PERFORMANCE ANALYSIS OF SWIRL SPRAY NOZZLES

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ABSTRACT:

In this paper, an experimental study of the characteristics of swirl spray nozzles has been made on a testing model 20 times as big as the practical nozzle. The tested model was constructed to represent the spiral passages, swirl chamber and exit orifice, with facilities to study the effects of swirl chamber height and nozzle size, in addition to flow parameters, on spray characteristics.

Empirical formula were obtained yielding good conformity between them and the experimental results.

INTRODUCTION:

Spraying has many important applications either in agriculture, such as irrigation and pest control, or industry such as atomization, painting and cleaning of equipments.

The swirl spray nozzle is considered the most common type of nozzles due to its simplicity. Some theoretical and experimental investigations concernint this nozzle were carried out, but controversy exists between the obtained results especially those giving the droplets size which is considered one of the most important characteristics of nozzle. Besides, no intention was given to the flow inside the swirl chamber although it is the key of the resulted spray.

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In this paper, the velocity and pressure distributions were measured inside the swirl chamber and the effects of flow and geometrical parameters are investigated. Empirical formula were obtained using the experimental observations in order to give the optimum design conditions for this type of nozzle.

EXPERIMENTAL SET UP:

The experimental set up consists of closed hydraulic circuit, apparatus and measuring devices.

1. The hydraulic circuit consists of a supply tank, pump, control valve, and pipe line ending with a common supply manifold.
2. The apparatus, shown in Fig. (1) is a model twenty times as big as the original nozzles usually used in Egypt to facilitate the experimental readings.

The apparatus consists of cylinder, cylindrical block, swirl chamber and discharge nozzles, these nozzles have the same outer diameter and length, but with different inner diameter.

EXPERIMENTAL RESULTS:

Pressure Distribution in Swirl Chamber:

Fig. (2) to Fig. (5) show the dimensionless pressure distribution in swirl chamber from these figures, it can be seen that the pressure inside the swirl chamber is nearly constant. For larger nozzle diameters a slight drop accurs in pressure keeping the trend of pressure distribution for free vortex flow field. This drop is due to the expected increase in flow rate and hence in vortex strength.

Velocity Distribution Across the Swirl Chamber:

Fig. (6) to Fig. (9) show the velocity profiles for different nozzles and supply pressure at test radii of 38 mm. and 60 mm. The profiles at the outer radius are not uniform. This can be attributed to the distribution in this area which is very close to the inlet ports. It can be seen that the maximum velocity at certain radius increases by increasing the nozzle diameter and or supply pressure. The velocity is also inversely proportional to the radius as the case of free vortex flow.

Flow Rate:

From Fig. (10) it can be seen that the increase in supply pressure leads to a corresponding increase in flow rate.

Fig. (11) shows that the decrease of the ratio L/d (where L is the length of nozzle discharge and d is the diameter of the nozzle) leads to increase in flow rate.

From the results it can be stated that, the flow rate is affected by the ratio L/d more than the supply pressure. An empirical formula which gives the discharge as a function of the supply pressure and nozzle size can be obtained from the experimental data in the form:-

$$Q = 1235(P_s)^{0.6} \quad (L/d)^{-1.5} \qquad cm^3/sec.$$

where the supply pressure P_s, is in Kg/cm^2.

Spray Angle:

From Fig. (12) it can be stated that, the increase in pressure leads to a corresponding increase in the spray angle up to a pressure of 1.2 Kg/cm^2, and after this pressure the spray angle is nearly constant.

Fig. (13) shows that the spray angle decrease with the increase of the ratio L/d.

From results it could be noticed that the spray angle is affected by the ratio L/d more than the supply pressure. An empirical formula which gives the spray angle as a function of the supply pressure and nozzle size can be obtained from the experimental data in the form:

$$= 77 \quad (P)^{0.135} \qquad (L/d)^{-0.52}$$

The Droplet Size:

The method to determine the droplet sizes is by receiving them in an oil bath. A good sample should consist of about 200 drops collected from random places. Counting and determination is done be using an overhead projector.

Classification of size is made according to a geometrical series.

Fig. (14) shows a typical distribution of drops in a sample. The cumulative curve Fig. (15) is used to determine the media diameters which represent 50% of the size of drops.

From the results, it can be noticed, for all nozzles, that, the median droplet diameter decreases by increasing the supply pressure and increase by increasing the nozzle diameter.

An empirical formula which gives the median droplet diameter as a function of the supply pressure and nozzle size can be obtained from the experimental data in the form:

$$MDD = 0.056 \quad (P)^{-0.25} \quad (L/d)^{0.47} \qquad Cm.$$

Swirl Chamber height:

The swirl chamber was changed from $0 \longrightarrow 4$ cm without any change in nozzle characteristics.

Comparison between the experimental results and the obtained empirical formula ? is shown in Fig. (16) to Fig. (18).

CONCLUSIONS:

From the discussion of the experimental results, the following conclusions can be stated:

1. The following discharge from the swirl spray nozzles increases by increasing the supply pressure and, or decreasing the nozzle length to diameter ratio (L/d) according to the empirical formula.

$$Q = 1235 \quad (P_s)^{0.6} \quad (L/d)^{-1.5} \qquad Cm^3/Sec.$$

2. The dimensionless pressure (P/P_s) inside the swirl chamber can be assumed constant away from the exit region. It decreases by increasing the supply pressure and, or decreasing the nozzle ratio (L/d).

3. The flow inside the swirl chamber is free vortex.

4. The spray angle of flow at nozzle exit increases by increasing the supply pressure up to certain value of 1.2 Kg/cm^2. The increase of the supply pressure than.this value has a very small effect on the spray angle.

The spray angle decreases also by increasing the ratio L/d and can be obtained using the empirical formula

$$= 77\ P^{0.135}\ (L/d)^{-0.52}.$$

5. The median diameter of sprayed droplets decreases by increasing the supply pressure and, or decreasing the ratio (L/d) according to the empirical formula.

$$MDD = 0.056\ P^{-0.25}\ (L/d)^{0.47} \quad Cm.$$

6. The swirl chamber height has a neglegible effect on the discharge, spray angle and median diameter of sprayed droplets.

