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by

M. V. ELIASON

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IN MEMORY OF MY FATHER

ABSTRACT

Tests were conducted to determine the discharge, uniformity and distribution profile of various sizes of spray nozzles. A computer program was developed to incorporate and overlap individual distribution patterns according to the specifications of an existing linear move irrigation system. Field testing was conducted in an effort to substantiate the computer results.

Individual nozzle discharge was measured for a range of lateral pressures. Unregulated discharges were compared to those for nozzles equipped with pressure regulators. Pressure regulators were effective in maintaining uniform output for pressures above 200 kPa.

Distribution profiles for various sizes of spray nozzles equipped with pressure regulators were obtained for various discharge heights. Spray nozzles exhibited a conical spray pattern with a circular ring shaped distribution profile. For the range of nozzle discharge heights evaluated, distribution uniformity increased with increasing discharge height.

The computer program adjusted and superimposed individual nozzle distribution profiles according to the discharge heights and nozzle spacing of a linear move irrigation system. A three-dimensional linear

interpolation was applied to each profile to arrive at a system distribution or application profile.

Performance of the program was evaluated by a comparison of the simulated coefficients of uniformity with those measured. Theoretical uniformities were higher than those obtained in field testing.

The effect of various extension boom lengths was evaluated using the computer model. Extension booms increased the application area and decreased the average instantaneous application rate.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

In recent years sprinkler irrigation has become increasingly more sophisticated. High labor costs coupled with high land prices have forced the development of more efficient sprinkler systems. Adaptation of new ideas is required to increase irrigation efficiency and to accommodate the range of soil types, topographies and field areas suited to sprinkler irrigation. The linear move sprinkler irrigation system is an adaptation designed to accommodate the irrigation of rectangular field areas.

A linear move irrigation system is an overhead sprinkler system which consists of a lateral line of sprinklers moving in a straight line. The lateral is supported by a number of self propelled towers mounted on wheels. Water is supplied either to the center or the end of the lateral from a ditch or supply hose connected to a pressurized pipeline. The pump, fuel and guidance system is mounted on a two or four wheeled cart which travels beside the water supply. Most linear systems are diesel powered with an electrical generator supplying current to the support towers and guidance systems.

Guidance systems use either ground posts, a guide wire or a small wheel in a trench to keep the linear move in a straight line. Small deviations are automatically corrected while safety devices permit system shut-down in the event of electrical or mechanical failure.

With the increased costs of energy, many irrigation systems are using low pressure devices to apply water. A spray nozzle is one such device which consists of a water jet hitting a deflector plate. Spray nozzles may be placed either on top, beside or below a lateral, and usually spray in either a 180° or 360° arc. Spray nozzles apply water over a relatively small area creating relatively high application rates. One method of extending the application area is to install booms or pipes in front of and behind the lateral.

This study is an attempt to examine the performance and application rates of a linear move irrigation system equipped with low pressure spray nozzles.

Objectives

The objectives of this study were:

1. To evaluate the performance characteristics of a linear move irrigation system operating under normal climatic conditions.
2. To obtain the water distribution patterns of low pressure spray nozzles operating under laboratory conditions.
3. To incorporate nozzle distribution patterns into a computer program to predict system application rates and uniformities.
4. To compare the predicted application uniformities to those measured.
5. To use the computer program to examine application rates under various lengths of boom extensions.

CHAPTER II

LITERATURE REVIEW

The uniformity of water distribution is one of the most important measures used in irrigation system evaluation. Research has shown that systems with poor distribution uniformities result in reduced yields and inefficient water usage. Many operators are using sprinkler systems to apply chemical fertilizers and herbicides. Poor water distribution uniformity or high application rates of these chemicals could result in serious crop damage or reduced yields.

2.1 Measures of Uniformity

Over the years, many expressions for the measurement of distribution uniformity have been developed. Christiansen (1942) proposed the coefficient of uniformity (UCC) expressed as a percentage.

$$UCC = 100 \left(1.0 - \frac{\Sigma | Xi - \bar{x} |}{N \bar{x}}\right) \quad (1)$$

where $\Sigma | Xi - \bar{x} |$ is the sum of the absolute deviations of individual observations (Xi) from the average of the observations ($\bar{x}$) and where N is the number of observations. For a perfectly uniform application the sum of the deviations is zero and the UCC is 100 per cent.

Heermann and Hein (1968) expanded equation (1) to provide a uniformity measure for center-pivot systems. Each observation was considered to represent an area rather than a point. By considering the volume of water applied to the area rather than the depth applied at a point, a weighting factor was applied to each observation.

Criddle et al (1956) described a United States Department of Agriculture uniformity measure known as pattern efficiency (PE) which compares the mean of the lowest one-quarter of deviations to the overall mean of all observations.

$$PE = 100 \left[\frac{\Sigma Xi,q}{Nq \bar{x}}\right]$$

where:

$X_{i,q}$ - sum of the lowest 25 per cent of observations

$\bar{x}$ - average of all observations

N_q - number of observations in lowest 25 per cent.

Wilcox and Swailes (1947) devised the statistical uniformity coefficient (UCS) which uses the coefficient of variation.

$$UCS = 100\ (1 - \frac{sd}{\bar{x}})$$

where:

sd - standard deviation of the observations

$\bar{x}$ - average of all observations

$\frac{sd}{\bar{x}}$ - the coefficient of variation.

Benami and Hore (1964) proposed a coefficient which considered absolute deviations from two grouped means. The general mean was calculated from all observations. Group means were then determined from observations above and below the general mean. This approach placed more emphasis on observations with extensive deviations from the general mean.

$$A = 166 \left(\frac{Na\ (2Tb + DbMb)}{Nb\ (2Ta + DaMa)} \right)$$

where:

- Ma - mean of all observations greater than $\bar{x}$
- Ta - sum of the observations above Ma
- Da - difference between the number of observations below and above Ma
- Na - number of values greater than $\bar{x}$
- Mb - mean of all observations less than $\bar{x}$
- Tb - sum of observatons below Mb
- Db - difference between the number of observations above and below Mb
- Nb - number of values less than $\bar{x}$
- $\bar{x}$ - mean of all observations.

Several researchers, such as Beale and Howell (1966), Hart (1961) and Korven (1968) studied various measures of distribution uniformity and concluded that there was very little difference between any of the measures.

2.2 Factors Affecting Uniformity

Many factors affect the distribution uniformity of a sprinkler system. These factors can be grouped into three main categories:

(a) Physical characteristics of the operating system; including sprinkler design, sprinkler overlap, nozzle size, height of sprinkler from field surface and operating pressure,

(b) Environmental conditions; mainly wind speed and direction, and

(c) Management practices; mainly orientation, speed and alignment of the lateral.

2.2.1 Physical Characteristics

Distribution uniformity as affected by sprinkler and system design has been studied by several authors. Seginer (1963) determined that minor differences in body configuration and nozzle construction of medium pressure sprinklers did not result in major differences in sprinkler performance. Bilanski and Kidder (1958) showed that the angle of inclination of a sprinkler nozzle affected the distribution of water. Maximum trajectory was achieved at nozzle angles of between 25° and 30° from the horizontal.

Bilanski and Kidder (1958) and Seginer (1963) demonstrated the effects of operating presure on distribution uniformity. Increasing operating pressure to a certain optimum range decreased the mean droplet diameter and increased distribution uniformity. High operating pressures caused a greater breakup of the jetstream and increased trajectory distance. Operating at pressures above the optimum range caused excessive jetstream breakup and resulted in excess water deposited near the sprinklers. Operating at pressures below the optimum range resulted in inadequate jetstream breakup and a doughnut type of distribution pattern.

Kohl (1974) studied the effects of nozzle size and operating pressure on the mean droplet diameter. For a constant nozzle size, increasing operating pressure decreased the mean droplet diameter. Similarly, for a constant operating pressure, decreasing nozzle size decreased the mean droplet diameter; however, the effect of increasing pressure on the mean droplet diameter was more pronounced. Small sprinkler nozzles operating at low pressures may result in larger mean droplet diameters than those produced by larger sprinklers operating at higher pressures.

For most sprinklers the amount of water applied to an area varies inversely with the distance from the sprinkler. Some overlap of sprinklers is necessary to provide uniform coverage of the irrigated area. The amount of overlap will depend on the particular sprinkler application pattern.

2.2.2 Environmental Conditions

Wind speed and direction are the most significant environmental factors affecting application uniformity. With high wind velocities (greater than 16 km/h), application patterns become distorted and result in high concentrations near the sprinklers and on the leeward side. Christiansen (1942) and Allison and Hesse (1969) concluded that the distribution uniformity decreased with higher wind velocities. Low wind velocity (less than 5 km/h) had little effect on distribution uniformity. Korven (1952) indicated that the average coefficient of uniformity for the sprinklers tested dropped from 82 to about 32 per cent when the wind velocity increased from 6 to 27 km/h.

Christiansen (1942) indicated that the effect of wind velocity on water distribution uniformity was less pronounced with closely spaced sprinklers. Wind influences uniformity in that evaporation and drift occurs while droplets are still in the air. Frost and Schwaler (1955) and (1960) compared spray losses for a variety of operating conditions including day and night, clear and cloudy weather and various temperatures, relative humidities, wind conditions and operating pressures. A direct and high correlation was shown for spray losses and vapor pressure deficit. Losses varied inversely with nozzle diameter and directly with nozzle pressure and wind speed.

Sternberg (1967) studied losses for day time and night time sprinkling. For low wind velocities spray losses varied from 17 to 22 per cent for day time operation compared to variations of 11 to 16 per cent for night time operation.

Kraus (1966) indicated that total application losses from sprinkler systems ranged from about 3 to 17 per cent for wind speeds of 4 to 16 km/h.

2.2.3 Management Factors

Consideration of management techniques may improve distribution uniformity depending on type and design of the system. Seginer (1969) indicated that orientation and direction of lateral movement relative to wind direction can have a significant effect on distribution uniformity. For self-propelled systems, uniformity will be affected by the speed and alignment of the lateral.

2.3 Distribution and Application Rate

Bittinger and Longenbaugh (1962) studied two types of distribution curves for application depths from single sprinklers. The curves were triangular and elliptical in cross section (FIGURE 1). From these curves, equations were derived for describing the distribution from a single sprinkler travelling in straight and circular paths.

From FIGURE 1, the precipitation rate at any distance from the sprinkler for the triangular (Ppt) and elliptical (Ppe) patterns was defined as:

$$Ppt = h \left(\frac{r - s}{r}\right)$$

$$Ppe = \frac{h}{r} (r^2 - s^2)^{1/2}$$

where:

h - maximum application rate at the sprinkler

r - wetted radius of the pattern

s - distance from the sprinkler.

The total depth applied at a point from a single pass of a single sprinkler was obtained by integrating the rate over the total time. For a sprinkler moving in a straight line at a constant velocity, the total depth for any point using triangular (D_T) and elliptical (D_E) patterns are:

$$D_T = \frac{rh}{v}\left((1 - m^2)^{1/2} - m^2 \ln \frac{(1 - m^2)^{1/2} + 1}{m}\right)$$

$$D_E = \frac{rh}{2v}(1 - m^2)$$

where:

h - maximum application rate at the sprinkler

s - distance from sprinkler

r - wetted radius of the pattern

v - travel speed

m - a ratio of the distance of any point from the line of travel to the pattern radius ($\frac{s - r}{r}$).

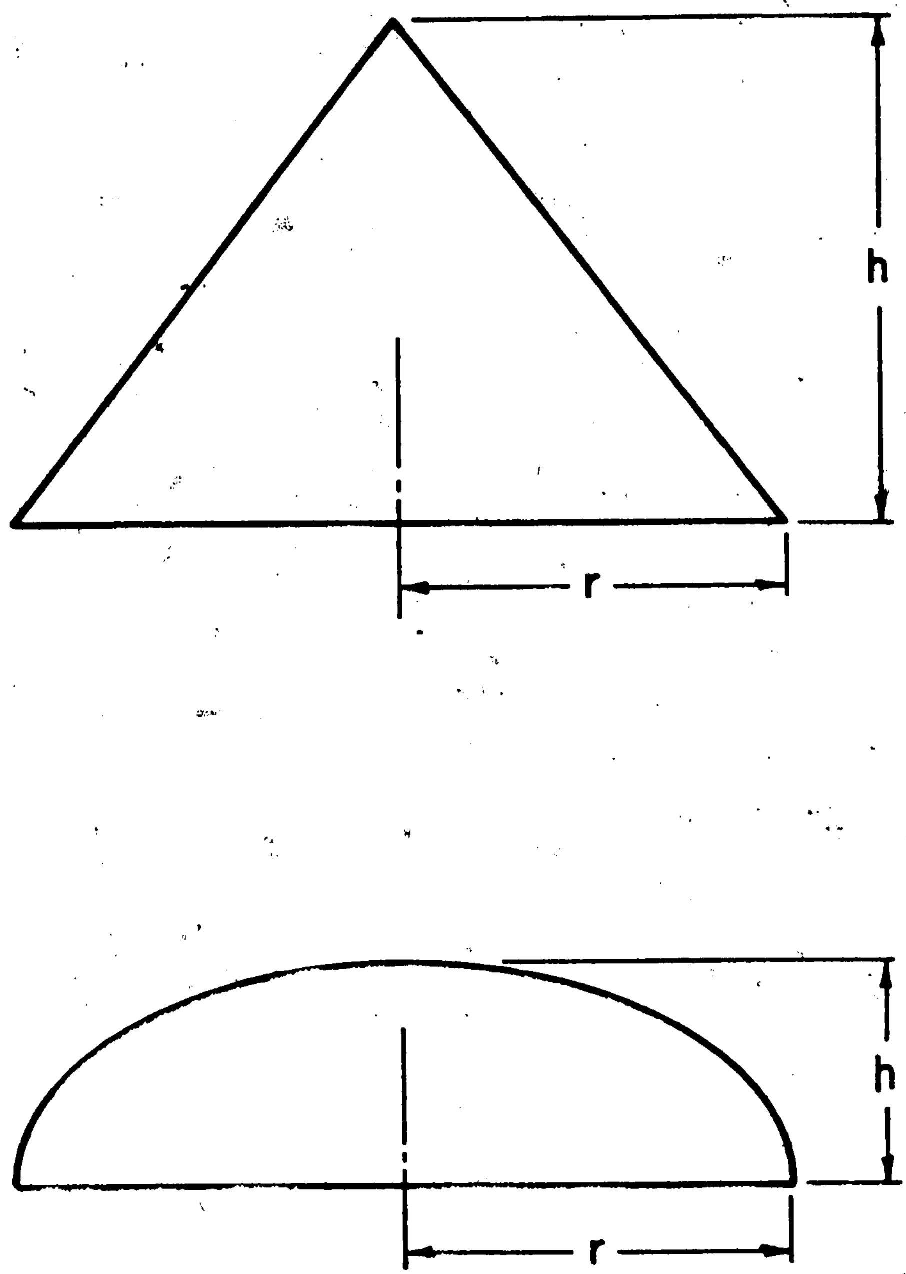


FIGURE 1. Application Rate Patterns of a Stationary Sprinkler.

Bittinger and Longenbaugh (1962) compared various valued of (D_T/r) and (D_E/r) to values of (m). The triangular pattern was shown to produce a more uniform distribution than the elliptical pattern when spaced at a distance equal to the pattern radius. The most even distribution for the elliptical pattern occurred at a spacing of about 1.4 times the pattern radius.

Christiansen (1942) studied several types of geometric distribution profiles and determined uniformities for various spacings. The various profiles (FIGURE 2) were designated as curves A through F. Curves A, B and C approximated rotating sprinkler profiles while curves D, E and F were more rectangular in cross-section. The coefficient of uniformity was determined for each profile at spacings of 5 per cent of the wetted diameter along the lateral and for various spacings between laterals. Curves A, B and C gave uniform distribution when spaced at about 55 to 60 per cent of the wetted diameter while curves D, E and F had uniform distribution at spacings of up to about 45 per cent and then again between 75 and 80 per cent of the wetted diameter.

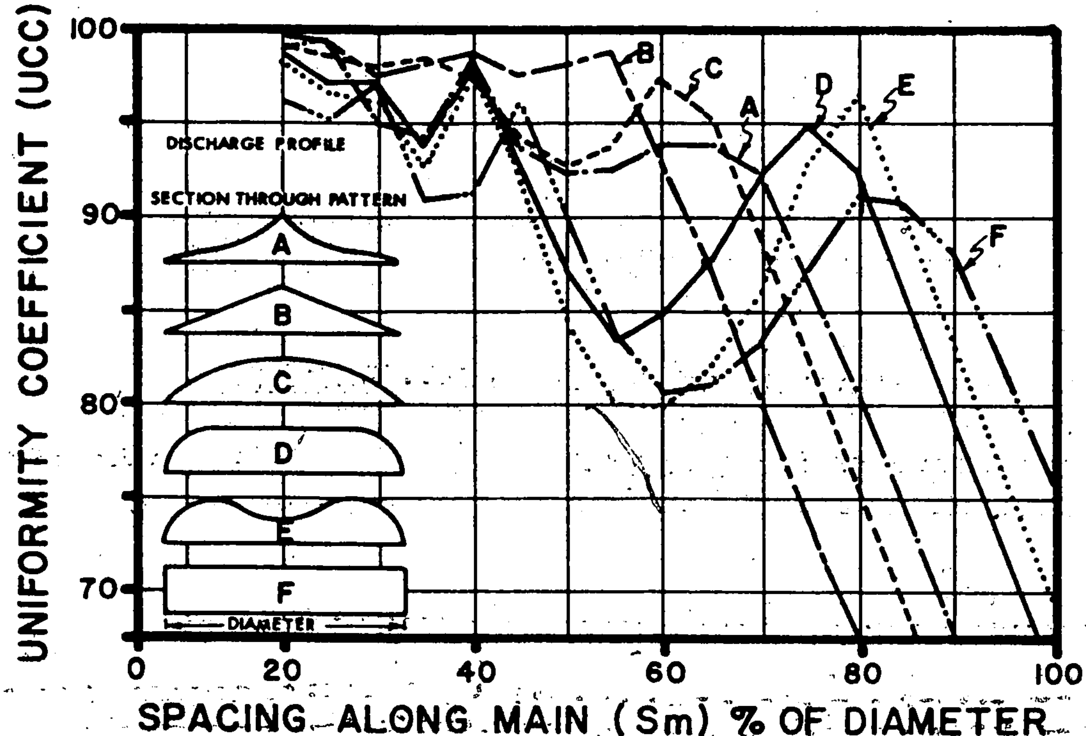


FIGURE 2. Christiansen's UCC Curves.

Wilcox and McDougald (1955) indicated that a pattern with a steady decrease in application rate from the sprinkler outwards gave the most uniform distribution. Square sprinkler spacings were shown to give better distribution than rectangular spacings and uniformities were highest when sprinkler spacings were less than 60 per cent of the wetted radius.

Much research effort has been directed towards the study of impact or rotating type sprinklers. With the advent of low pressure and spray nozzle systems, concern has been expressed about application rate and distribution characteristics. James and Stillmunkes (1980) examined the application rate characteristics for spray sprinklers and compared the results to impact nozzles. Five center-pivot systems were studied: two of the systems were equipped with impact sprinklers, two were equipped with spray nozzles and one was equipped with spray nozzles mounted on booms extending perpendicular to the lateral. Low pressure systems equipped with spray nozzles had lower instantaneous application rates but higher average application rates than did systems equipped with impact nozzles. The system with booms mounted perpendicular to the lateral had the lowest instantaneous application rate and an average application rate only slightly higher than the systems equipped with impact sprinklers, but lower than the other spray nozzle systems.

CHAPTER III

EXPERIMENTAL INSTRUMENTATION AND PROCEDURE

3.1 Location

Experimental work was initiated at two locations. Nozzle investigations were conducted at the Prairie Agricultural Machinery Institute in Lethbridge, Alberta. Field testing was conducted on a linear move irrigation system at a site near Taber, Alberta. The site was representative of southern Alberta conditions with predominately level topography and free of any wind barriers.

3.2 Equipment

The linear move irrigation system used in the field evaluation was a "Valley Rainger" Model 9880 manufactured by Valmont Industries Inc. of Valmont, Nebraska (FIGURE 3). The system was a diesel powered electrically driven machine with eleven support towers. Water was supplied to the center of the system via a ditch constructed the length of the irrigated area. Water distribution was through a series of similarly spaced spray nozzles mounted on booms 1525 mm in length placed perpendicular to and on alternate sides of the lateral. Pressure regulators were mounted with each nozzle. System design pressure at the pump was 240 kPa. Appendix I contains a detailed list of system specifications.

Laboratory testing was conducted using nylon Delavan 3/4 RA "Raindrop" spray nozzles (FIGURE 4) and Senninger (0.4 - 30.2 L/min) pressure regulators (FIGURE 5). Nozzles and regulators were of the same size and type as those used on the linear move irrigation system. Ten nozzles, consisting of two sets of five nozzle sizes, were studied. Nozzle sizes included: 3/4 RA 85/140, 3/4 RA 90/140, 3/4 RA 95/140, 3/4 RA 100/140, and 3/4 110/140. Two regulators, one for each set of five nozzle sizes, were used in the nozzle investigations.

3.3 Field Testing Procedure

Distribution testing of the linear move irrigation system was conducted during the summer of 1980. A cereal crop was grown under the system which necessitated a catch container grid system which caused

FIGURE 3. Valley Rainger.

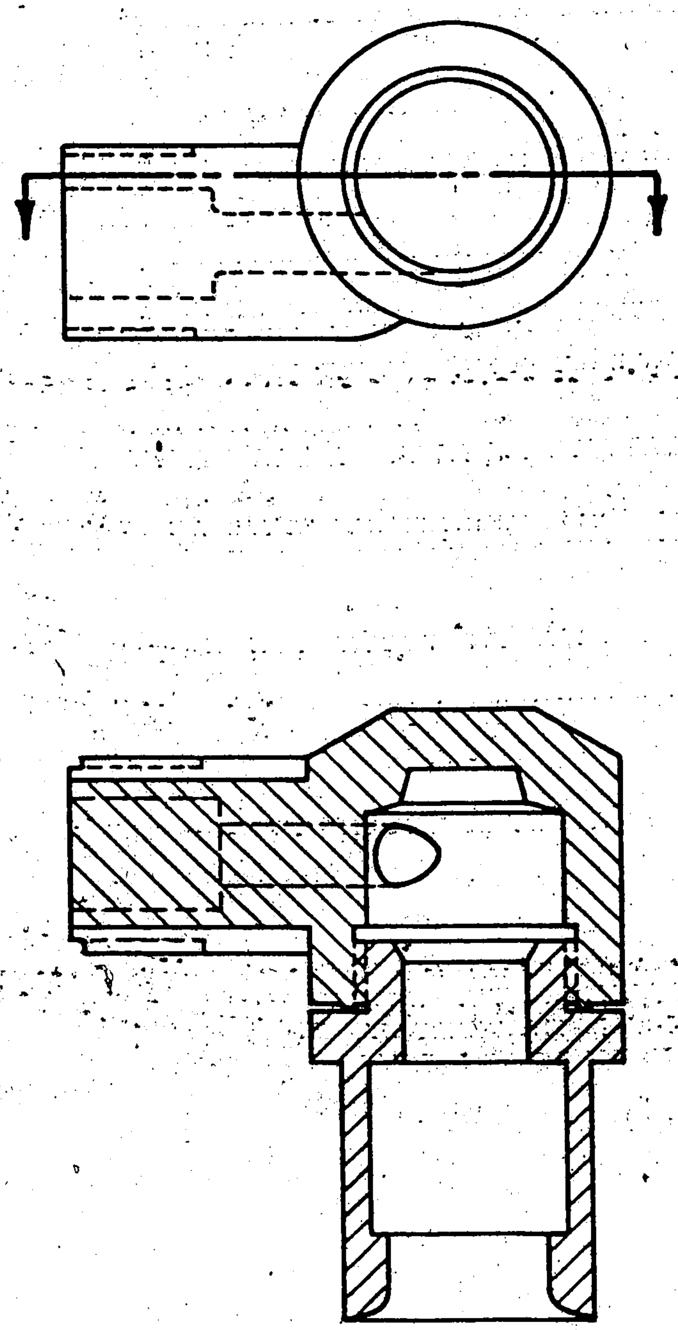


FIGURE 4. Delavan RA "Raindrop" Spray Nozzle.

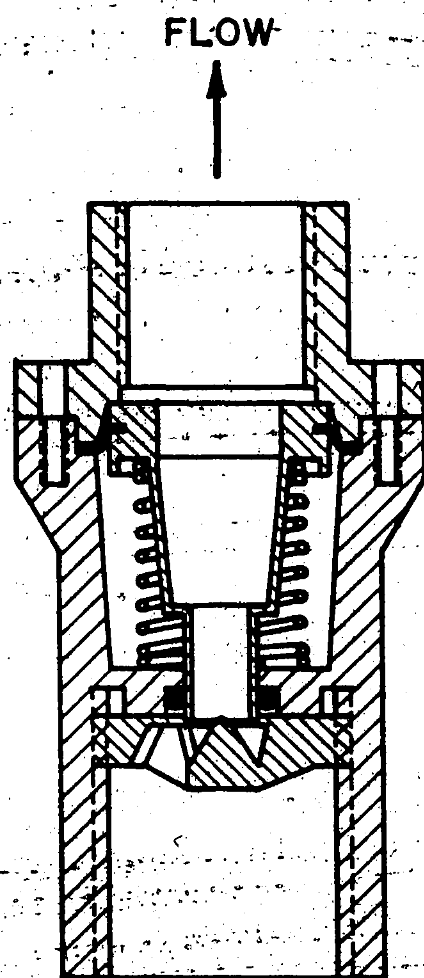


FIGURE 5. Senninger (0.4 - 30.2 L/min) Pressure Regulator.

mimimal crop interference. A single row of catch containers consisting of conventional one litre oil cans was used. Cans were placed at ground level and were secured in an upright position by wires and elastic bands. During later stages of testing removal of the crop canopy became necessary. To eliminate crop interference, one metre wide strips were cut the width of the irrigated area and to a height of about 100 mm. To coordinate application uniformity testing with normal irrigation scheduling, three test strip locations were used. FIGURE 6 shows the location of the test strips and the experimental field layout.

In field distribution evaluation, the catch container grid system must be fixed relative to a point on the system. For the linear move irrigation system the ball and socket pivot of the center tower was arbitrarily chosen as the reference point. The first catch container was placed one metre from this reference point. Successive containers were then placed at two metre intervals for the width of the irrigated area.

Uniformity measurements were conducted by passing the linear move irrigation system over a row of catch containers and measuring the volume of water collected. The amount of water collected in each container was measured with a 250 mL graduated cylinder. Measurements were usually taken immediately after the system passed over the containers. Three control containers identical to the measuring containers were set up outside the irrigated area to measure evaporation losses or precipitation gains. In instances where measurements were delayed, correction factors were applied to compensate for evaporation losses or precipitation gains.

Wind speed and direction were noted before each test. Measurements were taken at a height of three metres near the irrigated area.

The speed of the linear move system as well as the amount of time the receptacles received water was noted for each pass of the system. Uniformity measurements were made for a range of system speed settings.

Uniformity measurements were conducted for each side of the linear move system. A uniformity measurement for one side of the system took about two hours to complete.

Pressure losses were noted for various positions along the lateral. Pressure gauges were installed in the lateral at each tower location. Pressure at the reference point was monitored and adjusted to design pressure before each uniformity test.

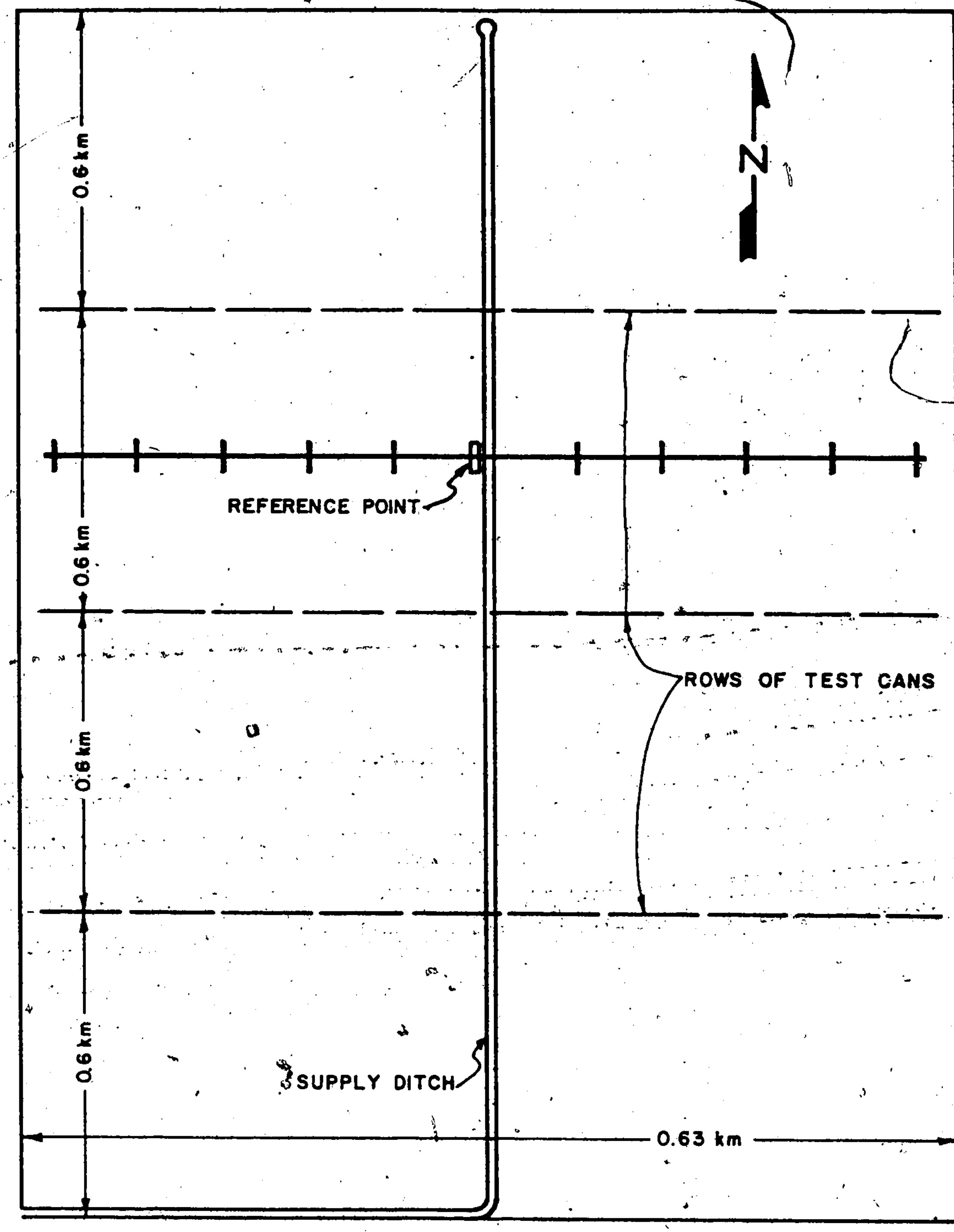


FIGURE 6. Schematic of Experimental Field Layout.

3.4 Laboratory Testing Procedure

The laboratory nozzle testing followed procedures similar to the American Society of Agricultural Engineers (ASAE) Recommendation S330 (1982) entitled, "Procedure for Sprinkler Distribution Testing for Research Purposes".

Nozzle discharge was measured volumetrically using a 22 L container and a stopwatch. Discharge was measured for a range of lateral pressures. Pressure was monitored with a recording pressure transducer installed in the line near the nozzle. Flow measurements were conducted for the various sizes of nozzles individually, and when used in conjunction with a pressure regulator. When a pressure regulator was installed, pressure measurements were recorded near the regulator inlet.

Distribution patterns were determined for the two sets of nozzles at operating heights of 3.75, 4.25 and 4.75 metres. One litre catch receptacles were placed on a 0.3 m square grid pattern to determine the distribution profile. The spray nozzle was placed in the center grid square midway between four adjacent collectors. FIGURES 7 and 8 show the layout of the laboratory arrangement for distribution testing. A distribution test involved operating the spray nozzle for about 15 minutes. A plastic tube was placed over the nozzle while the pressure was adjusted to prevent spray from collecting in the containers. The test began when the pressure was properly adjusted and the tube removed.

A 250 mL graduated cylinder was used to measure the volume collected. Measurements were recorded immediately after each test and were recorded to the nearest millilitre.

To facilitate data comparisons between nozzles, all laboratory distribution data were converted to an application rate. This was accomplished by applying the appropriate factor based on the area of the catch receptacle and the amount of time the receptacle received water.

3.5 Computer Program

A computer program was developed to study the application or distribution profile of the linear move irrigation machine. The program generates a system distribution grid similar to the laboratory distribution grid. The system reference point is placed in a grid square adjacent to four collectors. The program then

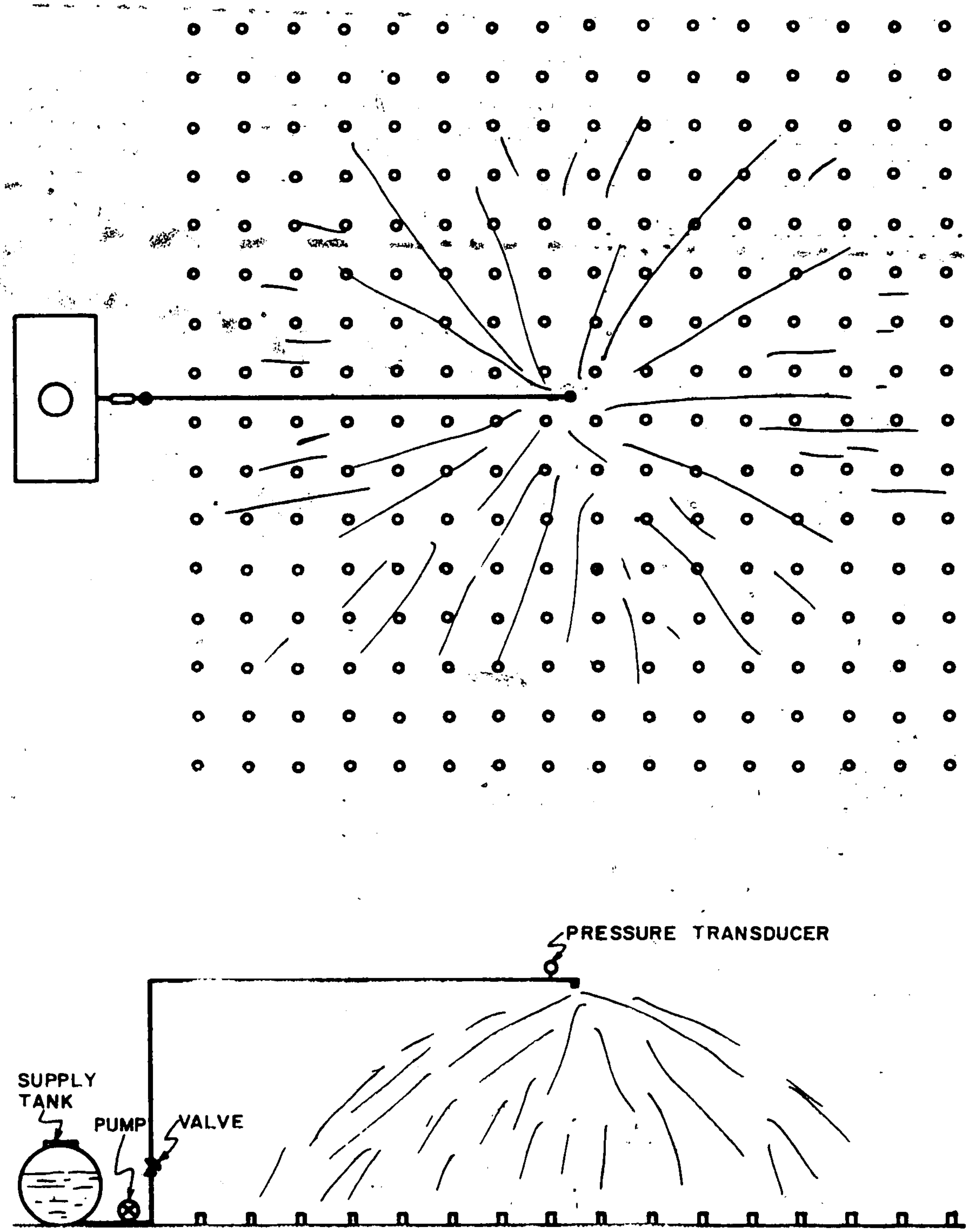


FIGURE 7. Schematic of Laboratory Nozzle Distribution Layout.

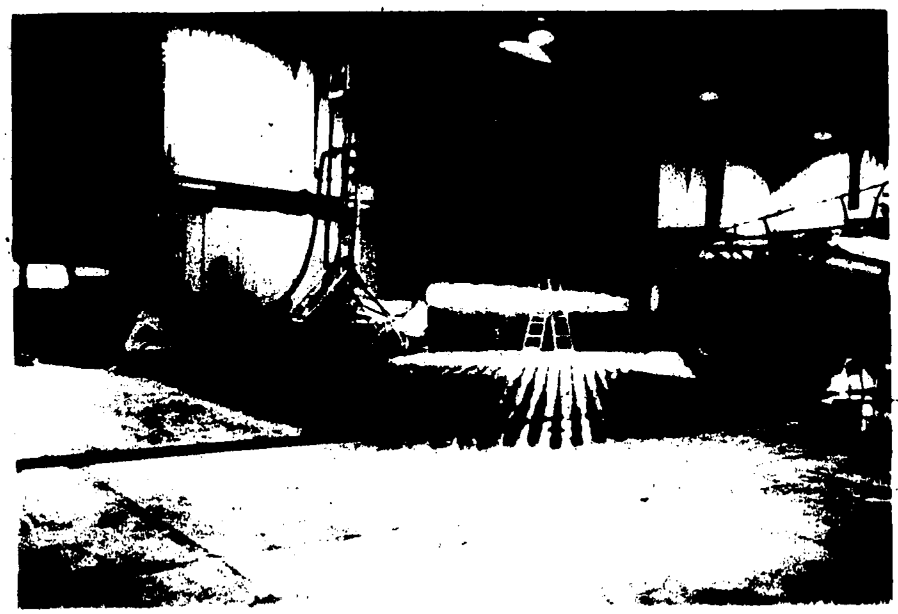


Figure 9. Laboratory Nozzle Distribution Layout

overlaps individual nozzle distribution patterns according to the physical specifications of the linear move system. A three-dimensional linear interpolation is used to adjust and superimpose individual nozzle pattern grid readings on to the system grid. The system grid then shows the theoretical application profile beneath a stationary linear move system.

The program with appropriate documentation is listed in APPENDIX II.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 System Pressure Losses

Pressure losses were measured at various locations along the lateral. Losses along the system lateral were uniform with lowest pressures occurring at the system ends. Design pressure at the reference point was 240 kPa. Pressures at lateral ends were 195 kPa and 190 kPa for the west and east ends, respectively.

4.2 Nozzle Discharge

FIGURE 9 shows the relationship of nozzle discharge and lateral pressure. Each nozzle shows a continually increasing discharge for the range of lateral pressures shown. For example, nozzle 95/140 has a discharge varying from 21.8 L/min at 100 kPa to 40.8 L/min at 350 kPa. Discharge variation between the two sets of nozzles was very small.

FIGURE 10 shows the discharge relationship for the various nozzles when equipped with a pressure regulator. Discharge for each nozzle increases rapidly for lateral pressures up to about 200 kPa. For lateral pressures above 200 kPa the discharge tends to increase less rapidly.

Table 1 shows the effect of pressure regulators on nozzle discharge variation for the lateral pressures of 190 and 240 kPa. The pressure regulators were effective in reducing nozzle discharge variations due to lateral pressure variations. For example, for the lateral operating pressure range, discharge variation of nozzle RA 95 was reduced from 10.6 to 2.8 per cent when equipped with a regulator. Average discharge variation for all nozzles tested was reduced from 11.2 to 3.1 per cent when equipped with the regulators.

TABLE 1. Nozzle Discharge Variation for Lateral Pressures of 190 and 240 kPa.

NOZZLE SIZE RA XX/140	DISCHARGE (L/min) NOZZLE ONLY				DISCHARGE (L/min) NOZZLE & REGULATOR			
	240 kPa Lateral Pressure	190 kPa Lateral Pressure	Discharge Decrease	% Change	240 kPa Lateral Pressure	190 KPa Lateral Pressure	Discharge Decrease	% Change
85	29.6	26.4	3.2	10.8	22.9	22.6	0.3	1.3
90	31.5	28.0	3.5	11.1	24.3	23.7	0.6	2.5
95	33.9	30.3	3.6	10.6	25.2	24.5	0.7	2.8
100	36.1	32.0	4.1	11.4	27.3	26.3	1.0	3.7
110	38.8	34.2	4.6	11.9	30.3	28.8	1.5	5.0
AVERAGE				11.2				3.1

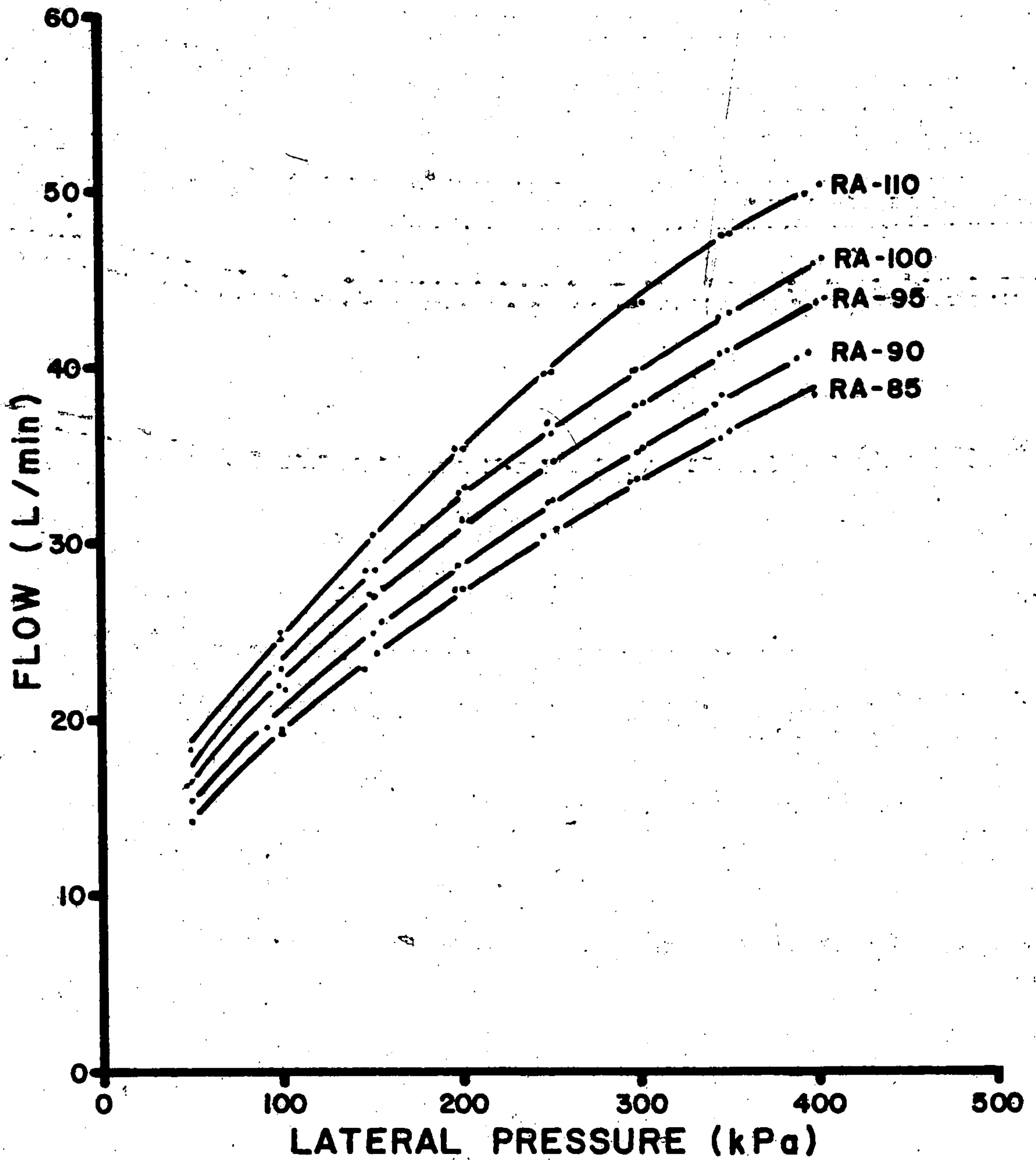


FIGURE 9. Nozzle Discharge at Various Lateral Pressures.

