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SUFFIELD REPORT

NO. 442

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ASSESSMENT OF THE PERSISTENCE OF VAPOUR EVOLVED FROM THICKENED AND NEAT DIMETHYL SULFOXIDE CONTAMINATION OF PRAIRIE TERRAIN (U)

RECORD OF FP No. 80

by

Stanley B. Mellsen

PCN 251SC-11

January 1987

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD, RALSTON, ALBERTA

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ABSTRACT

A series of sixteen trials, seven with neat (DMSO) and six with 80% DMSO and 20% water to reduce the freezing point temperature, and three with polyvinyl alcohol added to the latter solution to thicken the solution to a zero-shear viscosity of seven poise were conducted on prairie terrain. Explosive dissemination was used on all trials. Vapour sampling and drop sizing results were obtained. The persistence of DMSO and 80/20 DMSO/water on prairie terrain was found directly proportional to the mass median diameter of the drops and the recovery rate of the vapour from prairie terrain agrees favourably with the predictions of an existing DRES mathematical model.

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INTRODUCTION

1. Dimethyl Sulfoxide (DMSO) has been proposed for use as a total intake simulant. If it is to be suitable for use as a simulant in field experiments, then knowledge of its evaporative characteristics is necessary. The purpose of this report is to describe the results of a total of sixteen field trials using DMSO. The first seven trials were done using neat DMSO. The freezing point of the neat liquid is 18.6°C, which is impractical for many field situations. The freezing point is lowered greatly by addition of a small amount of water. Therefore, the intake simulant chosen for the remainder of the trials was a solution

of water in DMSO which provided a freezing point of -25°C. A total of six trials using unthickened solution were done and the final three trials were done using a thickened solution which produces larger drops.

TRIAL OBJECTIVES

2. a. To contaminate an area of prairie terrain, 24 m crosswind x 16 m downwind, to a mean contamination density of 2 g m^{-2} with DMSO using explosive dissemination from polyethylene bottles.

b. To determine drop size and ground contamination densities produced from the dissemination.

c. To sample vapour dosages sequentially at heights 0.3 m to 1.5 m above ground.

EXPERIMENTAL DETAILS

3. a. Material

Six 250 mL linear polyethylene bottles were charged with a nominal total of 1500 mL for each trial. The screw cap of each bottle was modified to provide a well for up to 400 gr of Primacord. A No. 12 detonator was used to initiate the burst. The three variations of DMSO used in the series of trials, with only one type used in each trial, are listed as follows:

(1) Pure DMSO (99.9%)

Pure DMSO with 0.1% amaranth added to improve the contrast of drops on detector paper was used. The physical properties of pure DMSO are shown in Table A1 (Appendix A).

(2) Water/DMSO Solution

The liquid consisted of 20% water dissolved in 80% DMSO by volume. 0.1% amaranth was added to improve the contrast of drops on detector paper as for the pure agent. The freezing point and viscosity of the solution can be estimated using Figures A1 to A4 (Appendix A).

(3) Thickened Water/DMSO Solution

4:1 dimethyl sulfoxide/water solution, thickened with polyvinyl alchohol (PVA) with an added dye was used. The concentration of PVA was 5.26% by weight. The grade of PVA was Dupont Elvanol 71-30 (fully hydrolyzed). The dye used was 0.1% methyl violet since amaranth in DMSO/H_2O/PVA did not give satisfactory color with the 3-way detector paper used in the trials. The zero-shear viscosity was estimated to be 6.99 poise [1].

b. Layouts

The sampling layout covered a 24 x 14 m rectangular area on the DRES Vertical Grid Site with ground contamination sampling positions on a 2 x 3 m grid and five vapour sampling positions on the downwind edge. Gallows of 1.5 cm steel rods, with arms at 1 and 2 m above ground to support the bottles were emplaced as indicated (Figures 1 and 2).

c. Ground Contamination Sampling

On all trials, sampling of drop sizes was carried out with 20 x 20 cm sheets of 3-way detector paper mounted on cardboard sheets while contamination densities were sampled with similar sized polyethylene sponges, 3 mm thick (Figure 3).

d. Vapour Sampling

(1) Bubblers

Vapour dosage samples were taken in bubblers charged with 3 mL distilled water and aspirated at 1 L min^{-1}. A blank and five sequential samples were taken at heights of 0.3, 0.5, 1.0 and 1.5 m on all trials.

(2) IR Analyzers

Foxboro Miran 1-A Infrared Gas Analyzers, each equipped w... 20 m pathlength gas cell, were used to provide rea... monitoring of DMSO vapour concentration. Samples we... at a height of 1.0 m. The IR analyzers were not ...vs vailable.

e. Meteor..og.

Meteorological observations were made at a position cross-wind from the layout. Windspeeds at 0.5, 1.0, 1.5 and 2.0 m above ground, wind direction at 2 m, air and ground temperatures and relative humidity were recorded for the duration of the sampling.

PROCEDURE

a. General

The layout was oriented according to the expected 2 m wind direction for each trial. After taking a blank sample, the bubbler arrays were covered with clear plastic sheeting to protect them from direct spray. The liquid-charged bottles were then armed and suspended at 1 m above ground from the gallows for windspeeds of 10 km per hour or greater. For lower windspeeds the bottles were suspended 2 m above the ground. About five minutes before the liquid was to be disseminated the infrared analyzers were started, to allow time for warm up and to sample vapour immediately after dissemination occurred. At time zero, the bottles were exploded electrically and vapour sampling by the bubblers commenced. As quickly as possible, the plastic covers were removed from the vapour samplers. The sponge samplers were removed and placed in wide mouth bottles which were immediately sealed and transported to the laboratory for analysis. The detector paper samplers were placed in racks and allowed to dry before measurement of the drop sizes.

b. Zero

Zero in all trials was generally in the forenoon, usually between 0930 and 1130, so that weather conditions were suitable and ample time was available to complete the vapour sampling before the end of the normal working day. The date and exact time of zero is shown for each trial in Appendix B along with the meteorological observations.

c. Vapour Sampling Schedules

(1) Bubblers

z to z + 1 minute
z + 1 to z + 2 minutes
z + 2 to z + 5 minutes
z + 5 to z + 10 minutes
z + 10 to z + 30 minutes
z + 30 to z + 90 minutes
z + 90 to z + 150 minutes

(2) Infrared analyzers

Continuous operation from z - 5 minutes.

d. Analysis

The bubbler vapour samples and ground contamination samples were analyzed by high pressure liquid chromatography (HPLC). Stain sizes on detector papers were measured by a Quantimet System 23 Image Analyzer. The results were then analyzed mathematically for drop-number distribution.

7. RESULTS

a. Weather Conditions

The series of sixteen trials reported herein were carried out from early May to early November with trials in every month during the interval. This provided a wide range of ground temperatures. The two meter wind speed was always between four and thirty-one km per hour. Most of the trials were carried out in sunny weather, but some were carried out under partial or full cloud cover. Air and ground temperatures, windspeeds at various heights and wind direction at two meters are given in detail in Appendix B. Relative humidity is also shown for some of the trials.

b. Ground Contamination

(1) The shape and size of the stains from neat DMSO and unthickened 80/20 DMSO/water are indicated by a typical sampling card (Figure 4). A typical sampling card for thickened 80/20 DMSO/water is also shown (Figure 5). The total number of drops of various sizes counted from representative areas of the cards in each trial are shown in Tables C1 to C3 (Appendix D). These results are also plotted along with fitted curves (Figures 6 to 21). The mass median diameters, D_0, and overall mass median diameters when the distributions are bimodal are shown in Figures 6 to 21 and tabulated along with the mass median diameter of each distribution in Table C4. Also, tabulated is the primacord charge used in each of the six bottles in each trial.

(2) The relationship between drop size and stain size as determined experimentally [2] is shown in Appendix C along with the method of fitting curves to the data points shown in Figures 6 to 21. Also shown in Appendix C is a comparison of the ground contamination density obtained from drop size-number count and sponge data analysis.

(3) The detailed ground contamination density data as measured by sponge samplers are shown in Appendix D.

c. Vapour Sampling

Sequential vapour dosages from bubblers at 0.3, 0.5, 1.0 and 1.5 m over the period z to z + 150 minutes are given in Tables E1 to E16 (Appendix E). Vapour concentrations measured by infrared analyzers with comparison to cumulative dosages from bubblers are given in Tables F1 to F6 (Appendix F). The comparisons were made to the bubblers sampling at the height of the intake of the infrared analyzer which was one metre.

d. DMSO Recovery

(1) Ground Sampling

Using a point-count method in which each sample represents a 3 x 2 m area, the ground contamination was calculated in terms of weight per meter of crosswind width from the mean contamination density over the 18 x 16 m sampling area. The results are shown in Table G1 (Appendix G).

(2) Vapour Recovery

Vapour recovery, the integrated flux of agent through a 1 m crosswind width of the vertical plane, was calculated from the vapour dosage and wind profile data. The results are given in Table G1 (Appendix G) along with the ground contamination information.

8. DISCUSSION OF RESULTS

a. Comparison of Vapour Recovery to Predicted Recoveries

The time profile of vapour recovery has been shown to be predicatable by means of a mathematical model [3]. The model considers the evaporation of liquid sprayed on a rough natural surface which may absorb the sprayed material in both the liquid and vapour phases and the subsequent atmospheric diffusion of the vapour evolved. To compare experimental data with a predicted curve, standard conditions of wind-speed and ground temperature were selected and the observed lengths of the vapour sampling intervals were normalized to these conditions. A wind speed of 18 km h^{-1} at 2 m and a ground temperature of 20°C were used. The data from all sixteen trials except from trial FP 80-2 were plotted as shown (Figures 22 to 36). The results of trial FP 80-2 were not plotted because freezing temperatures occurred throughout most of the trial and little vapour was evolved. The predicted curves, which assumed no absorption of DMSO into the substrate, were fitted to the data points of each trial and provided a good fit, indicating negligible absorption. The data was further normalized by the model normalizing parameter, T, derived from these curves of vapour recovery.

These results are shown in Figures 37, 38 and 39 for all sixteen trials except for FP 80-2.

b. The Relationship Between Mass Median Diameter and Persistence.

The parameter T determines the rate of vapour recovery and, hence, persistence at a given ground temperature and wind speed. It is related to M, the mean liquid loading on the substrate [3]. M has been found to be a function of contamination density, as well as the mass median diameter (mmd) of the drop. As mmd of neat liquid increases above 0.5 mm, M appears to become more directly related to drop diameter [4]. This latter relationship appears to hold in general for the trials with DMSO, where M was derived from the value of T obtained from the curve fit to the experimental data. The direct proportionality relationship of M to mmd between the larger drops of the thickened liquid to the small drops of neat liquid is indicated in Table 2, where the average values given in Table I for each trial, are shown. For higher contamination densities, the small drops would tend to overlap more and thus change the relationship. Apparently the M values derived for 80/20 DMSO/water are not appreciably different than those for neat DMSO; on the basis of a direct proportionality relationship between M and mmd. From this and the similarity of evaporative characteristics illustrated in Figures 37, 38 and 39, it is apparent that the water does not significantly alter the volatility of DMSO contamination on grassland.

c. Comparison of Infrared and Bubbler Sampler Results

The cumulative dosages calculated from the real time concentration measurements of the infrared analyzers were compared to the cumulative dosages measured by the bubbler samplers. The results, which are shown in Appendix F for FP 80-6, 8, 9, 10, 11, 12 and 14, indicate the following general characteristics.

(1) The dosages in the time interval 2 to 10 minutes agree favorably in most of the trials. Note that the bubblers are covered with plastic sheets for approximately one minute following trial zero which causes total dosages to differ somewhat.

(2) At times later than ten minutes, the dosages from the infrared analyzers deviated increasingly with time from the bubbler dosages in some of the trials. This was due to the fact that the concentrations approached the lower limit sensitivity of the infrared analyzers. Baseline drift was also observed occasionally, and this caused greater error with smaller concentrations than larger. Baseline drift could be eliminated by allowing a warm uptime of 30 minutes. Only 5 minutes warm up was used, however, because of trial constraints. The power must be shut off during bottle arming, which prevents the more desirable longer warm period.

(3) The results shown for FP 80-9 and 10 show similar discrepancies, which could also have been due to calibration errors in the analyzers, but was probably due to the fact that the intake nozzles were erroneously placed at a lower height than the bubbler intakes.

CONCLUSIONS

9. The persistence of DMSO and 80/20 DMSO/water on prairie terrain was found to be directly proportional to mass median diameter of the drops.

10. The recovery rate of the vapour from prairie terrain agrees favorably with the predictions of an existing DRES mathematical model.

11. The normalized recovery rate of thickened 80/20 DMSO/water was not found to be affected by temperatures below the freezing point of pure DMSO.

12. The dosages obtained by the bubblers and IR analyzers agreed favorably between 2 and 10 minutes after zero. At later times when the IR analyzers became inaccurate, they deviated increasingly with time in most of the trials.

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1. Armour, S.J. Private communication, 1985.

2. Hicken, R.P. and McAndless, J.M. Private communications, 1986.

3. Monaghan, J. and McPherson, W.R. A Mathematical Model for Predicting Vapor Dosages on and Downwind of Contaminated Areas of Grassland (U). Suffield Technical Paper No. 386, September 1971. UNCLASSIFIED.

4. Pasquill, F. Memorandum on the Persistence of and Vapour Concentrations from CW Agents when Dispersed on the Ground. Porton Report No. 2515, June 1984. UNCLASSIFIED.

TABLE I

CHARACTERISTIC VARIABLES OBTAINED FROM FIELD EXPERIMENTS

Trial No	Basic Quantities				Derived Quantities	
	Type	[1]T(min)	[2]R(g m^{-1})	D_0 mmd (mm)	[3]R (g m^{-2})	M(g m^{-2})
1		0.16	13	0.29	0.81	9
2	NEAT	-	5	0.35	0.31	-
3	DMSO	0.50	12	0.28	0.75	29
4		0.19	9	0.41	0.56	11
5		0.72	49	0.16	3.06	42
6		1.53	34	0.17	2.13	89
7		1.14	48	0.27	3.00	67
8	UNTHICKENED	1.21	39	0.31	2.44	71
9	80/20	0.75	11	0.47	0.69	44
10	DMSO/	0.38	27	0.25	1.69	22
11	WATER	1.13	28	0.22	1.75	66
12		0.67	30	0.12	1.88	39
13		1.06	20	0.11	1.25	62
14	THICKENED	2.56	16	0.72	1.00	149
15	80/20 DMSO/	2.70	14	0.68	0.88	158
16	WATER	2.00	15	1.11	0.94	117

[1] For ground temperature 20°C, wind speed 18 km h^{-1} at 2 m

[2] Recovery per unit crosswind width of contaminated ground

[3] Recovery per unit area of contaminated ground upwind of the vapour samplers

TABLE II

COMPARISON OF DROP SIZES WITH EVAPORATION RATES
USING MEAN VALUES FROM EACH TYPE OF LIQUID

Type	mmd mm	Contamination Density g m^{-2}	M g m^{-2}	T* min
Neat DMSO	0.26	1.7	41	0.71
Unthickened 80/20 DMSO/Water	0.25	1.8	51	0.87
Thickened 80/20 DMSO/Water	0.84	2.2	141	2.42