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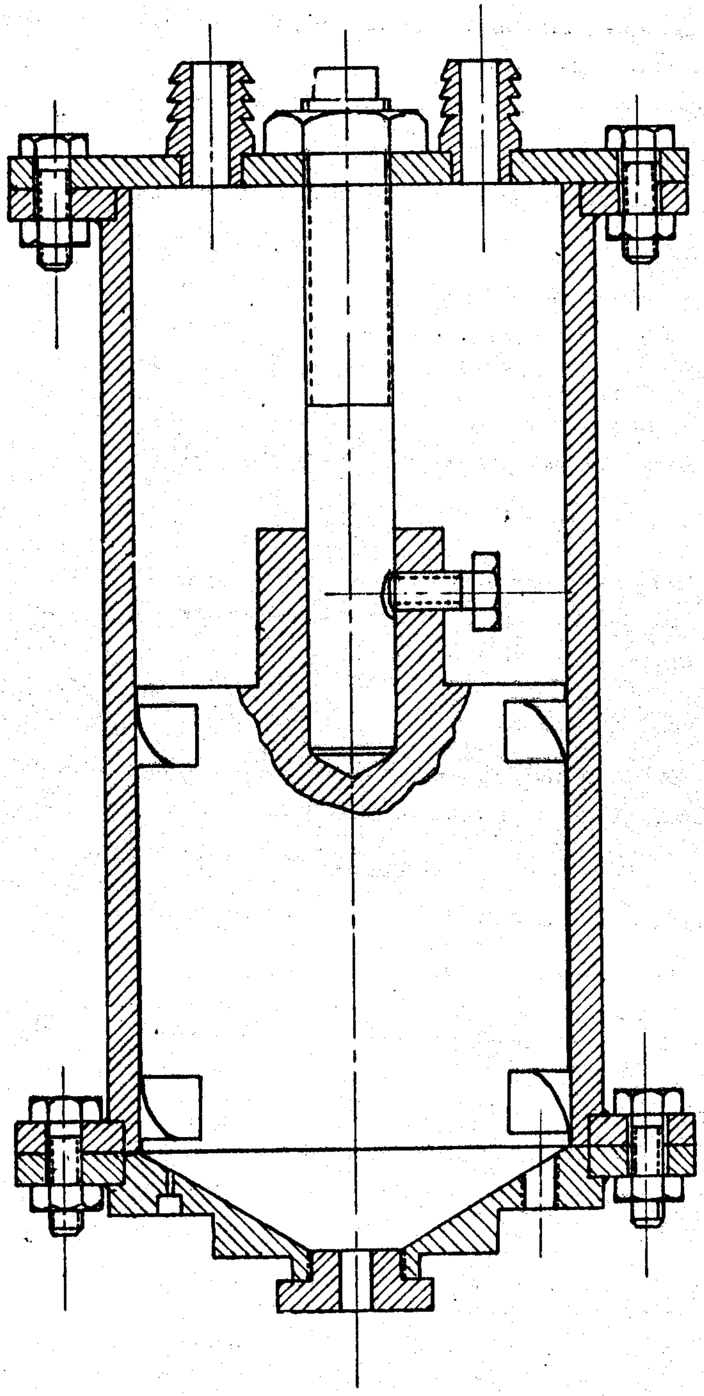

FIG (1): THE APPARATUS SCALE 1-2

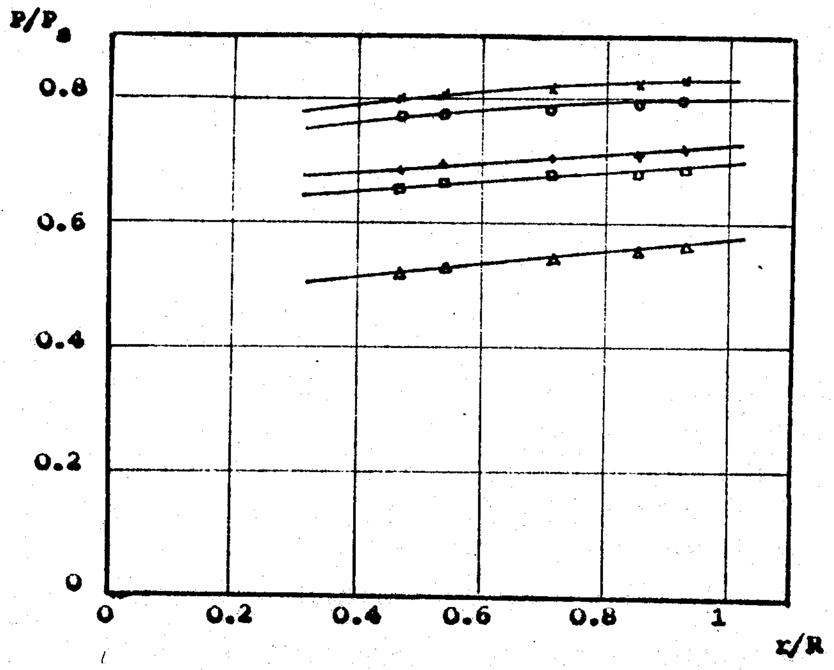

FIG. (2): PRESSURE DISTRIBUTION IN SWIRL CHAMBER FOR L/d = 1.

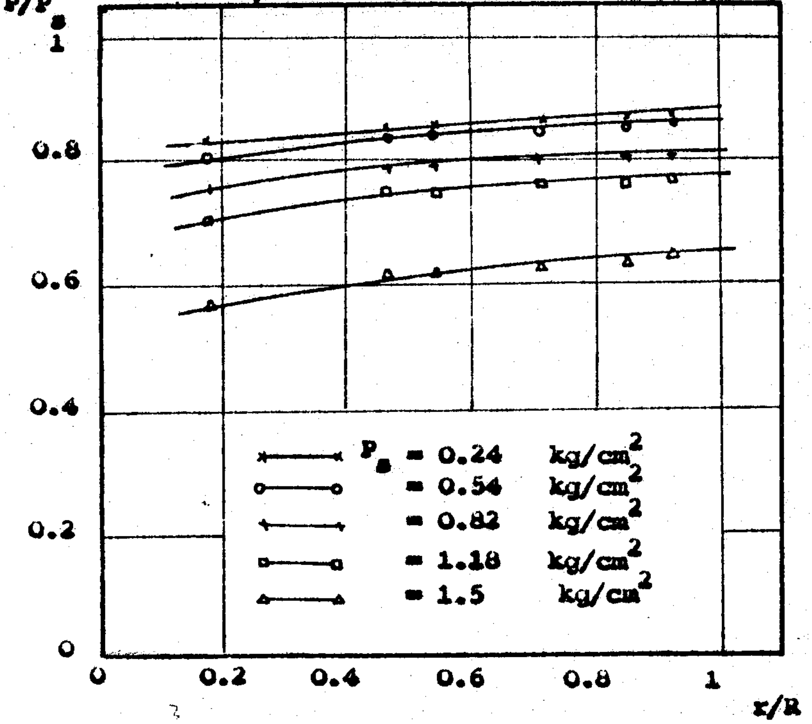

FIG. (3): PRESSURE DISTRIBUTION IN SWIRL CHAMBER FOR L/d = 1.33.

