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SPRINKLER SYSTEM DISTRIBUTION EVALUATION USING THE SUPERIMPOSED METHOD

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AUGUST, 1971

SPRINKLER SYSTEM DISTRIBUTION EVALUATION USING THE "SUPERIMPOSED METHOD

INTRODUCTION:

Coefficient of uniformity (C_u) is the term used to evaluate how evenly water is distributed from sprinklers. Small cans are placed within a square (or grid) of 4 sprinklers, or within the triangle of 3 sprinklers, depending upon whether a square or triangle spacing of sprinklers is used, and the amount of water collected in each can is used to calculate the C_u. The cans are placed on a 10 foot grid one at each corner of the 10 ft grid, or one in the center of each grid.

The C_u is a percentage, determined as explained latter.

TESTING A SPRINKLER SYSTEM IN OPERATION:

To test a sprinkler system in operation cans are placed between two sprinklers on the line as shown in Fig 1. In this test cans are normally placed at the center of the 10 foot grids. A sufficient number of cans must be used to assure that no water falls beyond the cans.

Superimposing the Can-Catch Data *

The number of rows of cans depends upon the sprinkler spacing on the lateral. Thus Fig 1 with 5 rows of cans would be for a 50 ft sprinkler spacing.

The lines of cans to superimpose depends upon the distance the sprinkler lateral is moved. Fig 2 is an example of how to determine the lines to superimpose if the lateral is moved 40 ft each time.

* "Can-Catch" is a term used to mean the amount of water caught in the cans.

Fig 1 Grid System for Placement of Cans between Two Sprinklers

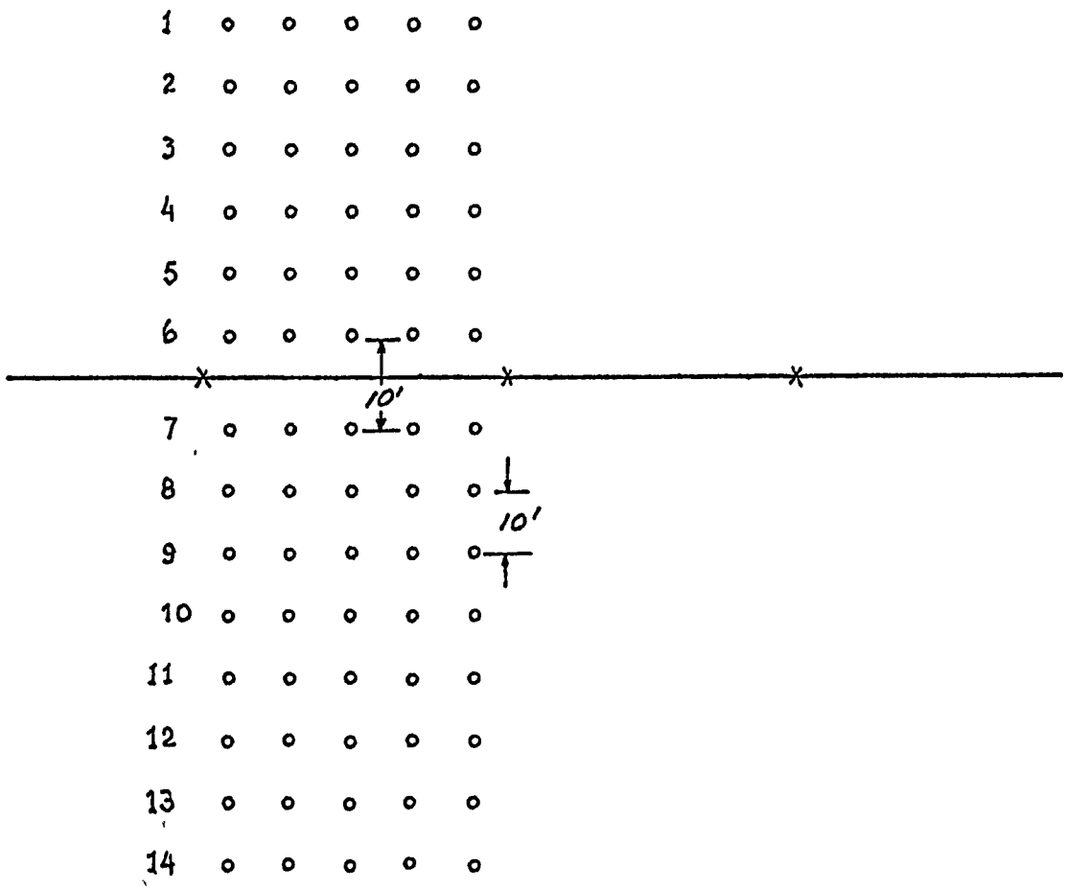
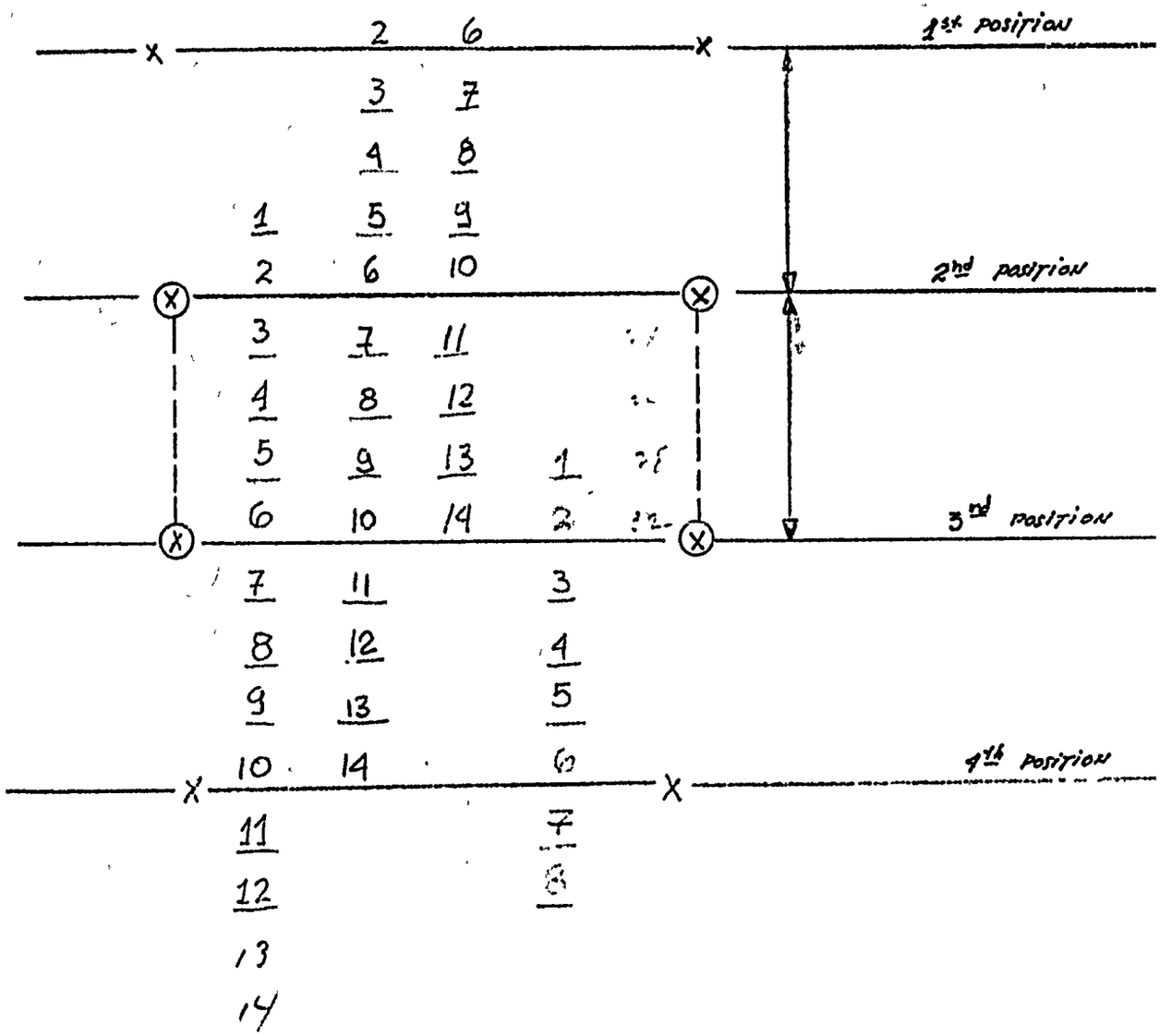


Figure 2: The lines of cans, from Fig 1, to add together to determine the water falling, within a rectangle for a 40 ft lateral move.



The first position of the sprinkler lateral is shown in red and the water falling within the rectangle would be collected in cans from lines 11, 12, 13 and 14. The water falling within the rectangle from the second position, shown in blue, would be collected in cans from lines 7, 8, 9 and 10, from the third position, shown in black in cans from lines 3, 4, 5 and 6 and from the fourth position, shown in green from 1 and 2.

Thus from Fig's 1 and 2 the lines of cans to add together for a 40 feet lateral spacing would be:

1, 5, 9, 13

2, 6, 10 14

3, 7, 11, 15

4, 8, 12, 16

A diagram similar to Fig 2 can be constructed for any lateral spacing and Fig 3 shows the lines which would be added together for a 20, 30, 40, 50 or 60 lateral move.

Fig. 3 Lines of Cans To Be Added Together for Different Lateral Spacing

20 Foot Spacing

1, 3, 5, 7, 9, 11, 13, 15

2, 4, 6, 8, 10, 12, 14, 16

30 Foot Spacing

1, 4, 7, 10, 13, 16

2, 5, 8, 11, 14, 17

3, 6, 9, 12, 15, 18

60 Foot Spacing

1, 7, 13, 19

2, 8, 14, 20

3, 9, 15, 21

4, 10, 16, 22

5, 11, 17, 23

6, 12, 18, 24

50 Foot Spacing

1, 6, 11, 16

2, 7, 12, 17

3, 8, 13, 18

4, 9, 14, 19

5, 10, 15, 20

40 Foot Spacing

1, 5, 9, 13

2, 6, 10, 14

3, 7, 11, 15

4, 8, 12, 16

This method reduces the time and effort to collect the necessary water. To obtained good results all measurements must be accurate.

The water collected in the cans is usually measured with a graduated cylinder and converted to inches or centimeters of depth.

Appendix A Fig's 9 through 19 show the field data collected and the evaluations for different sprinkler lateral spacing. The test was made on August 19, 1971 in the Zapotitan Valley, El Salvador.

Fig 9 is the test data and Fig 10 is the distribution pattern.

DETERMINING THE COEFFICIENT OF UNIFORMITY

The coefficient of Uniformity (C_u) is the most commonly used statistical method for evaluating sprinkler system preformance. The C_u is a percentage from) - 100% however, any value less than 80% generally indicates poor uniformity.

The water caught in the cans is plotted as shown in Fig 10 and the appropriate can lines are added together to determine the total amount of water applied at each point for any given spacing (See Fig 3).

The formula for determining the C_u is as follows:

$$C_u = 100 \left(1.0 - \frac{\bar{x}}{mn}\right)$$

When:

C_u = coefficient of uniformity

XX = difference between individual observations and the mean observation.

$\bar{x}$ = Sum of all the x differences

M = Mean value (observation)

N = Number of observation points

CALCULATIONS FOR C_u

The calculations for the field test of 19 August are shown in Fig's 11, 12 and 13 for a 40, 50 and 60 ft sprinkler lateral spacing. Thus - from one set of field data the best spacing can be determined. The results of this test shown that a 40 x 40 ft spacing gave a C_u of 93.88% 40x50 ft gave 92.8% and 40x60 83.6%. Either the 40x40 or the 40x50 spacing would give good results.

These tests were conducted under conditions of no wind. Windy conditions would affect the C_u and perhaps a different spacing would be necessary.

Fig's 14, 15 and 16 show contour lines of equal distribution of water from the three spacing.

Additional information, in Fig'4, 5 and 6 is the percent of water applied to each 10 x 10 ft area. Note that with the 40 x 40 ft spacing 37.5% of the area received less than 100% of the water applied. The 40 x 50 spacing had 45% of the area receiving less than 100% of water applied and the 40 x 60 spacing had 54.2% receiving less than 100% of water applied. The calculations are shown in the appendices Fig's 17 and 18 and 19.

Fig A Percent of Water Applied to Each Area. 40 x 40 Spacing

% of Area	Receiving less than % of water applied
6.25 %	85 %
18.75 %	90 %
25.0 %	95 %
37.5 %	100 %
87.5 %	105 %
87.5 %	110 %
	115 %

Fig 5. Percent of Water Applied to Each Area. 40 x 50 Spacing

% of Area	Receiving less than % of water applied
25 %	90 %
45 %	100 %
75 %	105 %
85 %	110 %
100 %	115 %

Fig 6. Percent of Water Applied to Each Area. 40 x 60 Spacing.

% of Area	Receiving less than % of Water Applied
100 %	140 %
95.9 %	130 %
87.5 %	125 %
79.2 %	120 %
70.9 %	115 %
66.7 %	110 %
62.6 %	105 %
54.2 %	100 %
41.7 %	95 %
25.0 %	90 %
20.9 %	80 %
12.5 %	75 %
4.2 4.2 %	65 %

CALCULATING C_u FROM A SINGLE SPRINKLER TEST

It is also possible to calculate C_u from the water collected in cans from a single sprinkler. The advantages are that any combination of sprinkler spacing or line spacing can be used to calculate and determine C_u.

