Influence of Errors in Spread Factor Measurements on NMD, VMD and D_{max} of a Spray Droplet Spectrum

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Table of Contents

Introduction

To understand the effects of aerial application of pesticides, it is important to determine relationships between formulation properties, efficiency of atomization, application rate (litre/ha), spray swath distribution and meteorological parameters. Spray deposit assessment is the key to understand the combined influence of the above factors. The efficiency of spray atomization together with volume-application rate, directly determine the droplet size spectrum and indirectly determine the efficiency of targetability and coverage. To obtain a knowledge of droplet size spectrum, we must employ a corrective spread factor to convert the stain marks on our sampling surfaces to the aerodynamic droplet sizes.

This report summarizes the practical difficulties encountered in our laboratory in the effort of obtaining accurate spread factor data for spray mixes. The currently available techniques, and measurement practices are subject to some uncontrollable errors. The following is a brief outline to indicate the advantages of having and disadvantages of not having spread factor data.

1) Aerial application of pesticides onto forests is susceptible to non-uniform distribution and deposition on trees so that some trees are likely to receive heavier doses than others. For tree protection, it is necessary for the initial deposit

to reach a prescribed level in the target zone, and therefore it is very important to obtain information on deposit density (mass of AI/unit area) to monitor the efficiency of every aerial spray operation.

2) A knowledge of droplet density (drops/unit area or spots on card/unit area) is also useful to understand the degree of coverage, i.e., the higher the droplet density, the greater the coverage.

3) Some researchers feel the need to extend the spot counting procedure to include spot sizing and droplet size assessment as well, in order to obtain NMD, VMD and D_{max} values for a spray droplet spectrum. The understanding is: closely spaced NMD and VMD values indicate a narrow droplet spectrum while those which are far apart from each other indicate the heterogeneity of the spray droplet distribution; and a large D_{max} is indicative of low efficiency of spray atomization resulting in low droplet density, poor coverage and wastage of pesticide material.

4) In order to obtain the "droplet size spectrum" it is essential to convert the "spot size spectrum" on card to the corresponding droplet sizes, using spread factor data. The conventional procedure is to use the field tank mixes in the laboratory, to produce droplets of variable size range with a

droplet generator, to measure their aerodynamic size and to capture them on card for measuring the spot sizes formed. This sounds quite simple, but in fact most of the currently available techniques are subject to large experimental errors.

Problem Definition

Spray droplets impacting on card in the field are from a concentrated spray mix (not from the same tank mixes that are loaded in the aircraft) because of the inevitable droplet evaporation that occurs in the field. This means, spread factor values under the field situation are bound to be lower than those obtained in the laboratory with tank mixes.

Relative humidity differences between the laboratory and field conditions contribute to different degrees of spreading of the same material on cards, thus causing a large error in spread factor values. (Those under the field conditions are bound to be higher than those obtained in the laboratory because of the higher relative humidity (RH) values in the field.)

If tank mixes are not homogeneous solutions, (which is the case with the present Aminocarb flowable tank mixes), the present droplet generator at my laboratory and the one at NRC-NAE are both not suitable for accurate spread factor measurements, because of the presence of suspended material which tends to interfere with uniform drop size formation and uniform spreading. Measurements can be made after making some approximations but these will inevitably inherit significant experimental errors.

If in the field the micronair nozzles had produced extremely small droplet size range (this appears to be the case in recent years with many formulations), then it is necessary to produce the same small size range in the laboratory, to obtain spread factor data. This requirement introduces an additional complication since the present droplet generator is not suitable for producing extremely small droplets, unless extremely high rpm is used for the chopper. A high rpm introduces an additional momentum to the small droplets produced, causing them to spread more than normal (a normal spread factor results from the droplet momentum due to its terminal velocity only). In order to prevent this abnormal spreading, it is necessary to place a K-card several feet down from the chopper, to give the droplet enough time and distance to loose the extra momentum. This however results in droplet evaporation which again results in errors in spread factor.

Need for Approximation

Now the question arises: What do we do to minimize these errors in spread factor data? Errors can be reduced if (i) droplets produced in the laboratory were allowed to evaporate under the same conditions as those in the field before impingement on card, (ii) cards were exposed to the same RH conditions and for the same length of time as in the field, (iii) expensive droplet generators can be used to produce very small droplets. We, however, realize that there is no monodisperse aerosol generator yet available to handle tank mixes containing suspended particles. Here we still have to make a compromise.

The compromise lies in asking ourselves why it is necessary to aim at an extremely high accuracy in spread factor data. The answer lies in what we want from the NMD, VMD, and D_{max} values. Do we need these data for quantitative calculations to arrive at certain deductions, or do we need these just merely for a qualitative understanding of the spray droplet spectrum? As far as my knowledge goes, I have not seen anyone in FPMI using NMD, VMD, and D_{max} for any quantitative relationships. (Even if anyone wants to do quantitative calculations, card data are not suitable because they will not represent foliar data.) Therefore, the only current use of NMD, VMD, and D_{max} data is for a simple understanding of a spray spectrum. For this, an approximate value of spread factor is quite adequate, and this is demonstrated in calculations presented in the enclosed tables. As a matter of fact many forest researchers are interested only in deposit and droplet densities and not in NMD, VMD, and D_{max}. Some researchers calculate these using spot size measurements, ignoring spread factor values; they feel that for the intended use, the spot data are adequate enough to provide a relative measure of the spray spectrum though not in absolute droplet sizes. The spot D_{max}, they feel, is adequate enough to indicate the degree of coverage.

The enclosed tables present parameters of droplet spectra assuming a 15% error in spread factor resulting in, first systematically higher values and second, systematically low values. The third sets of data arise from averaging a wide range of spread factor values. It is evident that for the intended use, the NMD, VMD, and D_{max} values are not alarmingly different from the true values listed in Tables 1 and 2.

Table 9 presents spread factor values for Suncropspray 11N and corn oil. The data are from six replicates, all of them carefully measured. It is evident from the table that the spread factor (SF) values are valid only for two significant figures, i.e., up to one decimal only. This would be the case even if we use the most expensive monodisperse aerosol generator for droplet production (refer to the two separate measurements on Suncropspray 11N; for a 720 μm droplet, the most precise droplet ever measured at two separate occasions was either 112 or 118 μm, giving a variation in SF of 0.3). Also note that the increase in SF with drop size is not dramatic but only slight and gradual.

Attempts were made to find out which of the listed sources of errors would contribute to the largest errors in NMD and VMD values. Humidity variations were found to cause the greatest errors in spread factor data. In some preliminary trials, values obtained at 95% RH were as high as 175% (maximum error observed so far) of the values obtained at 48% RH for the Aminocarb OSC formulation in Sunspray 6N (a tank mix used for Plot PV in the New Brunswick 1981 summer trial). Table 10 presents spread factor values for the above tank mix at 95% RH (Table 1 presents spread factor data for the same tank mix at 48% RH). Tables 10 and 11 present NMD, VMD, and D_{max} for the droplet spectrum calculated using spread factor values containing +75% error. It is evident that an NMD of 32 µm (Table 10) was obtained instead of the 58 µm in Table 1, giving an error of (26/58) x 100 = -45%. The new value of VMD is 40 µm (Table 11) instead of the 68 µm obtained in Table 2, giving an error of (28/68) x 100 = -41%. Nevertheless, the new NMD and VMD values are still not alarmingly low. These calculations indicate that for the intended purpose, the errors inherited in the current practices of spread factor measurements do not introduce drastic variations in the parameters related to spray droplet spectrum.