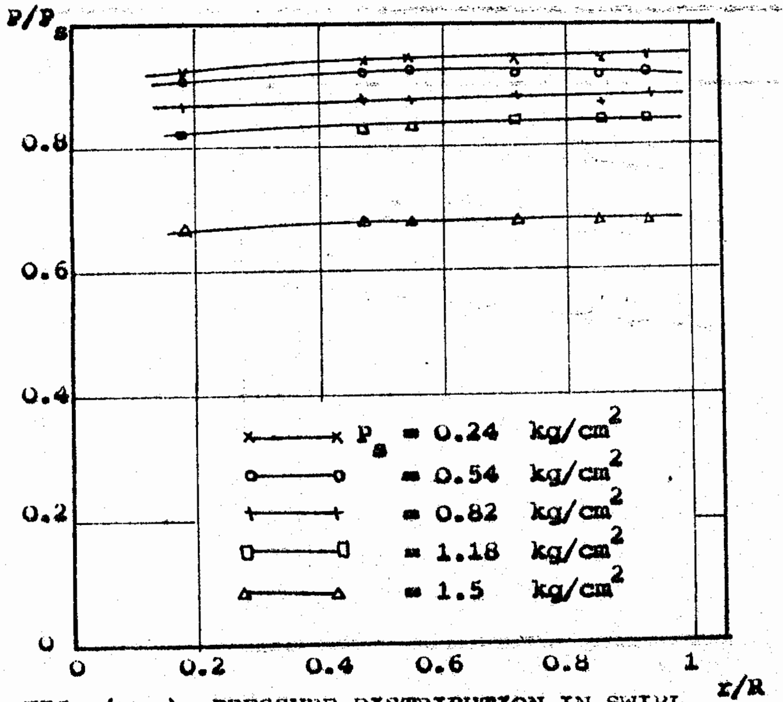

FIG. (4): PRESSURE DISTRIBUTION IN SWIRL CHAMBER FOR L/d = 2.

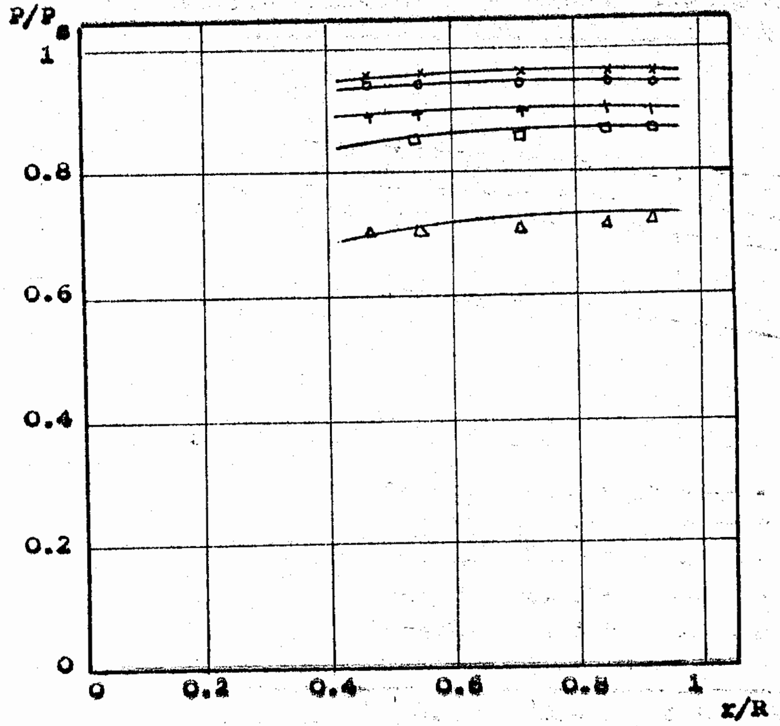

FIG. (5): PRESSURE DISTRIBUTION IN SWIRL CHAMBER FOR L/d = 4.

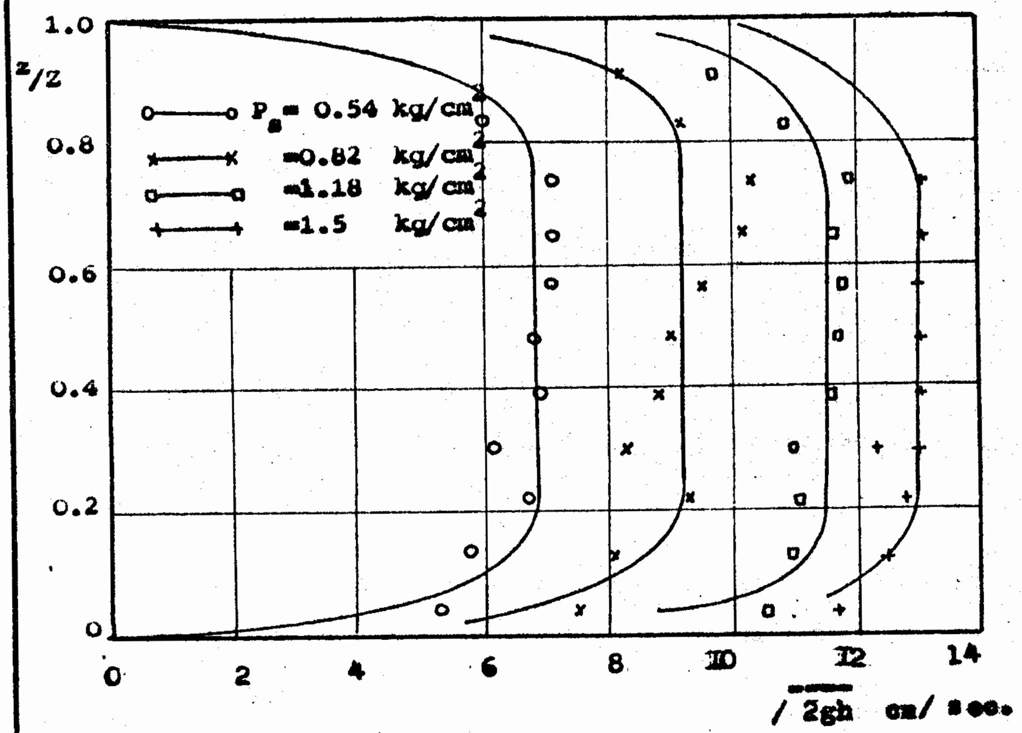

Fig. (6): VELOCITY DISTRIBUTION IN THE SWIRL CHAMBER AT r = 38 mm, FOR L/d = 2

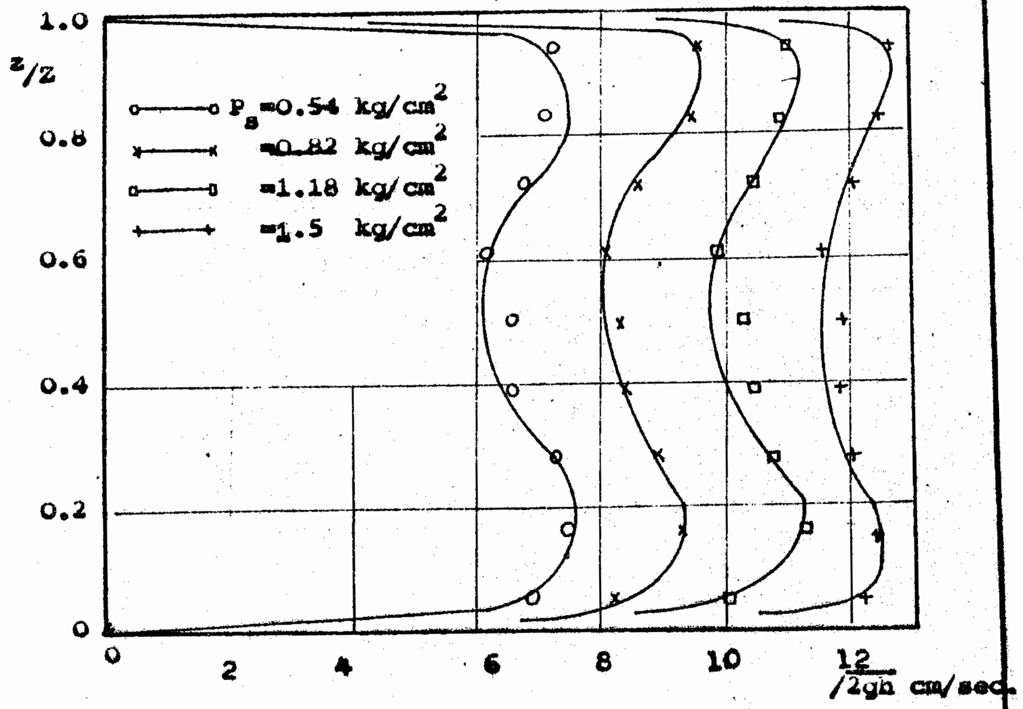

FIG. (7): VELOCITY DISTRIBUTION IN THE SWIRL CHAMBER AT r = 60 mm, For L/d = 2.