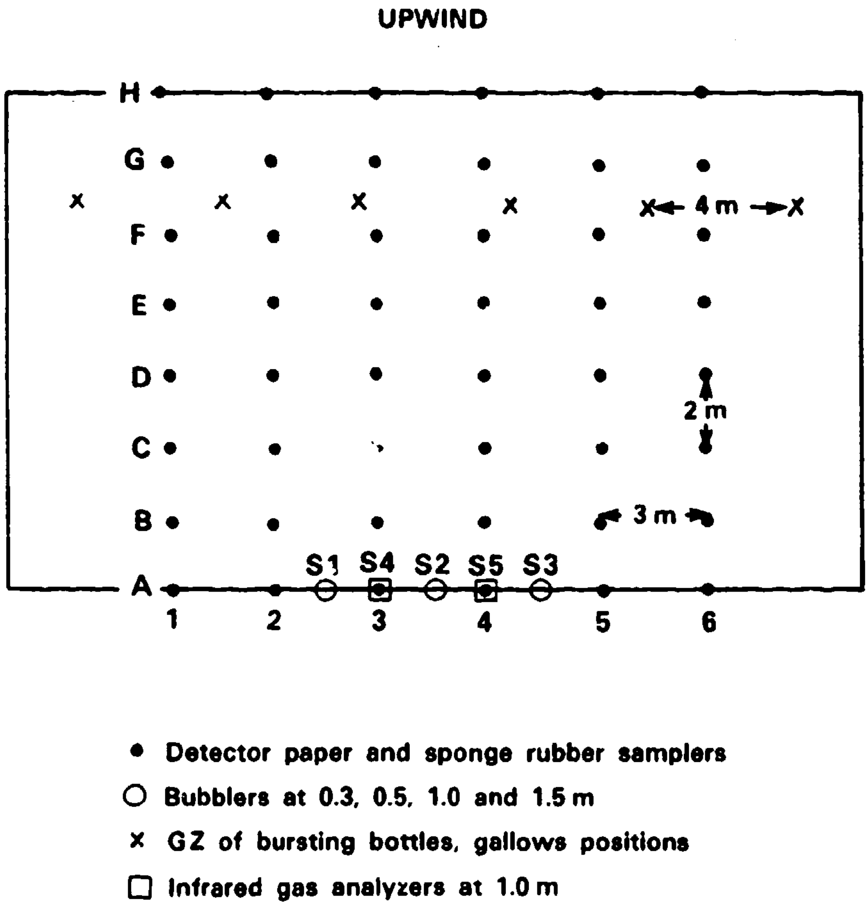

Figure 1

LAYOUT DIAGRAM FOR EXPLOSIVE DISSEMINATION FROM BOTLES

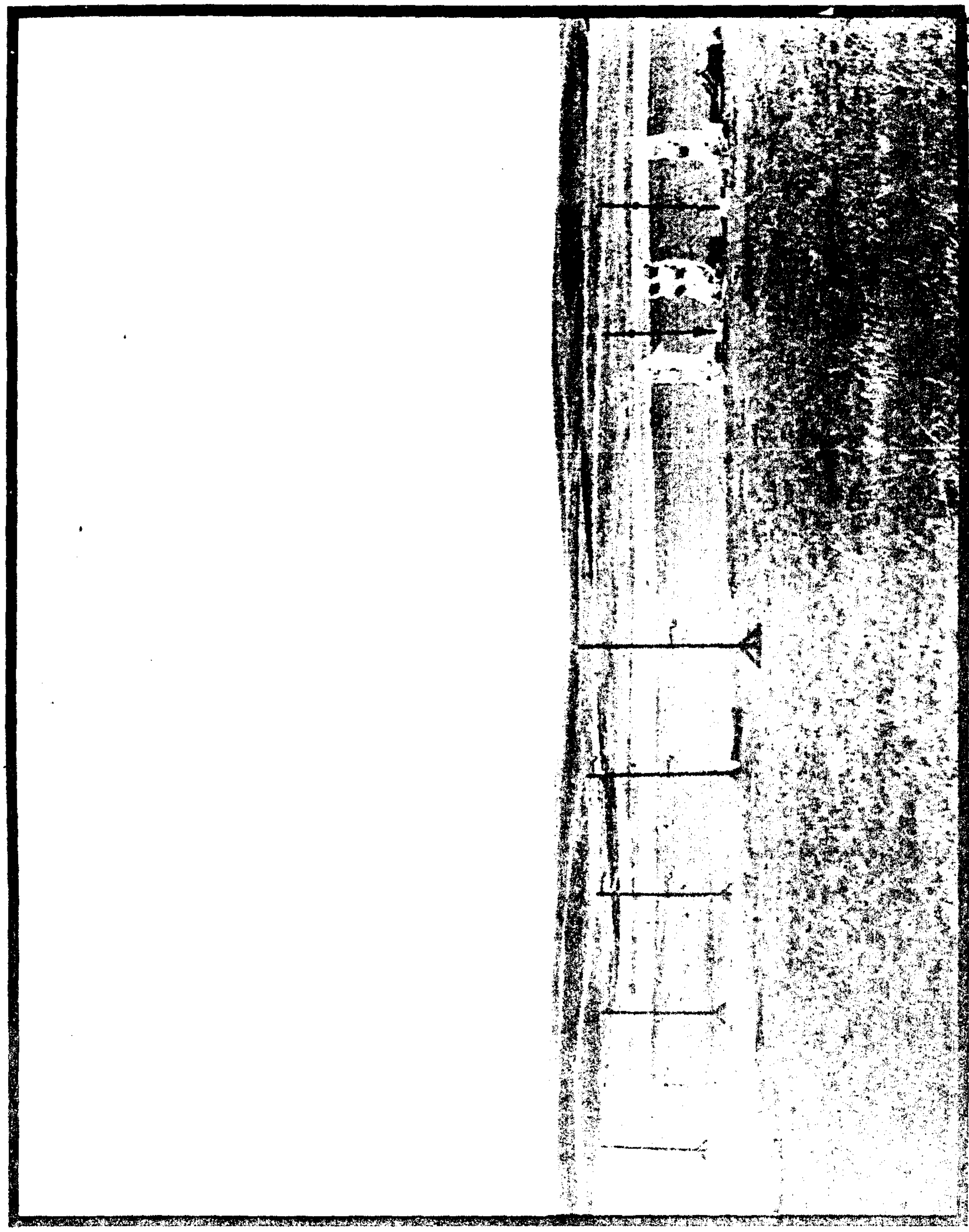

Figure 2
PHOTOGRAPH OF A TYPICAL LAYOUT

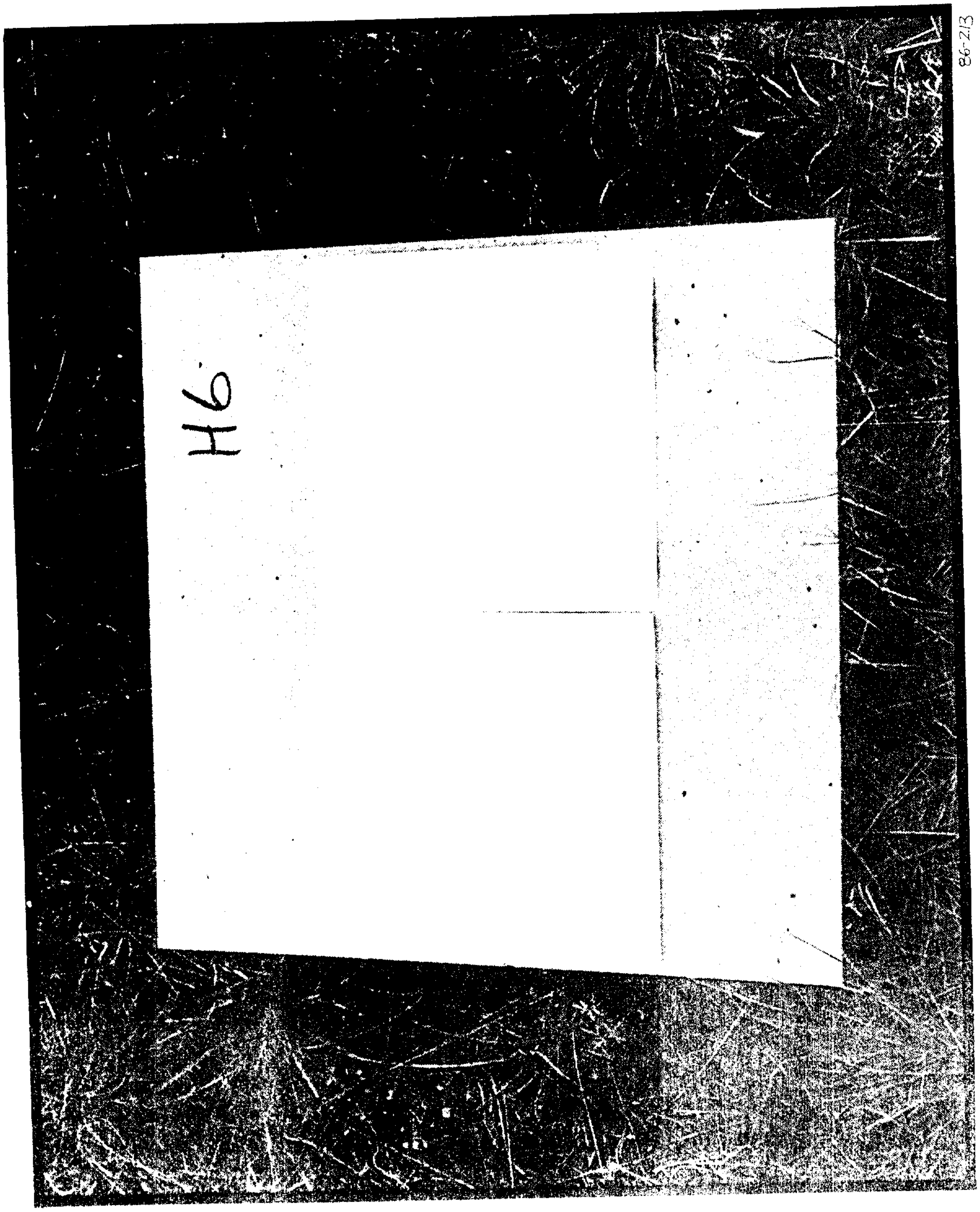

Figure 3

DETECTOR PAPER AND SPONGE SAMPLERS

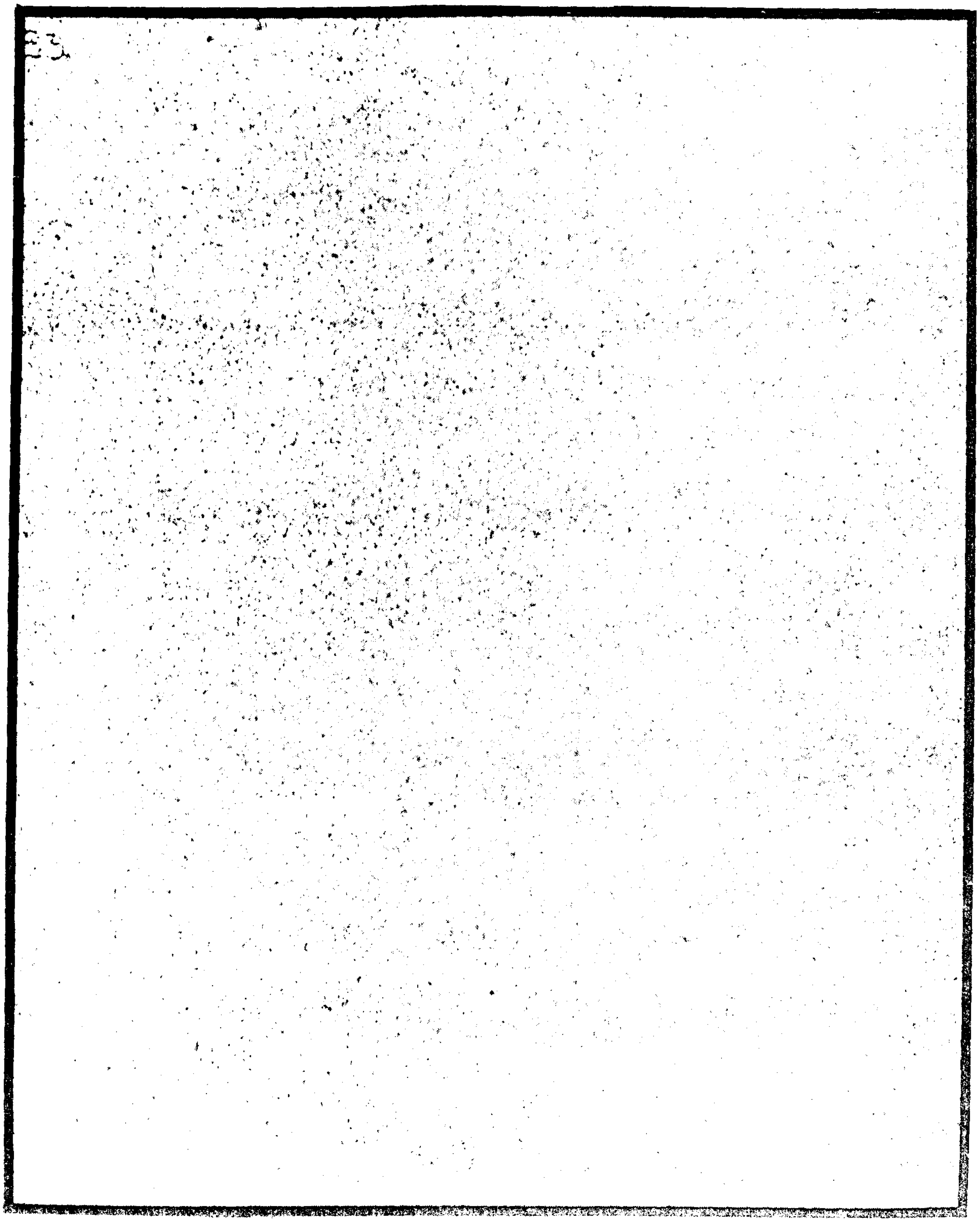

Figure 4

SAMPLING CARD SHOWING STAINS FROM UNTHICKENED 80/20 DMSO/WATER

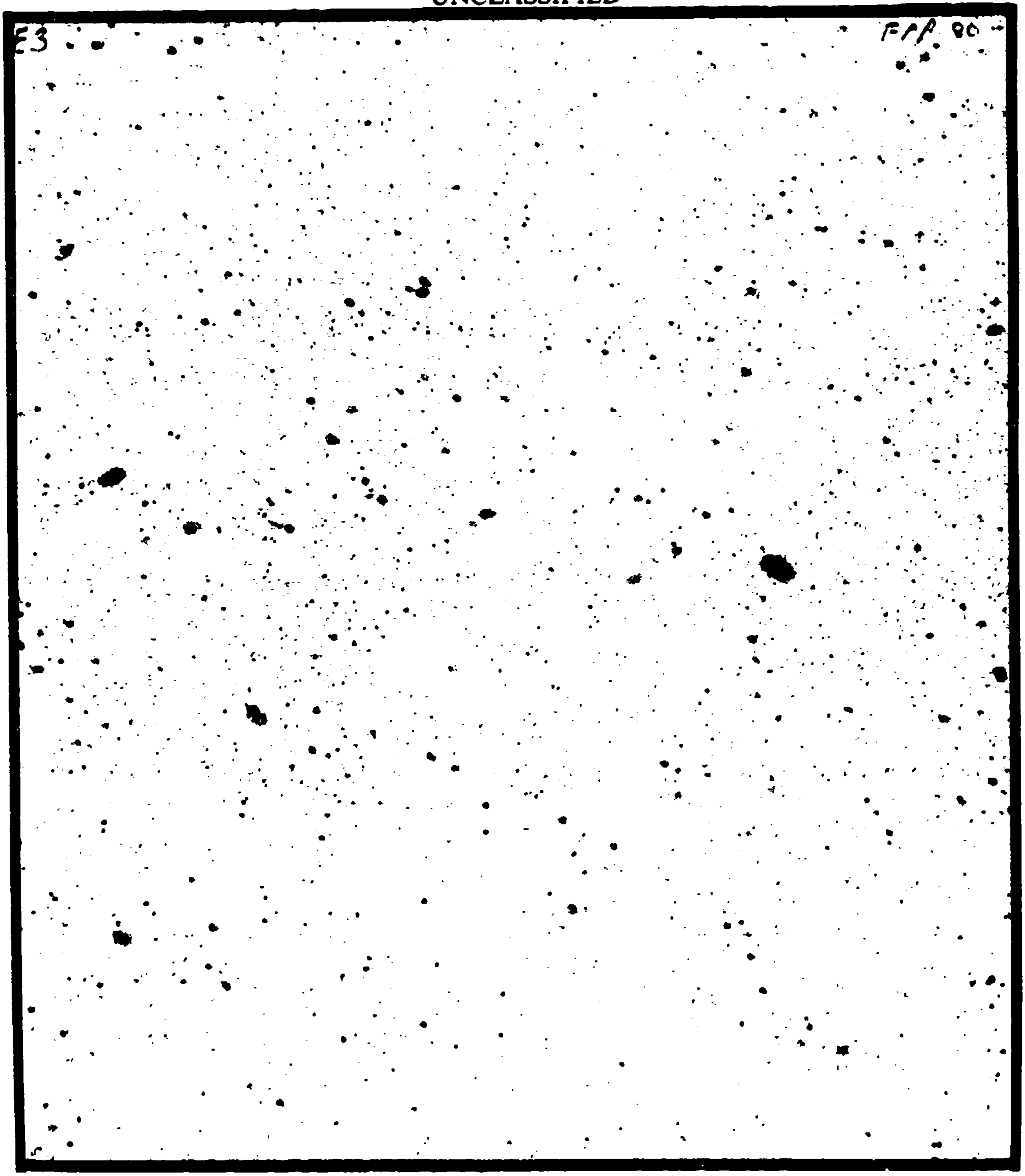

Figure 5

SAMPLING CARD SHOWING STAINS FROM THICKENED 80/20 DMSO/WATER

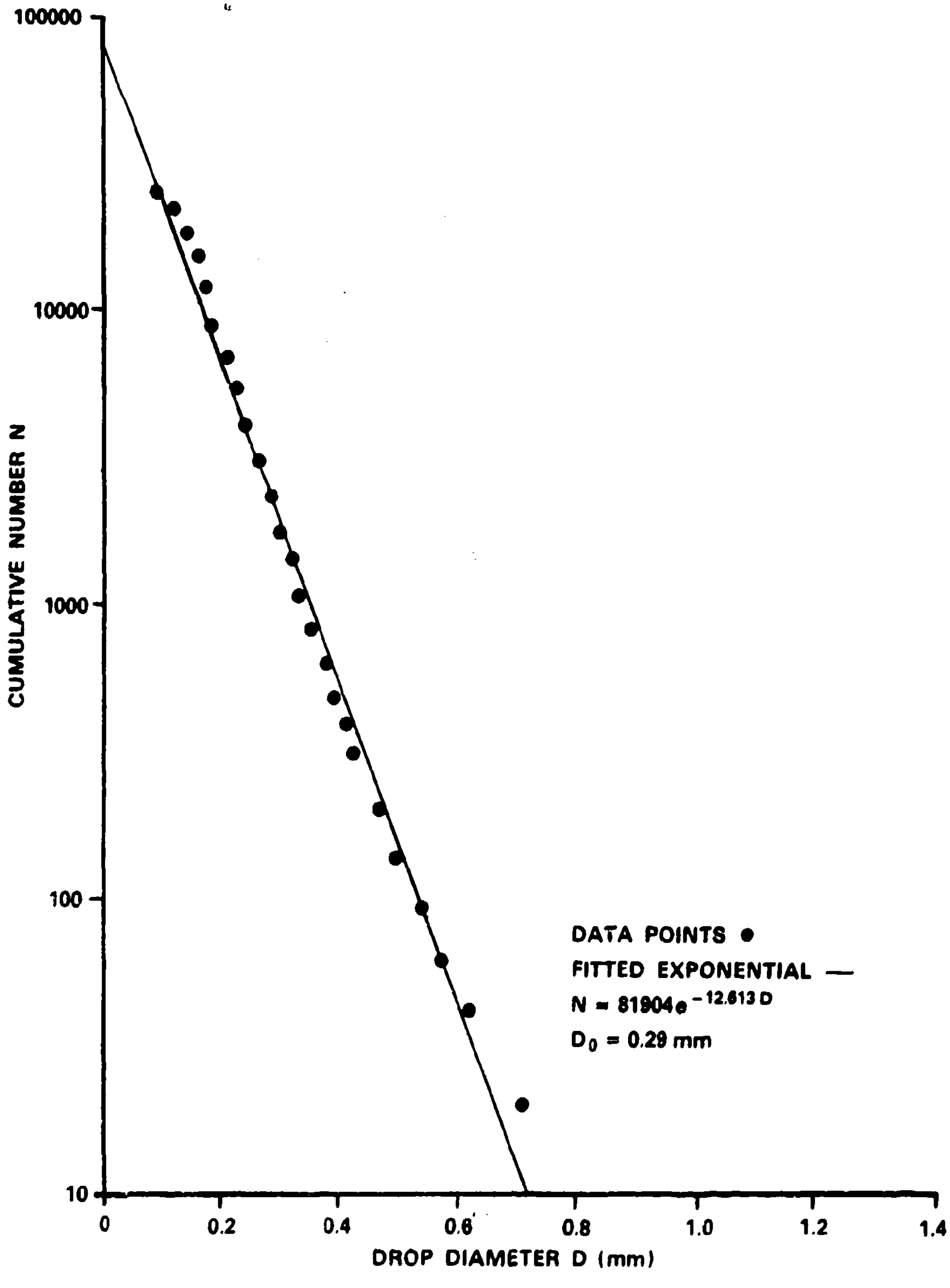

Figure 6

DROP DIAMETER NUMBER DISTRIBUTION
FPP 80 - 1

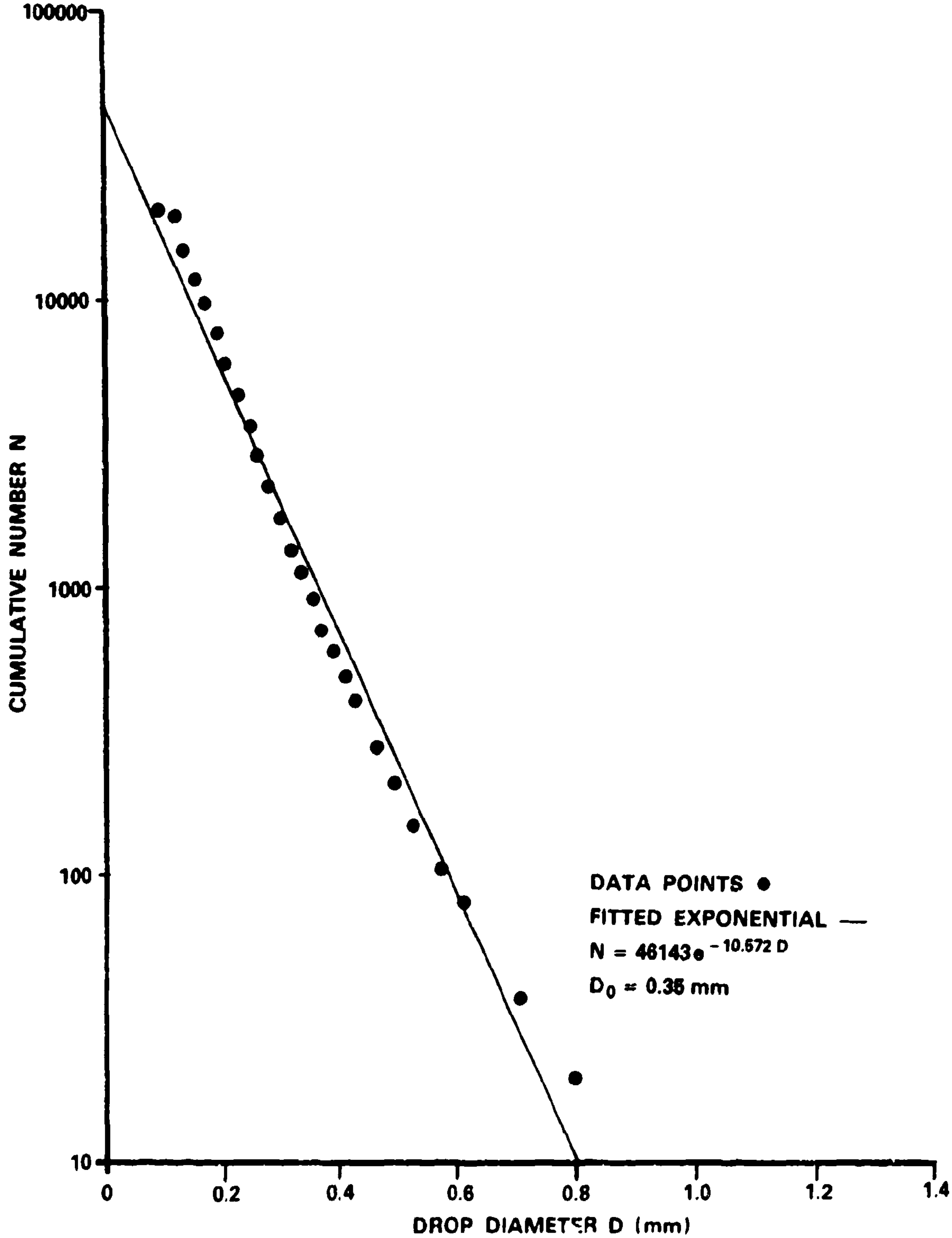

Figure 7

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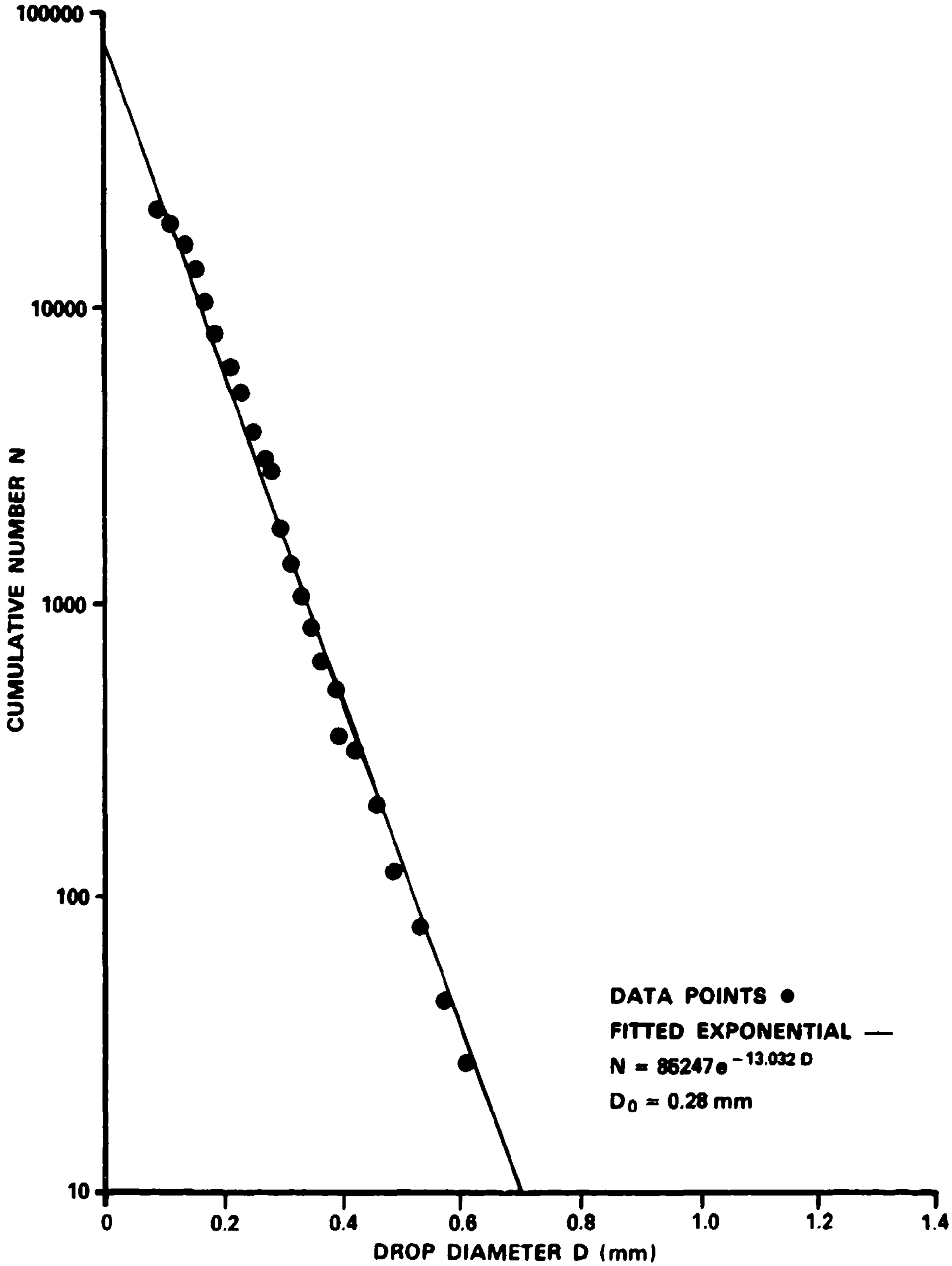

