A COMPARATIVE EVALUATION OF STORAGE STABILITY, MIXING CAPABILITY, PHYSICOCHEMICAL PROPERTIES AND SPRAY BEHAVIORAL PATTERN OF ZECTRAN® UCZF19 FORMULATIONS AND TWELVE SPRAY FORMULATIONS CURRENTLY REGISTERED FOR FORESTRY USE.

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ABSTRACT

Zectran® UCZF19 (Zect-UC-19) is an oil-based formulation concentrate of mexacarbate (4-dimethylamino-3,5-xylyl N-methylcarbamate) insecticide, introduced recently by Union Carbide, North Carolina, USA. It is a low viscosity liquid that is insoluble in water, but miscible readily with nonaqueous solvents. It contains a volatile solvent with a high solubilizing power, in order to prevent the crystallization of the active ingredient during storage in the winter months under field conditions. Because of its high volatility, the use of ID 585 diluent, a volatile petroleum oil, was considered unsuitable for aerial spraying and therefore, a new diluent mixture made up of Cyclosol® 63, canola oil and ID 585 in the ratio of 1:2:3, was recommended for field use.

The present study describes an investigation carried out to explore the physicochemical properties, stability considerations, mixing capabilities, spray behavioral pattern and deposit characteristics of two spray mixtures, one in the diluent oil recommended, and the other one in water as an emulsion with Triton® X-114. These spray mixtures were prepared to provide a field application rate of 70 g AI in 1.5 L/ha. In addition, twelve more spray mixtures were investigated. These are prepared from fenitrothion technical and aminocarb formulation Matacil® 180F. These were chosen because they are already registered and listed on the label; and a comparative study with these formulations would provide information on the suitability of the new spray mixtures for field use, since the registered formulations have been shown to be acceptable for use under field conditions.

The present study indicated that the Zectran UCZF19 formulation concentrate is quite suitable for field use for spruce budworm control. The spray diluent, Cyclosol:canola oil:ID 585 mixture provided optimum evaporation characteristics; and because of this, the oil-based spray mixture yielded much higher deposits than the currently used, oil-based fenitrothion formulation. The emulsion formulation provided much lower deposits than the oil-based mixture, but this is because of the low humidity of the study, i.e., 45% under which the spray was applied. At any rate, the new emulsion provided comparable deposits to those of the currently used fenitrothion formulations. This finding indicates that both spray mixtures, oil-based and water-based, are very suitable for field use under operational spray conditions. In addition, the optimum viscosity of the formulation concentrate and of the final end-use mixtures provided a great advantage of this new formulation over the currently used fenitrothion and aminocarb formulations. Moreover, the emulsion spray mixture is a very stable one as compared to the currently used fenitrothion and aminocarb emulsions with Atlox 3409F emulsifier. This means that the active ingredient would be very uniformly distributed over the entire forest canopy and would have a high degree of insect control, and with minimum environmental impact.

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INTRODUCTION

Zectran® UCZF19 (Zect-UC-19) is a new formulation concentrate of mexacarbate insecticide (4-dimethylamino-3,5-xylyl N-methylcarbamate) introduced recently by Union Carbide. The active ingredient was field-tested in different eastern provinces of Canada during 1972-1973 spray seasons, for the control of spruce budworm (*Choristoneura fumiferana* Clemens) larvae. The chemical is currently being re-examined for large scale forestry use in Canada because of its desirable properties such as pest selectivity, low mammalian toxicity and low persistence in the environment.

The commercial formulation concentrate contains a volatile solvent with a high solubilizing power. The presence of this solvent was found to be essential in order to keep the active ingredient (AI) from crystallizing out in the storage containers, under the field conditions of storage during the winter months, and during spraying under cold weather conditions. Because of the volatile nature of this formulation, the use of ID 585 diluent, a highly volatile oil, was considered unsuitable. Therefore a new diluent oil mixture was recommended for this purpose. Since the diluent should also have a high solubilizing power to prevent the AI from crystallizing out during mixing, and in the aircraft tank, the presence of Cyclosol® 63 was found to be necessary in the diluent. Therefore, a mixture of Cyclosol 63, canola oil and ID 585 was investigated in the ratio of 1:2:3 and was found to be suitable for the commercial formulation Zect-UC-19. The same formulation was also investigated for spraying as an emulsion using an emulsifier. For this purpose, Triton® X-114 was found to be

most suitable since it provided a very stable emulsion with low evaporation characteristics even when sprayed at low humidity conditions such as 60 to 70 percent relative humidity values.

The present study describes an investigation carried out to explore the physicochemical properties, stability considerations, mixing capabilities and spray behavioral pattern of two spray mixtures of Zect-UC-19, one in a diluent oil mixture (C-CA-ID-585) to provide a spray mixture ZE-UC-19-DIL and one as an emulsion in water (ZE-UC-19-EMUL), at a dosage rate of 70 g AI in 1.5 L/ha. In addition twelve more spray mixtures were investigated. These are: fenitrothion with Cyclosol 63 at a dosage rate of 420 g AI in 0.75 L/ha (FC-22); fenitrothion with Cyclosol 63 and ID 585 to provide a rate of 210 g AI in 1.5 L/ha (FCID-585-35 and FCID-585-40); Matacil® 180F with ID 585 to provide AID-585 spray mixture at a rate of 70 g AI in 1.5 L/ha; fenitrothion with Dowanol® TPM and ID 585 to form a mixture FDID-585-35 at a rate of 210 g AI in 1.5 L/ha; fenitrothion with Dowanol TPM to provide FD-22 mixture at a dosage rate of 420 g AI in 0.75 L/ha; fenitrothion with Cyclosol 63 and Atlox® 3409F in water to provide the spray mixture FCA-3409-4.0 at a dosage rate of 210 g AI in 1.5 L/ha; fenitrothion with Dowanol TPM and Atlox 3409F to provide FDA-3409-1.5 and FDA-3409-4.0 spray mixtures for an application rate of 210 g AI in 1.5 L/ha; fenitrothion with Triton® X-114 emulsifier to provide FT-114-5.0 and FT-114-7.0 mixtures at a rate of 210 g AI in 1.5 L/ha; and Matacil 180F with Atlox 3409F to provide AA-3409 spray mixture at a rate of 70 g AI in 1.5 L/ha. These are chosen because they are already regis-

tered and listed on the label; a comparative study with these registered formulations would provide information on the suitability of the formulation concentrate and the end-use mixtures for field use, since the registered formulations have been shown to be acceptable for use under field conditions.

MATERIALS AND METHODS

1. *Spray Formulations and Other Necessary Ingredients*

The formulation concentrates and the other necessary ingredients used in the study are listed in Table 1, along with the names of companies who supplied them. The percentage compositions of ingredients used in preparing the spray formulations are given in Table 2.

2. *Physical Properties of Ingredients*

Since viscosities of ingredients would provide an insight into their pumping and mixing capabilities, they were measured and listed in Table 3, along with their densities which are needed for calculating the proportions of ingredients for preparing the spray formulations.

3. *Mixing Capabilities of Spray Formulations*

The commercial formulation ZE-UC-19 has a relatively low viscosity when compared to those of the fenitrothion technical and Matacil 180F (ZE-UC-19 10.8; Fe-tech 126; Mat-180F 157 cp at 5°C). This shows that Ze-UC-19 would be very much easier to be pumped out as compared to Fe-tech and Mat-180F. The diluent oil mixture C-CA-ID-585 has a viscosity of 8.99 as compared to the other field diluents currently used (Cyclosol 63 1.62; ID 585 2.39; Dow-TPM 20.2 cp at 5°C). Since C-CA-ID-585 has a viscosity less than that of Dow-TPM, there should

be no difficulty in pumping the new diluent, especially when Dow-TPM has not been known to pose any difficulty in the field conditions. However, three ingredients, viz., Atlo-3409, Trit-114 and can-oil are very viscous and may require powerful pumps for transferring them into the mixing tanks.

With regard to the ease of mixing, ZE-UC-19 poses no problems when mixing with C-CA-ID-585 diluent, since both are of low viscosity and the final mixture is also of similar low viscosity. However, the emulsion with the Trit-114 emulsifier should be mixed with care; since Trit-114 would form a gel if it comes into direct contact with water, this emulsifier should be thoroughly mixed with ZE-UC-19 before it was added to water. Mixing of ZE-UC-19 with Trit-114 is much easier than mixing Fe-tech and Trit-114 because of the low viscosity of ZE-UC-19 and also because of the nature of the solvents present in ZE-UC-19.

4. *Appearance, Solubility in Water, Pour Points, Freezing Points, and Flash Points for Ingredients*

These properties were also gathered for the ingredients used in the study and listed in Table 4.

5. *Physical Properties of Spray Formulations*

Viscosities of spray formulations are indicative of the ease with which they can be pumped into the aircraft tank, their stability in the aircraft tank during the duration of spray, atomization efficiency in the nozzle used, and the evaporation characteristics of spray droplets after the release of the spray, and also possibly the rate of evaporation of droplets from the target surface (ex. the leaf surface

Table 1. Pesticide formulations, spray diluents and surfactants used in the study.

Name	Abbreviations used	Source
Fenitrothion technical	Fe-tech	Sumitomo Chemical (Osaka, Japan)
Matacil® 180F	Mat-180F	Chemagro Ltd. (Mississauga, Ont., Canada).
Zectran® UCZF-19	Zect-UC-19	Union Carbide (North Carolina, USA).
Cyclosol® 63	Cycl-63	Shell (Toronto, Ont., Canada).
ID 585	ID-585	Shell (Toronto, Ont., Canada).
Dowanol® TPM	Dow-TPM	Dow Chemical (Sarnia, Ont., Canada).
Canola oil	Can-oil	Canada Packers (Toronto, Ont., Canada).
Atlox® 3409F	Atlo-3409	Atkemix Inc. (Brantford, Ont., Canada).
Triton® X-114	Trit-114	Rohm and Haas (Scarborough, Ont., Canada).

of the host plant). Therefore these were measured and listed in Table 5. The densities and surface tension values affect the spray atomization characteristics, and the evaporation pattern affects the droplet deposition characteristics; and therefore these were also measured and listed in Tables 6, 7, and 8-14. The evaporation characteristics were expressed in terms of the residual weight percentages at time 't' and are also presented in Figures 1 and 2.

Table 2. Percentage composition of spray mixtures and diluent oil-mixture

Spray mixture abbreviation	Composition (v/v%)*								
	Diluent oil-mixture								
C-CA-ID-585	Cycl-63	16.67	/	Can-oil	33.38	/	ID-585	50	
	Oil-based spray mixtures								
ZE-UC-19-DIL	Zect-UC-19	22	/	C-CA-ID-585	78				
FC-22	Fe-tech	22	/	Cycl-63	78				
FCID-585-35	Fe-tech	11	/	Cycl-63	35	/	ID-585	54	
FCID-585-40	Fe-tech	11	/	Cycl-63	40	/	ID-585	49	
AID-585	Mat-180F	26	/	ID-585	74				
FDID-585-35	Fe-tech	11	/	Dow-TPM	35	/	ID-585	54	
FD-22	Fe-tech	22	/	Dow-TPM	78				
	Emulsion type spray mixtures								
ZE-UC-19-EMUL	Zect-UC-19	22	/	Trit-114	3	/	water	75	
FCA-3409-4.0	Fe-tech	11	/	Cycl-63	4	/	Atlo-3409	1.5	/ water 83.5
FDA-3409-1.5	Fe-tech	11	/	Dow-TPM	1.5	/	Atlo-3409	1.5	/ water 86.0
FDA-3409-4.0	Fe-tech	11	/	Dow-TPM	4.0	/	Atlo-3409	1.5	/ water 83.5
FT-114-5.0	Fe-tech	11	/	Trit-114	5.0	/	water	84	
FT-114-7.0	Fe-tech	11	/	Trit-114	7.0	/	water	82	
AA-3409	Mat-180F	26	/	Atlo-3409	1.3	/	water	72.7	

* To all spray mixtures, a tracer dye was added to facilitate droplet analysis on sample cards. For water-based emulsions, Erio Acid Red was added at 0.2 w/v % and for oil-based mixtures, Automate Red B was added at 2% v/v. Correspondingly, the amount of the diluent (or water) was adjusted so that the volume of the final mixture would not exceed 100 ml.

Table 3. Viscosities and densities of pesticide formulations, ingredients and spray diluents

Materials	Temperature °C of				
	5	10	15	20	25
	Viscosity (cp)				
Fe-tech	126	82.5	53.4	40.0	27.7
Mat-180F	157	111	80.0	62.0	45.8
Zect-UC-19	10.8	8.72	7.12	6.23	4.78
Cycl-63	1.62	1.47	1.33	1.28	1.13
ID-585	2.39	2.12	1.89	1.78	1.56
Dow-TPM	20.2	16.3	13.1	10.8	9.27
Can-oil	161	110	86.1	67.7	51.7
Atlo-3409	Paste	5660	443	329	217
Trit-114	1470	974	600	380	204
	Density (g/ml)				
Fe-tech	1.336	1.328	1.322	1.318	1.315
Mat-180F	0.917	0.914	0.911	0.908	0.906
Zect-UC-19	0.955	0.952	0.949	0.945	0.941
Cycl-63	0.923	0.920	0.917	0.914	0.911
ID-585	0.823	0.819	0.816	0.812	0.809
Dow-TPM	0.996	0.992	0.988	0.983	0.979
Can-oil	0.926	0.922	0.919	0.916	0.912
Atlo-3409	1.042	1.037	1.031	1.026	1.022
Trit-114	1.065	1.059	1.054	1.050	1.047

Table 4

Properties of ingredients and pesticide formulations

Ingredient abbreviation	Appearance & colour	Solubility in water	Product nature	Pour point/ freezing point	Flash point
Fe-tech	Clear brownish yellow liquid	Insoluble	Single product	Below 0 °C	----
Mat-180F	Heavy creamy beige liquid	Insoluble	Formulated product	Below 0 °C	93 °C
Zect-UC-19	Clear amber-coloured liquid	Insoluble	Formulated product	Pour point -18 °C Freezing point -25 °C	68 °C
Cycl-63	Clear thin colourless liquid	Insoluble	Mixture of aromatic hydrocarbons	Below 0 °C	57 °C
ID-585	Clear pale yellow thin liquid	Insoluble	Mixture of aliphatic hydrocarbons	Below 0 °C	52 °C
Dow-TPM	Clear thin clourless liquid	Soluble	Single product	Below 0 °C	110 °C
Can-oil	Heavy clear viscous liquid	Insoluble	Vegetable oil	Pour point -7 °C Freezing point -12 °C	288 °C
Atlo-3409	Cloudy amber-coloured liquid	Soluble	Formulated product	Pour point 4 °C Freezing point 3 °C	12.2 °C
Trit-114	clear colour-less liquid	Soluble	Single product	Pour point -9 °C	>150 °C

Table 5. Viscosities of spray mixtures

Spray formulations	Viscosity (cp) at °C of				
	5	10	15	20	25
			Diluent oil-mixture		
C-CA-ID-585	8.99	7.29	5.76	5.10	4.13
			Oil-based spray mixtures		
ZE-UC-19-DIL	8.93	7.41	6.39	5.80	4.52
FC-22	2.83	2.32	2.04	1.92	1.67
FCID-585-35	2.80	2.38	2.06	1.85	1.66
FCID-585-40	2.66	2.30	1.97	1.78	1.62
AID-585	5.36	4.24	3.48	3.23	2.80
FDID-585-35	6.18	4.98	3.92	3.63	2.98
FD-22	19.2	15.5	11.1	9.76	7.32
			Emulsion type spray mixtures		
ZE-UC-19-EMUL	5.72	4.11	2.73	2.28	1.90
FCA-3409-4.0	9.10	5.23	4.39	3.79	2.36
FDA-3409-1.5	2.89	2.53	2.13	1.80	1.49
FDA-3409-4.0	18.7	12.2	11.1	7.57	6.14
FT-114-5.0	6.50	5.33	4.53	8.50	5.30
FT-114-7.0	25.6	15.7	24.6	47.8	22.2
AA-3409	2.94	2.58	2.12	1.80	1.54

6. *Viscosity-Temperature Relationships of Ingredients, Spray Diluent and Spray Formulations*

The variation of viscosity with temperature can provide an insight into the strength of the inter-molecular interactions within a liquid medium. Therefore, these were investigated for the ingredients, spray diluent and end-use spray mixtures and listed in Table 15. It is clear that the inter-molecular interactions in ZE-UC-19-DIL

Table 6. Densities of spray mixtures

Spray formulations	Density (g/ml) at °C of				
	5	10	15	20	25
			Diluent oil-mixture		
C-CA-ID-585	0.873	0.869	0.866	0.862	0.859
			Oil-based spray mixtures		
ZE-UC-19-DIL	0.896	0.892	0.889	0.886	0.881
FC-22	0.998	0.993	0.988	0.984	0.980
FCID-585-35	0.923	0.920	0.916	0.912	0.908
FCID-585-40	0.912	0.908	0.905	0.900	0.897
AID-585	0.8418	0.8384	0.8347	0.8319	0.8294
FDID-585-35	0.938	0.934	0.929	0.925	0.921
FD-22	1.085	1.081	1.076	1.072	1.067
			Emulsion type spray mixtures		
ZE-UC-19-EMUL	0.997	0.995	0.991	0.987	0.983
FCA-3409-4.0	1.035	1.034	1.034	1.032	1.031
FDA-3409-1.5	1.012	1.011	1.010	1.009	1.008
FDA-3409-4.0	1.041	1.040	1.038	1.037	1.035
FT-114-5.0	1.038	1.037	1.036	1.035	1.034
FT-114-7.0	1.044	1.043	1.042	1.040	1.038
AA-3409	1.0133	1.0125	1.0116	1.0108	1.0096

and ZE-UC-19-EMUL are indicative of their field suitability, since ZE-UC-19-DIL is comparable to AID-585, and ZE-UC-19-EMUL, comparable to FCA-3409-4.0, both of which are registered and have been shown to be suitable for field use.