Field tests Nos. 15, 18, 27, 29, 46 and 47 conducted by Mike Monahan and Lanny graduate students from Utah State University are shown in appendix B as Fig's 20 through 37.

Using test No. 29 as an example the calculations are as follows: The distribution pattern is divided into 4 querter-sections, N.W. - N.E. S.W. and E.S. as shown in Fig 7. In Fig 8 a rectangle is drawn on a 40 x 40 ft spacing. The S.W. quarter-section of Fig 7 is then placed with the sprinkler in the upper right hadd corner of the rectangle and the water collected in the cans within the rectangle is recorded as shown in black. The querter-section is then placed on all other positions which affect the rectangle. First it is placed directly above with the figures shown in blue, then to the right with the figures shown in red and then to the upper-right wiht the figures shown in green. Other positions above and to the right which might affect the designated rectangle must also be considered. None of the water from the green area reach the rectangle. Note that the cans for these tests are located on a 10 ft grid, starting at the sprinkler.

In a like manner the N.W., N.E. and S.E. quarter-section would need to be placed on Fig 8 and the cans of water which fall within the rectangle added. The water collected in a 40' x 40 ft spacing is shown in Fig 37 and the calculations for C_u, done in a slightly different manner are shown in Fig 38.

In Fig's 39 through 44 the calculations for a 40 x 50 ft spacing, a 40 x 60 ft spacing and a 30 x 50 ft spacing from test No. 29 are given. The C_u for each spacing is:

Spacing	C_u
40 x 40 ft	84.4 %
40 x 50 ft	81.1 %
40 x 60 ft	72.0 %
30 x 50 ft	85.9 %

In Fig's 45 thrpugh 52 the calculations for different tests and spacing are:

Test No.	Spacing	C_u
18	40 x 40 ft	90.7 %
46	30 x 50 ft	80.3 %
46	30 x 40 ft	91.7 %
46	40 x 50 ft	80.3 %

These results show the importance of choosing the correct spacing for a sprinkler depending upon the operating caondtions.

Fig. 7 DISTRIBUTION PATTERN FROM FIELD TEST No. 29 29 AUGUST, 1971

RAINBIRD No. 30 E WITH 7/32 NOZZLE

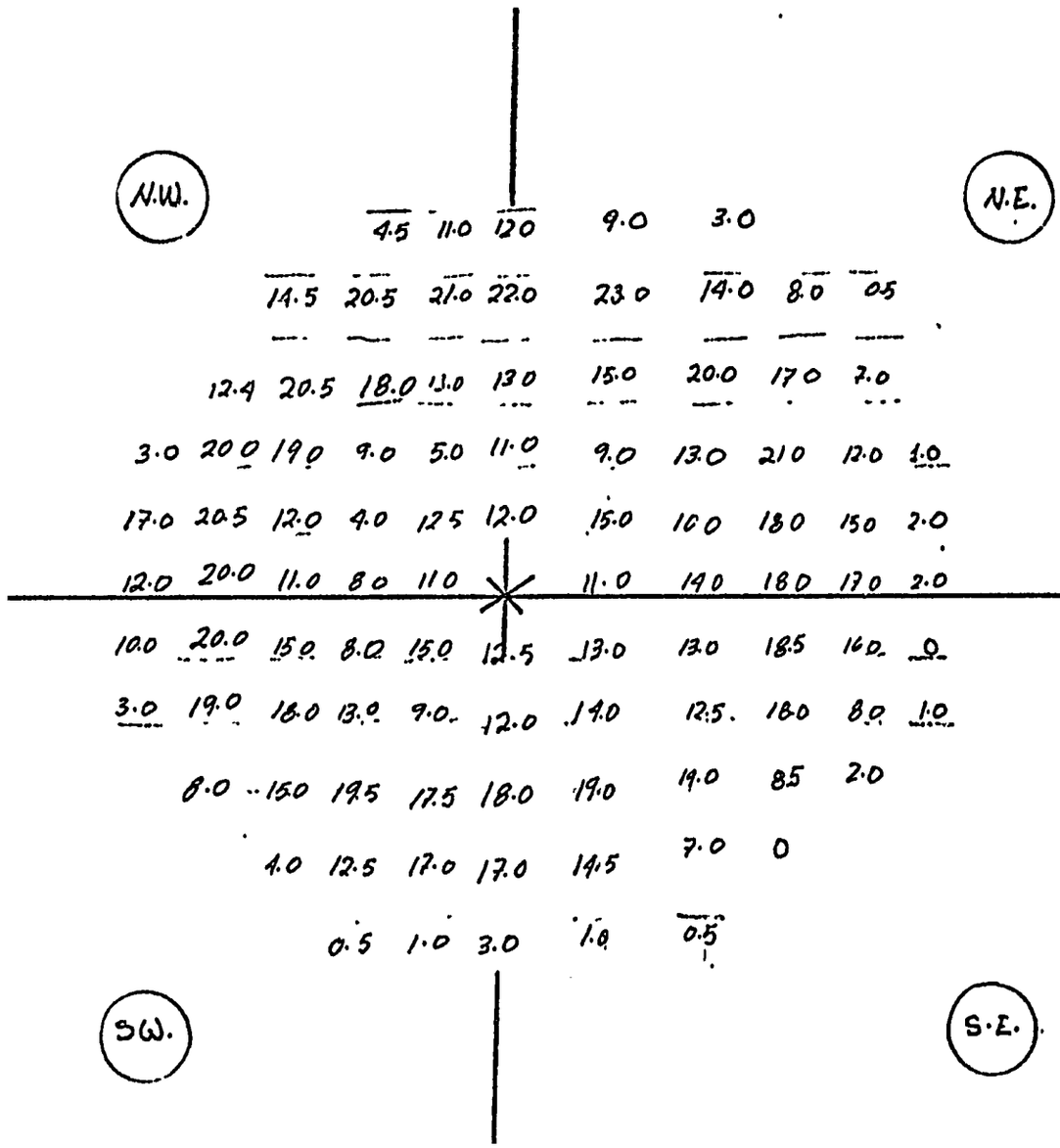
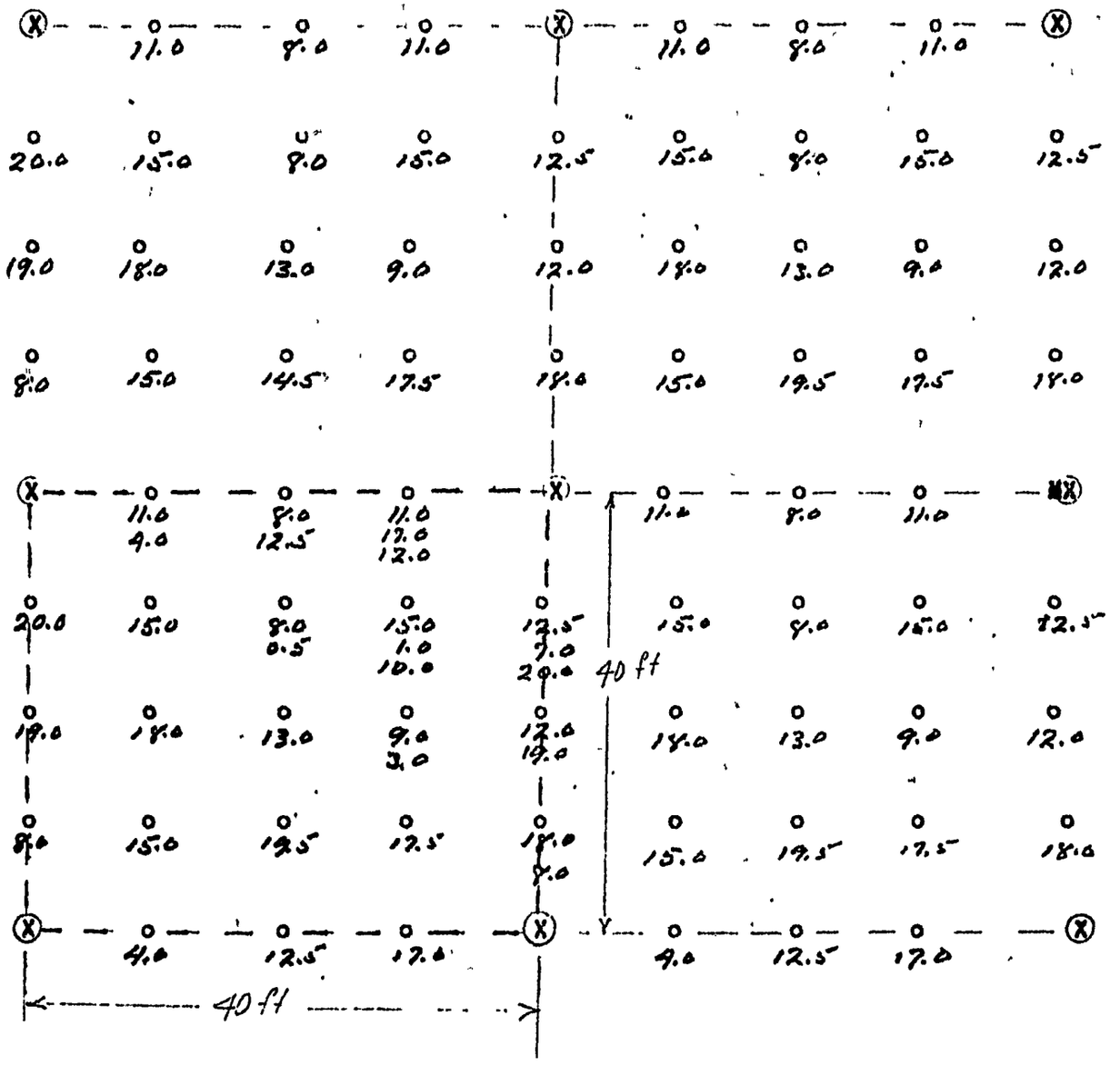


Fig. 8: Placement of S.W. quarter-section of Fig. 7 in the four locations which affect the 40x40 ft area.



A P E N D I X A

FIELD DATA AND CALCULATIONS FOR COEFFICIENT OF UNIFORMITY (C_u) FROM TESTS CONDUCTED.

19 AUGUST 1971

ZAPOTITAN VALLEY

EL SALVADOR, C. A.

FIG 9 SPRINKLER TEST DATA RAINBIRD No. 30 WITH 9/64 x 3/32 NOZZLES

1) Date 19 August 1971

2) Time End 11:14

Start 10:14

Total 1 hours

3) Pressure (psi)

Start	44	44
End	42	42

4) Discharge

Handbook 55 gpm

Bucket 5.64

5) Application

	Spacing		
	40x40	40x50	40x60
a- Hand book	.33 11/hr	.265 11/hr	.22 11/hr
b- Bucket	.34 11/hr	.271 11/hr	.226 11/hr
c- Mean value from can catch	.281 11/hr	.225 11/hr	.187 11/hr

6) Wind 1.78 mph

Direction North-East

FIG 10, DISTRIBUTION PATTERN FROM FIELD TEST. RAINBIRD No. 30 WITH 9/64" x 3/32" NOZZLES. 19 AUGUST 1971 40 FT SPACING

Cubic Centimeters

1	o 0	o 0	o 0	o 0
2	o 8	o 4	o 10	o 11
3	o 24	o 28	o 27	o 23
4	o 47	o 43	o 45	o 46
5	o 49	o 56	o 62	o 58
6	o 52	o 54	o 58	o 55
7	o 40	o 43	o 43	o 46
8	o 24	o 24	o 31	o 25
9	o 9	o 13	o 15	o 11
10	o 0	o 0	o 0	o 5

1 cc = 0.0105 cm = 0.00413 in.