Figure 8

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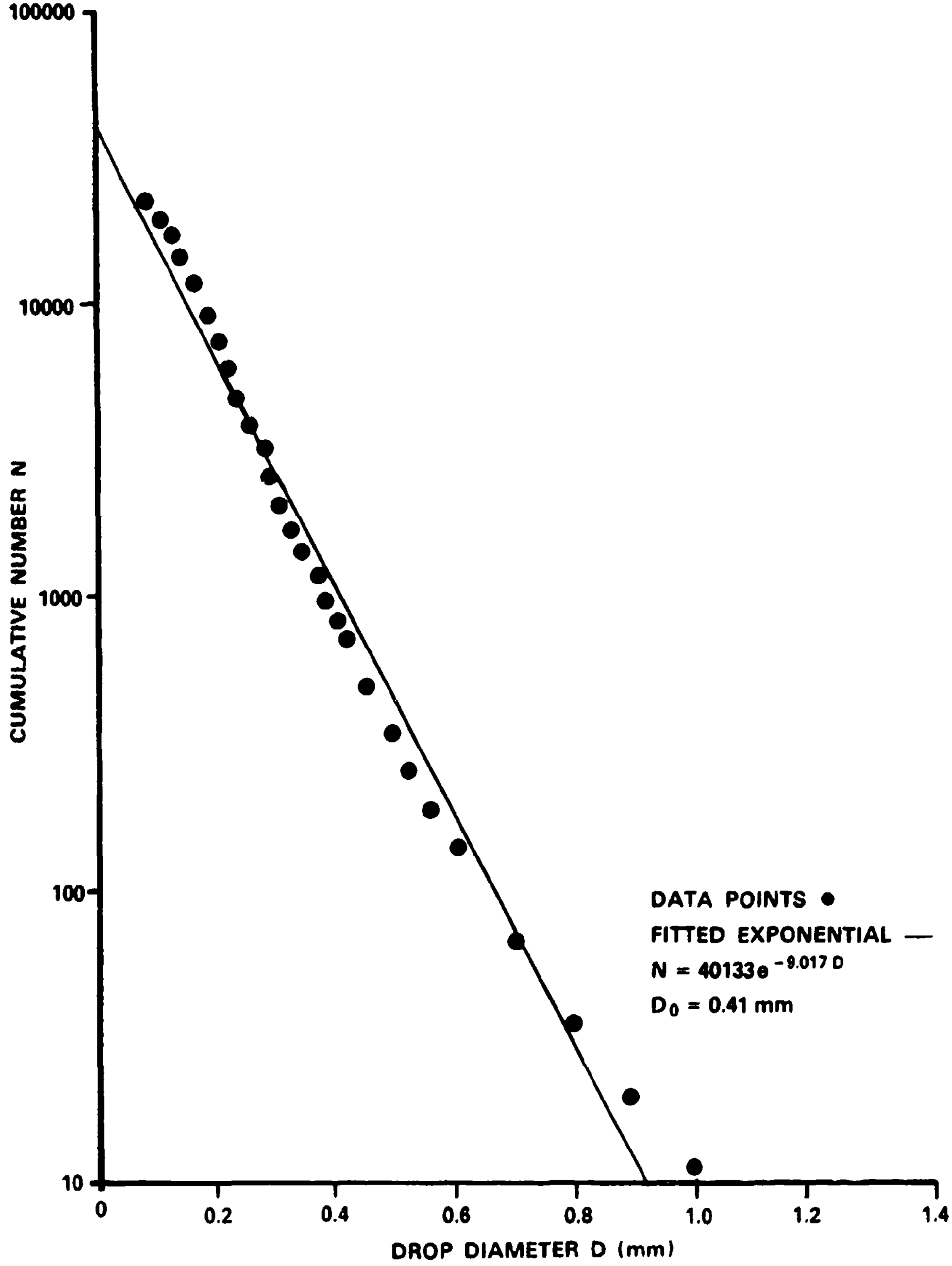

Figure 9

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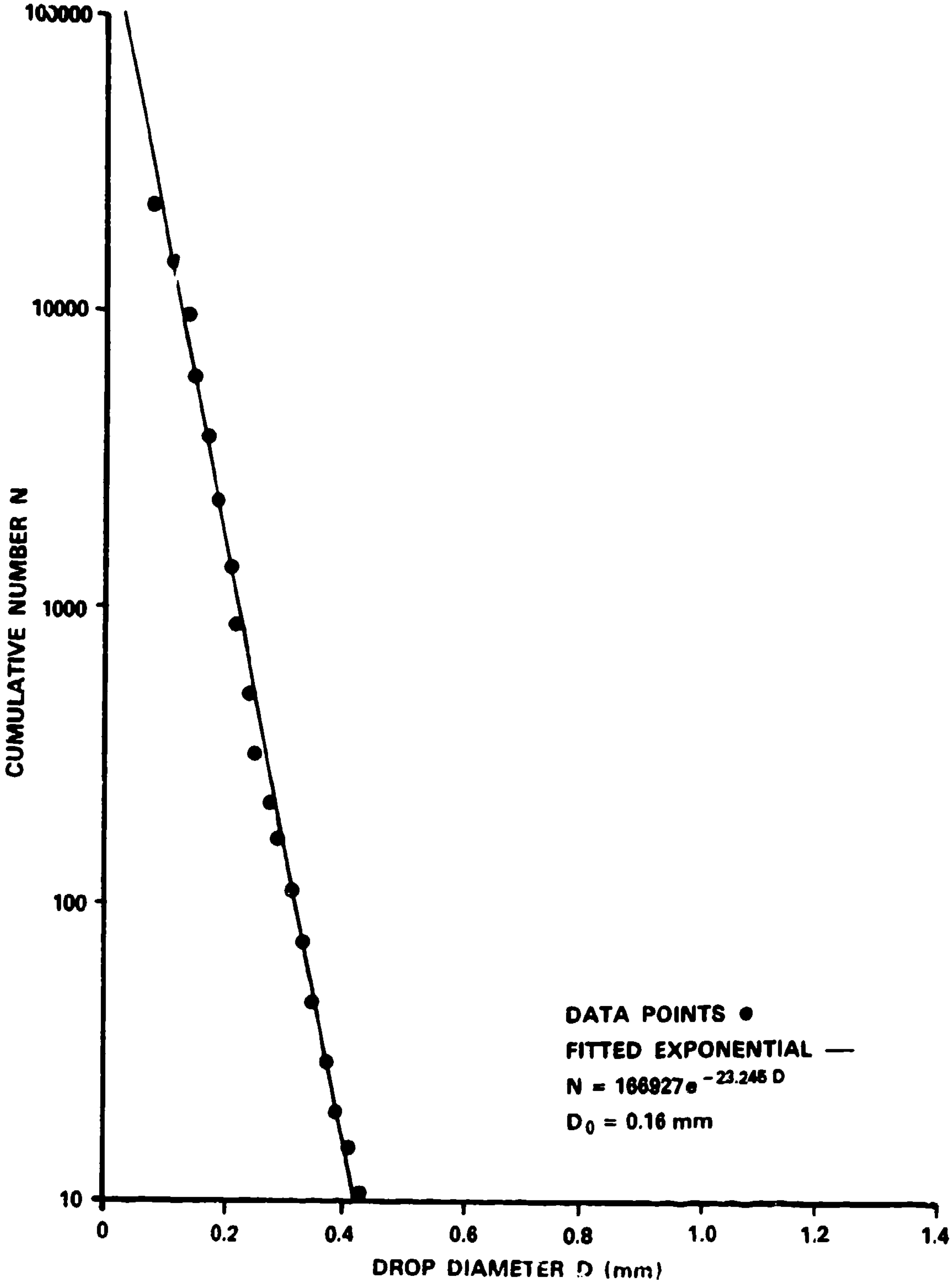
FPP 80 – 4



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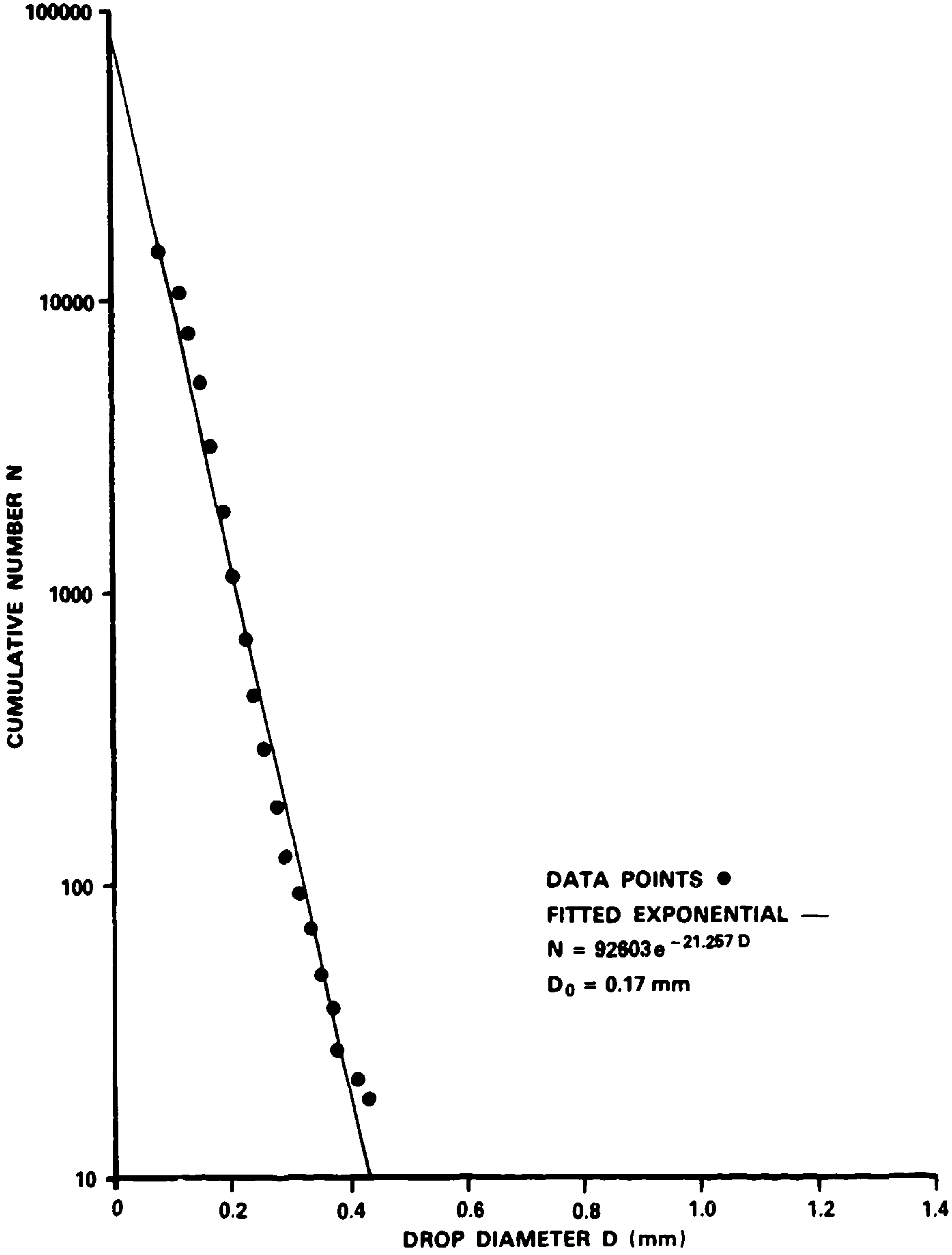

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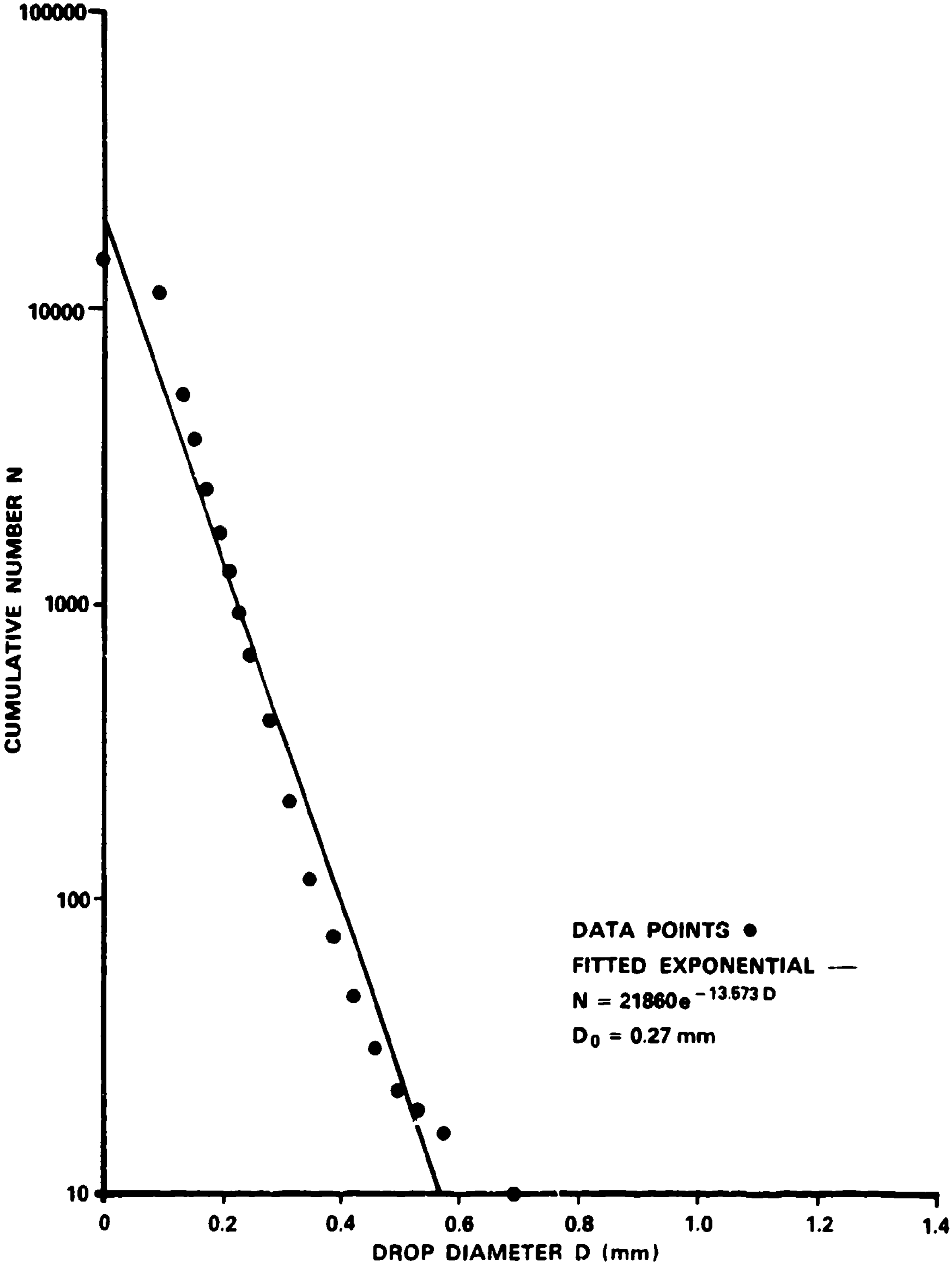

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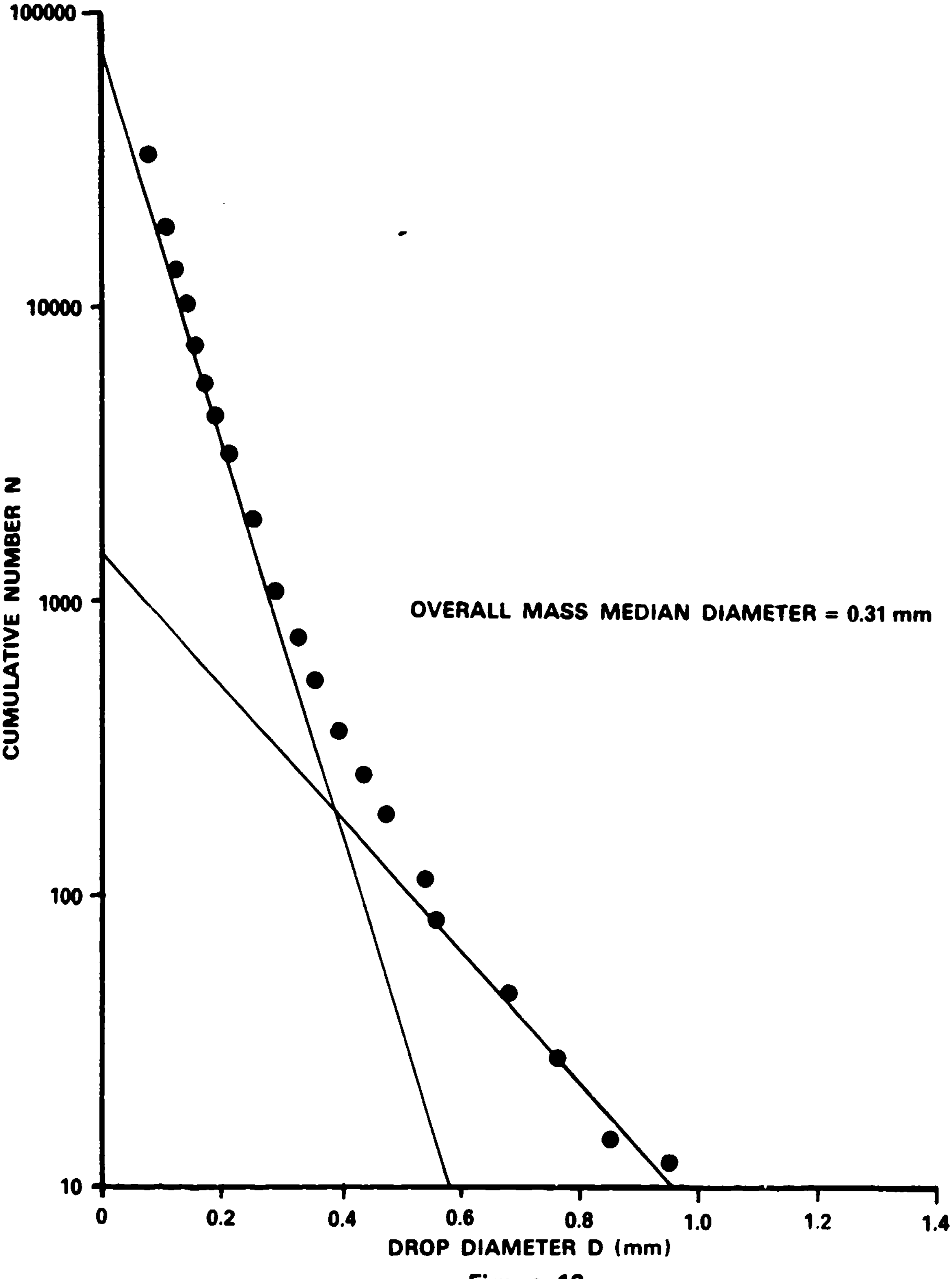

