle has most numbers. And next, propeller type nozzle and pneumatic type nozzle. And with a difference in number of 30, air and chemical jet type nozzle and breaker disc type nozzle had minimum value.

VI. Conclutions

In this paper, the author has been experimenting on five mist nozzles. And so, these results are as follows :

(1) On the whirl nozzle with breaker net type and propeller type nozzle, distribution pattern of particles were diffusing type.

(2) On the breaker disc nozzle, the characteristics are varied by mutual relationship between disc and nozzle sizes, i.e., they have characteristics both diffusing type and arriving type. And travelling force is much better than other type nozzles.

(3) On the pneumatic type nozzle, particle arrived at a full distance from the nozzle and the reduction of particle number is less than the others. And also, on the air and chemical jet impact type nozzle, travelling force is worse than the former.

Acknowledgement

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摘　　要

背負式ミスト機用ノズルの微粒化特性

石　原　　昂
(鳥取大学農学部農業機械学研究室)

濃厚液剤撒布機の近年における急速な発達にともない有気噴射系，分散式微粒化に基くミストスプレー用ノズルは各種構造のものが製作されている。これら諸種ノズルの薬液微粒化機構は無気噴射系ノズル型式をとる動力噴霧機とかなり異なる特性を有するが，これに関する基礎的研究に乏しい現状にかんがみ，著者はその代表的型式ノズルの5種（衝突網つきうず巻ノズル式，吹き返し式，衝突プロペラ式，衝突板式，空気噴射式）に関して各種ノズルの霧化，到達力，分散，分布の各特性を解明し，且つそれらの規定構造条件下の相互性を比較検討した。微粒化性能の判定には，平均粒径，粒数の顕微鏡写真による静的計測法を採用した。本報文はそれらの内，特に霧化特性に関する部分のみについて欧文にて取纒め論じたものであるが，実験研究の結果，ミストスプレー用ノズルの霧化特性を要約すると次の如くである。

1)　衝突網つきうず巻ノズル式及び衝突プロペラ式は，2段微粒化機構に基くもので平均粒径小さく，拡散ノズル系分布を呈した。

2)　衝突板式にては，衝突板径の大きさの変化により広範囲の粒径粒子を生成する特異性を有する。衝突板径，ノズル孔径の相互組合せ関係により，拡散系，到達系の両分布模様を呈した。

3)　空気噴射式は，むしろ到達系分布を呈し，粒径，粒数の減衰が少ない。吹き返し式も到達系の性状を有する。