Bathurst Spray Trial

Table 1: Aminocarb 180 D

Plot PV: Second Application

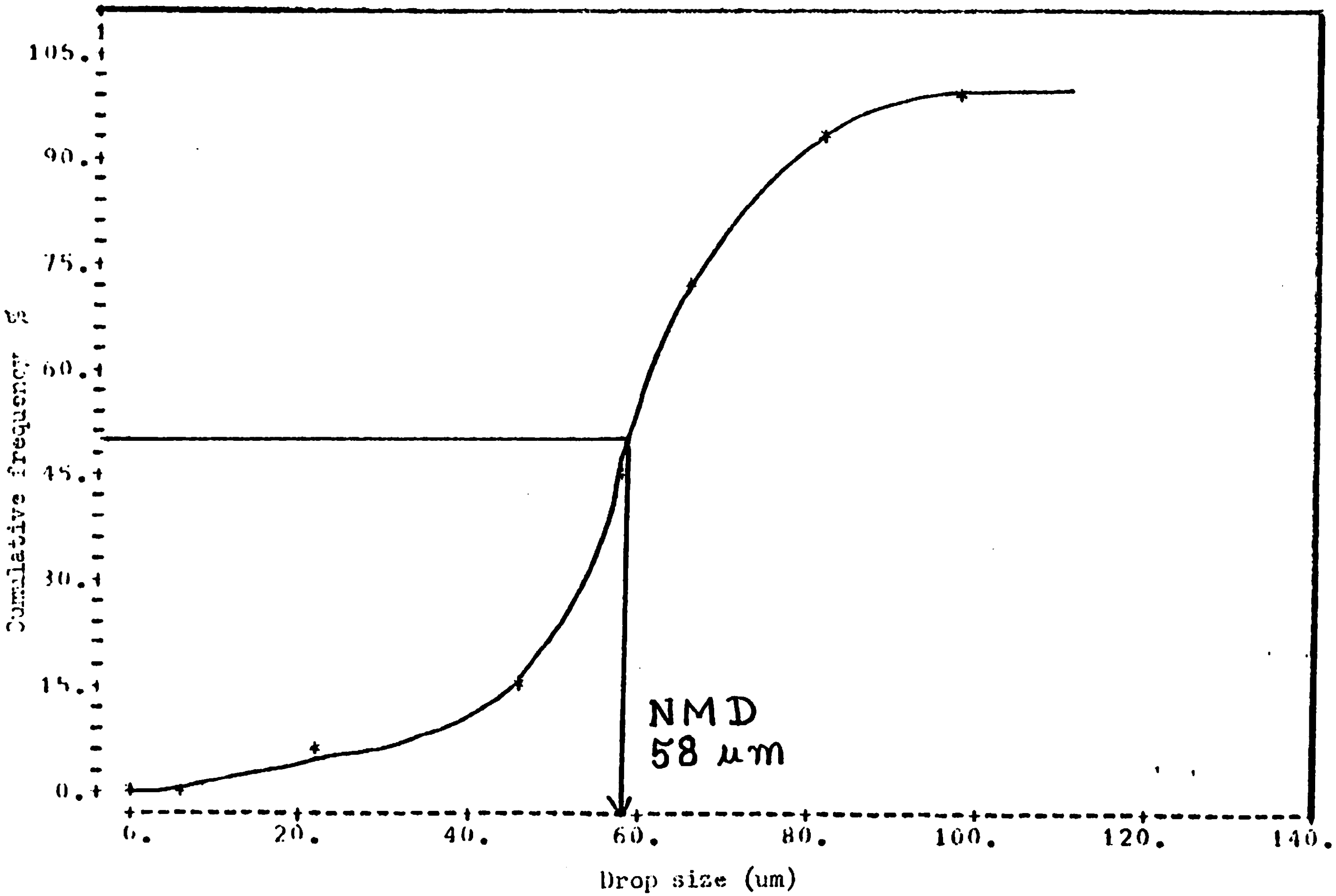
Droplet Size Distribution

(Measured Spread Factor Data)

Stain size range (μm)	Spread factor (mean)	Drop size range (μm)	Average drop size (μm)	Drops per 100 cm^2	Frequency %	Cumulative frequency %
15 - 35	3.8	4 - 9	6	0	0	0
35 - 125	3.8	9 - 32	21	73	5.6	5.6
125 - 220	4.7	32 - 47	45	140	10.8	16.4
220 - 275	4.7	47 - 58	57	354	27.2	43.6
275 - 410	5.5	58 - 73	65	360	27.7	71.3
410 - 495	5.5	73 - 90	82	290	22.3	93.6
495 - 580	5.5	90 - 105	98	83	6.4	100.0

NMD = 58 μm

Fig. 1. NMD for data in Table 1.