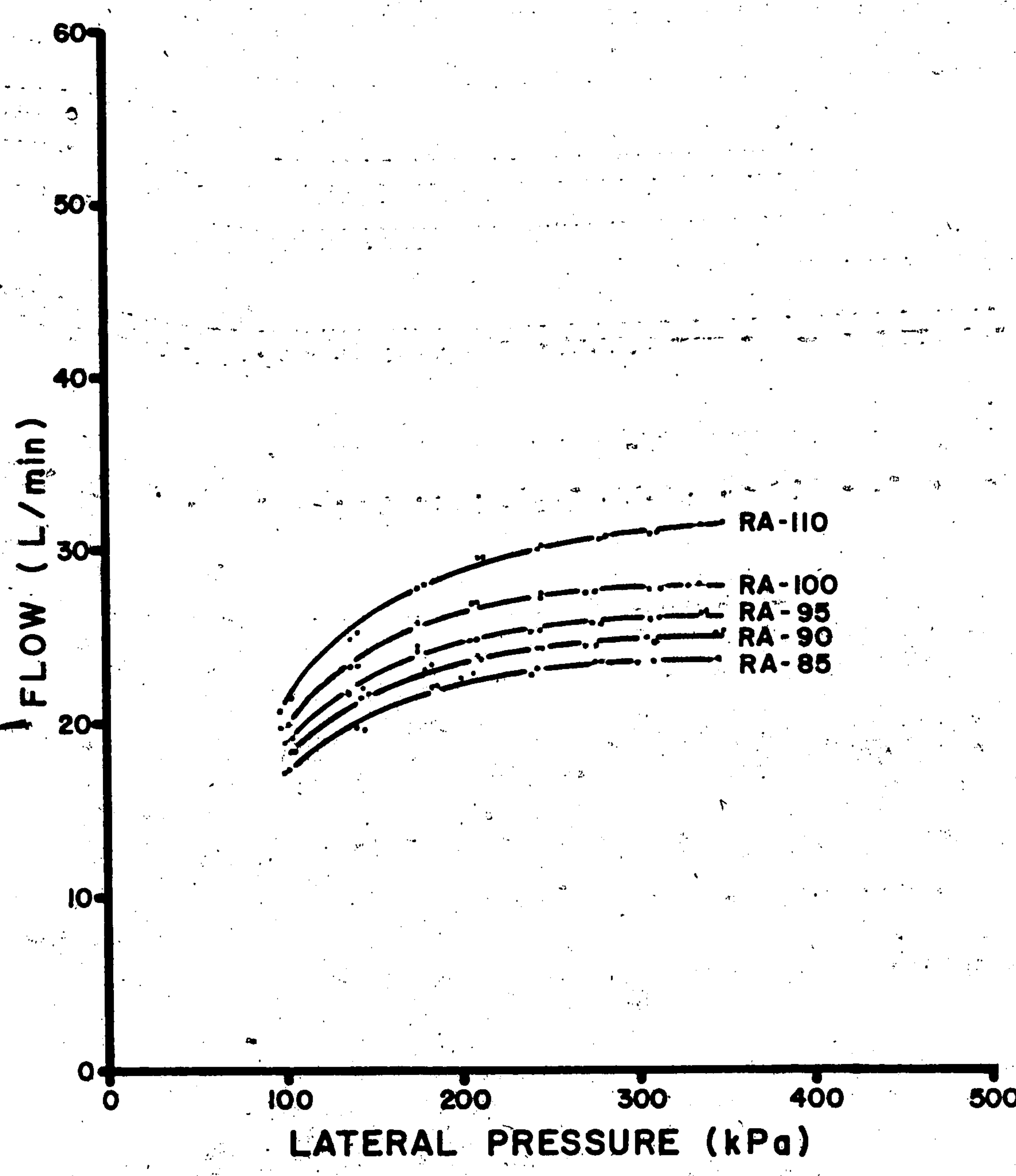


FIGURE 10. Nozzle Discharge at Various Lateral Pressures When Equipped With a Pressure Regulator.

4.3 Distribution Patterns

Tests were undertaken to determine the distribution profiles for the two sets of spray nozzles and pressure regulators. Five nozzles sizes (85, 90, 95, 100, and 110/140) operating at heights of 3.75, 4.25 and 4.75 m were evaluated. Nozzle discharge heights were similar to those on the linear move system.

The spray nozzles directed spray downward in a conical fashion. FIGURE 11 shows the distribution profile for nozzle 100/140 operating at a height of 4.25 m and a lateral pressure of 240 kPa. The profile shows a characteristic doughnut or ring type of application. Heavier applications occurred at the perimeter of the ring than on the interior. Very heavy applications occurred in one section of the profile. This section was characteristic of all nozzles tested and occurred in a similar relative position in the pattern.

Table 2 summarizes distribution results for the two sets of spray nozzles operating at a lateral pressure of 240 kPa. For each nozzle tested, increasing discharge height increased the application area and decreased the average instantaneous application rate. For example, the average instantaneous application rate of nozzle RA 90/140 decreased from 34.2 mm/h at 3.75 m discharge height to 29.1 mm/h at 4.75 m discharge height. Increasing discharge height distributes water over a larger area resulting in more uniform distribution. Uniformity coefficients of each nozzle increased for increasing operating heights. For example, the uniformity coefficient for nozzle RA 90/140 increased from 28.7 per cent at 3.75 m discharge height to 35.7 per cent for a 4.75 m discharge height.

High nozzle uniformity coefficients may be more desirable. Nozzle patterns are normally overlapped to increase overall distribution uniformity. The amount of overlap required to obtain optimum overall distribution uniformity will vary and depends on the particular nozzle distribution patterns.

A complete listing of nozzle profiles and distribution results is given in APPENDIX IV.

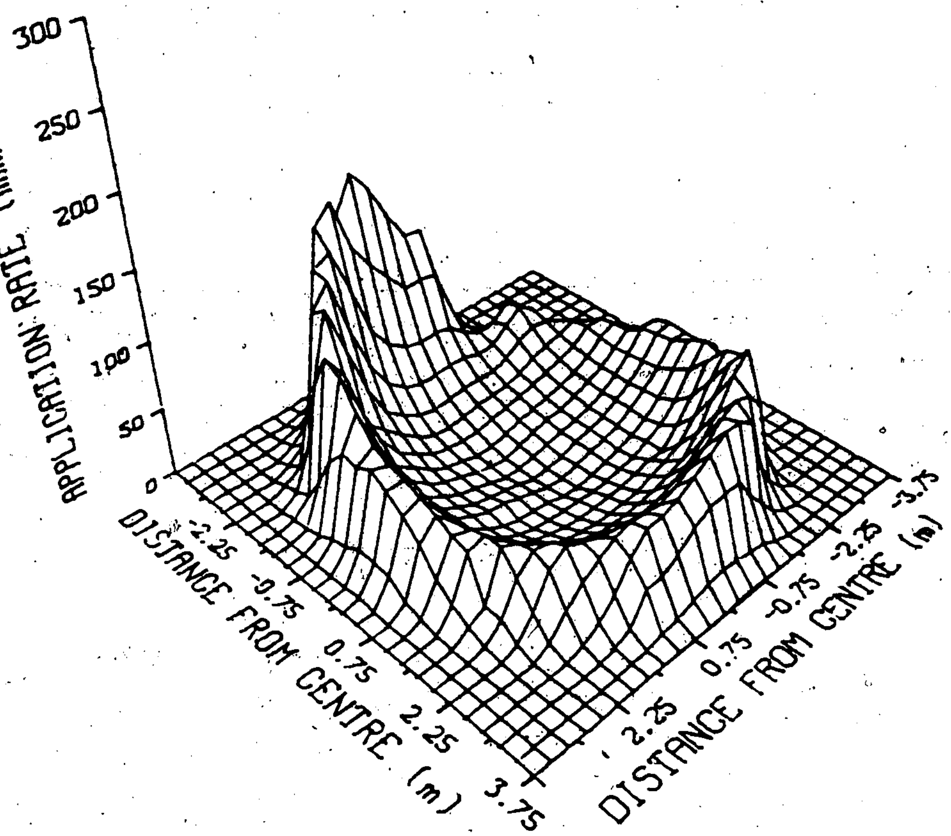


FIGURE 11. Distribution Profile for Nozzle RA 100/140 at 4.25 m Discharge Height and 240 kPa Lateral Pressure.

TABLE 2. Spray Nozzle Distribution Summary

NOZZLE SIZE RA XX/140	OPERATING HEIGHT (m)	NUMBER OF READINGS	AVERAGE READING (mm/h)	UCC OF READINGS (%)
85	3.75	436	32.0	29.3
85*	3.75	454	32.8	30.1
85	4.25	522	29.9	36.4
85*	4.25	500	29.9	32.5
85	4.75	544	27.3	40.7
85*	4.75	548	26.9	38.5
90	3.75	473	34.2	28.7
90*	3.75	476	33.9	29.2
90	4.25	512	31.6	32.6
90*	4.25	507	32.4	32.8
90	4.75	535	29.1	35.7
90*	4.75	547	29.6	36.6
95	3.75	478	35.4	26.5
95*	3.75	472	36.3	29.4
95	4.25	534	32.1	30.4
95*	4.25	499	32.6	31.8
95	4.75	556	31.1	40.5
95*	4.75	553	30.2	37.2
100	3.75	478	36.9	29.6
100*	3.75	479	36.5	25.5
100	4.25	511	33.5	34.5
100*	4.25	494	33.5	28.3
100	4.75	547	31.3	37.6
100*	4.75	547	31.2	33.1
110	3.75	481	42.2	23.4
110*	3.75	491	42.2	21.4
110	4.25	520	38.8	29.1
110*	4.25	512	38.2	25.0
110	4.75	565	36.0	31.8
110*	4.75	570	36.3	31.4

* indicates second set of nozzles and regulator

4.3 Field Application Uniformity

Table 3 summarizes the results of field uniformity testing for the linear move system. Uniformity coefficients are shown for each side of the system and for various system speeds. Uniformity coefficients for the west side were generally higher than those for the east side. Average uniformity was 78.0 per cent for the west compared to 74.7 per cent for the east. This difference was significant at the 0.05 level of an unpaired t-test and may be due in part to excessive nozzle spacing at two locations on the east side and the generally higher wind velocities encountered during east side testing.

FIGURE 12 shows a typical application uniformity for the east side at a system speed of 830 mm/min. Average application depth was 11.8 mm while application uniformity was 73 per cent. Low applications occurred at 205 and 257 m from system center. Nozzle spacings at these locations were much greater than those of the rest of the system. This resulted in inadequate overlap and insufficient coverage.

FIGURE 13 shows a typical uniformity application for the west side at an average system speed of 860 mm/min. Average application depth was 11.5 mm while application uniformity was 77.5 per cent.

Uniformity tests were conducted at the various average system speeds in an attempt to offset the effects of single row testing. Speed effects were masked, however, due to the movement characteristics of the linear move system. System guidance and alignment adjustments caused the system to pass over the test row in a random manner, usually at an angle askew to the test row orientation. Often, the angle was large enough to permit one end of the system to pass over the test row before the other end reached the test row. As a result, analysis of speed effects was not conducted.

TABLE 3. Field Application Uniformity

TEST NUMBER	AVERAGE DEPTH (mm)	AVERAGE SYSTEM SPEED (mm/min)	AVERAGE APPLICATION RATE (mm/h)	UCC OF READINGS (%)
WEST				
1	15.7	540	45.3	79.6
2	16.3	500	44.5	80.1
3	13.4	660	49.9	80.0
4	12.0	690	45.6	74.4
5	11.5	860	----	77.5
6	12.9	820	56.5	76.7
7	9.7	1080	53.9	76.3
8	9.1	1090	54.1	79.3
AVERAGE			50.0	78.0
EAST				
9	19.9	450	46.3	73.0
10	17.1	480	----	73.5
11	13.0	670	48.8	74.4
12	11.8	710	46.0	73.0
13	11.8	830	54.5	73.0
14	12.8	820	58.2	74.1
15	8.3	1110	51.9	79.0
16	11.2	1010	59.5	77.8
AVERAGE			52.2	74.7

The average application rate for each uniformity test was obtained by dividing the average application depth by the amount of time that cans actually received water. Tests 5 and 10 were overnight tests where the amount of time during which cans received water was not obtained. Overall average application rates were 50.0 and 52.2 mm/h for the west and east sides, respectively.

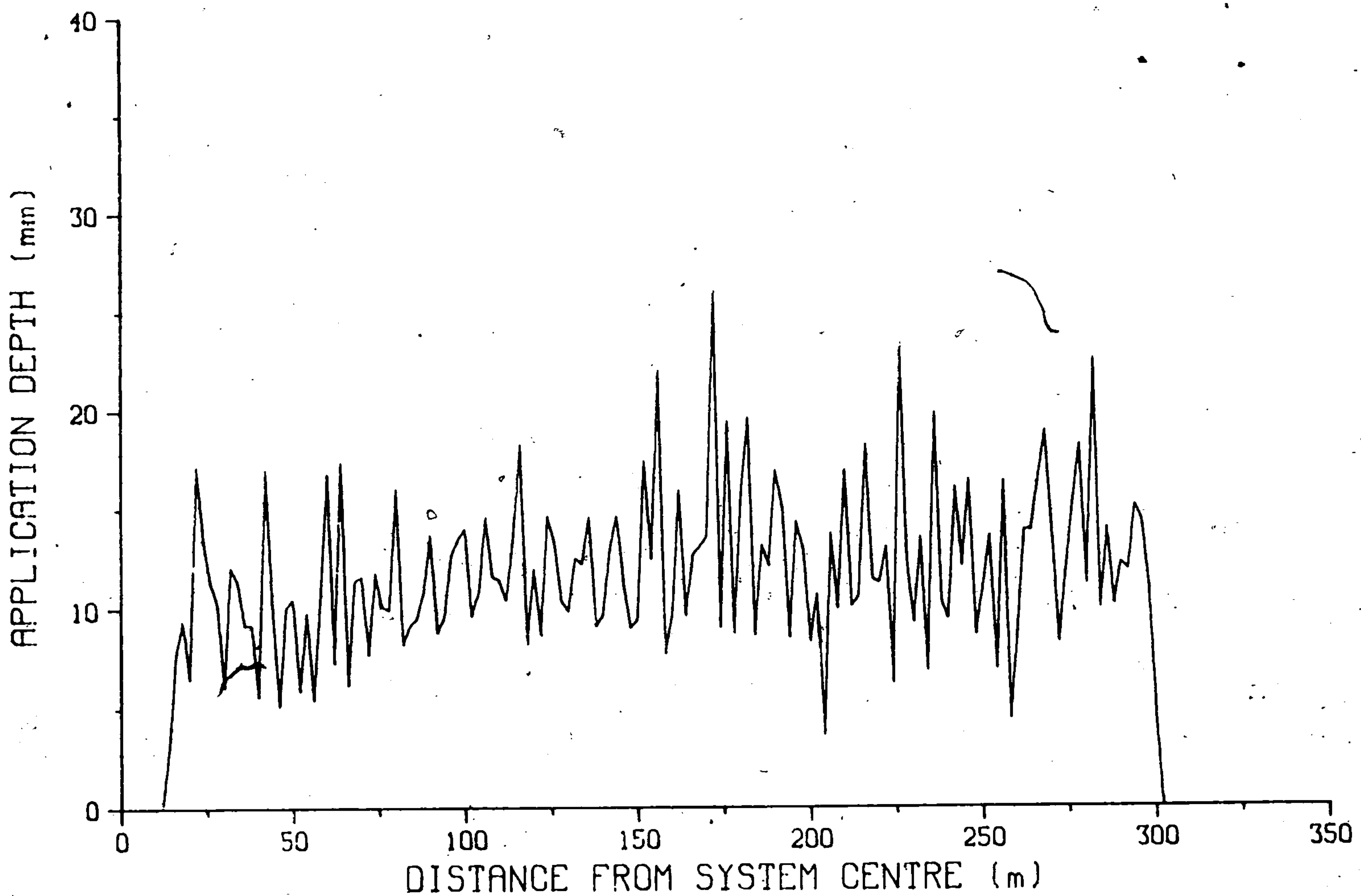


FIGURE 12. East Side Application Uniformity at 830 mm/min Average System Speed.

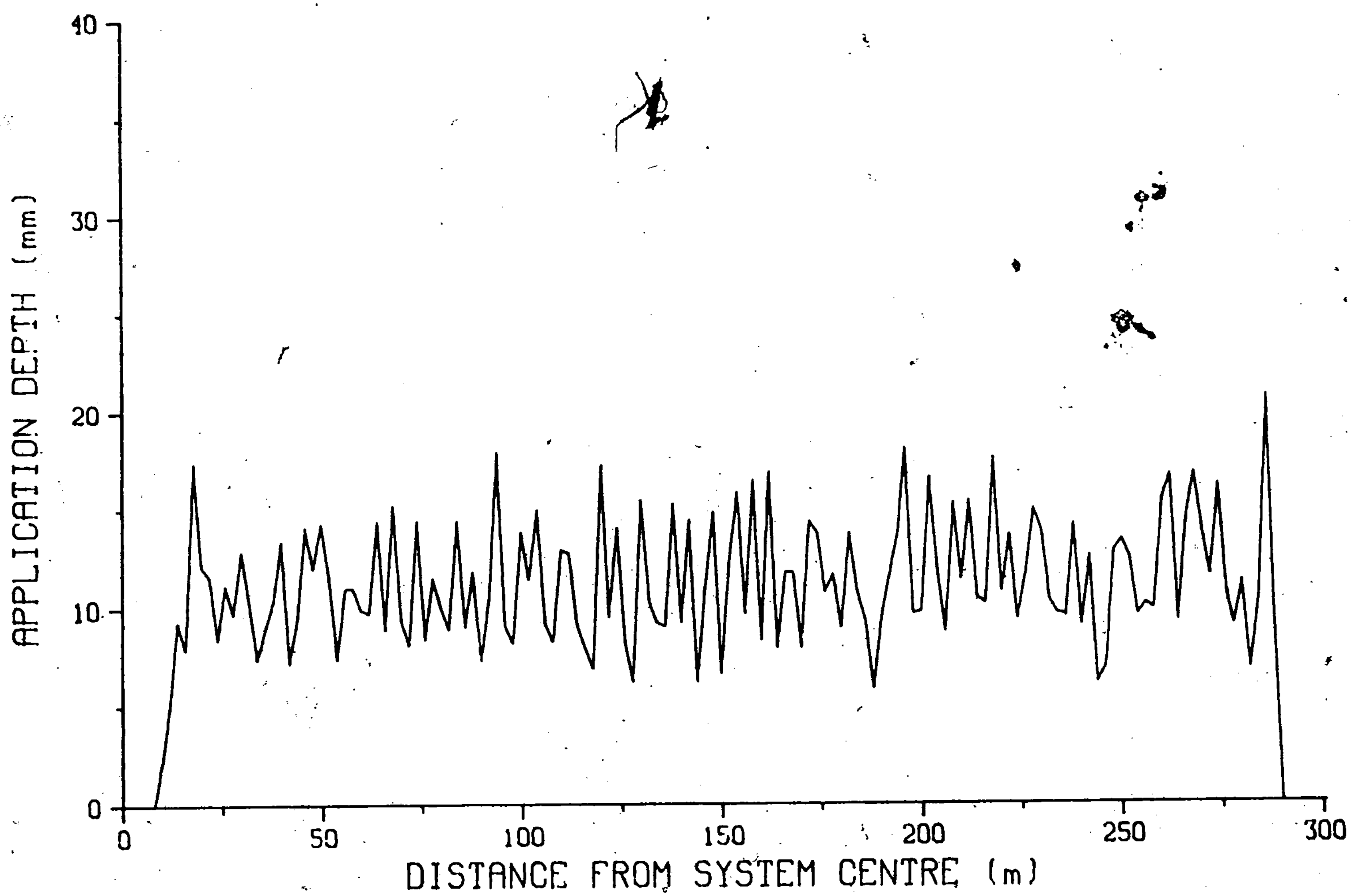


FIGURE 13. West Side Application Uniformity at 860 mm/min Average System Speed.

4.5 Computer Simulation

4.5.1 Application Parallel to Lateral

Information from laboratory nozzle distribution tests was incorporated into the system application computer program to determine the application pattern for the linear move system. FIGURE 14 shows a three-dimensional representation of the instantaneous application rates beneath a west side section of the linear move system. Low application rates occur directly below each nozzle, corresponding to the interior portion of the individual application profiles. Higher applications occur at the pattern perimeters which, when overlapped, produce high application rates directly below the lateral. Very high application rates occur near the lateral opposite each adjacent nozzle and are a result of the very high application areas of the individual profiles.

Table 4 summarizes the results of the application simulation for the linear move system. The average instantaneous application rate was 56 mm/h for both sides of the system. Maximum instantaneous application rates for the east and west sides were 348 and 310 mm/h, respectively.

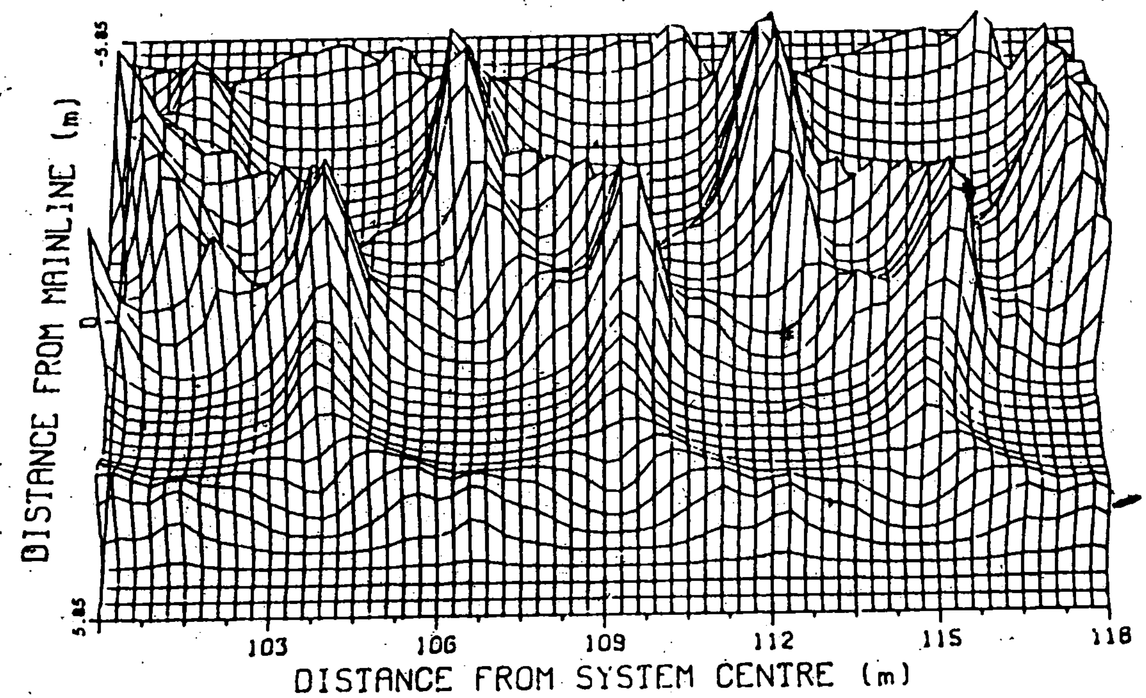


FIGURE 14. A Section of the Theoretical System Instantaneous Application Pattern.

Averaging instantaneous application rates for various positions along the lateral (i.e. system grid columns) indicates an average application rate for a continuously moving system. By assuming a continuously moving system, the uniformity of average application rates can be evaluated and compared to field uniformities.

FIGURES 15 and 16 show the theoretical average application rates for various positions along the linear move system. High applications occur under each nozzle. The uniformity coefficients were 82.2 and 81.3 per cent for the west and east sides, respectively. This compares to average values of 78.0 and 74.7 per cent obtained in field investigations.

Discrepancy between predicted and actual uniformity coefficients may be a result of several factors. The model assumes ideal environmental conditions. Each nozzle distribution profile was obtained in the laboratory under no-wind conditions. The model also neglects interference between droplets from adjacent nozzles or between droplets and the truss-support system. Also, in calculating the average application values, an equal weight was applied to each instantaneous application value, thereby assuming a continuously moving system.

The on-off movement nature of electric systems implies an unequal weighting or one such outlined by a function describing the movement nature of the particular system. Obtaining and incorporating such a function is beyond the scope of this project.

Table 4. Application Rate Summary of Linear Move System.

	AVERAGE INSTANTANEOUS APPLICATION RATE (mm/h)	MAXIMUM INSTANTANEOUS APPLICATION RATE (mm/h)
West Side	56.1	310.0
East Side	56.1	347.7

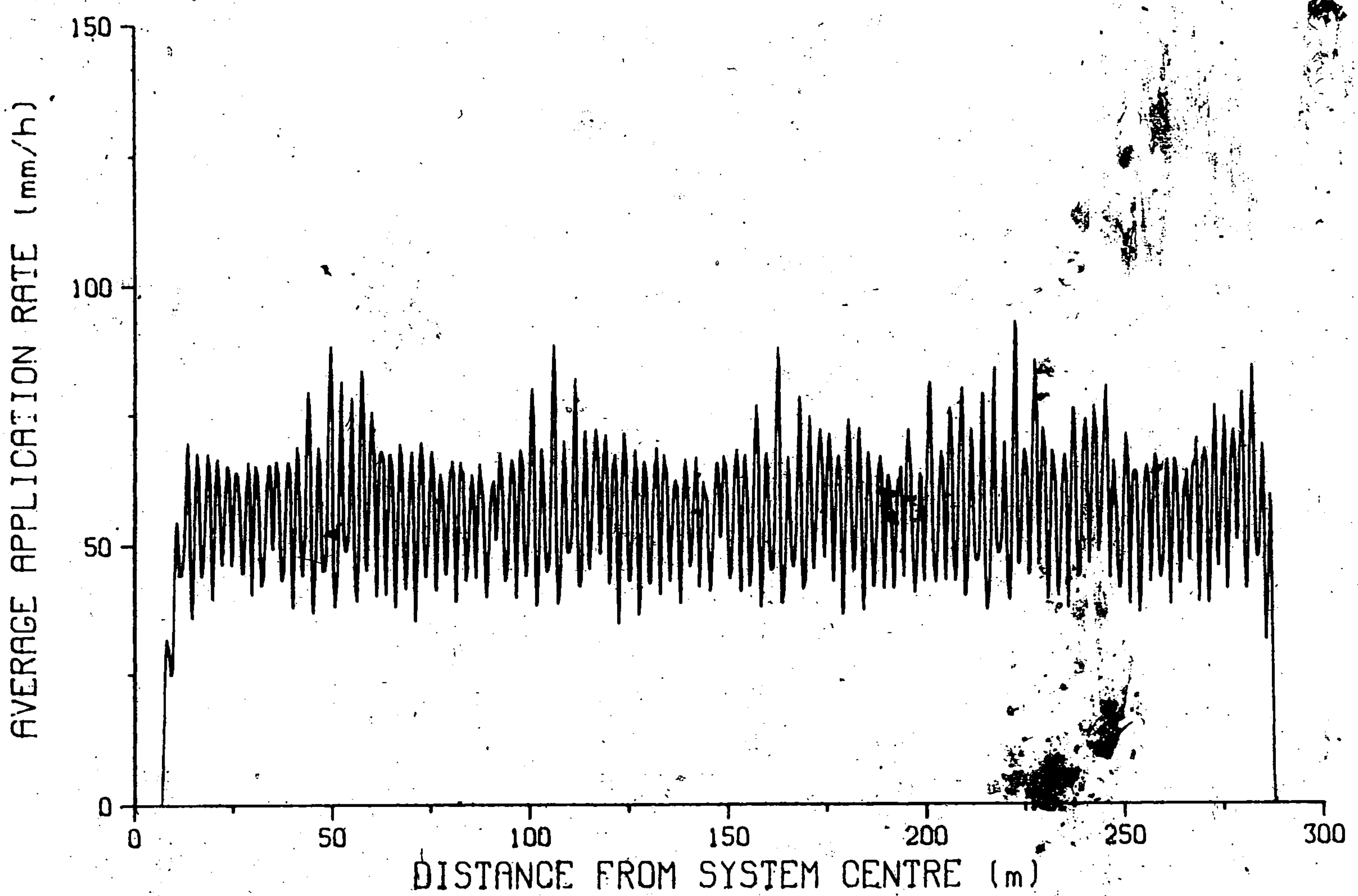


FIGURE 15. Theoretical Average Application Rates for Various Positions Along West Side of System.

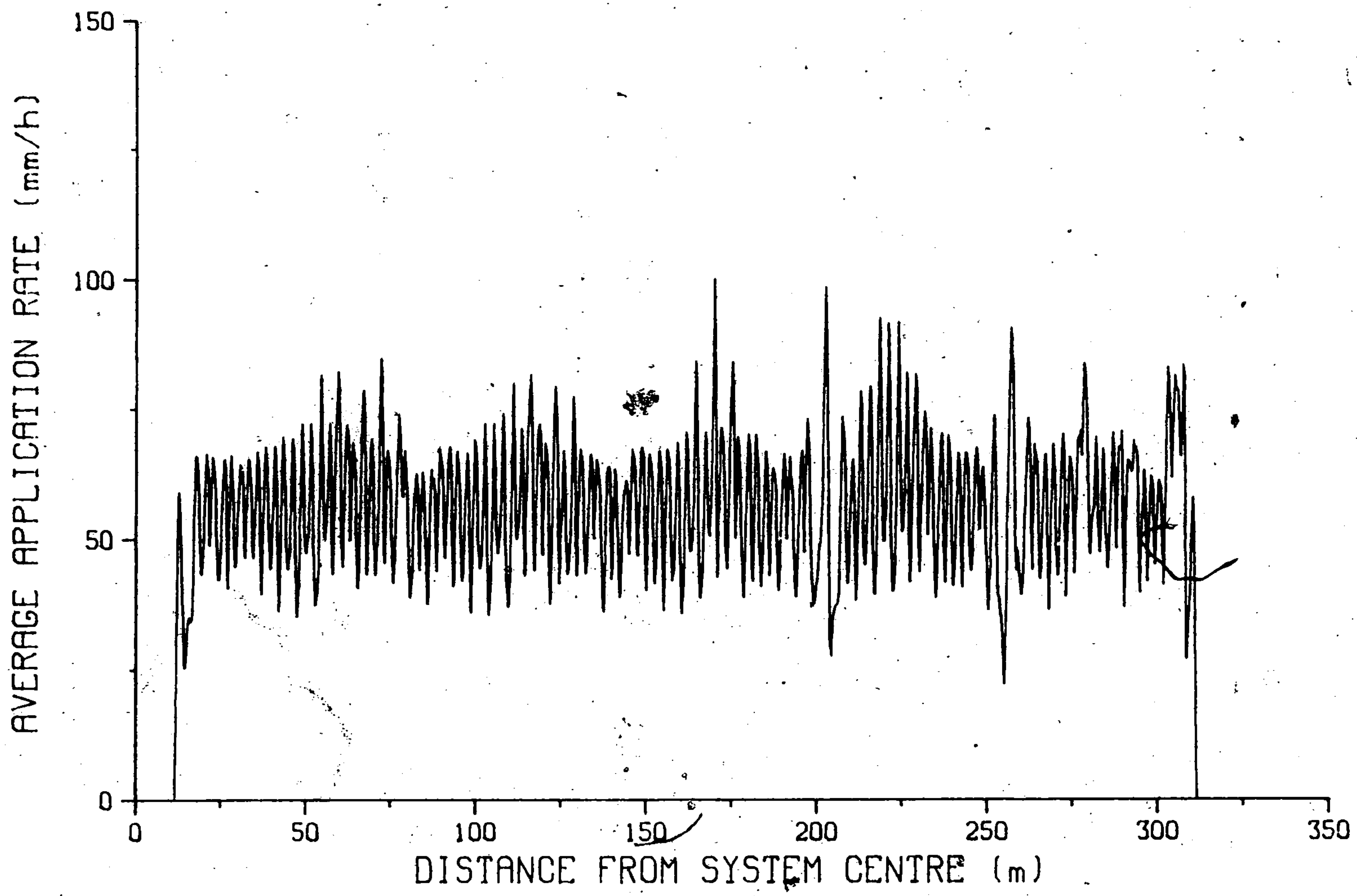


FIGURE 16. Theoretical Average Application Rates for Various Positions Along East Side of System.

4.5.2 Application Perpendicular to Lateral

As a means of increasing the area over which water is applied, nozzles were mounted on 1525 mm booms extending perpendicular to and on alternate sides of the lateral.

FIGURE 17 shows the theoretical average instantaneous application rates for various positions about the lateral (i.e. system grid rows). Very high application rates occur below the lateral and are a result of individual distribution profile perimeter overlap. High application rates also occur at positions slightly offset from the lateral and are a result of the leading and trailing perimeters of the individual pattern profiles.

FIGURE 18 shows the theoretical average instantaneous application rates for various lengths of extension booms. For nozzle extension boom lengths of 765 and 2290 mm, maximum average instantaneous application rates occur beneath the lateral. For boom lengths of 100 and 3050 mm, maximum average instantaneous application rates occur at positions slightly offset from the lateral.

Table 5 summarizes the theoretical instantaneous application rates for various lengths of nozzle extension booms. Extending boom length increased the application area and decreased the average instantaneous application rate. For example, a 100 mm boom length has a wetted length of 8.4 m and an average instantaneous application rate of 76 mm/h. Increasing the nozzle boom length to 3050 mm increased the wetted width to 14.4 m and decreased the average instantaneous application rate to 44 mm/h.

Maximum theoretical instantaneous application rates varied from 254 mm/h for 100 mm booms to 367 mm/h for 765 mm booms. Maximum instantaneous application rates occur over a relatively small area. Local ponding and runoff may occur if a particular point is exposed for long periods of time. Exposure times will depend on system speed.

Large variations in instantaneous application rates may cause local ponding and runoff. Small variations result in more uniform application rate distribution and are more desirable. For the lengths of nozzle extension booms evaluated, uniformity was greatest for the 100 mm length. Uniformity decreased for boom lengths of up to 2290 mm while a slight increase was noted for the 3050 mm booms.

TABLE 5. Instantaneous Application Rate Summary for Various Extension Boom Lengths.

BOOM LENGTH	AVERAGE INSTANTANEOUS APPLICATION[a] RATE	WETTED WIDTH	MAXIMUM INSTANTANEOUS APPLICATION RATE	UCC (SYSTEM VARIATION)
mm	mm/h	m	mm/h	%
100	76	8.4	254	48.6
765	67	9.6	367	39.6
1525	56	11.4	348	26.8
2290	51	12.6	321	26.3
3050	44	14.4	301	31.8

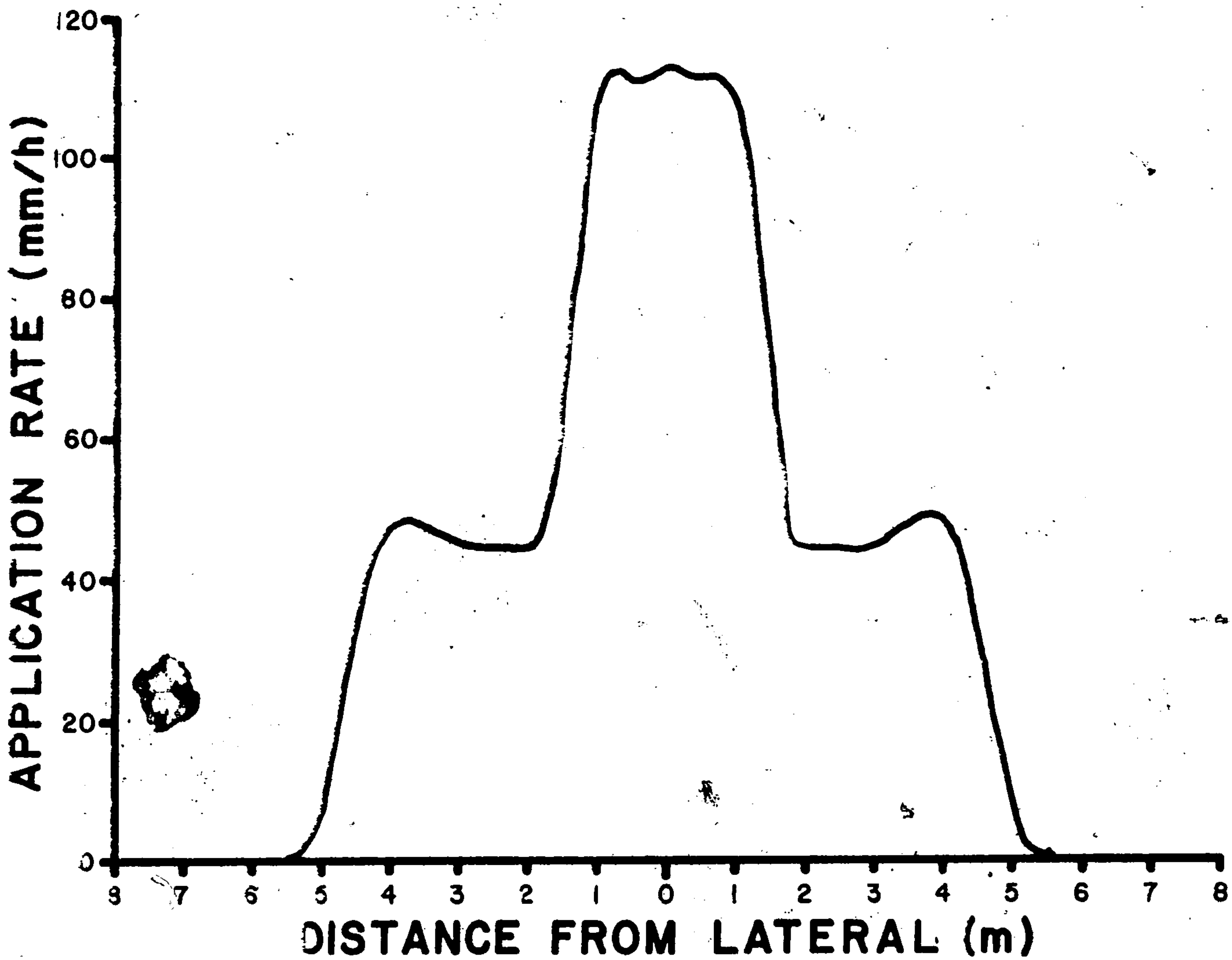


FIGURE 17. Theoretical Average Instantaneous Application Rates for Various Positions About the System Lateral.

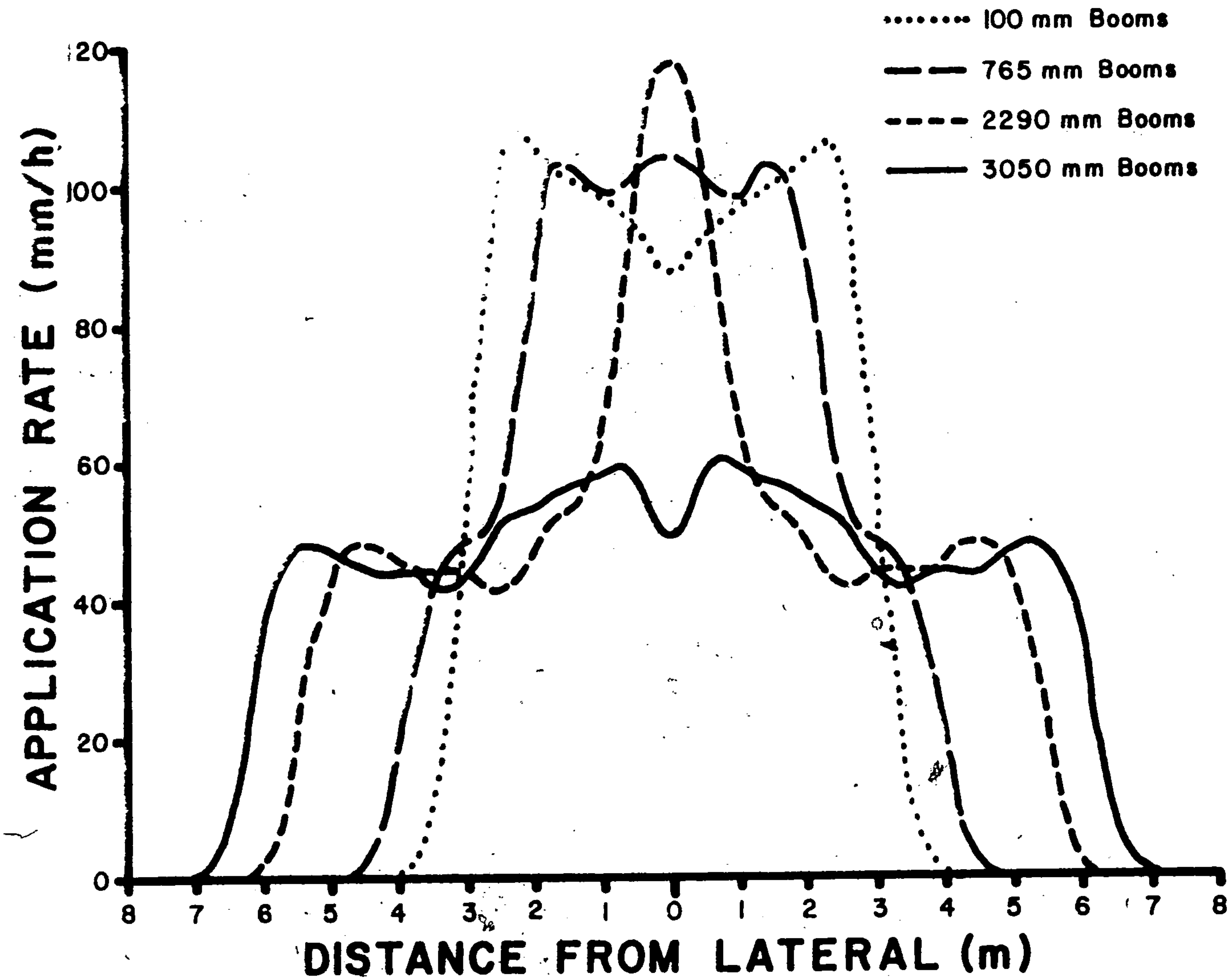


FIGURE 18. Theoretical Average Instantaneous Application Rates for Various Lengths of Extension Booms.