7. *Exponential Decay Equations for Evaporation Pattern of Spray Formulations, Decay Constants and Half-lives of Evaporation.*

The data from the evaporation study were fitted into exponential decay equations to obtain the decay constants and half-lives

Table 7. Surface tension values of spray mixtures

Spray formulations	Surface tension (dyne/cm) at °C of				
	5	10	15	20	25
		Diluent oil-mixture			
C-CA-ID-585	33.7	33.0	32.3	31.7	31.0
		Oil-based spray mixtures			
ZE-UC-19-DIL	33.1	32.4	31.7	31.0	29.3
FC-22	32.7	32.0	31.2	29.0	28.4
FCID-585-35	28.8	28.2	27.7	27.2	26.8
FCID-585-40	29.2	28.5	28.0	27.5	27.1
AID-585	31.7	31.0	30.3	29.7	29.0
FDID-585-35	27.6	27.5	27.3	27.2	27.1
FD-22	32.6	31.8	30.9	30.0	29.4
		Emulsion type spray mixtures			
ZE-UC-19-EMUL	29.7	29.0	28.2	27.4	26.9
FCA-3409-4.0	33.6	33.0	32.4	31.8	31.0
FDA-3409-1.5	28.9	28.4	28.0	27.5	27.0
FDA-3409-4.0	33.6	33.0	32.3	31.6	31.0
FT-114-5.0	35.6	34.6	33.8	33.0	32.2
FT-114-7.0	33.6	32.9	31.9	30.6	29.5
AA-3409	31.7	31.0	30.3	29.8	29.0

of evaporation, and the results are listed in Table 16. From the decay constants and half-lives of evaporation, it is clear that ZE-UC-19-DIL is similar to FC-22; and ZE-UC-19-EMUL is simlar to FT-114-5.0. Both FC-22 and FT-114-5.0 are currently registered and found to be suitable for field use, and therefore both ZE-UC-19-DIL and ZE-UC-19-EMUL should also be suitable for field use in a similar manner.

Table 8 . Evaporation characteristics of liquid film. Filter paper method. Temp. = 22 ± 1.5 °C. Relative humidity = 45 ± 2%.

Time (min)	Wt. of liquid film			Residual wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				ZE-UC-19-DIL				
0	0.0882	0.0907	0.0900	100	100	100	100	0.00
2	0.0834	0.0852	0.0866	94.6	93.9	96.2	94.9	1.18
4	0.0818	0.0829	0.0846	92.7	91.4	94.0	92.7	1.30
6	0.0784	0.0799	0.0823	88.9	88.1	91.4	89.5	1.72
10	0.0726	0.0739	0.0764	82.3	81.5	84.9	82.9	1.78
20	0.0651	0.0663	0.0685	73.8	73.1	76.1	74.3	1.57
30	0.0595	0.0594	0.0614	67.5	65.5	68.2	67.1	1.40
60	0.0538	0.0533	0.0538	61.0	58.8	59.8	59.8	1.10
120	0.0460	0.0467	0.0463	52.2	51.5	51.4	51.7	0.44
180	0.0402	0.0401	0.0396	45.6	44.2	44.0	44.6	0.87
				FC-22				
0	0.0950	0.0931	0.0935	100	100	100	100	0.00
2	0.0901	0.0892	0.0887	94.8	95.8	94.9	95.2	0.55
4	0.0855	0.0838	0.0838	90.0	90.0	89.6	89.9	0.23
6	0.0798	0.0784	0.0796	84.0	84.2	85.1	84.4	0.59
10	0.0719	0.0716	0.0708	75.7	76.9	75.7	76.1	0.69
20	0.0558	0.0567	0.0545	58.7	60.9	58.3	59.3	1.40
30	0.0425	0.0450	0.0433	44.7	48.3	46.3	46.4	1.80
60	0.0308	0.0308	0.0301	32.4	33.1	32.2	32.6	0.47
120	0.0248	0.0236	0.0234	26.1	25.4	25.0	25.5	0.56
180	0.0209	0.0203	0.0212	22.0	21.8	22.7	22.2	0.47

Table 9 . Evaporation characteristics of liquid film. Filter paper method. Temp. = 22 ± 1.5 °C. Relative humidity = 45 ± 2%.

Time (min)	Wt. of liquid film			Residual wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				FCID-585-35				
0	0.0927	0.0889	0.0898	100	100	100	100	0.00
2	0.0874	0.0833	0.0842	94.3	93.7	93.8	93.9	0.32
4	0.0827	0.0785	0.0795	89.2	88.3	88.5	88.7	0.47
6	0.0791	0.0753	0.0745	85.3	84.7	83.0	84.3	1.23
10	0.0732	0.0693	0.0687	79.0	78.3	76.5	77.9	1.27
20	0.0587	0.0553	0.0556	63.3	62.2	61.9	62.5	0.74
30	0.0524	0.0488	0.0487	56.5	54.9	54.2	55.2	1.18
60	0.0379	0.0353	0.0346	40.9	39.7	38.5	39.7	1.18
120	0.0260	0.0248	0.0230	28.1	27.9	25.6	27.2	1.37
180	0.0225	0.0207	0.0192	24.3	23.3	21.4	23.0	1.49
				FCID-585-40				
0	0.0899	0.0903	0.0866	100	100	100	100	0.00
2	0.0824	0.0818	0.0806	91.7	90.6	93.1	91.8	1.24
4	0.0765	0.0787	0.0766	85.1	87.5	88.5	86.9	1.69
6	0.0734	0.0751	0.0727	81.7	83.2	84.0	82.9	1.17
10	0.0694	0.0711	0.0658	77.2	78.7	76.0	77.3	1.38
20	0.0574	0.0593	0.0542	63.9	65.7	62.6	64.0	1.55
30	0.0492	0.0499	0.0459	54.7	55.3	53.0	54.3	1.18
60	0.0372	0.0372	0.0342	41.4	41.2	39.5	40.7	1.04
120	0.0260	0.0260	0.0232	28.9	28.8	26.8	28.2	1.19
180	0.0186	0.0192	0.0167	20.7	21.3	19.3	20.4	1.02

Table 10 . Evaporation characteristics of liquid film. Filter paper method. Temp. = 22 ± 1.5 °C. Relative humidity = 45 ± 2%.

Time (min)	Wt. of liquid film			Residual wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				AID-585				
0	0.0893	0.0839	0.0860	100	100	100	100	0.00
2	0.0868	0.0815	0.0833	97.2	97.1	96.9	97.1	0.15
4	0.0844	0.0788	0.0805	94.5	93.9	93.6	94.0	0.46
6	0.0826	0.0771	0.0786	92.5	91.9	91.4	91.9	0.55
10	0.0795	0.0739	0.0749	89.0	88.1	87.1	88.1	0.95
20	0.0725	0.0669	0.0672	81.2	79.7	78.1	79.7	1.55
30	0.0690	0.0635	0.0636	77.3	75.7	74.0	75.7	1.65
60	0.0629	0.0574	0.0572	70.4	68.4	66.5	68.4	1.95
120	0.0552	0.0507	0.0505	61.9	60.4	58.7	60.4	1.60
180	0.0510	0.0467	0.0473	57.1	55.7	55.0	55.9	1.07
				FDID-585-35				
0	0.0883	0.0908	0.0912	100	100	100	100	0.00
2	0.0856	0.0882	0.0888	96.9	97.1	97.4	97.2	0.22
4	0.0847	0.0867	0.0864	95.9	95.5	94.7	95.4	0.60
6	0.0829	0.0850	0.0847	93.9	93.6	92.9	93.5	0.52
10	0.0812	0.0825	0.0831	92.0	90.9	91.1	91.3	0.57
20	0.0776	0.0779	0.0783	87.9	85.8	85.9	86.5	1.19
30	0.0760	0.0761	0.0762	86.1	83.8	83.6	84.5	1.39
60	0.0680	0.0680	0.0687	77.0	74.9	75.3	75.7	1.12
120	0.0596	0.0588	0.0578	67.5	64.8	63.4	65.2	2.10
180	0.0561	0.0551	0.0530	63.5	60.7	58.1	60.8	2.71

Table 11. Evaporation characteristics of liquid film. Temp. = 22 + 1.5 °C.
Relative humidity = 45 ± 2%.

Time (min)	Wt. of liquid film			Residual wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				FD-22 (Filter paper method)				
0	0.1068	0.0982	0.1028	100	100	100	100	0.00
2	0.1076	0.0988	0.1026	100.8	100.6	99.8	100.4	0.53
4	0.1068	0.0986	0.1022	100	100.4	99.4	99.9	0.50
6	0.1064	0.0984	0.1020	99.6	100.2	99.2	99.7	0.50
10	0.1062	0.0980	0.1016	99.4	99.8	98.8	99.3	0.50
20	0.1048	0.0974	0.1004	98.1	99.2	97.7	98.3	0.78
30	0.1042	0.0962	0.1000	97.6	98.0	97.3	97.6	0.35
60	0.1008	0.0948	0.0976	94.4	96.5	94.9	95.3	1.10
120	0.0968	0.0912	0.0934	90.6	92.9	90.9	91.5	1.25
180	0.0940	0.0880	0.0900	88.0	89.6	87.6	88.4	1.06
				ZE-UC-19-EMUL (Blue screen method)				
0	0.2469	0.2579	0.2033	100	100	100	100	0.00
2	0.2278	0.2404	0.1853	92.3	93.2	91.2	92.2	1.03
4	0.2095	0.2211	0.1662	84.9	85.7	81.8	84.1	2.09
6	0.1917	0.2037	0.1479	77.6	79.0	72.8	76.5	3.28
10	0.1568	0.1720	0.1148	63.5	66.7	56.5	62.2	5.23
20	0.0873	0.0955	0.0515	35.4	37.0	25.3	32.6	6.33
40	0.0564	0.0524	0.0381	22.9	20.3	18.7	20.6	2.07
60	0.0518	0.0481	0.0360	21.0	18.7	17.7	19.1	1.68
120	0.0492	0.0458	0.0346	19.9	17.8	17.0	18.2	1.51
180	0.0482	0.0444	0.0335	19.5	17.2	16.5	17.7	1.59

Table 12 . Evaporation characteristics of liquid film. Blue screen method. Temp. = 22 ± 1.5 °C. Relative humidity = 45 ± 2%.

Time (min)	Wt. of liquid film			Residual wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				FCA-3409-4.0				
0	0.3032	0.2374	0.2635	100	100	100	100	0.00
2	0.2864	0.2215	0.2470	94.5	93.3	93.7	93.8	0.59
4	0.2713	0.2059	0.2320	89.5	86.7	88.1	88.1	1.38
6	0.2555	0.1912	0.2176	84.3	80.5	82.6	82.5	1.87
10	0.2240	0.1614	0.1881	73.9	68.0	71.4	71.1	2.96
20	0.1587	0.0978	0.1219	52.3	41.2	46.3	46.6	5.58
30	0.0925	0.0677	0.0698	30.5	28.5	26.5	28.5	2.00
40	0.0564	0.0326	0.0373	18.6	13.7	14.2	15.5	2.70
60	0.0396	0.0321	0.0354	13.1	13.5	13.4	13.3	0.25
120	0.0388	0.0316	0.0349	12.8	13.3	13.2	13.1	0.28
180	0.0388	0.0316	0.0349	12.8	13.3	13.2	13.1	0.28
				AA-3409				
0	0.2333	0.2475	0.2514	100	100	100	100	0.00
2	0.2205	0.2349	0.2373	94.5	94.9	94.4	94.6	0.27
4	0.2078	0.2219	0.2228	89.1	89.7	88.6	89.1	0.52
6	0.1952	0.2089	0.2110	83.7	84.4	83.9	84.0	0.37
10	0.1708	0.1844	0.1866	73.2	74.5	74.2	74.0	0.68
20	0.1203	0.1302	0.1318	51.6	52.6	52.4	52.2	0.56
40	0.0622	0.0753	0.0762	26.7	30.4	30.3	29.1	2.14
60	0.0554	0.0708	0.0717	23.8	28.6	28.5	27.0	2.78
120	0.0547	0.0699	0.0710	23.5	28.2	28.2	26.6	2.77
180	0.0541	0.0698	0.0707	23.2	28.2	28.1	26.5	2.87

Table 13. Evaporation characteristics of liquid film. Temp. °C = 22 ± 1.5. Relative humidity = 45 ± 2%.

Time (min)	Wt. of Liquid Film			Residual Wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				FT-114-5.0				
0	0.3027	0.3125	0.3296	100	100	100	100	0.00
2	0.2888	0.2978	0.3152	95.4	95.3	95.6	95.5	0.17
4	0.2750	0.2840	0.3016	90.9	90.9	91.5	91.1	0.37
6	0.2614	0.2703	0.2879	86.4	86.5	87.4	86.7	0.54
10	0.2348	0.2442	0.2630	77.6	78.1	79.8	78.5	1.15
20	0.1716	0.1812	0.2008	56.7	58.0	60.9	58.5	2.17
40	0.0800	0.0820	0.0993	26.4	26.2	30.1	27.6	2.19
60	0.0558	0.0564	0.0584	18.4	18.1	17.7	18.1	0.36
120	0.0554	0.0562	0.0581	18.3	18.0	17.6	18.0	0.34
180	0.0554	0.0562	0.0580	18.3	18.0	17.6	18.0	0.35
				FT-114-7.0				
0	0.3335	0.3410	0.3326	100	100	100	100	0.00
2	0.3172	0.3250	0.3166	95.1	95.3	95.2	95.2	0.10
4	0.2990	0.3097	0.3016	89.7	90.8	90.7	90.4	0.63
6	0.2827	0.2962	0.2872	84.8	86.9	86.4	86.0	1.09
10	0.2539	0.2676	0.2592	76.1	78.5	77.9	77.5	1.23
20	0.1851	0.2018	0.1921	55.5	59.2	57.8	57.5	1.86
40	0.0910	0.1002	0.0909	27.3	29.4	27.3	28.0	1.20
60	0.0724	0.0751	0.0710	21.7	22.0	21.4	21.7	0.34
120	0.0723	0.0734	0.0710	21.7	21.5	21.4	21.5	0.17
180	0.0718	0.0734	0.0710	21.5	21.5	21.4	21.5	0.10

Table 14. Evaporation characteristics of liquid film. Temp. °C = 22 ± 1.5. Relative humidity = 45 ± 2%.