Bathurst Spray Trial

Table 2: Aminocarb 180 D

Plot PV: Second Application

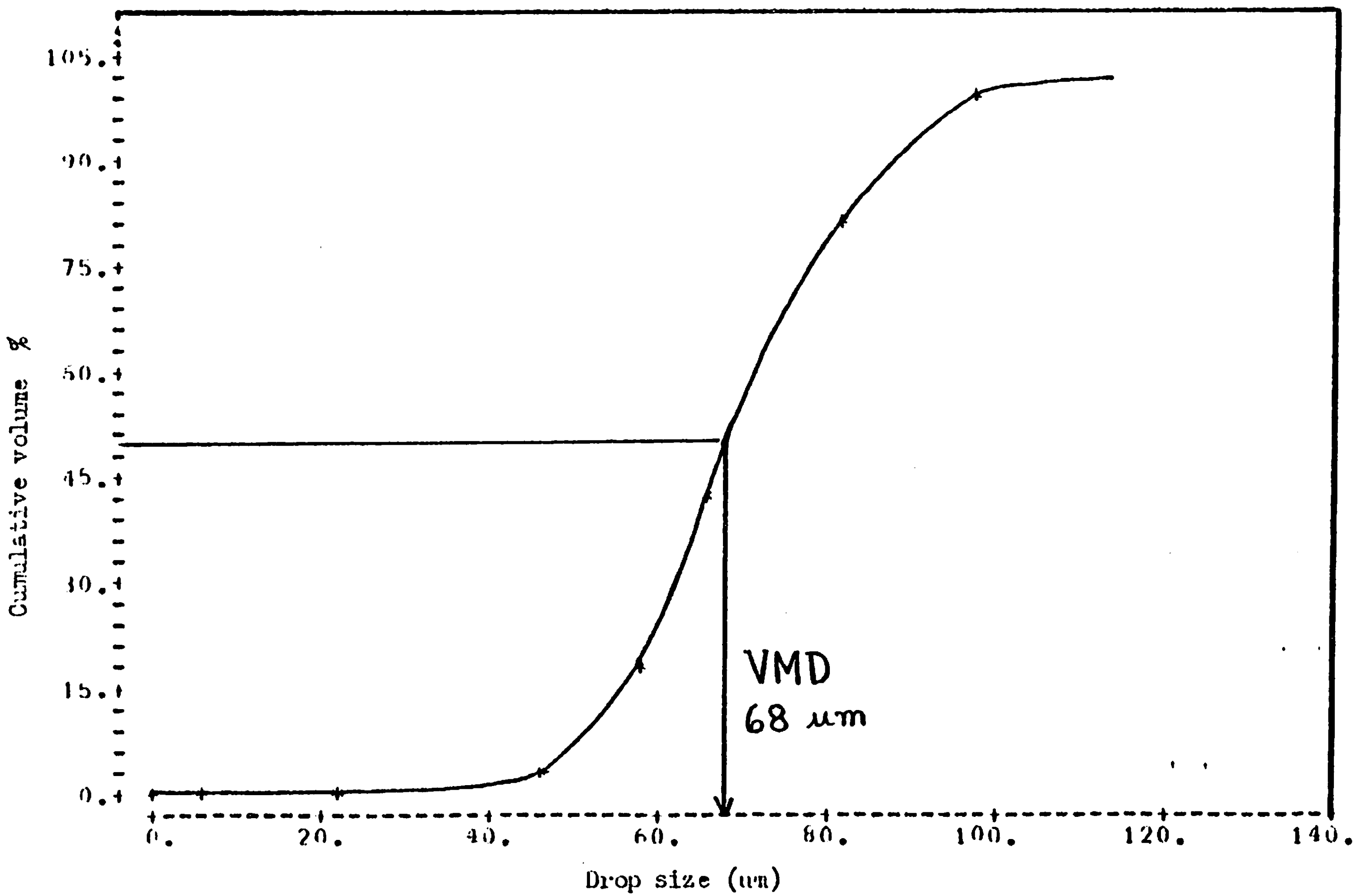
Spray Volume Distribution

(Measured Spread Factor Data)

Average drop size (μm)	Volume of one drop (10^{-8} cc)	Drops per cm^2	Volume distribution per cm^2 (10^{-8} cc)	Volume distribution %	Cumulative volume distribution %
6	0.02	0	0.0	0.0	0
21	0.50	0.73	0.37	0.17	0.17
45	4.83	1.40	6.76	3.06	3.23
57	9.82	3.54	34.76	15.75	18.98
65	14.60	3.60	52.56	23.82	42.80
82	29.20	2.90	84.68	38.38	81.18
98	50.00	0.83	41.50	18.82	100.00

VMD = 68 μm

Fig. 2. VMD for data in Table 2.



Bathurst Trial: Table 3

Plot PV. Second Application

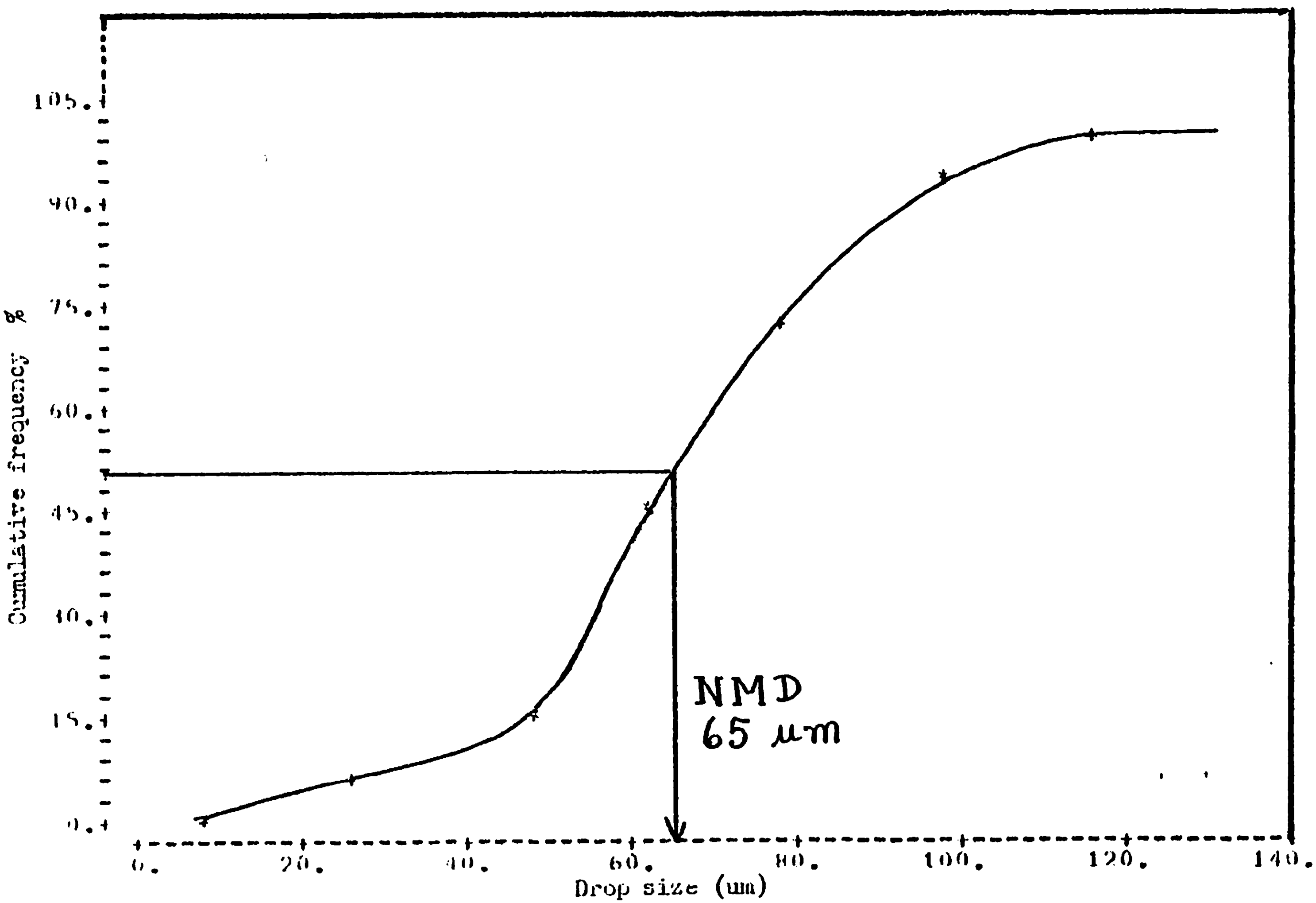
Droplet Size Distribution

Spread Factor (15% Lower)

Stain size range (μm)	Spread factor (mean)	Drop size range (μm)	Average drop size (μm)	Drops per 100 cm^2	Frequency %	Cumulative frequency %
15 - 35	3.23	5 - 11	8	0	0	0
35 - 125	3.23	11 - 39	25	73	5.6	5.6
125 - 220	4.00	39 - 55	47	140	10.8	16.4
220 - 275	4.00	55 - 69	62	354	27.2	43.6
275 - 410	4.68	69 - 88	78	360	27.7	71.3
410 - 495	4.68	88 - 106	97	290	22.3	93.6
495 - 580	4.68	106 - 124	115	83	6.4	100.0

NMD = 65 μm

Fig. 3. NMD for data in Table 3.