Figure 13

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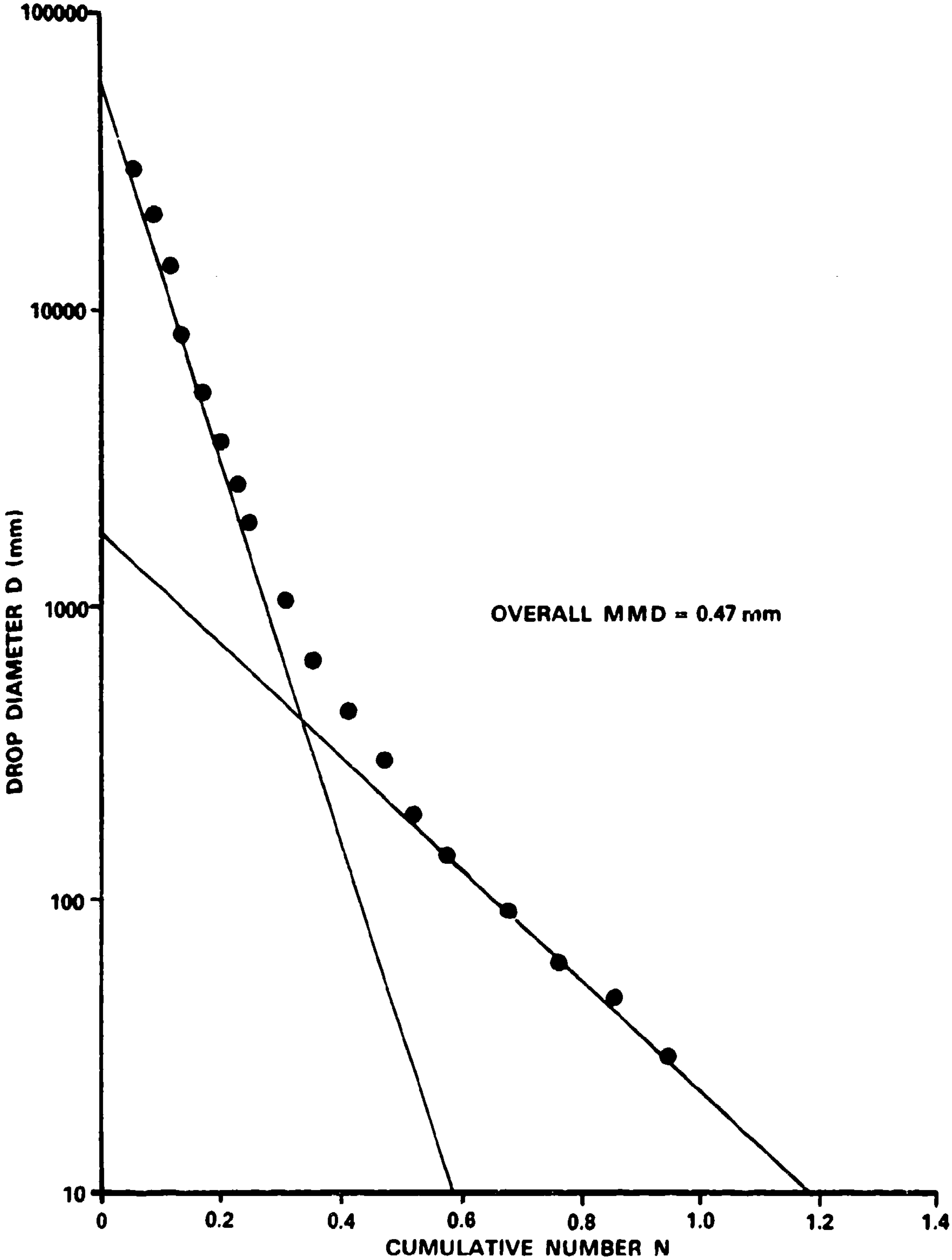

Figure 14

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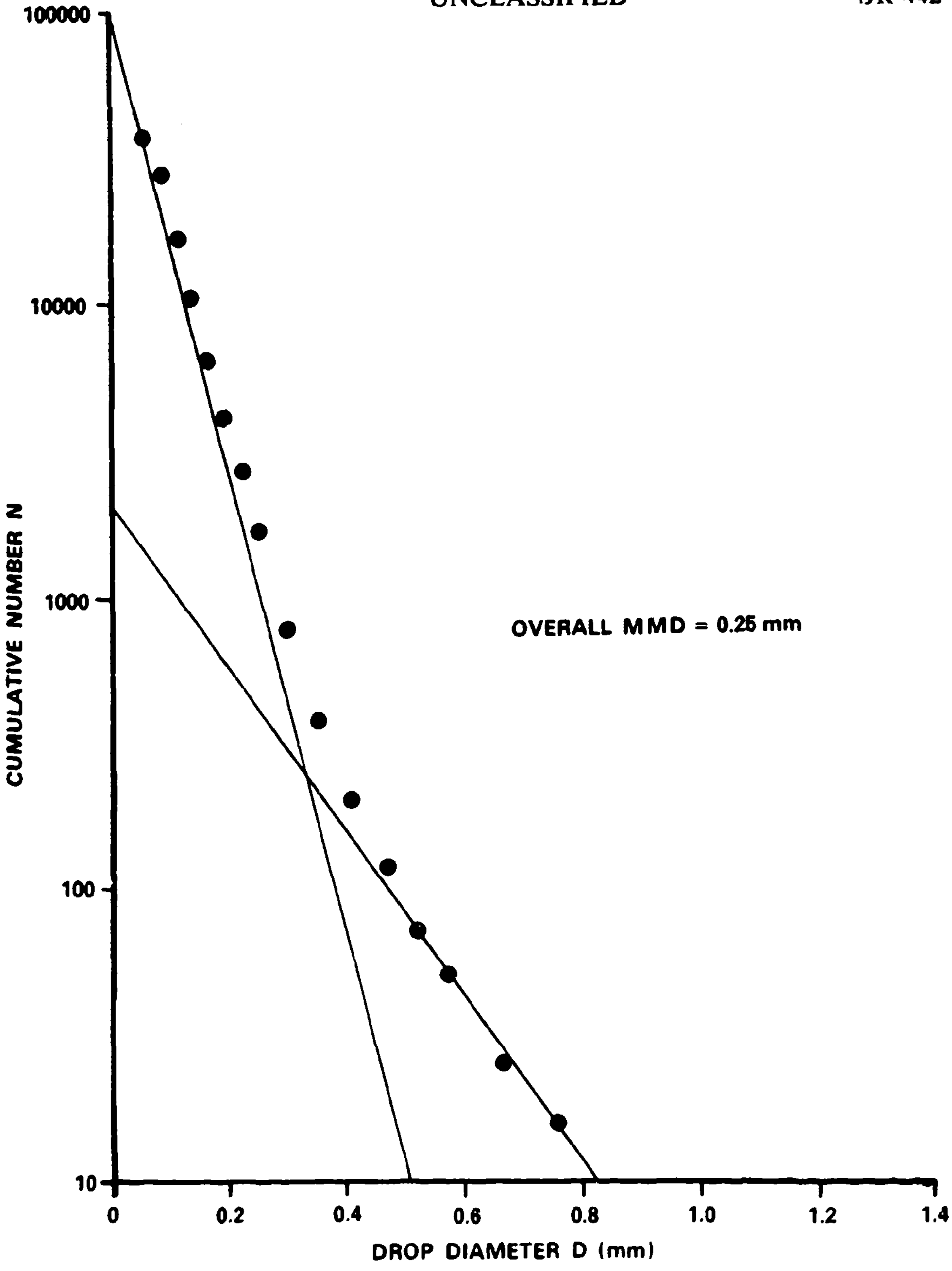

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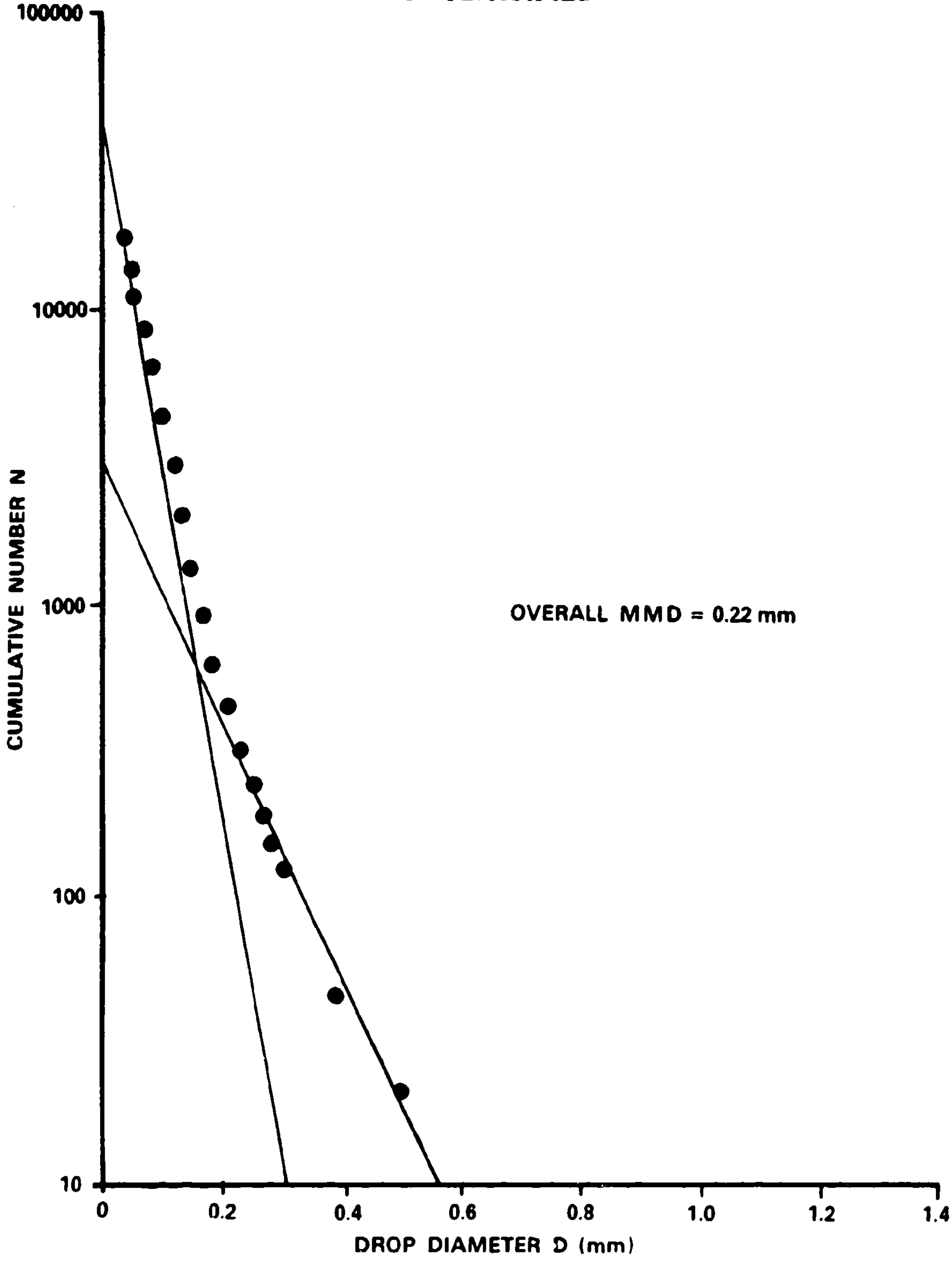

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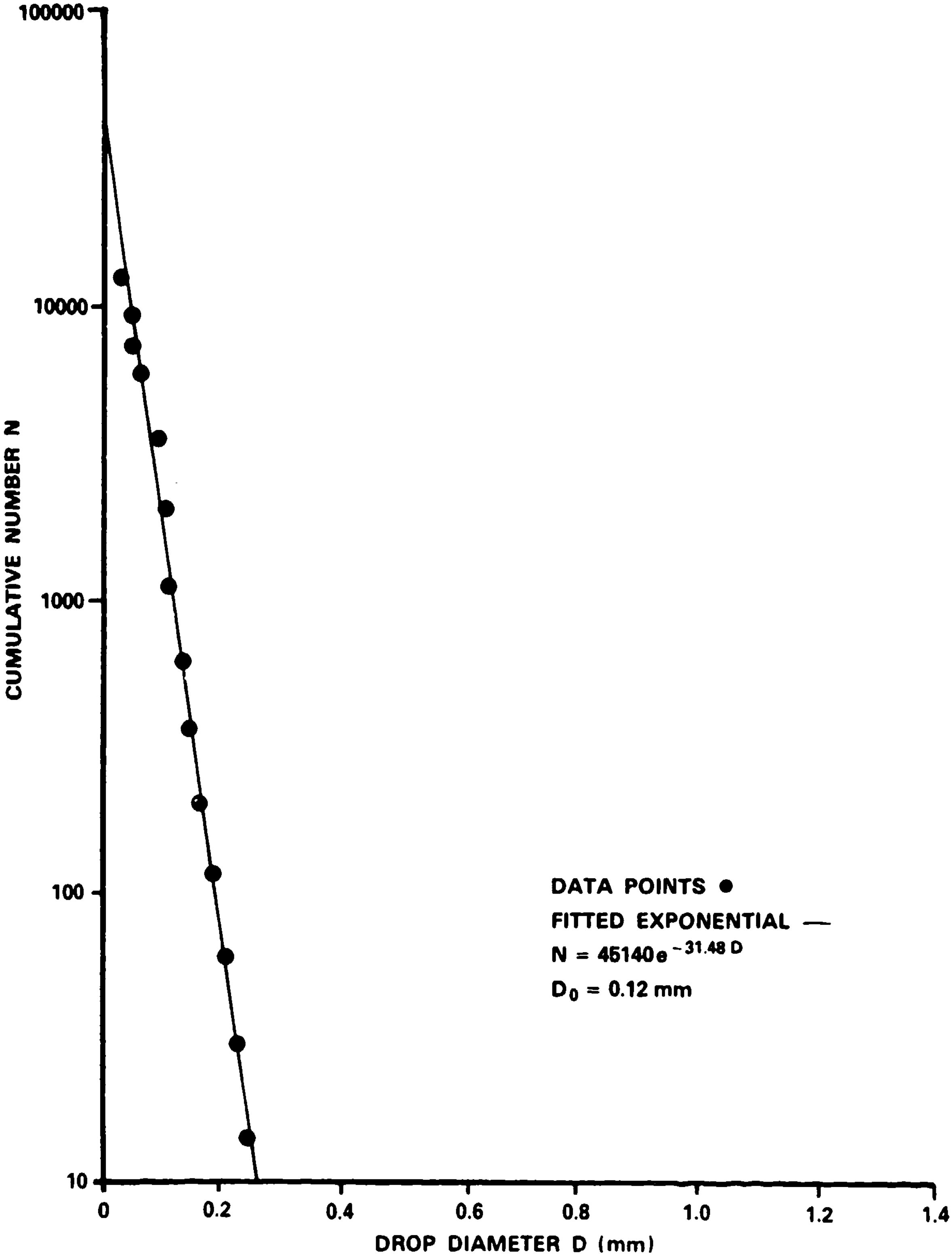

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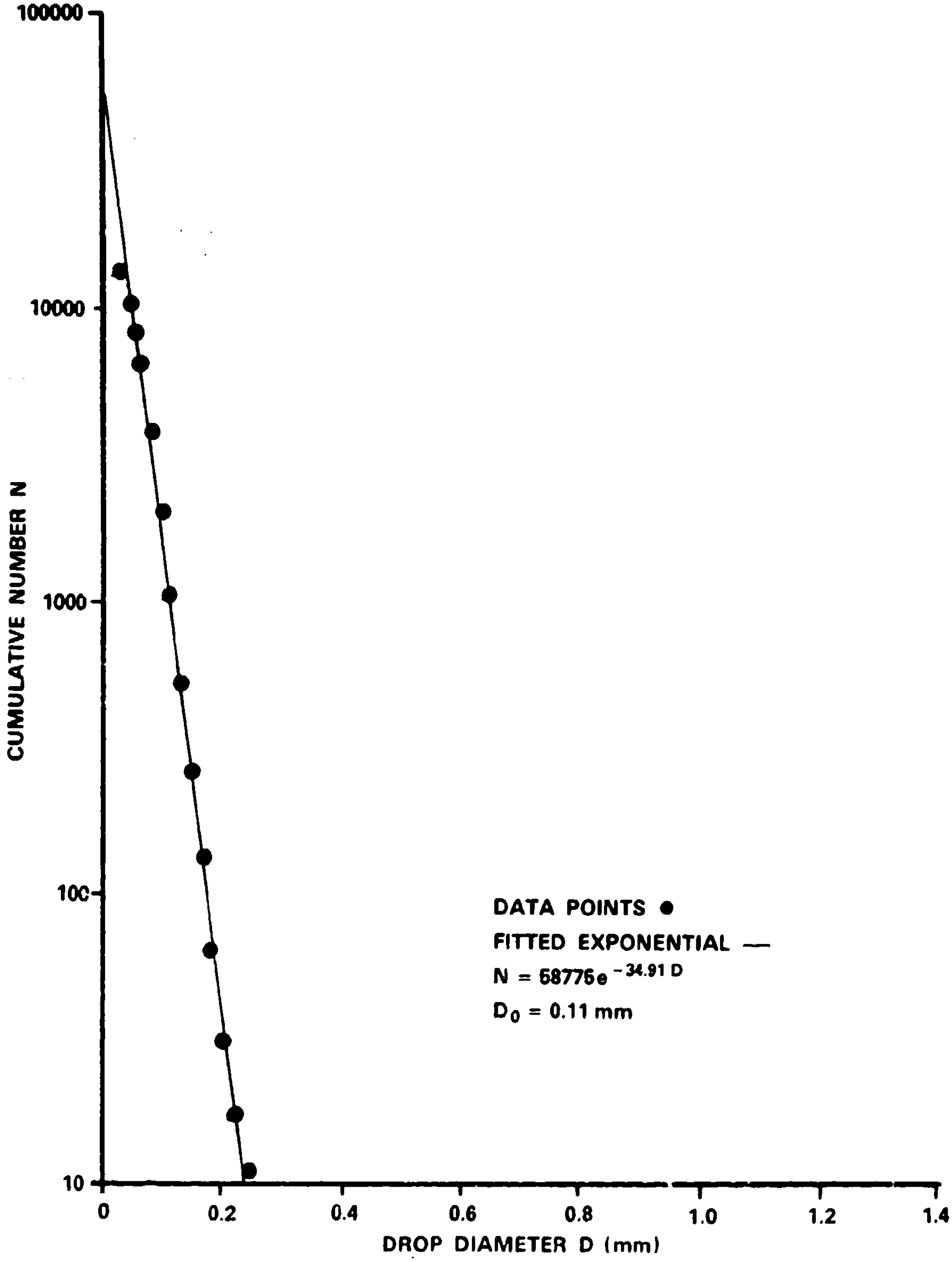