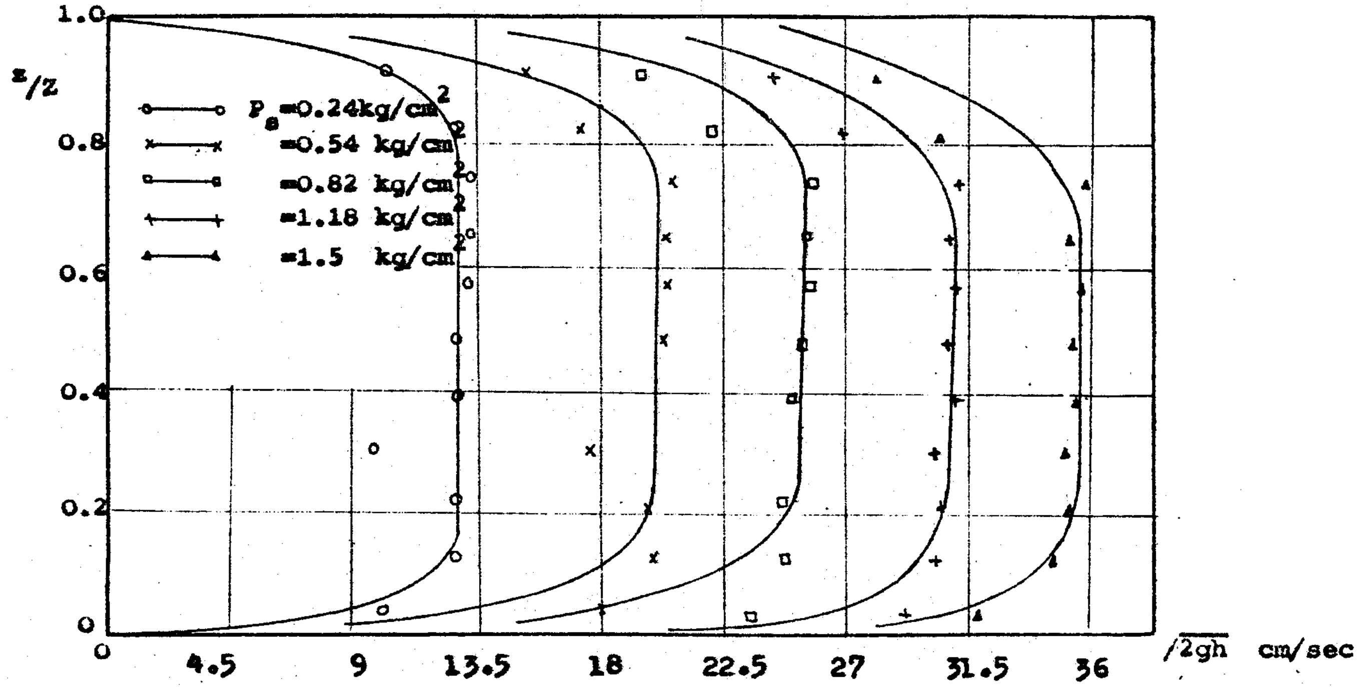

FIG. (8): VELOCITY DISTRIBUTION IN THE SWIRL CHAMBER AT r = 38 mm. FOR L/d = 1

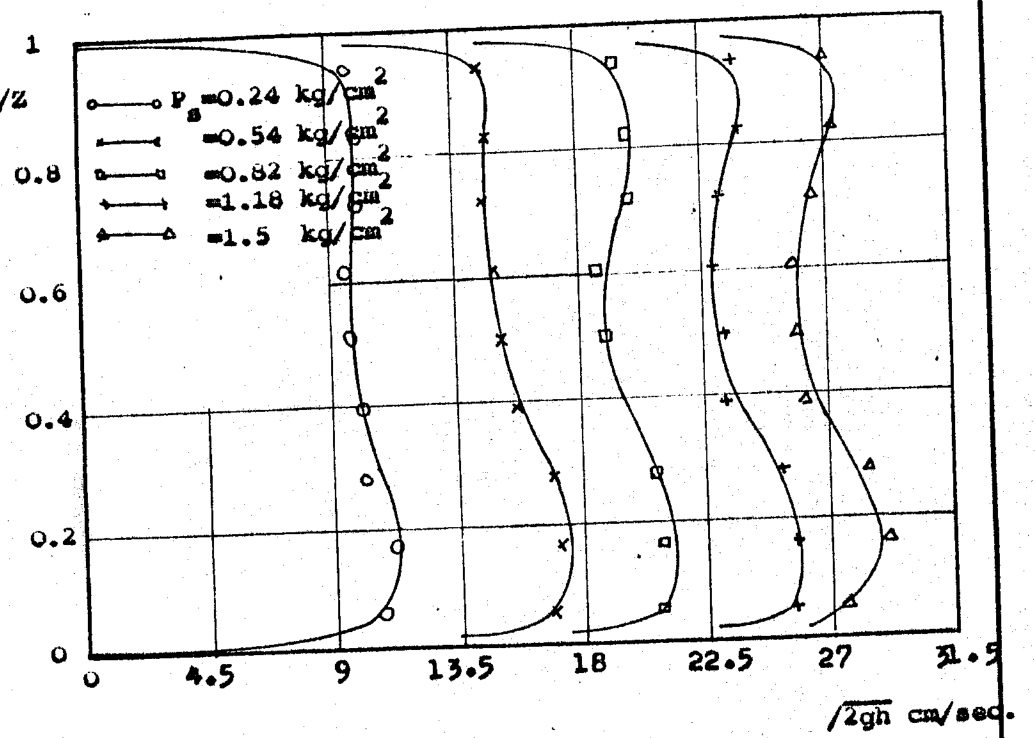

FIG. (9): VELOCITY DISTRIBUTION IN THE SWIRL CHAMBER AT r = 60 mm, for L/d = 1.