Bathurst Trial: Table 4

Plot PV. Second Application

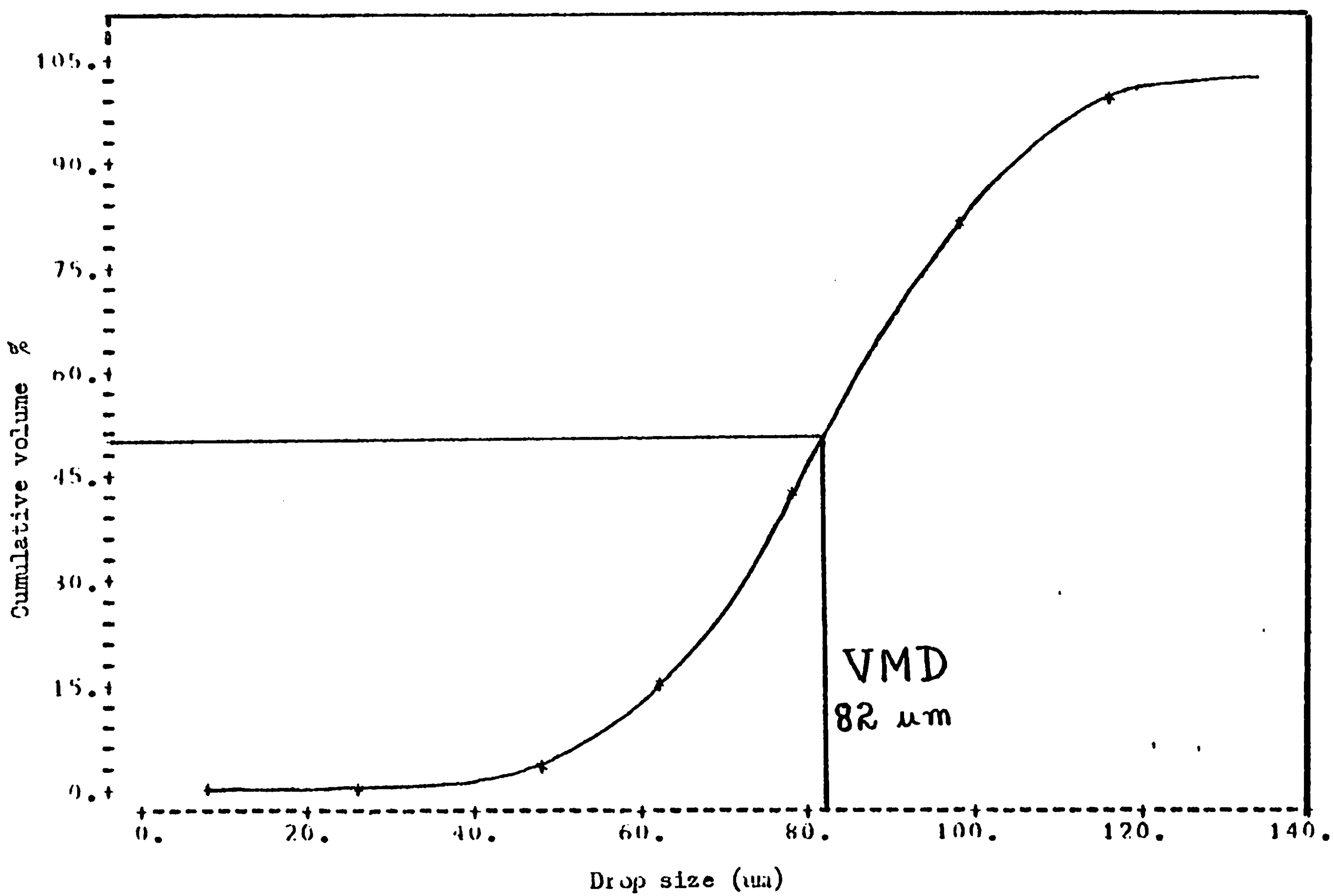
Spray Volume Distribution

Spread Factor (15% Lower)

Average drop size (μm)	Volume of one drop (10^{-8}cc)	Drops per cm^2	Volume distribution per cm^2 (10^{-8} cc)	Volume distribution %	Cumulative volume distribution %
8	0.027	0	0	0	0
25	0.816	0.73	0.60	0.17	0.17
47	5.44	1.40	7.62	2.20	2.37
62	12.45	3.54	44.1	12.73	15.10
78	24.86	3.60	89.5	25.83	40.93
97	47.78	2.90	138.6	40.10	81.03
115	79.60	0.83	66.1	19.10	100.13

VMD = 82 μm

Fig. 4. VMD for data in Table 4.