FIG 11 CALCULATIONS 40x40 FT SPACING FROM FIELD TEST OF 19 AUGUST 1971

CUBIC CENTIMETERS

	A	B	C	D	
1	0	0	0	0	
5	49	56	62	58	
9	9	13	15	11	
	58	69	77	69	273
X_1 =	10.06	0.94	8.94	0.94	
2	8	4	10	11	
6	52	54	58	55	
10	0	0	0	5	
	60	58	68	71	
X_2 =	8.06	10.06	0.06	2.94	257
3	24	28	27	23	
7	40	43	43	46	
	64	71	70	69	274
X_3 =	4.06	2.94	1.94	0.94	
4	47	43	45	46	
8	24	24	31	25	
	71	67	76	71	
X_4 =	2.94	1.06	7.94	2.94	285
					1089

$N = 16$ $\qquad M = \frac{1089}{16} = 68.06$

$\bar{X} \times 66.76$

$Cu = 100 \left(1.0 - \frac{\bar{x}}{mn}\right)$

$= 100 \left(1.0 - \frac{66.76}{1089}\right)$

$= 93.88\ \%$

FIG 12 CALCULATIONS 40x50 FT SPACING FROM FIELD TEST OF 19 AUGUST 1971

	CUBIC CENTIMETERS				
	A	B	C	D	
6	52	54	58	55	
X -	2.45	0.45	3.55	0.55	219
2	8	4	10	11	
7	40	43	43	46	
	48	47	53	57	
X -	6.45	7.45	1.45	2.55	205
3	24	28	27	23	
8	24	24	31	25	
	48	52	58	48	206
X -	6.45	2.45	3.55	6.45	
4	47	43	45	46	
9	9	13	15	11	
	56	56	60	57	229
X -	1.55	1.55	5.55	2.55	
5	49	56	62	58	
10	0	0	0	5	
	49	56	62	63	230
X -	5.45	1.55	7.55	8.55	1089

N = 20 $\quad M = \frac{1089}{20} = 54.54$

$\bar{x} = 78.10$

$Cu = 100 \left(1.0 - \frac{\bar{x}}{mn}\right)$

$= 100 \left(1.0 - \frac{78.1}{1089}\right)$

$= 100 \left(1.0 - .0718\right)$

$= 92.8\%$

FIG 13 CALCULATIONS 40x60 FT SPACING FOR FIELD TEST OF 19 AUGUST 1971

CUBIC CENTIMETERS

	A	B	C	D	
1	0	0	0	0	
7	40	43	43	46	
	40	43	43	46	172
X̄ -	5.38	2.38	2.38	.63	
2	8	4	10	11	
8	24	24	31	25	
	32	28	41	36	137
X -	13.28	17.38	4.38	9.38	
3	24	28	27	23	
9	9	13	15	11	
	33	41	42	34	150
X -	12.38	4.38	3.38	11.38	
4	47	43	45	46	
10	0	0	0	5	
	47	43	45	51	186
X -	1.63	2.38	0.38	5.63	
5	49	56	62	58	225
X -	3.63	10.63	16.63	12.63	
6	52	54	58	55	219
X -	6.63	8.63	12.63	9.63	

$N = 24$

$\bar{x} = 177.87$ $\qquad M = \frac{1089}{24} = 4538$

$Cu = 100\ (1.0 - \frac{\bar{x}}{mn})$

$= 100\ (1.0 - \frac{177.87}{1089})$

$= 83.6\%$

Figure 14: Contour lines of equal distribution of water inches per hour 40 x 40 spacing. Field test 19 August 1971.

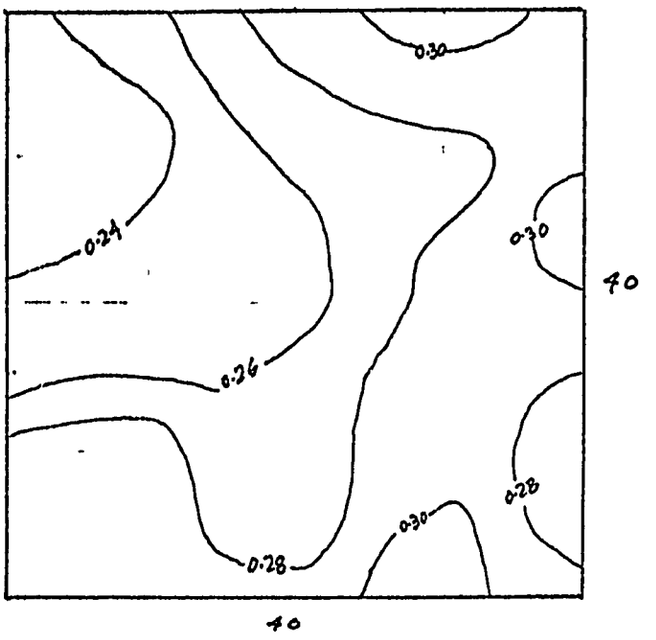


Fig. 15: Contour lines of equal distribution of water inches per hour 40x50 spacing. Field test 19 August, 1971

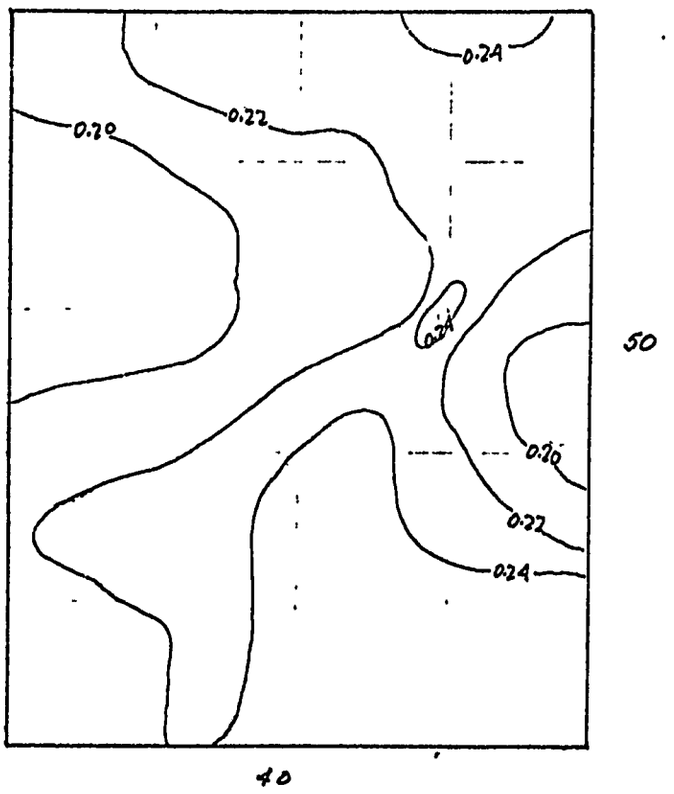


FIG 17 CALCULATIONS FOR DETERMINING PRECENT OF WATER APPLIED TO EACH 10x10 FT AREA 40x40 SPRINKLER SPACING FIELD TEST 19 AUGUST 1971

% of Area	in/hr	% of Ave	Receiving less than: % of water applied
100	0.316	113	115 %
	0.312	112	110
87.5			
87.5	0.291	104	105
	0.291	104	
	0.291	10.4	
	0.291	104	
	0.287	103	
	0.283	101	
37.5	0.283	101	100
	0.279	98	
	0.275	98	95
18.75	0.262	94	90
	0.246	88	
6.25	0.238	86	85
	0.230	82	
Total	4.458		
Ave	278		

FIG 18 CALCULATIONS FOR DETERMINING PERCENT OF WATER APPLIED TO EACH 10x10 FT AREA 40x50 FT SPRINKLER SPACING FIELD TEST 19 AUGUST 1971

% of Area	in/hr	% of Ave	Receiving less than % of water applied
100	0.258	115	115
	0.254	113	
85	0.246	110	110
	0.238	106	
75	0.238	106	105
	0.234	104.5	
	0.234	104.5	
	0.230	102.5	
	0.230	102.5	
	0.230	102.5	
	0.226	101	100
45	0.221	98.7	
	0.217	97	
	0.213	95	
	0.213	95	
75	0.201	89.5	
	0.197	88	
	0.197	88	
	0.197	88	
	0.193	86	
TOTAL	4.467		
Ave.	.224		

FIG 19 CALCULATIONS FOR DETERMINING PERCENT OF WATER APPLIED TO EACH 10x10 FT AREA 40x60 SPRINKLER SPACING RAINBIRD No. 30 WITH 9/64x3/32
FIELD TEST 19 AUGUST 1971

%.of Area	in/hr	% of Ave	Receiving less than % of water applied
100	0.256	137	140
95.9	0.240	129	130
87.51	0.240	129	125
	0.230	123	
79.2	0.227	121	120
	0.223	119	
70.9	0.215	115	115
66.7	0.210	112	110
62.6	0.202	108	105
	0.194	104	
54.2	0.190	101	100
	0.186	99.5	
	0.178	95.5	
41.70	0.178	95.5	95
	0.176	94	
	0.173	92	
	0.169	90.3	
25	0.169	90.3	90
20.9	0.165	88	80
	0.148	79	
12.5	0.140	75	75
	0.136	73	
	0.133	71	65
	0.116	62	
TOTAL	4.494		
AVE	.187		

A P P E N D I X B

FIELD DATA AND CALCULATIONS FOR COEFFICIENT OF UNIFORMITY (C_u) USING A SINGLE SPRINKLER TEST 15, 18, 27, 29, 46 AND 47

CONDUCTED BY

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GRADUATE STUDENTS
UTAH STATE UNIVERSITY

AT

ZAPOTITAN VALLEY
EL SALVADOR
JULY - AUGUST 1971

Fig 20 Sprinkler Test Data

1. Test No. 29
2. Sprinkler No. D6
3. Sprinkler Depth 30E
4. Nozzle Size & Range 7/32 Spreader –
5. Vane yes
6. Riser Height 24"

7. Date Aug 20, 1971
8. Time 12:00 noon
9. Loc. Ian Ft Schaffer
10. Weather sunny warm
11. Barometer Begin Test 30 End Test 65
Depression 30 End Read 27

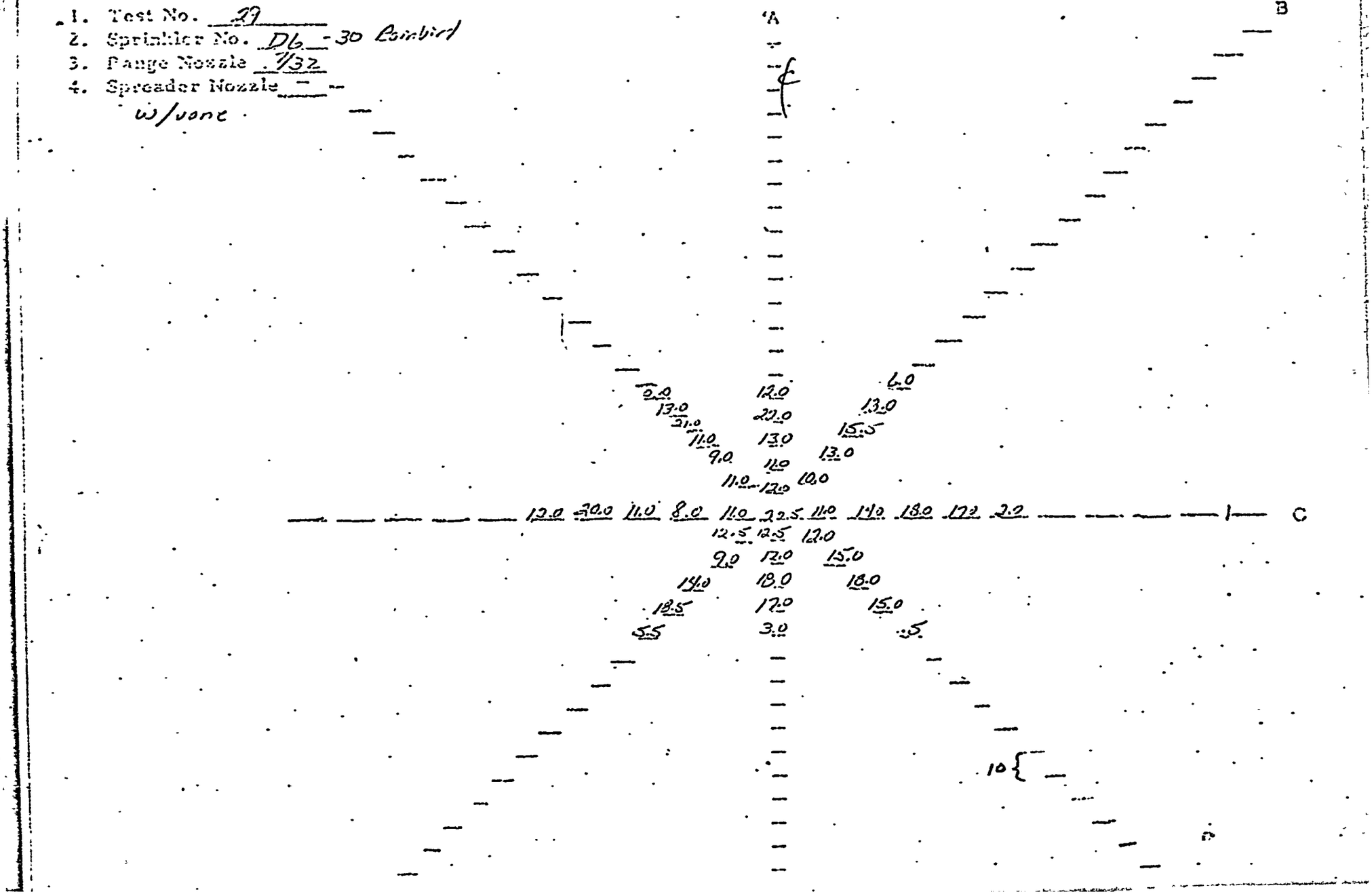
Min.	Wind Dir.	Wind Dir. Read.	Speed KM/HR	Temp °C DB	Temp °C WB	RH, %	Rotation Time	Rotation No. Rev.	R.P.M.	Flow Rate Begin Nozzle Time	Flow Rate Begin Nozzle Gal.	Flow Rate Begin Nozzle C	Flow Rate Diff. Nozzle Time	Flow Rate Diff. Nozzle Gal.	Flow Rate Diff. Nozzle C	Depth Gauge	Pressure Psi Nozzle	Pressure Psi Gauge
0.00	Var.	586.3	4.0	86	76	64				.63	5	7.94	—	—	—	7.91	35	37
15.00	Var.	587.3	3.6	85	75	63	16.17	10	1.612									36
30.00	Var.	588.2	4.0	87	77	64	32.26											37
45.00	SE	589.2	2.8	82	75	72												37
60.00	Var	587.9	3.6	83	75	70				.62	5	8.07	—	—	—	8.07	35	37