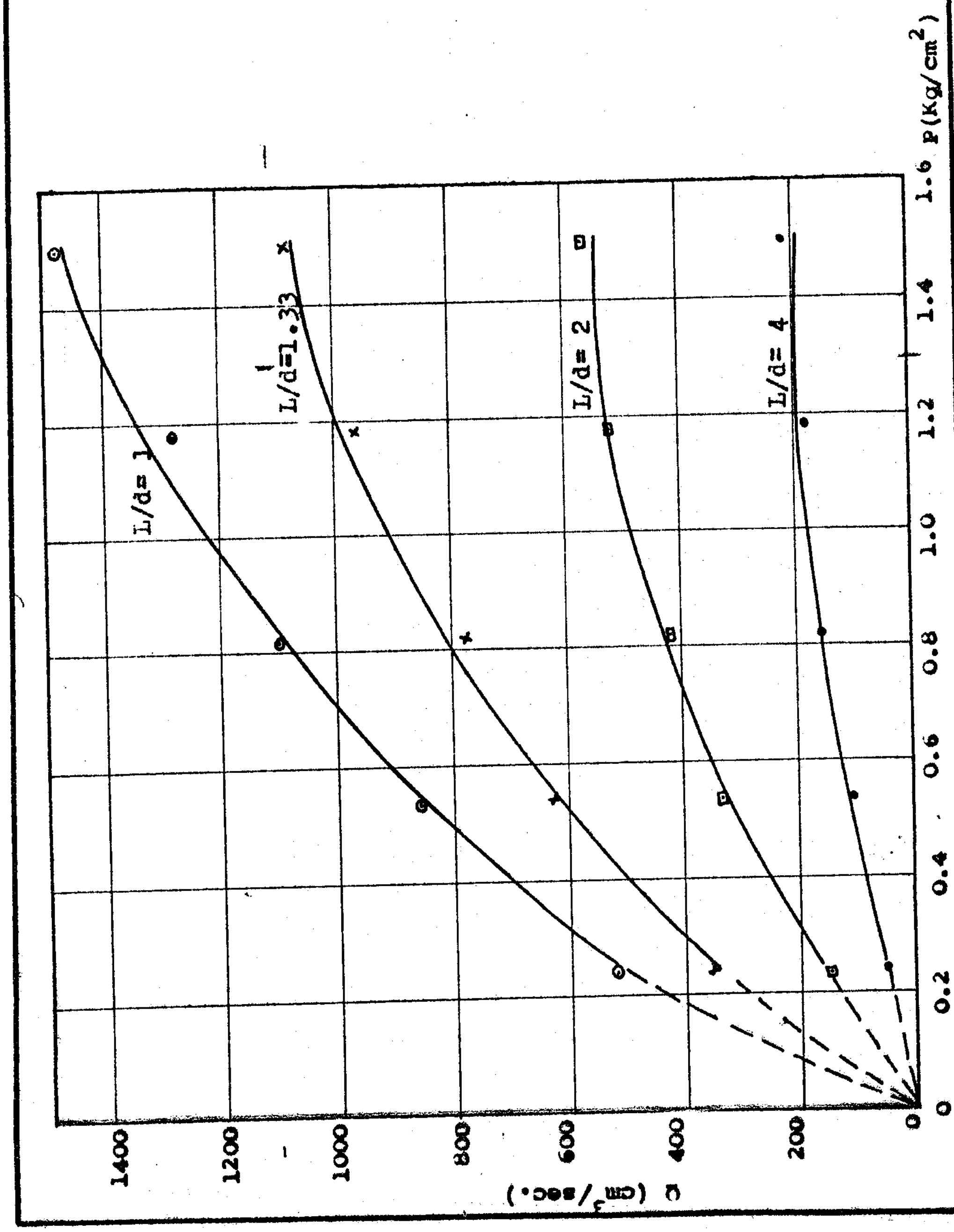

FIG.(10): EFFECT OF SUPPLY PRESSURE ON FLOW RATE

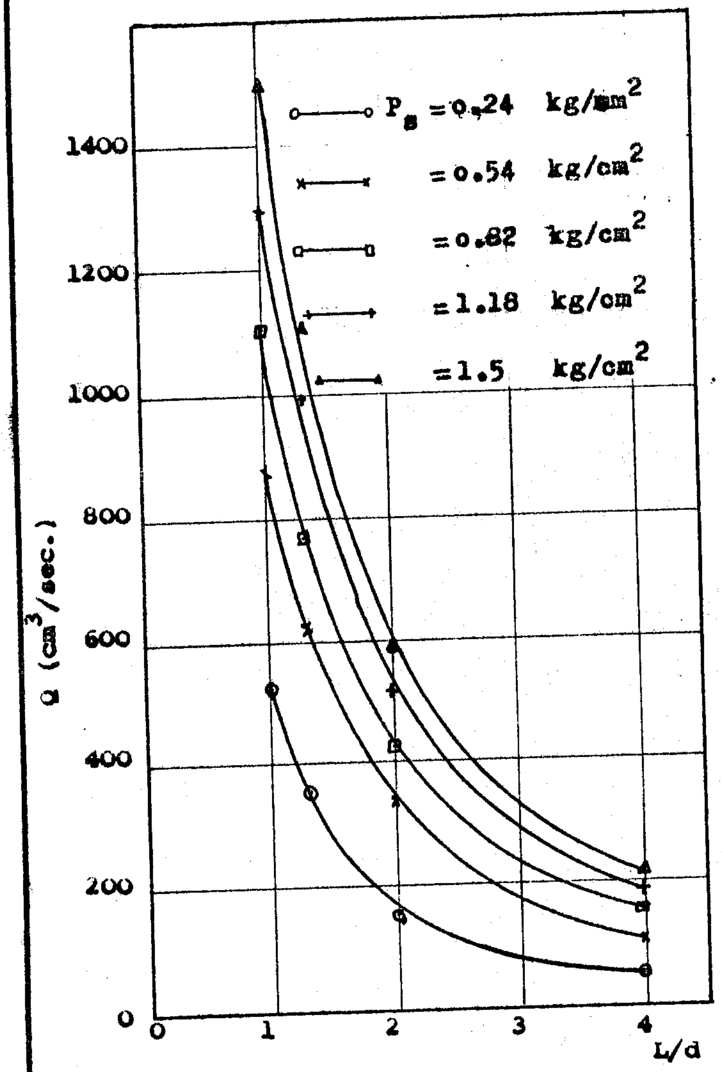

FIG. (11): EFFECT OF THE RATIO L/d ON FLOW RATE

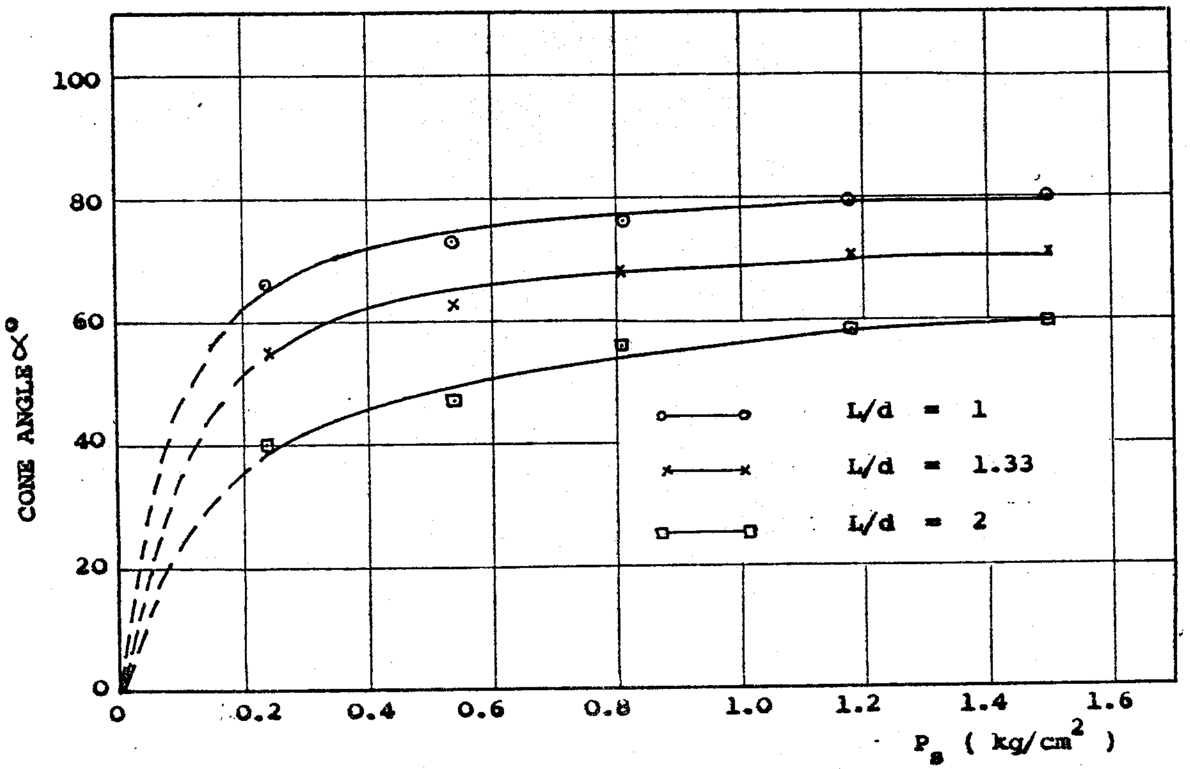