Time (min)	Wt. of Liquid Film			Residual Wt. %			Mean residual weight %	S.D.
	1st	2nd	3rd	1st	2nd	3rd		
				FDA-3409-1.5				
0	0.2150	0.2205	0.2195	100	100	100	100	0.00
2	0.2002	0.2062	0.2060	93.1	93.6	93.9	93.5	0.37
4	0.1871	0.1917	0.1904	87.0	87.0	86.8	86.9	0.14
6	0.1742	0.1781	0.1775	81.0	80.8	80.9	80.9	0.14
10	0.1488	0.1516	0.1515	69.2	68.8	69.0	69.0	0.23
20	0.0866	0.0894	0.0894	40.3	40.6	40.8	40.5	0.24
40	0.0286	0.0304	0.0301	13.3	13.8	13.7	13.6	0.26
60	0.0283	0.0304	0.0301	13.3	13.8	13.7	13.6	0.26
120	0.0283	0.0304	0.0301	13.3	13.8	13.7	13.6	0.26
180	0.0283	0.0304	0.0301	13.3	13.8	13.7	13.6	0.26
				FDA-3409-4.0				
0	0.2092	0.2505	0.2604	100	100	100	100	0.00
2	0.1968	0.2380	0.2490	94.1	95.0	95.6	94.9	0.78
4	0.1842	0.2252	0.2370	88.1	89.9	91.0	89.7	1.50
6	0.1728	0.2128	0.2237	82.6	85.0	85.9	84.5	1.70
10	0.1471	0.1857	0.1964	70.3	74.1	75.4	73.3	2.65
20	0.0900	0.1238	0.1362	43.0	49.4	52.3	48.3	4.75
40	0.0307	0.0388	0.0401	14.7	15.5	15.4	15.2	0.44
60	0.0304	0.0332	0.0341	14.5	13.3	13.1	13.6	0.79
120	0.0294	0.0319	0.0328	14.1	12.7	12.6	13.1	0.80
180	0.0285	0.0310	0.0321	13.6	12.4	12.3	12.8	0.73

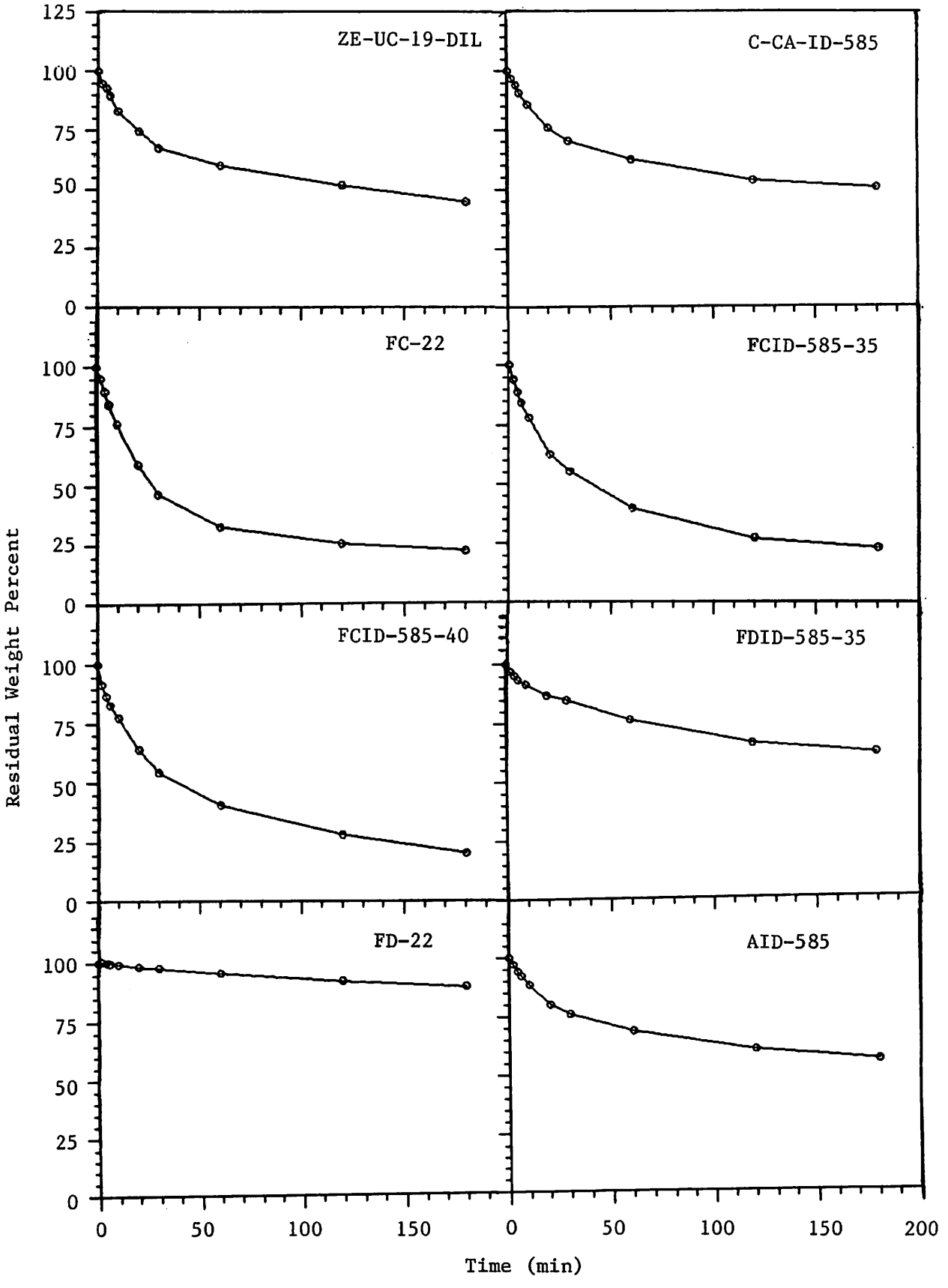

Fig. 1. Evaporation Characteristics of Oil-Based Spray Formulations.

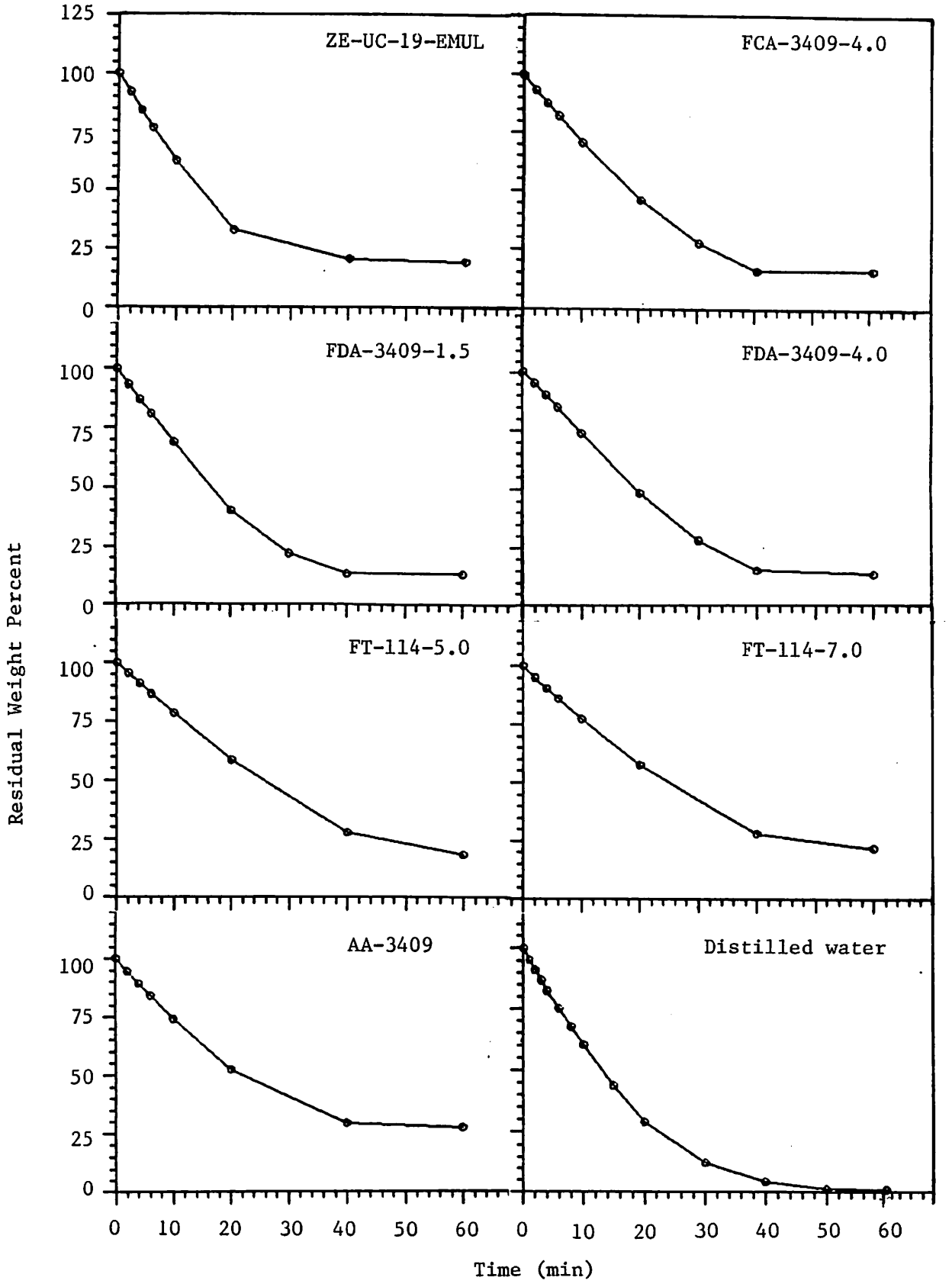

Fig. 2. Evaporation Characteristics of Emulsion Formulations.

Table 15 . Viscosity-temperature relationships of ingredients, spray diluent and spray mixtures

Liquid abbreviation	Linear regression equation	R^2(%)	Intercept* 'I'	Slope* 'S'	D§	E§ (kJ/mol.K)
		Ingredients				
Fe-tech	$\log \eta$ = -7.64 + 2704 (1/T)	99.7	-7.64	2704	0.00×10^{-5}	51.8
Mat-180F	$\log \eta$ = -5.70 + 2194 (1/T)	99.8	-5.70	2194	0.20	42.0
Zect-UC-19	$\log \eta$ = -4.05 + 1414 (1/T)	99.1	-4.05	1414	8.91	27.0
Cycl-63	$\log \eta$ = -2.12 + 647 (1/T)	99.9	-2.12	647	759	12.4
ID-585	$\log \eta$ = -2.29 + 740 (1/T)	99.0	-2.29	740	513	14.2
Dow-TPM	$\log \eta$ = -3.80 + 1419 (1/T)	99.8	-3.80	1419	16.0	27.1
Can-oil	$\log \eta$ = -4.94 + 1981 (1/T)	99.4	-4.94	1981	1.15	37.9
Atlo-3409	$\log \eta$ = -22.8 + 7437 (1/T)	79.3	-22.8	7437	0.00	142
Trit-114	$\log \eta$ = -9.44 + 3514 (1/T)	99.1	-9.44	3514	0.00	67.3
Water	$\log \eta$ = -3.14 + 923 (1/T)	99.2	-3.14	923	72.4	17.7
		Spray diluent				
C-CA-ID-585	$\log \eta$ = -4.01 + 1378 (1/T)	99.4	-4.01	1378	9.77	26.4
		Oil-based spray formulations				
ZE-UC-19-DIL	$\log \eta$ = -3.20 + 1155 (1/T)	98.0	-3.20	1155	63.1	22.1
FC-22	$\log \eta$ = -2.93 + 937 (1/T)	98.1	-2.93	937	117	17.9
FCID-585-35	$\log \eta$ = -2.92 + 935 (1/T)	99.4	-2.92	935	120	17.9
FCID-585-40	$\log \eta$ = -2.82 + 900 (1/T)	99.2	-2.82	900	151	17.2
AID-585	$\log \eta$ = -3.37 + 1134 (1/T)	97.1	-3.37	1134	43	21.7
FDID-585-35	$\log \eta$ = -3.82 + 1279 (1/T)	98.2	-3.82	1279	15	24.5
FD-22	$\log \eta$ = -4.76 + 1666 (1/T)	99.2	-4.76	1666	1.7	31.9
		Emulsion type spray formulations				
ZE-UC-19-EMUL	$\log \eta$ = -6.52 + 2016 (1/T)	97.6	-6.52	2016	0.03	38.6
FCA-3409-4.0	$\log \eta$ = -6.91 + 2176 (1/T)	94.8	-6.91	2176	0.012	41.6
FDA-3409-1.5	$\log \eta$ = -3.83 + 1197 (1/T)	99.4	-3.83	1197	14.8	22.9
FDA-3409-4.0	$\log \eta$ = -5.75 + 1948 (1/T)	97.4	-5.75	1948	0.18	37.3
FT-114-5.0	$\log \eta$ = -3.71 + 1256 (1/T)	99.8	-3.71	1256	19.5	24.1
AA-3409	$\log \eta$ = -3.80 + 1189 (1/T)	99.6	-3.80	1189	16.0	22.7

* The intercept 'I' and 'S' values are from the linear equation $\log \eta = I + S\ (1/T)$

§ The constants 'D' and 'E' are from the Arrhenius equation $\eta = D\ e^{E/RT}$

Table 16. Exponential decay equation* for evaporation characteristics of spray formulations, regression coefficients and half-lives of decay.

Liquid abbreviation	Exponential equation	R^2 (%)	A	B	C	$T_{1/2}$ (min)**
	Oil-based spray formulations					
ZE-UC-19-DIL	$Y = 34 + 66\ e^{-0.0318\ t}$	98.4	34	66	0.0318	21.8
FC-22	$Y = 22 + 78\ e^{-0.0309\ t}$	98.1	22	78	0.0309	22.5
FCID-585-35	$Y = 14 + 86\ e^{-0.0128\ t}$	95.5	14	86	0.0128	54.2
FCID-585-40	$Y = 14 + 86\ e^{-0.0139\ t}$	98.2	14	86	0.0139	49.8
AID-585	$Y = 30 + 70\ e^{-0.0054\ t}$	91.0	30	70	0.0054	128
FDID-585-35	$Y = 22 + 78\ e^{-0.0039\ t}$	95.5	22	78	0.0039	178
FD-22	$Y = 28 + 72\ e^{-0.0010\ t}$	99.4	28	72	0.0010	687
	Emulsion type spray formulations					
ZE-UC-19-EMUL	$Y = 14.5 + 85.5\ e^{-0.0534\ t}$	94.8	14.5	85.5	0.0534	13.0
FCA-3409-4.0	$Y = 17.0 + 83.0\ e^{-0.0647\ t}$	97.6	17.0	83.0	0.0647	10.7
FDA-3409-1.5	$Y = 15.0 + 85.0\ e^{-0.0811\ t}$	96.1	15.0	85.0	0.0811	8.55
FDA-3409-4.0	$Y = 16.0 + 84.0\ e^{-0.0629\ t}$	96.7	16.0	84.0	0.0629	11.0
FT-114-5.0	$Y = 19.5 + 80.5\ e^{-0.0569\ t}$	96.4	19.5	80.5	0.0569	12.2
FT-114-7.0	$Y = 21.5 + 78.5\ e^{-0.0615\ t}$	96.4	21.5	78.5	0.0615	11.3
AA-3409	$Y = 27.3 + 72.7\ e^{-0.0914\ t}$	95.4	27.3	72.7	0.0914	7.58

* The decay equation $Y = A + B\ e^{-C\ t}$ represents the exponential decrease of the residual weight % with time 't'.

** The half-life '$T_{1/2}$' represents the time required for the volatile portion of the spray formulations to reach 50 percent of their initial values.

8. *Stability Determinations of the End-Use Spray Formulations*

The term stability refers to the tendency of a liquid emulsion to resist separation into its ingredients. Actual separation of the component phases can occur if the stability is low. This phenomenon was studied when the spray formulations were left standing with no stirring or agitation. The findings are listed in Table 17. With gentle stirring however, phase separation may not be observed visually, but a reduction in viscosity can result due to changes in micelle formation and stability. These aspects were also studied at different temperatures and the findings are presented in Table 17.

9. *Re-emulsification Capabilities*

The term re-emulsifiability refers to the tendency of the separated phases to revert to the emulsion state having the same stability as that of the freshly prepared one. This aspect was studied after gentle and vigorous agitation. Findings are listed in Table 18.

Table 17. Stability of the emulsion formulations

Formulation abbreviation	Time (h) required for			
	Phase separation with no agitation		Reduction in viscosity by approx. 20% with agitation	
	5°- 15°C	20°- 25°C	5°- 15°C	20°- 25°C
ZE-UC-19-EMUL	62 - 110	28 - 36	72 - 120	56 - 90
FCA-3409-4.0	56 - 90	36 - 56	80 - 110	66 - 110
FDA-3409-1.5	2 - 3	1.5	10 - 15	6
FDA-3409-4.0	3 - 4	2.0	24 - 36	10
FT-114-5.0	3 - 4	2.0	24 - 36	15
FT-114-7.0	28 - 36	18 - 24	32 - 48	26 - 36
AA-3409	1.5 - 2.0	0.75	6 - 8	3

Table 18. Re-emulsification upon storage at 5° - 15°C for upto four days

Formulation abbreviation	With gentle mixing	With good agitation	Resettling time (h) after vigorous shaking
ZE-UC-19-EMUL	Excellent	Excellent	70 - 116
FCA-3409-4.0	Excellent	Excellent	70 - 116
FDA-3409-1.5	Good	Very good	2.5 to 4.5
FDA-3409-4.0	Very good	Excellent	26 - 36
FT-114-5.0	Very good	Excellent	18 - 28
FT-114-7.0	Excellent	Excellent	48 - 72

10. *Spread Factor Data of Spray Formulations on Kromekote® Cards*

Spread factor data are required for estimating spray droplet size spectra obtained on Kromekote® cards following atomization. These were measured and the results are given in Table 19.