CHAPTER V

SUMMARY AND CONCLUSIONS

The main purpose of this study was to examine the water application of a low pressure spray nozzle irrigation system. A computer program was developed to overlap and superimpose individual nozzle application profiles according to the specifications of an existing system. Field testing was conducted in an effort to substantiate the application model.

Investigations into the performance of individual nozzles indicated that nozzle delivery increases in a curvilinear fashion with increasing lateral pressure. Pressure regulators were effective in reducing variations in nozzle delivery due to lateral pressure variations. Nozzle delivery, when equipped with a pressure regulator, increased rapidly for lateral pressures up to approximately 200 kPa, but increased less rapidly for lateral pressures above 200 kPa.

Spray nozzles directed spray downward in a 360° arc producing a conical spray pattern with a circular ring shaped distribution profile. Higher applications occurred at the perimeter of the pattern than in the interior. Very high applications occurred in one section of the perimeter and was characteristic of all nozzles tested.

Application uniformity of individual nozzles increased with increasing nozzle discharge height. High nozzle discharge heights distributed discharge over a greater area and resulted in a more uniform distribution.

Comparison between experimental and theoretical application uniformity coefficients for the linear move system showed only fair agreement. Average experimental uniformity coefficients were 78.0 and 74.7 per cent for the west and east sides, respectively, compared to average theoretical values of 82.2 and 81.3 per cent for the the west and east sides, respectively. Discrepancies may be attributed to the influences of environmental and physical conditions on field results. Simulation coefficients were calculated assuming ideal conditions.

The computer program was used to simulate the theoretical instantaneous application rates of the low pressure linear move system. Low instantaneous application rates occurred directly below each nozzle while high application rates occurred directly below the lateral. Very high applications occurred near the lateral opposite each adjacent nozzle and were a result of the very high application areas of the individual profiles. The maximum and average theoretical instantaneous application rates for the test system were 348 mm/h and 56 mm/h, respectively.

Examination of various nozzle extension boom lengths showed that extension booms are effective in reducing the average instantaneous application rates. Theoretical average instantaneous application rates decreased from 76 mm/h for nozzles mounted on 100 mm booms to 44 mm/h for nozzles mounted on 3050 mm booms.

CHAPTER VI

REFERENCES

1. American Society of Agricultural Engineers. ASAE S330. Procedure for sprinkler distribution testing for research purposes. 1982. Agricultural Engineers Yearbook, pp. 512-514.

2. Allison, S. V. and V. L. Hesse. 1969. Simulation of wind effects on sprinkler uniformity. J. Irr. and Dr. Div., Proc. Amer. Soc. Civ. Engrs. 90:(IR4) 537-550.

3. Beale, J. G. and D. T. Howell. 1966. Relationship among sprinkler uniformity measures. J. Irr. and Dr.Div., Proc. Amer. Soc. Civ. Engrs. 92:(IR1) 41-48.

4. Benami, A. and F. R. Hore. 1964. A new irrigation-sprinkler distribution coefficient. Trans. Amer. Soc. Agr. Eng. 7(10):157-158.

5. Bilanski, W. K. and E. H. Kidder. 1958. Factors that affect the distribution of water from a medium-pressure rotary irrigation sprinkler. Trans. Amer. Soc. Agr. Eng. 1(1):19-23, 28.

6. Bittinger, M. W. and R. A. Longenbaugh. 1962. Theoretical distribution of water from a moving irrigation sprinkler. Trans. Amer. Soc. Agr. Eng. 5(1):26-30.

7. Christiansen, J. E. 1942. Irrigation by sprinkling. California Agr. Expt. Sta. Bull. 670.

8. Criddle, W. D., et al. 1956. Methods for evaluating irrigation systems. U. S. Dept. Agr.-Soil Conserv. Service, Agriculture Handbook 82. U. S. Supt. Doc., Washington, D.C.

9. Frost, K. R. and H. C. Schwaler. 1955. Sprinkler evaporation losses. Agr. Eng. 36(1):526-528.

10. Frost, K. R. and H. C. Schwaler. 1960. Evapotranspiration during sprinkler irrigation. Trans. Amer. Soc. Agr. Eng. 3(1):18-20,24.

11. Hart, E. W. 1961. Overhead irrigation pattern parameters. Agr. Eng. 42(7):354-355.

12. Heermann, D. F. and P. R. Hein. 1968. Performance characteristics of self-propelled center-pivot sprinkler irrigation system. Trans. Amer. Soc. Agr. Eng. 11(1):11-15.

13. James, L. G. and R. T. Stillmunkes. 1980. Instantaneous application rates beneath center pivot irrigation systems. ASAE Paper PNW 80-206.

14. Kohl, R. A. 1974. Drop sizes distribution from medium sized agricultural sprinklers. Trans. Amer. Soc. Agr. Eng. 17(4):690-693.

15. Korven, H. C. 1952. The effect of wind on the uniformity of water distribution by some rotary sprinklers. Sci. Agr. 32(4):226-239.

16. Korven, H. C. 1968. An evaluation of three coefficients as a measure of uniformity of water application by sprinklers. Can. Ag. Eng. 10(2):83-84.

17. Kraus, J. H. 1966. App i ati n effi ien y of sprinkler irrigation and its effects on microclimate. Trans. Amer. Soc. Agr. Eng. 9(5):642-645.

18. Seginer, I. 1963. Water distribution from medium pressure sprinklers. J. Irr. and Dr. Div., Proc. Amer. Soc. Civ. Engrs. 89:(IR2) 13-29.

19. Seginer, I. 1969. Wind variation and sprinkler water distribution. J. Irr. and Dr. Div., Proc. Amer. Soc. Civ. Engrs. 95:(IR2) 261-274.

20. Sternberg, Y. M. 1967. Analysis of sprinkler irrigation losses. J. Irr. and Dr. Div., Proc. Amer. Soc. Civ. Engrs. 93:(IR4) 111-125.

21. Wilcox, J. C. and J. M. McDougald. 1955. Water distribution patterns from rotary sprinklers. Can. Jour. of Agr. Sc. 35:217-228.

22. Wilcox, J. C. and G. E. Swailes. 1947. Uniformity of water distribtuion of some undertree orchard sprinklers. Sci. Agr. 27(9):565-583.

APPENDIX IA

DETAILED CHARACTERISTIC DATA FOR THE EAST SIDE OF THE LINEAR MOVE SYSTEM

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
1	15.44	1525	4480	100
2	18.21	1525	4510	100
3	20.63	1525	4600	100
4	23.29	1525	4650	100
5	25.55	1525	4680	100
6	28.40	1525	4700	100
7	30.95	1525	4680	100
8	33.19	1525	4650	100
9	35.86	1525	4600	100
10	38.27	1525	4510	100
11	40.85	1525	4480	100
12	43.44	1525	4370	100
13	46.14	1525	4300	100
14	48.81	1525	4190	100
15	51.67	1525	4020	100
16	54.34	1525	3880	100
17	57.25	1525	3900	110
18	59.66	1525	4010	100
19	61.74	152[illegible]	4110	100
20	64.44	1525	4210	100
21	66.81	1525	4300	95
22	69.50	1525	4370	110
23	72.11	1525	4480	100
24	74.70	1525	4510	110
25	77.10	1525	4600	100
26	79.77	1525	4650	95
27	82.02	1525	4680	100
28	84.87	1525	4700	90
29	87.42	1525	4680	95
30	89.66	1525	4650	100
31	92.34	1525	4600	100
32	94.76	1525	4510	95
33	97.34	1525	4480	100
34	99.94	1525	4370	100
35	102.63	1525	4300	100
36	105.30	1525	4190	100
37	108.15	1525	4010	100
38	110.83	1525	3880	95
39	113.75	1525	3890	110

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
40	116.16	1525	4000	100
41	118.24	1525	4100	100
42	120.95	1525	4200	100
43	123.31	1525	4280	90
44	126.01	1525	4350	110
45	128.62	1525	4450	100
46	131.21	1525	4490	100
47	133.61	1525	4590	100
48	136.28	1525	4630	90
49	138.54	1525	4680	100
50	141.38	1525	4700	95
51	143.93	1525	4680	95
52	146.18	1525	4650	100
53	148.84	1525	4600	100
54	151.26	1525	4500	95
55	153.83	1525	4480	100
56	165.44	1525	4370	95
57	159.13	1525	4300	100
58	161.80	1525	4190	100
59	164.66	1525	4010	100
60	167.34	1525	3880	110
61	170.24	1525	3900	100
62	172.66	1525	4010	110
63	174.74	1525	4110	100
64	177.44	1525	4210	95
65	179.81	1525	4300	95
66	182.51	1525	4370	95
67	185.12	1525	4480	100
68	187.70	1525	4510	100
69	190.11	1525	4600	95
70	192.77	1525	4650	100
71	195.03	1525	4680	95
72	197.89	1525	4700	95
73	200.41	1525	4680	110
74	205.33	1525	4600	110
75	207.75	1525	4510	95
76	210.33	1525	4480	95
77	212.94	1525	4370	100
78	215.63	1525	4300	110
79	218.30	1525	4190	110
80	221.15	1525	4020	110
81	223.83	1525	3880	110

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
82	226.74	1525	3900	110
83	229.14	1525	4010	100
84	231.22	1525	4110	90
85	233.93	1525	4210	95
87	236.29	1525	4300	95
86	238.99	1525	4370	95
88	241.60	1525	4480	100
89	244.17	1525	4510	100
90	246.59	1525	4600	100
91	249.25	1525	4650	95
92	251.51	1525	4680	95
93	254.36	1525	4700	110
94	259.14	1525	4605	110
95	261.82	1525	4600	95
96	264.22	1525	4510	95
97	266.81	1525	4480	100
98	269.42	1525	4370	100
99	272.12	1525	4300	95
100	274.48	1525	4190	90
101	276.57	1525	4110	85
102	278.92	1525	4020	90
103	281.35	1525	3900	110
104	284.72	1525	3900	85
105	286.87	1525	4010	85
106	289.11	1525	4110	90
107	291.31	1525	4210	90
108	293.67	1525	4300	85
109	295.80	1525	4480	90
110	298.27	1525	4510	85
111	300.50	1525	4600	85
112	302.83	1525	4650	90
113	305.06	1525	4700	110
114	307.37	1525	4740	100

APPENDIX IB

DETAILED CHARACTERISTIC DATA FOR THE WEST SIDE OF THE LINEAR MOVE SYSTEM

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
1	10.82	1525	4300	100
2	13.52	1525	4370	100
3	16.14	1525	4480	100
4	187.2	1525	4510	100
5	21.13	1525	4600	100
6	23.79	1525	4650	100
7	26.04	1525	4680	100
8	28.58	1525	4700	100
9	31.43	1525	4680	100
10	33.69	1525	4650	100
11	36.35	1525	4600	100
12	38.76	1525	4510	100
13	41.37	1525	4480	100
14	44.07	1525	4370	100
15	46.77	1525	4300	110
16	49.44	1525	4190	100
17	52.30	1525	4010	110
18	54.98	1525	3880	110
19	57.89	1525	3900	90
20	60.30	1525	4010	100
21	62.37	1525	4110	95
22	65.08	1525	4210	90
23	67.45	1525	4300	100
24	70.15	1525	4370	95
25	72.76	1525	4480	100
26	75.34	1525	4510	100
27	77.75	1525	4600	100
28	80.41	1525	4650	95
29	82.67	1525	4680	95
30	85.52	1525	4700	100
31	88.05	1525	4680	95
32	90.29	1525	4650	100
33	92.96	1525	4600	100
34	95.36	1525	4510	100
35	97.95	1525	4480	100
36	100.56	1525	4370	100
37	103.26	1525	4300	110
38	105.93	1525	4190	100
39	108.78	1525	4020	110
40	111.46	1525	3880	100

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
41	114.37	1525	3900	95
42	116.78	1525	4010	100
43	118.85	1525	4110	90
44	121.57	1525	4210	95
45	123.93	1525	4300	100
46	126.63	1525	4370	95
47	129.25	1525	4480	100
48	131.83	1525	4510	95
49	134.24	1525	4600	95
50	136.90	1525	4650	100
51	139.16	1525	4680	100
52	142.01	1525	4700	100
53	144.54	1525	4680	100
54	146.79	1525	4650	95
55	149.46	1525	4600	100
56	151.87	1525	4510	100
57	154.44	1525	4480	95
58	157.05	1525	4370	100
59	159.75	1525	4300	110
60	162.43	1525	4190	100
61	165.28	1525	4010	110
62	167.95	1525	3880	90
63	170.86	1525	3890	95
64	173.27	1525	4000	100
65	175.35	1525	4100	90
66	178.05	1525	4200	95
67	180.41	1525	4280	100
68	183.11	1525	4350	100
69	185.7[illegible]	1525	4450	95
70	188.30	1525	4490	100
71	190.71	1525	4590	95
72	193.38	1525	4630	95
73	195.63	1525	4680	95
74	198.48	1525	4630	100
75	201.15	1525	4590	100
76	203.56	1525	4520	110
77	206.14	1525	4450	100
78	208.75	1525	4320	95
79	211.44	1525	4240	110
80	214.12	1525	4120	100
81	216.97	1525	4010	100
82	219.65	1525	3880	110

NOZZLE NUMBER	DISTANCE FROM SYSTEM CENTRE (m)	NOZZLE BOOM LENGTH (mm)	NOZZLE HEIGHT (mm)	NOZZLE SIZE RA xxx/140
83	222.56	1525	3900	90
84	224.98	1525	4010	110
85	227.05	1525	4110	100
87	229.75	1525	4210	90
86	232.12	1525	4300	95
88	234.82	1525	4370	95
89	237.42	1525	4480	95
90	240.00	1525	4510	110
91	242.41	1525	4600	110
92	245.09	1525	4650	100
93	247.34	1525	4680	110
94	150.19	1525	4700	95
95	252.86	1525	4680	100
96	255.26	1525	4650	90
97	257.84	1525	4600	100
98	260.45	1525	4510	100
99	263.15	1525	4480	85
100	265.51	1525	4370	95
101	267.60	1525	4250	90
102	269.95	1525	4090	90
103	272.38	1525	3950	90
104	275.18	1525	3950	100
105	277.39	1525	4020	85
106	279.73	1525	4110	90
107	281.97	1525	4210	110
108	284.29	1525	4300	110

APPENDIX II

This appendix contains the Fortran program used in calculating the distribution pattern of the linear move system. The program is coded in a DEC Fortran and is designed to run on a DEC PDP-11 computer. Coding can be easily modified to suit most other operating systems. Documentation in the form of comment statements is supplied with the coding.

To use the program, two types of files must be set up. Data files must contain individual nozzle data. Data controlling files must contain information relating data files to the linear move system characteristic data. Both data and data controlling files must be set up in a standard format. The first line of each file must contain a description of the file contents. The description can be of any form. The second line of a file must contain two integers, the first indicating the number of data lines, and the second indicating the number of columns contained within the file. Data items may be separated with blanks, commas or both blanks and commas.

Data controlling files must contain the following:

(a) the names of individual nozzle distribution data files with one data file name per line,

(b) detailed linear move system characteristic data. This file must contain four integers per line and must be as follows:

(i) the first integer is the distance along the lateral in millimetres from a reference point to the nozzle,

(ii) the second integer is the nozzle extension boom length,

(iii) the third integer, the nozzle height and

(iv) the fourth integer, the nozzle size.

(c) information which cross references nozzle size to the appropriate nozzle data file name. This file must also contain four integers per line. The first integer is the nozzle size; second, the nozzle data file name which contains 3750 mm nozzle height distribution data; third, data file name which contains 4250 mm nozzle height distribution data; and fourth, data file name which contains 4750 mm nozzle height distribution data.

The problem definition is interactive. In most cases an input mistake can be recovered; however, the program is not perfect so some mistakes will cause the execution to abort. To execute this program type: EXECUTE IRRSIM.FOR.

DESCRIPTION OF PARAMETERS:

Main is the most global block. It allocates memory for the main arrays, call "SUB. define" to define the problem, "SUB. irrsim" to do the calculations and "SUB. output" to output the results.

areal-4 -- Areas involved with the nozzle pattern and field pattern.

both------ Logical which indicates if two nozzle patterns are to be read.

crsref---- A 4 by "nonzty" array which identifies which files contain data for the nozzles at each height.

Col. 1. Contains the nozzle size number.

Col. 2. Contains the file number in which data for the 3750 mm height is stored.

Col. 3. Contains the file number in which data for the 4250 mm height is stored.

Col. 4. Contains the file number in which data for the 4750 mm height is stored.

datfil --- Name of file which contains the names of all the data files.

debug -- Logical used to activate write statements for the purpose of debugging the program.

desc A character array used to read a line describing the contents of a file.

Distances associated with the nozzle and field pattern overlaps

```
                +
     dist1      +       dist2
*****************************
*               +           *
*    area1      +    area2  *   dist3
+++++++++++++++++++++++++++++
*               +           *
*               +           *
*    area3      +    area4  *   dist4
*               +           *
*****************************
                +
                +
```

dm-------- Equivalent to dstmrk.
dstmrk---- Distance mark. Used to keep track of the row in the fldpat matrix where each column of the present nozzle starts.
echo------ Logical used to determine when certain print statements are active. It is useful for debugging the program.
error----- Logical used to indicate that a possible error has been found in the data. A warning statement will be made but the program will continue to run providing the "stop" variable has not been activated as well.
fdptcl---- Dummy variable which contains the number of columns in fldpat.
fdptln---- Field pattern length. This variable stores the length of the irrigation pattern. The program creates a matrix which will cover an area slightly longer at each end (25 rows). This data must be entered in metres.
fdptrw---- Dummy variable which contains the number of rows in fldpat.
fdptwd---- Field pattern width. This variable stores the width of the required field pattern. The program adds four columns to the field pattern matrix. This width must be in metres.
file------ Local variable used to input the file name from which data is to be read.
fillnk---- Contains the file name which links the data files to the nozzles.
filmsp---- Contains the file name which contains the data for the machine specifications.
filnam---- Contains the file name which contains the names of the files that contain nozzle data.
fldpat---- Field pattern. This is the master array in which the final simulated field pattern is developed. It is set up with 50 rows or more than required for the machine length and 4 more columns.
gdarea---- Area of one grid unit.
gridsz---- Size in (mm) of the grid dimension.
help------ Logical used to indicate that a long prompt is required for the inputs.
hitea----- Actual height being interpolated to.
hitel----- One of the data heights.
hite2----- Second data height.
last------ Nozzle number of last nozzle processed.
latmrk---- Lateral mark. Used to keep track of the column in the fldtpat matrix where each row of the present nozzle starts.

```
lm-------- Equivalent to latmrk.
lstrng---- A value of 2 or 4 depending on which column
           in crsref the last nozzle used to place the
           actual height in the right range.
ltnzds---- Lateral nozzle distance. Distance from the
           lateral to the nozzle. This is the value in
           mcnspc(,2).
mcnlen---- Machine specs. A 6 by "numnoz" array which
           stores system characteristic data.
           Col. 1.  Distance along the lateral from a
                    reference point (mm).
           Col. 2.  Nozzle extension boom length.
                    Distances to one side are neg.
                    (mm).
           Col. 3.  Actual nozzle height.
           Col. 4.  Nozzle size.
mcnwid---- Maximum width for the field pattern.
min------- Minimum value to be expected in the data
           file. Used for the plotter.
mxnzwd---- Maximum number of rows or columns required
           for the nozzle pattern matrix.
nodtfl---- Number of data files.
nonzty---- Number of nozzle types. This contains the
           number of nozzle types for which there is
           data in the data files. Do not reduce this
           number if all the nozzles are not used in a
           particular run and do not count the same
           nozzle more than once even if more than one
           data file contains data for this nozzle.
nozpat---- Three layer matrix which stores nozzle
           pattern data.
numabv---- Number of rows in the "nozpat" matrix above
           the nozzle. Used by the plotter.
numblw---- Number of rows in the "nozpat" matrix below
           the nozzle. Used by the plotter.
numcol---- Number of columns.
numlft---- Number of columns in the "nozpat" matrix to
           the left of the nozzle. Used by the
           plotter.
numnoz---- Number of nozzles. This is the number of
           nozzles on the machine being simulated.
numrit---- Number of columns in the "nozpat" matrix to
           the right of the nozzle.
numrow---- Number of rows.
nzptsz---- Nozzle pattern size. Number of rows and
           columns in nozpat.
nzptwd---- Nozzle pattern width. This is the width in
           metres of the nozzle patterns stored in the
           data files. This program produces a square
           matrix for the nozzle pattern and uses the
```

same matrix for all nozzles so make sure this is the maximum width for all nozzles.

optech---- Logical which allows the status of echo to be changed through the run (optional echo).

optbug---- Logical which allows the status of debug to be changed through the run (optional debug).

opthlp---- Logical which allows the status of help to be changed through the run (optional help).

outdvc---- Stores the type of output device to be used for final output.

outfil---- Stores the name of the output file if the final output is to go to a file.

skip------ Logical used to skip parts of the program.

start----- A local variable used to read data from one or two nozzle pattern data files. If start=1 two data files are read, if start=2 only one is read.

stop------ Logical which stops the run if a serious error is found.

title----- A character variable which stores the title output.