FIG. (12): EFFECT OF SUPPLY PRESSURE ON SPRAY ANGLE

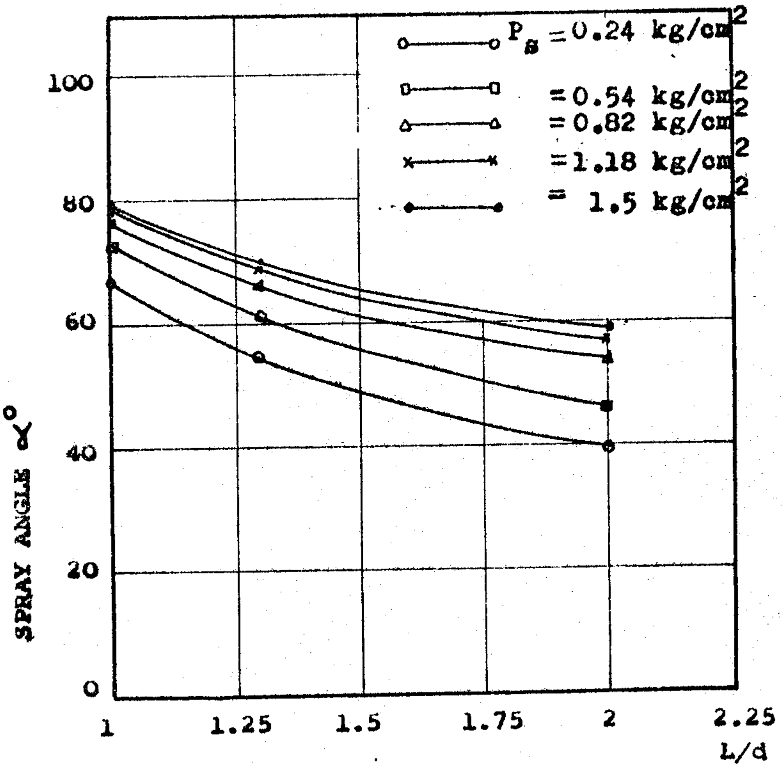

FIG. (13): EFFECT OF L/d ON SPRAY ANGLE

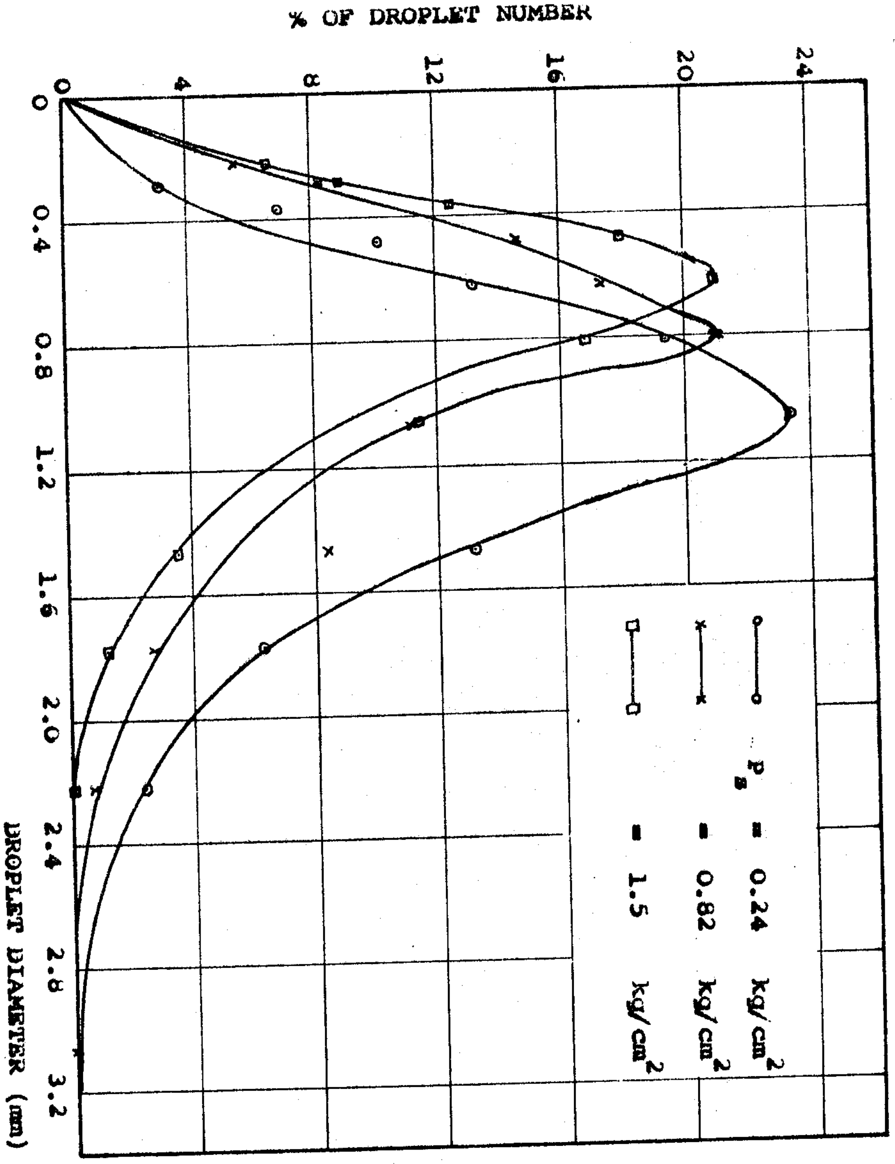

FIG. (14): SIZE FREQUENCY DISTRIBUTION CURVES FOR L/d = 1.33