	20.5	x	23															
		22.5				N.W										N.E		
									4.5	11.0	12.0	9.0	3.0					
								14.5	20.5	21.0	22.0	23.0	14.0	2.0	0.5			
							12.0	20.5	18.0	13.0	13.0	15.0	20.0	17.0	7.0			
						3.0	20.0	19.0	9.0	5.0	11.0	9.0	13.0	21.0	12.0	1.0		
						12.0	20.5	12.0	4.0	12.5	12.0	15.0	10.0	18.0	15.0	2.0		
						12.0	20.0	11.0	8.0	11.0	22.5	11.0	14.0	18.0	17.0	2.0		
						10.0	20.0	15.0	8.0	15.0	12.5	13.0	13.0	18.5	16.0	0.0		
						3.0	17.0	18.0	7.0	9.0	12.0	14.0	17.5	18.0	8.0	1.0		
							8	15.0	19.5	17.5	18.0	19.0	19.0	8.5	2.0			
								4.0	12.5	17.0	17.0	14.5	7.0	0.0				
									5	1.0	3.0	1.0	.5					
						SW										S.E		

N

Fig 21 Can-Catch Data For Profiles

1. Test No. 27
2. Sprinkler No. D6 - 30 Coinbird
3. Range Nozzle 1/32
4. Spreader Nozzle —
   w/vane



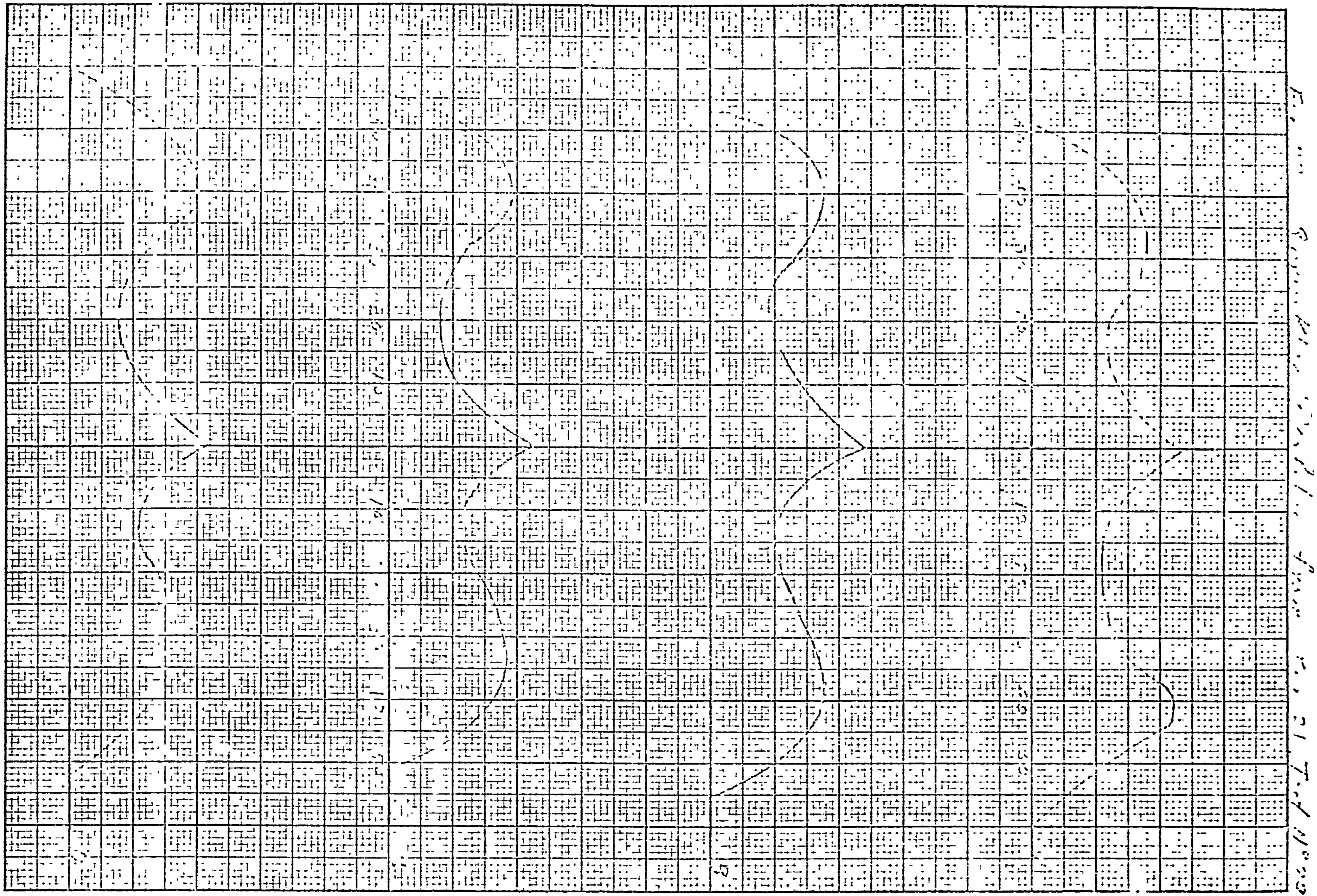


Fig 23 Sprinkler Test Data

1. Test No. 18
2. Sprinkler No. F4
3. Sprinkler Model Rainbird 30
4. Nozzle Size: Range 11/64 Spreader —
5. Vane No
6. Riser Height 24"
7. Date Aug 16, 1971
8. Time 11:30 AM
9. Location Zagarton El Sahaabi
10. Weather Partly cloudy, warm
11. Evaporation: Begin Pan 30.0 End Pan 22.0
    Begin Rain 30.0 End Rain 28.0

Time	Wind Direct.	Wind Anem. Read.	Wind Speed KM/HR	Temp °F DB	Temp °F WB	RH, %	Rotation Time	Rotation No. Rev.	RPM	Flow Rate Range Noz. Time	Flow Rate Range Noz. Cal.	Flow Rate Range Noz. C	Flow Rate Cor. Noz. Time	Flow Rate Cor. Noz. Cal.	Flow Rate Cor. Noz. C	Total Q	Pressure PSI Nozzle	Pressure PSI Base
0:00	E	416.0	1.6	80	72	68				.83	5	6.02	—	—	—	6.02	50	52
0:15	N	416.4	2.0	79	73	75												52
0:30	N	416.9	3.6	84	75	67	20.94	8	1.18									53
0:45	SE	417.8	2.8	82	74	69	27.11											52
1:00	S	418.5	2.5							.82	5	6.10	—	—	—	6.10	51	53

—	26.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25.0	X	27.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	28.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	N.W	—	1.0	0.5	—	N.E	—	—	—	—	—	—
—	—	—	—	—	—	—	3.0	7.0	10.0	6.0	3.0	0	—	—	—	—	—	—
—	—	—	—	—	—	3.0	12.0	15.0	14.5	13.0	11.0	9.0	1.0	—	—	—	—	—
—	—	—	—	—	—	0	12.0	16.0	13.0	15.0	13.0	13.0	13.0	3.0	0	—	—	—
—	—	—	—	—	—	6.0	15.0	13.0	14.0	14.0	14.0	14.0	14.0	7.0	1.0	—	—	—
—	—	—	—	—	—	9.0	15.0	14.0	15.0	26.3 X	14.0	15.0	15.0	6.5	0	—	—	—
—	—	—	—	—	—	7.0	16.0	15.0	15.0	15.0	13.0	14.0	14.0	6.5	—	—	—	—
—	—	—	—	—	—	2.0	11.0	15.0	15.0	14.0	15.0	14.0	12.5	3.0	—	—	—	—
—	—	—	—	—	—	0	3.0	12.0	16.0	15.0	15.0	10.0	5.0	0.5	—	—	—	—
—	—	—	—	—	—	—	—	3.0	5.0	3.0	7.0	3.0	0.5	—	S-E	—	—	—
—	—	—	—	—	—	—	S.W	—	—	0	0	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Fig 24 Can-Catch Data

1. Test No. 18
2. Sprinkler No. FL-Rainbird 30
3. Range Nozzle 11/64
4. Spreader Nozzle No

w/o

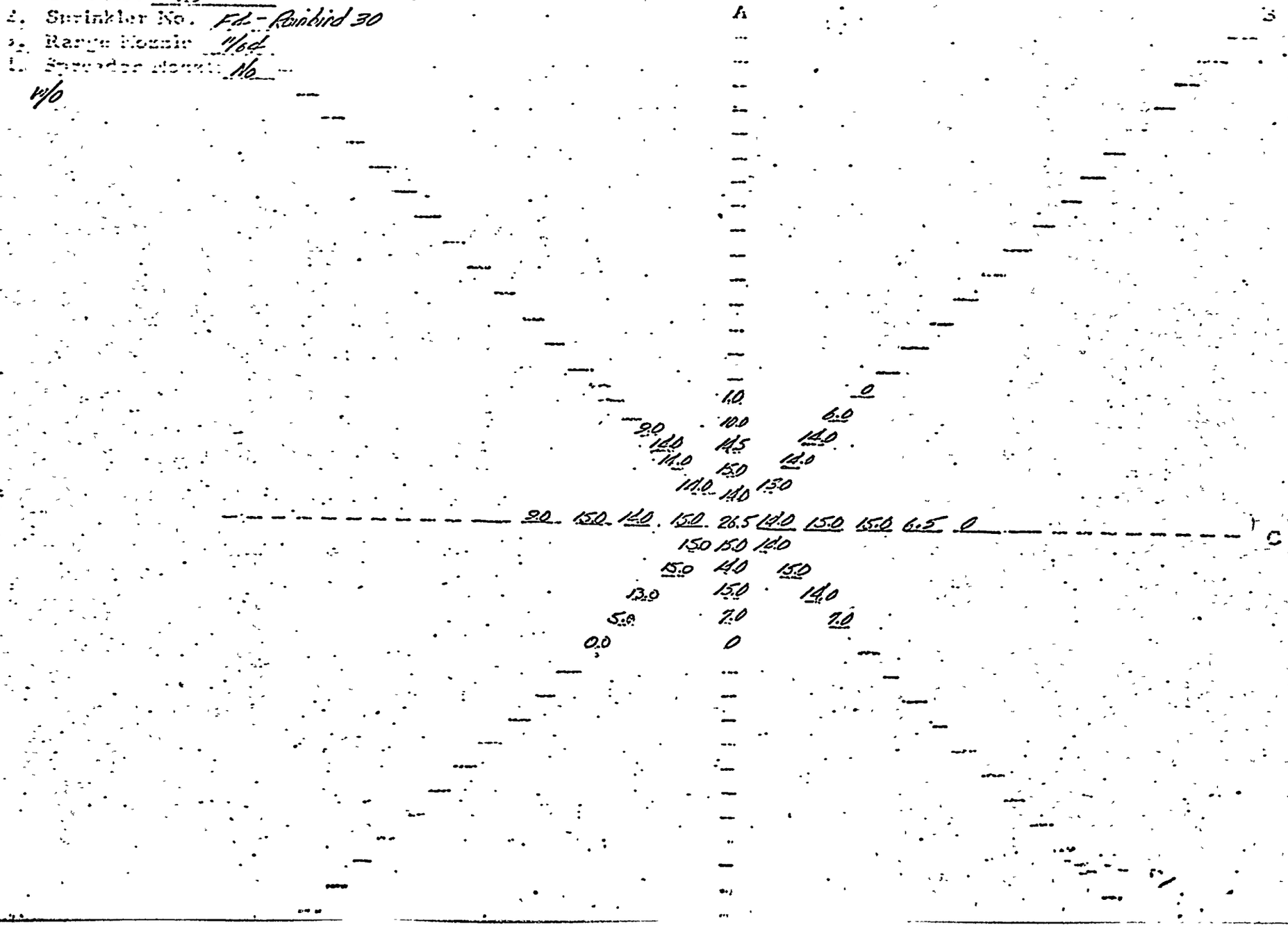
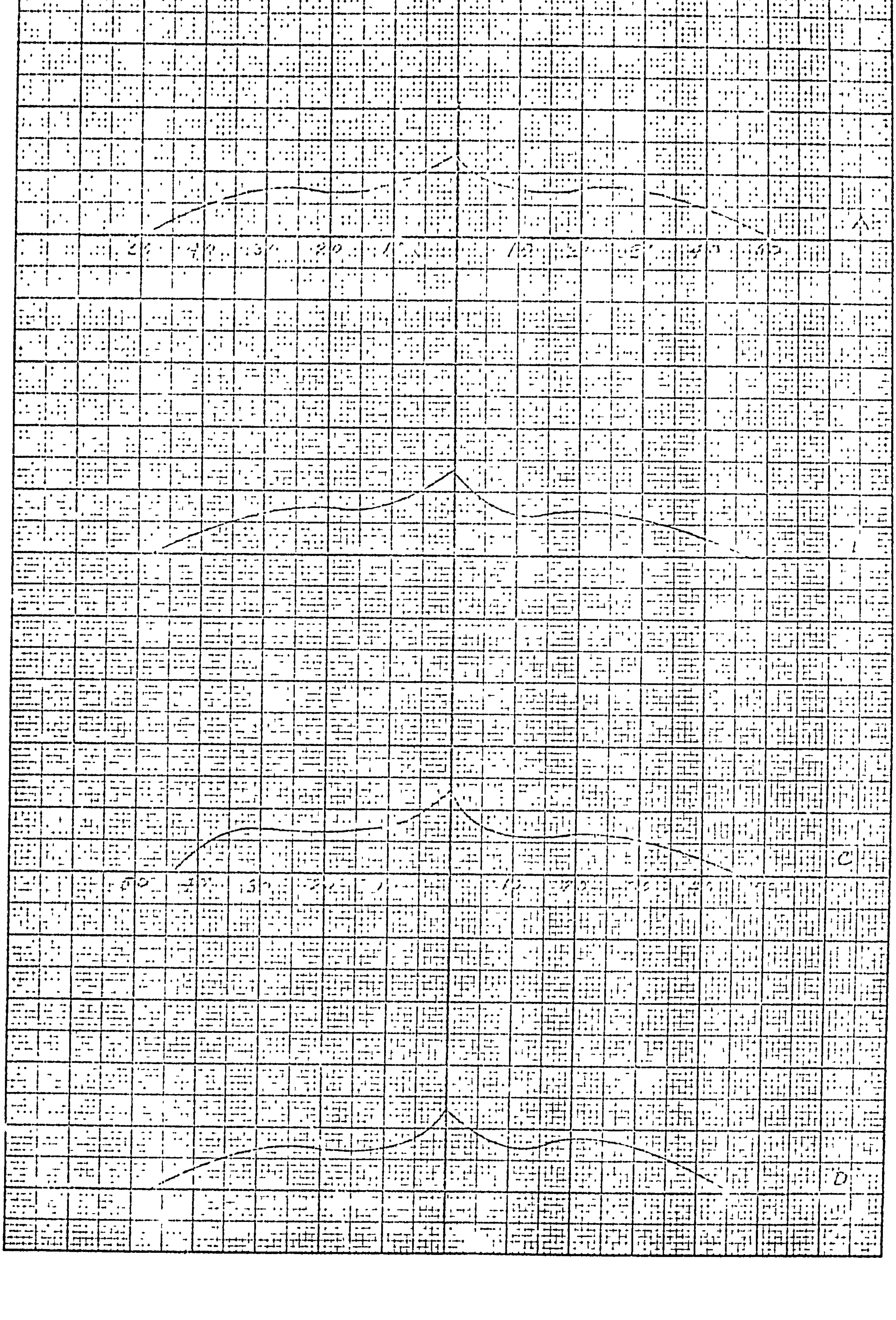