11. *Spray Atomization in the Spray Chamber and Droplet Spectra on Kromekote Cards*

Spray atomization was carried out in a spray chamber of dimensions of 430 cm x 90 cm x 305 cm. A spinning disc nozzle, mounted on a central rail to facilitate movement from end to end of the chamber was calibrated to deliver the exact amount of 210 g AI/1.5 L/ha, or 420 g AI/0.75 L/ha for fenitrothion formulations; and 70 g AI/1.5 L/ha for the mexacarbate formulations. Spray was applied about 2.90 m above the Kromekote card/glass plate units which were placed about 15 cm above the floor level of the chamber. Four of such units were used for each formulation, and the droplets were allowed to settle on the sampling units for 15 min before they were removed from the chamber. Spray application was made in triplicate, to provide a total of

Table 19. Spread factor data of spray formulations

Stain diam. (μm)	Droplet diam. (μm)	Spread factor
ZE-UC-19-DIL		
252	55	4.58
320	69	4.64
388	80	4.85
469	95	4.94
616	115	5.36
Linear regression equation: $d = 15.6 + 0.164\ D$, $R^2 = 99.4\%$		
FC-22		
248	55	4.51
320	68	4.71
380	79	4.81
460	92	5.00
648	127	5.10
785	151	5.20
Linear regression equation: $d = 10.6 + 0.179\ D$, $R^2 = 100\%$		
FCID-585-35		
249	55	4.53
306	67	4.57
391	85	4.60
442	95	4.65
603	127	4.75
753	154	4.89
Linear regression equation: $d = 7.71 + 0.197\ D$, $R^2 = 99.9\%$		
FCID-585-40		
263	54	4.87
321	69	4.65
398	88	4.52
456	93	4.90
616	119	5.18
768	148	5.19
Linear regression equation: $d = 11.3 + 0.178\ D$, $R^2 = 99.0\%$		
AID-585		
344	60	5.73
450	78	5.77
506	88	5.75
607	106	5.73
799	138	5.79
883	151	5.85
Linear regression equation: $d = 2.02 + 0.170\ D$, $R^2 = 100.0\%$		
FDID-585-35		
190	55	3.45
243	71	3.42
292	80	3.65
340	92	3.70
535	129	4.15
778	178	4.37
Linear regression equation: $d = 19.9 + 0.204\ D$, $R^2 = 99.8\%$		

Table 19 cont'd

Stain diam. (μm)	Droplet diam. (μm)	Spread factor	Stain diam. (μm)	Droplet diam. (μm)	Spread factor
FD-22			ZE-UC-19-EMUL		
249	68	3.66	175	50	3.50
243	71	3.42	231	65	3.55
307	80	3.84	272	78	3.49
316	83	3.81	306	85	3.60
365	96	3.80	355	96	3.70
680	153	4.44	410	108	3.80
Linear regression equation: $d = 22.4 + 0.193\ D$, $R^2 = 99.6\%$			Linear regression equation: $d = 8.48 + 0.246\ D$, $R^2 = 99.4\%$		
FCA-3409-4.0			FDA-3409-1.5		
155	57	2.72	175	55	3.18
185	65	2.85	230	73	3.15
220	81	2.72	300	95	3.16
270	97	2.78	455	145	3.14
310	114	2.72	672	210	3.20
390	141	2.77	870	270	3.22
Linear regression equation: $d = -0.24 + 0.364\ D$, $R^2 = 99.8\%$			Linear regession equation: $d = 2.71 + 0.309\ D$, $R^2 = 100.0\%$		
FDA-3409-4.0			FT-114-5.0		
220	65	3.38	180	75	2.40
370	105	3.52	240	98	2.45
565	158	3.58	315	125	2.52
735	205	3.59	400	148	2.70
995	275	3.62	490	175	2.80
1145	315	3.63	615	215	2.86
Linear regression equation: $d = 5.20 + 0.271\ D$, $R^2 = 100.0\%$			Linear regression equation: $d = 21.4 + 0.316\ D$, $R^2 = 99.8\%$		

Table 19 cont'd

Stain diam. (um)	Droplet diam. (um)	Spread factor	Stain diam. (um)	Droplet diam. (um)	Spread factor
	FT-114-7.0			AA-3409	
165	65	2.54	169	55	3.07
200	78	2.56	225	74	3.04
255	93	2.74	281	92	3.05
335	115	2.91	338	110	3.07
440	145	3.03	394	129	3.05
650	210	3.10	450	147	3.06
Linear regression equation:			Linear regression equation:		
d = 17.2 + 0.295 D			d = 0.097 + 0.327 D		
R^2 = 99.9%			R^2 = 100.0%		

12 cards for each formulation. The droplet stains were counted using a dissecting microscope at 40X, 100X and 200X magnifications. The data obtained from the 12 cards were grouped according to diameter classes to calculate the cumulative percentages (P_i and P_i'), according to the equations described by Johnstone (1978):

$$P_i \text{ (by droplet number)} = \left(\sum_{i=1}^{i} n_i/n \right) \times 100 \text{ , and}$$

$$P_i' \text{ (by droplet volume)} = \left(\sum_{i=1}^{i} n_i v_i \Big/ \sum_{i=1}^{h} n_i v_i \right) \times 100 \text{, or}$$

$$P_i' \text{ (by droplet volume)} = \left(\sum_{i=1}^{i} n_i d_i^3 \Big/ \sum_{i=1}^{h} n_i d_i^3 \right) \times 100$$

where

n_i = the number of droplets in the i th class

(h classes, labelled 1....i....h)

$\sum n_i$ = the total number of droplets (i = 1 to h) = n

v_i = the 'average' volume of a droplet in the i th class

d_i = the 'average' diameter of a droplet in the i th class

The number median diameter (NMD) is the diameter that divides the number of droplets into two equal groups, i.e., 50% by number of the droplets are greater and 50% smaller in size. Similarly, the volume median diameter (VMD) is the size that divides the spray volume into two equal parts: 50% by volume of the sampled spray is contained in droplets that are greater, and 50% by volume in droplets that are smaller than the median size. These values were calculated and in addition, the maximum diameter (D_{max}), observed in all the 15 cards in each spray block was also noted. The data are presented in Tables 20 and 21. The droplet number and volume distribution percentages were also presented in Figs. 3 to 14, in two ways, viz., as histograms and as the cumulative percentages.

12. *Deposit Assessment on Glass Plates*

The spray deposits on the glass plates were eluted using methanol as the solvent, followed by ethyl acetate to remove any traces of the active ingredient remaining. The extracts were flash-evaporated, reconstituted in a suitable solvent and analysed by GLC technique as described by Sundaram and Nott (1985), for the fenitrothion formulations. For the two mexacarbate formulations ZE-UC-19-DIL and ZE-UC-19-EMUL, however, 2.0% v/v of a fenitrothion standard was added to the spray formulation, for using as a tracer to obtain

Table 20. Spray application details, droplet size spectra and deposit assessment of active ingredient

Measurements	Formulation abbreviation					
	ZE-UC-19-DIL	FC-22	FCID-585-35	FCID-585-40	FDID-585-35	FD-22
Floor area of the chamber (m^2)	3.87	3.87	3.87	3.87	3.87	3.87
Spray nozzle	Spin. disc.*	Spin. disc.	Spin. disc.	Spin. disc.	Spin. disc.	Spin. disc.
Temperature °C	22 ± 2	22 ± 2	22 ± 2	22 ± 2	22 ± 2	22 ± 2
Wind conditions	Still air@	Still air	Still air	Still air	Still air	Still air
Relative humidity (%)	45 ± 3	45 ± 3	45 ± 3	45 ± 3	45 ± 3	45 ± 3
Application rate (g AI/ha)	70	210	210	210	210	210
Volume rate (l/ha)	1.5	0.75	1.5	1.5	1.5	0.75
Droplets/cm^2	57	32	91	90	72	33
NMD (µm)	55	23	46	44	52	76
VMD (µm)	63	26	50	48	54	83
D_{max}	110	44	100	100	90	109
Volume deposit (l/ha)**	855	165	705	630	825	698
Percent deposition**	57.0	22	47	42	55	93

* Flak™ from Micron Corporation, Wingham, Ont., Canada.

@ Still air except for the minor turbulence generated by the moving nozzle along the central rail of the spray chamber.

** Volume deposit was calculated from the AI concentration determined by GLC. From this the percent deposition was estimated.

Table 21. Spray application details, droplet size spectra and deposit assessment of active ingredient

Measurements	Formulation abbreviation					
	ZE-UC-19-EMUL	FCA-3409-4.0	FDA-3409-1.5	FDA-3409-4.0	FT-114-5.0	FT-114-7.0
Floor area of the chamber (m^2)	3.87	3.87	3.87	3.87	3.87	3.87
Spray nozzle	Spin. disc.*	Spin. disc.	Spin. disc.	Spin. disc.	Spin. disc.	Spin. disc.
Temperature °C	22 ± 2	22 ± 2	22 ± 2	22 ± 2	22 ± 2	22 ± 2
Wind conditions	Still air@	Still air	Still air	Still air	Still air	Still air
Relative humidity (%)	45 ± 3	45 ± 3	45 ± 3	45 ± 3	45 ± 3	45 ± 3
Application rate (g AI/ha)	70	210	210	210	210	210
Volume rate (l/ha)	1.5	1.5	1.5	1.5	1.5	1.5
Droplets/cm^2	17	25	36	87	65	75
NMD (µm)	42	28	28	31	38	36
VMD (µm)	53	49	55	42	49	47
D_{max}	110	114	100	100	90	100
Volume deposit (l/ha)**	258	225	254	425	375	475
Percent deposition**	17.2	15.0	16.9	28.3	25.0	31.7

* Flak™ from Micron Corporation, Wingham, Ont., Canada.

@ Still air except for the minor turbulence generated by the moving nozzle along the central rail of the spray chamber.

** Volume deposit was calculated from the AI concentration determined by GLC. From this the percent deposition was estimated.

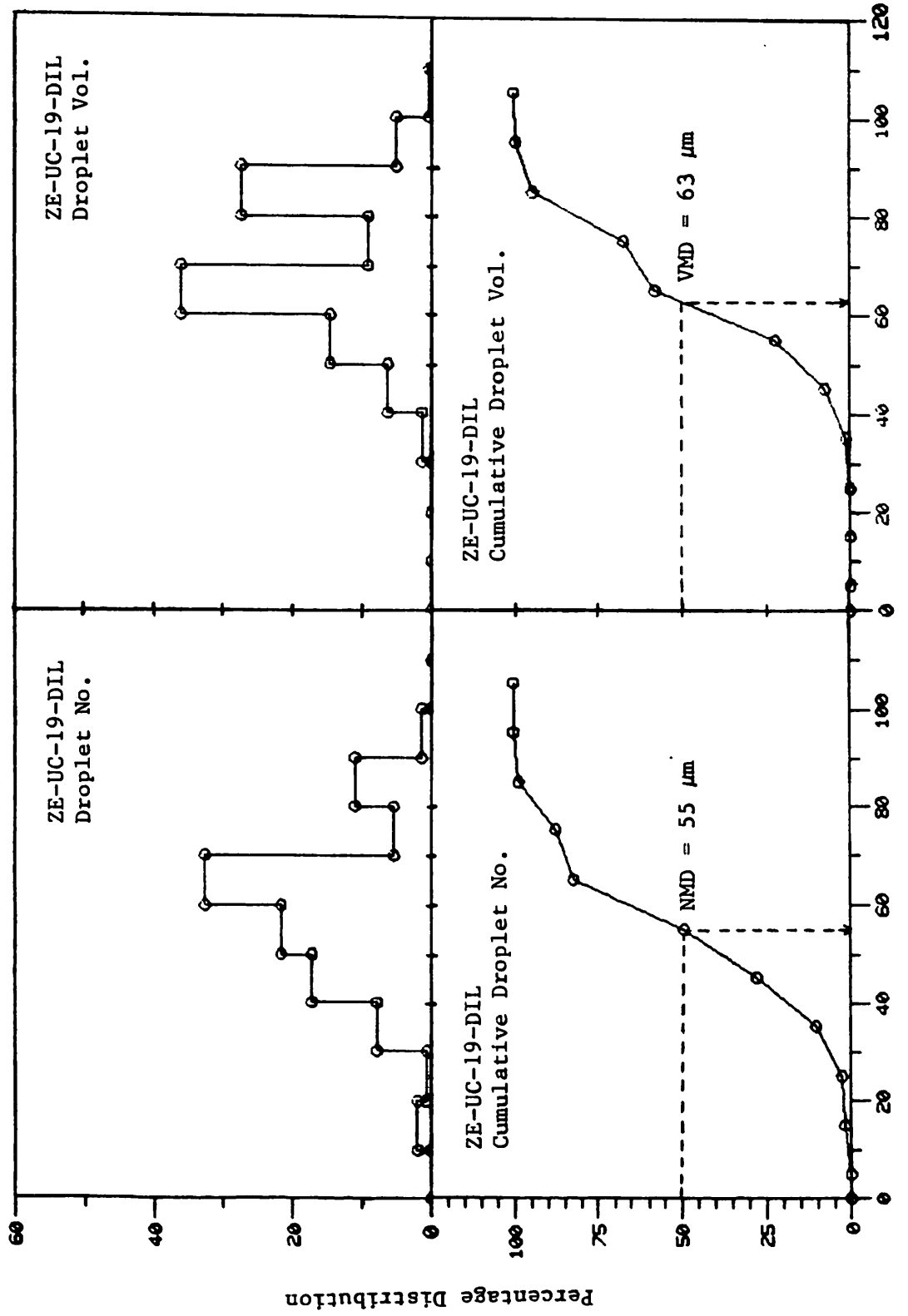

Fig. 3. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote cards.