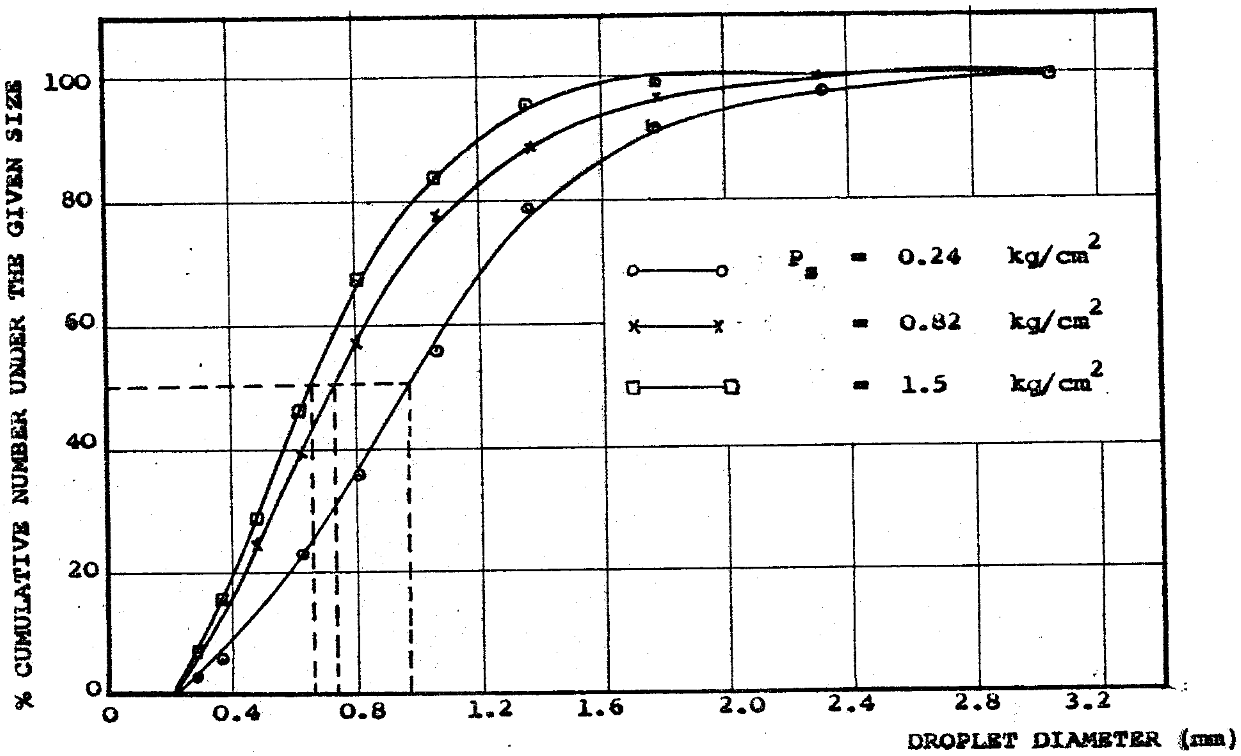

FIG. (15) CUMULATIVE DISTRIBUTION CURVES FOR L/d = 1.33

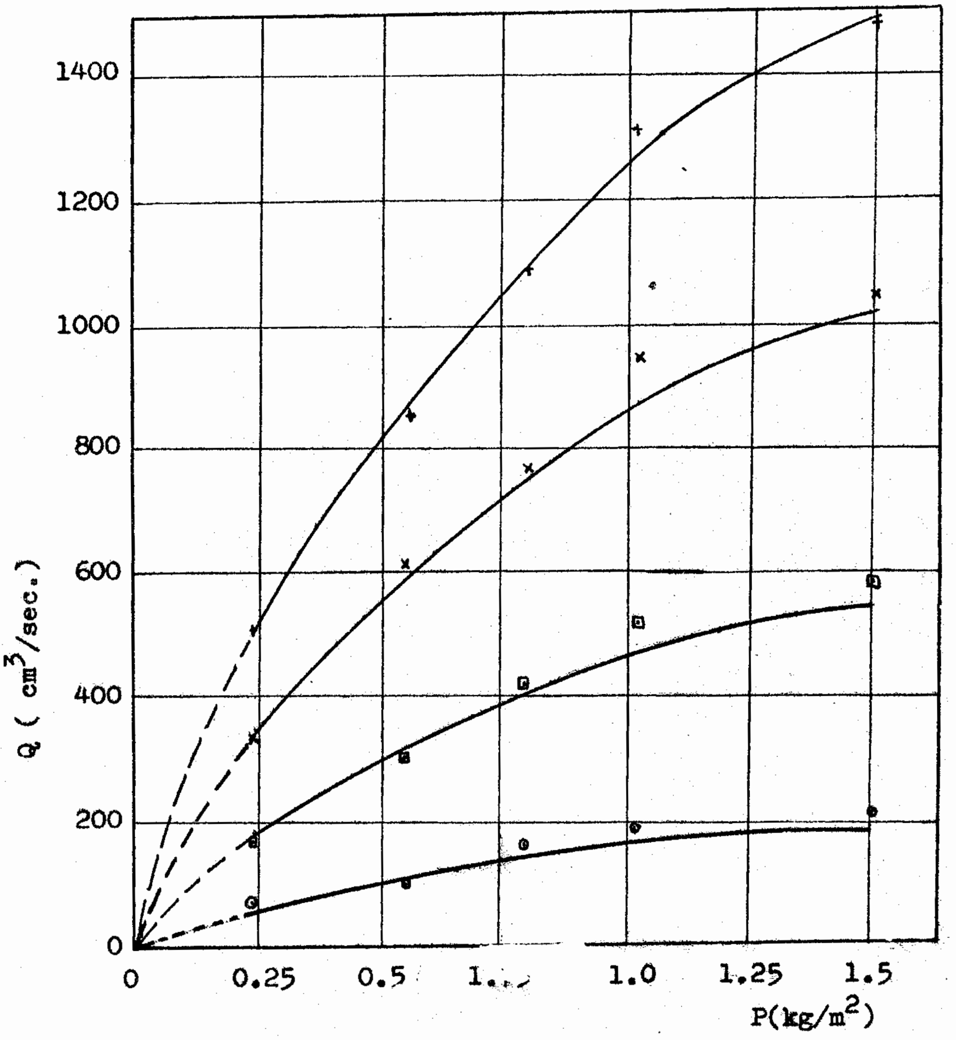

Fig.(16)Comparison between empirical formula
and experimental results for the flow rate.