warnng---- Logical which is set to true when a minor problem has been found that is not serious enough to stop the program. Warning messages are printed where the error could influence the output.

```
*********************************************************************

        PROGRAM main

*********************************************************************

        REAL fdptln, fdptwd, nzptsz, fldpat, mcnwid, mcnlen, nozpat,
     *    gridsz
        INTEGER fdptcl, fdptrw, filord, mxnzwd, nonzty, numcol,
     *          numnoz, numrow, nodtfl, mcnspc, crsref, intpat
        DOUBLE PRECISION filnam, fillnk, filmsp, datfil, title, outdvc,
     *                   outfil
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp

c       DIMENSION fldpat(50000)
        DIMENSION fldpat(100000)
        DIMENSION nozpat(5000)
c       DIMENSION mcnspc(500)
        DIMENSION mcnspc(1000)
        DIMENSION crsref(400)
        DIMENSION datfil(1000)
        DIMENSION title(10)

        COMMON /logflg/ debug, echo, error, help, skip, stop, warnng,
     *                  optbug, optech, opthlp

        DATA debug, echo, error, help, skip, stop, warnng,
     *    optbug, optech, opthlp /10*.FALSE./

        IF (debug) TYPE 7000

c       Define the problem parameters.
        CALL define(datfil, crsref, mcnspc,fdptrw,fdptcl,nonzty,numnoz,
     *              nodtfl, mxnzwd, outdvc, gridsz, outfil, title)

        IF (stop) GO TO 99999

c       Create the simulated field pattern.
        CALL irrsim(fdptcl, fdptrw, mxnzwd, numnoz, nonzty,
     *              nodtfl, filnam, filmsp, fillnk, fldpat,
     *              nozpat, crsref, datfil, mcnspc, gridsz)
        IF (stop) GO TO 99999
```

```
      gridsz = gridsz * 1000
c     Output completed field pattern.
  20  TYPE 7050
      ACCEPT 1000, (title(i), i=1,8)
      CALL output(fdptrw,fdptcl,fldpat, mcnspc, gridsz, numnoz,
     *               outdvc, outfil, title)
      IF (stop) GO TO 99999
      TYPE 7020
      IF (yesno(dummy)) 40,80
  40    TYPE 7030
  45    ACCEPT 1000, outdvc
        IF (outdvc .EQ. 8Hterminal .OR. outdvc .EQ. 10Hlineprintr .OR.
     *      outdvc .EQ. 4Hfile) 20,50
  50    TYPE 7040, outdvc
        GO TO 45
c     Problem was successfully solved!
  80  TYPE 7010

1000  FORMAT(8A10)
7000  FORMAT (' PROGRAM main')
7010  FORMAT(' Problem was successfully solved!')
7020  FORMAT(' Would you like to output to another device? (yes no)'$)
7030  FORMAT(' Which device do you want to use? (file terminal
     *lineprintr)'$)
7040  FORMAT(' Please reenter! ',A10,' is not a valid output device.')

7050  FORMAT(' Please enter up to 80 characters for the output title')

99999 END

*******************************************************************************

      SUBROUTINE define(datfil, crsref, mcnspc,fdptrw,fdptcl,nonzty,
     *      numnoz, nodtfl, mxnzwd, outdvc, gridsz, outfil, charin)

*******************************************************************************

      REAL mcnlen, mcnwid, nzptsz, gridsz
      INTEGER crsref, mcnspc, fdptrw, fdptcl, nonzty, numnoz, nodtfl,
     *        mxnzwd
      DOUBLE PRECISION datfil, charin, filnam, fillnk, filmsp, outdvc,
     *                 outfil
      LOGICAL debug, echo, error, help, skip, stop, warning,
     *        optbug, optech, opthlp

c     DIMENSION mcnspc(5,0:99)
      DIMENSION mcnspc(5,0:200)
      DIMENSION crsref(4,100)
      DIMENSION datfil(1000)
      DIMENSION charin(10)
```

```
      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      IF (debug) TYPE 7000

      mcnspc(3,0) = 999999999
c     Request optional output.
      CALL option
c     Insert initial data by file or terminal.
   10 TYPE 7010
   13     ACCEPT 1000, charin(1)
C     IF the problem is to be defined interactively THEN DO:
        IF (charin(1) .EQ. 8Hterminal) 15,8
   15   CALL intact
     *  (mcnlen,mcnwid,nzptsz,gridsz,numnoz,nonzty,nodtfl,
     *   filnam, filmsp, fillnk)
        GO TO 7
C     ELSE IF input is from a file THEN DO:
    8   IF (charin(1) .EQ. 4Hfile)  5,12
    5 TYPE 7170
c     What file?
        TYPE 7150
    9   ACCEPT 1000, charin(1), charin(2)
        IF (charin(2) .EQ. 3H ok) GO TO 11
c     Spelt correctly?
        TYPE 7045, charin(1)
        ACCEPT 1000, charin(2)
        IF (charin(2) .EQ. 3Hyes) GO TO 11
c     If no then reenter filename.
        TYPE 7155
        GO TO 9
   11   CALL rdinit
     *  (mcnlen,mcnwid,nzptsz,gridsz,numnoz,nonzty,nodtfl,
     *   filnam, filmsp, fillnk, charin(1))
       IF (stop) RETURN
       GO TO 7
   12  TYPE 7020, charin(1)
       GO TO 13

    7  IF (echo) 19,20
   19    TYPE 7050, mcnlen
         TYPE 7060, mcnwid
         TYPE 7070, nzptsz
         TYPE 7080, gridsz
         TYPE 7090, numnoz
         TYPE 7100, nonzty
         TYPE 7110, nodtfl
         TYPE 7120, filnam
         TYPE 7130, fillnk
         TYPE 7140, filmsp
```

```
c       Calculation of the matrix dimensions for fldpat and nozpat
c         using the input gridsize and pattern measurements.

   20   fdptrw = mcnlen/gridsz + 25
        fdptcl = (mcnwid/(2*gridsz) + 1) *2
        mxnzwd = (nzptsz/(gridsz*2) + 1) *2

        IF (debug) TYPE 7200, fdptrw, fdptcl, mxnzwd

c       What device for output?
  310   TYPE 7030
        ACCEPT 1000, outdvc
C       IF the output is to go to a file THEN DO:
          IF (outdvc .EQ. 4Hfile) 320,340
c         What is the name of the output file?
  320     TYPE 7040
          ACCEPT 1000, outfil, charin(2)
          IF (charin(2) .EQ. 3H ok) GO TO 40
c         Is file name spelt correctly?
            TYPE 7045, outfil
          IF (yesno(dummy)) 40,320
C       ELSE IF output is to go to the terminal THEN DO:
  340     IF (outdvc .EQ. 8Hterminal) 345, 360
  345       TYPE 7160
            GO TO 40
C       ELSE IF the output is to go to a line printer THEN DO:
  360     IF (outdvc .EQ. 10Hlineprintr) GO TO 40
C       ELSE Invalid input
  370     TYPE 7020
          GO TO 310
C       END IF THEN--IF THEN ELSE
c       Make sure enough memory is available for storage.
   40   IF (chkdim(fdptcl,fdptrw,mxnzwd,numnoz,nonzty,nodtfl))
     *                        GO TO 99999
c       Read data from data files.

        CALL rdflnm(nodtfl,filnam,datfil)
         IF (stop) RETURN
        CALL rddtmx(0,numnoz,5,4,filmsp,mcnspc)
         IF (stop) RETURN
        CALL rddtmx(1,nonzty,4,4,fillnk,crsref)


        RETURN

 1000   FORMAT(8A10)


 7000   FORMAT(' SUB define--defuine problem')
 7010   FORMAT(' How would you like to input data? (file terminal)')
```

```
7020   FORMAT(' Please reenter.', A10,' is not a valid input.')
7030   FORMAT(' Where do you want the final output? (file terminal
     *lineprintr)')
7040   FORMAT(' In what file should the output be placed?')
7045   FORMAT(' Is ',A10,' the correct spelling of file name?(yes no)')
7050   FORMAT(' Machine length = ',F8.3,' meters.')
7060   FORMAT(' The field pattern width =', F6.3, ' meters')
7070   FORMAT(' The maximum nozzle pattern dimension =',F6.3,' meters')
7080   FORMAT(' The grid size =',F5.3,' meters.')
7090   FORMAT(' The number of nozzles to be processed =',I8)
7100   FORMAT(' The number of different nozzle types =',I8)
7110   FORMAT(' The number of files containing nozzle data =',I8)
7120   FORMAT(' The file containing the nozzle data file names =',A10)
7130   FORMAT(' The file which cross references nozzle types, heights,
     * and nozzle pattern files is ',A10)
7140   FORMAT(' The file where the machine specs are stored is ',A10)
7150   FORMAT(' The file which contains the initialization data is:')
7155   FORMAT(' Please retype file name')
7160   FORMAT(' Caution output to terminal has not been fully debugged!
     * * Debugged Feb. 82 M. Eliason.')
7170   FORMAT(' Caution inputting from a file has not been fully
     * debugged! ')
7200   FORMAT(' fdptrw =', I8, ' fdptcl = ' ,I8, ' mxnzwd = ',I8)

99999  END

************************************************************************

       LOGICAL FUNCTION assist(dummy)

************************************************************************

       LOGICAL debug, echo, error, help, skip, stop, warnng,
     *        optbug, optech, opthlp
       DIMENSION charin(10)
       COMMON /logflg/ debug, echo, error, help, skip, stop, warnng,
     *                 optbug, optech, opthlp

       assist = .FALSE.

       IF (debug) TYPE 7000
       ACCEPT 1000, charin(1)
       IF (charin(1) .EQ. 2Hno) RETURN
       IF (charin(1) .EQ. 3Hyes) GO TO 10

         TYPE 7002, charin(1)
         help = assist

10     TYPE 7005; TYPE 7010; TYPE 7020; TYPE 7030; TYPE 7040; TYPE 7050
       TYPE 7060; TYPE 7070; TYPE 7080; TYPE 7090
       TYPE 7100; TYPE 7110; TYPE 7120; TYPE 7130; TYPE 7140; TYPE 7150
```

```
      TYPE 7160; TYPE 7170; TYPE 7180; TYPE 7185; TYPE 7190
       ENTRY help1(dummy)
      TYPE 7200; TYPE 7210; TYPE 7220; TYPE 7230; TYPE 7240; TYPE 7250
      TYPE 7260; TYPE 7270; TYPE 7280; TYPE 7290
      TYPE 7300; TYPE 7310; TYPE 7320; TYPE 7330; TYPE 7340; TYPE 7350
      TYPE 7360; TYPE 7370; TYPE 7380; TYPE 7390
       ENTRY help2(dummy)
      TYPE 7400; TYPE 7410; TYPE 7420; TYPE 7430; TYPE 7440; TYPE 7450
      TYPE 7455; TYPE 7460; TYPE 7470; TYPE 7475; TYPE 7480; TYPE 7485
      TYPE 7490

      RETURN

1000  FORMAT(8A10)

7000  FORMAT(' LOGICAL FUNCTION assist')
7002  FORMAT(A10, ' was entered. Answer question again. (yes no)')
7005  FORMAT('                    Useful information for starting program')
7010  FORMAT(' Before you can run this program you must have files')
7020  FORMAT(' with data in them.  These files are for the nozzle')
7030  FORMAT(' pattern data, the machine specifications, the file')
7040  FORMAT(' which cross references the nozzle pattern file names')
7050  FORMAT(' to the different nozzles and heights and a file which')
7060  FORMAT(' contains a list of the files which contain nozzle')
7070  FORMAT(' pattern data.')
7080  FORMAT(' You will soon be asked if you want to have your input')
7090  FORMAT(' echoed out.  If you say yes the values the computer')
7100  FORMAT(' has for the input variables at that time will be '
7110  FORMAT(' printed out.  This will allow you to check this data')
7120  FORMAT(' before the major part of the computation takes place')
7130  FORMAT(' If you request the input data be printed when read')
7140  FORMAT(' you will not get the nozzle patterns printed out ')
7150  FORMAT(' unless you confirm that you want these to be printed.')
7160  FORMAT(' If you input data by the terminal the')
7170  FORMAT(' computer will prompt you for each data required.')
7180  FORMAT(' If you choose to read the data from a file this file')
7185  FORMAT(' must be created before the run in the following way.')
7190  FORMAT(' First line--Description of file contents.')
7200  FORMAT(' Second line--Amount of data in file')
7210  FORMAT(' Third line--Machine length in meters.')
7220  FORMAT(' Forth line--Machine width.')
7230  FORMAT(' Fifth line--Maximum nozzle dimension.')
7240  FORMAT(' Sixth line--Grid size in meters.')
7250  FORMAT(' Seventh line--Number of nozzles on machine.')
7260  FORMAT(' Eighth line--Number of possible nozzle types.')
7270  FORMAT(' Ninth line--Number of nozzle data files.')
7280  FORMAT(' Tenth line--File name where machine specs are found.')
7290  FORMAT(' Eleventh line--File name where names of nozzle data')
7300  FORMAT(' files are stored.')
7310  FORMAT(' Twelvth line--File name where the machine ')
7320  FORMAT(' specifications are stored.')
```

```
7330  FORMAT(' Regardless of the way problem is setup files for the')
7340  FORMAT(' nozzle pattern data will have to be setup.')
7350  FORMAT(' These files must start with first a descriptive line')
7360  FORMAT(' followed by a line which contains 6 numbers.')
7370  FORMAT(' The first number is the number of columns above the')
7380  FORMAT(' nozzle position on the grid.')
7390  FORMAT(' Second the number of rows below the nozzle position')
7400  FORMAT(' the third the number of columns to the right.')
7410  FORMAT(' The forth the number of columns to the left.')
7420  FORMAT(' The fifth the maximum number in the file.')
7430  FORMAT(' The sixth the minimum number in the file.')
7440  FORMAT(' Finally the output device must be specified.')
7450  FORMAT(' Outputing to the terminal will send the output to you')
7455  FORMAT(' but is slow.')
7460  FORMAT(' Outputting to the line printer is fast for a large')
7470  FORMAT(' output but you must pickup the output.')
7475  FORMAT(' Outputting to a file must be done if the output is to')
7480  FORMAT(' be saved for further computation.')
7485  FORMAT(' A printing can be make by printing the file on the ')
7490  FORMAT(' line printer or at a terminal.')
99999 END

*************************************************************************

      SUBROUTINE intact
     *  (mcnlen,mcnwid,nzptsz,gridsz,numnoz,nonzty,nodtfl,
     *   filnam, filmsp, fillnk)

*************************************************************************

      REAL mcnlen, mcnwid, nzptsz, gridsz
      INTEGER numnoz, nonzty, nodtfl
      DOUBLE PRECISION filnam, filmsp, fillnk, charin
      LOGICAL debug, echo, error, help, skip, stop, warnng,
     *        optbug, optech, opthlp
      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      IF (debug .OR. optbug .OR. optech) TYPE 7000
      IF (optbug .OR. optech) CALL cngopt
 10   TYPE 7010
      ACCEPT 1000, mcnlen
      TYPE 7020
      ACCEPT 1000, mcnwid
      TYPE 7030
      ACCEPT 1000, nzptsz
      TYPE 7040
      ACCEPT 1000, gridsz
      TYPE 7050
      ACCEPT 1010, numnoz
      TYPE 7060
```

```
      ACCEPT 1010, nonzty
      TYPE 7070
      ACCEPT 1010, nodtfl
      TYPE 7080
      ACCEPT 1020, filnam
      TYPE 7090
      ACCEPT 1020, filmsp
      TYPE 7100
      ACCEPT 1020, fillnk

  20  TYPE 7110
      IF (yesno(dummy)) 30,10

  30  RETURN

1000  FORMAT(F8.3)
1010  FORMAT(I8)
1020  FORMAT(A10)

7000  FORMAT(' SUB intact--interactive defining of problem')
7010  FORMAT(' What is the machine length in meters?')
7020  FORMAT(' What is the machine width in meters?')
7030  FORMAT(' What is the maximum nozzle dimension in meters?')
7040  FORMAT(' What is the grid size in meters?')
7050  FORMAT(' How many nozzles are to be processed?')
7060  FORMAT(' How many possible nozzle types are there?')
7070  FORMAT(' How many nozzle data files are there?')
7080  FORMAT(' What file contains the names of the files containing
    * nozzle data?')
7090  FORMAT(' What file is the machine specs data in?')
7100  FORMAT(' What file cross references the nozzle types, heights,
    * and pattern locations?')
7110  FORMAT(' Are all the starting parameters correct? (yes no)')
7120  FORMAT(A10,' is not yes or no. Please reenter. (yes no)')

99999 END

***********************************************************************

      SUBROUTINE rdinit
    *  (mcnlen,mcnwid,nzptsz,gridsz,numnoz,nonzty,nodtfl,
    *   filnam, filmsp, fillnk, file)

***********************************************************************

      REAL mcnlen, mcnwid, nzptsz, gridsz
      INTEGER numnoz, nonzty, nodtfl, numrow
      DOUBLE PRECISION filnam, filmsp, fillnk, file, charin, descr
      LOGICAL debug, echo, error, help, skip, stop, warnng,
    *         optbug, optech, opthlp
      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
```

```
     *                    optbus, optech, opthlp

          DIMENSION descr(10)

          IF (debug .OR. optbus .OR. optech) TYPE 7000
          IF (optbus .OR. optech) CALL cnsopt

          OPEN (UNIT=20, ACCESS='seqin', MODE='ascii', FILE=file)
          READ (20,3000)(descr(i), i=1,8)
          READ (20,*)numrow
          READ(20,*) mcnlen, mcnwid, nzptsz, gridsz
          READ(20,*) numnoz, nonzty, nodtfl
          READ(20,3000,END=50) filnam
          READ(20,3000,END=50) filmsp
*    gridsz--Size in mm of the grid dimension.
*  help----Logical used to indicate that a long prompt is required for
*              the inputs.
          READ(20,3000,END=50) fillnk

          RETURN
    50    TYPE 7000; TYPE 7010
          RETURN


 3000     FORMAT(8A10)
 7000     FORMAT(' SUB rdinit--read initial defining data')
 7010     FORMAT(' Found less data in file than expected')
 7020     FORMAT(' Data was read from ', A10)

99999     END
******************************************************************************

          LOGICAL FUNCTION chkdim(fdptcl,fdptrw,mxnzwd,numnoz, nonzty,
     *                              nodtfl)

******************************************************************************

          INTEGER fdptcl, fdptrw, mxnzwd, numnoz, nodtfl, nonzty


          chkdim = .FALSE.

c     20  IF (fdptrw*fdptcl .LE. 50000) GO TO 30
      20  IF (fdptrw*fdptcl .LE. 100000) GO TO 30
            TYPE 7010, fdptrw
            chkdim = .TRUE.

     30   IF (mxnzwd*mxnzwd*3 .LE. 5000) GO TO 40
            TYPE 7020, mxnzwd
            chkdim = .TRUE.
```

```
   40   IF (numnoz .LE. 300) GO TO 50
          TYPE 7030, numnoz
          chkdim = .TRUE.

   50   IF (nonzty .LE. 100) GO TO 60
          TYPE 7040, nonzty
          chkdim = .TRUE.

   60   IF (nodtfl .LE. 1000) GO TO 70
          TYPE 7050, nodtfl
          chkdim = .TRUE.

   70   IF (.NOT. chkdim) GO TO 80
          TYPE 7060
          TYPE 7070
          TYPE 7080
          TYPE 7090
   80   RETURN
 7010   FORMAT (' Calculated rows required for field pattern =', I8)
 7020   FORMAT (' Calculated rows and columns for nozzle pattern =',I8)
 7030   FORMAT (' The number of nozzles you want to process is', I8)
 7040   FORMAT (' The number of nozzle types you want to process is',I8)
 7050   FORMAT (' The number of data files you have data in is', I8)
 7060   FORMAT (' The dimensionihg of the arrays in the program has')
 7070   FORMAT (' allowed for sufficient storage space for the data')
 7080   FORMAT (' indicated above.  The problem will need to be split')
 7090   FORMAT (' or the program altered to accomidate the problem.')

 9999   END

^L^L^L^L
************************************************************************

        SUBROUTINE irrsim(fdptcl, fdptrw, mxnzwd, numnoz, nonzty,
     *                    nodtfl, filnam, filmsp, fillnk, fldpat,
     *                    nozpat, crsref, datfil, mcnspc, gridsz)

************************************************************************

        REAL fldpat,hitea, hite1, hite2, nozpat, gridsz
        INTEGER fdptcl, fdptrw, mxnzwd, nonzty, nucol1, noznum,
     *          numnoz, nurow1, nurow2, nucol2, nodtfl, last,
     *   lstrng, range, typmrk,mcnspc,crsref
        DOUBLE PRECISION filnam, fillnk, filmsp, datfil
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp

        COMMON /logflg/ debug, echo, error, help, skip, stop, warnng,
     *                  optbug, optech, opthlp

        DIMENSION fldpat(fdptcl,-25:fdptrw)
```

```
      DIMENSION nozpat(mxnzwd,mxnzwd,3)
      DIMENSION mcnspc(5,0:numnoz)
      DIMENSION crsref(4,nonzty)
      DIMENSION datfil(nodtfl)


      IF (debug .OR. optbug .OR. optech) TYPE 7000
      IF (optbug .OR. optech) CALL cngopt
c     Determine the order the nozzles will be processed.
      CALL calord(numnoz,nonzty,crsref,mcnspc)
      IF (stop) GO TO 99999
c     Process all the nozzles.
      last = mcnspc(5,0)
      hite2 = 4250.0
      typmrk = 1
      lstrng = 0
       skip = .TRUE.
c     This DO loop places each nozzle pattern on the field pattern.
      DO 100 i=1,numnoz
      noznum = mcnspc(5,i)
      hitea = mcnspc(3,noznum)
       IF (skip) GO TO 12
C     IF this nozzle is not the same as the last to be processed
c       increment the type marker and read middle nozzle pattern.
       IF (debug) TYPE 7020, mcnspc(4,noznum), crsref(1,typmrk)
        IF (mcnspc(4,noznum) .NE. crsref(1,typmrk)) 10,20
   10   typmrk = typmrk + 1
   12  skip = .FALSE.
       IF (debug) TYPE 7020, mcnspc(4,noznum), crsref(1,typmrk)
        IF (mcnspc(4,noznum) .NE. crsref(1,typmrk)) 10,15
   15   CALL rdnzdt(datfil(crsref(3,typmrk)),nozpat,mxnzwd,2,nurow2,
     *             nucol2)
C      END IF
c      Determine the range of height the nozzle is in.
        IF ( hitea .LT. hite2) 16,18
   16   range = 2
        GO TO 27
   18   range = 4
        GO TO 27
   20   IF (hitea .LT. hite2) 22,24
   22   range = 2
        GO TO 25
   24   range = 4
C      END
C      IF this nozzle is not in the same height range as the last then
c        read pattern into first level.
   25   IF (lstrng .NE. range) 27,30
   27   CALL rdnzdt(datfil(crsref(range,typmrk)),nozpat,mxnzwd,1,
     *             nurowl, nucoll)
         lstrng = range
C      IF this nozzle height is not the same as the last then interpula
```

```
te.
   30   IF (debug) TYPE 7030,last, noznum, range
           IF (mcnspc(4,numnoz) .NE. mcnspc(4,last) .OR. hitea .NE.
     *          mcnspc(3,last)) 50,90

c              Choosing the correct height for the nozzles.

   50          IF (hitea - hite2) 60,70,70
   60            hite1 = 3750.0
                 GO TO 80
   70            hite1 = 4750.0

   80          IF (debug) TYPE 7010, hitea, hite1, hite2

c              Calculate nozzle pattern for actual height.

               CALL interp(nurow1,nucol1,nozpat,hitea,hite1,hite2,
     *                       mxnzwd)
c              Place nozzle pattern on field pattern.

   90      CALL clfdpt(mcnspc(1,noznum),mcnspc(2,noznum),nozpat,
     *             fldpat, gridsz,nurow1, nucol1, mxnzwd, fdptcl, fdptrw)
           last =mcnspc(5,i)
  100   CONTINUE

        IF (debug) 110,210
c       Every fifth column of fldpat at the row numbers specified.
  110   DO 200 i=1,fdptrw,fdptrw/10
          WRITE(5,5000) i, (fldpat(j,i), j=1,fdptcl,5)
  200   CONTINUE


  210   RETURN
 5000   FORMAT(' Row ',I4,'  ',100F8.3)
 7000   FORMAT (' SUB  irrsim--irrigation simulation')
 7010   FORMAT (' hitea=',F8.1,' hite1=',F8.1,' hite2=',F8.1)
 7020    FORMAT(' This nozzle = ',I4, ' Type of reference = ',I4)
 7030   FORMAT(' last = ',I4,' thisnz = ',I4,' this range =','I2)

99999   END

************************************************************************

        SUBROUTINE rdflnm(nodtfl, file, output)

************************************************************************

        DOUBLE PRECISION file, output, descr
        INTEGER nodtfl, numrow
        LOGICAL debug, echo, error, help, skip, stop, warnng,
```

```
*          optbus, optech, opthlp

      DIMENSION output(nodtfl)
      DIMENSION descr(10)

      COMMON /logflg/ debug, echo, error, help, skip, stop, warnng,
*                    optbus, optech, opthlp

      IF (debug .OR. optbus .OR. optech) TYPE 7000
      IF (optbus .OR. optech) CALL cngopt
c     Open file which contains the list of files that contain data.
      OPEN (UNIT=20, ACCESS='segin', MODE='ascii', FILE=file)
      READ (20, 3000) (descr(i), i=1,8)
      READ (20, *) numrow
      IF (echo) 5,6
 5      TYPE 7100, file
        TYPE 7110, (descr(i), i=1,8)
        TYPE 7120, nodtfl, numrow
c     Check to make sure correct amount of data is in file.
 6    IF (nodtfl-numrow) 10,30,20
 10     TYPE 7010, numrow, nodtfl
        warnng = .TRUE.
        GO TO 30
 20     TYPE 7010, numrow, nodtfl
        error = .TRUE.

 30   READ (20, 3010, END=40) (output(i), i=1,nodtfl)

      IF (echo) 35,37
 35     DO 100 i=1,nodtfl
          TYPE 7130, i, output(i)
 100    CONTINUE

c     If an incorrect amount of data is expected or found error
c     messages will be printed.

 37   IF (warnng) GO TO 50
      IF (error) 50,900
 40     TYPE 7020
        TYPE 7120, nodtfl, numrow
 50     TYPE 7100, file
        TYPE 7110, (descr(i), i=1,8)

 900  RETURN

 3000 FORMAT(8A10)
 3010 FORMAT(A10)

 7000 FORMAT(' SUB rdflnm--read file names.')
 7010 FORMAT(I5,' data rows indicated in file ',I5,' expected')
 7020 FORMAT(' Found less data in file than expected')
```

```
 7100   FORMAT(' File from which data is read is ',A10)
 7110   FORMAT(' ',8A10)
 7120   FORMAT(' ',I5, ' Rows requested', I5, ' In file')
 7130   FORMAT(' output(',I5,') is   ',A10)

99999   END

*

**************************************************************************

                         SUBROUTINE rddtmx
     *     (fstrow, amtrow, nuclar, amtcol, file, output)

**************************************************************************

        DOUBLE PRECISION file, descr, charin
        INTEGER amtcol, amtrow, numcol, numrow, output, fstrow, nuclar
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp

        COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                  optbug, optech, opthlp

        DIMENSION output(nuclar, fstrow:amtrow)
        DIMENSION descr(10)

        DIMENSION charin(10)
        IF (debug .OR. optbug .OR. optech) TYPE 7050
        IF (optbug .OR. optech) CALL cngopt
        error = .FALSE.; warnng = .FALSE.
c       Open file from which data is to be read and read intro. lines.

        OPEN (UNIT=20, ACCESS='seqin', MODE='ascii', FILE=file)

        READ (20, 3000) (descr(i), i=1,8)
        READ (20, *) numrow, numcol

        IF (echo) 5,6
    5     WRITE(5,5000) file
          WRITE(5,5010) (descr(i), i=1,8)
          WRITE(5,5020) amtrow, numrow
          WRITE(5,5030) amtcol, numcol

c       Decide if data file contains the amount of data expected.
c                 If not print our an error message.

    6   IF (amtrow-numrow) 10, 30, 20
   10     TYPE 7000
          error = .TRUE.
          GO TO 30
```

```
   20    TYPE 7010
         error = .TRUE.
   30   IF (amtcol-numcol) 40,60,50
   40    TYPE 7030
         error = .TRUE.
         GO TO 60
   50    TYPE 7040
         error = .TRUE.
   60   IF (error) 70,90
   70    TYPE 7070
   71    ACCEPT 1000, charin(1)
         IF (charin(1) .EQ. 4Hstop) 72,75
   72    stop = .TRUE.
         RETURN
   75    IF (charin(1) .EQ. 8Hredefine) 77,80
   77            TYPE 7080
           ACCEPT 1010, amtrow
           TYPE 7090
           ACCEPT 1010, amtcol
           GO TO 90
   80    IF (charin(1) .EQ. 8Hcontinue) 90,85
   85    TYPE 7100, charin(1)
           GO TO 71
c       Read data.
   90   DO 100 i=1,amtrow
         READ (20,*,END=150) (output(j,i),j=1,amtcol)
  100   CONTINUE

        IF (echo) 110,152
  110    DO 125 i=1,amtrow
           DO 125 j=1,amtcol
             WRITE (5,5040) j,i,output(j,i)
  125    CONTINUE

        GO TO 152

c                If an error is suspected print out a message describing
error.

  150   TYPE 7020
  152   IF (error) 155,900
  155    WRITE(5,5000) file
         WRITE(5,5010) (descr(i), i=1,8)
         WRITE(5,5020) amtrow, numrow
         WRITE(5,5030) amtcol, numcol

  900   RETURN

 1000   FORMAT(8A10)
 1010   FORMAT(10018)
 3000   FORMAT (8A10)
```

```
5000    FORMAT(' File from which data is read is ',A10)
5010    FORMAT(' ',8A10)
5020    FORMAT(' ',I5,' Rows requested', I5, ' In file')
5030    FORMAT(' ',I5, ' Columns requested', I5, ' In file')
5040    FORMAT(' output(',I5,',',I5,') is   ',I8)
5050    FORMAT(' Headings are: ', 10G5.3)

7000    FORMAT(' More data rows indicated in file than expected')
7010    FORMAT(' Less data rows indicated in file than expected')
7020    FORMAT(' Found less data in file than expected')
7030    FORMAT(' More columns indicated in file than expected')
7040    FORMAT(' Less columns indicated in file than expected')
7050    FORMAT(' SUB rddtmx--read data matrix')
7060    FORMAT(' ',10I8)
7070    FORMAT(' What would you like to do? (redefine continue stop) '$)
7080    FORMAT(' How many rows of data are to be read? '$)
7090    FORMAT(' How many columns of data are to be read? '$)
7100    FORMAT(' Please reenter. ',A10,'Is not a valid input.')

99999   END

************************************************************************

        SUBROUTINE calord(numnoz, nonzty, crsref, mcnspc)

************************************************************************

        INTEGER mcnspc, numnoz, crsref, turn, nonzty, errors, nztypr,
     *          pointr, noznum, hold, hold2, thisnz, thisht
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp

        DIMENSION crsref(4,nonzty)
        DIMENSION mcnspc(5,0:numnoz)

        COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                  optbug, optech, opthlp

        IF (debug .OR. optbug .OR. optech) TYPE 7000
        IF (optbug .OR. optech) CALL cngopt
c       Determine order that files will be processed.

        turn=0
C       WHILE there are still nozzles to process DO:
          DO 100 i=1,nonzty
          nztypr = crsref(1,i)
          DO 100 j=1,numnoz
          thisnz = mcnspc(4,j)
          thisht = mcnspc(3,j)
          IF (debug) TYPE 7030, crsref(1,i), mcnspc(4,j), mcnspc(3,j)
```

```
C        IF the nozzle is the type we want to find THEN DO:
          IF (thisnz .EQ. nztwpr) 10,100
C         WHILE this nozzle is the same type as that under
c           consideration and this height is less than that DO:
   10        IF (thisnz .EQ. mcnspc(4,mcnspc(5,turn))) 15,50
   15        IF (thisht .LT. mcnspc(3,mcnspc(5,turn))) 20,40
   20        turn = turn - 1
             GO TO 10
C          END WHILE DO
C          WHILE this height is greater than that of the nozzle under
c            consideration and the nozzle under consideration exists DO
   40        turn = turn + 1
             IF (thisht .GT. mcnspc(3,mcnspc(5,turn))) 40,60
C          END WHILE DO
   50    turn = turn + 1
         IF (thisnz .EQ. mcnspc(4,mcnspc(5,turn))
     *       .OR. mcnspc(5,turn) .EQ. 0) 60,50
c          Process nozzle in this position and move any nozzles to be
c          processed later down one.
   60      hold = J
           pointr = turn
C          WHILE there are still nozzles to be processed DO:
   65      IF (mcnspc(5,pointr) .GT. 0) 70,80
   70      hold2 = mcnspc(5,pointr)
           mcnspc(5,pointr) = hold
           hold = hold2
           pointr = pointr + 1
           GO TO 65
C          END WHILE DO
   80    mcnspc(5,pointr) = hold
         IF (pointr .EQ. numnoz) 110,100
  100   CONTINUE

c        If all the nozzles have been processed this block will not be
c          entered.  If all the nozzles havn't been processed one or
c          more of the numbers in column 4 of mcnspc is wrong or not
c          enough nozzle types are found in crsref.

        errors = numnoz-pointr
        WRITE(5,5000) (errors)
        stop= .TRUE.
  110    IF (debug .OR. stop) 120,900
  120    TYPE 7010
         DO 200 i=1,pointr
          noznum = mcnspc(5,i)
          TYPE 7020, i, noznum, mcnspc(4,noznum), mcnspc(3,noznum)
  200   CONTINUE

  900   RETURN
c
 5000   FORMAT(' ',i3, ' Errors in 2nd column of crsref')
```

```
5010   FORMAT(' Error in mcnspc(4,',I3,') Value should be',I8,' Is',I8)
5020   FORMAT(' nozzle number', I8, ' height ',I8, ' turn',I8)

7000   FORMAT(' SUB calord--calculate order of processing')
7010   FORMAT(' The nozzles will be processed in this order.')
7020   FORMAT(I4,') Nozzle no.',I4,' Nozzle ',I3,'/140 Height ',I5,
     * ' mm')
7030   FORMAT(' nztypr = ',I5,' thisnz = ',I5,' thisht = ',I5)
7040    FORMAT(' int5 = ',I5,' crsref = ',I5)

99999  END

**********************************************************************

       SUBROUTINE rdnzdt(file,nozpat, mxnzwd,level,numrow,numcol)

**********************************************************************

       DOUBLE PRECISION file, descr
       INTEGER max, min, numrow, numcol, mxnzwd, level
       LOGICAL debug, echo, error, help, skip, stop, warnng,
     *        optbug, optech, opthlp
       REAL nozpat

       DIMENSION nozpat(mxnzwd,mxnzwd,3)
       DIMENSION descr(10)

       COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                 optbug, optech, opthlp

       IF (debug .OR. optbug .OR. optech) TYPE 7020
       IF (optbug .OR. optech) CALL cngopt

         OPEN (UNIT=20, ACCESS='seqin', MODE='ascii', FILE=file)
         READ (20, 3000) (descr(j), j=1,8)
         READ (20, *) numrow, numcol

         IF (echo .OR. debug) 35,36
35         WRITE (5,5000) file
           WRITE (5,5005) (descr(j),j=1,8)
           WRITE (5,5010) numrow, mxnzwd
           WRITE (5,5020) numcol, mxnzwd


c        Decide if expected amount of data is present.

36       IF ((numrow .LE. mxnzwd) .AND. (numcol .LE. mxnzwd)) GO TO 40
           TYPE 7000
         stop = .TRUE.
         RETURN
```

```
c         Read data.

 40       READ (20,*,END=250)
   *          ((nozpat(k,j,level),k=1,numcol), j=1,numrow)

          IF (echo) 50,200
 50         DO 200 j=1,numrow
              WRITE(5,5030)(nozpat(k,j,level),k=1,numcol)

 200      CONTINUE

          RETURN

 250      TYPE 7010

          RETURN

 3000     FORMAT(8A10)

 5000     FORMAT(' Data is read from ', A10)
 5005     FORMAT(' ',8A10)
 5010     FORMAT(' ',I5, ' Rows in file with ',I5, ' allowed.')
 5020     FORMAT(' ',I5, ' Columns in file with ',I5, ' allowed.')
 5030     FORMAT (' ',30F4.0)

 7000     FORMAT(' Too much data in file to store in nozpat.')
 7010     FORMAT(' END OF FILE found before expected data read')
 7020     FORMAT(' SUB rdnzdt--read nozzle data')

99999     END

**************************************************************************

          SUBROUTINE interp(numrow, numcol, nozpat, hitea, hite1, hite2,
   *                        mxnzwd)

**************************************************************************

          INTEGER mxnzwd, numrow, numcol
          REAL const1, const2, hitea, hite1, hite2, nozpat
          LOGICAL debug, echo, error, help, skip, stop, warnng,
   *              optbug, optech, opthlp

          DIMENSION nozpat(mxnzwd,mxnzwd,3)

          COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
   *                      optbug, optech, opthlp

          IF (debug .OR. optbug .OR. optech) TYPE 7000
          IF (optbug .OR. optech) CALL cngopt
```

```
c       Calculate interpulation constants.

        const1=(hites - hite1) / (hite1 - hite2)
        const2= 1+const1

        IF (debug) 10,20
   10     TYPE 7010, hites, hite1, hite2
          TYPE 7020, const1, const2

c       Do the interpulation for all the data.

   20   DO 100 i=1,numcol
          DO 100 J=1,numrow
            IF (nozpat(i,J,1) .NE. nozpat(i,J,2)) 30,40
   30         nozpat(i,J,3) = nozpat(i,J,1)*const2 -
     *                        nozpat(i,J,2)*const1
              GO TO 100
   40       nozpat(i,J,3) = nozpat(i,J,2)
  100   CONTINUE

        IF (debug)  150,210
  150     DO 200 i=1,numrow
            TYPE 7030,(nozpat(J,i,3), J=1,numcol)
  200     CONTINUE
  210   RETURN

 7000   FORMAT(' SUB interp--interpulate data for acuual height')
 7010   FORMAT(' hitea=',F8.3,' hite1=',F8.3,' hite2=',F8.3)
 7020   FORMAT(' const1=',F8.6,' const2=',F8.6)
 7030   FORMAT(' ',30F4.0)

99999   END

^L***********************************************************************
**

        SUBROUTINE clfdpt(nozdst, ltnzds, nozpat, fldpat, gridsz,
     *                    numrow, numcol, mxnzwd, fdptcl, fdptrw)

***********************************************************************

        REAL sdarea, prara1,prara2,prara3,prara4, fldpat, nozpat, gridsz
        INTEGER dist1, dist2, dist3, dist4, ltnzds, insdsz, numrow,
     *          latmrk, distmk, dm, lm, nzptsz, fdptcl, nozdst, mxnzwd,
     *          numcol,   fdptrw
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp

        DIMENSION nozpat(mxnzwd,mxnzwd,3)
        DIMENSION fldpat(fdptcl,-25:fdptrw)
```

```
      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      EQUIVALENCE(latmrk,lm)

      IF (debug .OR. optbug .OR. optech) TYPE 7010
      IF (optbug .OR. optech) CALL cngopt

c     Calculate all the constants.

      ingdsz = gridsz*1000
      IF (ltnzds) 3,2,2

 2    dist2= MOD( ltnzds, ingdsz )
      dist1= ingdsz - dist2
      dist4= MOD( nozdst, ingdsz )
      dist3= ingdsz - dist4
      GO TO 4

 3    dist1= MOD( -ltnzds, ingdsz )
      dist2= ingdsz - dist1
      dist4= MOD( nozdst, ingdsz )
      dist3= ingdsz - dist4

 4    gdarea = FLOAT(ingdsz*ingdsz)

      prara1 = (dist1*dist3)/gdarea
      prara2 = (dist2*dist3)/gdarea
      prara3 = (dist1*dist4)/gdarea
      prara4 = (dist2*dist4)/gdarea

      IF (debug) 5,6
 5      TYPE 7020, dist1, dist2, dist3, dist4
        TYPE 7030, prara1, gdarea
        TYPE 7040, prara2, gdarea
        TYPE 7050, prara3, gdarea
        TYPE 7060, prara4, gdarea

c     Decide if the nozzle is a left-hand nozzle or a right-hand one.

 6    IF (ltnzds) 10,120,120

c     If the nozzle pattern is right do this.

 10     latmrk=(fdptcl-numrow)/2 + ltnzds/ingdsz -1
        distmk=(nozdst/ingdsz) + numcol/2 - 1

      DO 100 i=1,numrow
        dm=distmk
```

```
          lm=lm+1
          DO 100 J=1,numcol
            fldpat(lm,dm) = fldpat(lm,dm) + nozpat(J,i,3) * prara1
            fldpat(lm+1,dm)=fldpat(lm+1,dm)+nozpat(J,i,3) * prara2
            fldpat(lm,dm+1)=fldpat(lm,dm+1)+nozpat(J,i,3) * prara3
            fldpat(lm+1,dm+1)=fldpat(lm+1,dm+1) +
     *                                      nozpat(J,i,3) * prara4
            dm=dm-1
 100    CONTINUE

        RETURN

c       If nozzle pattern is left or centred do this.

 120      distmk=(nozdst/insdsz) - numcol/2
          latmrk=(fdptcl+numrow)/2 + ltnzds/insdsz + 1
          DO 200 i=1,numrow
            dm=distmk
            lm=lm-1
            DO 200 J=1,numcol
              fldpat(lm,dm)=fldpat(lm,dm)+nozpat(J,i,3)*prara1
              fldpat(lm+1,dm)=fldpat(lm+1,dm)+nozpat(J,i,3)*prara2
              fldpat(lm,dm+1)=fldpat(lm,dm+1)+nozpat(J,i,3)*prara3
              fldpat(lm+1,dm+1)=fldpat(lm+1,dm+1) +
     *                                        nozpat(J,i,3)*prara4
              dm=dm+1
 200      CONTINUE
        RETURN


 7000   FORMAT(' Lateral distance for nozzle given as zero')
 7010   FORMAT(' SUB clfdpt--calculate field pattern')
 7020   FORMAT(' dist1=',I8,' dist2=',I8,' dist3=',I8,' dist4=',I8)
 7030   FORMAT(' Proportional area1=',F8.6,' of ',F8.1,' grid area')
 7040   FORMAT(' Proportional area2=',F8.6,' of ',F8.1,' grid area')
 7050   FORMAT(' Proportional area3=',F8.6,' of ',F8.1,' grid area')
 7060   FORMAT(' Proportional area4=',F8.6,' of ',F8.1,' grid area')

99999   END

*************************************************************************

        SUBROUTINE output(fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz,
     *                  outdvc, outnam, title)

*************************************************************************

        REAL fldpat, distmk, gridsz
        INTEGER fdptrw,fdptcl, output, mcnspc,  numnoz, rows
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp
```

```
      DOUBLE PRECISION title(10), outnam, outdvc

      DIMENSION fldpat(fdptcl,-25:fdptrw)
      DIMENSION mcnspc(5,0:numnoz)

      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      IF (debug .OR. optbug .OR. optech) TYPE 7000

 10   IF (outdvc .EQ. 10Hlineprintr) 20,30
 20     CALL outlpr
     *   (fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz, title)
        RETURN

 30   IF (outdvc .EQ. 8Hterminal) 40,50
 40     CALL outtrm
     *   (fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz, title)
        RETURN

 50   IF (outdvc .EQ. 4Hfile) 60,70
 60     CALL outfil
     *   (outnam,fdptrw,fdptcl,fldpat,mcnspc, gridsz, numnoz, title)
        RETURN

 70   TYPE 7010
      ACCEPT 1000, title(9)
        GO TO 10
 1000 FORMAT(8A10)
 6000 FORMAT(8A10)
 6010 FORMAT(100F10.3)
 6020 FORMAT(100I8)

 7000 FORMAT(' SUB output--output the final result(s).')
 7010 FORMAT(' A legal output device has not been specified.  Which wo
     *uld you like the output to go? (file, terminal, lineprintr)')
 7020 FORMAT(' Enter up to an 80 character string for the output headi
     *ng.')

 9000 FORMAT(8A10)
 9010 FORMAT(' Number of rows = ',I8,' Number of columns = ',I8)
 9020 FORMAT(' ',16F4.0,'|',16F4.0)
99999 END
c     Print out fldpat.

***********************************************************************

      SUBROUTINE outtrm
     *   (fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz, title)

***********************************************************************
```

```
      REAL fldpat, distmk, gridsz
      INTEGER fdptrw,fdptcl, output, mcnspc,  numnoz, rows, first,last
      LOGICAL debug, echo, error, help, skip, stop, warnng,
     *        optbug, optech, opthlp
      DOUBLE PRECISION title(10)

      DIMENSION fldpat(fdptcl,-25:fdptrw)
      DIMENSION mcnspc(5,0:numnoz)
      DIMENSION char(10)

      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      IF (debug .OR. optbug .OR. optech) TYPE 7000

      char(1) = ' '
      char(2) = '"'
      char(3) = '*'
      char(4) = '|'

c     Type output.

      TYPE 7020, (title(i), i=1,8)
      TYPE 7030, char(1)

      first = 1
      last = fdptcl
      DO 100 i=-25,-1
        TYPE 7030, char(1)
        TYPE 7070, (fldpat(j,i), j=first,last)
100   CONTINUE

      TYPE 7030, char(2)
      TYPE 7040, (fldpat(i,0), i=first,last)

      distmk = .5*gridsz
      i2 = 1

      DO 200 i=1,fdptrw-25
        distmk = distmk + gridsz
        IF (distmk .GE. mcnspc(1,i2) .AND. i2 .LE. numnoz) 110,150
110       IF (mcnspc(2,i2)) 120,130,140
120         TYPE 7050, mcnspc(4,i2), mcnspc(1,i2)
            i2 =i2 +1
            GO TO 160

130         TYPE 7030, char(3)
            i2 = i2 +1
            GO TO 160
```

```
140       TYPE 7060, mcnspc(1,i2), mcnspc(4,i2)
            i2 =i2 +1
            GO TO 160

150         TYPE 7030, char(4)

160       TYPE 7040, (fldpat(J,i), J=first,last)

200   CONTINUE

      TYPE 7030, char(2)
      TYPE 7070, (fldpat(i,fdptrw-24), i=first,last)

      DO 300 i=fdptrw-23,fdptrw
        TYPE 7030, char(1)
        TYPE 7070, (fldpat(J,i), J=first,last)
300   CONTINUE

      RETURN

1000  FORMAT(8A10)

7000  FORMAT(' SUB outtrm--output final results to the terminal')
7010  FORMAT(' TYPE a maximum of 80 characters for the output title.')
7020  FORMAT(8A10)
7030  FORMAT(' ',80X,A5)
C 7030 FORMAT(' ',100X,A5)
7040  FORMAT(' ',20F4.0,'|',20F4.0)
C 7040 FORMAT(' ',25F4.0,'|',25F4.0)
7050  FORMAT(' ',60X,'*-',I3,'/140-',I8,'--|')
C 7050 FORMAT(' ',75X,'*-',I3,'/140-',I8,'--|')
7060  FORMAT(' ',80X,'|--',I8,'--',I3,'/140-*')
C 7060 FORMAT(' ',100X,'|--',I8,'--',I3,'/140-*')
7070  FORMAT(' ',20F4.0,' ',20F4.0)
C 7070 FORMAT(' ',25F4.0,' ',25F4.0)

99999 END

*************************************************************************
*************************************************************************

                          SUBROUTINE outfil
  *  (outfil,fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz, title)

*************************************************************************

      REAL fldpat, distmk, gridsz
      INTEGER fdptrw,fdptcl, output, mcnspc,  numnoz, rows
      LOGICAL debug, echo, error, help, skip, stop, warnng,
```

```
     *          optbug, optech, opthlp
        DOUBLE PRECISION title(10), outfil

        DIMENSION fldpat(fdptcl,-25:fdptrw)
        DIMENSION mcnspc(5,0:numnoz)

        COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                 optbug, optech, opthlp

        IF (debug .OR. optbug .OR. optech) TYPE 7000
        IF (optbug .OR. optech) CALL cnsopt

        OPEN (UNIT=20, ACCESS='seqout', MODE='ascii', FILE=outfil )

        rows = fdptrw + 26

c       Output into file.

        WRITE(20,6000) (title(i), i=1,8)
        WRITE(20,6010) rows, fdptcl

        DO 100 i=-25,fdptrw
          WRITE(20,6020) (fldpat(J,i), J=1,fdptcl)
  100   CONTINUE

        RETURN

 1000   FORMAT(8A10)

 6000   FORMAT(' ',8A10)
 6010   FORMAT(100I8)
 6020   FORMAT(100(X,F8.4))

 7000   FORMAT(' SUB outfil--output final results to a file')
 7005   FORMAT(' What file would you like the output to go to?')
 7010   FORMAT(' Type a maximum of 80 characters for the output title.')

99999   END
*************************************************************************

                         SUBROUTINE outlpr
     *    (fdptrw,fdptcl, fldpat, mcnspc, gridsz, numnoz, title)

*************************************************************************

        REAL fldpat, distmk, gridsz
        INTEGER fdptrw,fdptcl, output, mcnspc, numnoz, outdvc, rows,
     *          first, last
        LOGICAL debug, echo, error, help, skip, stop, warnng,
     *          optbug, optech, opthlp
        DOUBLE PRECISION title(10)
```

```
      DIMENSION fldpat(fdptcl,-25:fdptrw)
      DIMENSION mcnspc(5,0:numnoz)
      DIMENSION char(10)

      COMMON /logflg/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp
      IF (debug .OR. optbug .OR. optech) TYPE 7000
      IF (optbug .OR. optech) CALL cngopt


      char(1) = ' '
      char(2) = '"'
      char(3) = '*'
      char(4) = '|'

      first = (fdptcl-30)*.5
      last = first + 31

      PRINT 9020, (title(i), i=1,8)
      PRINT 9030, char(1)

      DO 100 i=-25,-1
        PRINT 9030, char(1)
        PRINT 9010, (fldpat(j,i), j=first,last)
100   CONTINUE

      PRINT 9030, char(2)
      PRINT 9040, (fldpat(i,0), i=first,last)


      distmk = .5*gridsz
      i2 = 1

      DO 200 i=1,fdptrw-25
        distmk = distmk + gridsz
        IF (distmk .GE. mcnspc(1,i2) .AND. i2 .LE. numnoz) 110,150
110       IF (mcnspc(2,i2)) 120,130,140
120         PRINT 9050, mcnspc(4,i2), mcnspc(1,i2)
            i2 =i2 +1
            GO TO 160

130         PRINT 9030, char(3)
            i2 = i2 +1
            GO TO 160

140         PRINT 9060, mcnspc(1,i2), mcnspc(4,i2)
            i2 =i2 +1
            GO TO 160
```

```
150          PRINT 9030, char(4)

160       PRINT 9040, (fldpat(j,i), j=first,last)

200    CONTINUE

       PRINT 9030, char(2)
       PRINT 9010, (fldpat(i,fdptrw-24), i=first,last)

       DO 300 i=fdptrw-23,fdptrw
         PRINT 9030, char(1)
         PRINT 9010, (fldpat(j,i), j=first,last)
300    CONTINUE

       RETURN

1000   FORMAT(8A10)

7000   FORMAT(' SUB outlpr--output to the line printer.')
7010   FORMAT(' Type a maximum of 80 characters for the output title.')

9010   FORMAT('*',16F4.0,' ',16F4.0)
9020   FORMAT('1',8A10)
9030   FORMAT('*',64X,A1)
9040   FORMAT('*',16F4.0,'|',16F4.0)
9050   FORMAT('*',44X,'*-',I3,'/140-',I8,'--|')
9060   FORMAT('*',64X,'|--',I8,'--',I3,'/140-*')

99999  END
**********************************************************************

                        SUBROUTINE cnsopt

**********************************************************************

       LOGICAL debug, echo, error, help, skip, stop, warnng,
     *         optbug, optech, opthlp

       COMMON /lgsfls/ debug, echo, error, help, skip, stop, warnng,
     *                 optbug, optech, opthlp

       IF (optbug) 10,50
10     TYPE 7010
       debug = yesno(dummy)
       TYPE 7020
       optbug = yesno(dummy)
50     IF (optech) 60,900
60     TYPE 7030
       echo = yesno(dummy)
       TYPE 7040
       optech = yesno(dummy)
```

```
 900   RETURN
7010   FORMAT(' Do you want to output the calculated values from here
    * on? (yes no)'$)
7020   FORMAT(' Do you want to be able to start or stop output of the
    * calculated values? (yes no)'$)
7030   FORMAT(' Do you want to output the values read in from here on?
    * (yes no)'$)
7040   FORMAT(' Do you want to be able to start or stop output of the
    * values read in? (yes no)'$)

99999  END

^L^L
**************************************************************************
^L
                LOGICAL FUNCTION yesno(dummy)

**************************************************************************
   10   ACCEPT 1000, ch
C       IF answer is yes THEN DO:
          IF (ch.EQ.3Hyes.OR.ch.EQ.1Hy.OR.ch.EQ.3HYES.OR.ch.EQ.1HY)20,30
   20     yesno = .TRUE.
          RETURN
C       ELSE IF the answer is no THEN DO:
   30     IF (ch.EQ.2Hno.OR.ch.EQ.1Hn.OR.ch.EQ.2HNO.OR.ch.EQ.1HN) 40,50
   40     yesno = .FALSE.
          RETURN
C       ELSE input is invalid
   50     TYPE 7010
          GO TO 10
C       END IF THEN--IF THEN ELSE

 1000   FORMAT(A5)

 7010   FORMAT(' Please reenter.', A5,' is not a valid input')

99999   END

**************************************************************************

                          SUBROUTINE option

**************************************************************************

        DOUBLE PRECISION charin
        LOGICAL debug, echo, error, help, skip, stop, warnng,
    *           optbug, optech, opthlp

        DIMENSION charin(10)
```

```
      COMMON /logfls/ debug, echo, error, help, skip, stop, warnng,
     *                optbug, optech, opthlp

      IF (debug .OR. optbug .OR. optech) TYPE 7000
c     What options?
   10 TYPE 7010
   20   ACCEPT 1000, charin(1)
        IF (none(charin(1))) 900,100
  100   IF (charin(1) .EQ. 4Hecho) 110,200
c     Do you want to start echoing output at next read?
  110     TYPE 7030
      echo = yesno(dummy)
c     Do you want to be able to start or stop echoing?
  155         TYPE 7040
      optech = yesno(dummy)
      GO TO 500

  200   IF (charin(1) .EQ. 5Hdebug) 210,300
c     Do you want to start debug output at next calcualtions?
  210     TYPE 7050
      debug = yesno(dummy)
c     Do you want to be able to start or stop debug output?
  255         TYPE 7060
      optbug = yesno(dummy)
      GO TO 500

  300   IF (charin(1) .EQ. 4Hhelp) 310,400
  310   CALL help1(dummy)
c     Automatic assistance?
  320   TYPE 7070
      help = yesno(dummy)
      GO TO 500
  400   TYPE 7020, charin(1)
      GO TO 10

  500 TYPE 7090
      GO TO 20

  900 RETURN

 1000 FORMAT(8A10)
 7000 FORMAT(' SUB option--optional output.')
 7010 FORMAT(' What optional output would you like?(echo
     * debug none)')
 7020 FORMAT(' Please reenter.', A10,'is not a valid input.')
 7030 FORMAT(' Do you want to start echoing at next read?
     *(yes no)')
 7040 FORMAT(' Do you want to be able to stop echoing? (yes no)')
 7050 FORMAT(' Do you want to start debug output at next calculations?
     *(yes no)')
 7060 FORMAT(' Do you want to be able to stop debug output? (yes no)')
```

```
7070   FORMAT(' Do you want to automatically set assistance at each inp
      *ut request? (yes no)')
7080   FORMAT(' If you need help it can be obtained anywhere help is li
      *sted as an input.')
7090   FORMAT(' What other optional output would you like?
      *(echo debug none)')
99999  END
************************************************************************

       LOGICAL FUNCTION none(charin)

************************************************************************

       DOUBLE PRECISION charin

       none = (charin .EQ. 4Hnone .OR. charin .EQ. 4HNONE .OR.
     *         charin .EQ. 1Hn    .OR. charin .EQ. 1HN)

       RETURN
       END
@
```

APPENDIX III

This appendix contains results of the individual nozzle distribution tests. Each test contains some statistical information along with a three-dimensional representation of the actual profile. Tests are shown for the various nozzle sizes operating at various heights.

All nozzle tests were conducted with a pressure regulator and a 240 kPa lateral pressure. The symbol "*" indicates a nozzle from the second set of nozzles and regulator.

Statistical results are also shown for the various radial rows or legs of the profile. No rows exist in the centre and perpendicular to the grid edges. Results for rows perpendicular to grid edges were obtained by averaging the closest adjacent rows. Rotating the radial leg schematic 40 degrees clockwise orientates the leg numbers to the three-dimensional representation.

SPRAY NOZZLE: RA 85/140 TEST NUMBER: 1

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 436

TOTAL OF READINGS: 13954.7 mm/h

MAXIMUM READING: 180.4 mm/h

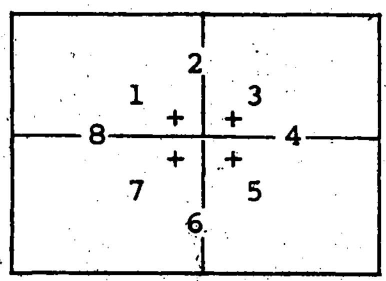
MEAN OF READINGS: 32.0 mm/h

STANDARD DEVIATION OF READINGS: 30.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 29.3%

COEFFICIENT OF VARIATION FOR READINGS: 95.6%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.9	15.1
2)	27.8	23.0
3)	28.8	29.2
4)	18.4	13.0
5)	17.0	12.5
6)	26.0	28.5
7)	36.9	52.1
8)	28.2	23.6

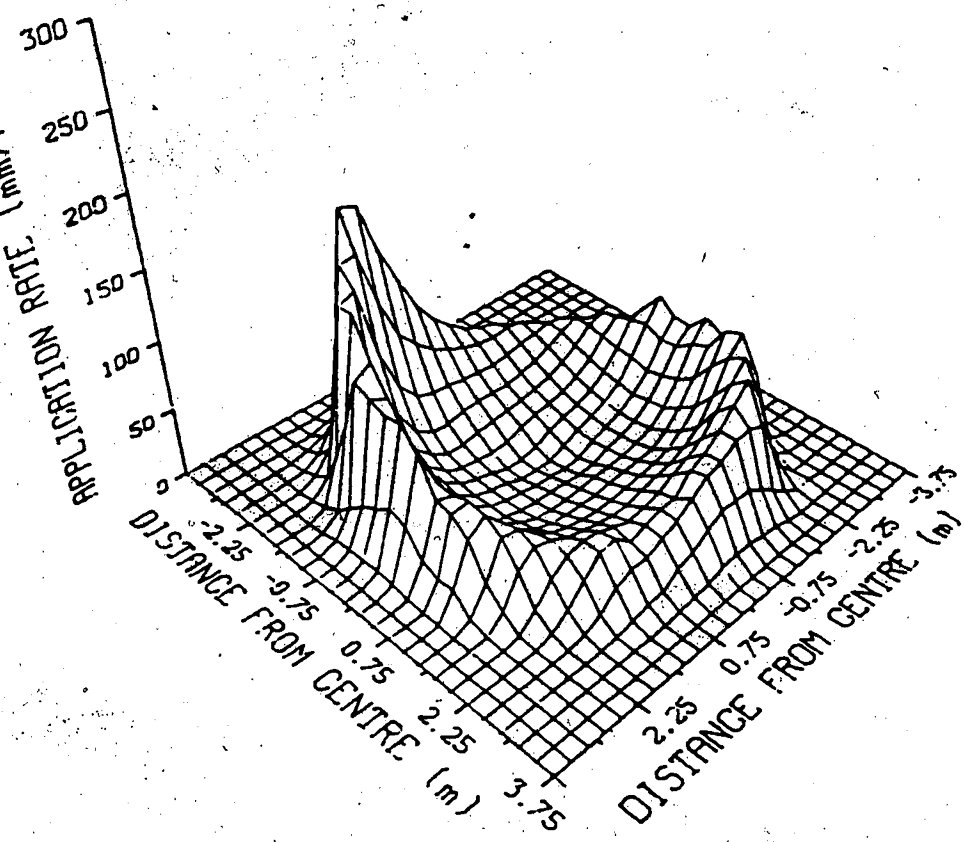


FIGURE III - 1. Distribution Profile of Nozzle RA 85/140 at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 85/140 * TEST NUMBER: 2

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 454

TOTAL OF READINGS: 14912.0 mm/h

MAXIMUM READING: 188.2 mm/h

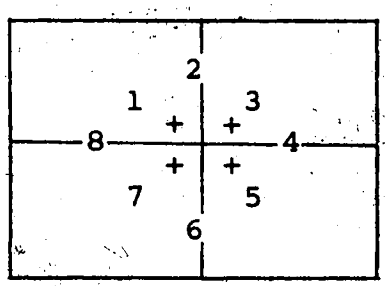
MEAN OF READINGS: 32.8 mm/h

STANDARD DEVIATION OF READINGS: 31.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 30.1%

COEFFICIENT OF VARIATION FOR READINGS: 96.1%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.3	9.0
2)	27.5	20.3
3)	30.7	26.2
4)	20.1	16.6
5)	18.3	17.5
6)	28.2	29.3
7)	46.2	57.9
8)	25.6	16.2

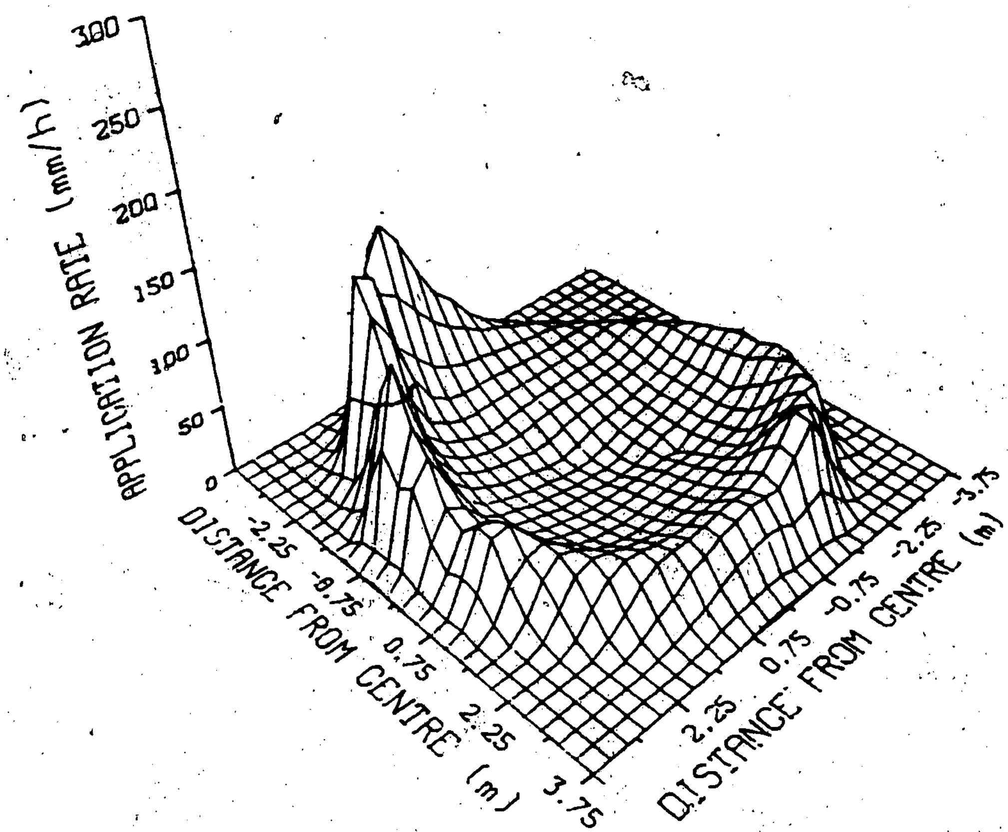


FIGURE III - 2. Distribution Profile of Nozzle RA 85/140* at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 85/140 TEST NUMBER: 3