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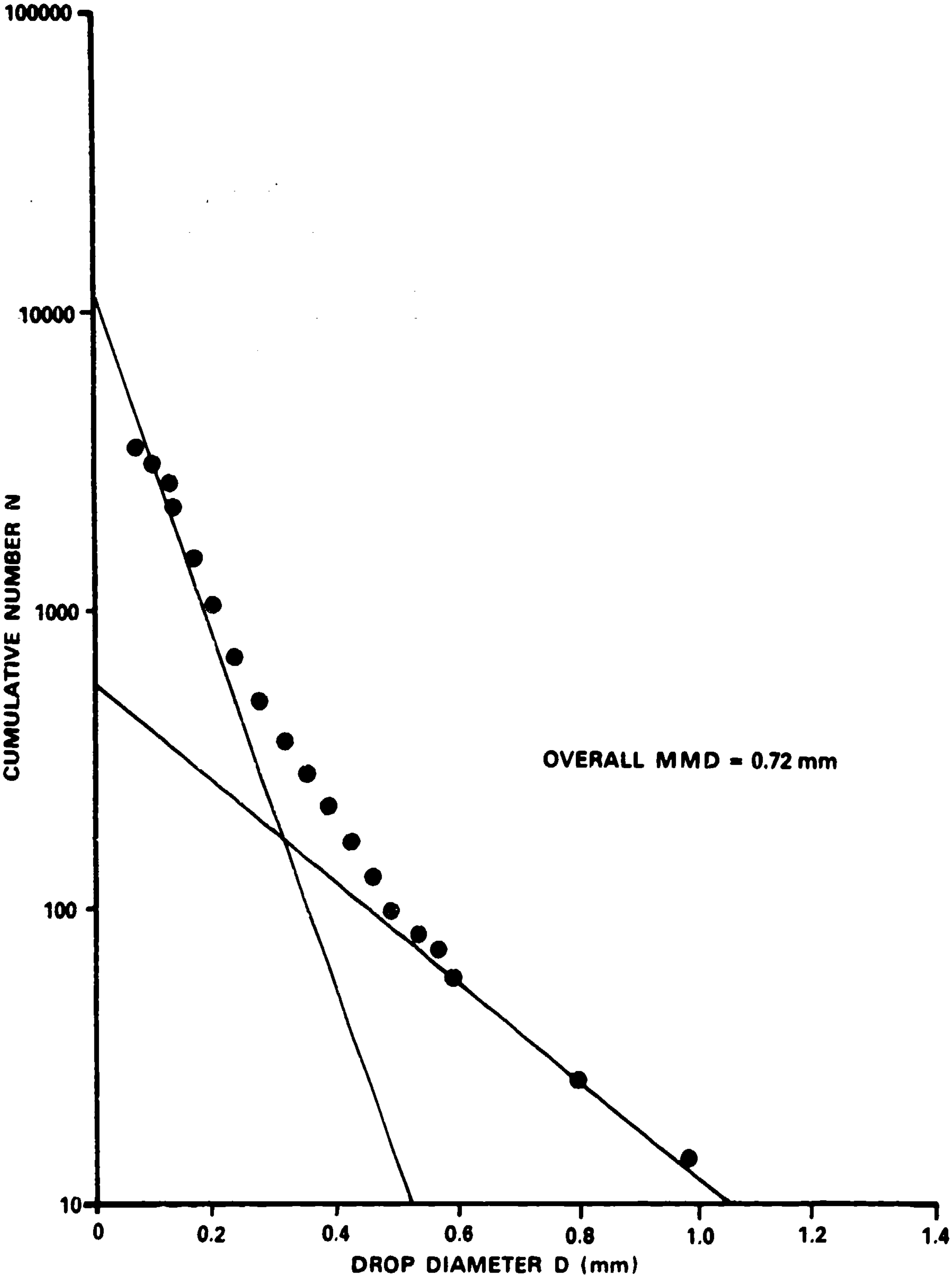

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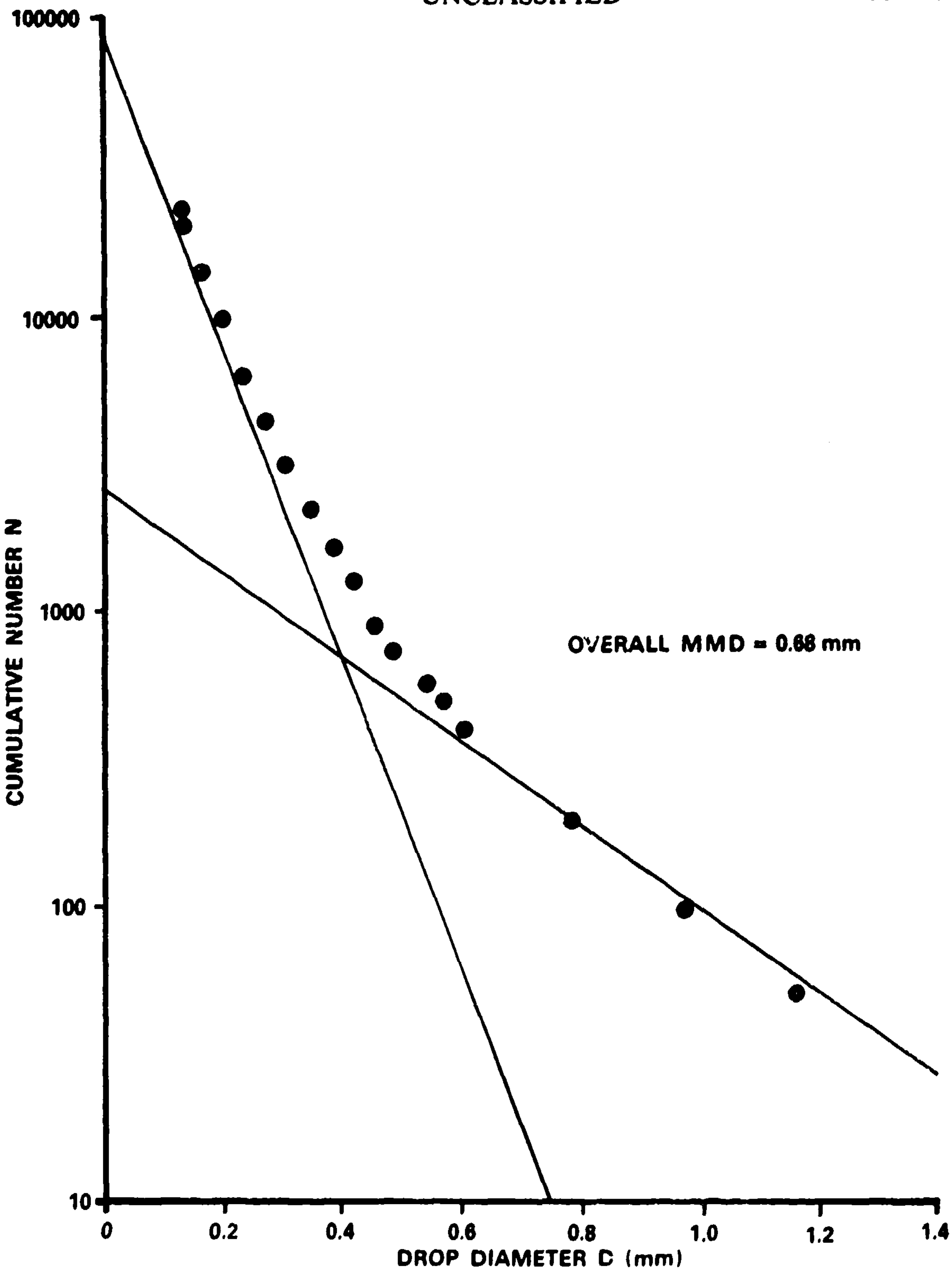

Figure 20

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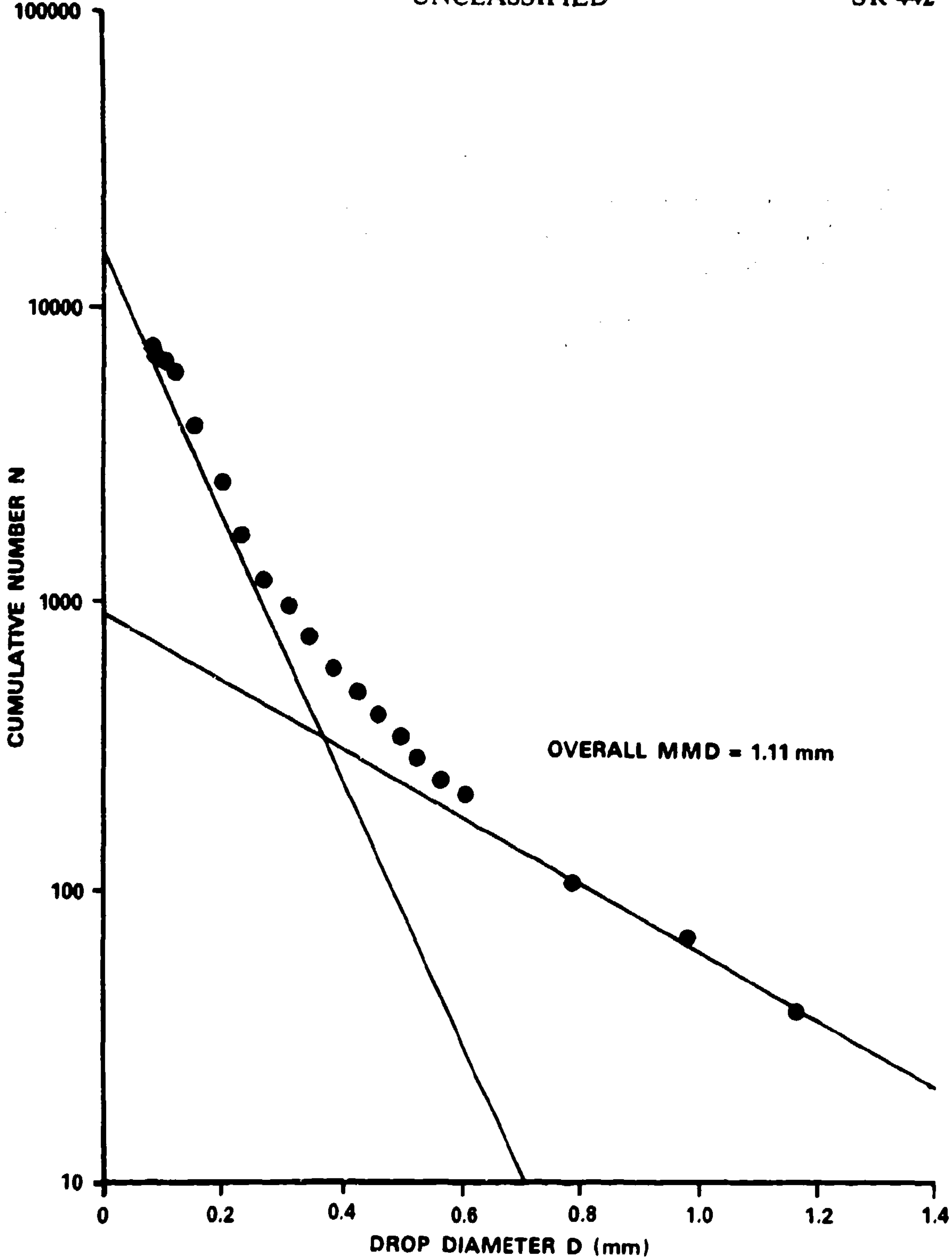

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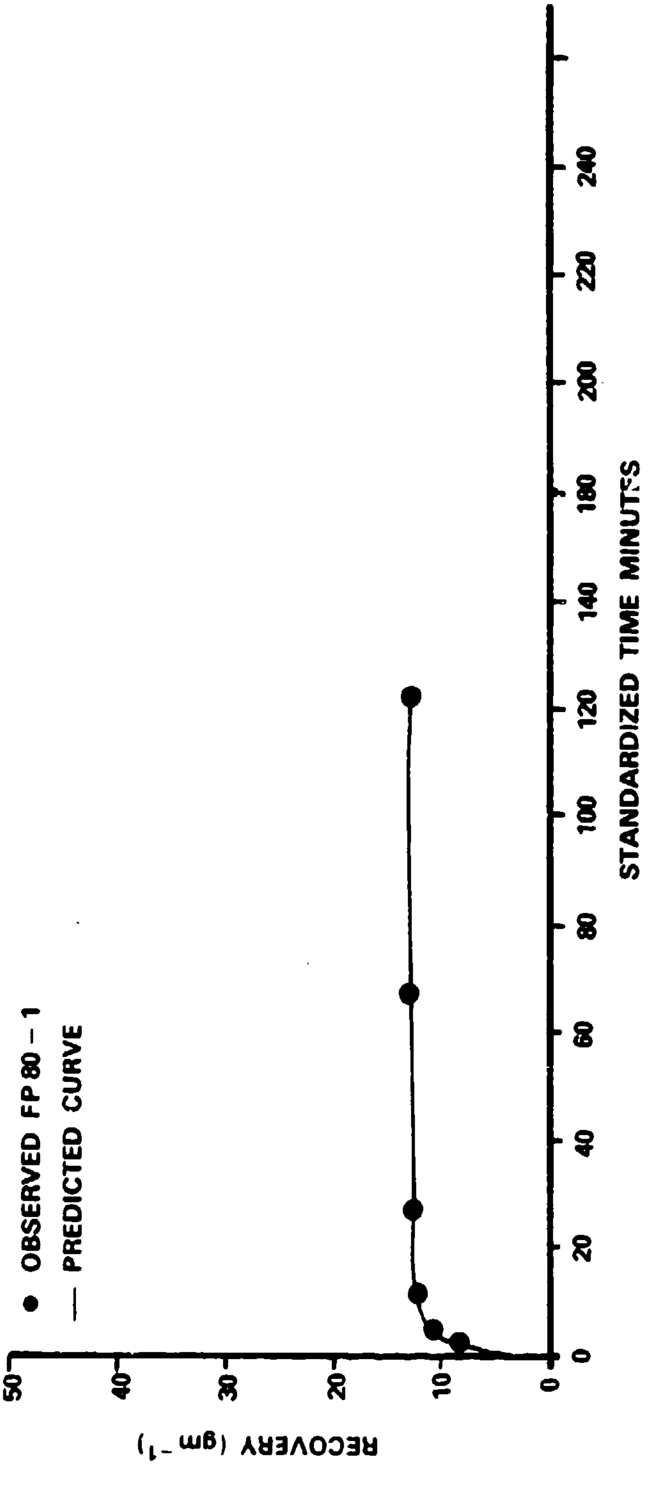