Bathurst Trial: Table 5

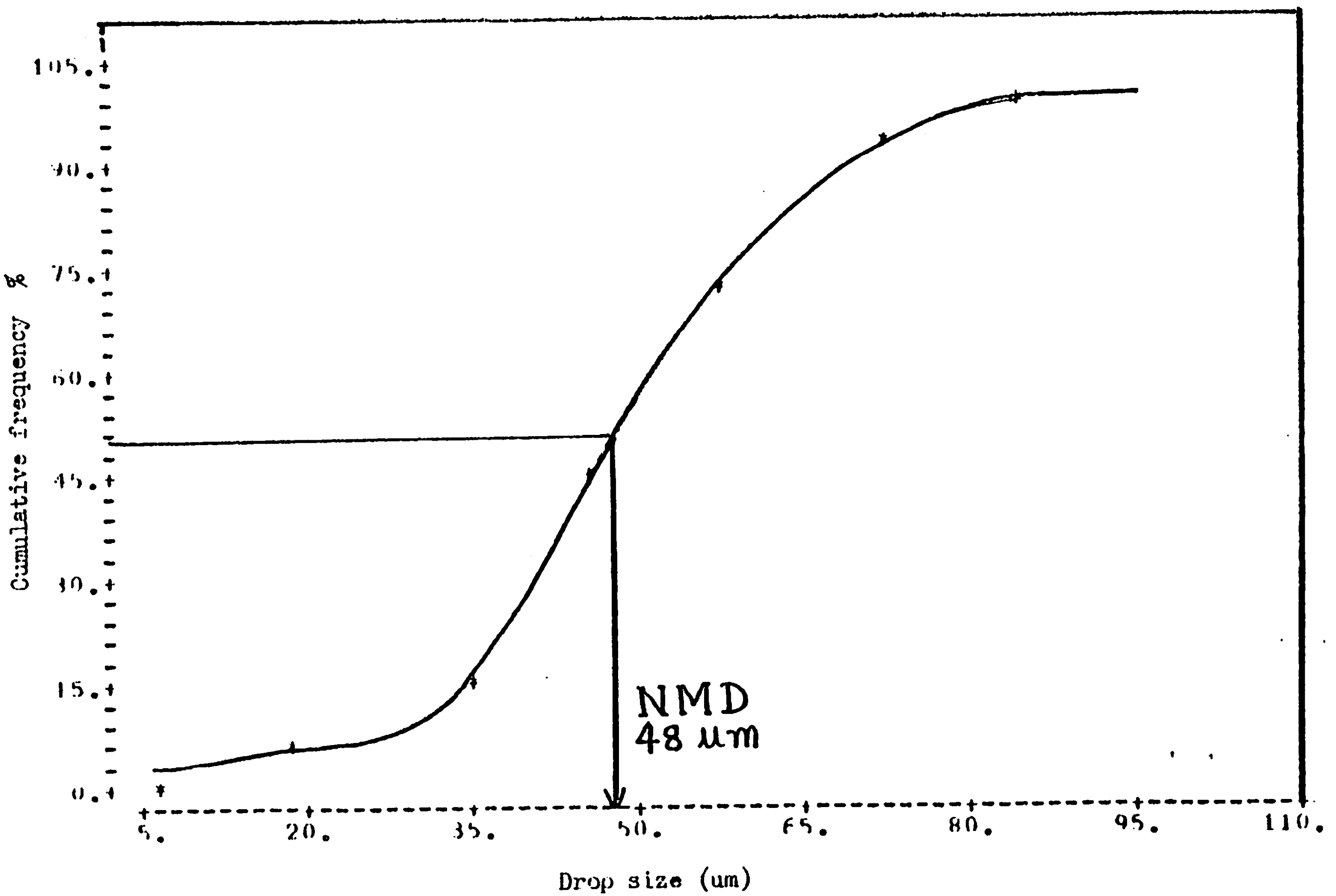
Plot PV. Second Application

Droplet Size Distribution Spread Factor (15% higher)

Stain size range (µm)	Spread factor (mean)	Drop size range (µm)	Average drop size (µm)	Drops per 100 cm^2	Frequency %	Cumulative frequency %
15 - 35	4.37	3 - 8	6	0	0	0
35 - 125	4.37	8 - 29	18	73	5.6	5.6
125 - 220	5.40	29 - 41	35	140	10.8	16.4
220 - 275	5.40	41 - 51	46	354	27.2	43.6
275 - 410	6.32	51 - 65	58	360	27.7	71.3
410 - 495	6.32	65 - 78	72	290	22.3	93.6
495 - 580	6.32	78 - 92	85	83	6.4	100.0

NMD = 48 µm

Fig. 5. NMD for data in Table 5.



Bathurst Trial: Table 6

Plot PV. Second Application

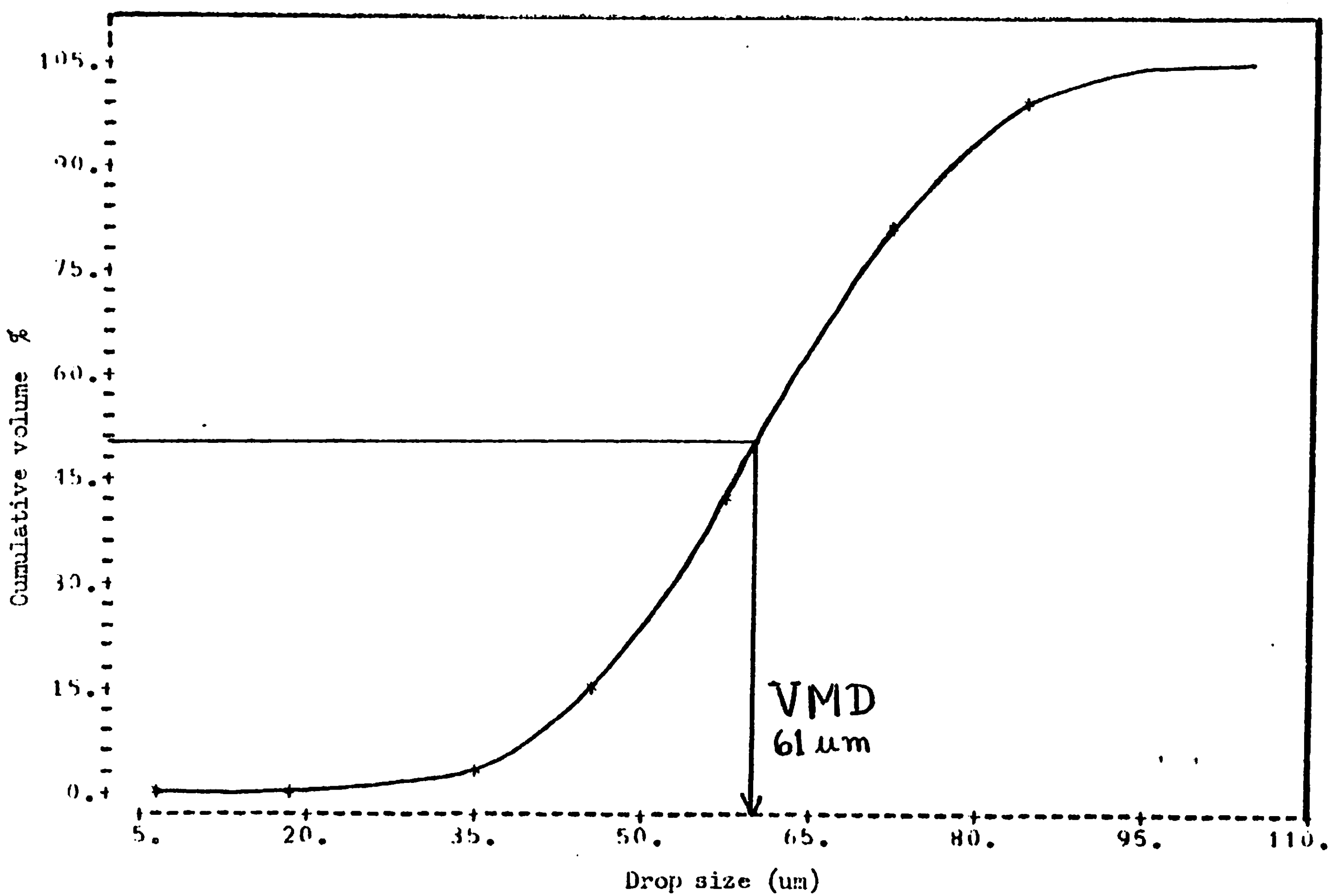
Spray Volume Distribution

Spread Factor (15% Higher)

Average drop size (um)	Volume of one drop (10^{-8} cc)	Drops per cm^2	Volume distribution per cm^2 (10^{-8} cc)	Volume distribution %	Cumulative volume distribution %
6	0.01	0	0	0	0
18	0.30	0.73	0.22	0.16	0.16
35	2.25	1.40	3.15	2.23	2.39
46	5.09	3.54	18.02	12.74	15.13
58	10.21	3.60	36.76	26.00	41.13
72	19.53	2.90	56.64	40.04	81.17
85	32.14	0.83	26.68	18.86	100.03

VMD = 61 μm

Fig. 6. VMD for data in Table 6.