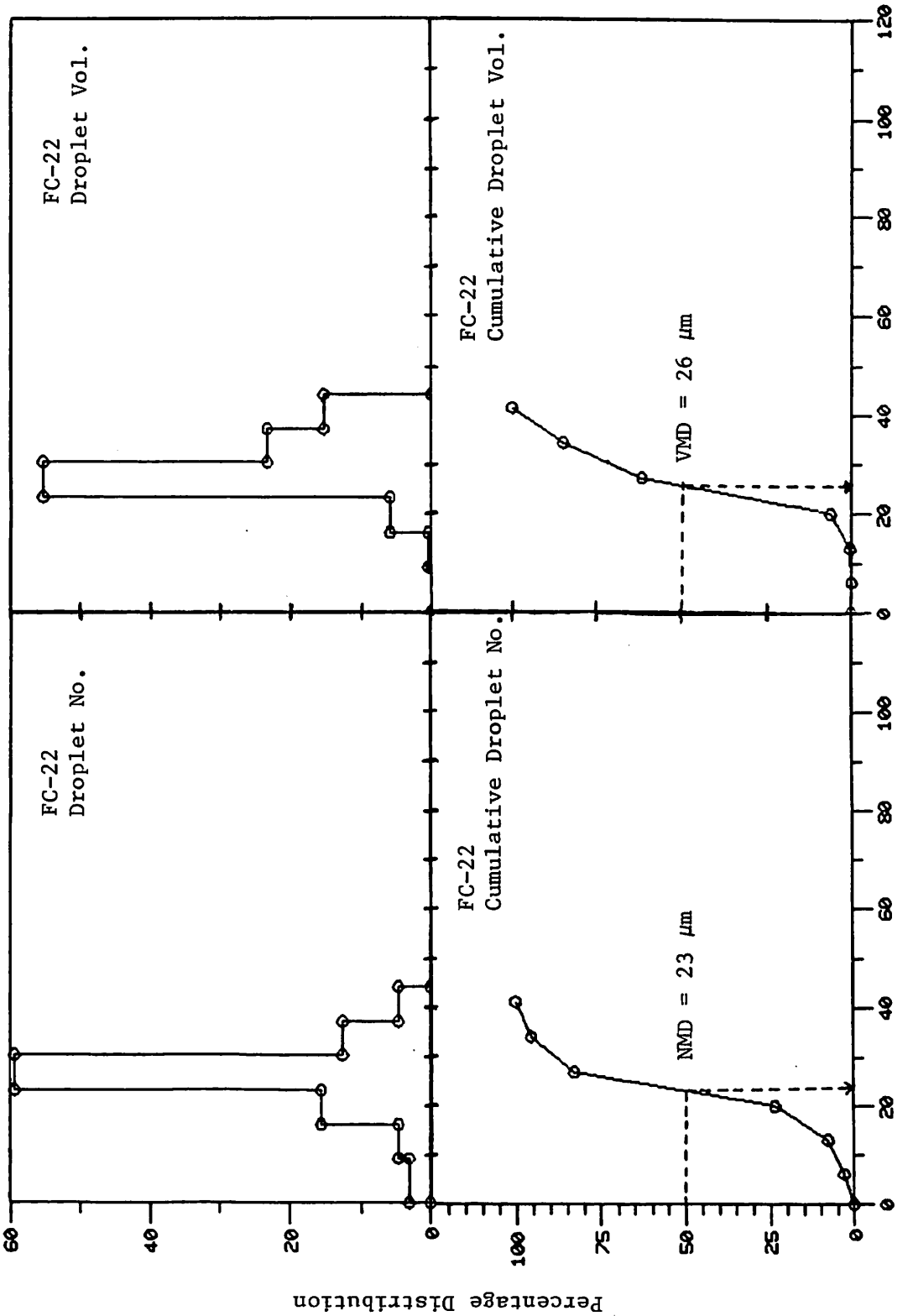

Fig. 4. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

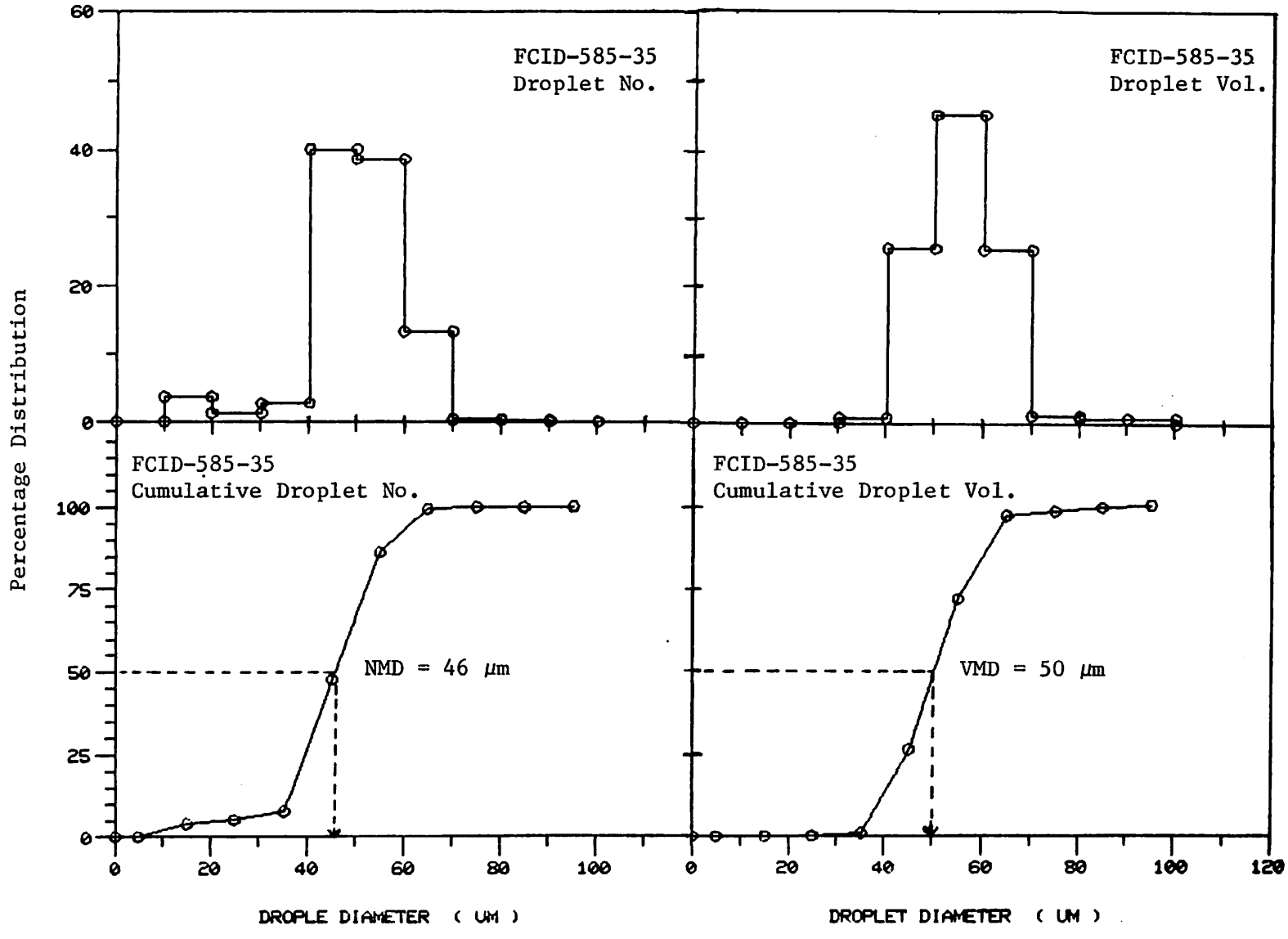

Fig. 5. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

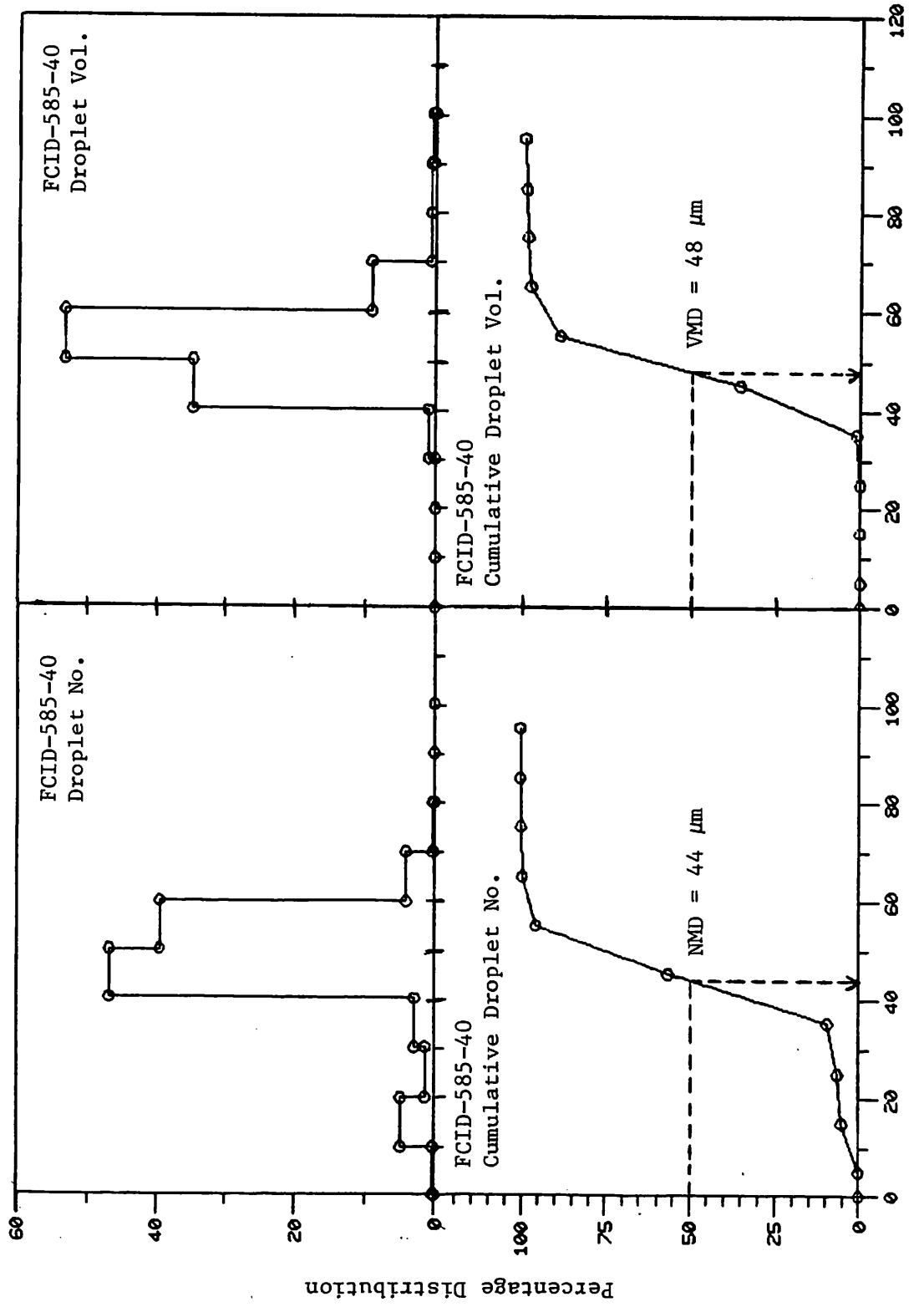

Fig. 6. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

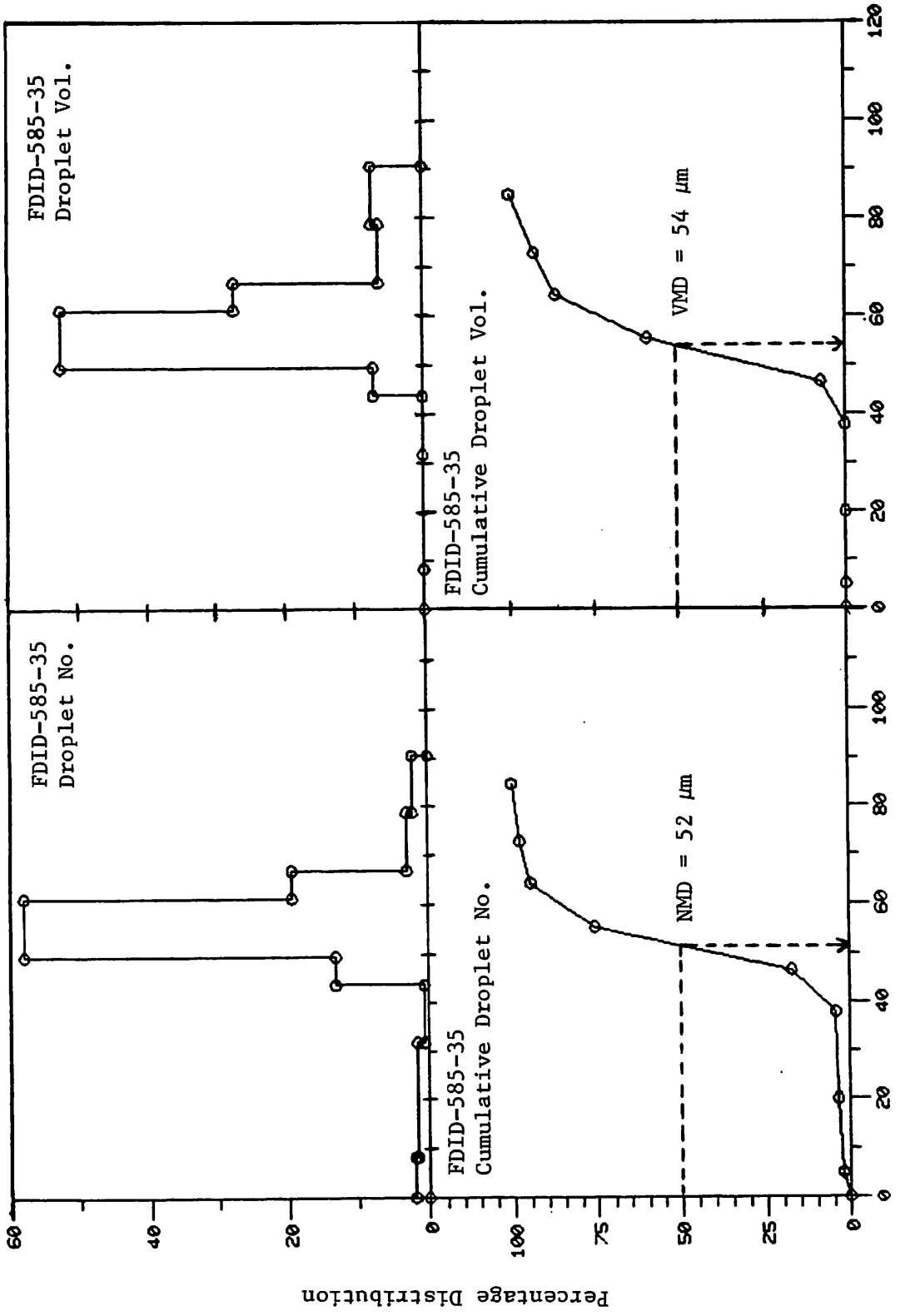

Fig. 7. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

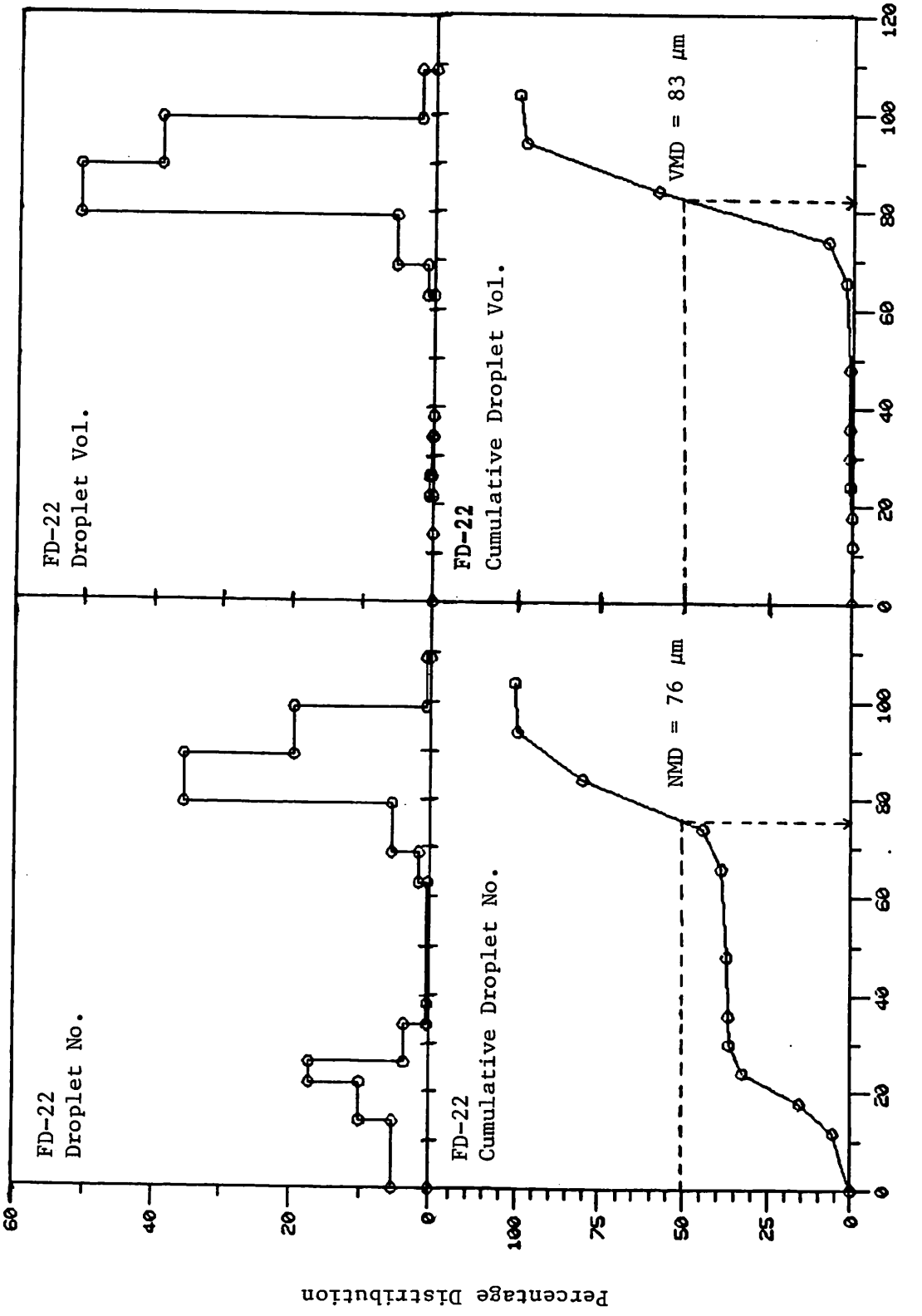

Fig. 8. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

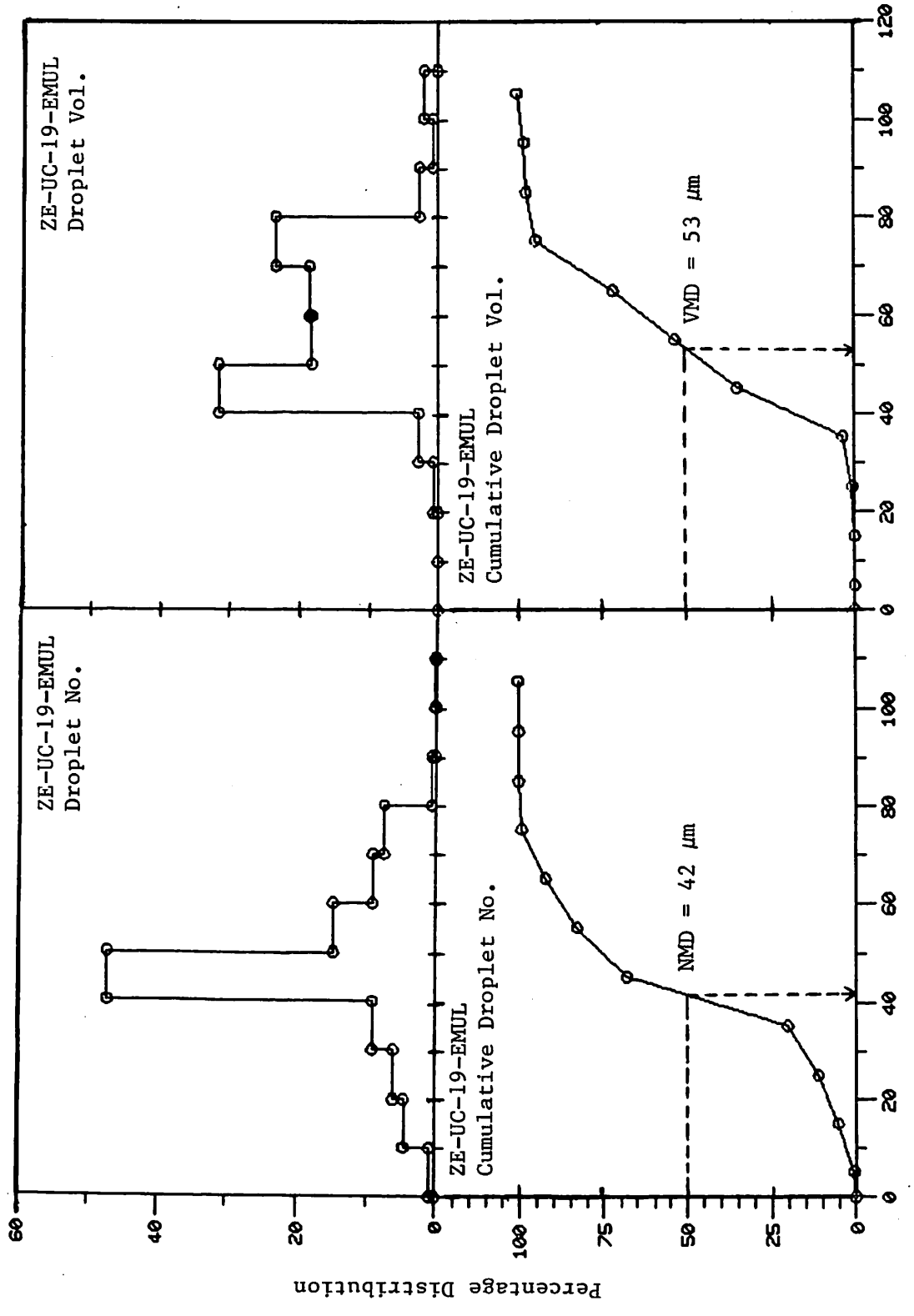

Fig. 9. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

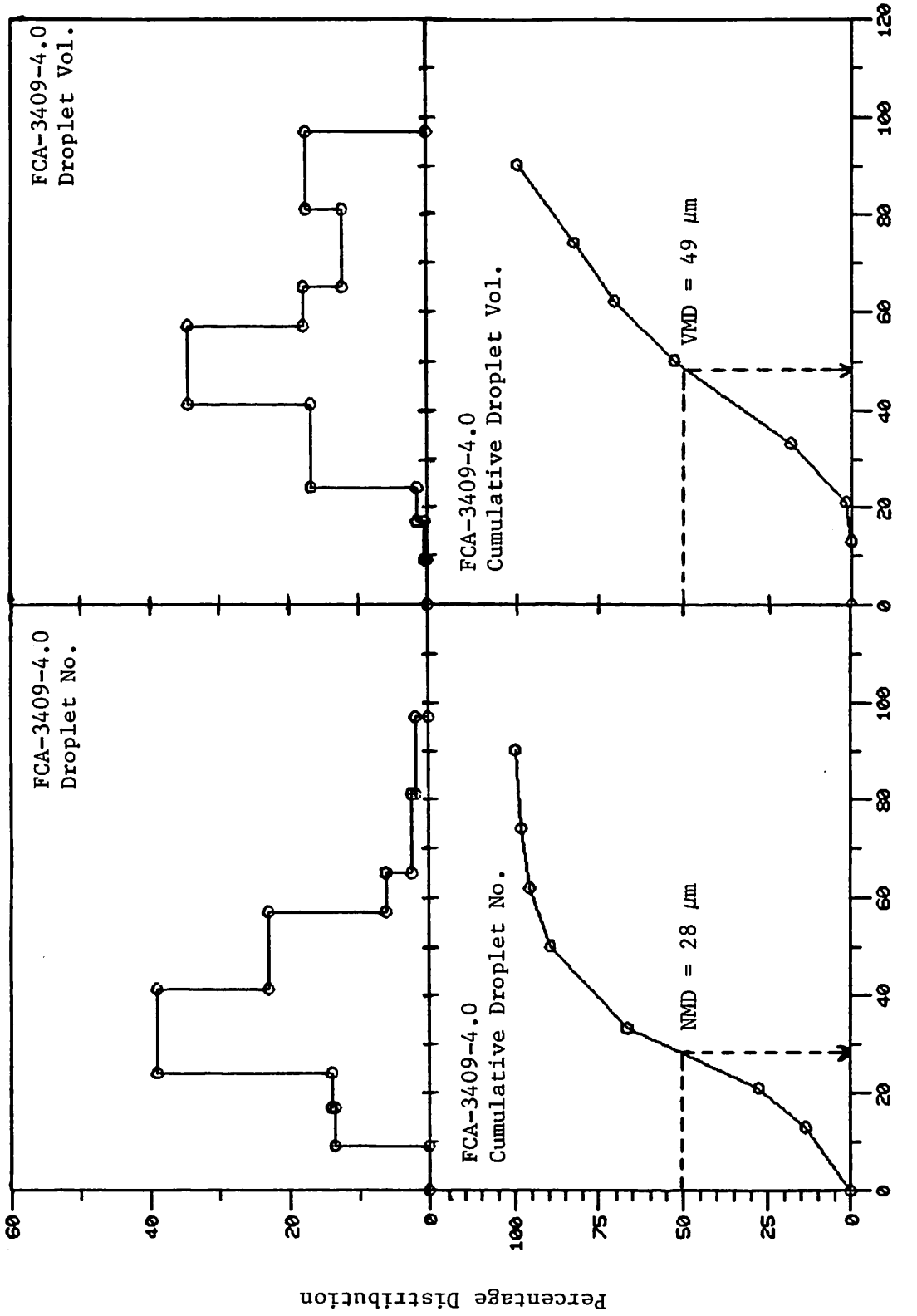

Fig. 10. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

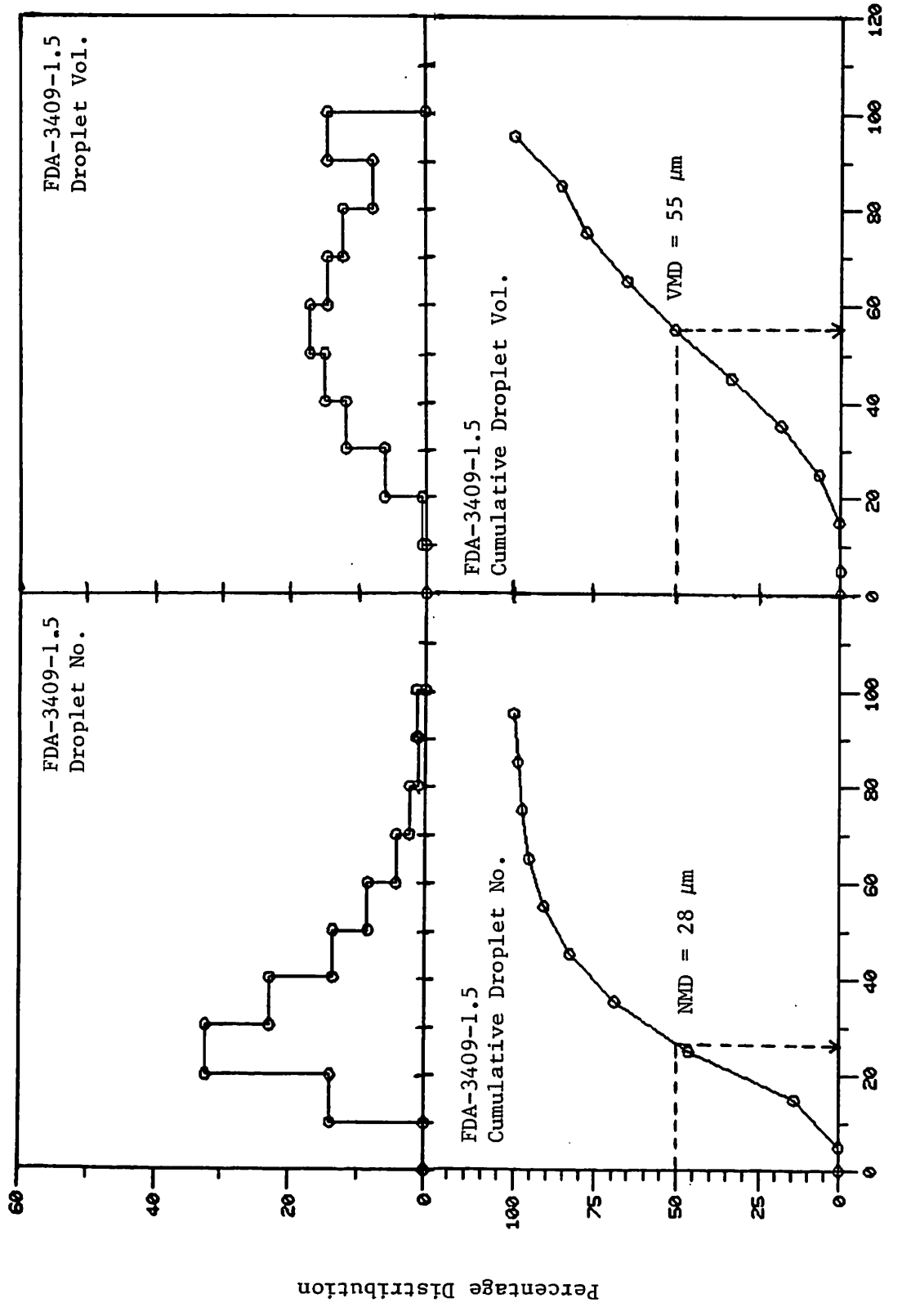

Fig. 11. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

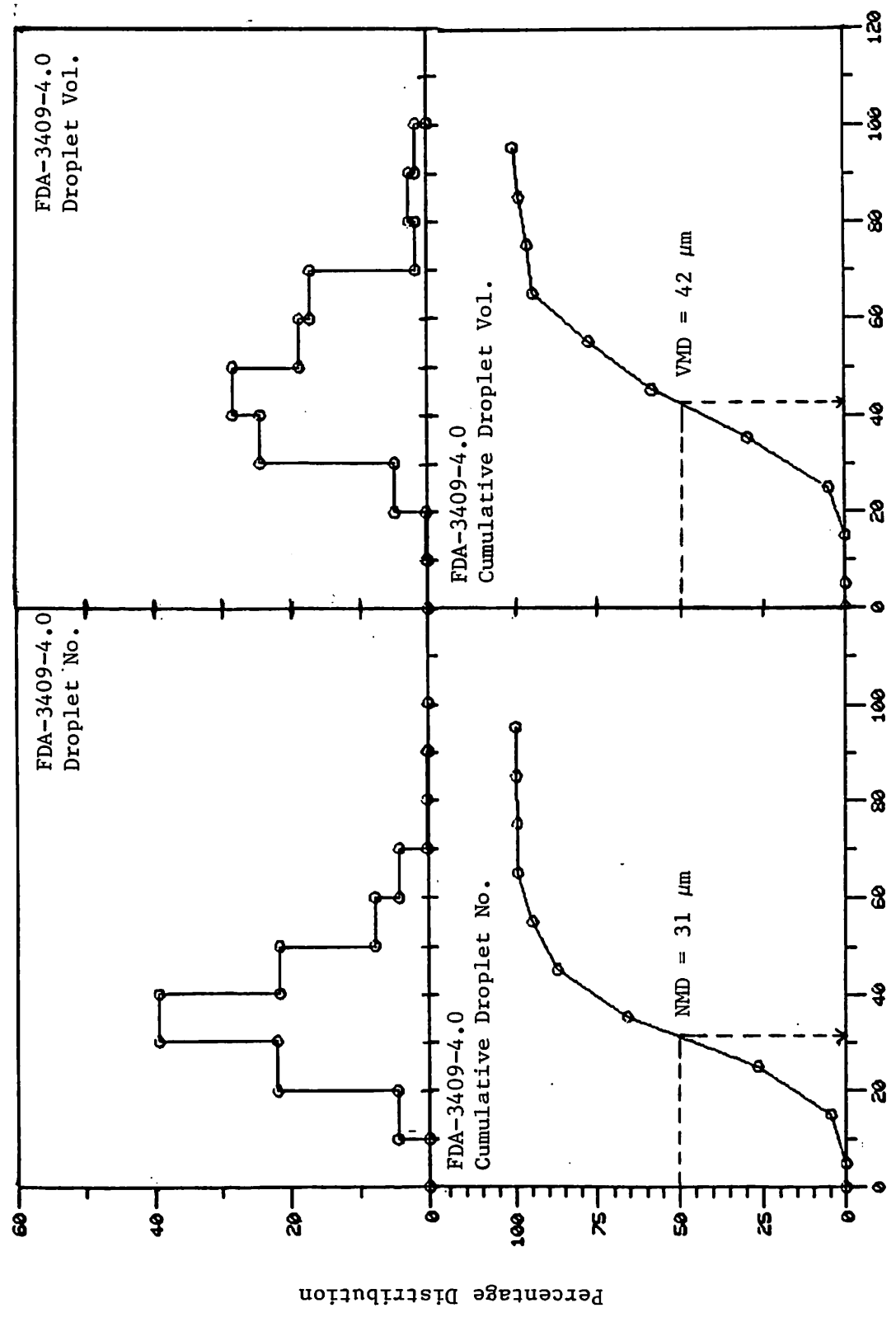

Fig. 12. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

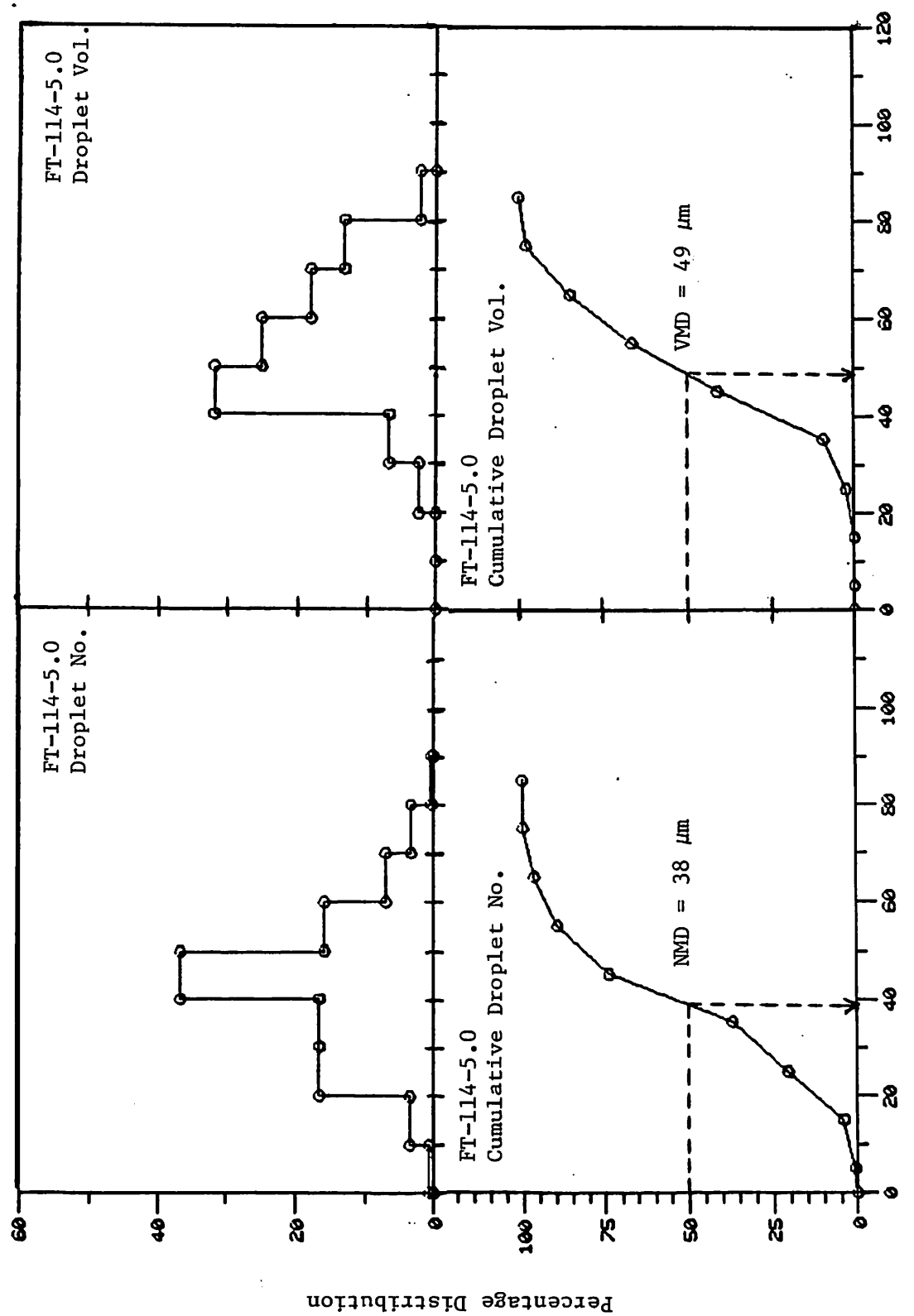

Fig. 13. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

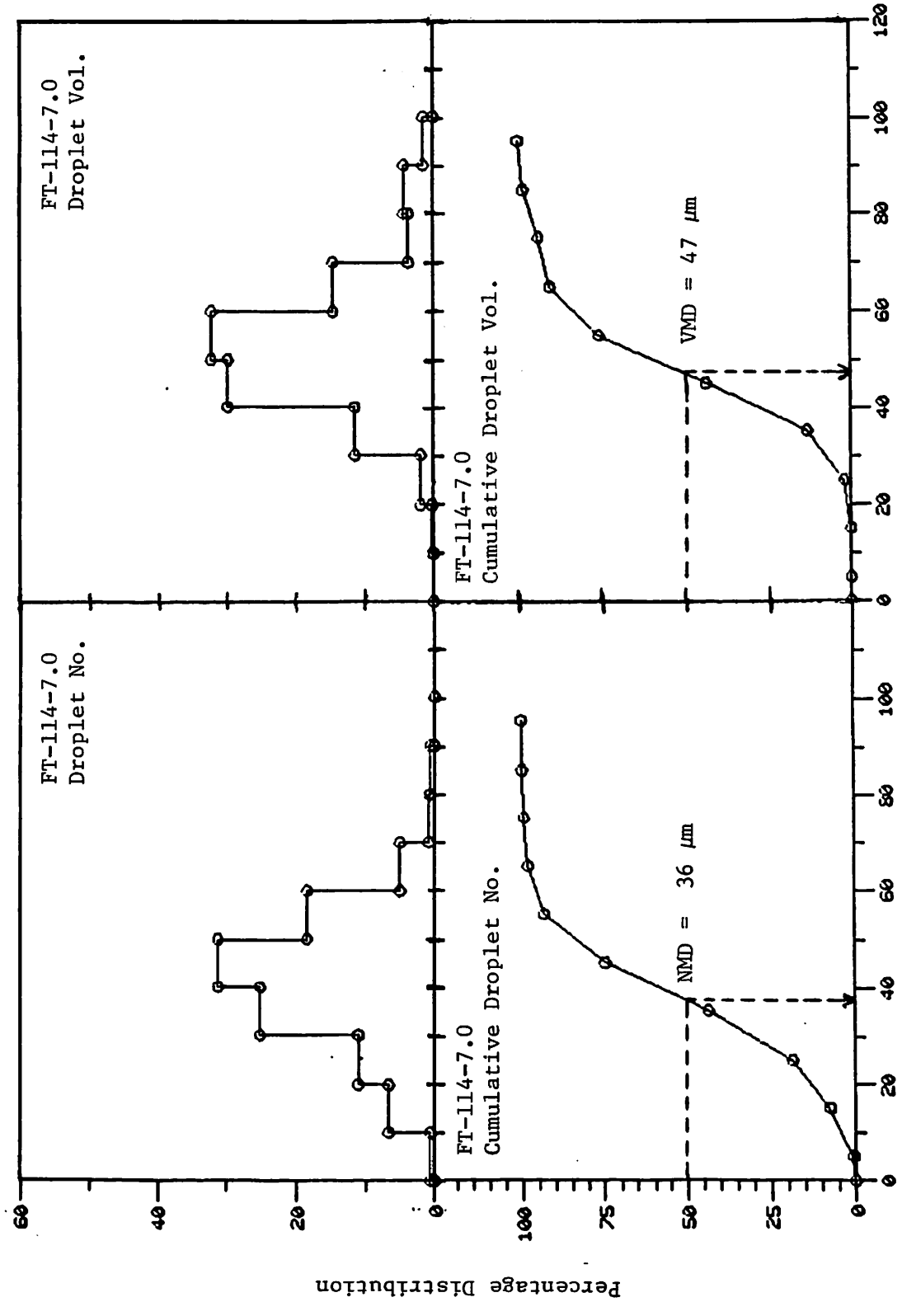

Fig. 14. Percentage Distribution and Cumulative Percentage Distribution of Droplet No. and Droplet Vol. on Kromekote Cards.

a comparative picture of spray deposits on glass plates with other fenitrothion formulations. In these cases, the volume of the diluents (C-CA-ID-585, or water) was adjusted so that the final volume of the spray mixture would not exceed 100 ml. From the concentration of the fenitrothion measured, the volume of the spray deposited per unit area of the glass plates was calculated in litre/ha units. The data are presented in Tables 20 and 21. From these, the percentages of the active ingredient deposited was estimated.

RESULTS AND DISCUSSION

1. *Physical Properties*

Viscosity — Viscosity is the most important intrinsic property that provides information on liquid behaviour under various handling conditions. Formulation stability, especially that of emulsions, is related to this property. The ease of mixing, pumping and spray atomization characteristics are also related to viscosity. Data in Table 5 show that the formulation concentrate ZE-UC-19 would be easy to handle under field conditions, even under the cold conditions of the spray season.

Surface tension — Surface tension is another intrinsic property of a liquid that plays an important role in droplet formation during atomization through a nozzle. Oil-based liquids generally have low surface tension values, ranging from about 29 to 33 dyne/cm. However, water-based formulations can possibly show a wide range in surface tension values, viz., from as low as 26 to as high as 72 dyne/cm. Because of the very narrow range through which the oil-based liquids can vary in surface tension, the spray atomization is usually more

influenced by the viscosities, than by the surface tension values. This is because oil-based liquids can show a very wide range in viscosities as opposed to the surface tension. The water-based liquids, however, can show a wide variation in both viscosities and surface tension values, and therefore, the spray atomization characteristics are influenced by both properties. In this study, however, there is very little variation in the surface tension values of the oil-based and the emulsion-type spray formulations. This finding indicates that in this study, the viscosities and evaporation characteristics are the most important properties that would contribute to differences in the droplet deposit characteristics of the spray formulations.

Evaporation Characteristics — Tables 8 to 14 and Figs 1 and 2 provide data on comparative evaporation pattern of the 14 spray formulations. Table 16 provides the half-lives of evaporation, together with the non-volatile portion (the constant A in the exponential equation) of the end-use formulations. From the data it is evident that ZE-UC-DIL would provide a field deposit that is comparable to the other six oil-based formulations. ZE-UC-19-EMUL is also likely to provide a deposit similar to those of the other six emulsions, if not greater. It is important to remember that not only the $T_{\frac{1}{2}}$ values but also the 'A' values play a role in the final droplet size that impinges on the target. Therefore, when comparing the evaporation characteristics of different formulations, both values should be taken into account. The evaporation pattern of emulsions can also provide information on their stabilities, because of the way by which