Figure 22

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

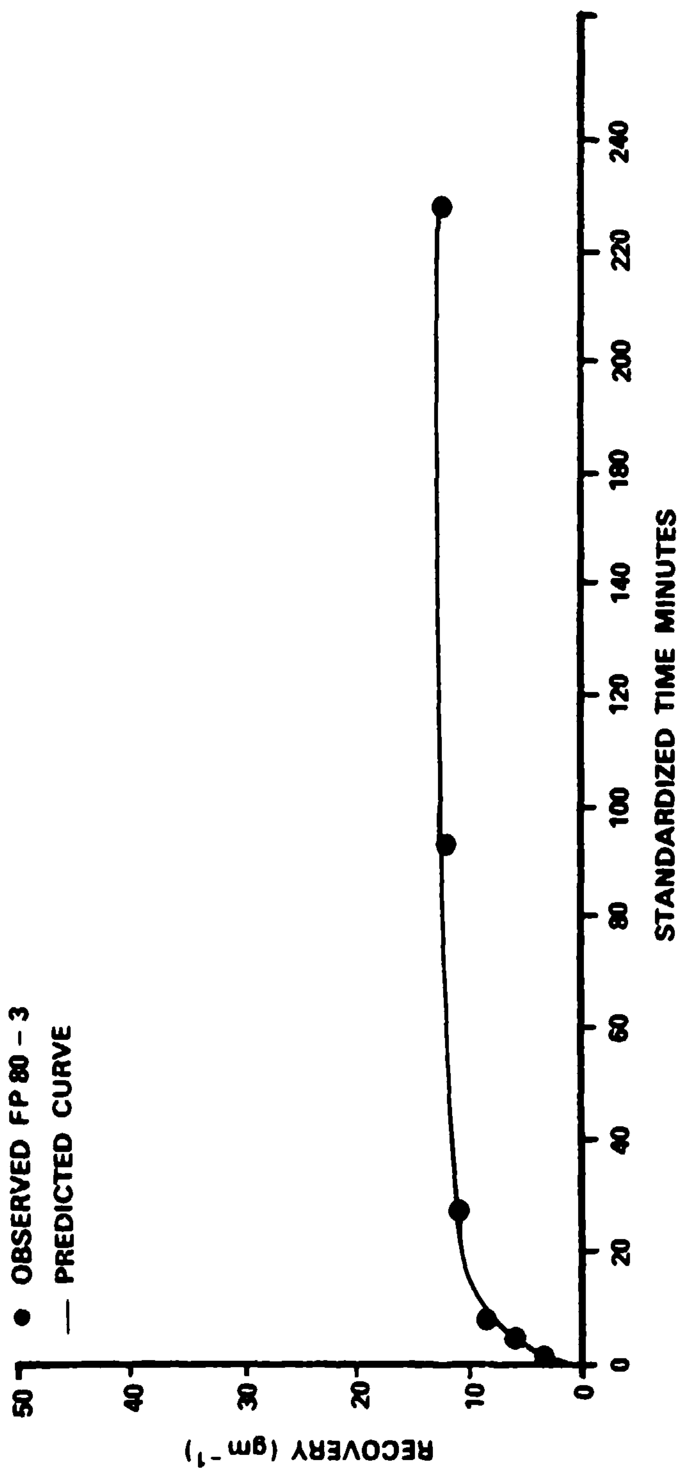

Figure 23

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

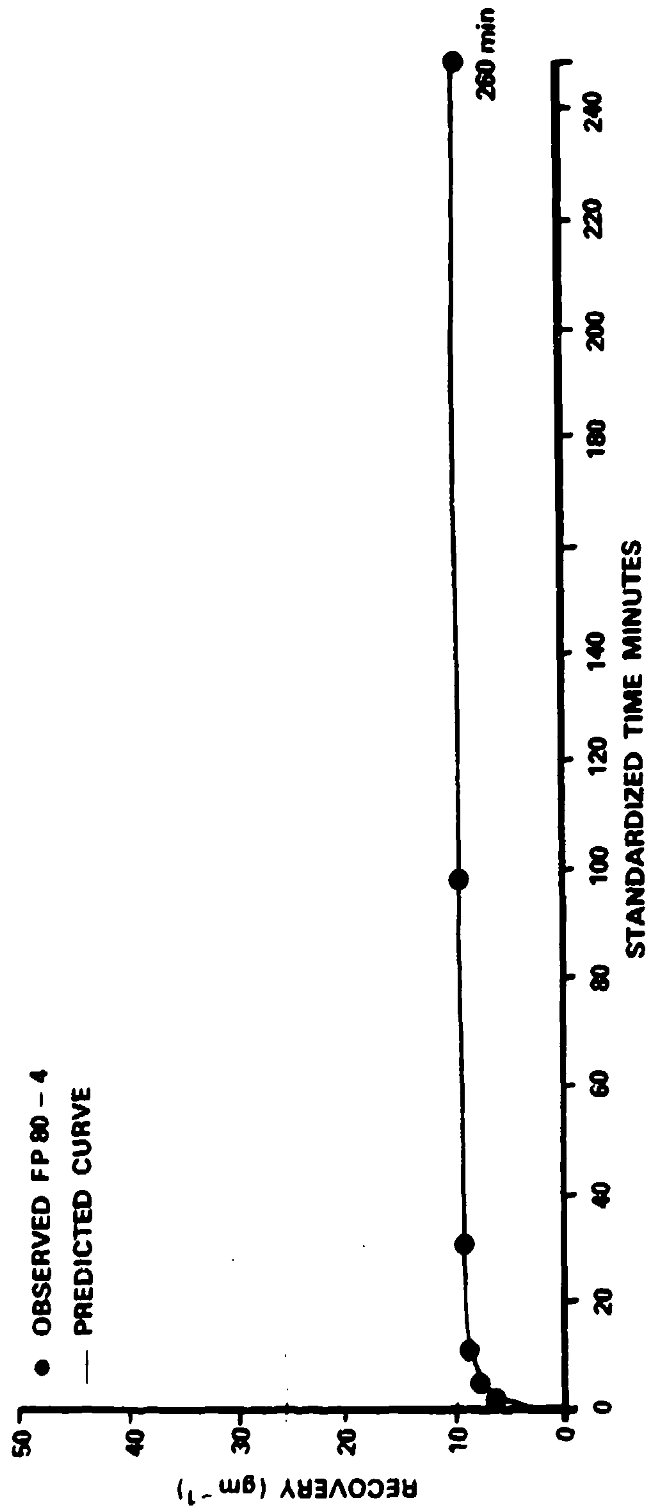

Figure 24

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

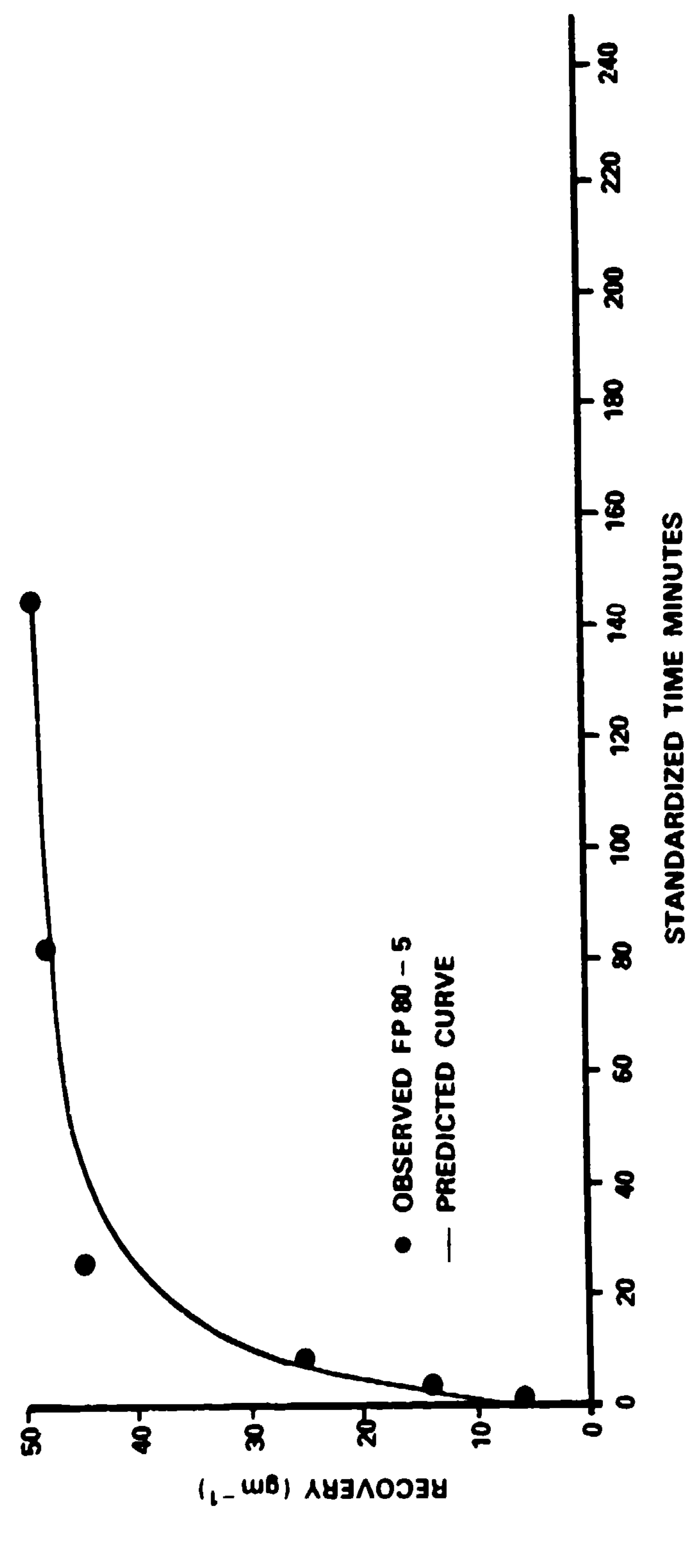

Figure 25

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

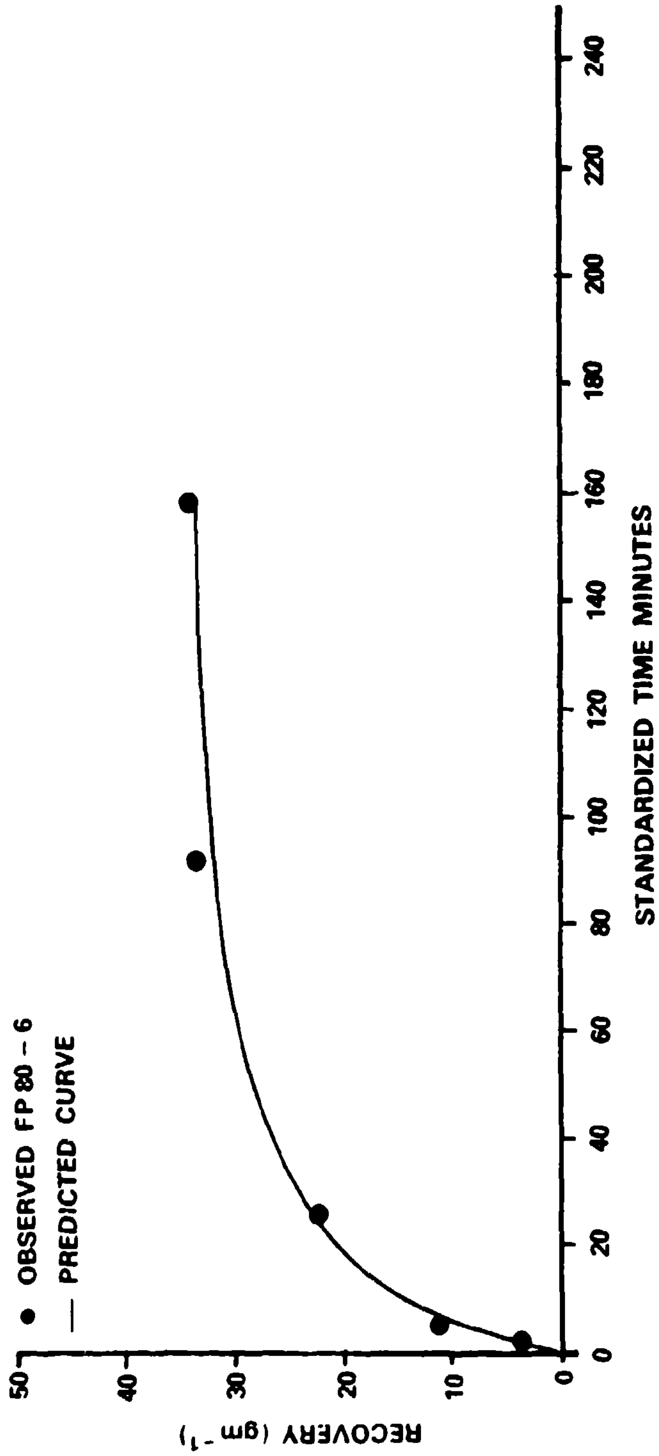

Figure 26

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

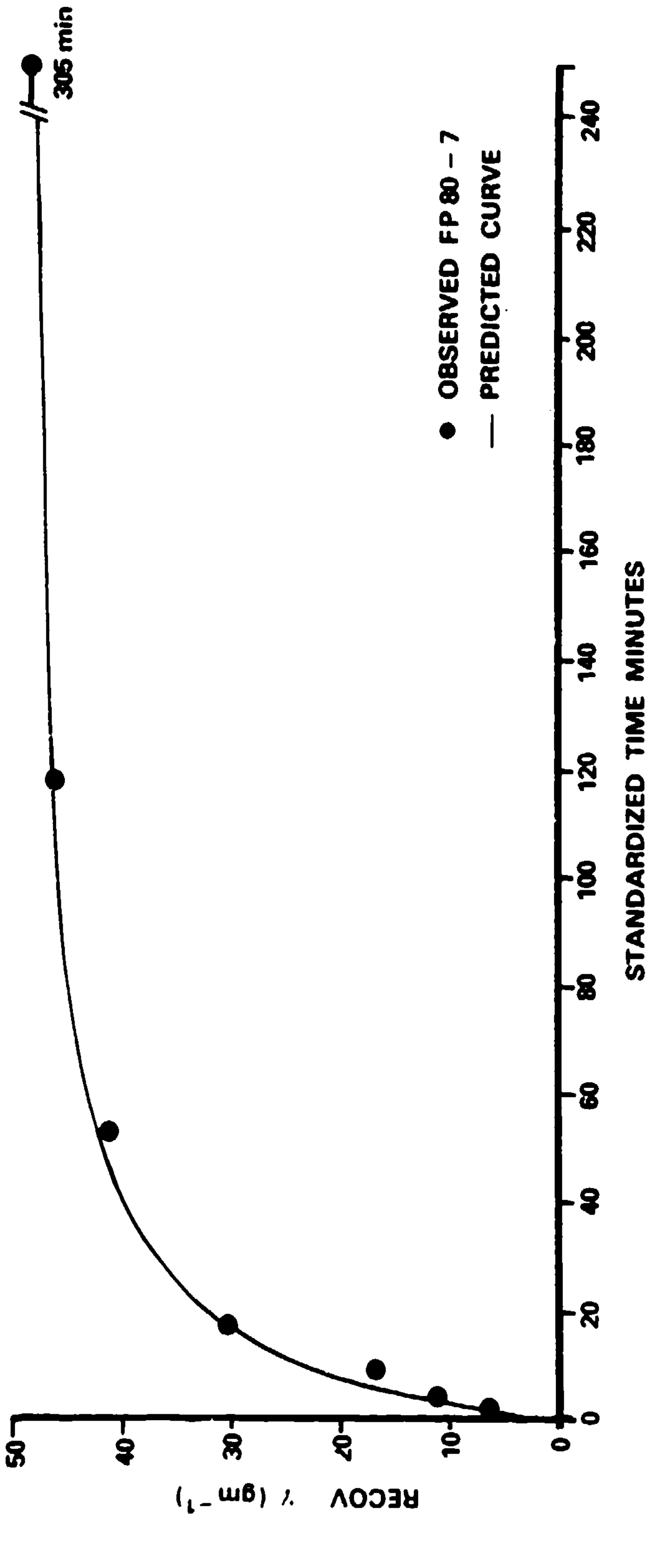

Figure 27

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

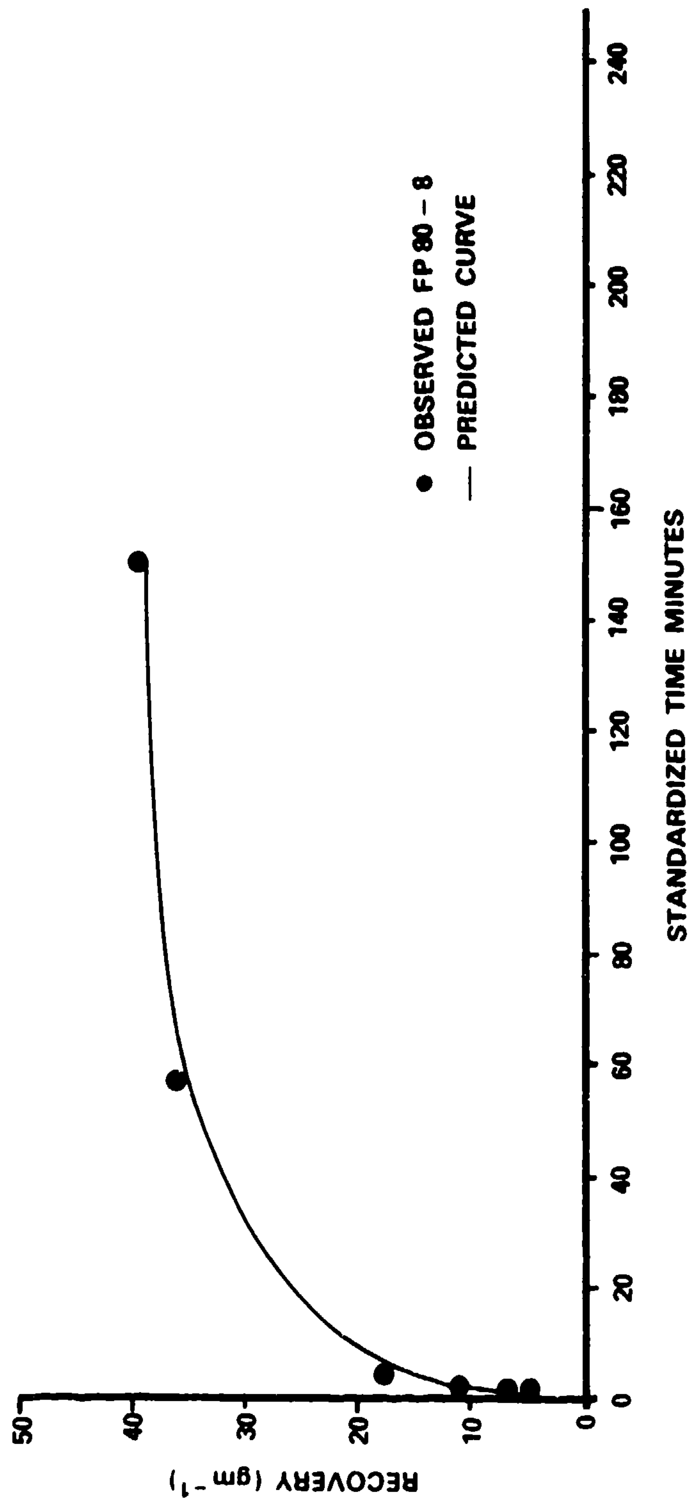

Figure 28

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

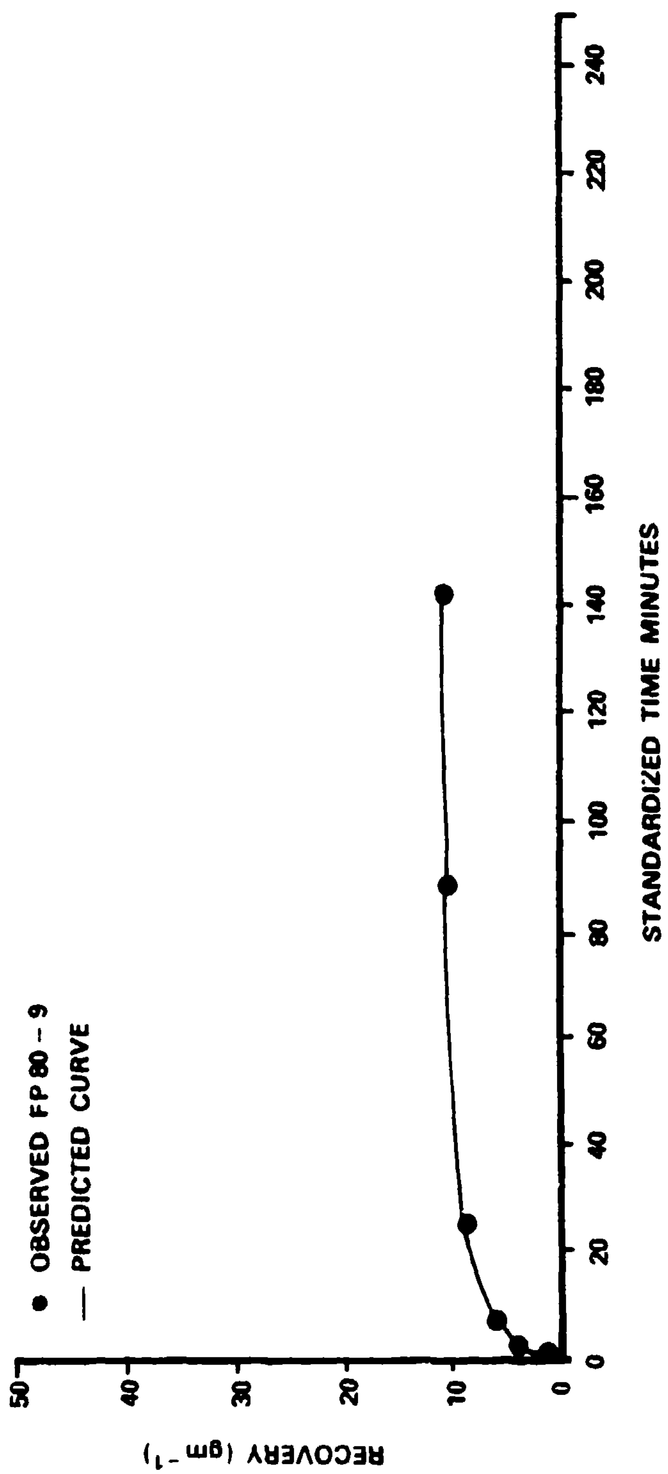

Figure 29

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

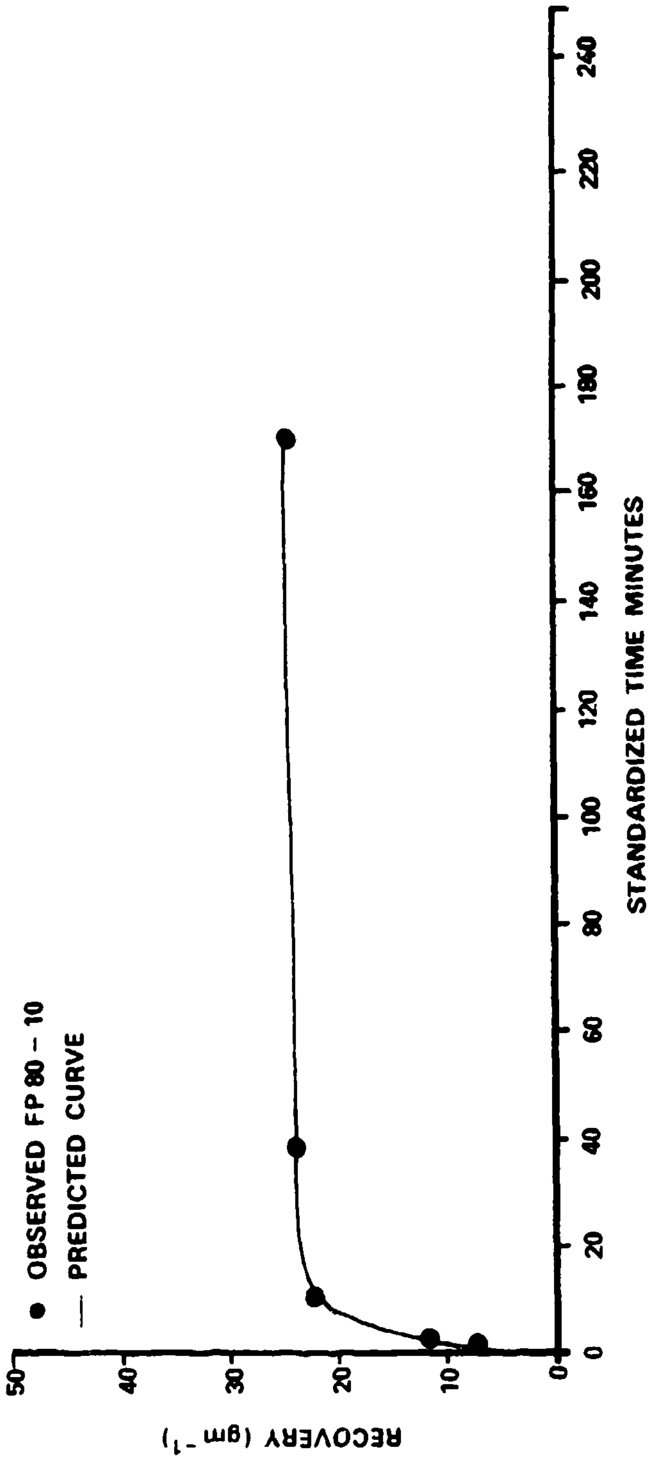

Figure 30

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

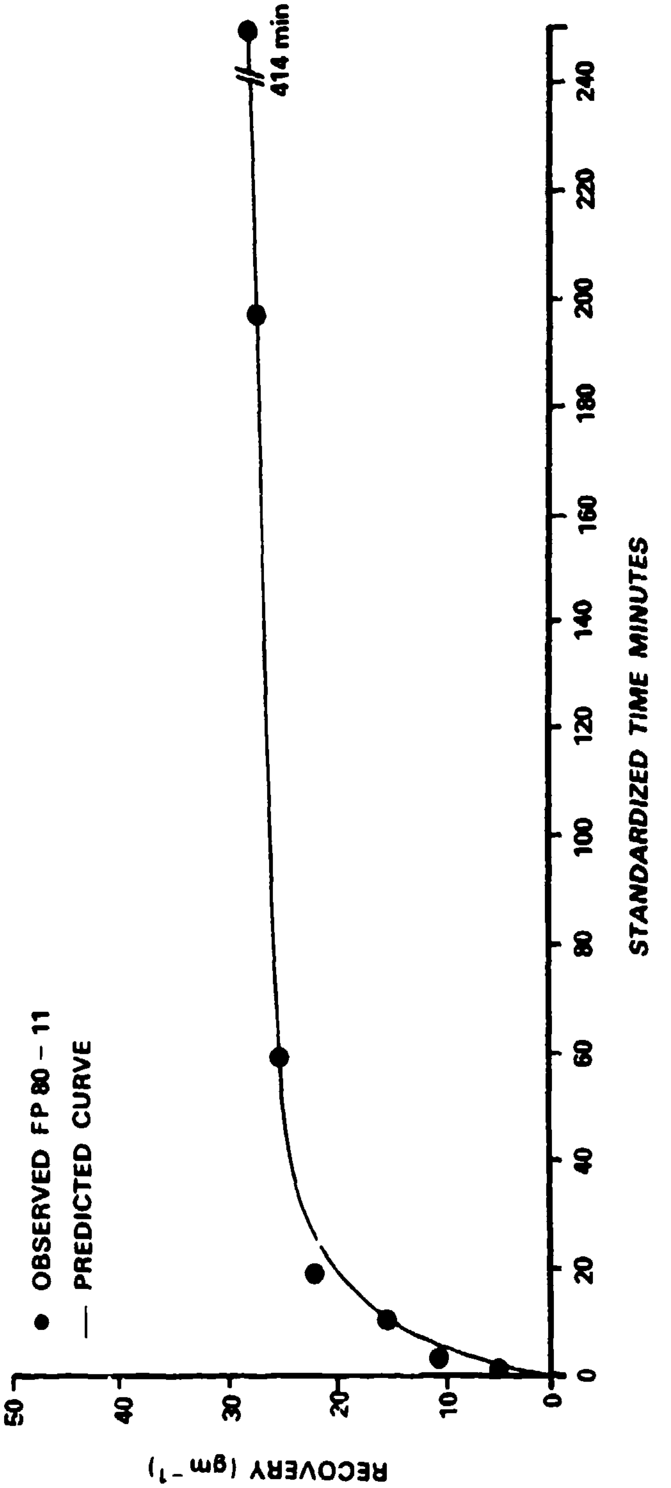

Figure 31

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

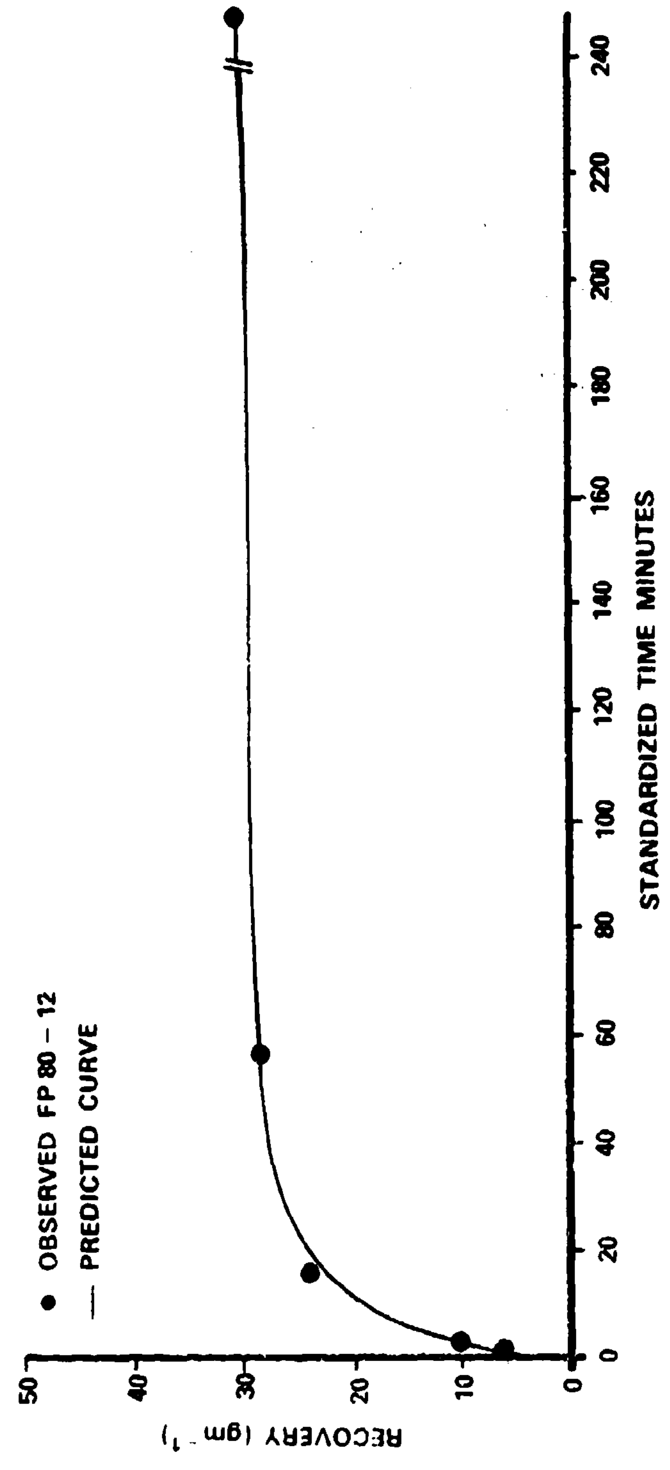

Figure 32

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

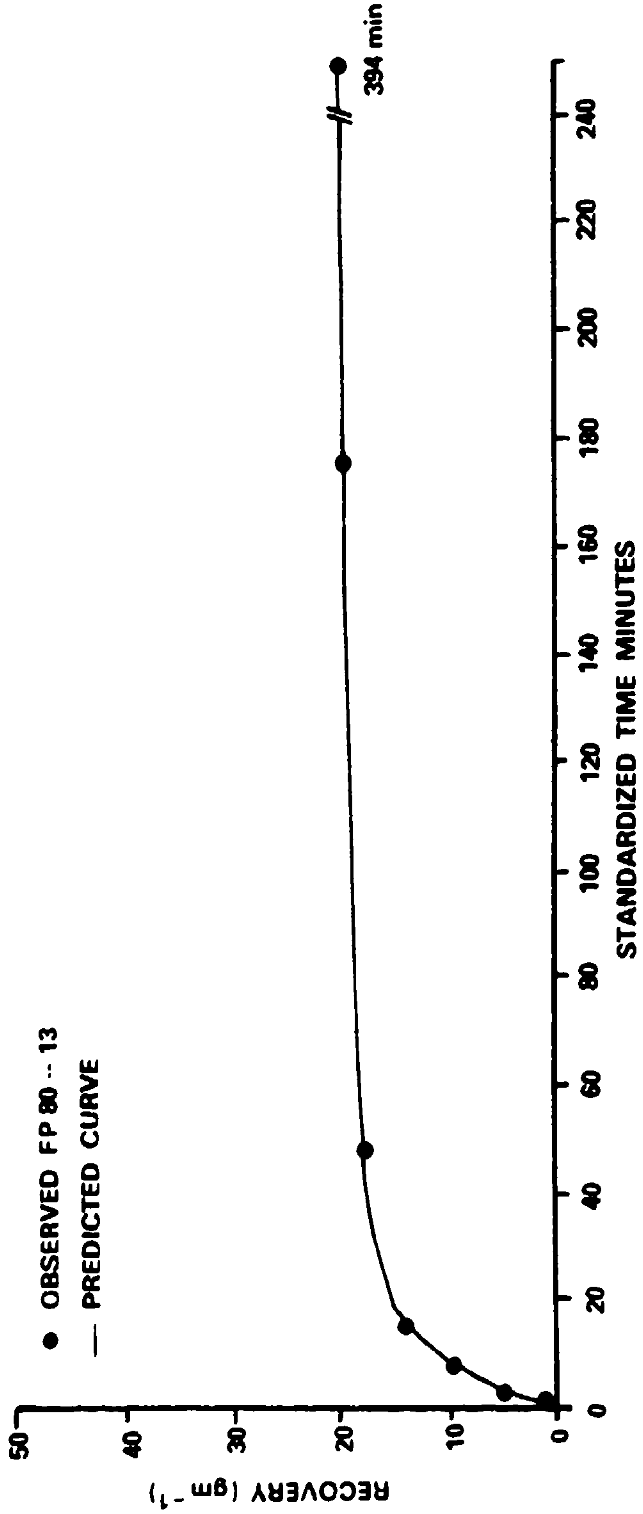

Figure 33

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

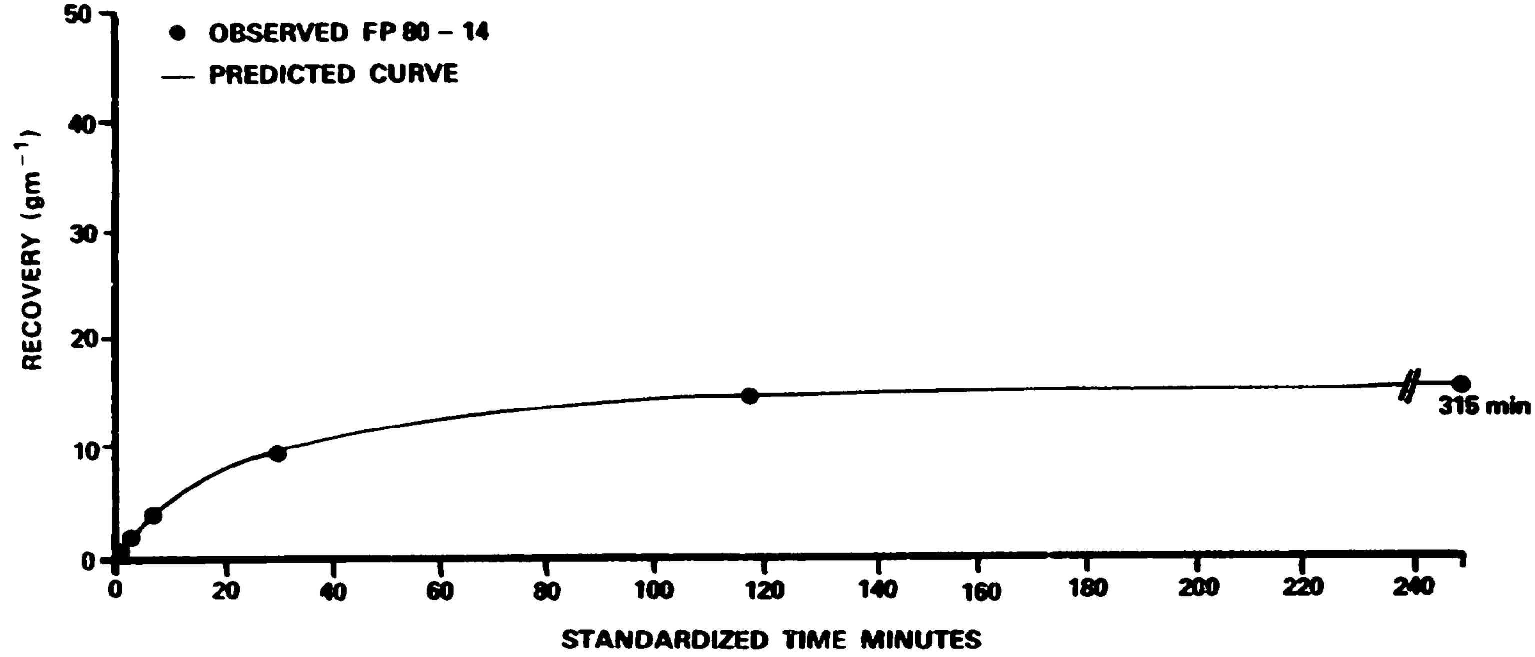

Figure 34

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

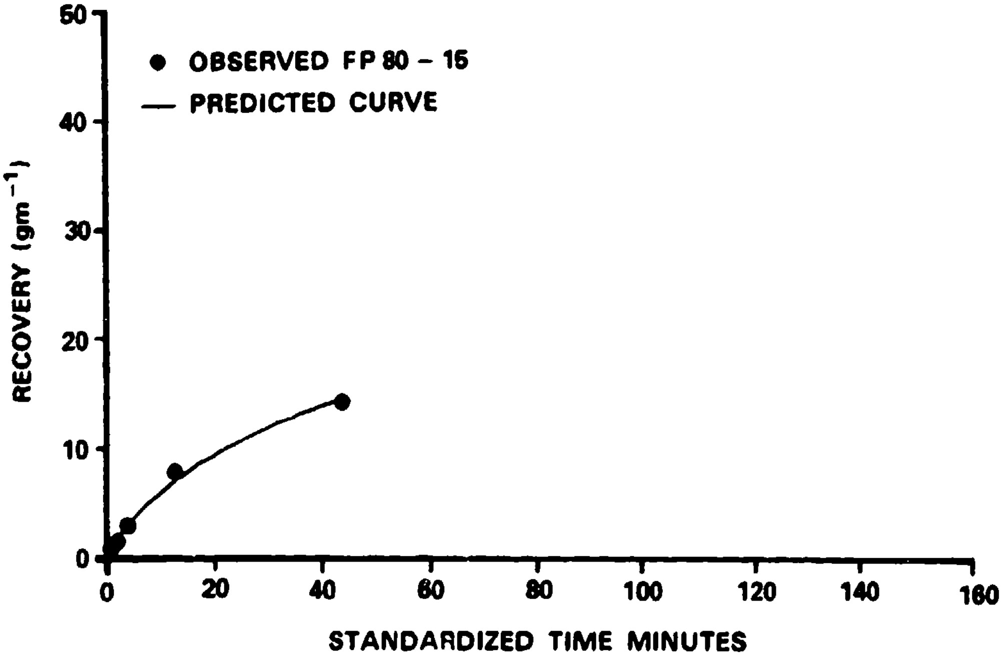

Figure 35

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

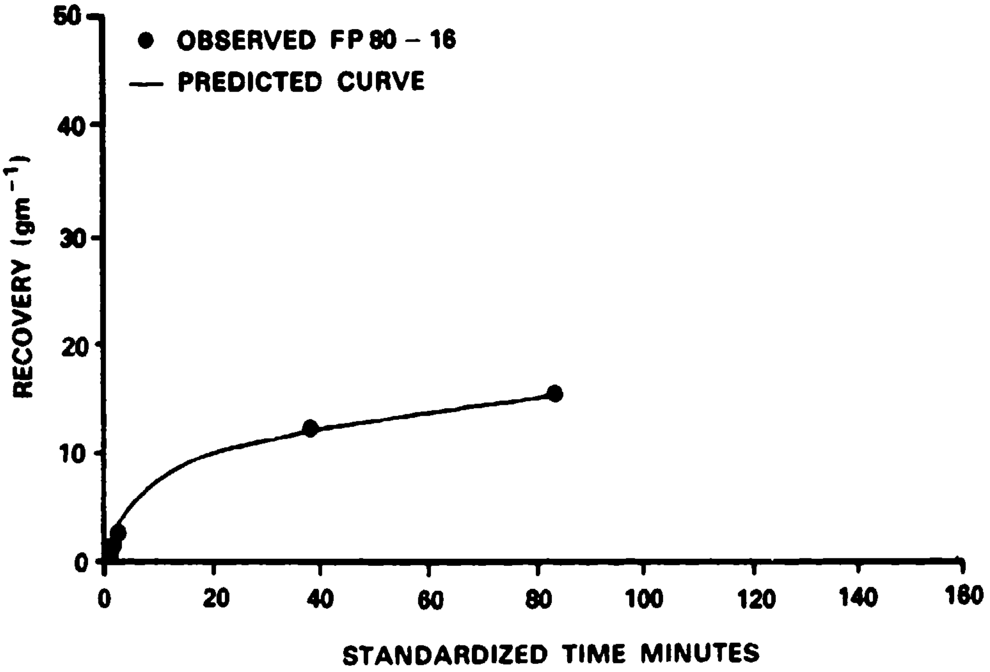

Figure 36

VAPOUR RECOVERY DATA NORMALIZED TO GROUND TEMPERATURE 20°C AND 2 m WINDSPEED 18 Km h^{-1}

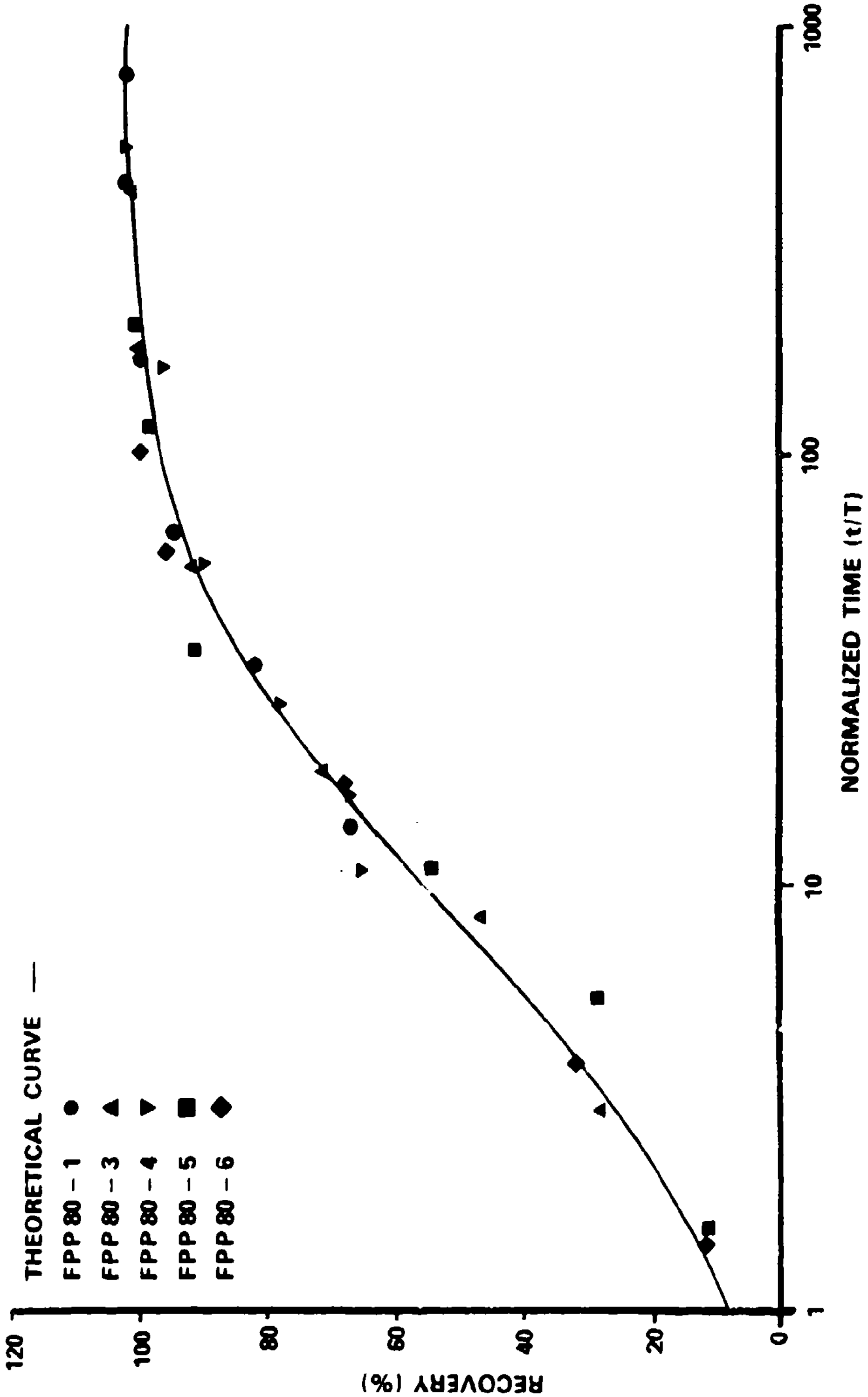

Figure 37

NORMALIZED VAPOUR RECOVERY DATA

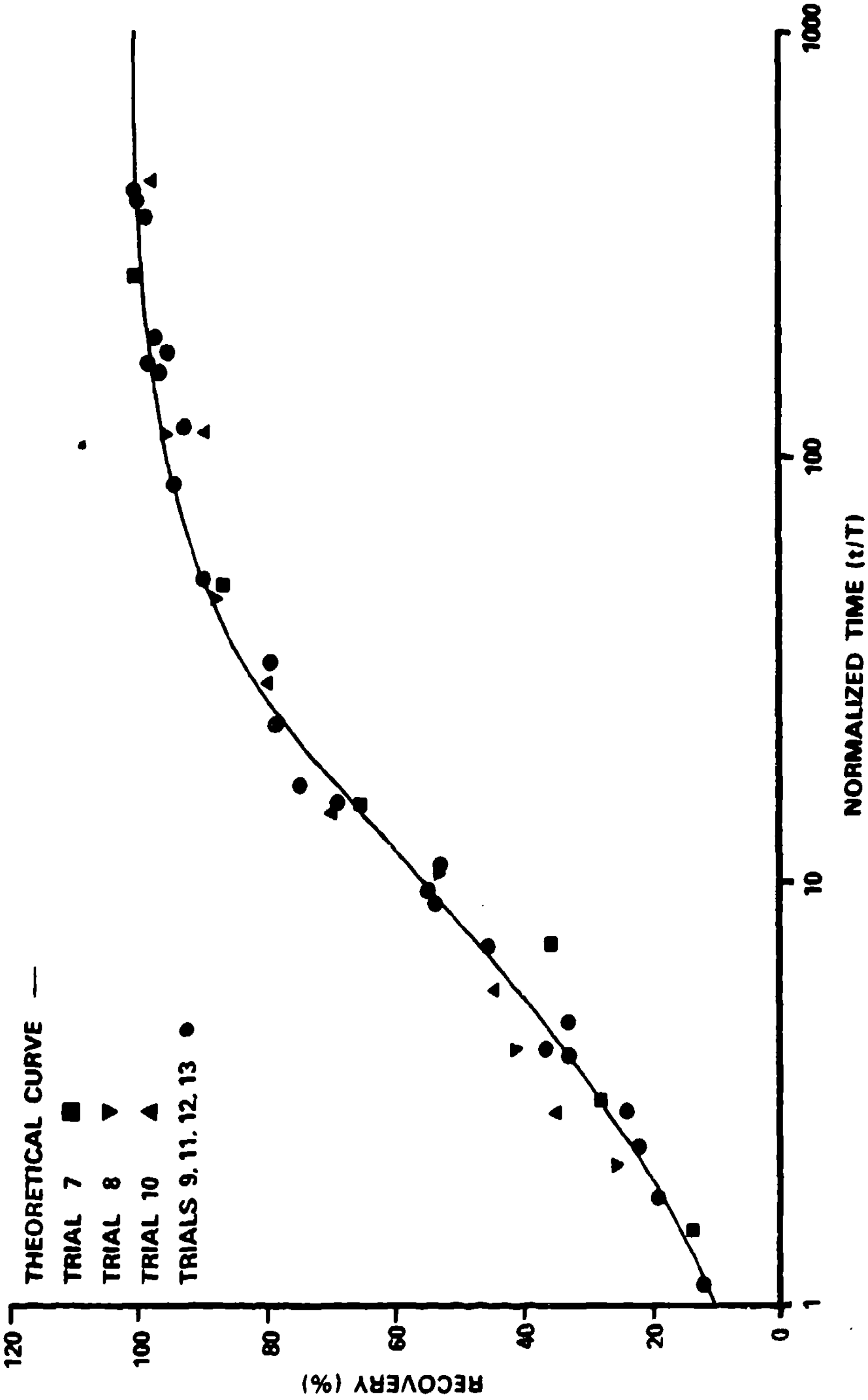

Figure 38
NORMALIZED VAPOUR RECOVERY DATA

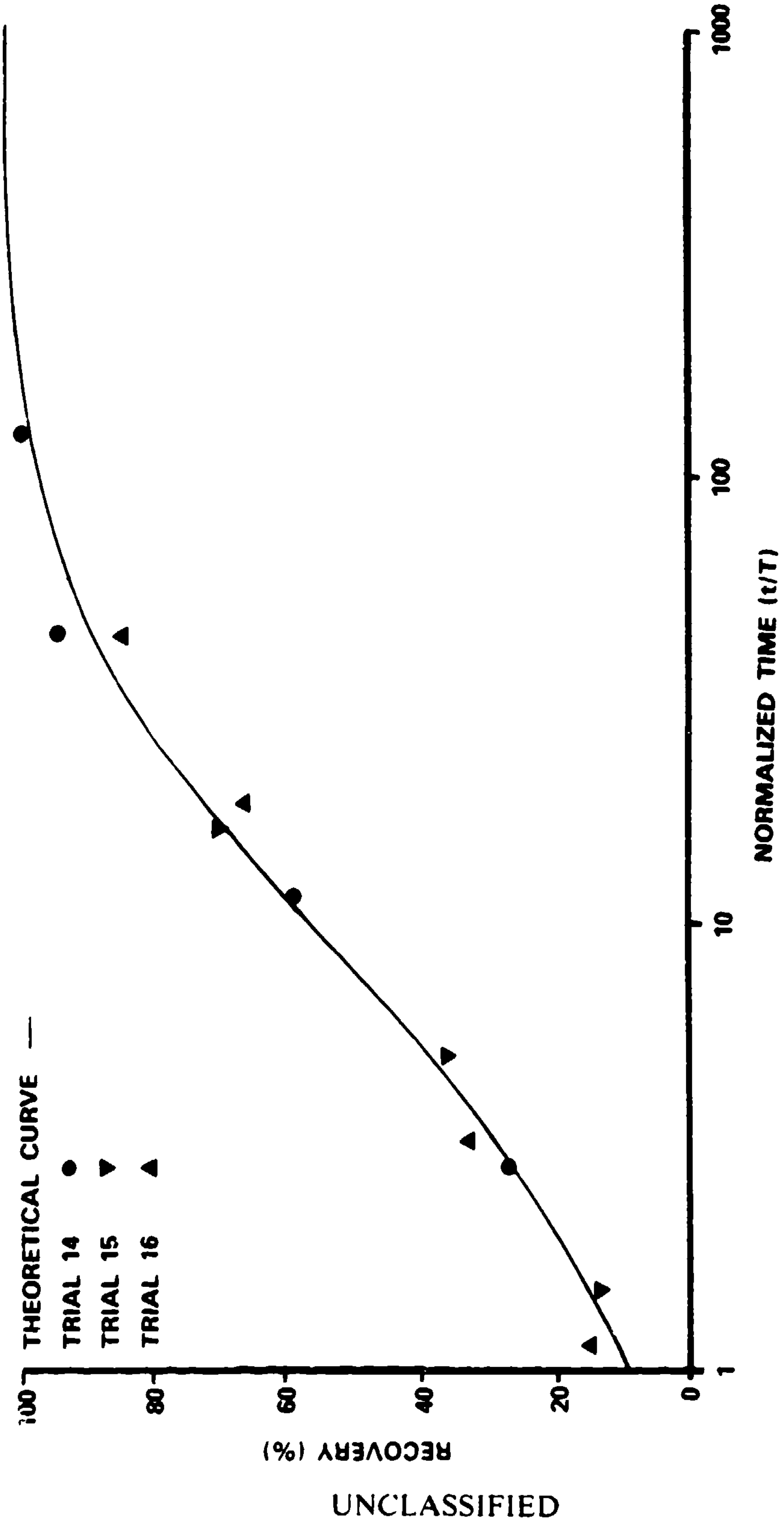

Figure 39

NORMALIZED VAPOUR RECOVERY DATA

APPENDIX A

PHYSICAL PROPERTIES OF DMSO

REFERENCE: DIMETHYL SULFOXIDE TECHNICAL BULLETIN
CROWN ZELLERBACH CHEMICAL PRODUCTS DIVISION
P.O. BOX 4266
VANCOUVER (ORCHARDS), WA 98663

Molecular Weight	78.13
Boiling Point at 760 mm Hg	189°C (372°F)
Freezing Point	18.55°C (65.4°F)
Molal freezing point constant, °C/(mol)(kg)	4.07
Refractive index $n_D 25$	1.4768
Surface tension at 20°C	43.53 dynes/cm
Vapor pressure, at 25°C	0.600 mm Hg
Density, g/cm^3, at 25°C	1.096
Viscosity, cP, at 25°C	2.0 (see Figs. 3&4)
Specific Heat at 29.5°C	0.47±0.015 cal/g/°C
Heat capacity (liq.), 25°C	0.47 cal/g/°C
Heat capacity (ideal gas), $Cp(T°K)=6.94+5.6x10^{-2}T-0.227x10^{-4}T^2$	
Heat of fusion	41.3 cal/g
Heat of vaporization at 70°C	11.3 kcal/mol (260 BTU/lb)
Heat of solution in water at 25°C	52 cal/g
Heat of combustion	6054 cal/g
Flash point (open cup)	95°C (203°F)
Auto ignition temperature in air	300-302°C (572-575°F)
Flammability limits in air	
lower 100°C	3-3.5% by volume
upper	42-63% by volume
Coefficient of expansion	0.00088/°C
Dielectric constant, 10 MHz	48.9 (20°C)
	45.5 (40°C)
Solubility parameter	13
Dipole moment, D	4.3
Conductivity, 20°C	$3 x10^{-8}$ (ohm^{-1} cm^{-1})
80°C	$7 x10^{-8}$ (ohm^{-1} cm^{-1})
pKa	35.1

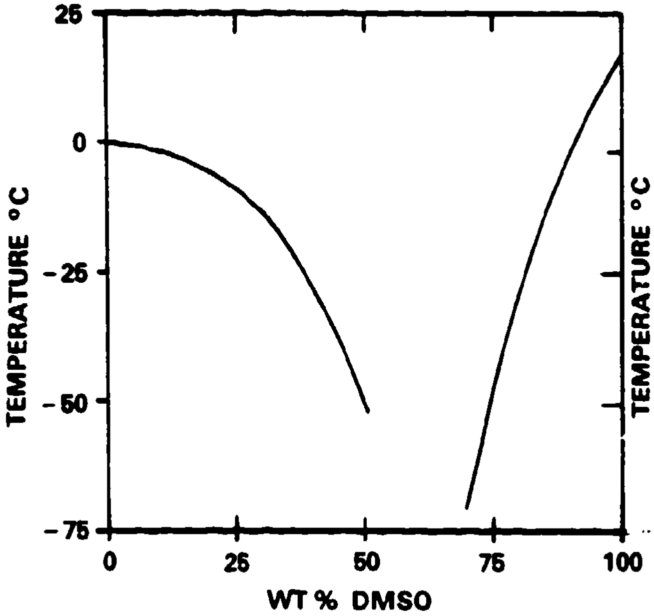

Figure A1

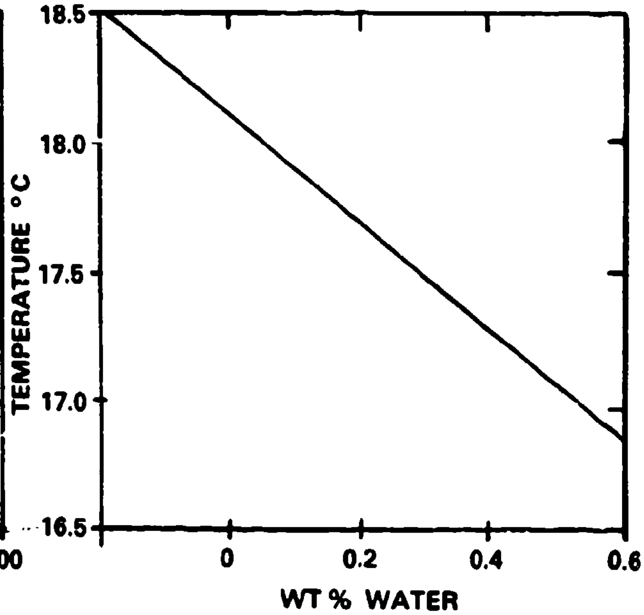

Figure A2

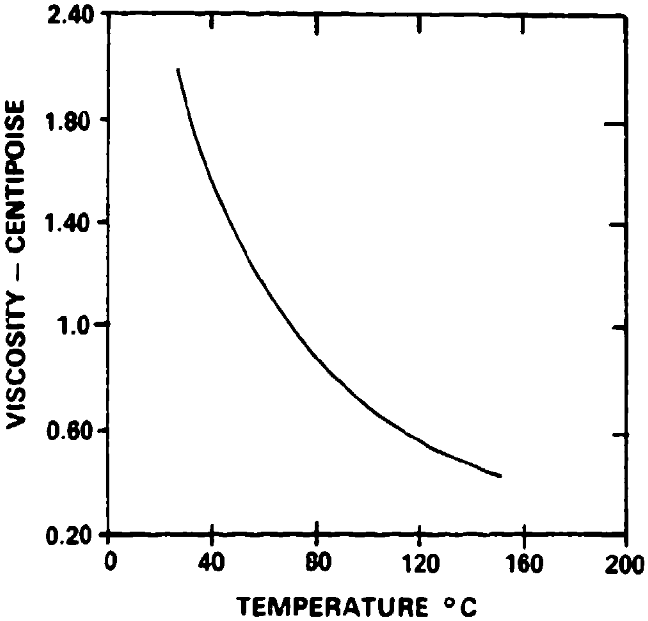

Figure A3

VISCOSITY OF DMSO

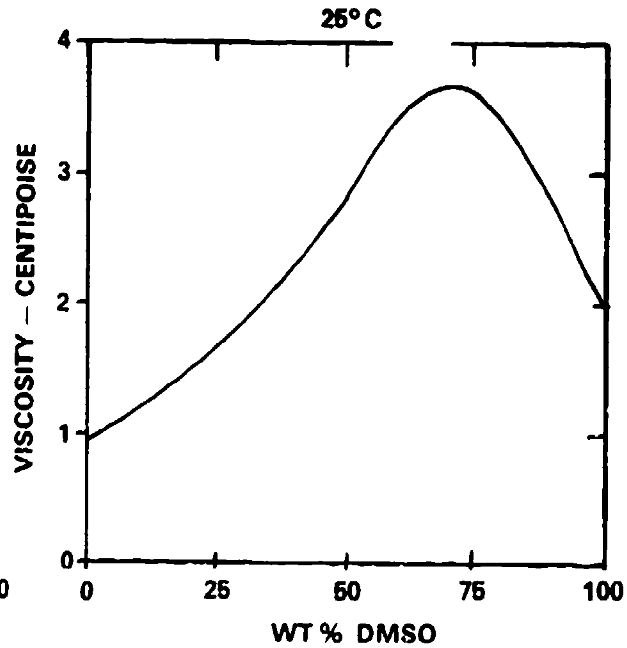