Bathurst Trial: Table 7

Plot PV. Second Application

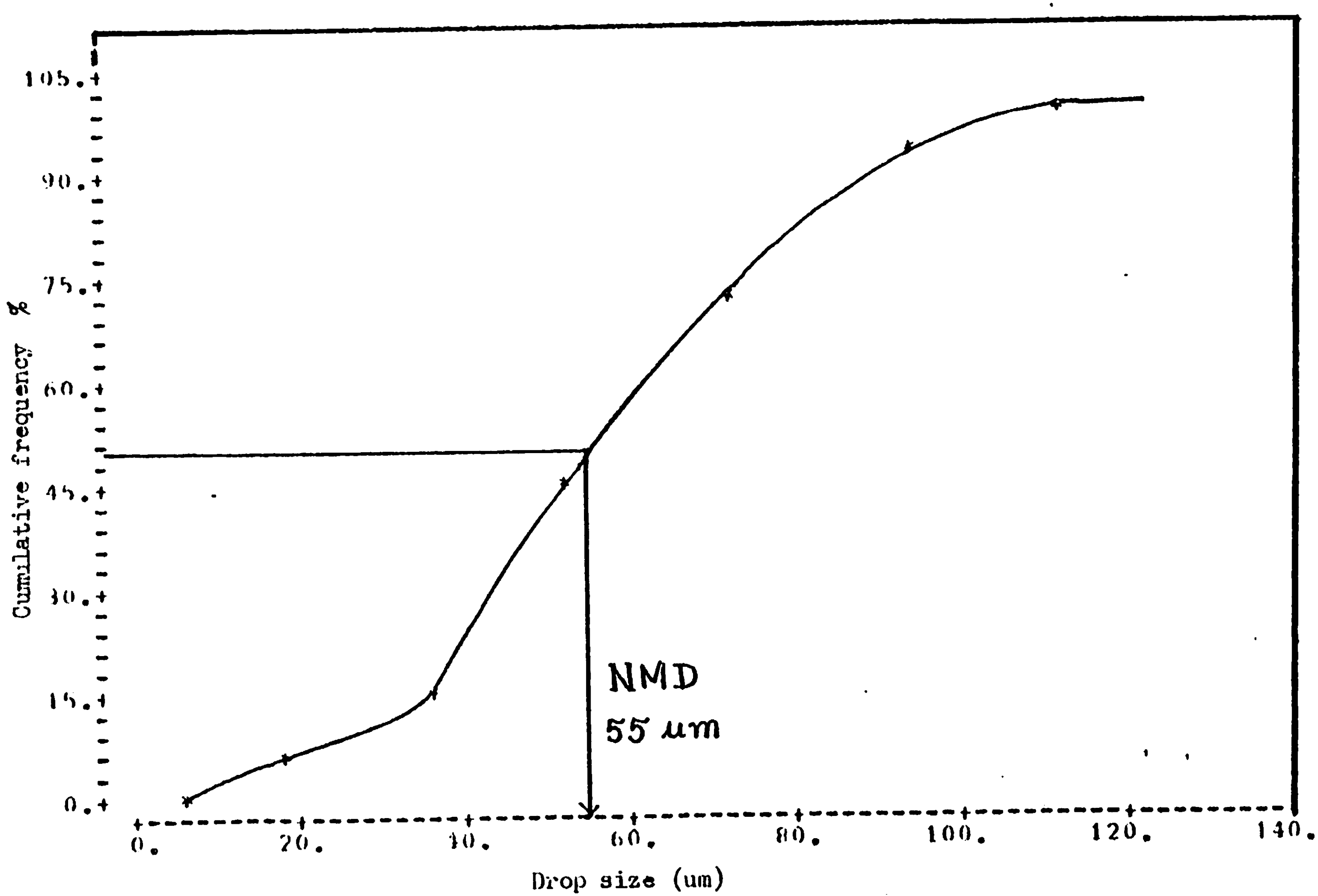
Droplet Size Distribution Using Average Spread Factor

Stain size range (µm)	Spread factor (mean)*	Drop size range (µm)	Average drop size (µm)	Drops per 100 cm^2	Frequency %	Cumulative frequency %
15 - 35	4.8	3 - 7	5	0	0	0
35 - 125	4.8	7 - 26	17	73	5.6	5.6
125 - 220	4.8	26 - 46	36	140	10.8	16.4
220 - 275	4.8	46 - 57	52	354	27.2	43.6
275 - 410	4.8	57 - 85	71	360	27.7	71.3
410 - 495	4.8	85 - 103	94	290	22.3	93.6
495 - 580	4.8	103 - 121	112	83	6.4	100.0

NMD = 55 µm

* Average of 3.8, 3.8, 4.7, 4.7, 5.5, 5.5, 5.5.

Fig. 7. NMD for data in Table 7.



Bathurst Trial: Table 8

Plot PV. Second Application

Spray Volume Distribution

Using Average Spread Factor

Average drop size (μm)	Volume of one drop (10^{-8} cc)	Drops per cm^2	Volume distribution per cm^2 (10^{-8} cc)	Volume distribution %	Cumulative volume distribution %
5	0.005	0	0	0	0
17	0.260	0.73	0.19	0.07	0.07
36	2.44	1.40	3.42	1.20	1.27
52	7.36	3.54	26.05	9.13	10.40
71	18.73	3.60	68.55	24.02	34.42
94	43.47	2.90	126.10	44.19	78.61
112	73.52	0.83	61.02	21.39	100.00

VMD = 80 μm

Fig. 8. VMD for data in Table 8.