the water molecules are bound (or attracted) to the micelle in the medium. This process is called 'hydration' in the emulsion. The greater the hydration, the greater its stability. The force with which the water molecules are bound to the micelle determines the readiness with which the water molecules would be lost during droplet evaporation. It is therefore evident from Table 16 that ZE-UC-19-EMUL is a very stable emulsion because it has the highest $T_{\frac{1}{2}}$ value among the seven emulsions tested. This indicates the highest degree of hydration (or hydrogen bonding) in the emulsion. This is a very desirable property of an emulsion because it can have an important implication on the droplet size formation during atomization, droplet evaporation after the release of the spray, and on the final droplet size at the target site. The present study indicates that the emulsifier of choice Trit-114 has contributed to some extent to this desirable property of the emulsion ZE-UC-19-EMUL.

2. *Spray Droplet Spectra on Kromekote Cards and Deposits on Glass Plates*

Tables 20 and 21, and Figs. 3 to 14 provide data on comparative droplet size spectra, droplets/cm^2, NMD, VMD, D_{max}, volume deposit and percentage deposition of the twelve spray formulations used in the study. The spinning disc nozzle used in the study is known to generate a narrow droplet spectrum at the point of spray release. However, the droplet sizes reaching the spray cards placed at the floor level of the chamber, would depend on a combined influence of viscosity, density, surface tension and evaporation characteristics of the end-use mixtures. In Table 20, the oil-based ZE-UC-19-DIL mixture is compared with the oil-based fenitrothion formulations currently being used and are on the

label. The number of droplets/cm^2 of ZE-UC-19-DIL was much higher than those of FC-22 and FD-22 but somewhat lower than those of FCID-585-35, FCID-585-40 and FDID-585-35. The NMD, VMD and D_{max} values showed that the droplet sizes of ZE-UC-19-DIL are quite comparable to those of the other five formulations. The volume deposit data indicated that ZE-UC-19-DIL produced a deposit that was comparable to that of FDID-585-35, but higher than FCID-585-35 (the one that was sprayed operationally in Quebec for many years) and FC-22, and lower than FD-22.

The water-based emulsions, on the other hand, provided in general much lower deposits than the oil-based formulations. However, the droplets/cm^2 values, NMD, VMD, D_{max}, and volume deposits of ZE-UC-19-EMUL were quite comparable to those of the other five emulsions. The volume deposits of ZE-UC-19-EMUL were very similar to those of the fenitrothion-Atlox-based emulsion currently being used in New Brunswick indicating the field suitability of ZE-UC-19-EMUL.

CONCLUSIONS

The present study indicates that the formulation concentrate Zectran® UCZF19 is suitable for the field use for spruce budworm control. The spray diluent recommended for this concentrate provided optimum evaporation characteristics of the spray mixture, and because of this, the oil-based spray mixture provided much higher deposits than the currently used fenitrothion oil-bsed formulation. The water-based emulsion provided much lower deposits than the oil-based spray mixture, but the new emulsion of Zectran UCZF19 provided comparable deposits to those of the currently used fenitrothion formulations.

This finding indicates that both the oil-based and water-based spray mixtures of Zectran UCZF19 are very suitable for field use for aerial applications. In addition, the optimum viscosity of the formulation concentrate and of the final end-use mixtures provides a great advantage of this new formulation over the currently used fenitrothion and aminocarb formulation concentrate. Moreover, ZE-UC-19-EMUL is a very stable emulsion as compared to the currently used FDA-3409-1.5 and AA-3409. This means that the active ingredient would be very uniformly sprayed over the entire forest canopy and would have a high degree of insect control, and with minimum environmental impact.

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2. Sundaram, K.M.S. and Nott, R. Fenitrothion Residues in Selected Components of A Conifer Forest Following Aerial Application of Tank Mixes Containing Triton X-100. Agric. Can. For. Serv. For. Pest Mangmt. Inst. Inf. Rept. FPM-X-65, 1984, 14pp.