Fig. 25 Sprinkler Profiles from Fig. 24 [illegible]



1. Test No. 46
2. Sprinkler No. —
3. Sprinkler Model 323 Naan (Israel)
4. Nozzle Sizes: Range 4.5mm Spreader 2.5mm
5. Vane No
6. Riser Height 24"

7. Date Sept 4, 1971
8. Time 11:45 AM
9. Location El Salvador
10. Weather Cloudy, warm
11. Evaporation: Begin Test 30 End Test 27.5
Begin Read 30 End Read 28.0

Cum. Test Time	Wind Direct.	Wind Anem. Read.	Wind Speed KM/HR	Temp °F DB	Temp °F WB	RH,%	Rotation Time	Rotation No. Rev.	RPM	Flow Rate Range Noz. Time	Flow Rate Range Noz. Gal.	Flow Rate Range Noz. Q	Flow Rate Spr. Noz. Time	Flow Rate Spr. Noz. Gal.	Flow Rate Spr. Noz. Q	Total Q	Pressure Psi Noz.	Pressure Psi Base
0:00	Var	833.5	2.4	78	72	84				0.91	5.0	5.5	3:14	5	1.6	7.1	40	42
0:15	Var	834.1	4.4	79	74	80												42
0:30	Var	835.2	4.0	79	74	80	19.65	10	3.8									42
0:45	Var	836.2	4.0	78	73	80	22.36											42
1:00	Var	837.2	4.0	81	75	77				0.90	5.0	5.5	3.10	5	1.6	7.1	40	42
			5.7															

920
23 x 23
104

N

N.W

N.E

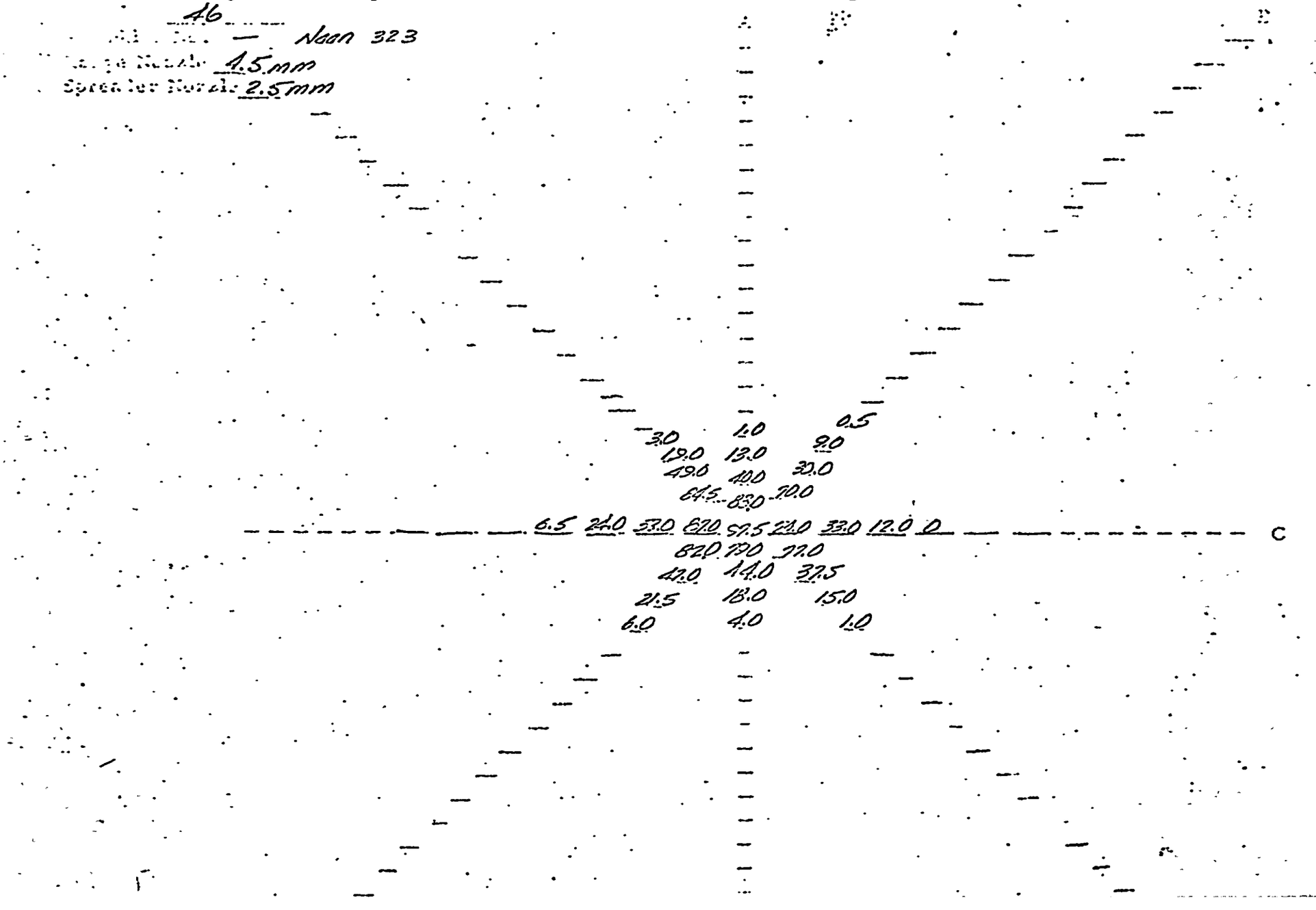
							1.0	1.0										
						1.0	5.0	13.0	13.0	8.0	0.5							
					1.0	8.0	23.0	33.0	100	25.0	13.0	1.0						
					2.5	20.0	42.0	57.0	1.0	56.0	25.0	2.5						
					6.5	24.0	53.0	67.0	1.5	20.0	32.0	12.0	0					
					5.0	21.0	38.0	70.0	12.0	61.0	28.0	11.0						
					1.0	13.0	25.0	39.0	44.0	25.0	12.0	5.0						
						4.0	13.0	17.0	18.0	18.0	2.0	0						
						0	1.0	3.0	4.0	1.0								