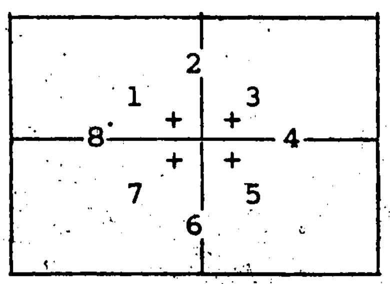
LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT:	4.25 m
NUMBER OF READINGS:	522
TOTAL OF READINGS:	15608.3 mm/h
MAXIMUM READING:	156.0 mm/h
MEAN OF READINGS:	29.9 mm/h
STANDARD DEVIATION OF READINGS:	25.6 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 36.4%

COEFFICIENT OF VARIATION FOR READINGS: 85.7%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	18.2	12.3
2)	23.5	19.7
3)	28.3	24.7
4)	19.6	11.1
5)	16.1	10.9
6)	24.7	24.0
7)	32.8	40.1
8)	25.0	17.4

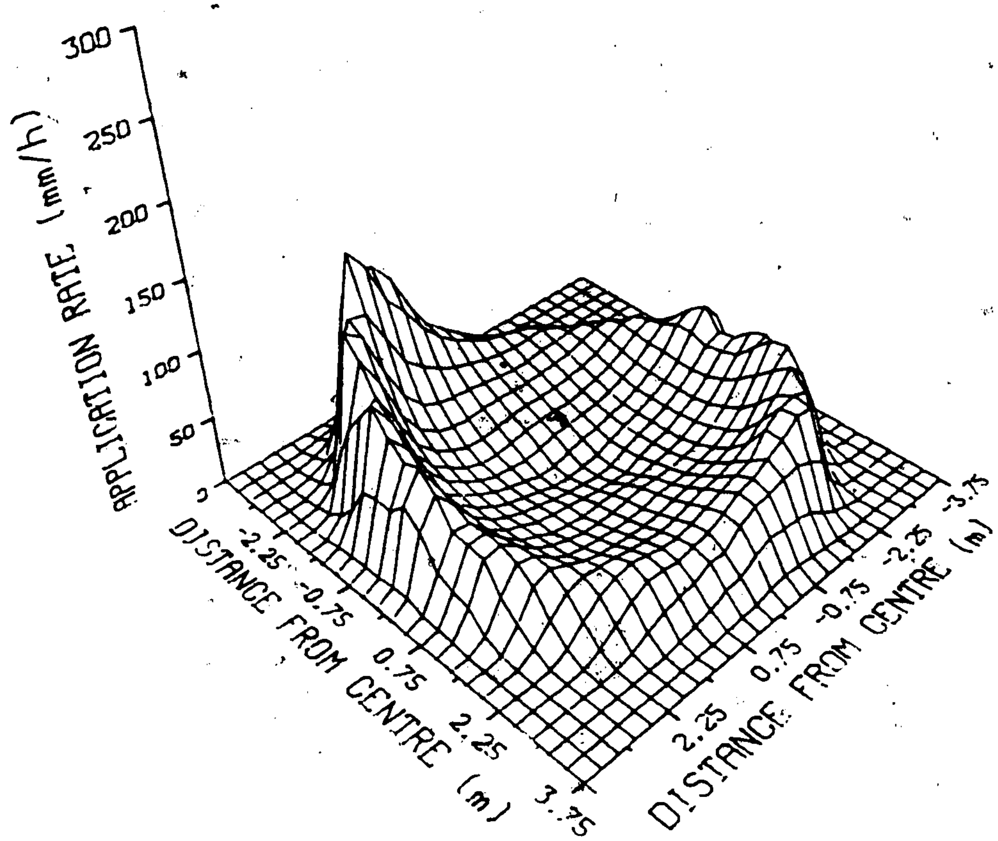


FIGURE III - 3. Distribution Profile of Nozzle RA 85/140 at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 85/140 * TEST NUMBER: 4

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 500

TOTAL OF READINGS: 14952.6 mm/h

MAXIMUM READING: 227.2 mm/h

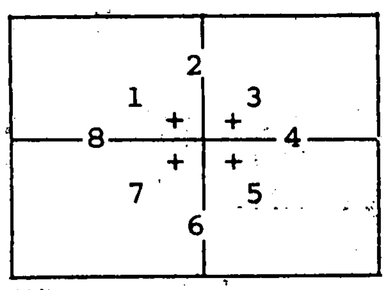
MEAN OF READINGS: 29.9 mm/h

STANDARD DEVIATION OF READINGS: 29.4 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 32.5%

COEFFICIENT OF VARIATION FOR READINGS: 98.5%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	16.6	7.9
2)	19.0	12.6
3)	28.2	25.9
4)	19.7	13.2
5)	20.0	18.5
6)	31.2	35.9
7)	48.5	71.1
8)	20.8	11.7

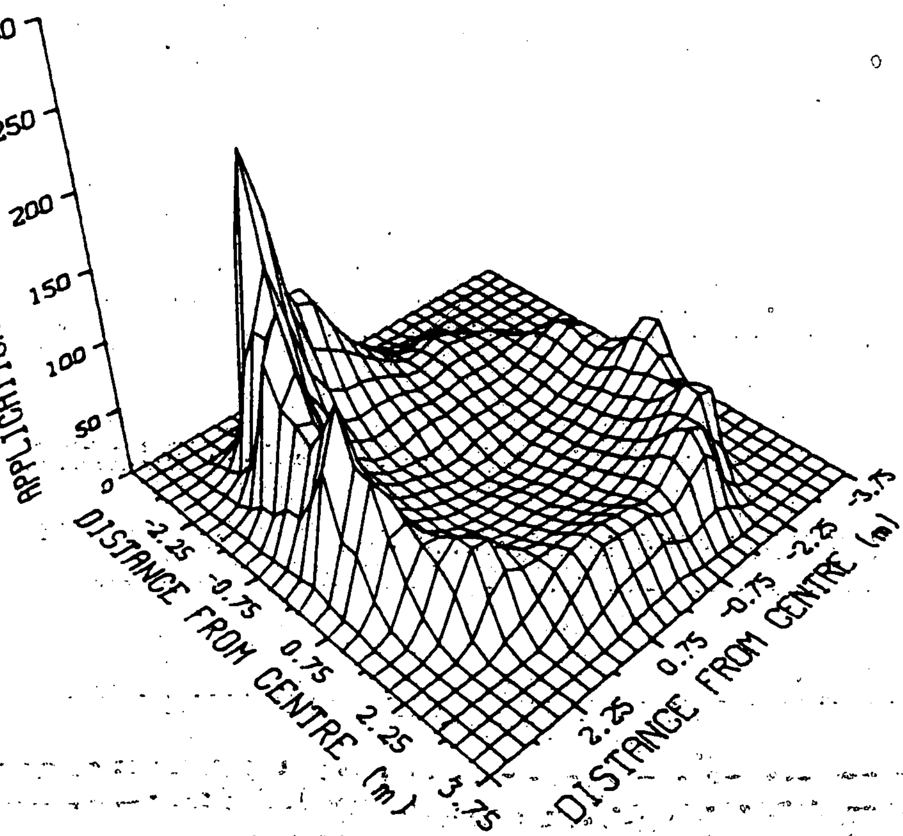


FIGURE III - 4. Distribution Profile of Nozzle RA 85/140* at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 85/140 TEST NUMBER: 5

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 544

TOTAL OF READINGS: 14857.9 mm/h

MAXIMUM READING: 125.8 mm/h

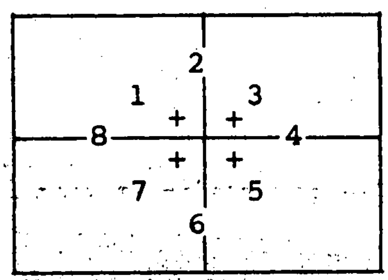
MEAN OF READINGS: 27.3 mm/h

STANDARD DEVIATION OF READINGS: 21.9 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 40.7%

COEFFICIENT OF VARIATION FOR READINGS: 80.2%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	17.9	11.3
2)	22.8	17.4
3)	23.7	20.4
4)	17.2	9.1
5)	14.5	9.3
6)	21.9	20.1
7)	30.3	32.7
8)	23.3	14.8

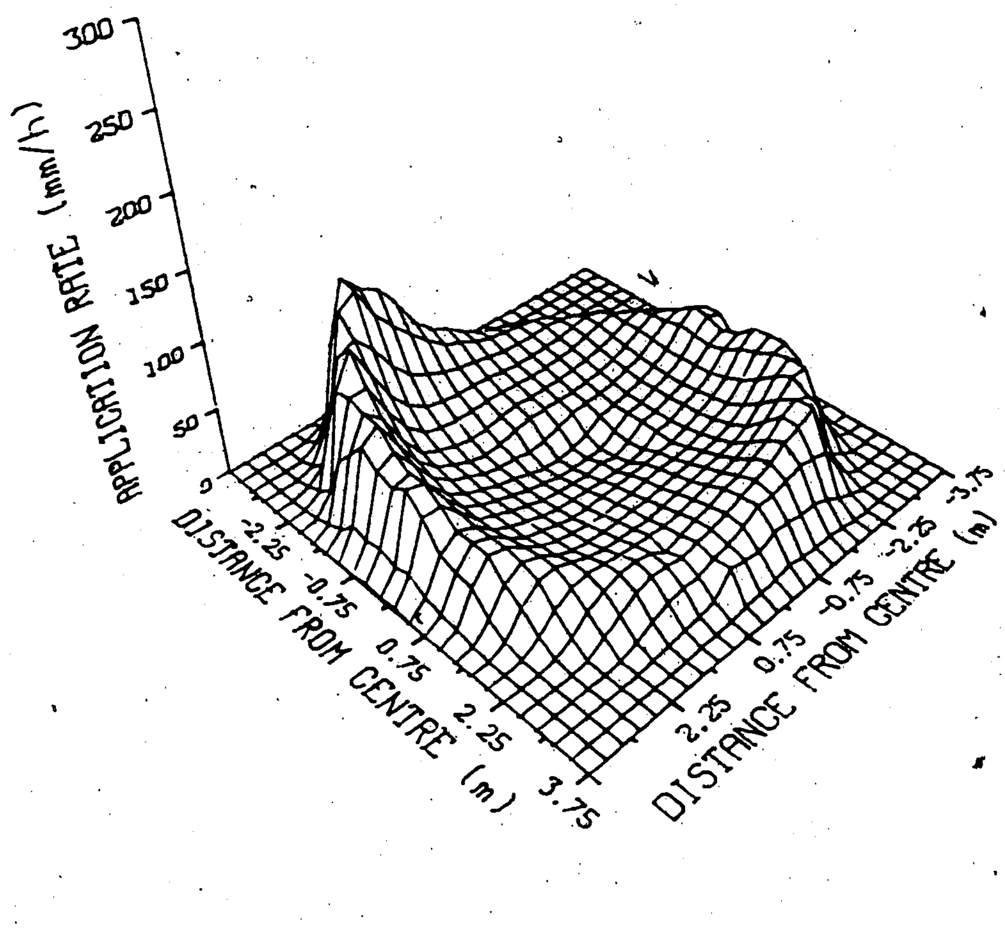


FIGURE III - 5. Distribution Profile of Nozzle RA 85/140 at 4,75 m Discharge Height.

SPRAY NOZZLE: RA 85/140 * TEST NUMBER: 6

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 548

TOTAL OF READINGS: 14719.6 mm/h

MAXIMUM READING: 185.1 mm/h

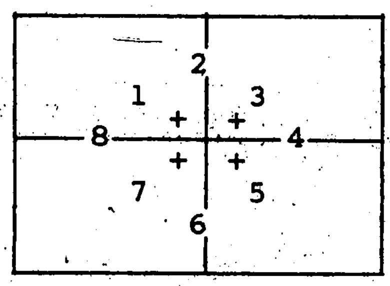
MEAN OF READINGS: 26.9 mm/h

STANDARD DEVIATION OF READINGS: 23.8 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 38.5%

COEFFICIENT OF VARIATION FOR READINGS: 88.9%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	15.4	7.9
2)	19.6	12.2
3)	18.2	17.1
4)	16.6	11.3
5)	17.3	13.6
6)	27.5	25.3
7)	32.8	38.3
8)	19.7	11.0

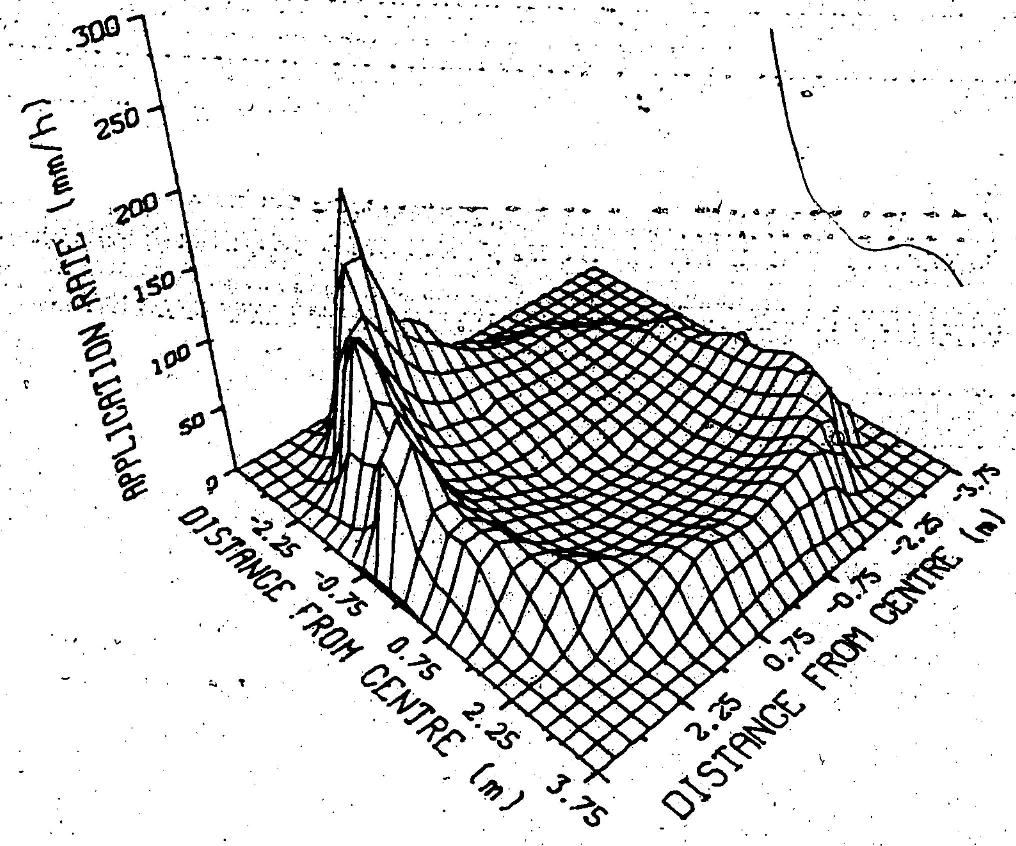


FIGURE III - 6. Distribution Profile of Nozzle RA 85/140* at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 90/140 TEST NUMBER: 7

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 473

TOTAL OF READINGS: 16177.7 mm/h

MAXIMUM READING: 206.9 mm/h

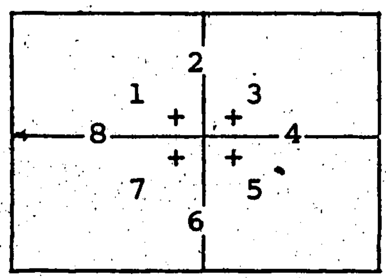
MEAN OF READINGS: 34.2 mm/h

STANDARD DEVIATION OF READINGS: 33.7 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 28.7%

COEFFICIENT OF VARIATION FOR READINGS: 98.5%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.5	11.2
2)	22.6	18.6
3)	29.0	30.3
4)	22.2	16.8
5)	21.3	18.3
6)	25.5	26.1
7)	38.2	49.6
8)	32.1	26.9

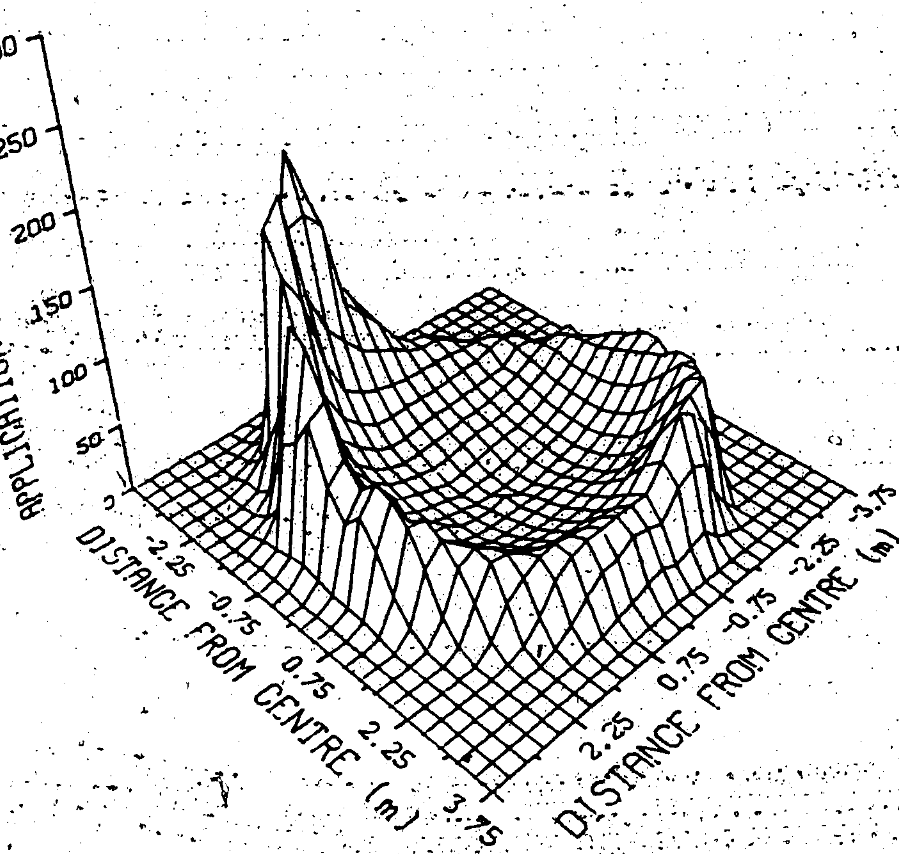


FIGURE III - 7. Distribution Profile of Nozzle RA 90/140 at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 90/140 * TEST NUMBER: 8

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 476

TOTAL OF READINGS: 16126.7 mm/h

MAXIMUM READING: 214.2 mm/h

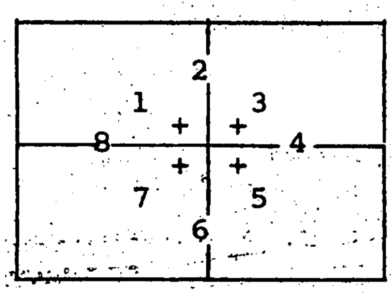
MEAN OF READINGS: 33.9 mm/h

STANDARD DEVIATION OF READINGS: 33.8 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 29.2%

COEFFICIENT OF VARIATION FOR READINGS: 99.8%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	22.0	14.5
2)	23.0	18.3
3)	27.0	27.1
4)	22.2	16.7
5)	20.2	16.0
6)	27.5	30.1
7)	38.5	50.9
8)	33.5	30.8

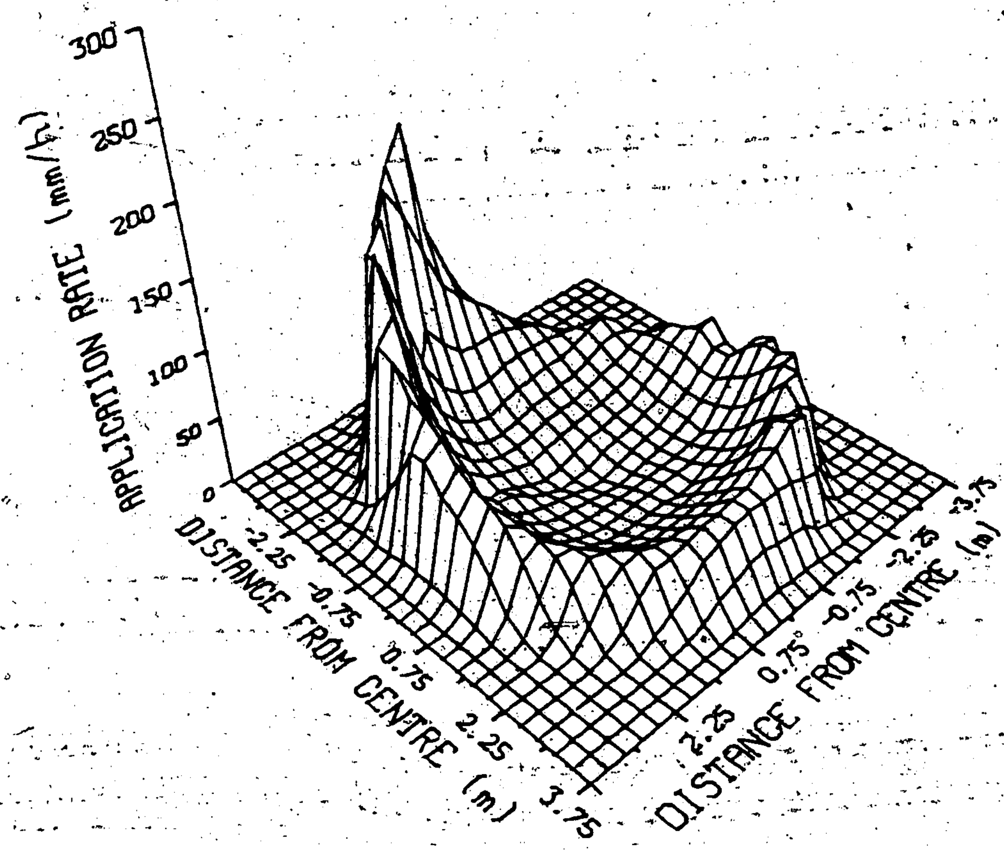


FIGURE III - 8. Distribution Profile of Nozzle RA 90/140* at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 90/140 TEST NUMBER: 9

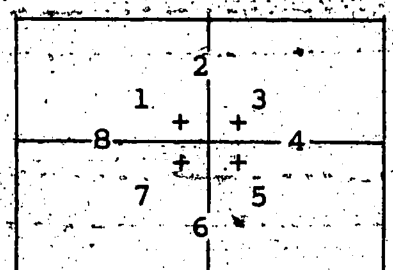
LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT:	4.25 m
NUMBER OF READINGS:	512
TOTAL OF READINGS:	16194.3 mm/h
MAXIMUM READING:	199.6 mm/h
MEAN OF READINGS:	31.6 mm/h
STANDARD DEVIATION OF READINGS:	29.8 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 32.6%

COEFFICIENT OF VARIATION FOR READINGS: 94.4%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.5	9.3
2)	20.5	16.1
3)	28.1	26.7
4)	21.9	14.7
5)	18.8	15.5
6)	21.4	20.2
7)	31.6	36.6
8)	30.4	22.9

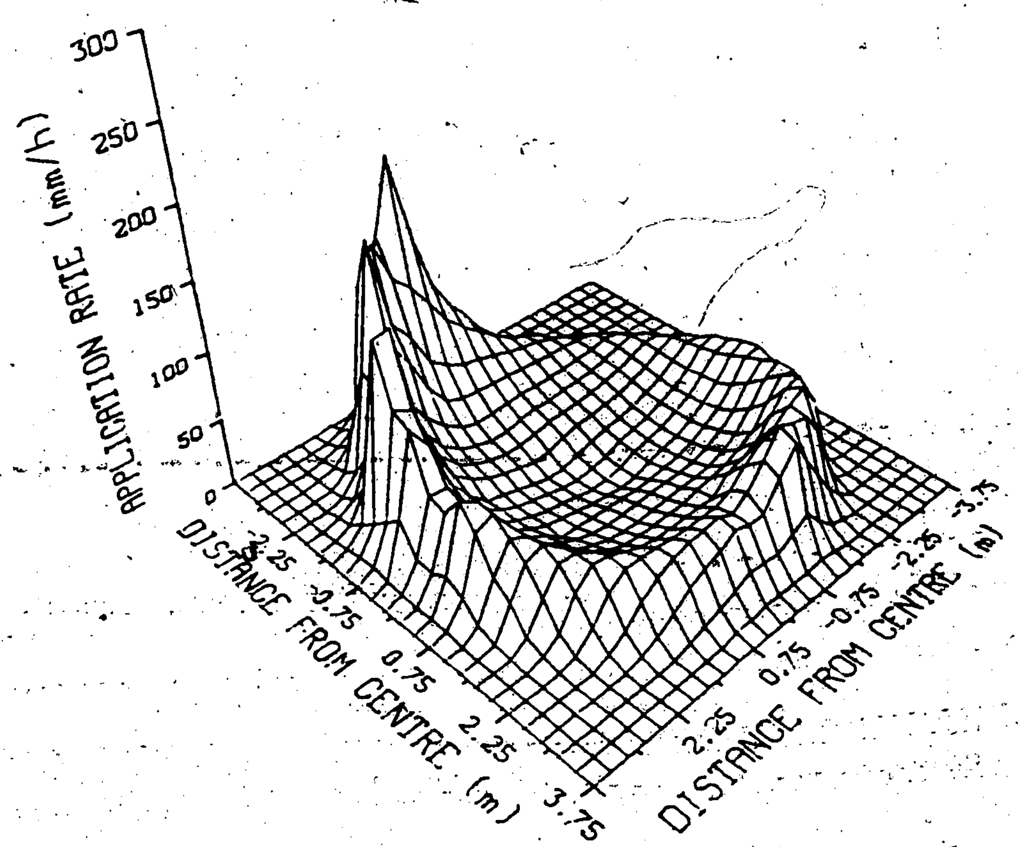


FIGURE III - 9. Distribution Profile of Nozzle RA 90/140 at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 90/140 * TEST NUMBER: 10

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 507

TOTAL OF READINGS: 16422.0 mm/h

MAXIMUM READING: 210.1 mm/h

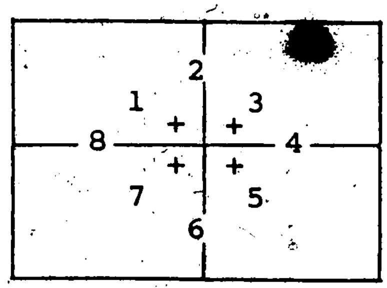
MEAN OF READINGS: 32.4 mm/h

STANDARD DEVIATION OF READINGS: 32.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 32.8%

COEFFICIENT OF VARIATION FOR READINGS: 100.4%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.8	12.9
2)	18.9	12.9
3)	23.5	20.1
4)	19.9	15.3
5)	17.4	15.1
6)	28.1	29.3
7)	38.5	51.2
8)	32.3	25.7

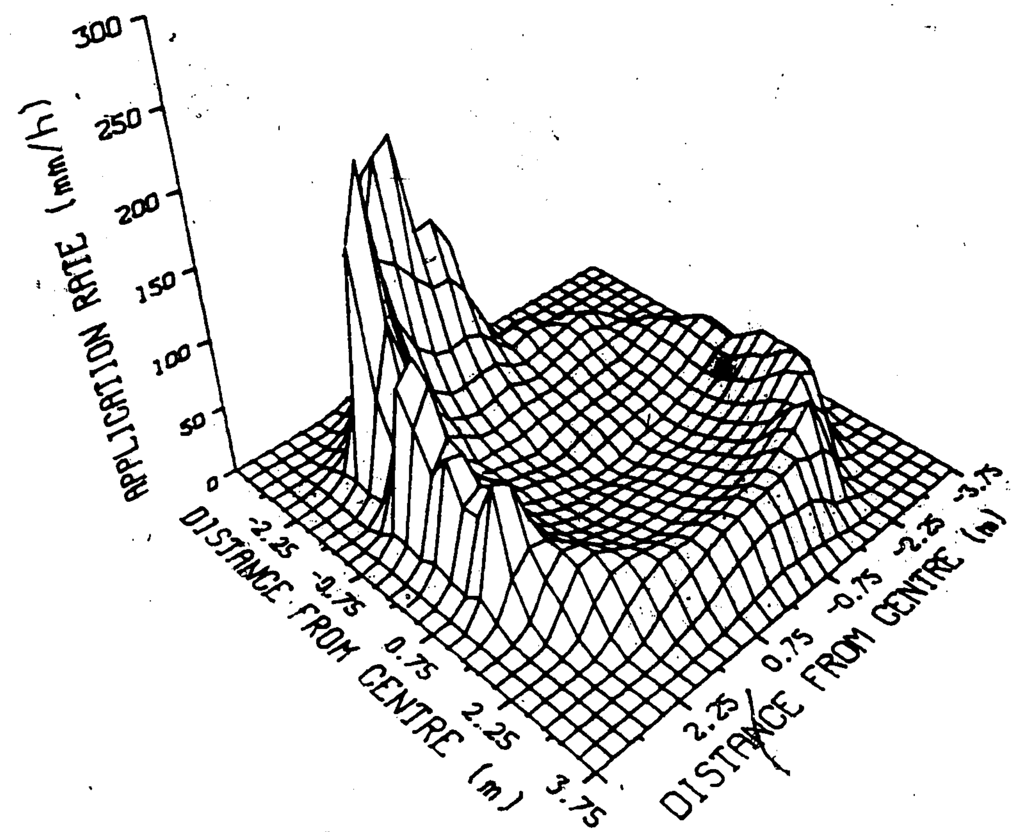


FIGURE III - 10. Distribution Profile of Nozzle RA 90/140* at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 90/140 TEST NUMBER: 11

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 535

TOTAL OF READINGS: 15570.8 mm/h

MAXIMUM READING: 150.2 mm/h

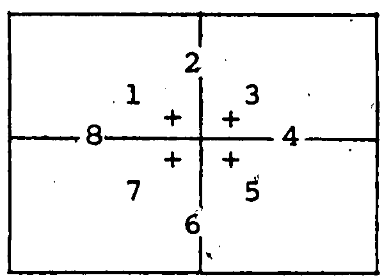
MEAN OF READINGS: 29.1 mm/h

STANDARD DEVIATION OF READINGS: 25.8 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 35.7%

COEFFICIENT OF VARIATION FOR READINGS: 88.7%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	16.5	10.0
2)	20.0	14.8
3)	25.8	24.3
4)	20.2	14.3
5)	17.3	13.0
6)	22.1	21.2
7)	36.9	47.7
8)	28.9	20.6

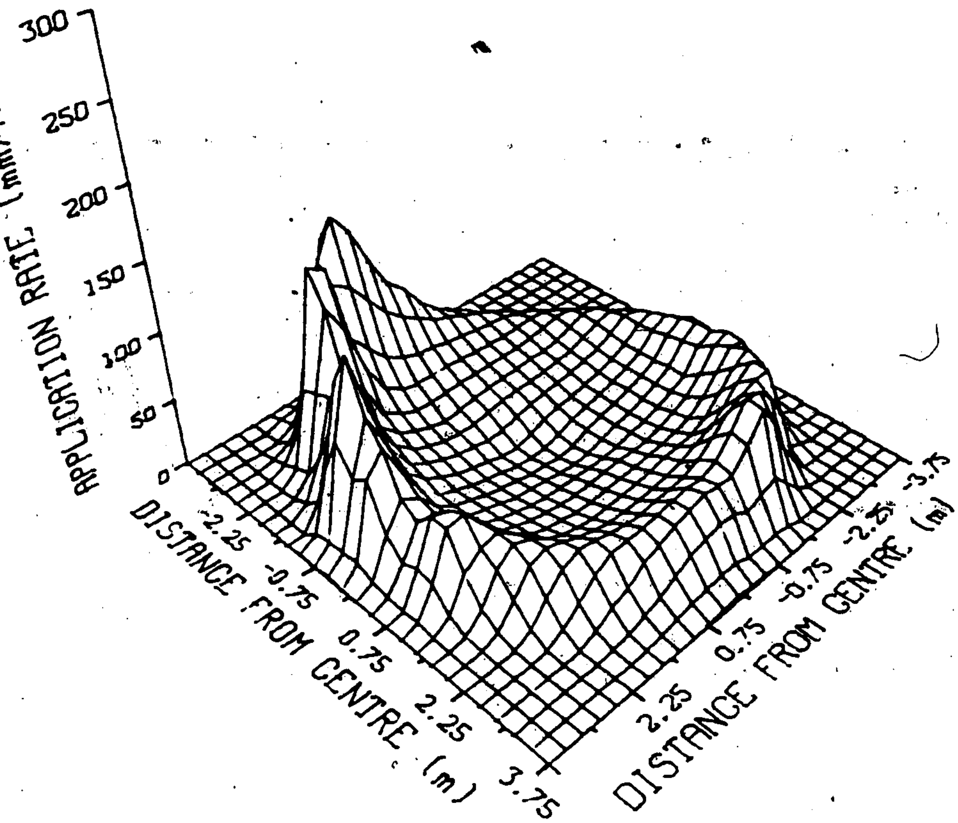


FIGURE III - 11. Distribution Profile of Nozzle RA 90/140 at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 90/140 * TEST NUMBER: 12

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 547

TOTAL OF READINGS: 16215.1 mm/h

MAXIMUM READING: 192.4 mm/h

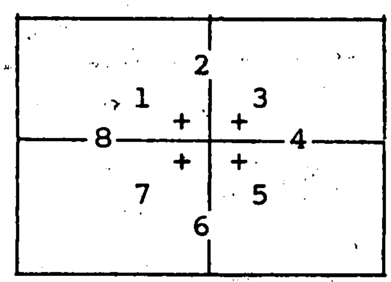
MEAN OF READINGS: 29.6 mm/h

STANDARD DEVIATION OF READINGS: 27.9 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 36.6%

COEFFICIENT OF VARIATION FOR READINGS: 94.1%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.3	10.9
2)	17.5	11.8
3)	19.4	17.6
4)	19.4	13.6
5)	16.8	13.0
6)	24.8	24.9
7)	35.8	44.5
8)	33.0	24.6

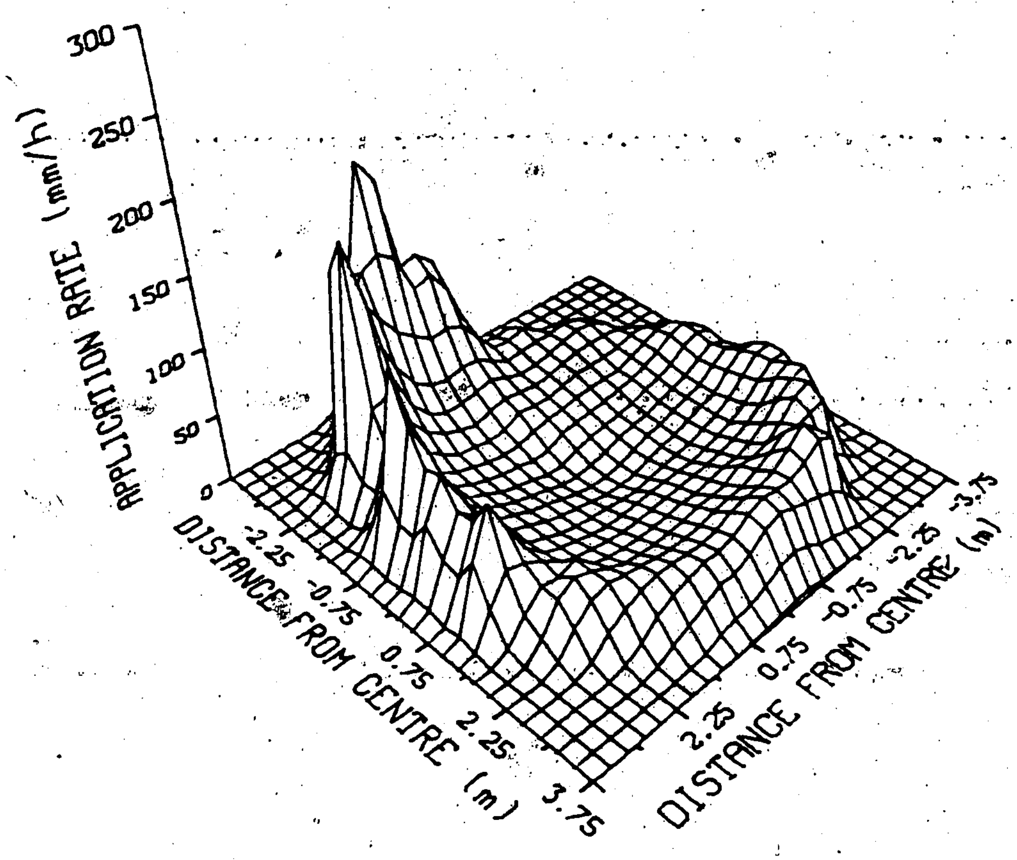


FIGURE III - 12. Distribution Profile of Nozzle RA 90/140* at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 95/140 TEST NUMBER: 13

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 478

TOTAL OF READINGS: 16902.0 mm/h

MAXIMUM READING: 247.0 mm/h

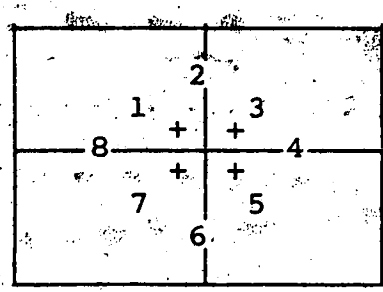
MEAN OF READINGS: 35.4 mm/h

STANDARD DEVIATION OF READINGS: 36.4 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 26.5%

COEFFICIENT OF VARIATION FOR READINGS: 103.0%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	24.1	18.8
2)	25.9	22.8
3)	30.7	27.4
4)	21.2	16.5
5)	21.7	17.8
6)	28.6	29.6
7)	41.4	58.1
8)	31.4	33.7

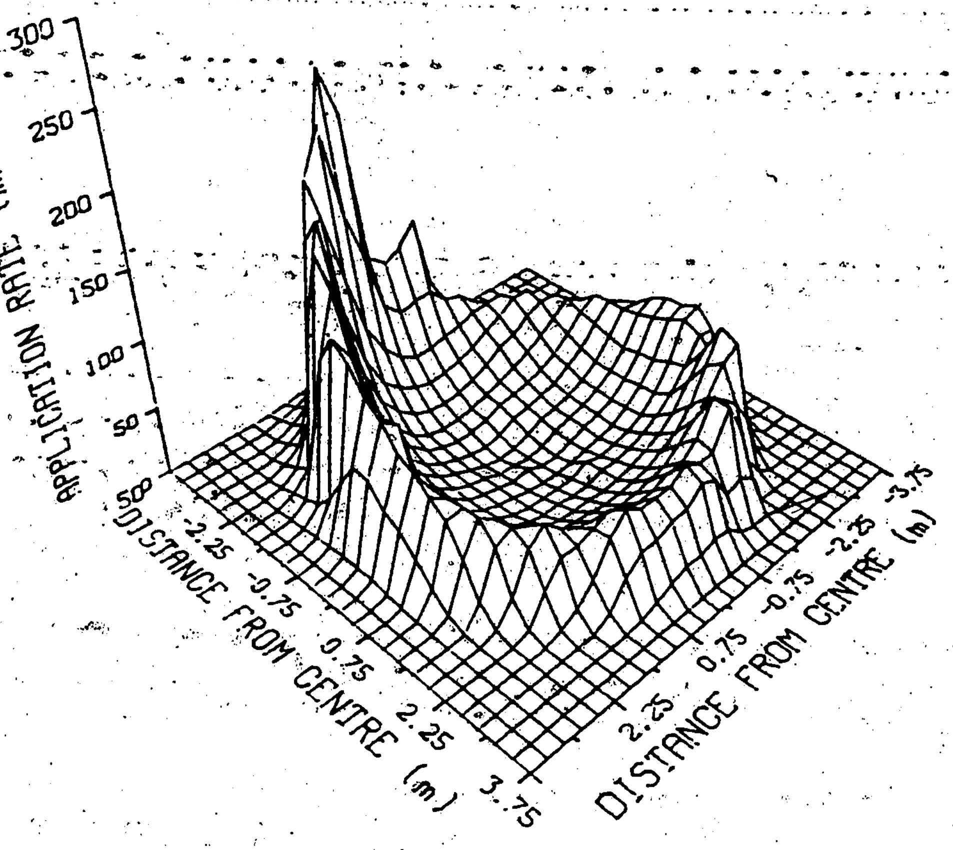


FIGURE III - 13. Distribution Profile of Nozzle RA 95/140 at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 95/140 * TEST NUMBER: 14

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 472

TOTAL OF READINGS: 17118.4 mm/h

MAXIMUM READING: 203.8 mm/h

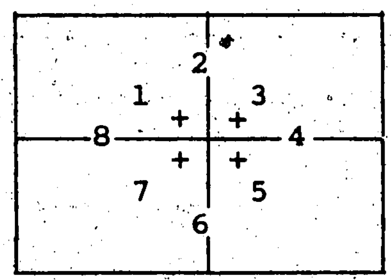
MEAN OF READINGS: 36.3 mm/h

STANDARD DEVIATION OF READINGS: 34.4 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 29.4%

COEFFICIENT OF VARIATION FOR READINGS: 94.8%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	23.9	18.6
2)	28.8	27.1
3)	31.1	31.5
4)	22.4	16.1
5)	22.7	18.0
6)	24.6	22.6
7)	31.4	38.3
8)	26.6	26.3

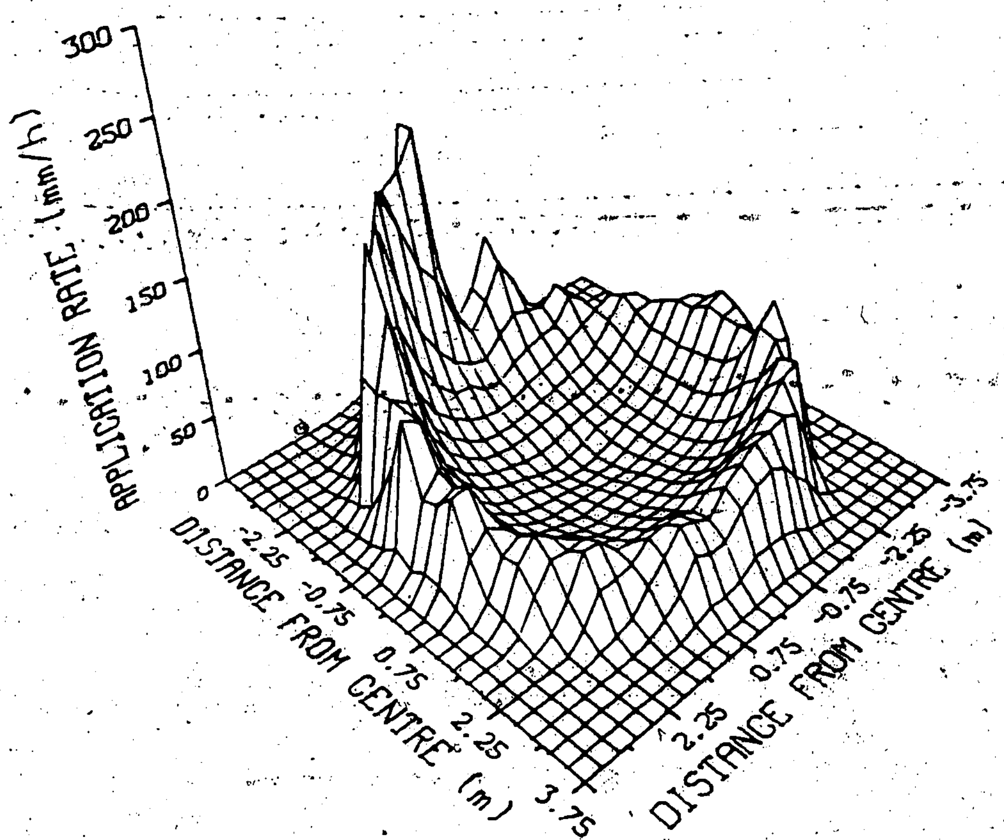


FIGURE III - 14. Distribution Profile of Nozzle RA 95/140* at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 95/140°　　　　TEST NUMBER: 15