APPENDIX

DROPLET NUMBER and DROPLET VOLUME DISTRIBUTION

ACCORDING TO SIZE CATEGORY

TABLES 22 to 45

Table 22. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 1.5 ; Relative Humidity = 45 ± 2%

Formulation ZE-UC-19-DIL

Stain diameter range (µm)	Spread factor	Droplet diameter range (µm)	Average droplet diameter (µm)	Total droplets per 48 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 30	3.00	⩽ 10	5	0	0.00	0.00	0.00
31 - 60	3.05	11 - 20	15	53	1.10	1.92	1.92
61 - 100	3.45	21 - 30	25	17	0.35	0.62	2.54
101 - 160	4.00	31 - 40	35	216	4.50	7.83	10.37
161 - 210	4.25	41 - 50	45	475	9.90	17.22	27.59
211 - 270	4.50	51 - 60	55	598	12.46	21.68	49.27
271 - 325	4.65	61 - 70	65	901	18.77	32.66	81.93
326 - 385	4.80	71 - 80	75	150	3.13	5.44	87.37
386 - 445	4.95	81 - 90	85	305	6.35	11.06	98.43
446 - 500	5.05	91 - 100	95	41	0.85	1.49	99.92
501 - 570	5.25	101 - 110	105	3	0.06	0.11	100.00
				Total = 2759	57.47		

Table 23. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation ZE-UC-19-DIL

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.00	0.00	0.000	0.000
11 - 20	15	0.18	1.10	0.198	0.0264	0.0264
21 - 30	25	0.82	0.35	0.287	0.0382	0.0646
31 - 40	35	2.24	4.50	10.08	1.342	1.407
41 - 50	45	4.77	9.90	47.22	6.285	7.692
51 - 60	55	8.71	12.46	108.53	14.44	22.13
61 - 70	65	14.38	18.77	269.91	35.92	58.05
71 - 80	75	22.09	3.13	69.14	9.202	67.25
81 - 90	85	32.16	6.35	204.22	27.18	94.43
91 - 100	95	44.89	0.85	38.16	5.078	99.51
101 - 110	105	60.61	0.06	3.637	0.484	99.99
			Total = 57.47	751.38		

Table 24. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 2; Relative Humidity = 45 ± 3%

Formulation FC-22

Stain diameter range (µm)	Spread factor	Droplet diameter range (µm)	Average droplet diameter (µm)	Total droplets per 8 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 27	3.00	⩽ 9	6	8	1.0	3.125	3.125
28 - 52	3.25	10 - 16	13	12	1.5	4.688	7.813
53 - 79	3.45	17 - 23	20	40	5.0	15.625	23.438
80 - 110	3.65	24 - 30	27	152	19.0	59.375	82.813
111 - 142	3.85	31 - 37	34	32	4.0	12.500	95.313
143 - 178	4.05	38 - 44	41	12	1.5	4.688	100.00
				Total = 256	32.00		

Table 25. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 2.5 ; Relative Humidity = 45 ± 3%

Formulation FC-22

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
⩽ 9	6	0.0113	1.0	0.0113	0.0319	0.0319
10 - 16	13	0.1150	1.5	0.1726	0.486	0.5179
17 - 23	20	0.4189	5.0	2.0944	5.899	6.4169
24 - 30	27	1.0306	19.0	19.58	55.15	61.567
31 - 37	34	2.058	4.0	8.232	23.19	84.757
38 - 44	41	3.609	1.5	5.413	15.25	100.00
			Total = 32.00	35.50		

Table 26. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation FCID-585-35

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 32 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
≤ 40	4.45	≤ 10	5	3	0.09	0.10	0.10
41 - 90	4.50	11 - 20	15	108	3.38	3.70	3.80
91 - 135	4.50	21 - 30	25	36	1.13	1.24	5.04
136 - 180	4.50	31 - 40	35	80	2.50	2.73	7.77
181 - 225	4.50	41 - 50	45	1168	36.50	39.92	47.69
226 - 275	4.55	51 - 60	55	1124	35.13	38.42	86.11
276 - 320	4.55	61 - 70	65	384	12.00	13.12	99.23
321 - 365	4.55	71 - 80	75	12	0.38	0.42	99.65
366 - 415	4.60	81 - 90	85	6	0.19	0.21	99.86
416 - 460	4.60	91 - 100	95	4	0.13	0.14	100.00
			Total =	2925	91.43		

Table 27. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 1.5 Relative Humidity = 45 ± 2%

Formulation FCID-585-35

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.09	0.001	0.0001	0.0001
11 - 20	15	0.18	3.38	0.608	0.09	0.09
21 - 30	25	0.82	1.13	0.927	0.14	0.23
31 - 40	35	2.24	2.50	5.60	0.82	1.05
41 - 50	45	4.77	36.50	174.1	25.60	26.65
51 - 60	55	8.71	35.13	306.0	45.00	71.65
61 - 70	65	14.38	12.00	172.6	25.37	97.02
71 - 80	75	22.09	0.38	8.394	1.23	98.25
81 - 90	85	32.16	0.19	6.110	0.90	99.15
91 - 100	95	44.89	0.13	5.836	0.86	100.01
			Total=91.43	680.12		

Table 28. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation FCID-585-40

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 16 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 40	4.45	⩽ 10	5	5	0.25	0.28	0.28
41 - 90	4.50	11 - 20	15	88	4.41	4.91	5.18
91 - 135	4.50	21 - 30	25	24	1.20	1.34	6.52
136 - 180	4.50	31 - 40	35	51	2.56	2.84	9.36
181 - 225	4.50	41 - 50	45	839	42.09	46.77	56.13
226 - 275	4.55	51 - 60	55	706	35.42	39.35	95.48
276 - 320	4.55	61 - 70	65	74	3.71	4.12	99.61
321 - 365	4.55	71 - 80	75	4	0.20	0.22	99.83
366 - 415	4.55	81 - 90	85	2	0.10	0.11	99.94
416 - 460	4.55	91 - 100	95	1	0.05	0.06	100.00
				Total = 1794	90.0		