S.E

S.W

Fig 26 Sprinkler Test Data

Fig 27 Can-Catch Data For Profiles



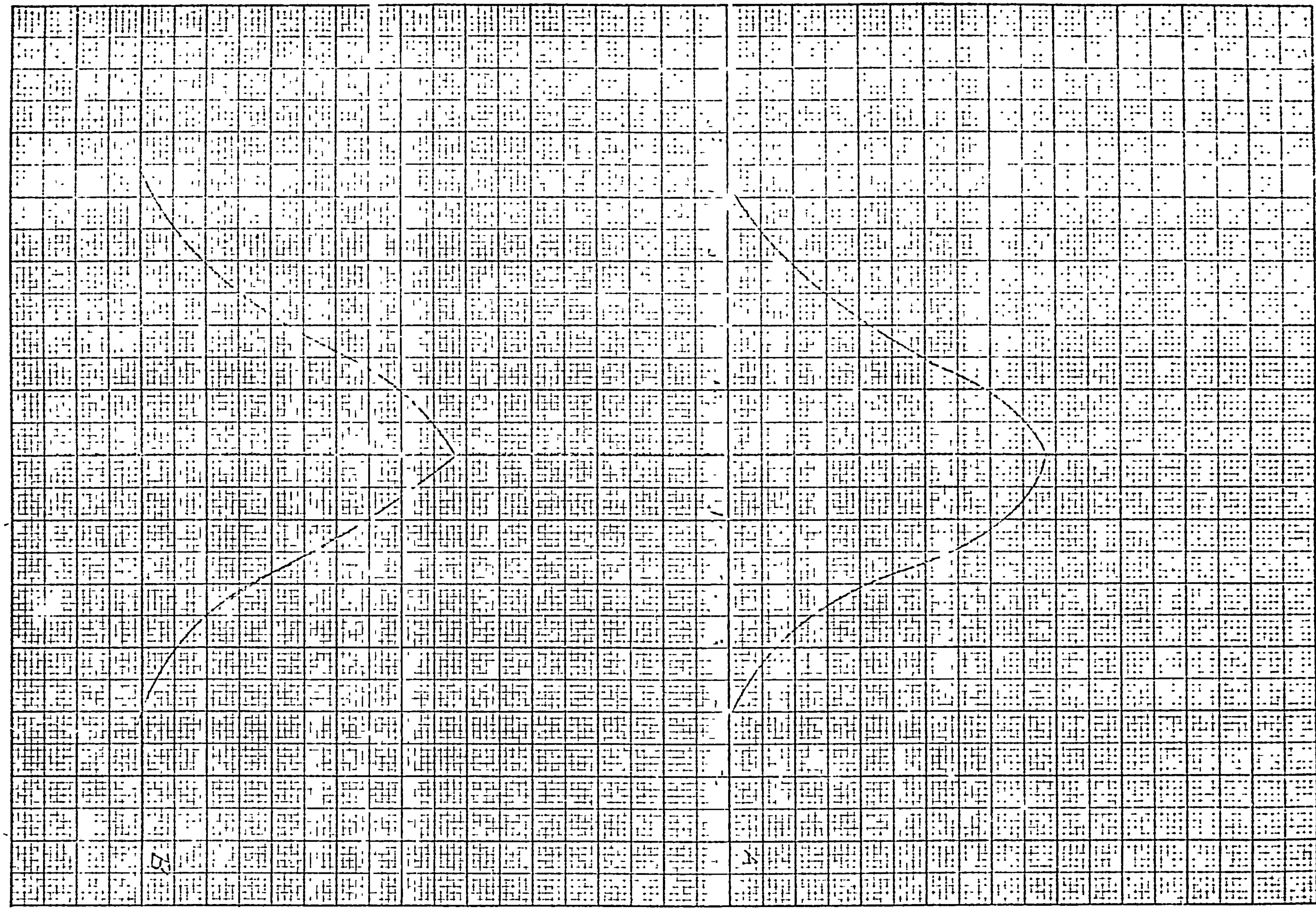


Fig. 28 Comparative Profiles ... for 27 Test 11-4/5

Fig 29 Sprinkler Test Data

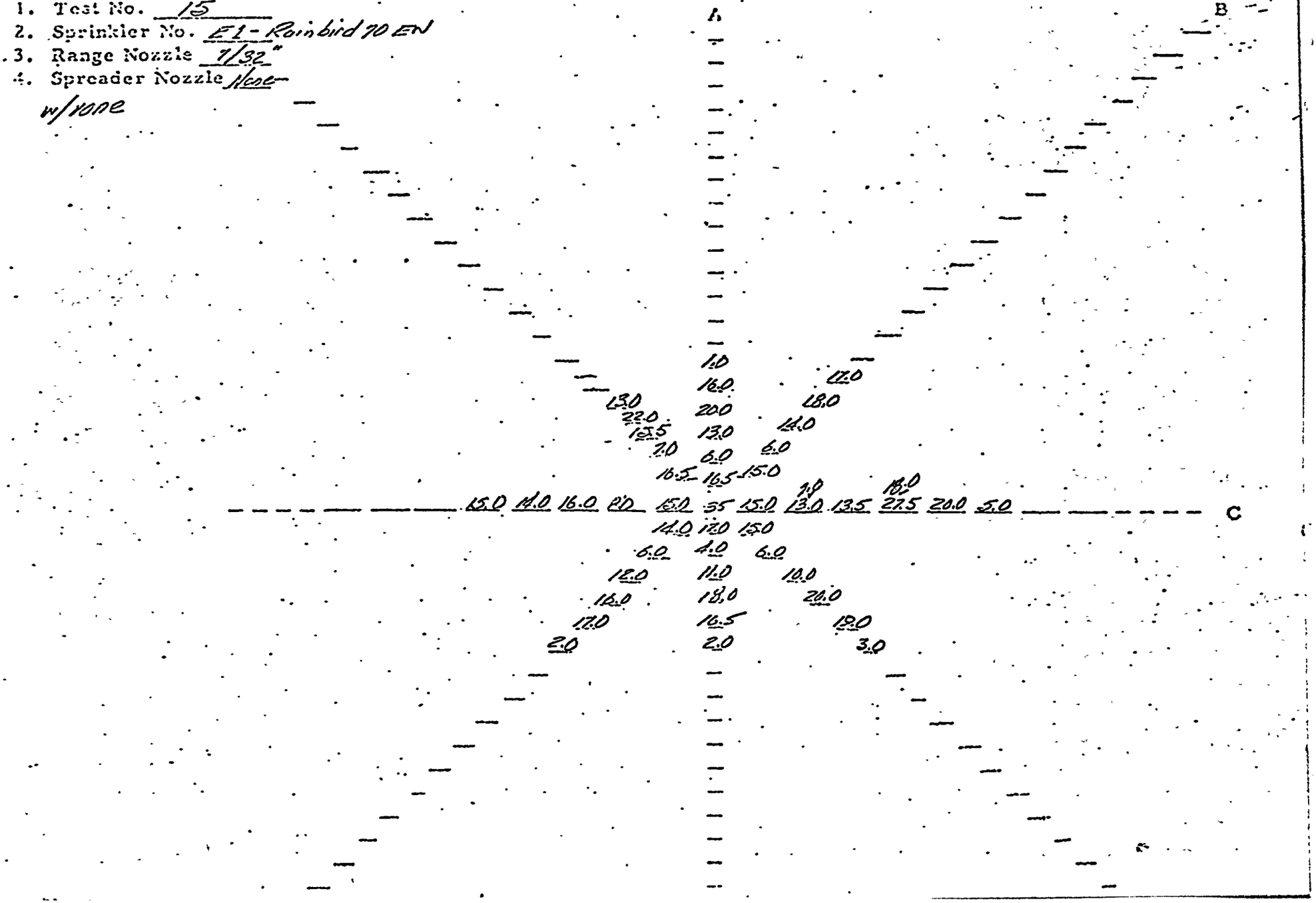
1. Test No. 15
2. Sprinkler No. E1
3. Sprinkler Model 10EW - Rainbird
4. Nozzle Size: Range 7/32" Spreader
5. Vane Yes
6. Riser Height 21"
7. Date Aug 13, 1971
8. Time 8:30
9. Location Zapotitan, El Salvador
10. Weather Sunny, Warm
11. Evaporation: Begin Test 30.0 ml End Test 27.0 ml
    Begin Read 30.0 ml End Read 27.5 ml

Elapsed Test Time	Wind Direct.	Wind Anem. Read.	Wind Speed KM/HR	Temp °F DB	Temp °F WB	RH, %	Rotation Time	Rotation No. Rev.	Rotation RPM	Flow Rate Range Noz. Time	Flow Rate Range Noz. Gal.	Flow Rate Range Noz. Q	Flow Rate Spr. Noz. Time	Flow Rate Spr. Noz. Gal.	Flow Rate Spr. Noz. Q	Total Q	Pressure Psi Noz.	Pressure Psi Base
0:00	NE	422.0		75	70	78				.57	5.0	8.77	—	—	—	8.77	37	39
0:15	NE	422.5	2.0	75	70	78	18.8	10										39
0:30	NE	423.0	2.0	76	71	78	38.3		0.51									38
0:45	NNE	423.6	2.4	76	72	82												39
1:00	NNE	424.0	1.6	76	72	82				.58	5.0	8.62	—	—	—	8.62	37	38
			2.0															

	32																		
34	*	36																	
	39						0		1.0	0									
						1.0	2.0	15.0	16.0	10.0	6.0	1.0							
					2.0	12.0	20.0	21.5	20.0	22.0	12.0	16.0	3.0						
					1.0	11.0	22.0	19.0	17.5	13.0	11.0	12.0	21	18.0	1.0				
					6.0	20.0	19.5	16.0	8.0	6.0	6.0	11.0	21.0	24.0	11.0				
					12.0	22.0	17.0	8.5	18.5	5	17.0	6.0	16.0	23.0	16.0				
					15.0	14.0	11.0	8.0	15.0	50	15.0	13.0	13.5	22.5	20.0	5.0			
					14.0	20.0	16.0	9.0	17.0	17.0	12.0	5.0	13.5	21.0	17.0	3.0			
					9.0	20.0	12.0	10.0	5.0	4.0	7.0	8.0	12.5	21.0	16.0				
					5.0	15.0	15.0	15.0	13.0	11.0	11.0	16.0	19.0	15.0	4.0				
					0	5.0	16.0	20.0	18.0	18.0	20.0	16.0	19.0	6.0	0				
						2.0	13.5	16.0	16.5	12.5	8.0	3.0	0						
							0	0	2.0	0	1.0								

Fig 30 Can-Catch Data For Profiles

1. Test No. 15
2. Sprinkler No. E1 - Rainbird 70 EN
3. Range Nozzle 7/32"
4. Spreader Nozzle None w/none



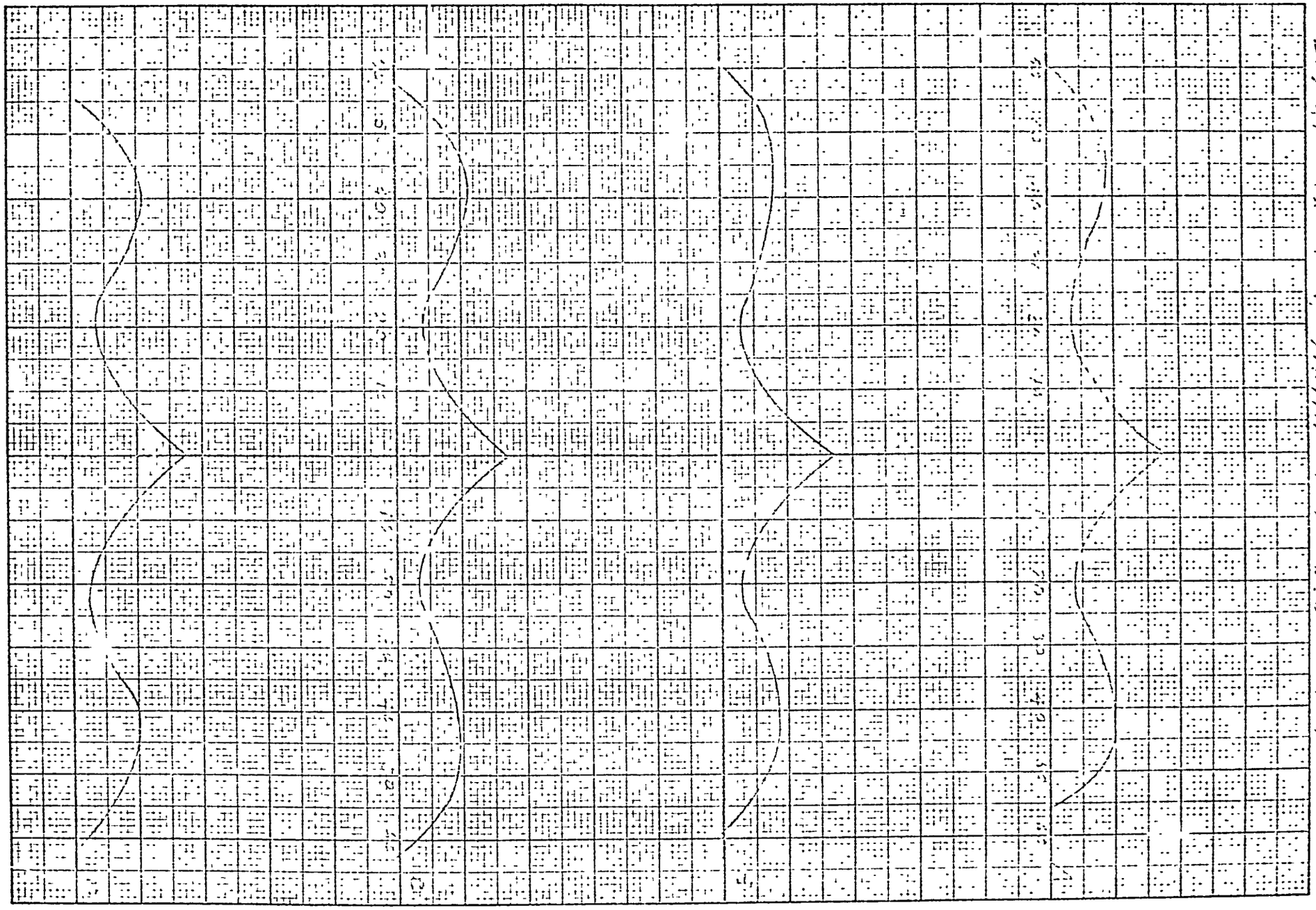


Fig. 32 Sprinkler Test Data

1. [illegible] 27 — Aug. 18, 1971
2. [illegible] F4 — Time 3:00 pm
3. Sprinkler Model 30 Rainbird — 9. [illegible] El Salvador
4. Nozzle Size [illegible] 9/64 Spreader 3/32 — 10. [illegible] Cloudy cool
5. [illegible] 10 — 11. [illegible] 30 [illegible] 27
6. Riser Height 24' — [illegible] 30 [illegible] 28

	Wind		Speed Km/Hr	DB	WB	RH,%	Rotation Time	No. Rev.	RPM	[illegible]						Q		
0.00	NW	551.9	18.4	79	75	83				1.28	5	3.90	2.94	5	1.70	5.60	.46	48
15.00	NW	555.5	13.6	79	75	83	16.69	10	.892									48
30.00	NW	558.9	14.0	78	74	83	27.90											48
45.00	NW	562.4	12.8	78	75	87												43
60.00	NW	565.7	13.8	78	74	83				1.28	5	3.90	2.94	5	1.70	5.60	.46	48

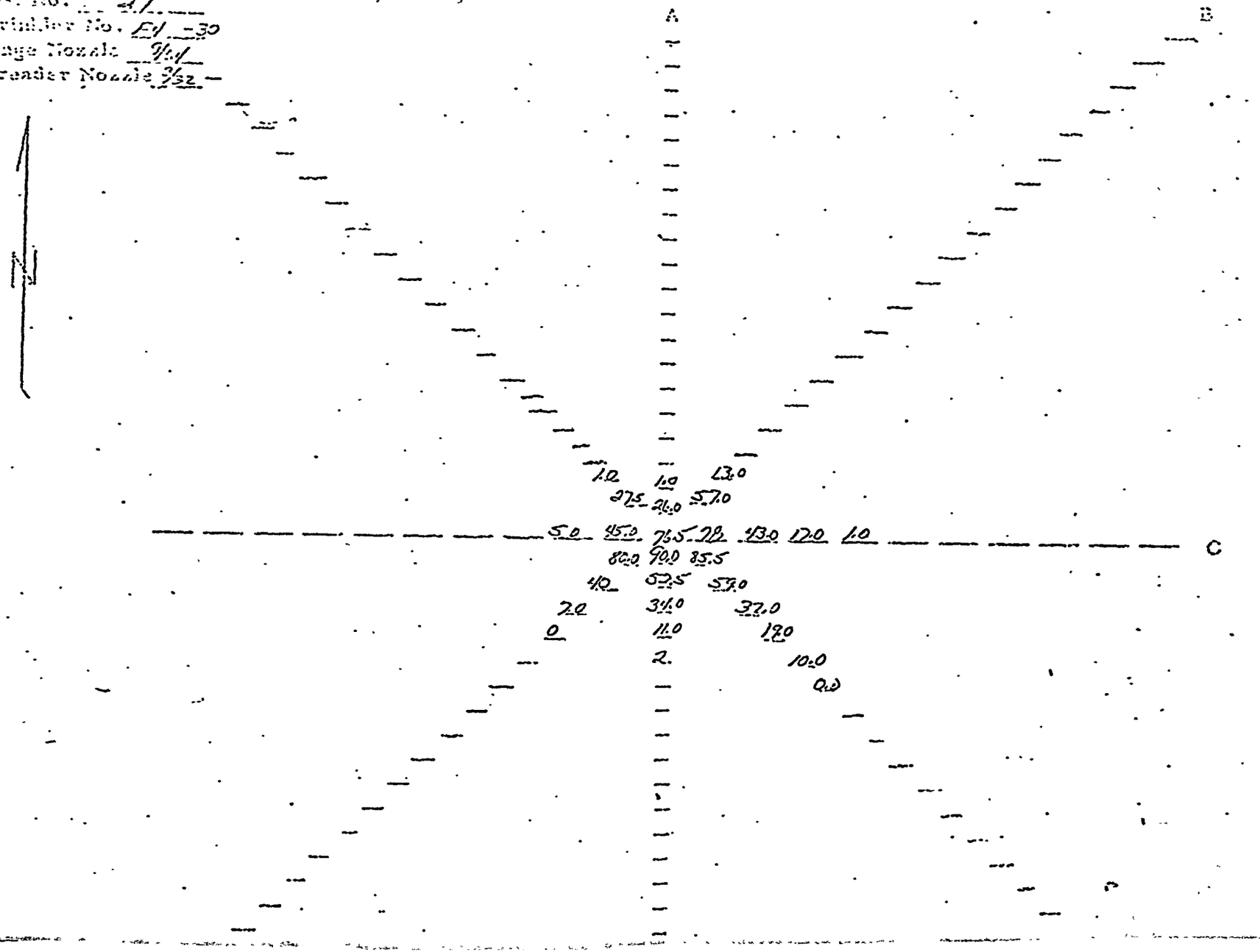
		69.5												
	72.0	x	24.0											
		91.0												
								0	1.0	1.0	.5			
							.5	11.0	26.0	33.0	17.5	3.0		
							5.0	45.0	76.5 X	73	43.0	17.0	1.0	
						0	13.5	67.0	90.0	61	53.0	27.0	8.0	.5
						.5	12.0	37.0	52.5	63.0	40.0	22.0	9.0	.5
							3.5	20.0	31	32.0	22.5	19.0	5.0	
							0	4.0	11	17.5	20.0	9.0	2.0	
									2	2.0	3.0	1.0		