Figure A4

VISCOSITY OF DMSO – WATER SOLUTIONS

FREEZING POINT CURVES FOR DMSO – WATER SOLUTIONS

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-1 - ZERO 1443 MDT - 15 OCTOBER 1979

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1443				12.0	220	20.7	24.1	Clear sky.
1445	6.0	9.0	11.8	14.3	220	20.5	24.1	
1448	5.4	8.6	10.7	12.5	210	21.8	24.2	
1453	7.7	11.1	13.3	15.4	230	21.6	22.6	
1513	6.0	8.8	11.3	14.1	220	19.4	19.0	
1543	5.6	8.7	10.0	12.2	190	20.4	18.3	AC2/10.
1613	6.0	7.0	9.4	11.8	220	20.9	17.8	AC2/10
1643	5.6	9.0	10.6	11.0	220	19.6	13.0	to
1713	5.4	9.2	10.0	10.8	210	21.4	13.8	1/10.
1743	4.2	7.0	8.4	9.0	200	18.9	11.8	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-2 - ZERO 1118 MDT - 22 OCTOBER 1981

Time	Wind Speed km h⁻¹				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1118				8.0	340	0.2	2.01	No cloud
1120	6.0	6.6	7.4	8.8	010	0.2	2.2	over
1123	6.0	6.5	7.08	8.03	340	0.2	2.2	layout.
1128	4.8	5.2	6.0	6.3	340	0.3	2.5	
1148	6.3	6.9	8.2	9.3	010	1.1	3.0	
1218	6.8	7.1	8.3	9.6	330	2.7	5.2	
1248	5.8	6.0	6.6	7.8	340	1.7	7.6	
1318	6.4	7.1	8.5	8.8	350	3.1	7.2	
1348	8.6	9.8	11.4	12.0	010	3.0	7.8	
1418	5.3	6.5	8.4	8.8	350	2.2	7.5	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-3 - ZERO 1109 MDT - 28 OCTOBER 1981

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1109				20.0	180	16.2	17.7	High
1111	6.9	9.3	11.1	13.6	170	15.8	17.9	thin
1114	8.4	10.5	12.7	16.4	180	16.4	17.8	cirrus
1119	10.0	12.9	15.9	18.3	180	17.4	17.7	over
1139	10.0	12.8	14.6	17.3	180	17.7	17.5	layout.
1209	11.4	13.8	15.6	17.5	170	17.2	18.3	Patches
1239	12.8	16.0	18.2	19.8	180	19.9	20.9	of AC.
1309	13.1	15.4	18.7	21.1	180	208	22.5	
1339	12.2	15.7	17.8	19.8	180	17.6	17.7	Layout
1409	9.9	12.0	14.1	16.7	170	18.3	18.5	in cloud

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-4 - ZERO 1057 MT - 02 NOVEMBER 1981

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1057				16.0	240	18.7	21.8	Patchy
1059	7.1	13.1	14.3	16.3	240	18.6	21.2	thin
1102	7.4	14.0	15.2	17.4	240	18.3	19.7	cirrus
1112	7.6	16.9	17.2	19.6	240	19.0	20.7	over
1127	8.1	15.0	16.8	17.4	230	18.9	20.3	layout.
1157	9.2	16.3	18.2	19.8	230	19.3	19.7	Layout
1227	10.6	19.0	20.8	21.6	230	20.2	23.1	clear of
1257	10.0	18.0	20.2	21.4	240	23.3	28.3	cloud.
1327	11.6	22.6	23.2	24.4	250	23.4	27.3	Layout
1357	11.5	21.1	22.3	23.1	250	21.5	21.1	covered with cloud.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-5 - ZERO 1001 MDT - 08 JUNE 1982

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1001				10.8	230	14.6	17.8	Clear.
1003	6.0	9.0	9.3	12.0	230	14.6	18.0	
1006	12.0	16.0	17.3	18.6	220	14.3	18.0	
1011	12.0	14.4	14.8	16.7	230	14.3	18.0	
1031	11.7	15.0	15.6	17.0	240	15.2	19.8	
1101	10.4	13.2	15.8	17.6	230	15.3	21.6	
1131	10.4	13.6	14.2	17.0	230	15.4	22.5	1/10
1201	10.0	12.0	12.6	14.0	220	16.1	25.7	cumulus
1231	10.2	12.6	12.8	13.6	240	16.9	26.5	6000 ft.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-6 - ZERO NOT RECORDED - 27 JULY 1982

Time	Speed km h⁻¹				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
Zero	1.2	1.5	2.8	2.0	360	22.5	24.8	3/10
+2	1.5	2.2	3.4	4.0	360	22.7	25.7	thin
5	1.4	3.6	4.7	5.6	350	22.9	26.6	high AC
10	4.2	6.0	6.9	7.5	360	23.5	27.2	cloud.
20	4.8	7.2	8.4	9.3	010	24.5	29.3	6/10
30	7.2	8.4	9.6	10.7	350	24.0	29.2	thin
60	7.2	9.0	9.8	10.8	010	24.3	28.3	high AC