Table 29. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation FCID-585-40

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.25	0.0016	0.00	0.00
11 - 20	15	0.18	4.41	0.7801	0.13	0.13
21 - 30	25	0.82	1.20	0.985	0.17	0.30
31 - 40	35	2.24	2.56	5.744	0.99	1.29
41 - 50	45	4.77	42.09	200.83	34.61	35.91
51 - 60	55	8.71	35.42	308.54	53.18	89.09
61 - 70	65	14.38	3.71	53.38	9.20	98.29
71 - 80	75	22.09	0.20	4.433	0.76	99.06
81 - 90	85	32.16	0.10	3.230	0.56	99.61
91 - 100	95	44.89	0.05	2.252	0.39	100.00
			Total = 90.00	580.17		

Table 30. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 3; Relative Humidity = 45 ± 3%

Formulation FDID-585-35

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 5 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 25	3.00	⩽ 8.3	5.0	7	1.40	1.955	1.955
26 - 103	3.27	8.4 - 31.6	20.0	6	1.20	1.682	3.637
104 - 148	3.40	31.7 - 43.5	37.6	2	0.40	0.568	4.205
149 - 170	3.45	43.6 - 49.2	46.4	47	9.40	13.11	17.32
171 - 214	3.50	49.3 - 61.1	55.2	208	41.60	58.07	75.39
215 - 237	3.55	61.2 - 66.8	64.0	69	13.80	19.27	94.66
238 - 287	3.65	66.9 - 78.7	72.8	11	2.20	3.068	97.72
288 - 347	3.85	78.8 - 90.2	84.5	8	1.60	2.273	99.99
				Total = 358	71.60		

Table 31. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 2; Relative Humidity = 45 ± 3%

Formulation FDID-585-35

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
⩽ 8.3	5.0	0.007	1.40	0.010	0.0014	0.0014
8.4 - 31.6	20.0	0.42	1.20	0.504	0.0718	0.0732
31.7 - 43.5	37.6	2.78	0.40	1.11	0.1582	0.2314
43.6 - 49.2	46.4	5.23	9.40	49.16	7.0048	7.2362
49.3 - 61.1	55.2	8.81	41.60	366.5	52.22	59.46
61.2 - 66.8	64.0	13.73	13.80	189.5	27.00	86.46
66.9 - 78.7	72.8	20.20	2.20	44.44	6.332	92.79
78.8 - 90.2	84.5	31.59	1.60	50.54	7.202	100.00
Total =		71.6		701.8		

Table 32. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 3; Relative Humidity = 45 ± 3%

Formulation FD-22

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 16 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 42	3.00	⩽ 13.9	11.8	27	1.72	5.33	5.33
43 - 70	3.25	14.0 - 21.6	17.8	51	3.27	10.06	15.38
71 - 87	3.35	21.7 - 25.9	23.8	87	5.58	17.16	32.54
88 - 116	3.45	26.0 - 33.6	29.8	19	1.22	3.75	36.29
117 - 135	3.55	33.7 - 37.9	35.8	2	0.13	0.39	36.69
136 - 235	3.76	38.0 - 62.6	47.8	2	0.13	0.39	37.08
236 - 268	3.89	62.7 - 68.8	65.8	8	0.52	1.58	38.66
269 - 315	4.00	68.9 - 78.8	73.8	28	1.80	5.52	44.18
316 - 377	4.25	78.9 - 88.8	83.8	180	11.54	35.50	79.68
378 - 430	4.35	88.9 - 98.8	93.8	99	6.35	19.53	99.21
431 - 484	4.45	98.9 - 108.8	103.8	4	0.25	0.79	100.00
				Total = 507	32.51		

Table 33. Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 3; Relative Humidity = 45 ± 3%

Formulation FD-22

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
⩽ 13.9	11.8	0.09	1.72	0.1489	0.02	0.02
14.0 - 21.6	17.8	0.30	3.27	0.9654	0.14	0.16
21.7 - 25.9	23.8	0.71	5.58	3.9367	0.56	0.72
26.0 - 33.6	29.8	1.39	1.22	1.6877	0.24	0.97
33.7 - 37.9	35.8	2.40	0.13	0.3080	0.04	1.01
38.0 - 62.6	47.8	5.72	0.13	0.7332	0.11	1.11
62.7 - 68.8	65.8	14.92	0.52	7.650	1.10	2.21
68.9 - 78.8	73.8	21.05	1.80	37.78	5.41	7.62
78.9 - 88.8	83.8	30.81	11.54	355.54	50.94	58.56
88.9 - 98.8	93.8	43.21	6.35	274.23	39.29	97.85
98.9 - 108.8	103.8	58.56	0.25	15.02	2.15	100.00
		Total = 32.51		698.00		

Table 34. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp.°C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation ZE-UC-19-EMUL

Stain diameter range (µm)	Spread factor	Droplet diameter range (µm)	Average droplet diameter (µm)	Total droplets per 48 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
⩽ 35	3.40	⩽ 10	5	7	0.15	0.87	0.87
36 - 70	3.45	11 - 20	15	38	0.79	4.56	5.43
71 - 105	3.50	21 - 30	25	51	1.06	6.12	11.55
106 - 140	3.50	31 - 40	35	76	1.58	9.12	20.67
141 - 175	3.50	41 - 50	45	391	8.15	47.06	67.73
176 - 210	3.50	51 - 60	55	123	2.56	14.78	82.51
211 - 245	3.50	61 - 70	65	76	1.58	9.12	91.63
246 - 290	3.60	71 - 80	75	62	1.29	7.45	99.08
291 - 325	3.60	81 - 90	85	5	0.10	0.58	99.66
326 - 380	3.80	91 - 100	95	1	0.02	0.12	99.78
381 - 420	3.80	101 - 110	105	2	0.04	0.23	100.01
				Total = 832	17.32		

Table 35 . Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category. Temp. °C = 22 ± 1.5; Relative Humidity = 45 ± 2%

Formulation ZE-UC-19-EMUL

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.15	0.002	0.0016	0.0016
11 - 20	15	0.18	0.79	0.142	0.1150	0.1166
21 - 30	25	0.82	1.06	0.869	0.7037	0.8203
31 - 40	35	2.24	1.58	3.539	2.866	3.686
41 - 50	45	4.77	8.15	38.88	31.48	35.17
51 - 60	55	8.71	2.56	22.30	18.06	53.23
61 - 70	65	14.38	1.58	22.72	18.40	71.63
71 - 80	75	22.09	1.29	28.50	23.08	94.71
81 - 90	85	32.16	0.10	3.216	2.60	97.31
91 - 100	95	44.89	0.02	0.900	0.73	98.04
101 - 110	105	60.61	0.04	2.420	1.96	100.00
		Total= 17.32		123.5		

Table 36. Kromekote® card data using spinning disc atomizer. Droplet number distribution according to size category. Temp. °C = 22 ± 2; Relative Humidity = 45 ± 3%

Formulation FCA-3409-4.0

Stain diameter range (µm)	Spread factor	Droplet diameter range (µm)	Average droplet diameter (µm)	Total droplets per 16 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
20 - 45	2.62	9 - 17	13	54	3.375	13.5	13.5
46 - 65	2.66	18 - 24	21	56	3.500	14.0	27.5
66 - 110	2.68	25 - 41	33	156	9.75	38.9	66.4
111 - 155	2.70	42 - 57	50	92	5.75	23.0	89.4
156 - 175	2.70	58 - 65	62	25	1.563	6.20	95.6
176 - 220	2.71	66 - 81	74	10	0.625	2.50	98.1
221 - 265	2.72	82 - 97	90	8	0.500	1.90	100.0
266 - 310	2.73	98 - 114	106	-	--	--	--
				Total = 401	25.06		

Table 37 . Kromekote® card data using spinning disc atomizer. Droplet volume distribution according to size category; Temp. °C = 22 ± 2. Relative Humidity = 45 ± 2%

Formulation FCA-3409-4.0

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (ml/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
9 - 17	13	0.1150	3.375	0.3882	0.3532	0.3532
18 - 24	21	0.4849	3.50	1.697	1.5441	1.8973
25 - 41	33	1.8817	9.75	18.35	16.69	18.59
42 - 57	50	6.545	5.75	37.63	34.24	52.83
58 - 65	62	12.48	1.563	19.50	17.74	70.57
66 - 81	74	21.22	0.625	13.26	12.07	82.64
82 - 97	90	38.17	0.500	19.09	17.36	100.00
98 - 114	106	-	--	--	--	--
		Total= 25.06		109.9		

Table 38. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2% . Formulation FDA-3409-1.5
Droplet number distribution according to size category

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 48 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
≤ 30	3.00	≤ 10	5	3	0.06	0.17	0.17
31 - 60	3.03	11 - 20	15	238	4.99	13.87	14.04
61 - 90	3.04	21 - 30	25	552	11.58	32.17	46.21
91 - 120	3.04	31 - 40	35	390	8.18	22.73	68.94
121 - 150	3.05	41 - 50	45	231	4.85	13.46	82.40
151 - 180	3.05	51 - 60	55	144	3.02	8.39	90.79
181 - 210	3.05	61 - 70	65	75	1.57	4.37	95.16
211 - 240	3.05	71 - 80	75	41	0.86	2.39	97.55
241 - 270	3.05	81 - 90	85	18	0.38	1.05	98.60
271 - 300	3.05	91 - 100	95	24	0.50	1.40	100.00
301 - 335	3.06	101 - 110	105	--	--	--	--
336 - 370	3.07	111 - 120	115	--	--	--	--
371 - 400	3.08	121 - 130	125	--	--	--	--
			Total =	1716	36.00		

Table 39. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2%. Formulation FDA-3409-1.5
Droplet volume distribution according to size category

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (mL/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.06	0.0004	0.00	0.00
11 - 20	15	0.18	4.99	0.8823	0.57	0.57
21 - 30	25	0.82	11.58	9.474	6.13	6.70
31 - 40	35	2.24	8.18	18.37	11.89	18.59
41 - 50	45	4.77	4.85	23.12	14.96	33.55
51 - 60	55	8.71	3.02	26.32	17.03	50.58
61 - 70	65	14.38	1.57	22.62	14.64	65.22
71 - 80	75	22.09	0.86	19.00	12.29	77.52
81 - 90	85	32.16	0.38	12.14	7.86	85.37
91 - 100	95	44.89	0.50	22.60	14.63	100.00
101 - 110	105	60.61	--	--	--	--
111 - 120	115	79.63	--	--	--	--
121 - 130	125	102.27	--	--	--	--
		Total =	36.00	154.5		

Table 40. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2% . Formulation FDA-3409-4.0
Droplet number distribution according to size category

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 8 cm²	Droplets per cm²	Frequency (%)	Cumulative frequency (%)
≤ 22	2.15	≤ 10	5	0	0.00	0.00	0.00
23 - 60	3.00	11 - 20	15	32	4.00	4.60	4.60
61 - 100	3.33	21 - 30	25	152	19.00	21.84	26.44
101 - 140	3.50	31 - 40	35	273	34.13	39.22	65.66
141 - 180	3.60	41 - 50	45	150	18.75	21.55	87.21
181 - 220	3.62	51 - 60	55	54	6.75	7.76	94.97
221 - 255	3.65	61 - 70	65	30	3.75	4.31	99.28
256 - 300	3.70	71 - 80	75	2	0.25	0.29	99.57
301 - 335	3.72	81 - 90	85	2	0.25	0.29	99.86
336 - 375	3.75	91 - 100	95	1	0.13	0.14	100.00
376 - 415	3.78	101 - 110	105	-	--	--	--
416 - 455	3.80	111 - 120	115	-	--	--	--
456 - 495	3.82	121 - 130	125	-	--	--	--
				Total = 696	87.00		

Table 41. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2%. Formulation FDA-3409-4.0
Droplet volume distribution according to size category

Droplet diameter range (µm)	Average droplet diameter (µm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (mL/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.00	0.0000	0.00	0.00
11 - 20	15	0.18	4.00	0.7069	0.22	0.22
21 - 30	25	0.82	19.00	15.54	4.95	5.17
31 - 40	35	2.24	34.13	76.61	24.38	29.55
41 - 50	45	4.77	18.75	89.46	28.47	58.02
51 - 60	55	8.71	6.75	58.80	18.71	76.74
61 - 70	65	14.38	3.75	53.92	17.16	93.90
71 - 80	75	22.09	0.25	5.522	1.76	95.66
81 - 90	85	32.16	0.25	8.039	2.56	98.21
91 - 100	95	44.89	0.13	5.612	1.79	100.00
		Total =	87.00	314.2		

Table 42. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2% . Formulation FT-114-5.0
Droplet number distribution according to size category

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 8 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
≤ 25	2.45	≤ 10	5	4	0.50	0.77	0.77
26 - 50	2.55	11 - 20	15	18	2.25	3.45	4.22
51 - 80	2.65	21 - 30	25	86	10.73	16.51	20.73
81 - 110	2.75	31 - 40	35	86	10.73	16.51	37.24
111 - 145	2.90	41 - 50	45	190	23.70	36.47	73.70
146 - 180	3.00	51 - 60	55	82	10.23	15.74	89.44
181 - 215	3.07	61 - 70	65	36	4.49	6.91	96.35
216 - 245	3.10	71 - 80	75	17	2.12	3.26	99.62
246 - 280	3.11	81 - 90	85	2	0.25	0.38	100.00
281 - 320	3.20	91 - 100	95	--	--	--	--
			Total =	521.00	65.00		

Table 45. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2%. Formulation FT-114-7.0
Droplet volume distribution according to size category

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (mL/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.50	0.0033	0.00	0.00
11 - 20	15	0.18	5.03	0.8895	0.24	0.24
21 - 30	25	0.82	8.31	6.795	1.82	2.06
31 - 40	35	2.24	18.88	42.375	11.38	13.45
41 - 50	45	4.77	23.41	111.7	29.99	43.44
51 - 60	55	8.71	13.84	120.6	32.39	75.82
61 - 70	65	14.38	3.78	54.28	14.58	90.40
71 - 80	75	22.09	0.63	13.90	3.73	94.14
81 - 90	85	32.16	0.50	16.19	4.35	98.48
91 - 100	95	44.89	0.13	5.650	1.52	100.00
		Total =	75.00	372.3		

Table 44. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2% Formulation FT-114-7.0
Droplet number distribution according to size category

Stain diameter range (μm)	Spread factor	Droplet diameter range (μm)	Average droplet diameter (μm)	Total droplets per 8 cm^2	Droplets per cm^2	Frequency (%)	Cumulative frequency (%)
≤ 25	2.45	≤ 10	5	4	0.50	0.67	0.67
26 - 50	2.55	11 - 20	15	40	5.03	6.71	7.38
51 - 80	2.60	21 - 30	25	66	8.31	11.07	18.46
81 - 105	2.65	31 - 40	35	150	18.88	25.17	43.62
106 - 130	2.75	41 - 50	45	186	23.41	31.21	74.83
131 - 170	2.83	51 - 60	55	110	13.84	18.46	93.29
171 - 210	3.00	61 - 70	65	30	3.78	5.03	98.32
211 - 250	3.12	71 - 80	75	5	0.63	0.84	99.16
251 - 290	3.22	81 - 90	85	4	0.50	0.67	99.83
291 - 330	3.30	91 - 100	95	1	0.13	0.17	100.00
				Total = 596	75.00		

Table 43. Kromekote card data. Spray chamber study. Temp. °C = 22 ± 1.5
Relative humidity = 45 ± 2%. Formulation FT-114-5.0
Droplet volume distribution according to size category

Droplet diameter range (μm)	Average droplet diameter (μm)	Volume of one droplet (10^{-8} cc)	Droplets per cm^2	Volume of deposit (mL/ha)	Droplet volume distribution (%)	Cumulative droplet volume distribution (%)
≤ 10	5	0.01	0.50	0.0033	0.00	0.00
11 - 20	15	0.18	2.25	0.3968	0.11	0.11
21 - 30	25	0.82	10.73	8.778	2.47	2.59
31 - 40	35	2.24	10.73	24.09	6.79	9.37
41 - 50	45	4.77	23.70	113.1	31.86	41.24
51 - 60	55	8.71	10.23	89.12	25.11	66.34
61 - 70	65	14.38	4.49	64.58	18.20	84.54
71 - 80	75	22.09	2.12	46.85	13.20	97.74
81 - 90	85	32.16	0.25	8.024	2.26	100.00
91 - 100	95	44.89	--	--	--	--
		Total =	65.00	354.9		