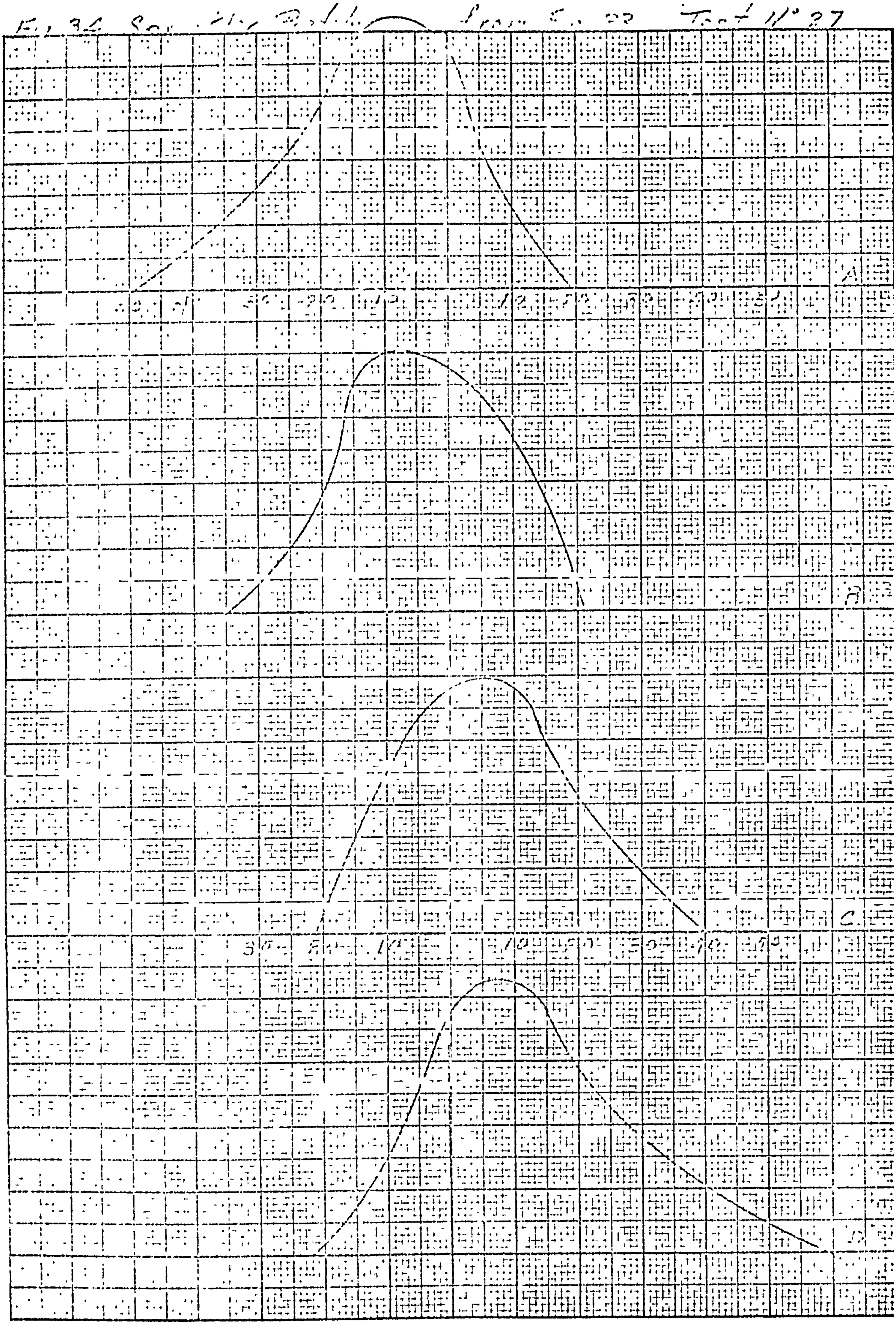
N

Fig 33 Can-Catch Data For Profiles

1. Test No. 27
2. Sprinkler No. E1-30
3. Range Nozzle 7/64
4. Spreader Nozzle 3/32

33





1. Test No. 47
2. Sprinkler No. Israel Naan
3. Sprinkler Model 303
4. Nozzle Sizes: Range 4.5mm spreader 2.5mm
5. Vane No
6. Riser Height 24"
7. Date Sept 4, 1971
8. Time 1:15 pm
9. Location E/S Loader
10. Weather Cloudy, warm
11. Evaporation: Begin Test 35 End Test 29
    Begin Read 30 End Read 28

Cum. Test Time	Wind Direct.	Wind Anem. Read.	Wind Speed KM/HR	Temp °F DB	Temp °F WB	RH,%	Rotation Time	Rotation No. Rev.	RPM	Flow Rate Range Noz. Time	Flow Rate Range Noz. Gal.	Flow Rate Range Noz. Q	Flow Rate Spr. Noz. Time	Flow Rate Spr. Noz. Gal.	Flow Rate Spr. Noz. Q	Total Q	Pressure Psi Noz.	Pressure Psi Base
0.00	Var	839.9	3.1	78	73	80 80				1.34	5	3.72	4.68	5	1.07	4.79	18	20
15.00	Var.	843.8	3.4	79	73	76	19.90	10	4.05									20
30.00	Var.	847.4	3.2	79	74	79	22.32											20
45.00	SE	850.2		79	74	79												20
48.00	SE	850.8								1.34	5	3.72	4.68	5	1.07	4.79	18	20

59
SB X SB
64

5.0	25	9.0	4.0	0	
13.5	22.0	24.	20.0	12.5	5.0
21.0	35.5	45.5	35.0	21.0	10.0
35.0	46	69.0	43.0	30.0	15.0
13.0	37	43.5	36.0	24.0	14.0
11.0	19.0	25	24.0	18.0	5
4.5	10.0	10.0	10.0	1.0	