LATERAL PRESSURE: 240 kPa　　　　CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 534

TOTAL OF READINGS: 17138.6 mm/h

MAXIMUM READING: 223.0 mm/h

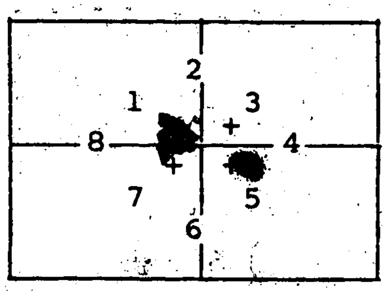
MEAN OF READINGS: 32.1 mm/h

STANDARD DEVIATION OF READINGS: 31.2 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 30.4%

COEFFICIENT OF VARIATION FOR READINGS: 97.5%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	21.0	14.9
2)	22.4	19.5
3)	25.8	22.9
4)	18.6	14.3
5)	17.7	15.2
6)	24.5	23.9
7)	37.4	49.3
8)	31.3	29.4

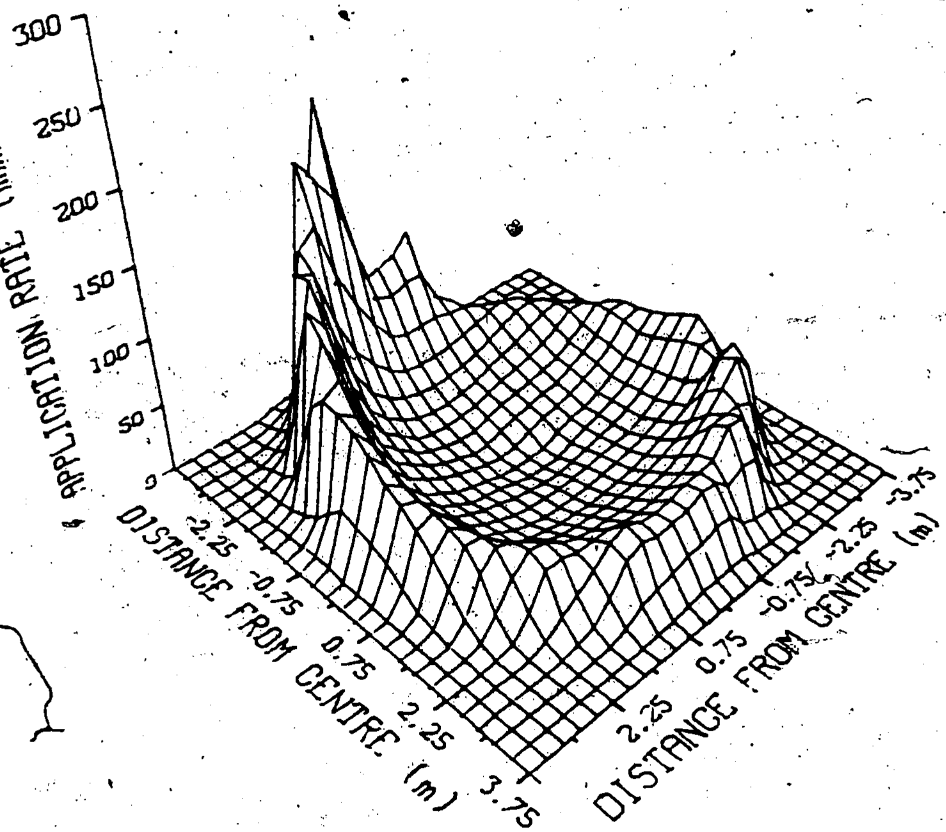


FIGURE III - 15. Distribution Profile of Nozzle RA 95/140 at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 95/140 * TEST NUMBER: 16

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 499

TOTAL OF READINGS: 16266.1 mm/h

MAXIMUM READING: 187.7 mm/h

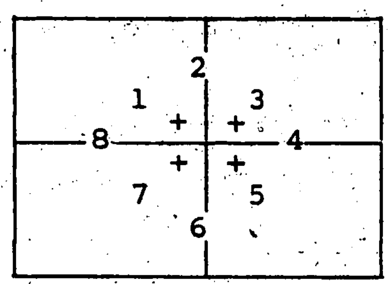
MEAN OF READINGS: 32.6 mm/h

STANDARD DEVIATION OF READINGS: 29.4 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 31.8%

COEFFICIENT OF VARIATION FOR READINGS: 90.3%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	21.2	17.2
2)	21.7	18.0
3)	27.3	27.6
4)	22.3	17.1
5)	21.0	15.5
6)	22.9	21.4
7)	29.6	31.9
8)	30.2	30.1

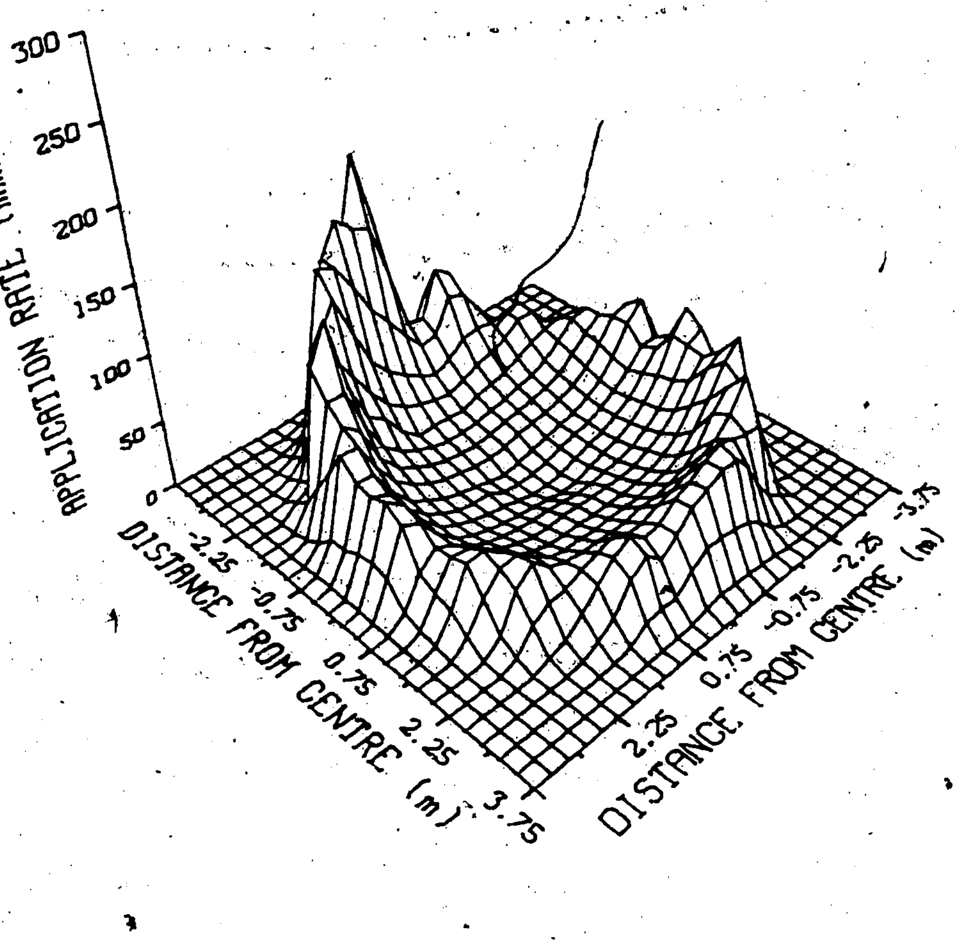


FIGURE III - 16. Distribution Profile of Nozzle RA 95/140* at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 95/140 TEST NUMBER: 17

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 556

TOTAL OF READINGS: 17288.9 mm/h

MAXIMUM READING: 167.9 mm/h

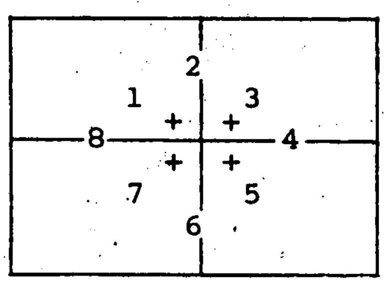
MEAN OF READINGS: 31.1 mm/h

STANDARD DEVIATION OF READINGS: 26.6 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 40.5%

COEFFICIENT OF VARIATION FOR READINGS: 85.5%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	20.1	12.1
2)	22.2	16.1
3)	22.3	18.3
4)	18.9	11.8
5)	17.6	11.8
6)	24.3	20.9
7)	35.8	40.2
8)	30.9	25.5

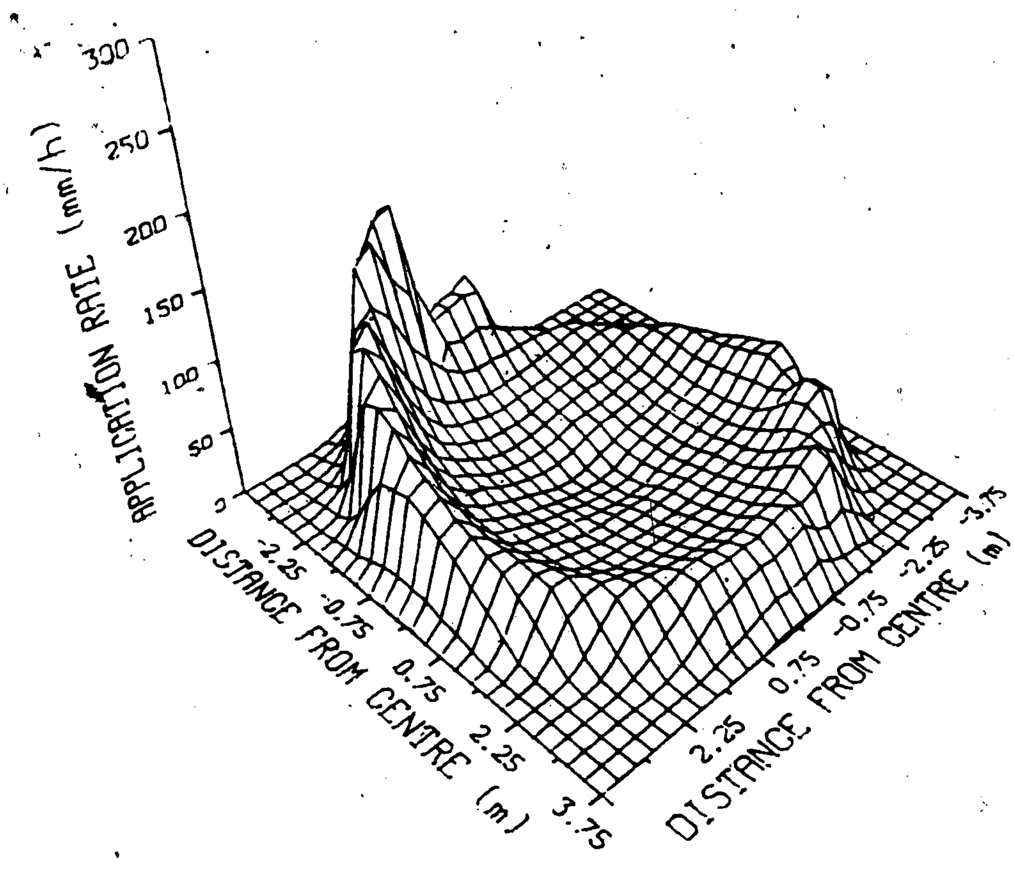


FIGURE III - 17. Distribution Profile of Nozzle RA 95/140 at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 95/140 * TEST NUMBER: 18

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 553

TOTAL OF READINGS: 16712.2 mm/h

MAXIMUM READING: 150.8 mm/h

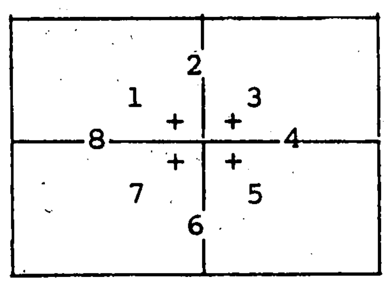
MEAN OF READINGS: 30.2 mm/h

STANDARD DEVIATION OF READINGS: 25.4 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 37.2%

COEFFICIENT OF VARIATION FOR READINGS: 84.0%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	21.3	15.1
2)	18.8	15.2
3)	21.7	22.9
4)	20.6	15.1
5)	16.1	12.2
6)	21.3	19.4
7)	28.3	31.7
8)	31.2	28.8

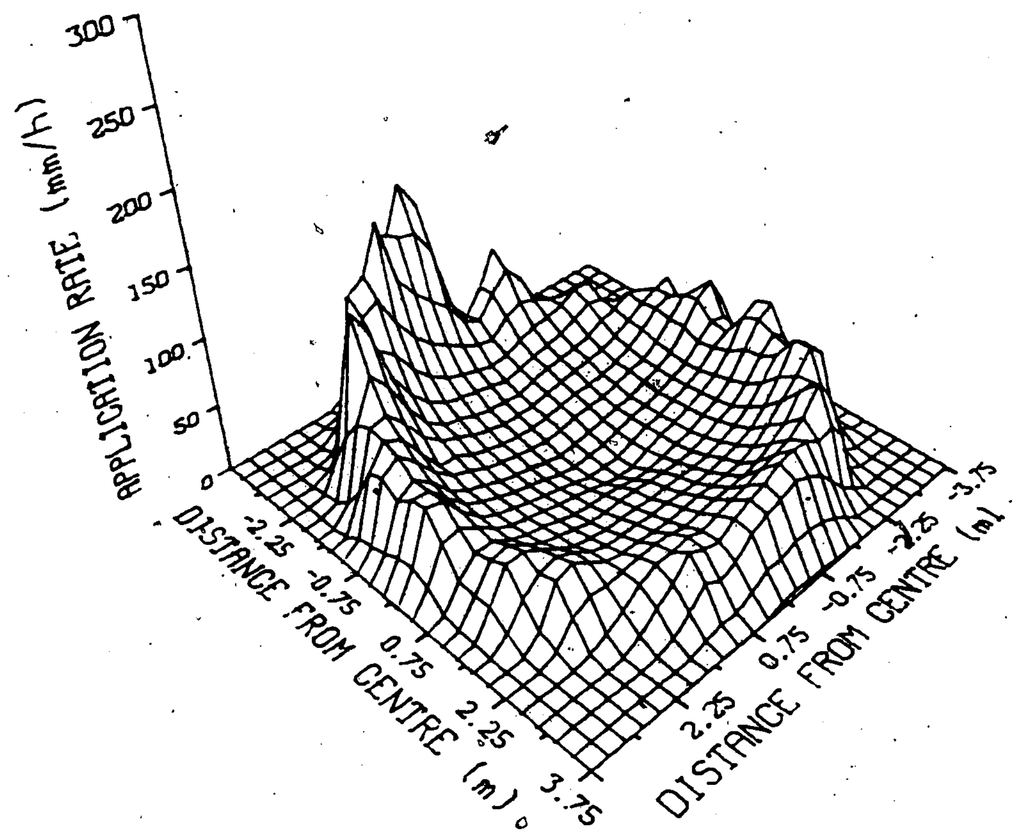


FIGURE III - 18. Distribution Profile of Nozzle RA 95/140* at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 100/140 TEST NUMBER: 19

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 478

TOTAL OF READINGS: 17633.2 mm/h

MAXIMUM READING: 203.8 mm/h

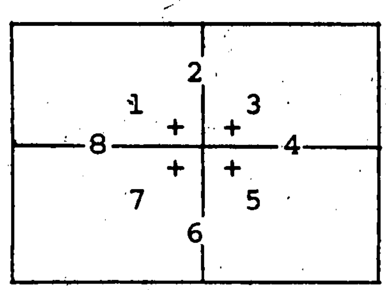
MEAN OF READINGS: 36.8 mm/h

STANDARD DEVIATION OF READINGS: 35.8 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 29.6%

COEFFICIENT OF VARIATION FOR READINGS: 97.2%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	25.5	17.7
2)	29.4	24.4
3)	29.1	27.6
4)	19.9	14.3
5)	22.1	17.8
6)	30.3	32.7
7)	42.3	56.1
8)	41.3	43.0

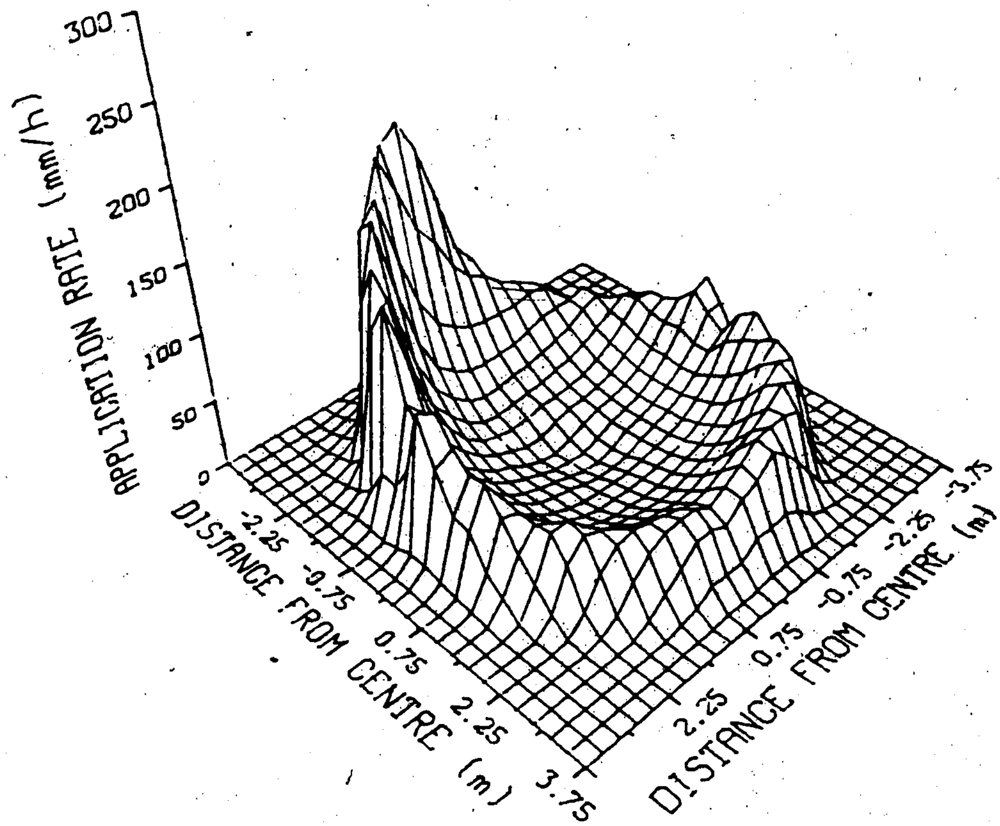


FIGURE III - 19. Distribution Profile of Nozzle RA 100/140 at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 100/140 * TEST NUMBER: 20

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 479

TOTAL OF READINGS: 17472.0 mm/h

MAXIMUM READING: 208.0 mm/h

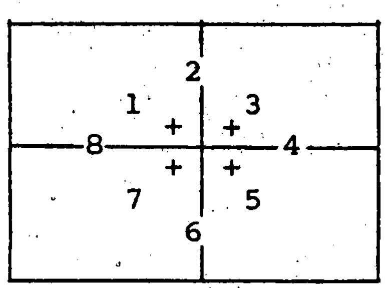
MEAN OF READINGS: 36.4 mm/h

STANDARD DEVIATION OF READINGS: 36.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 25.5%

COEFFICIENT OF VARIATION FOR READINGS: 100.3%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	22.6	15.6
2)	23.2	20.8
3)	30.9	36.3
4)	21.8	21.5
5)	20.9	17.8
6)	26.8	29.2
7)	39.5	53.7
8)	39.8	42.9

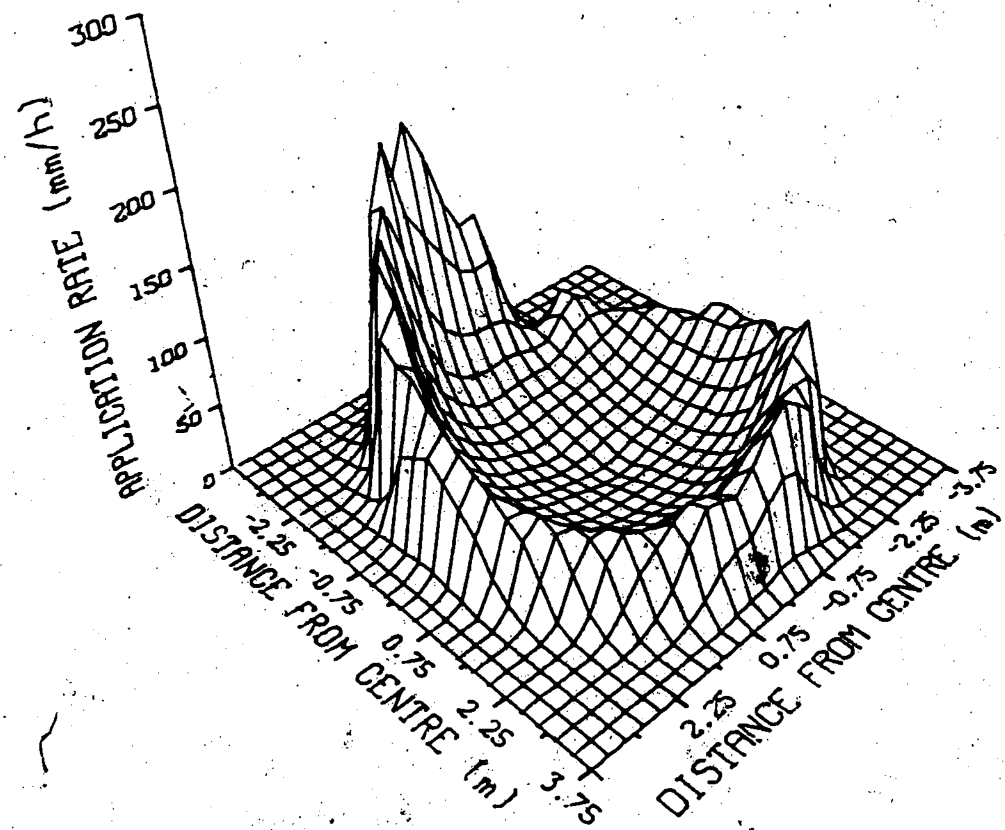


FIGURE III - 20. Distribution Profile of Nozzle RA 100/140* at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 100/140 TEST NUMBER: 21

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 511

TOTAL OF READINGS: 17131.9 mm/h

MAXIMUM READING: 172.1 mm/h

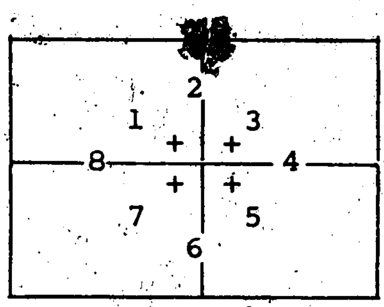
MEAN OF READINGS: 33.5 mm/h

STANDARD DEVIATION OF READINGS: 30.6 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 34.5%

COEFFICIENT OF VARIATION FOR READINGS: 91.5%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	20.9	14.3
2)	26.4	19.9
3)	27.6	24.4
4)	18.7	12.5
5)	18.7	14.9
6)	27.8	25.5
7)	38.5	48.5
8)	37.9	34.2

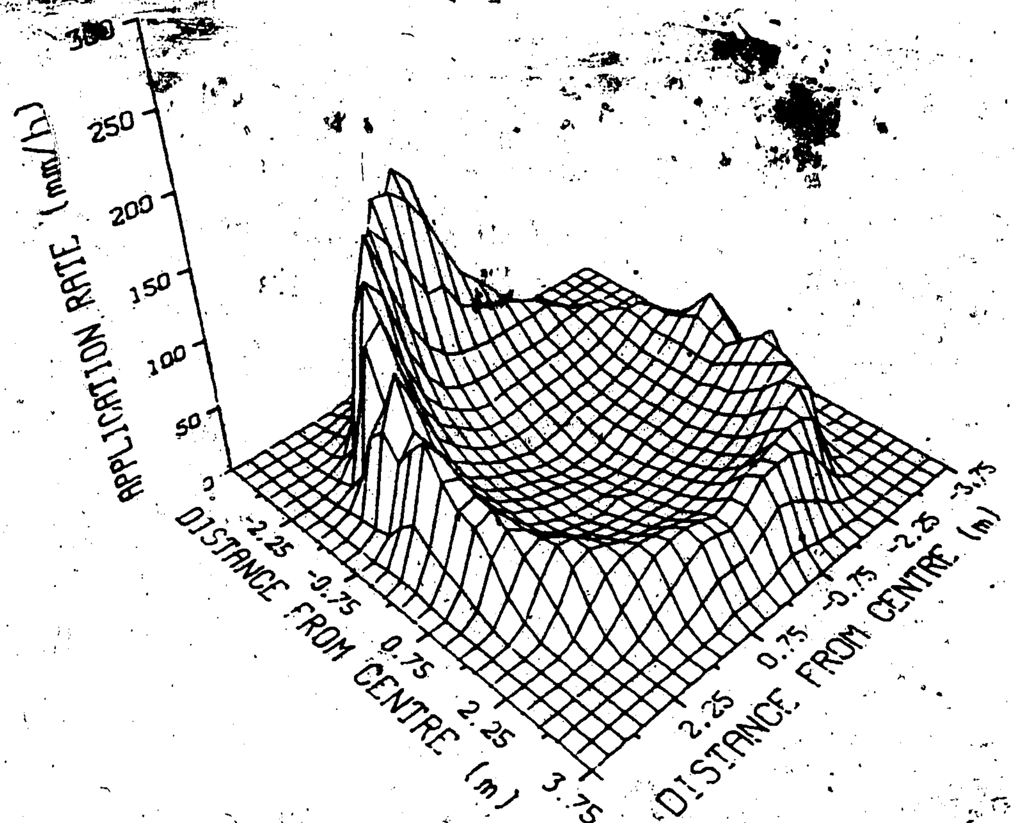


FIGURE III - 21. Distribution Profile of Nozzle RA 100/140 at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 100/140 * TEST NUMBER: 22

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 494

TOTAL OF READINGS: 16526.6 mm/h

MAXIMUM READING: 175.2 mm/h

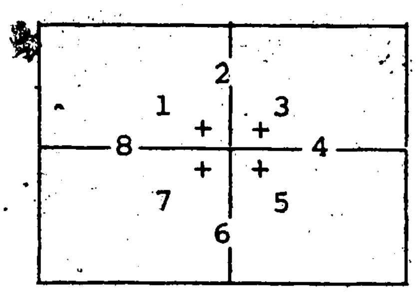
MEAN OF READINGS: 33.5 mm/h

STANDARD DEVIATION OF READINGS: 32.2 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 28.3%

COEFFICIENT OF VARIATION FOR READINGS: 96.3%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.5	14.3
2)	23.5	17.7
3)	28.0	30.7
4)	23.1	21.6
5)	20.3	15.2
6)	25.2	23.7
7)	37.3	45.7
8)	39.5	41.3

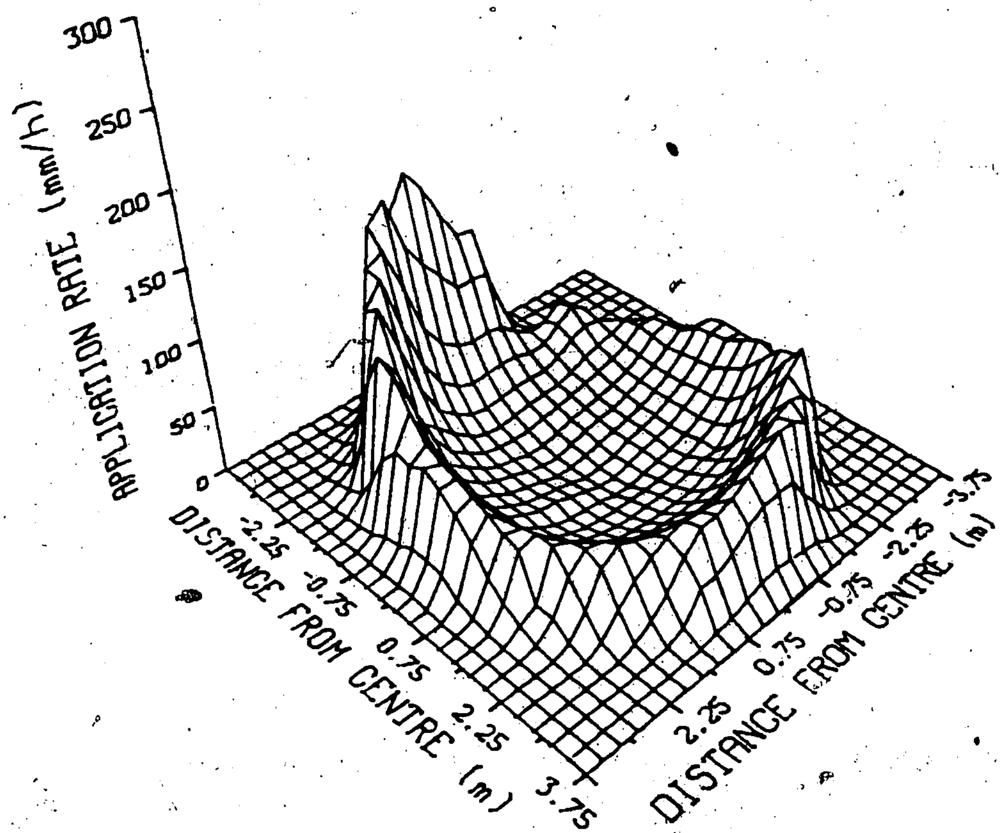


FIGURE III - 22. Distribution Profile of Nozzle RA 100/140* at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 100/140 TEST NUMBER: 23

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 547

TOTAL OF READINGS: 17097.6 mm/h

MAXIMUM READING: 158.0 mm/h

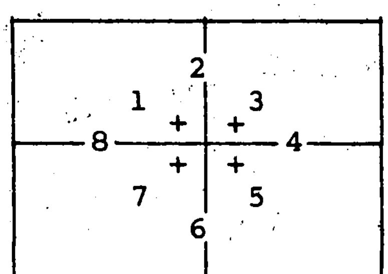
MEAN OF READINGS: 31.2 mm/h

STANDARD DEVIATION OF READINGS: 27.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 37.6%

COEFFICIENT OF VARIATION FOR READINGS: 88.0%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	19.6	11.8
2)	20.3	14.8
3)	22.5	21.1
4)	15.6	10.5
5)	17.5	13.1
6)	23.1	21.8
7)	35.8	43.3
8)	34.9	29.4

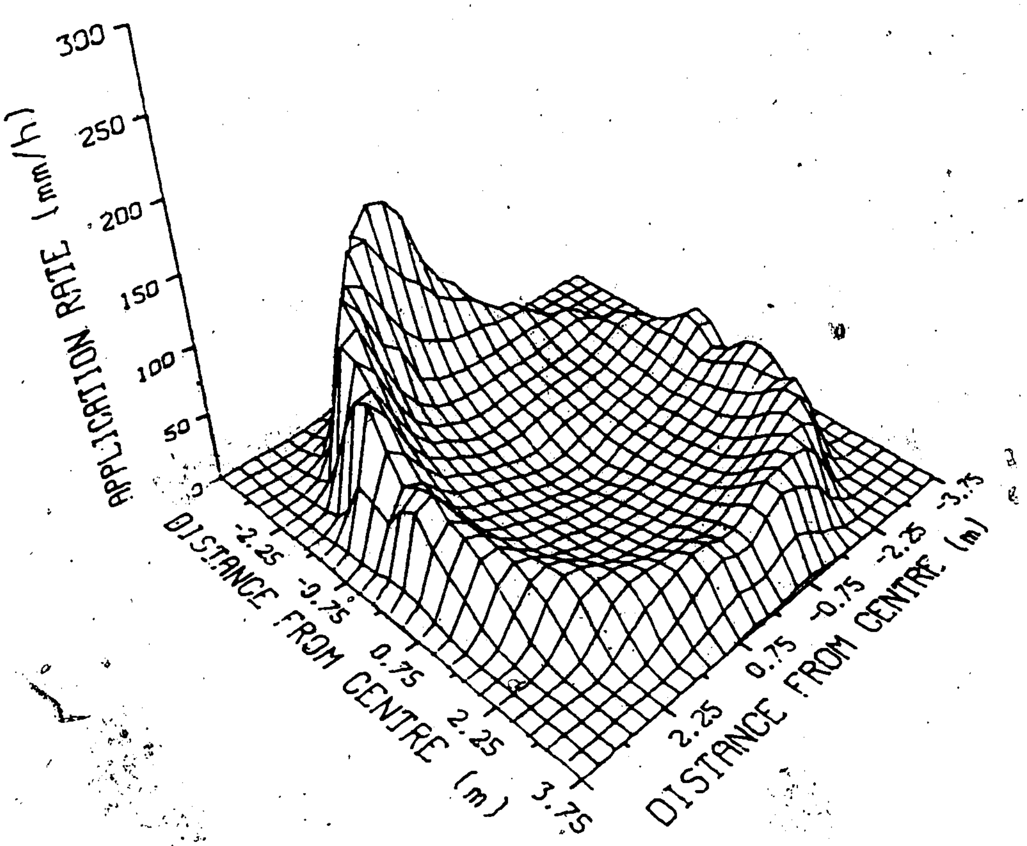


FIGURE III - 23. Distribution Profile of Nozzle RA 100/140 at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 100/140 * TEST NUMBER: 24

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 547

TOTAL OF READINGS: 17057.5 mm/h

MAXIMUM READING: 159.6 mm/h

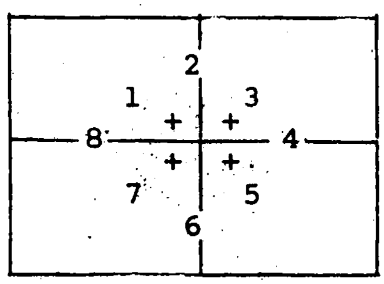
MEAN OF READINGS: 31.1 mm/h

STANDARD DEVIATION OF READINGS: 28.1 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 33.1%

COEFFICIENT OF VARIATION FOR READINGS: 90.3%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	18.7	11.6
2)	19.9	16.0
3)	28.8	30.5
4)	22.5	18.1
5)	17.5	13.7
6)	22.4	20.0
7)	32.8	40.7
8)	37.5	37.1

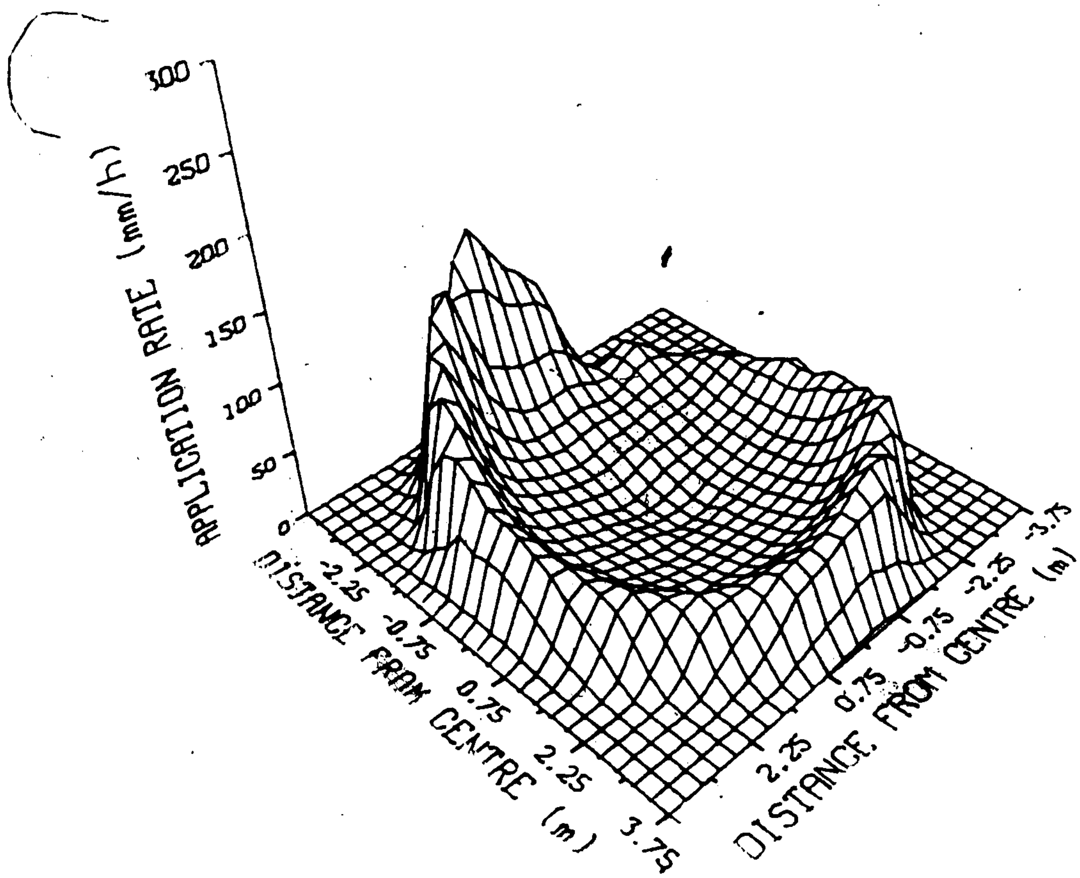


FIGURE III - 24 Distribution Profile of Nozzle RA 100/140° at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 110/140 TEST NUMBER: 25

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 481

TOTAL OF READINGS: 20308.7 mm/h

MAXIMUM READING: 215.7 mm/h

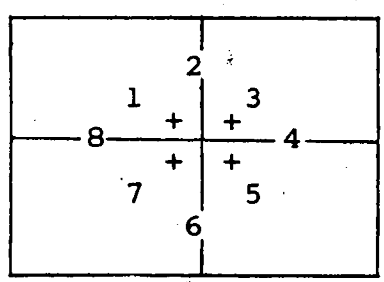
MEAN OF READINGS: 42.2 mm/h

STANDARD DEVIATION OF READINGS: 42.0 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 23.4%

COEFFICIENT OF VARIATION FOR READINGS: 99.4%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	24.3	30.3
2)	28.8	27.5
3)	40.2	50.4
4)	32.5	31.0
5)	19.5	14.1
6)	25.4	22.2
7)	32.8	38.5
8)	50.8	63.9

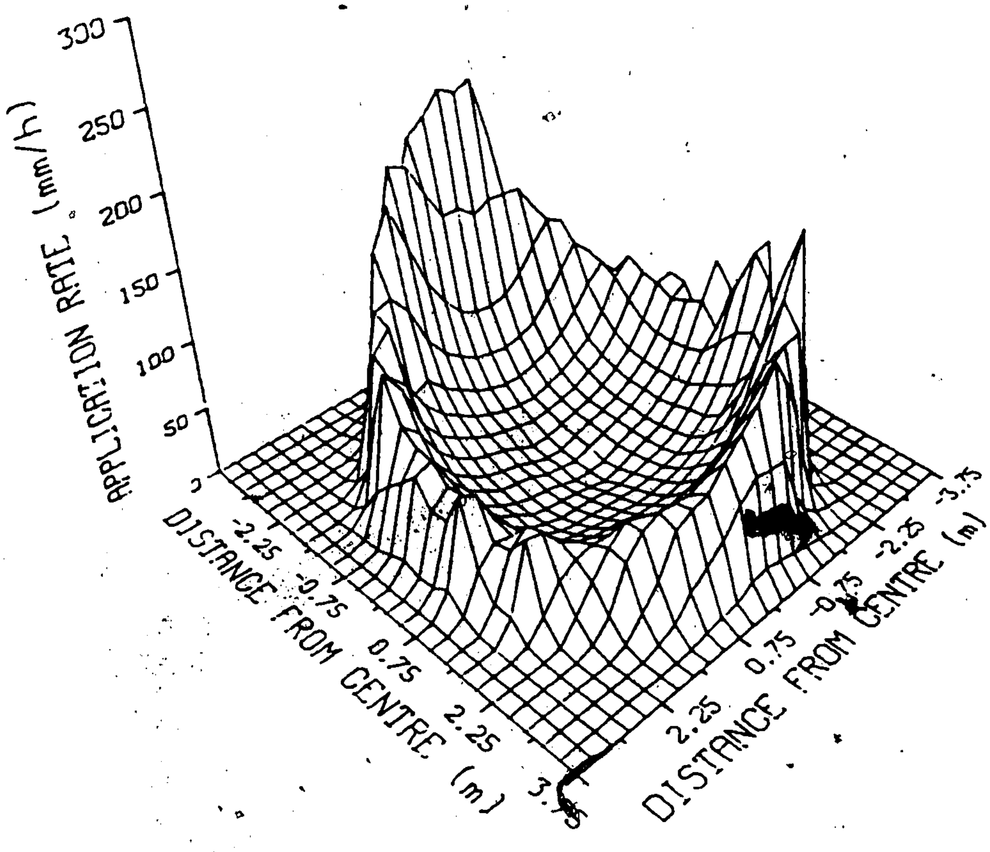


FIGURE III - 25. Distribution Profile of Nozzle RA 110/140 at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 110/140 * TEST NUMBER: 26

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 3.75 m

NUMBER OF READINGS: 491

TOTAL OF READINGS: 20743.8 mm/h

MAXIMUM READING: 248.0 mm/h

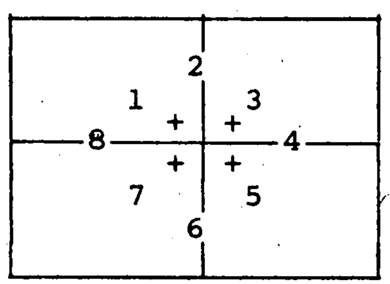
MEAN OF READINGS: 42.2 mm/h

STANDARD DEVIATION OF READINGS: 43.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 21.4%

COEFFICIENT OF VARIATION FOR READINGS: 103.0%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	34.2	42.0
2)	28.8	31.9
3)	26.2	28.4
4)	32.4	30.9
5)	22.3	19.4
6)	27.4	15.6
7)	36.1	46.4
8)	47.9	61.4

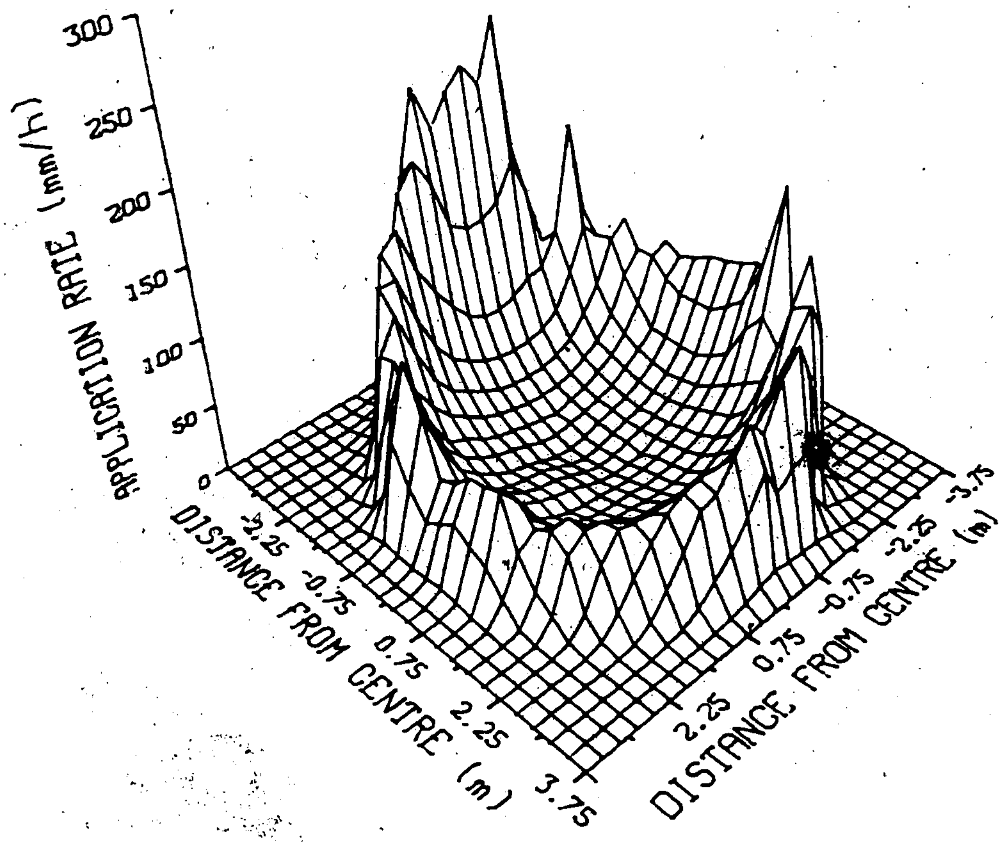


FIGURE III - 26. Distribution Profile of Nozzle RA 110/140* at 3.75 m Discharge Height.