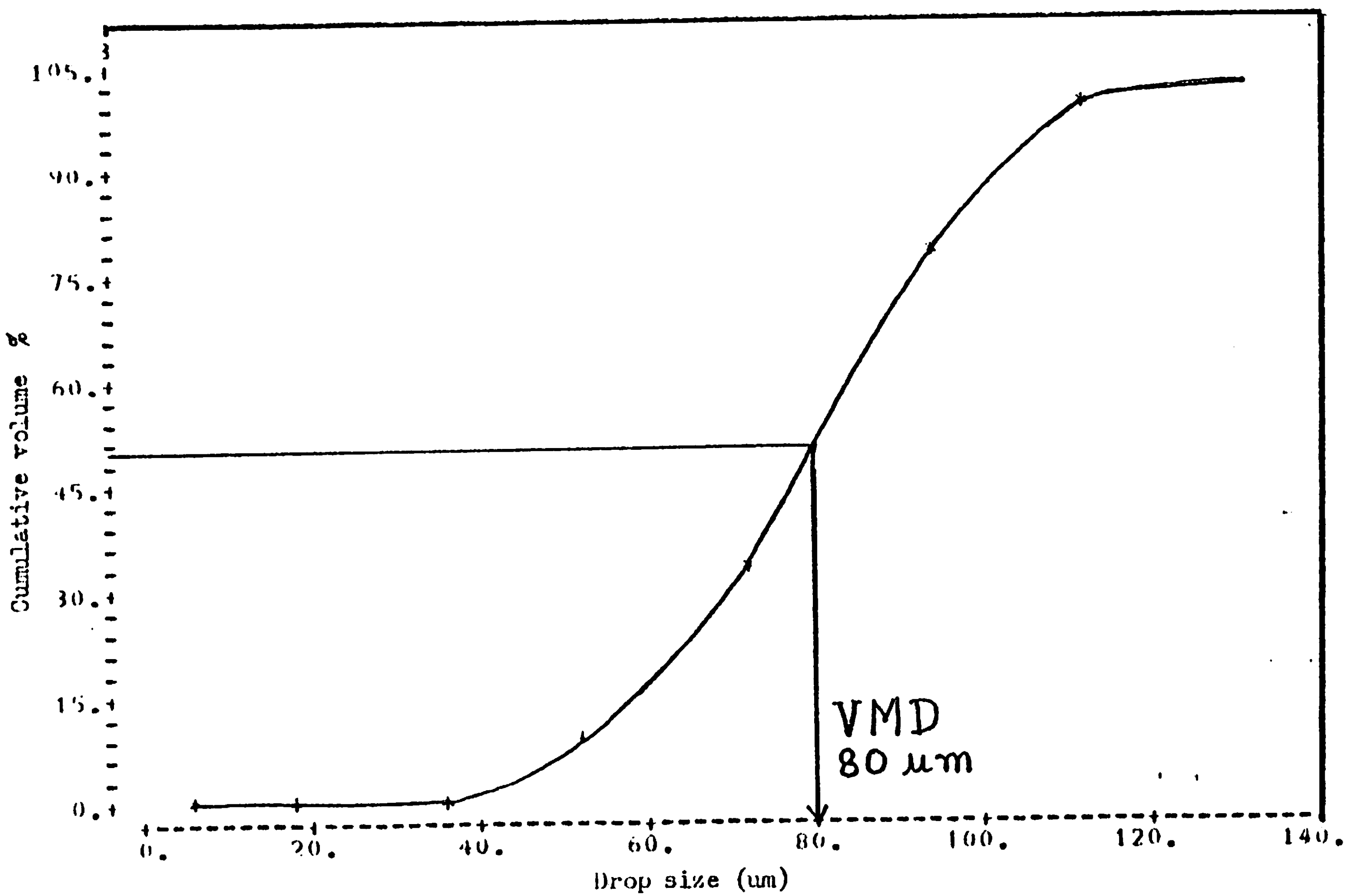


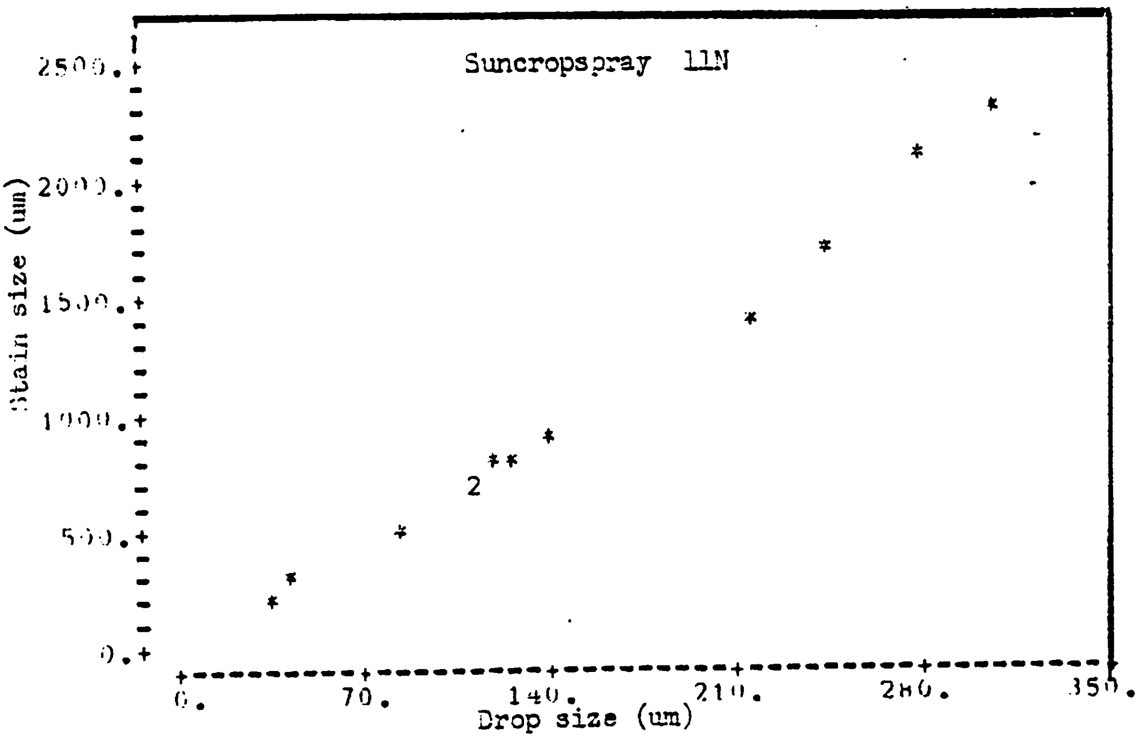
Table 9

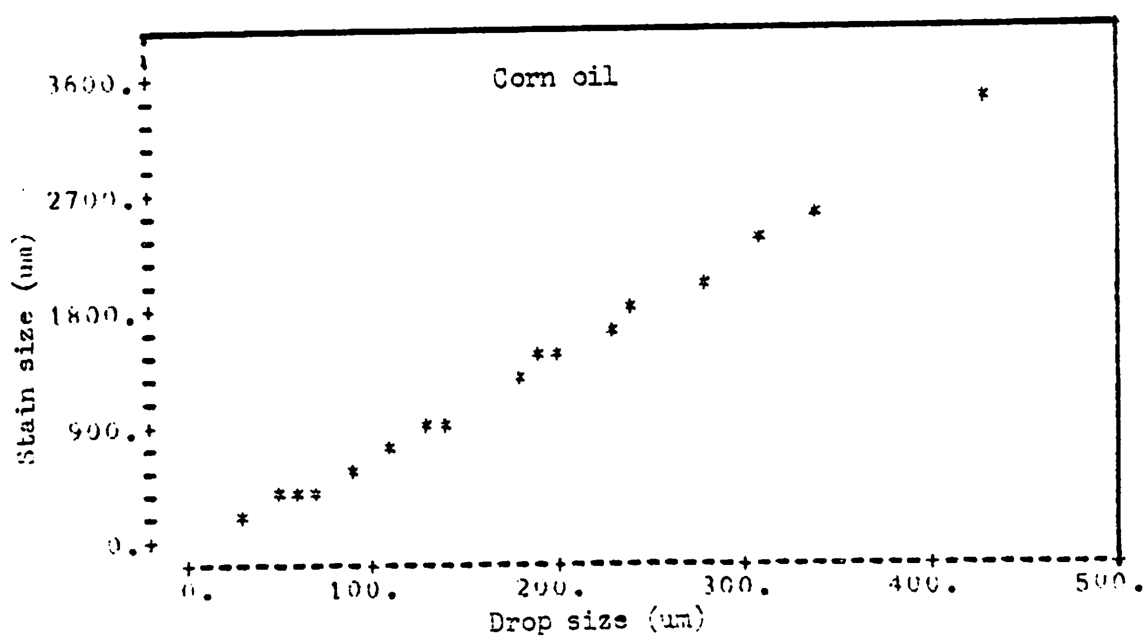
Observed Spread Factor Data for Suncropspray 11N and Corn Oil