Fig 35 Sprinkler Test Data

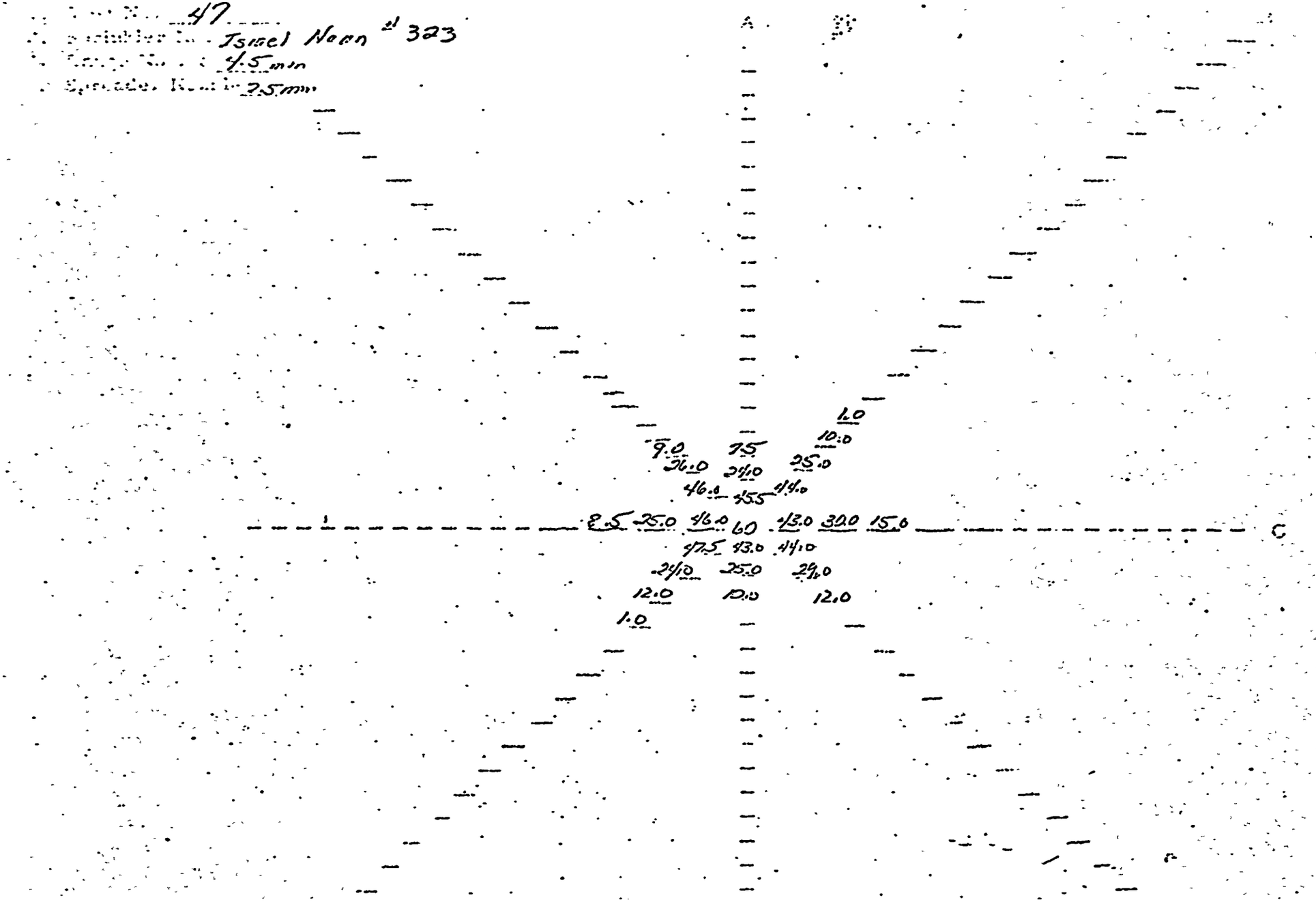
Fig 36 Can-Catch Data for Profiles

47

Tsimel Noon d' 323

4.5 min

2.5 mm



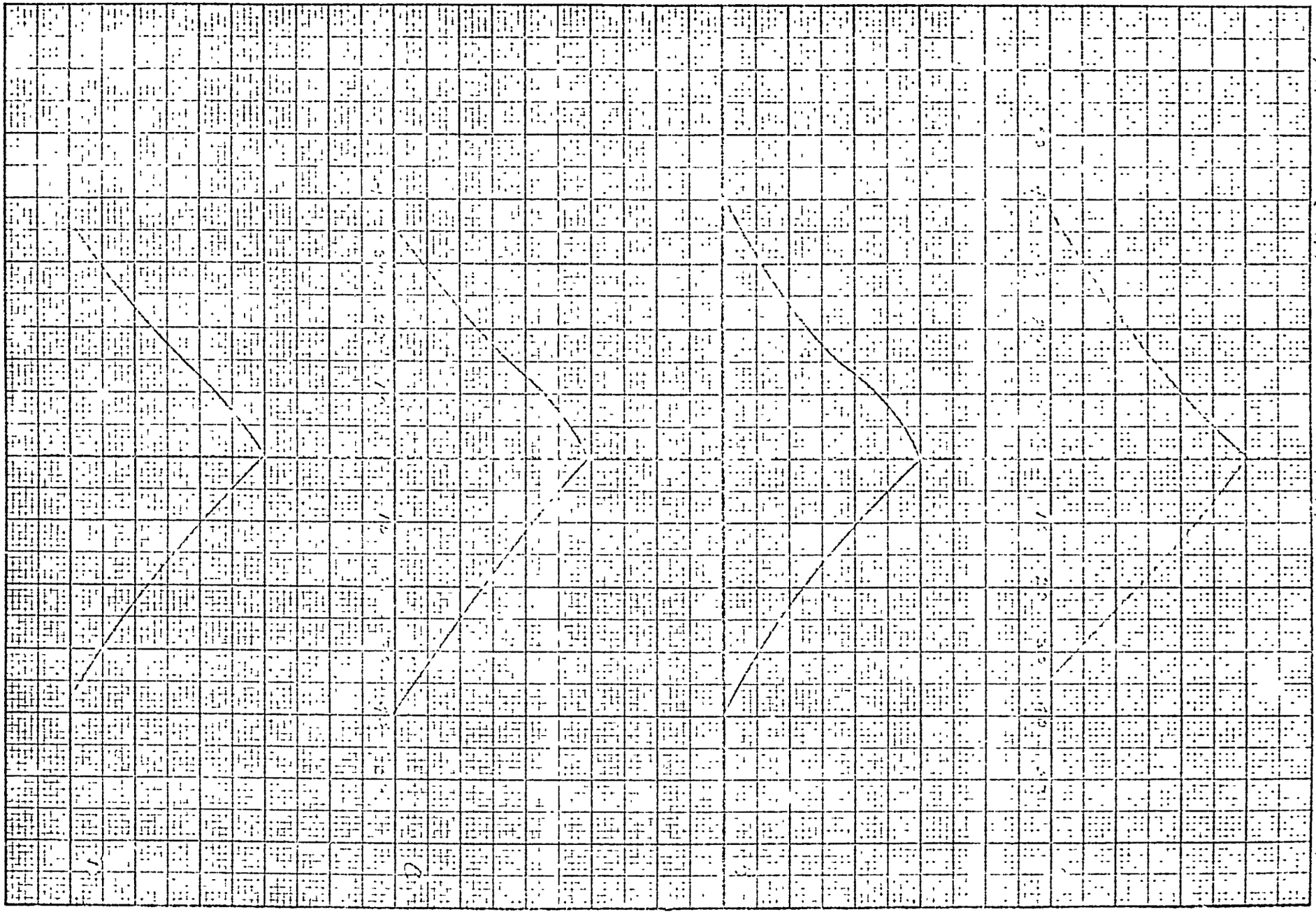


FIG. 38 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 40 FT. SPACING, AS SUPERIMPOSED FROM TEST No. 29

INCHES PER HOUR

X	.356	.283	.406	X
.306	.260	.242	.303	.332
.370	.254	.215	.242	.332
.392	.295	.246	.326	.356
X	.338	.311	.402	X

FIG 39 CALCULATIONS FOR C_u FROM DATA IN FIG 37 40x40 SPACING TEST 29

INCHES PER HOUR

RATE	No.	RN	X	NX	
.406	1	.406	.089	.089	
.402	1	.402	.085	.085	
.396	1	.396	.079	.079	
.392	1	.392	.075	.075	
.370	1	.370	.053	.053	
.356	2	.712	.039	.790	.078
.338	1	.338	.021	.021	
.332	2	.662	.015	.690	.030
.326	1	.326	.009	.009	
.311	1	.311	.006	.006	
.303	1	.303	.014	.014	
.295	1	.295	.002	.022	
.283	1	.283	.034	.034	
.260	1	.260	.057	.057	
.254	1	.254	.063	.063	
.246	1	.246	.071	.071	
.242	2	.484	.075	.150	
.215	1	.215	.102	.102	
	21 = n	6.654		1.038	= $\bar{x}$

$$\text{Mean} = \frac{6.654}{21} = .317 \text{ in/hr}$$

$$CU = 100 \left(1 - \frac{1.038}{6.65} \right)$$

$$= 100 (1 - .156)$$

$$= 84.4\ \%$$

FIG 40 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 50 FT SPACING AS SUPER-IMPOSED FROM TEST No. 29.

INCHES PER HOUR

X	.168	.156	.148	X
.224	.268	.228	.256	.248
.234	.277	.282	.234	.176
.238	.254	.248	.213	.189
.211	.187	.137	.195	.230
X	.094	.131	.168	X

FIG. 41 CALCULATIONS FOR C_u FROM DATA IN FIG 39 40 x 50 SPACING TEST

No. 29

INCHES PER HOUR

RATE	NUMBER	RN	X	NX
?281	1	.281	.070	.070
.277	1	.277	.066	.066
.268	1	.268	.057	.057
.256	1	.256	.045	.045
.254	1	.254	.043	.043
.248	2	.496	.037	.074
.238	1	.238	.027	.027
.234	2	.468	.023	.046
.230	1	.230	.019	.019
.228	1	.228	.017	.017
.224	1	.224	.013	.013
.213	1	.213	.002	.002
.211	1	.211	.000	.000
.195	1	.195	.016	.016
.189	1	.189	.022	.022
.187	1	.187	.024	.024
.176	1	.176	.025	.025
.168	2	.336	.043	.086
.156	1	.156	.055	.055
.148	1	.148	.063	.063
.137	1	.137	.074	.074
.137	1	.131	.080	.080
.094	$\frac{1}{26} = n$	$\frac{.094}{5.493}$	.117	$\frac{.111}{1.035}$ =

$$\text{Mean} = \frac{5.493}{26} = 0.211 \text{ In/hr}$$

$$Cu = 100\left(1 - \frac{1.035}{5.493}\right)$$

$$= 100\,(1 - .189)$$

$$= 81.1\ \%$$

FIG 42 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 60 FT SPACING AS SUPERIMPOSED FROM TEST No. 29

INCHES PER HOUR

X	.099	.091	.170	X
.250	.153	.118	.225	.250
.252	.291	.268	.244	.252
.248	.287	.316	.232	.248
.248	.196	.172	.190	.250
.208	.124	.081	.182	.208
X	.099	.091	.170	X

FIG 43 CALCULATIONS FOR C_u FROM DATA IN FIG 41 40 x 60 SPACING TEST No. 29

INCHES PER HOUR

RATE	N	RN	X	NX
.316	1	.316	.116	.116
.291	1	.291	.091	.091
.287	1	.287	.087	.087
.268	1	.268	.068	.068
.252	2	.504	.052	.104
.250	3	.750	.050	.150
.248	3	.744	.048	.144
.244	1	.244	.044	.044
.232	1	.232	032	.032
.225	1	.225	.025	.025
.208	2	.416	.008	.016
.196	1	.196	.004	.004
.190	1	.190	.010	.010
.182	1	.182	.018	.018
.172	1	.172	.028	.028
.170	2	.340	.030	.060
.153	1	.153	.047	.047
.124	1	.124	.076	.076
.118	1	.118	.082	.082
.099	2	.198	.101	.202
.091	2	.182	.109	.218
.081	1	.081	.119	.119
	N= 31	6.213		1.741 = $\bar{x}$

Mean $= \frac{6.213}{31} = 200$ in/hr

$C_u = 100\ (1-\frac{1.741}{6.213})$

$= 100\ (1-0.280)$

$= 72\ \%$

FIG 44 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 30 x 50 FT SPACING AS SUPERIMPOSED FROM TEST No. 29

INCHES PER HOUR

X	.283	.320	X
.351	.384	.408	.374
.405	.363	.407	.411
.426	.330	.353	.382
.289	.302	.283	.260
X	.279	.258	X

FIG 45 CALCULATIONS FOR C_u FROM DATA IN FIG 43 30 x 50 SPACING TEST

No. 29

		INCHES PER HOUR		
RATE	N	RN	X	NX
.426	1	.426	.033	.083
.416	1	.411	.069	.069
.408	1	.408	.065	.065
.407	1	.407	.064	.064
.405	1	.405	.062	.062
.384	1	.384	.041	.041
.382	1	.382	.039	.039
.374	1	.374	.031	.031
.303	1	.363	.020	.020
.353	1	.353	.010	.010
.351	1	.351	.009	.009
.330	1	.330	.013	.013
.320	1	.320	.023	.023
.302	1	.302	.041	.041
.289	1	.289	.054	.054
.283	2	.566	.060	.120
.279	1	.279	.064	..064
.260	1	.260	.083	.083
.258	1	.258	.085	.085
	20 = n	6.868		0.976 = $\bar{x}$

$$\text{Mean} = \frac{6.868}{20} = 0.343$$

$$C_u = \left(1.0 - \frac{0.976}{6.868}\right)$$

$$C_u = (1.0 - 0.141)$$

$$C_u = 85.9\ \%$$

FIG 46 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 40 FT SPACING AS SUPERIMPOSED FROM TEST No. 18

INCHES PER HOUR

X	.184	.169	.176	X
.182	.188	.214	.210	.182
.153	.210	.239	.221	.153
.180	.200	.202	.202	.180
X	.180	.169	.176	X

FIG 47 CALCULATIONS FOR C_u FROM DATA IN FIG 45 40 x 40 FT SPACING TEST No. 18

INCHES PER HOUR

RATE	N	RN	X	NX
.239	1	.239	.050	.050
.221	1	.221	.032	.032
.214	1	.214	.025	.025
.210	2	.420	.021	.042
.202	2	.402	.013	.026
.200	1	.200	.011	.011
.188	1	.188	.001	.001
.184	1	.184	.005	.005
.182	3	.546	.007	.021
.180	2	.360	.009	.018
.176	2	.352	.013	.026
.169	2	.338	.020	.040
.153	2	.306	.036	.072
	n = 21	3.970		0.369 = $\bar{x}$

Mean = $\frac{3.970}{21}$ = 0.189 in/hr

C_u = 100 $(1.0 - \frac{0.369}{3.97})$

= 100 (1.0 - .0928)

= 90.7 %

FIG 48 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 30 x 50 FT SPACING AS SUPERIMPOSED FROM TEST No. 46

INCHES PER HOUR

X	.508	.523	X
.462	.422	.30	.463
.314	.306	.295	.314
.293	.326	.314	.293
.472	.413	.422	.472
X	.508	.523	X

FIG 49 CALCULATIONS FROM C_u FROM DATA IN FIG 47 30 x 50 FT SPACING

TEST No. 46

INCHES PER HOUR

RATE	N	RN	X	NX
.523	2	1.046	.119	.238
.508	2	1.016	.104	.208
.472	2	.944	.068	.136
.463	1	.463	.059	.059
.462	1	.462	.058	.058
.430	1	.430	.026	.026
.422	2	.844	.018	.036
.413	1	.413	.009	.009
.326	1	.326	.078	.078
.314	3	.942	.090	.270
.306	1	.306	.098	.098
.295	1	.295	.109	.109
.293	2	.586	.111	.222
	n = 20	8.073		1.547 = $\bar{x}$

= m

Mean = $\frac{8.073}{20}$ = .404

Cu = 100 $(1 - \frac{1.547}{8.073})$

= 100 (1 - .191)

= 80.3 %

FIG 50 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 40 FT SPACING AS SUPERIMPOSED FROM TEST No. 46

INCHES PER HOUR

X	.388	.359	.425	X
.400	.388	.295	.388	.405
.355	.338	.328	.342	.361
.433	.405	.351	.411	.427
X	.392	.359	.425	X

FIG 51 CALCULATIONS FOR C_u FROM DATA IN FIG 49, 40 x 40 FT SPACING

TEST No. 46

INCHES PER HOUR				
RATE	N	RN	X	NX
.427	1	.427	.048	.048
.433	1	.433	.054	.054
.425	2	.850	.046	.092
.411	1	.411	.032	.032
.405	2	.810	.026	.052
.400	1	.400	.021	.021
.392	1	.392	.013	.013
.388	3	1.164	.009	.027
.361	1	.361	.018	.018
.359	2	.718	.020	.040
.355	1	.355	.024	.024
.351	1	.351	.028	.028
.342	1	.342	.037	.037
.338	1	.338	.041	.041
.328	1	.328	.051	.051
.295	$\frac{1}{21} = n$	$\frac{.295}{7.975}$	.084	$\frac{.084}{6.62} =$

$$\text{Mean} = \frac{7.975}{21} = 0.379 \text{ "/hr}$$

$$C_u = 100 \left(1 - \frac{6.62}{7.975}\right)$$

$$= 100 \, (1 - .083)$$

$$= 91.7 \%$$

FIG 52 AMOUNT OF WATER WHICH WOULD HAVE BEEN COLLECTED IN CANS ON A 40 x 50 FT SPACING AS SUPERIMPOSED FROM TEST No. 46

INCHES PER HOUR

X	.389	.356	.409	X
.351	.351	.272	.339	.351
.240	.240	.200	.236	.240
.244	.228	.231	.231	.244
.370	.318	.272	.350	.370
X	.389	.364	.409	X

FIG 53 CALCULATIONS FOR C_u FROM DATA IN TEST 51 40 x 50 FT SPACING

TEST No. 46

INCHES PER HOUR

RATE	N	RN	X	NX
.409	2	.818	.073	.146
.389	2	.778	.053	.106
.370	2	.740	.034	.068
.364	1	.364	.028	.028
.356	1	.356	.020	.020
.351	3	1.053	.015	.045
.350	1	.350	.014	.014
.339	1	.339	.003	.003
.318	1	.318	.018	.018
.272	2	.544	.064	.128
.244	2	.488	.092	.184
.240	3	.720	.096	.288
.239	1	.239	.097	.097
.236	1	.236	.100	.100
.231	2	.462	.105	.210
.200	1	.200	.136	.136
	n = 26	8.068 = m		1.591 = $\bar{x}$

Mean = $\frac{8.068}{26}$ = .336 "/hr

C_u = $(1 - \frac{1.591}{8.068})$

= 100 (1 - .197)

= 80.3 %