SPRAY NOZZLE: RA 110/140 TEST NUMBER: 27

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 520

TOTAL OF READINGS: 20163.5 mm/h

MAXIMUM READING: 217.8 mm/h

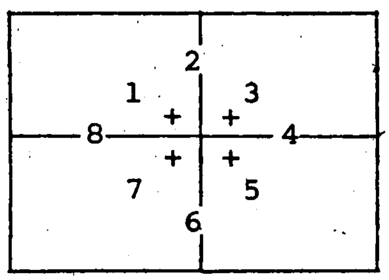
MEAN OF READINGS: 38.8 mm/h

STANDARD DEVIATION OF READINGS: 36.5 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 29.1%

COEFFICIENT OF VARIATION FOR READINGS: 94.1%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	28.3	26.5
2)	24.7	25.4
3)	38.4	50.8
4)	27.8	25.9
5)	16.5	13.1
6)	22.0	18.4
7)	27.3	28.5
8)	47.4	53.0

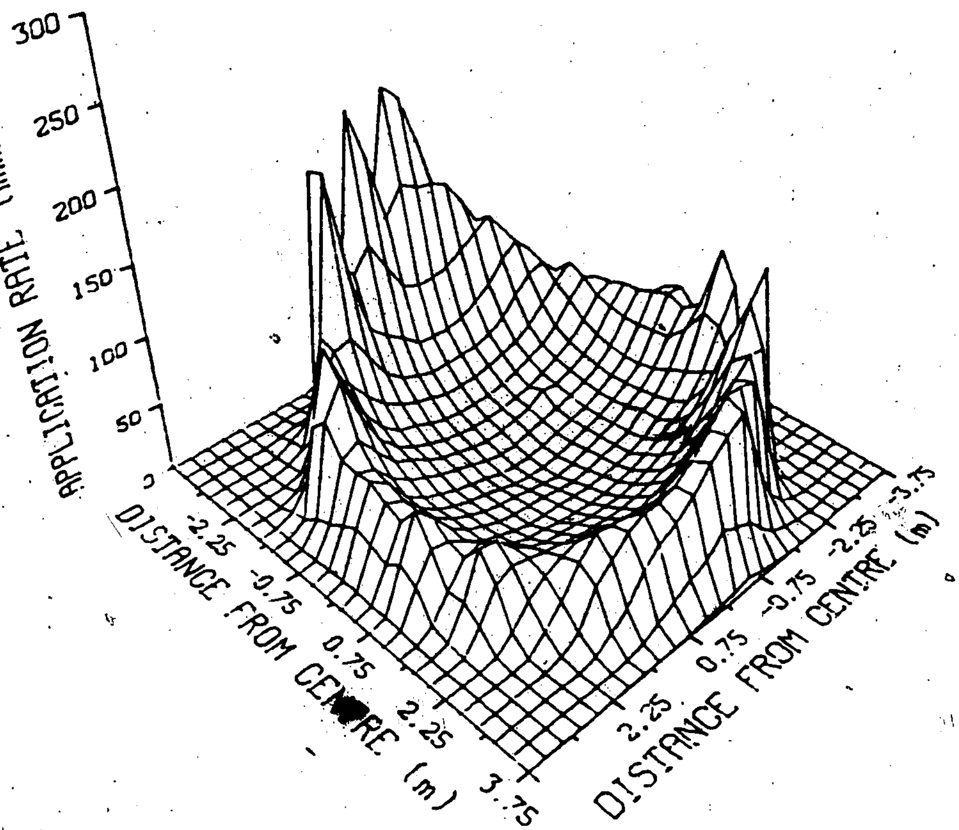


FIGURE III - 27. Distribution Profile of Nozzle RA 110/140 at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 110/140 * TEST NUMBER: 28

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm.

NOZZLE HEIGHT: 4.25 m

NUMBER OF READINGS: 512

TOTAL OF READINGS: 19537.9 mm/h

MAXIMUM READING: 201.7 mm/h

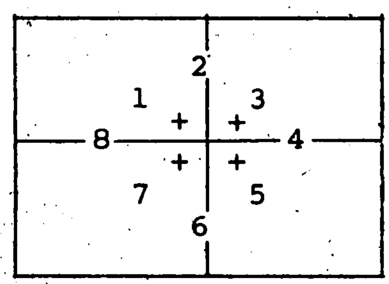
MEAN OF READINGS: 38.2 mm/h

STANDARD DEVIATION OF READINGS: 37.3 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 25.0%

COEFFICIENT OF VARIATION FOR READINGS: 97.8%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	29.1	31.1
2)	25.7	26.7
3)	24.9	26.0
4)	27.2	25.0
5)	15.3	15.4
6)	20.1	17.5
7)	30.3	35.9
8)	45.3	55.4

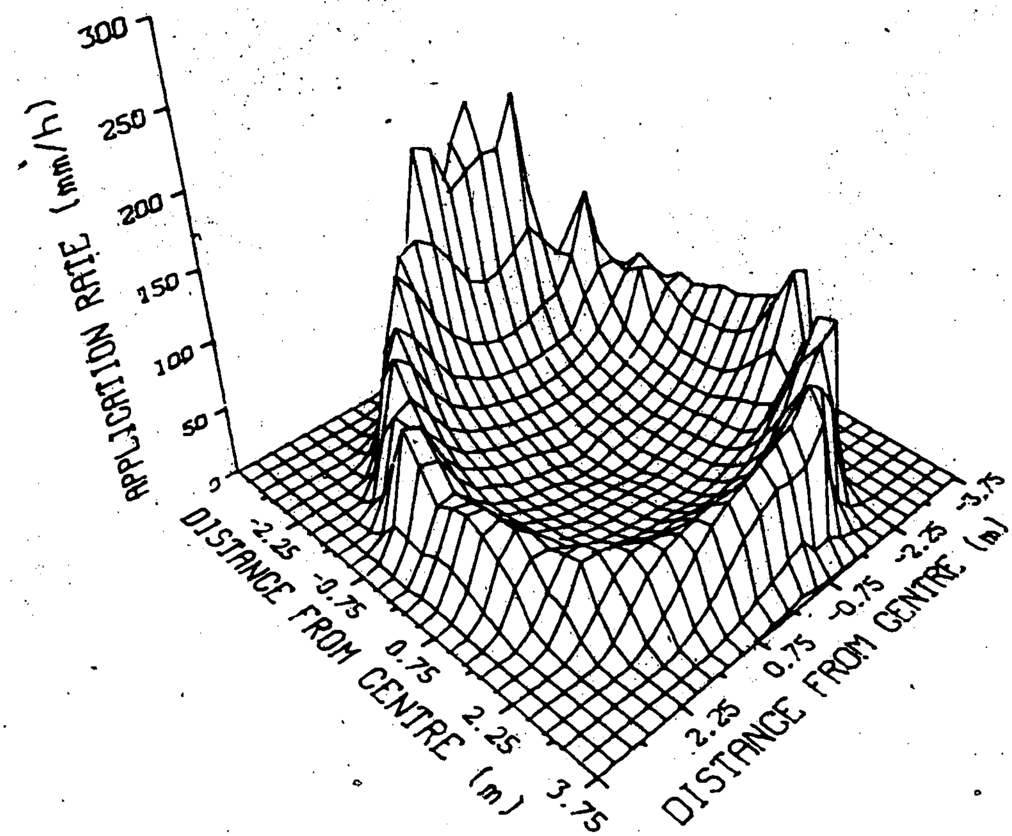


FIGURE III - 28. Distribution Profile of Nozzle RA 110/140* at 4.25 m Discharge Height.

SPRAY NOZZLE: RA 110/140 TEST NUMBER: 29

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 565

TOTAL OF READINGS: 20332.5 mm/h

MAXIMUM READING: 201.7 mm/h

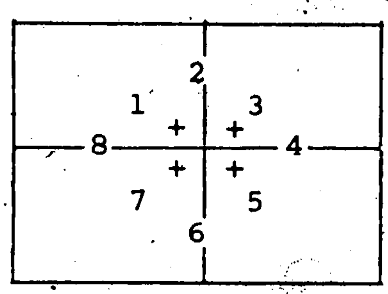
MEAN OF READINGS: 36.0 mm/h

STANDARD DEVIATION OF READINGS: 32.3 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 31.8%

COEFFICIENT OF VARIATION FOR READINGS: 89.8%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	22.0	20.4
2)	26.0	22.8
3)	36.5	39.9
4)	28.6	23.0
5)	16.9	11.7
6)	19.7	14.9
7)	23.4	23.6
8)	44.0	51.6

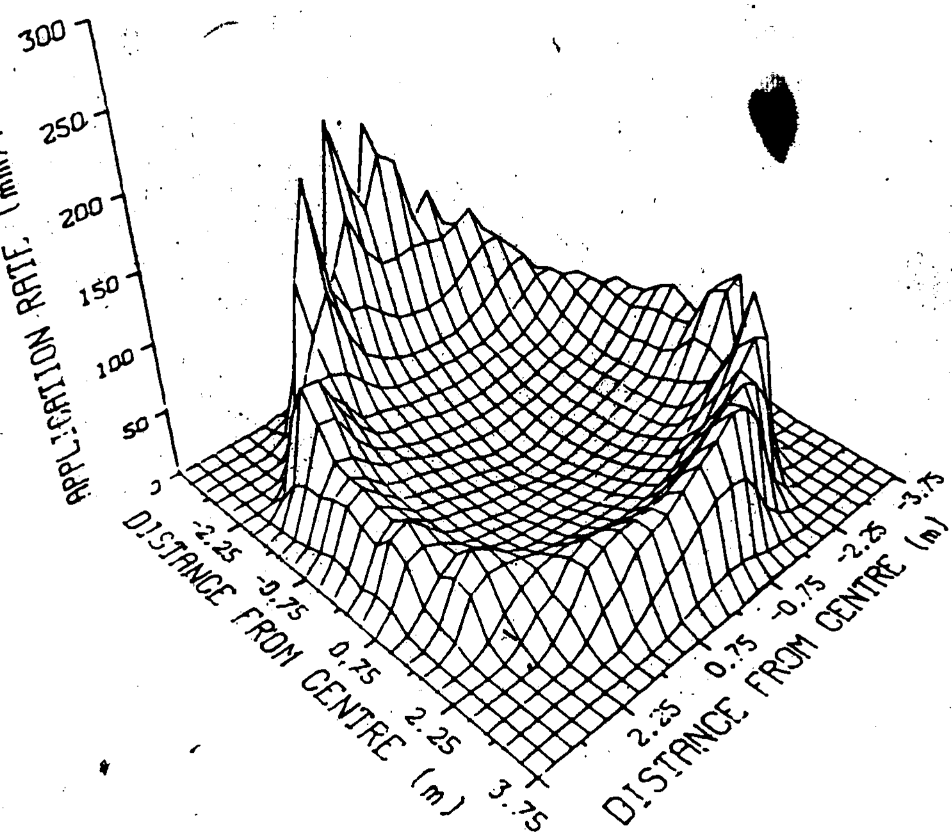


FIGURE III - 29. Distribution Profile of Nozzle RA 110/140 at 4.75 m Discharge Height.

SPRAY NOZZLE: RA 110/140 * TEST NUMBER: 30

LATERAL PRESSURE: 240 kPa CAN SPACING: 30 cm x 30 cm

NOZZLE HEIGHT: 4.75 m

NUMBER OF READINGS: 570

TOTAL OF READINGS: 20694.4 mm/h

MAXIMUM READING: 180.9 mm/h

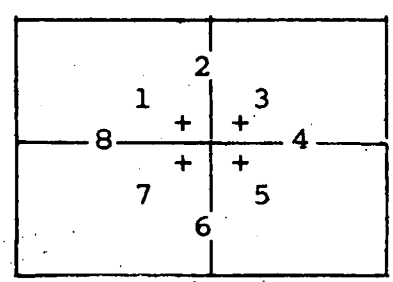
MEAN OF READINGS: 36.3 mm/h

STANDARD DEVIATION OF READINGS: 32.6 mm/h

CHRISTIANSEN'S UNIFORMITY COEFFICIENT FOR READINGS: 31.4%

COEFFICIENT OF VARIATION FOR READINGS: 90.0%

RADIAL LEG SCHEMATIC



RADIAL LEG NUMBER	MEAN mm/h	STANDARD DEVIATION mm/h
1)	25.3	24.8
2)	25.6	23.2
3)	23.8	21.0
4)	27.3	22.6
5)	20.8	15.1
6)	19.9	15.4
7)	34.4	35.3
8)	42.7	46.5

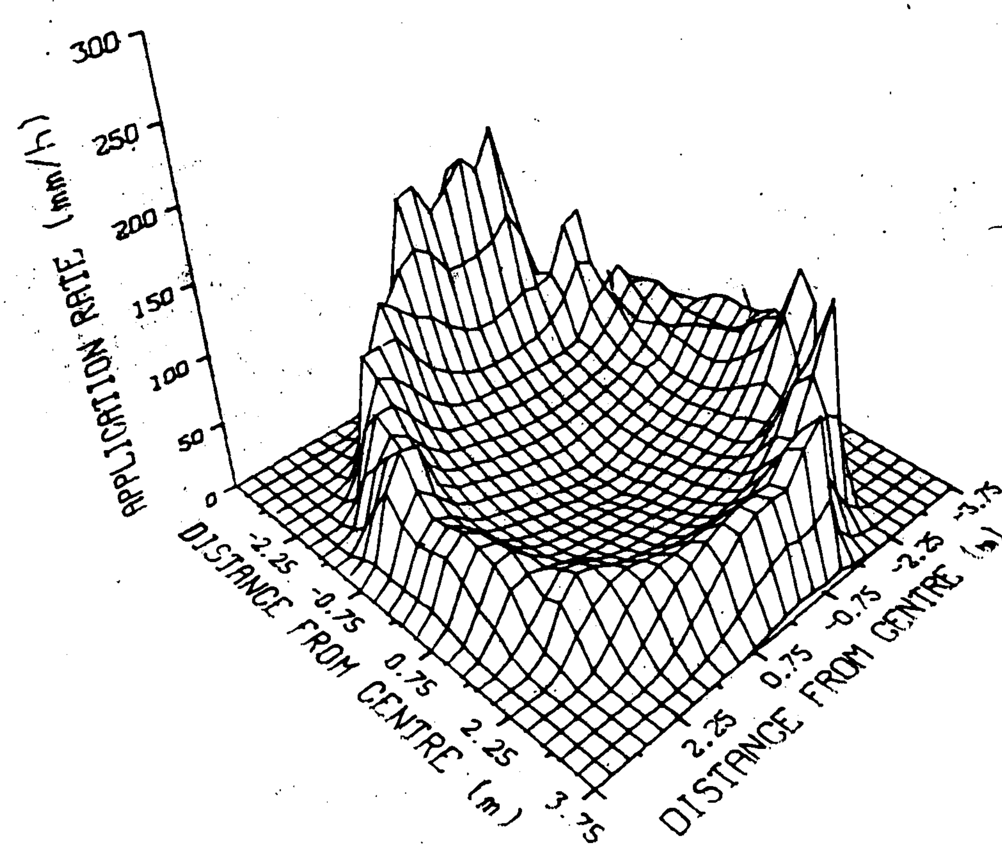


FIGURE III - 30. Distribution Profile of Nozzle RA 110/140* at 4.75 m Discharge Height.

APPENDIX IV

This appendix contains results of the field distribution uniformity measurements for the linear move system. Each test contains some information on the test conditions as well as a plot of the measured depths.

TEST NUMBER 1

DATE CANS FILLED .... July 25, 1980

DATE CANS EMPTIED .... July 25, 1980

TEST ROW LOCATION............... centre row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER . 140

TIMER SETTING 30%

SYSTEM SPEED .... 540 mm/min

TIME CANS RECEIVED WATER .... 20.8 min

TEMPERATURE .... 23°C

WIND DIRECTION .... south-west

WIND SPEED - MAXIMUM .... 12 km/h
MINIMUM .... 3 km/h
AVERAGE .... 7 km/h

AVERAGE APPLIED DEPTH .... 15.7 mm

AVERAGE APPLICATION RATE .... 45.3 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 79.6%

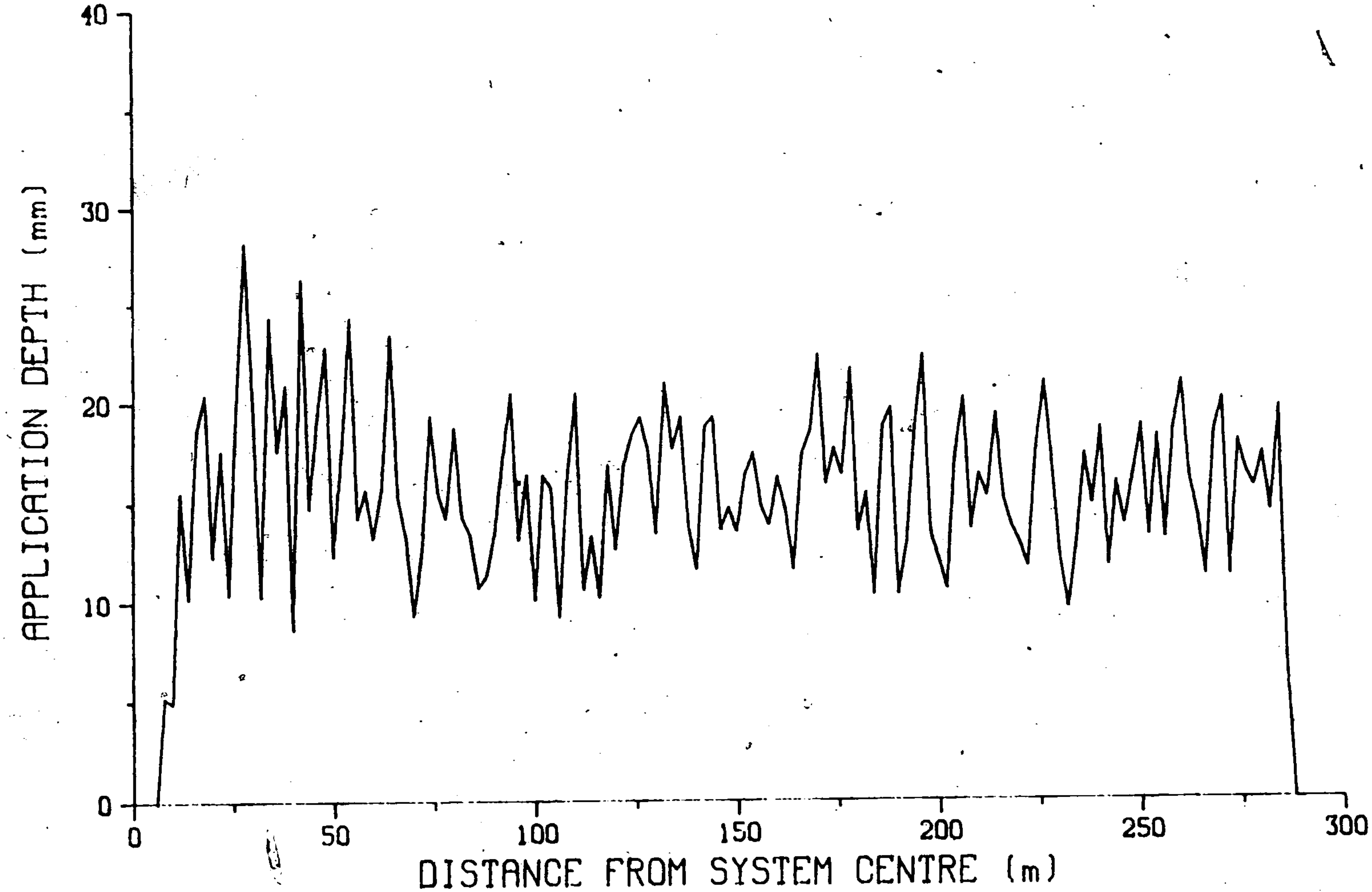


FIGURE IV - 1. Distribution of Application Depths for West Side of System - Test 1.

TEST NUMBER	2
DATE CANS FILLED	July 22, 1980
DATE CANS EMPTIED	July 22, 1980
TEST ROW LOCATION...............	north row - west side
CAN SPACING	2.0 m
NUMBER OF CANS RECEIVING WATER	139
TIMER SETTING	30%
SYSTEM SPEED	500 mm/min
TIME CANS RECEIVED WATER	22.0 min
TEMPERATURE	24°C
WIND DIRECTION	northwest
WIND SPEED - MAXIMUM	9 km/h
MINIMUM	0 km/h
AVERAGE	3 km/h
AVERAGE APPLIED DEPTH	16.3 mm
AVERAGE APPLICATION RATE	44.5 mm/h
UNIFORMITY COEFFICIENT (UCC) ...	80.1%

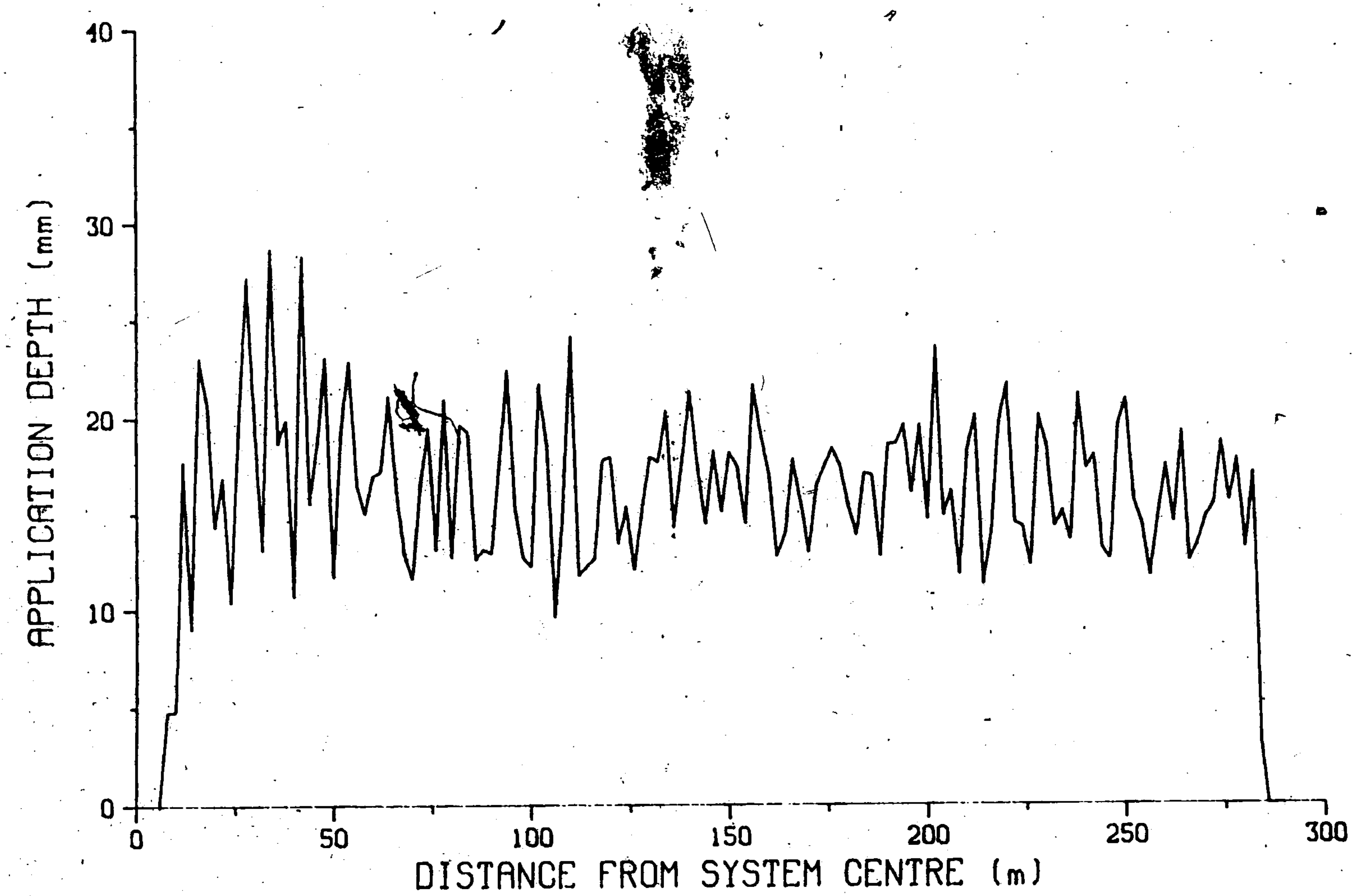


FIGURE IV - 2. Distribution of Application Depths for West Side of System - Test 2.

TEST NUMBER 3

DATE CANS FILLED .... October 10, 1980

DATE CANS EMPTIED .... October 10, 1980

TEST ROW LOCATION............... south row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 138

TIMER SETTING 40%

SYSTEM SPEED .... 660 mm/min

TIME CANS RECEIVED WATER .... 16.1 min

TEMPERATURE .... 14°C

WIND DIRECTION .... southeast

WIND SPEED - MAXIMUM .... 6 km/h
MINIMUM .... 0 km/h
AVERAGE .... 3 km/h

AVERAGE APPLIED DEPTH .... 13.4 mm

AVERAGE APPLICATION RATE .... 49.9 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 80.0%

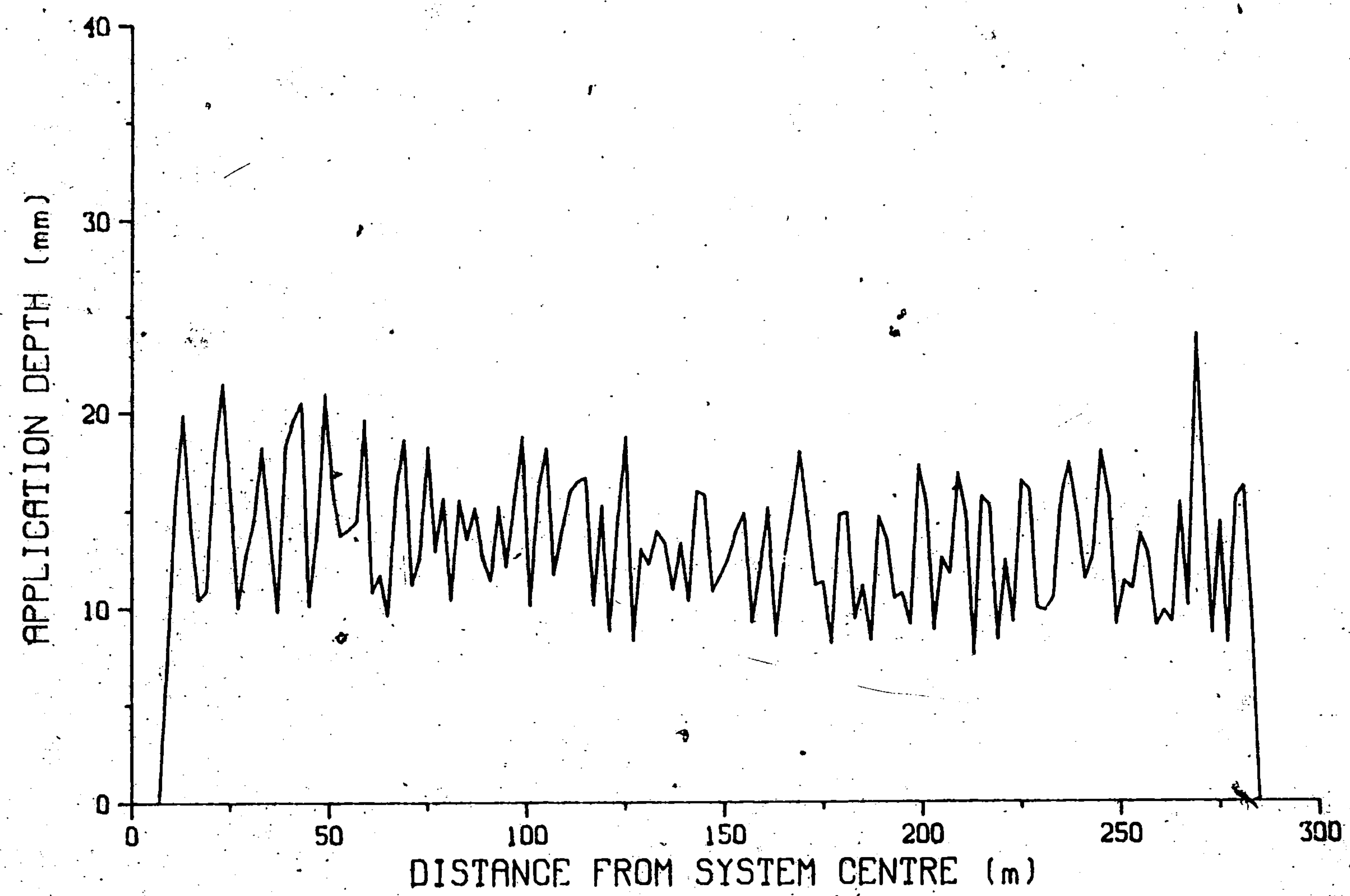


FIGURE IV - 3. Distribution of Application Depths for West Side of System - Test 3.

TEST NUMBER	4
DATE CANS FILLED	July 18, 1980
DATE CANS EMPTIED	July 18, 1980
TEST ROW LOCATION...............	centre row - west side
CAN SPACING	2.0 m
NUMBER OF CANS RECEIVING WATER	139
TIMER SETTING	40%
SYSTEM SPEED	690 mm/min
TIME CANS RECEIVED WATER	15.8 min
TEMPERATURE	25°C
WIND DIRECTION	northwest
WIND SPEED - MAXIMUM	13 km/h
MINIMUM	4 km/h
AVERAGE	8 km/h
AVERAGE APPLIED DEPTH	12.0 mm
AVERAGE APPLICATION RATE	45.6 mm/h
UNIFORMITY COEFFICIENT (UCC) ...	74.4%

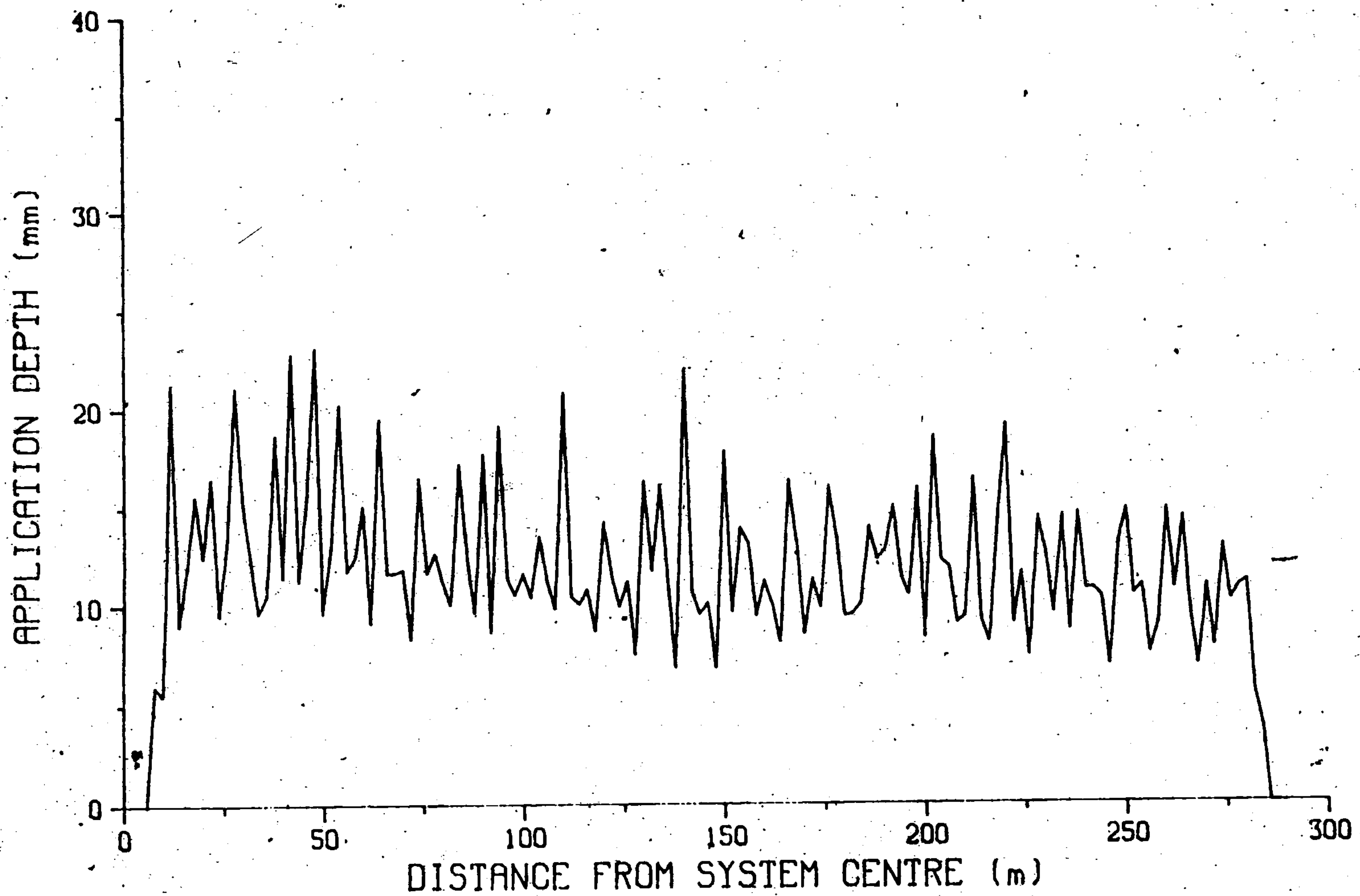


FIGURE IV - 4. Distribution of Application Depths for West Side of System - Test 4.

TEST NUMBER 5

DATE CANS FILLED .... July 24, 1980

DATE CANS EMPTIED .... July 25, 1980

TEST ROW LOCATION............... centre row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 140

TIMER SETTING 50%

SYSTEM SPEED .... 860 mm/min

TIME CANS RECEIVED WATER .... -- min

TEMPERATURE .... 23°C

WIND DIRECTION .... west

WIND SPEED - MAXIMUM .... 15 km/h
MINIMUM .... 4 km/h
AVERAGE .... 9 km/h

AVERAGE APPLIED DEPTH .... 11.5 mm

AVERAGE APPLICATION RATE .... -- mm/h

UNIFORMITY COEFFICIENT (UCC) ... 77.5%

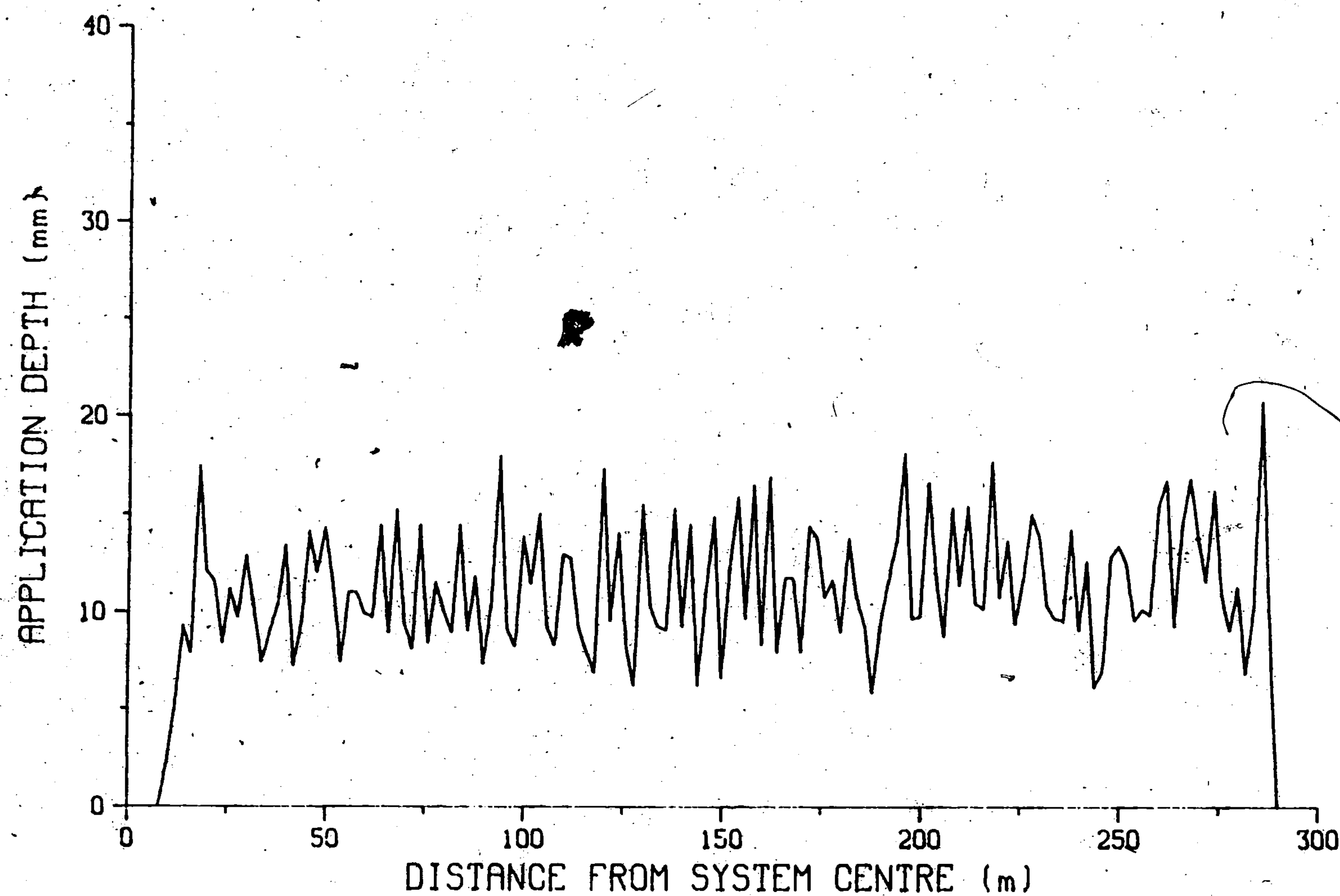


FIGURE IV - 5. Distribution of Application Depths for West Side of System - Test 5.

TEST NUMBER 6

DATE CANS FILLED .... July 22, 1980

DATE CANS EMPTIED .... July 22, 1980

TEST ROW LOCATION............... north row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 140

TIMER SETTING 50%

SYSTEM SPEED .... 820 mm/min

TIME CANS RECEIVED WATER .... 13.7 min

TEMPERATURE ....