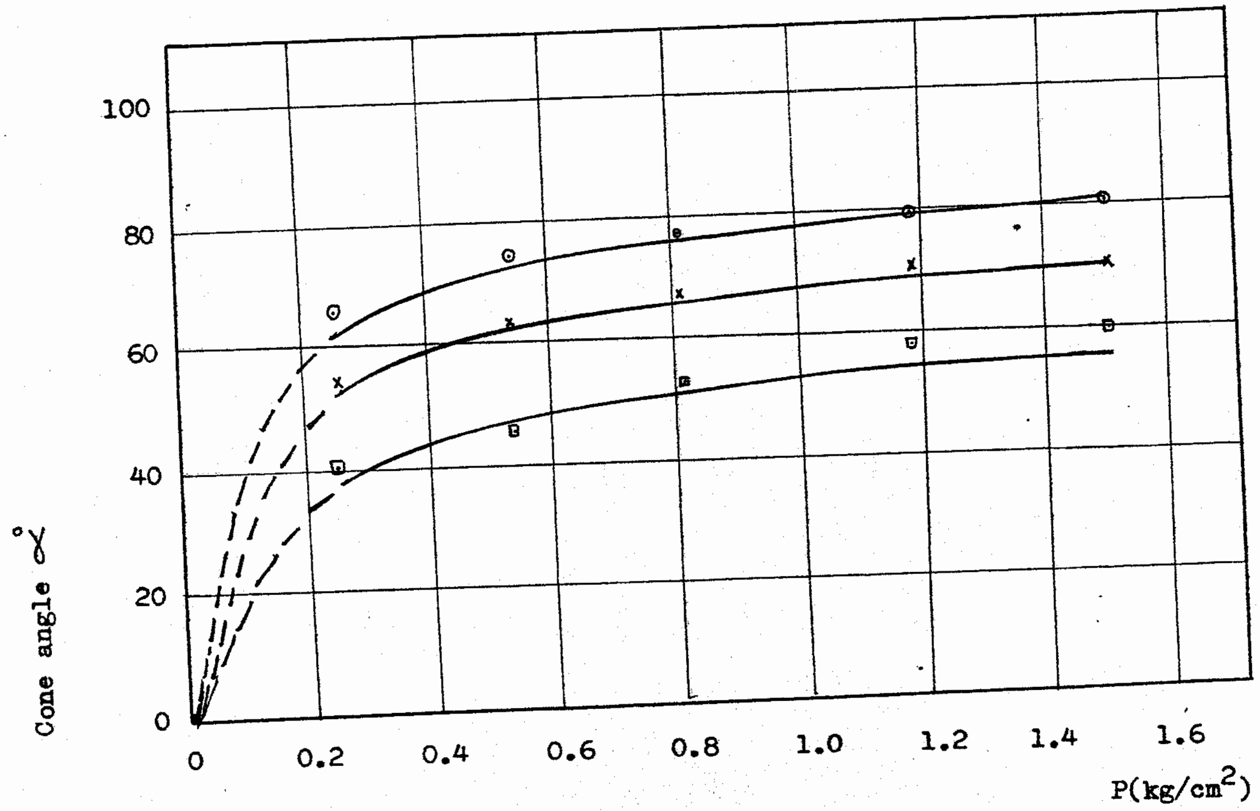

Fig.(17) Comparison between empirical formula and experimental results for the spray angle

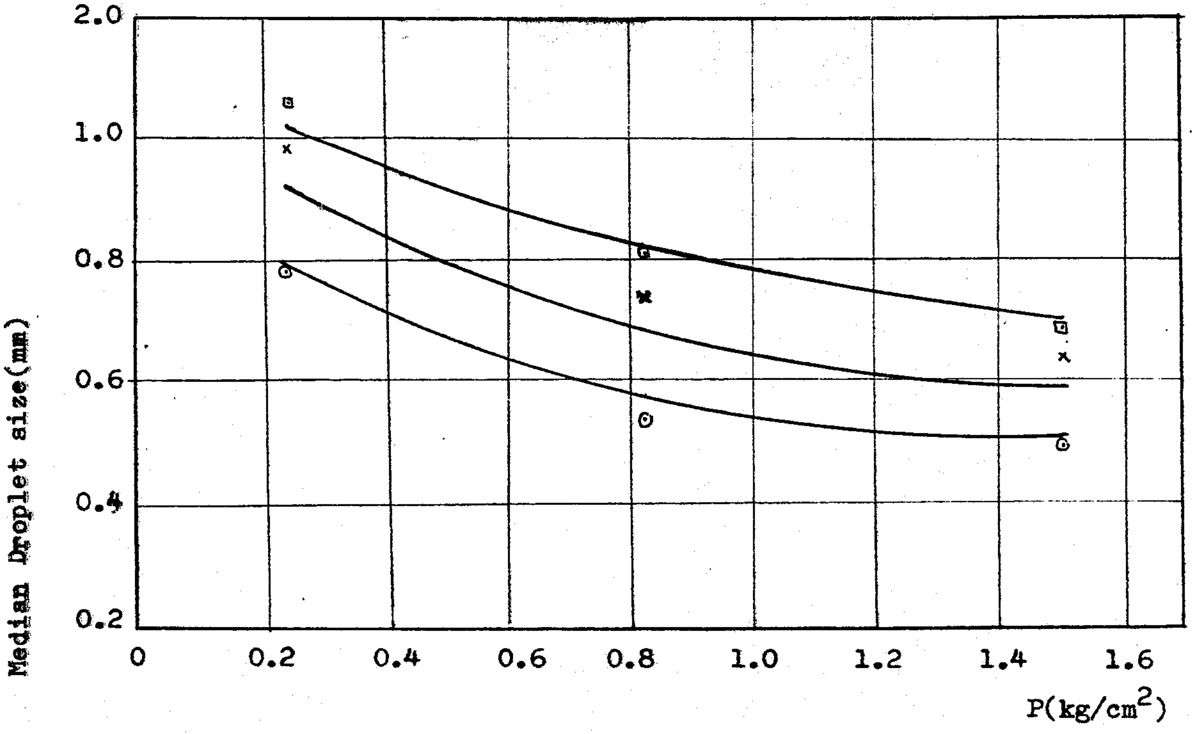

Fig.(18):Comparison between empirical formula and experimental results for the median droplet size

الملخص

تحليل خصائص بشابير الرش الالتفافية

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مهندسة سامية عبدالهادى الحفناوى

يتعلق هذا البحث بدراسة عملية للسريان فى بشابير الرش الالتفافية لايجاد العلاقات التى تربط خصائص الرش مثل كمية السريان وزاوية الرش وحجم القطرات بالمتغيرات الأساسية وهى ضغط التشغيل المستخدم والأبعاد الهندسية للفوهة عند الخروج وذلك باستخدام نموذج مكبر بنسبة ٢ : ١ ومماثل هندسيا للبشابير الفعلية المستخدمة فى جمهورية مصر العربية .

وقد أمكن فى النموذج المستخدم قياس الضغط والسرعة داخل غرفة الالتفاف كما أمكن تصوير عملية تكوين القطرات بأساليب التصوير العادية .

ومن النتائج أمكن استنتاج معادلات معملية تربط بين خصائص الرش وضغط التشغيل وأبعاد الفوهة .