Stain size (μm)	Drop size (μm)	Spread factor	Stain size (μm)	Drop size (μm)	Spread factor
202	36	5.6	182	32	5.7
270	44	6.1	284	48	5.9
540	81	6.7	360	57	6.3
720	112	6.4	408	68	6.0
720	118	6.1	585	90	6.5
765	121	6.3	630	105	6.0
765	128	6.0	900	127	7.1
855	140	6.1	945	135	7.0
1440	216	6.7	1305	184	7.1
1733	246	7.0	1395	192	7.3
2250	308	7.3	1440	202	7.1
2070	281	7.4	1598	225	7.1
			1718	242	7.1
			1990	276	7.2
			2330	311	7.5
			2570	338	7.6
			3338	428	7.8

Fig. 9.

Spread Factor Data For Oils





Bathurst Spray Trial

Table 10: Aminocarb 180 D

Plot PV: Second Application

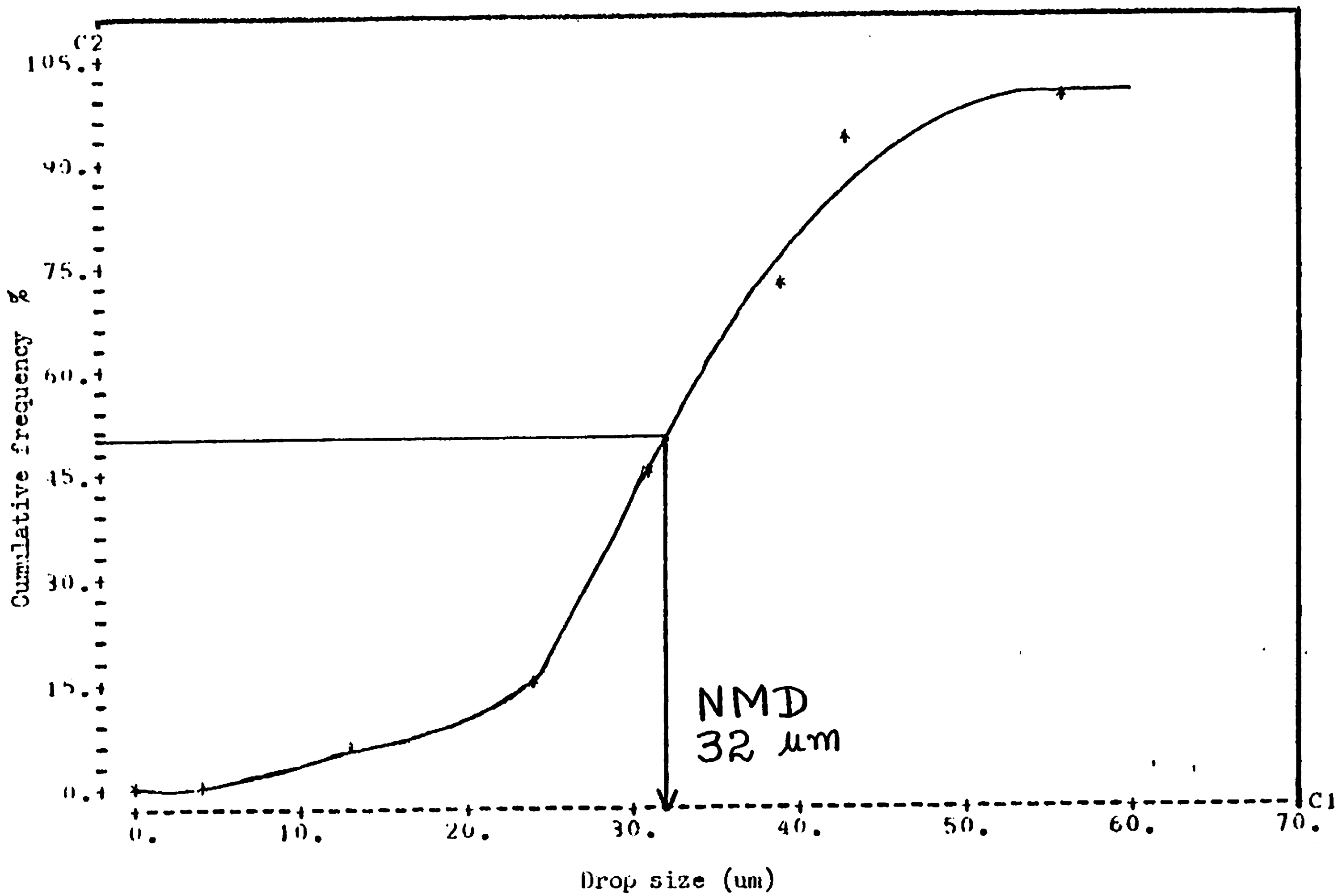
Droplet Size Distribution

(Spread Factor Data Contain +75% Error, Compared to Those Listed in Table 1)

Stain size range (μm)	Spread factor (mean)	Drop size range (μm)	Average drop size (μm)	Drops per 100 cm^2	Frequency %	Cumulative frequency %
15 - 35	6.65	2 - 5	3.5	0	0	0
35 - 125	6.65	5 - 19	12.5	73	5.6	5.6
125 - 220	8.23	19 - 27	23.5	140	10.8	16.4
220 - 275	8.23	27 - 33	30.5	354	27.2	43.6
275 - 410	9.63	33 - 43	38.5	360	27.7	71.3
410 - 495	9.63	43 - 51	42.5	290	22.3	93.6
495 - 580	9.63	51 - 60	56.0	83	6.4	100.0

NMD = 32 μm

Fig. 10. NMD for data in Table 10.



Bathurst Spray Trial

Table 11: Aminocarb 180 D

Plot PV: Second Application

Spray Volume Distribution

(Spread Factor Data With +75% Error)

Average drop size (μm)	Volume of one drop (10^{-8} cc)	Drops per cm^2	Volume distribution per cm^2 (10^{-8} cc)	Volume distribution %	Cumulative volume distribution %
3.5	0.0022	0	0	0	0
12.5	0.102	0.73	0.075	0.21	0.21
23.5	0.680	1.40	0.952	2.62	2.83
30.5	1.486	3.54	5.26	14.47	17.30
38.5	2.988	3.60	10.76	29.60	46.90
42.5	4.020	2.90	11.66	32.08	78.98
56.0	9.200	0.83	7.64	21.02	100.00

VMD = 40 μm

Fig. 11. VMD for data in Table 11.