WIND DIRECTION .... northwest

WIND SPEED - MAXIMUM .... 9 km/h
MINIMUM .... 2 km/h
AVERAGE .... 6 km/h

AVERAGE APPLIED DEPTH .... 12.9 mm

AVERAGE APPLICATION RATE .... 56.5 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 76.7%

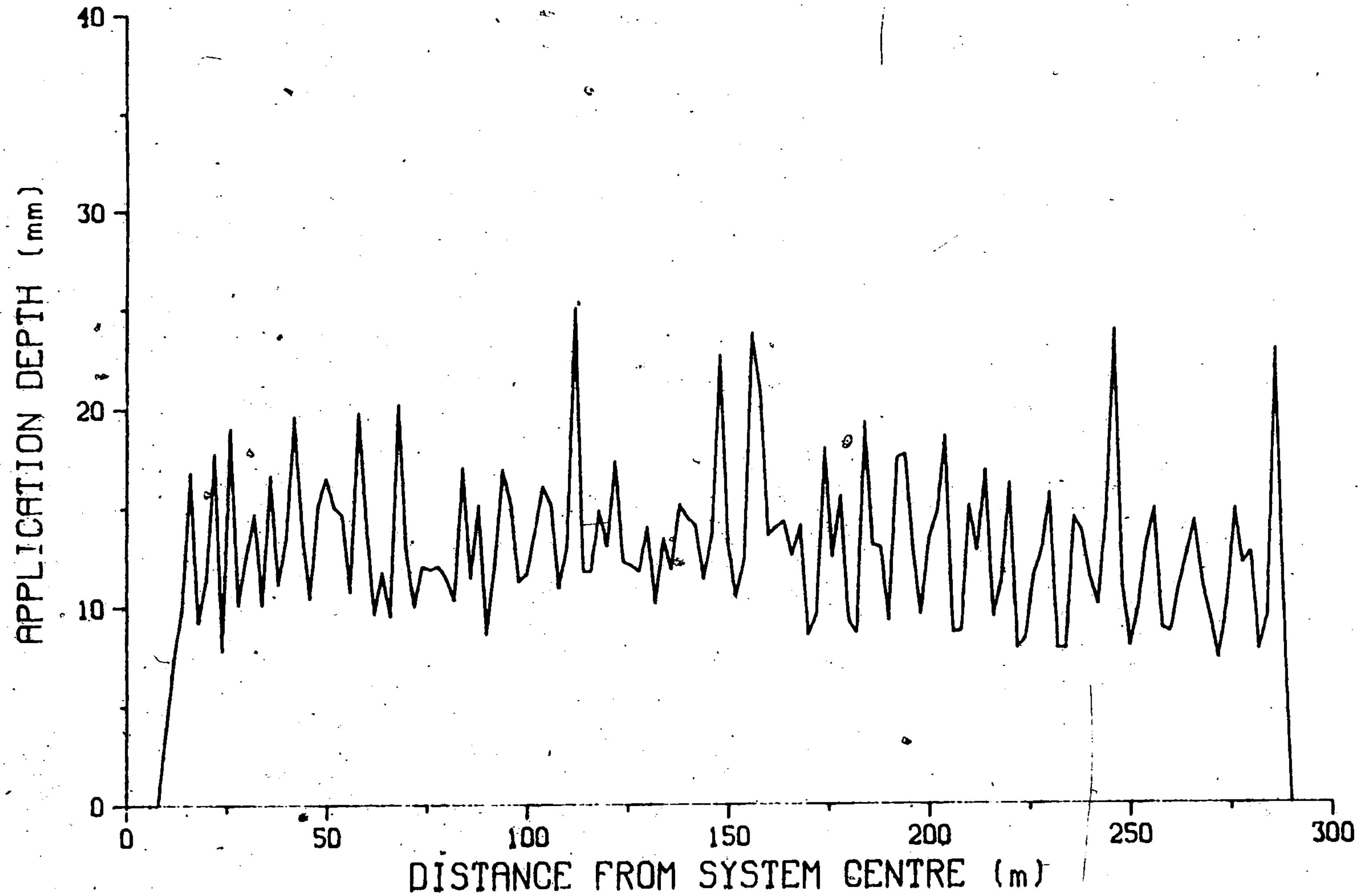


FIGURE IV - 6. Distribution of Application Depths for West Side of System - Test 6.

TEST NUMBER 7

DATE CANS FILLED .... July 25, 1980

DATE CANS EMPTIED .... July 25, 1980

TEST ROW LOCATION............... centre row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 139

TIMER SETTING 60%

SYSTEM SPEED .... 1080 mm/min

TIME CANS RECEIVED WATER .... 10.8 min

TEMPERATURE .... 21°C

WIND DIRECTION .... southwest

WIND SPEED - MAXIMUM .... 12 km/h
MINIMUM .... 3 km/h
AVERAGE .... 6 km/h

AVERAGE APPLIED DEPTH ....9.7 mm

AVERAGE APPLICATION RATE .... 53.9 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 76.3%

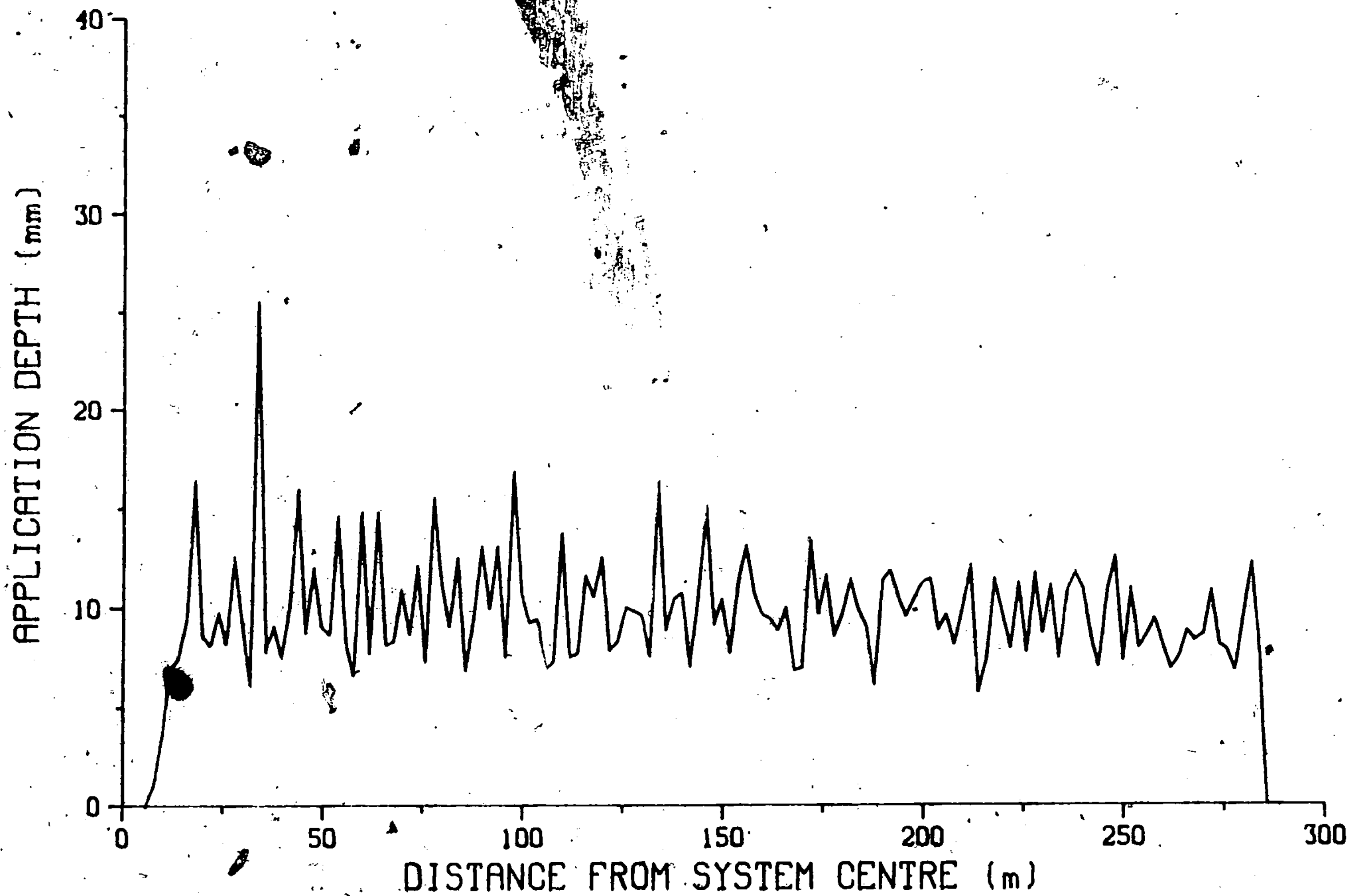


FIGURE IV - 7. Distribution of Application Depths for West Side of System - Test 7.

TEST NUMBER 8

DATE CANS FILLED .... July 25, 1980

DATE CANS EMPTIED .... July 25, 1980

TEST ROW LOCATION............... centre row - west side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 138

TIMER SETTING 60%

SYSTEM SPEED .... 1090 mm/min

TIME CANS RECEIVED WATER .... 10.1 min

TEMPERATURE .... 23°C

WIND DIRECTION .... southwest

WIND SPEED - MAXIMUM .... 13 km/h
MINIMUM .... 4 km/h
AVERAGE .... 8 km/h

AVERAGE APPLIED DEPTH .... 9.1 mm

AVERAGE APPLICATION RATE .... 54.1 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 79.3%

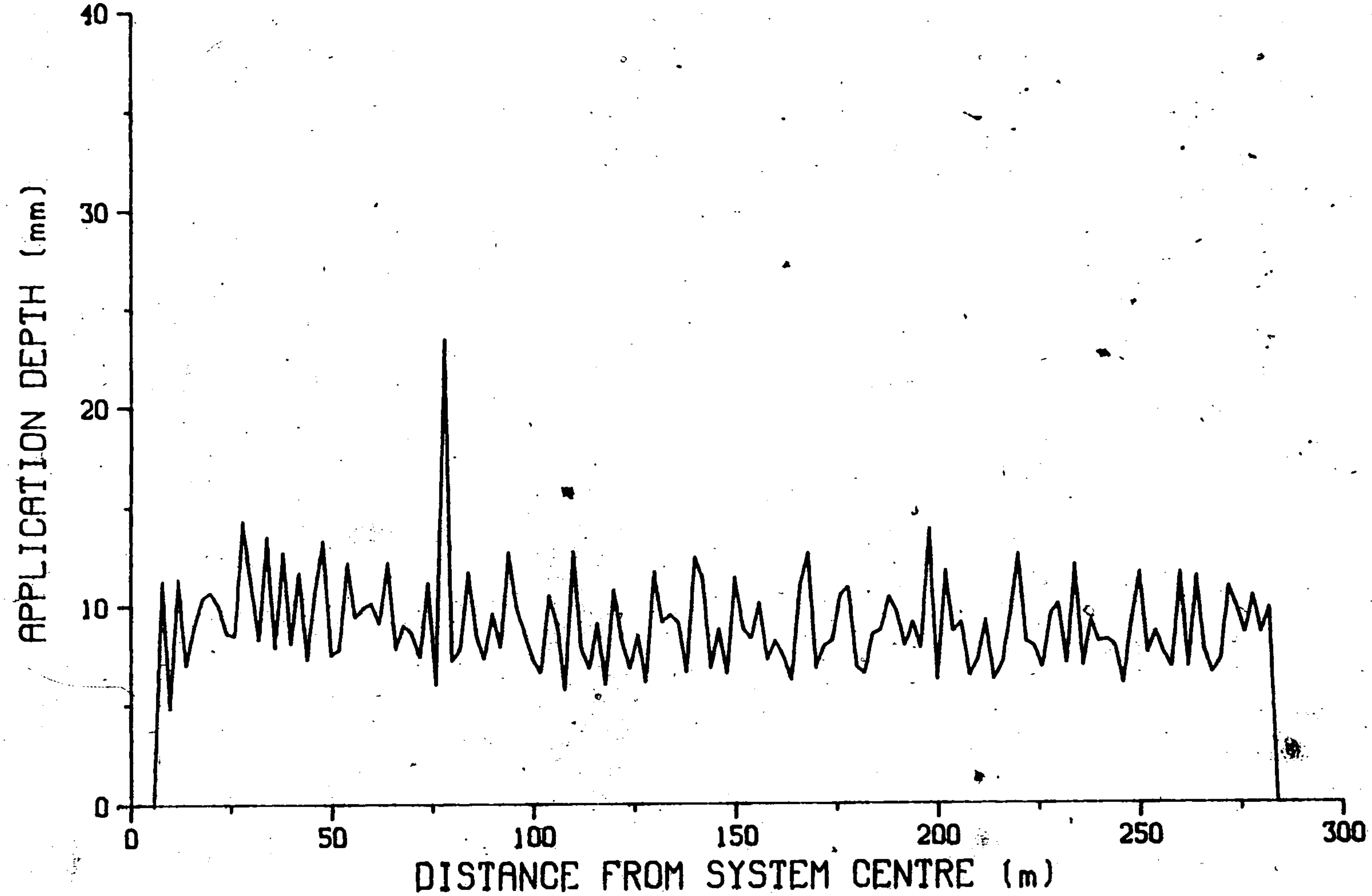


FIGURE IV - 8. Distribution of Application Depths for West Side of System - Test 8.

TEST NUMBER	9
DATE CANS FILLED	July 31, 1980
DATE CANS EMPTIED	July 31, 1980
TEST ROW LOCATION...............	north row - east side
CAN SPACING	2.0 m
NUMBER OF CANS RECEIVING WATER	143
TIMER SETTING	30%
SYSTEM SPEED	450 mm/min
TIME CANS RECEIVED WATER	25.8 min
TEMPERATURE	28°C
WIND DIRECTION	west
WIND SPEED - MAXIMUM	13 km/h
MINIMUM	5 km/h
AVERAGE	9 km/h
AVERAGE APPLIED DEPTH	19.9 mm
AVERAGE APPLICATION RATE	46.3 mm/h
UNIFORMITY COEFFICIENT (UCC) ...	73.0%

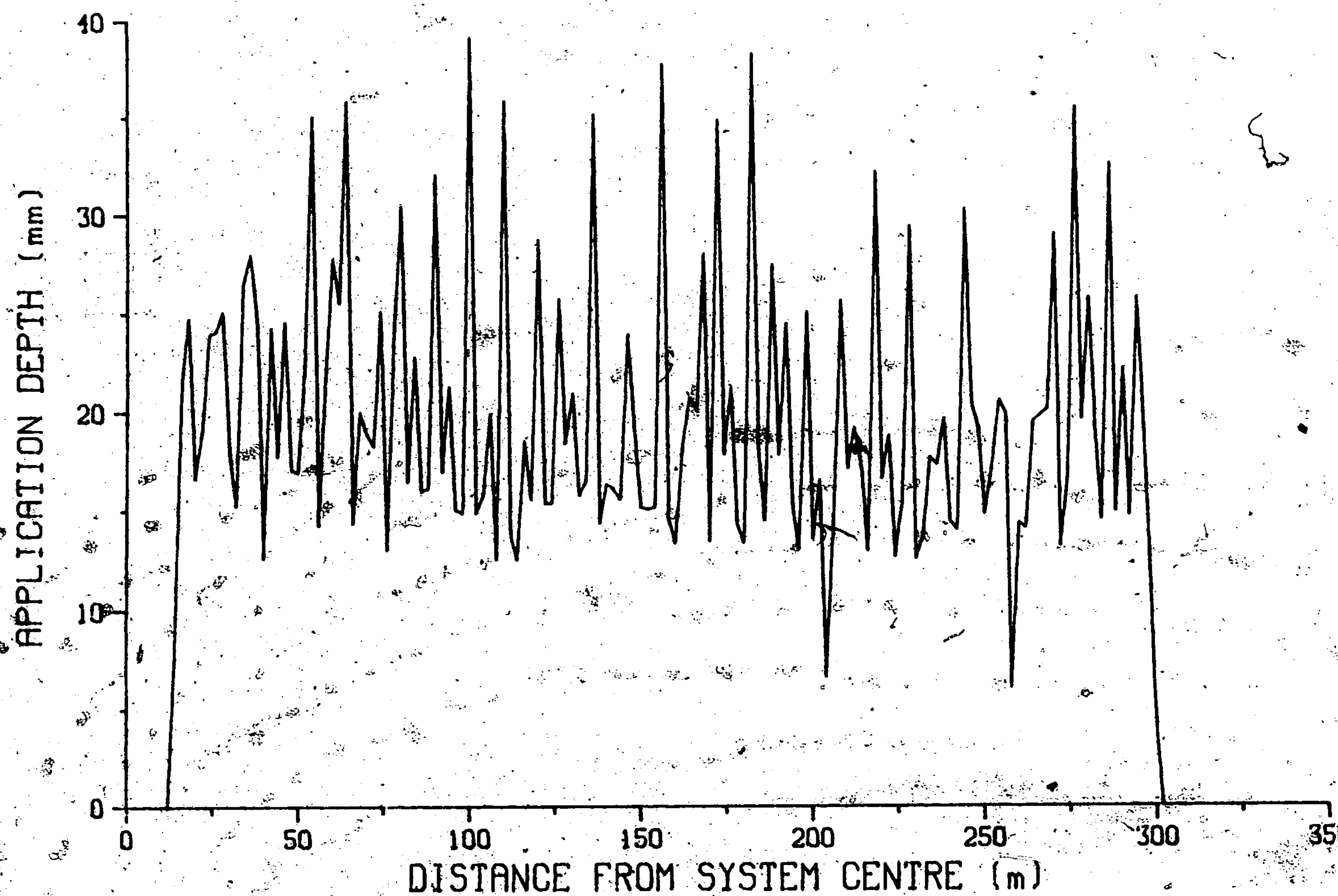


FIGURE IV - 9. Distribution of Application Depths for East Side of System - Test 9.

TEST NUMBER 10

DATE CANS FILLED .... August 1, 1980

DATE CANS EMPTIED .... August 2, 1980

TEST ROW LOCATION................. north row - east side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 143

TIMER SETTING 30%

SYSTEM SPEED .... 480 mm/min

TIME CANS RECEIVED WATER .... -- min

TEMPERATURE .... 24°C

WIND DIRECTION .... southwest

WIND SPEED - MAXIMUM .... 18 km/h
MINIMUM .... 3 km/h
AVERAGE .... 10 km/h

AVERAGE APPLIED DEPTH .... 17.1 mm

AVERAGE APPLICATION RATE .... -- mm/h

UNIFORMITY COEFFICIENT (UCC) 73.5%

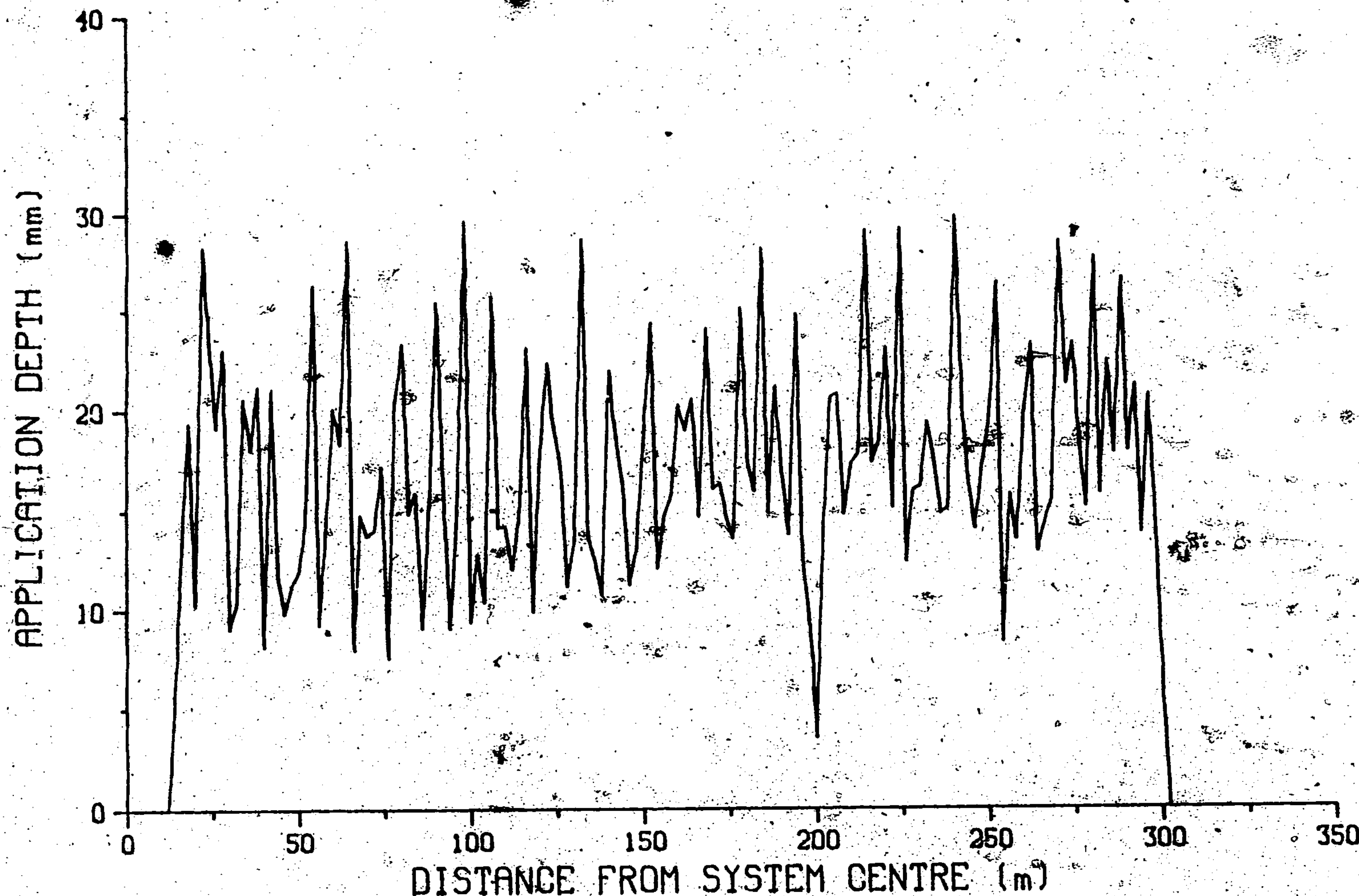


FIGURE IV - 10. Distribution of Application Depths for East Side of System - Test 10.

TEST NUMBER	11
DATE CANS FILLED	July 21, 1980
DATE CANS EMPTIED	July 21, 1980
TEST ROW LOCATION..................	north row - east side
CAN SPACING	2.0 m
NUMBER OF CANS RECEIVING WATER	143
TIMER SETTING	40%
SYSTEM SPEED	670 mm/min
TIME CANS RECEIVED WATER	16.0 min
TEMPERATURE	25°C
WIND DIRECTION	southwest
WIND SPEED - MAXIMUM	14 km/h
MINIMUM	5 km/h
AVERAGE	8 km/h
AVERAGE APPLIED DEPTH	13.0 mm
AVERAGE APPLICATION RATE	48.8 mm/h
UNIFORMITY COEFFICIENT (UCC) ...	74.4%

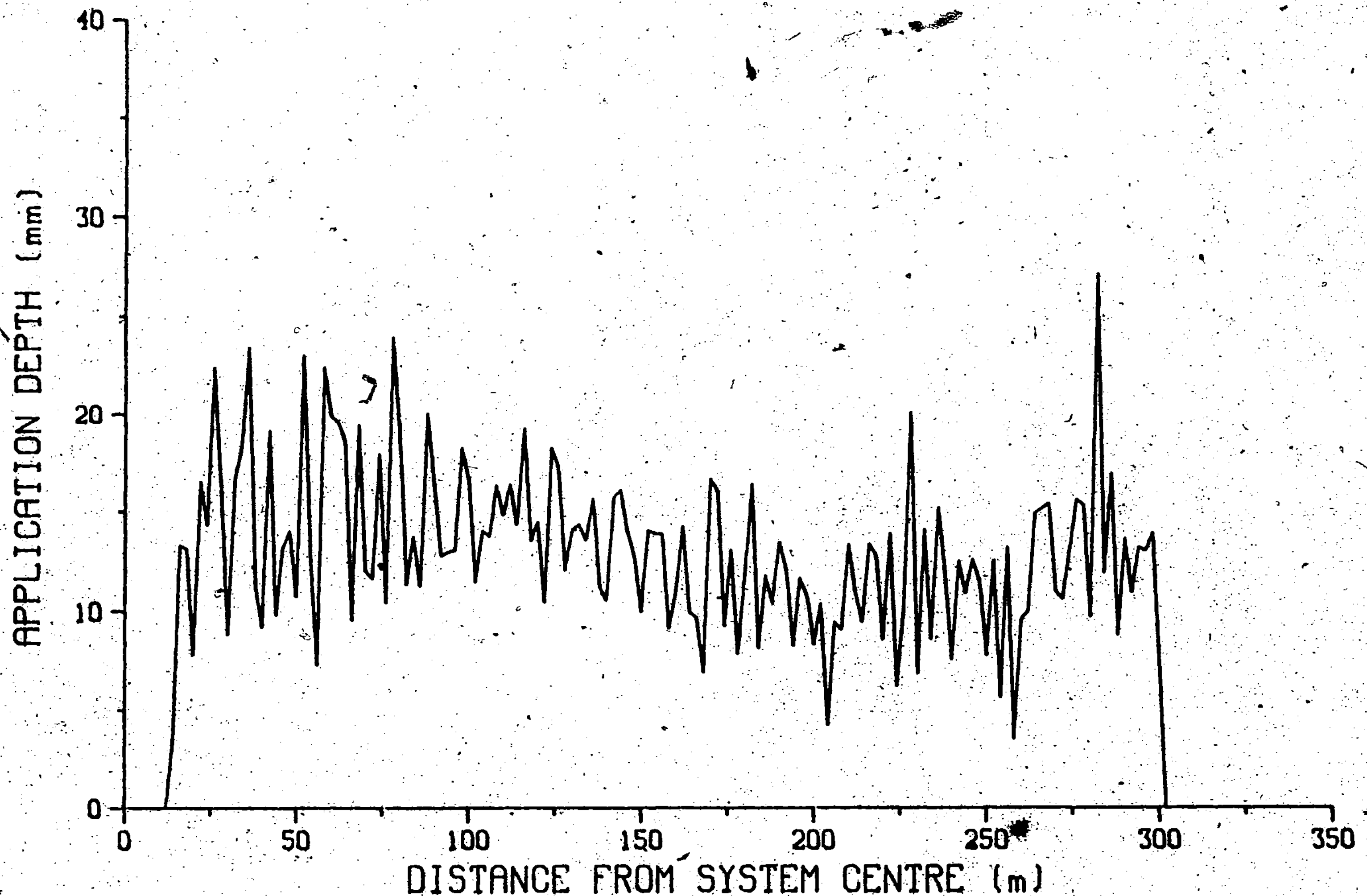


FIGURE IV - 11. Distribution of Application Depths for East Side of System - Test 11.

TEST NUMBER 12

DATE CANS FILLED .... July 30, 1980

DATE CANS EMPTIED .... July 30, 1980

TEST ROW LOCATION............... centre row - east side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 144

TIMER SETTING 40%

SYSTEM SPEED .... 710 mm/min

TIME CANS RECEIVED WATER .... 15.4 min

TEMPERATURE .... 26°C

WIND DIRECTION .... southwest

WIND SPEED - MAXIMUM .... 16 km/h
MINIMUM .... 5 km/h
AVERAGE .... 12 km/h

AVERAGE APPLIED DEPTH .... 11.8 mm

AVERAGE APPLICATION RATE .... 46.0 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 73.0%

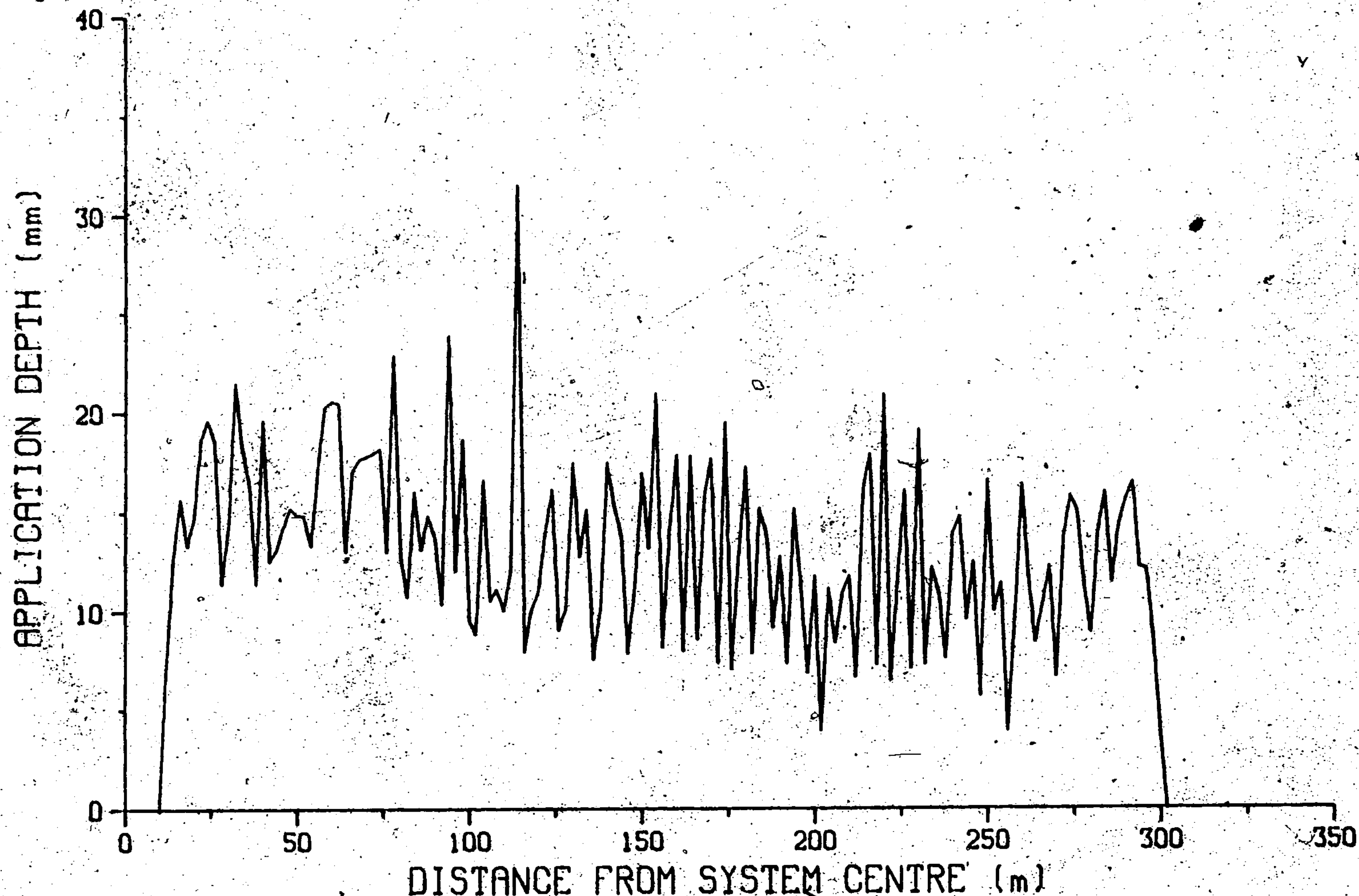


FIGURE IV - 12. Distribution of Application Depths for East Side of System - Test 12.

TEST NUMBER 13

DATE CANS FILLED .... July 30, 1980

DATE CANS EMPTIED .... July 30, 1980

TEST ROW LOCATION................ centre row - east side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 143

TIMER SETTING 50%

SYSTEM SPEED .... 830 mm/min

TIME CANS RECEIVED WATER .... 13.0 min

TEMPERATURE .... 26°C

WIND DIRECTION .... southwest

WIND SPEED - MAXIMUM .... 14 km/h
MINIMUM .... 5 km/h
AVERAGE .... 10 km/h

AVERAGE APPLIED DEPTH .... 11.8 mm

AVERAGE APPLICATION RATE .... 54.5 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 73.0%

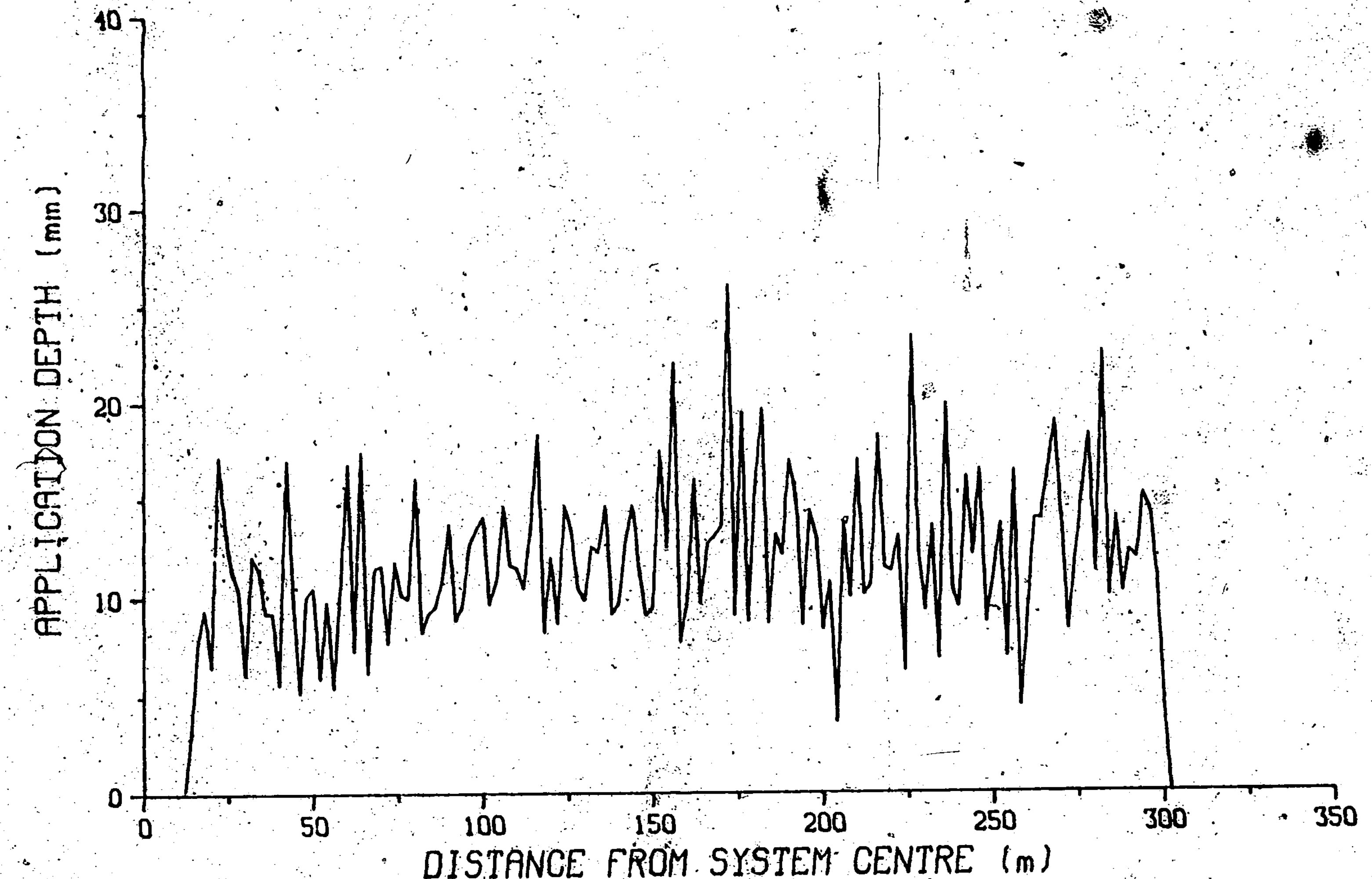


FIGURE IV - 13. Distribution of Application Depths for East Side of System - Test 13.

TEST NUMBER 14

DATE CANS FILLED .... July 31, 1980

DATE CANS EMPTIED .... July 31, 1980

TEST ROW LOCATION............... north row - east side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 143

TIMER SETTING 50%

SYSTEM SPEED .... 820 mm/min

TIME CANS RECEIVED WATER .... 13.2 min

TEMPERATURE .... 26°C

WIND DIRECTION .... northwest

WIND SPEED - MAXIMUM .... 9 km/h
MINIMUM .... 3 km/h
AVERAGE .... 5 km/h

AVERAGE APPLIED DEPTH .... 12.8 mm

AVERAGE APPLICATION RATE .... 58.2 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 74.1%

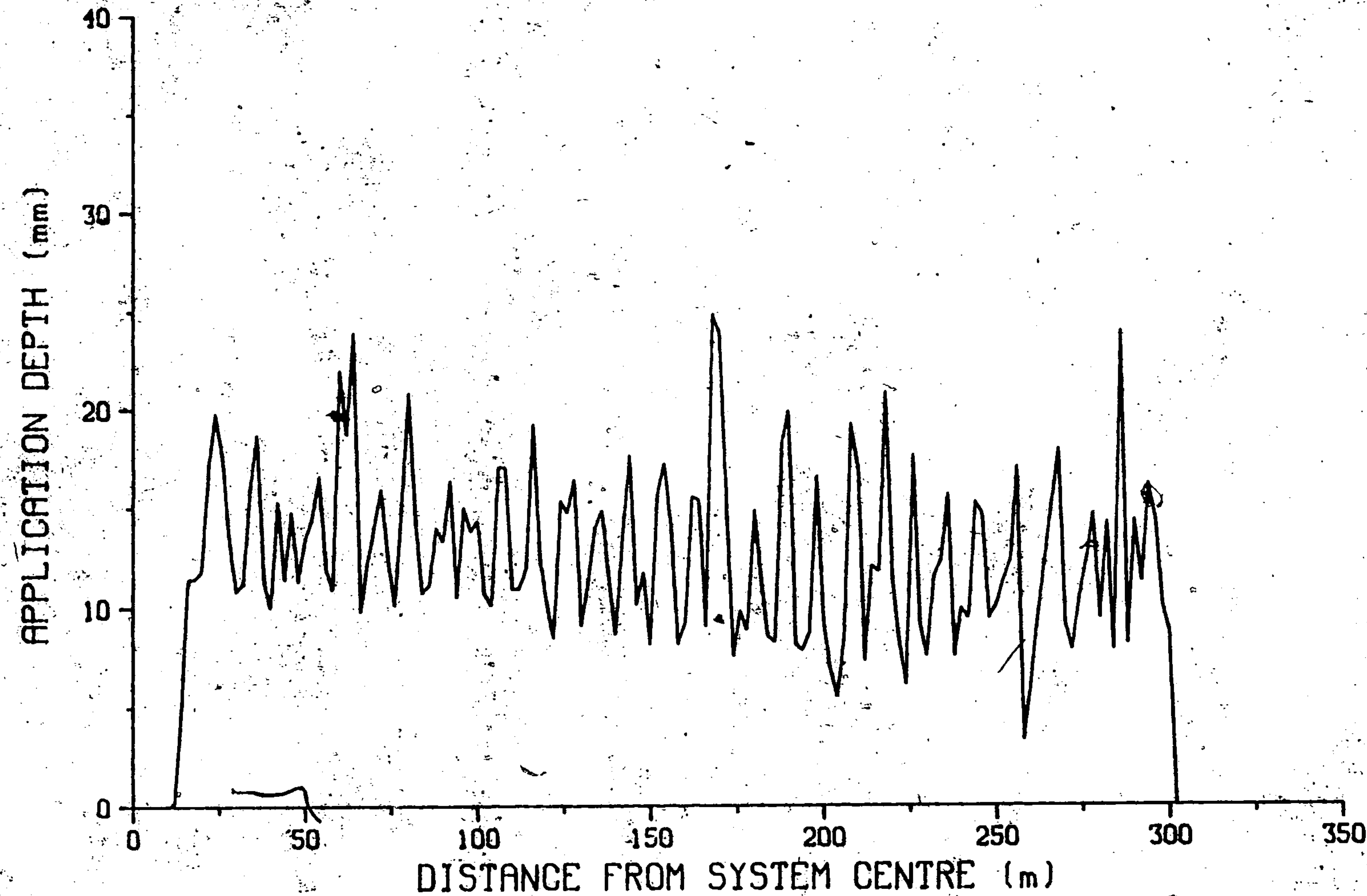


FIGURE IV - 14. Distribution of Application Depths for East Side of System - Test 14.

TEST NUMBER 15

DATE CANS FILLED .... July 29, 1980

DATE CANS EMPTIED .... July 29, 1980

TEST ROW LOCATION............... south row - east side

CAN SPACING .... 2.0 m

NUMBER OF CANS RECEIVING WATER 143

TIMER SETTING 60%

SYSTEM SPEED .... 1110 mm/min

TIME CANS RECEIVED WATER .... 9.6 min

TEMPERATURE .... 25°C

WIND DIRECTION .... west

WIND SPEED - MAXIMUM .... 18 km/h
MINIMUM .... 6 km/h
AVERAGE .... 13 km/h

AVERAGE APPLIED DEPTH .... 8.3 mm

AVERAGE APPLICATION RATE .... 51.9 mm/h

UNIFORMITY COEFFICIENT (UCC) ... 79.0%

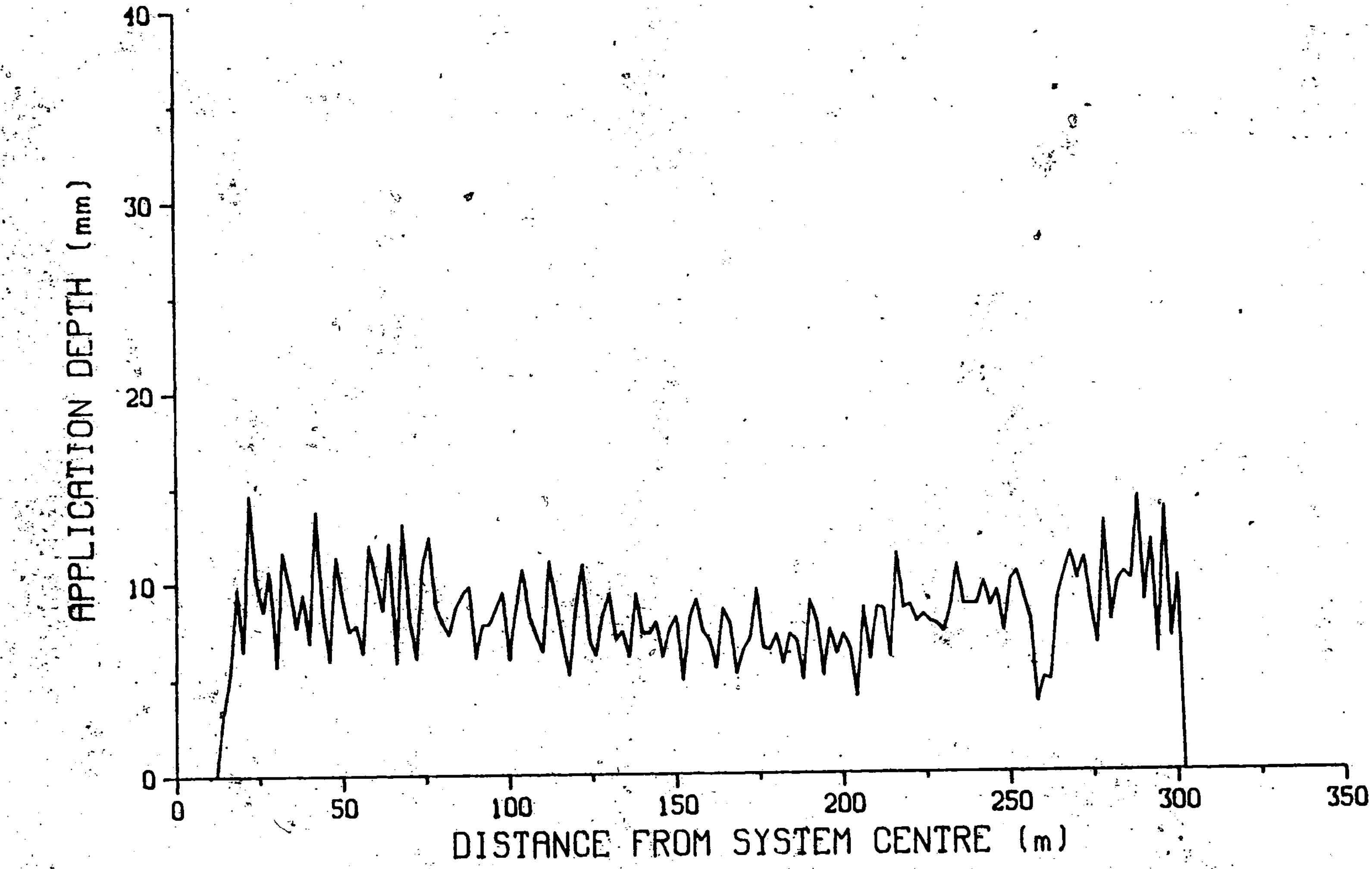


FIGURE IV - 15. Distribution of Application Depths for East Side of System - Test 15.