90	7.2	8.6	9.4	10.3	300	24.8	29.6	cloud.
120	6.6	8.2	8.8	9.0	300	25.5	31.8	
150	6.8	8.0	8.8	9.0	350	25.1	31.6	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-7 - ZERO 1222 - 21 JUNE 1983

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1222				8.0	280	18.0	31.4	Clear.
1224	10.0	12.0	13.3	14.7	300	18.9	31.7	
1227	8.0	10.0	11.7	12.3	270	19.0	32.3	
1232	10.1	11.7	12.9	14.0	290	19.0	32.4	
1252	10.9	11.5	12.3	12.8	300	20.5	35.8	Cloud
1322	9.7	10.6	12.0	12.7	270	17.9	33.8	patches
1352	11.0	12.6	13.9	14.9	310	21.4	36.0	over
1422	11.9	13.7	15.0	15.8	290	21.4	38.8	layout.
1452	9.3	11.2	11.6	12.2	280	19.6	27.6	Cloud covered layout.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-8 - ZERO 1025 MDT - 02 MAY 1984

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1025	13.7	17.7	26.4	30.3	200	10.7	10.0	Cloudy.
1027	13.4	17.2	24.3	27.5	200	10.4	9.9	______
1030	12.7	16.7	23.7	25.3	200	9.7	9.6	
1035	12.4	16.4	21.3	23.5	200	8.7	9.5	Rain.
1055	12.1	16.4	20.3	21.9	200	7.8	9.8	
1125	10.0	13.8	17.2	18.7	290	13.3	15.8	______
1155	10.6	14.0	17.4	19.0	210	14.9	22.2	Sunny.
1225	6.7	12.2	14.5	15.8	195	16.4	28.9	______
1255	7.9	11.1	11.9	13.7	200	16.7	24.0	Cloudy.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-9 - ZERO 1018 MDT - 21 AUGUST 1984

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1018				6.3	310	22.6	24.8	Light
1020	2.8	3.0	3.5	4.1	270	21.9	25.6	cirrus
1023	4.6	5.6	6.4	7.2	330	21.4	26.6	layout
1028	4.7	5.3	5.7	6.7	310	21.5	27.0	clear.
1048	4.7	5.5	5.9	8.3	320	22.5	31.3	
1148	4.6	5.4	5.8	6.5	250	22.1	32.6	
1248	4.1	4.6	5.0	5.7	160	20.0	31.6	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-10 - ZERO 0924 MDT - 22 AUGUST 1984

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
0924				11.1	150	21.4	22.0	Clear.
0926	10.6	12.5	14.0	16.0	140	22.8	22.6	
0929	11.7	13.7	14.8	15.8	140	22.2	22.6	
0934	10.2	12.3	13.5	14.4	160	23.6	24.0	
0954	11.0	13.2	14.0	16.0	140	25.1	25.8	
1054	13.0	15.8	16.6	17.8	160	26.8	31.6	
1154	14.7	17.7	18.5	18.9	180	27.4	38.5	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-11 - ZERO 1011 - 22 MAY 1985

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1011				16.0	080	21.6	27.8	RH 45%.
1013	14.6	16.8	17.8	18.3	080	21.7	28.0	Thin
1016	13.1	15.3	16.6	18.0	080	21.9	28.2	cirrus
1021	11.5	12.6	14.1	15.0	080	22.0	28.2	clouds
1041	12.3	14.0	15.6	16.4	100	22.8	28.4	all times.
1111	12.6	14.2	15.6	16.4	090	24.0	30.2	RH 45%.
1141	12.6	14.3	16.6	17.2	110	24.0	31.7	
1211	15.1	16.3	18.2	19.1	090	25.2	35.6	
1241	12.6	14.1	15.7	16.7	100	25.3	35.8	RH 37%.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-12 - ZERO 0941 - 23 MAY 1985

Time	Wind Speed km h⁻¹				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
0941				18.0	18.0	21.2	26.2	RH 42%.
0942	12.7	15.3	16.7	18.3	18.3	22.0	24.0	Cirrus
0946	12.6	14.5	15.9	16.8	16.8	22.4	24.3	clouds
0951	14.0	15.8	17.7	19.0	19.0	22.4	25.0	all
								times.
1011	14.4	16.2	18.0	18.9	18.9	23.5	30.8	RH 40%.
1041	12.7	14.2	16.0	16.7	16.7	23.5	35.8	
1111	14.0	16.3	18.6	19.1	19.1	24.2	36.5	RH 33%.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-13 - ZERO 1019 MDT - 4 JUNE 1985

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1019				16.0	170	16.0	26.6	RH 44%.
1021	9.0	12.0	13.5	14.4	170	16.6	27.1	Cirrus
1024	8.8	11.3	13.2	14.1	170	17.3	27.4	clouds.
1029	9.4	12.5	13.7	14.4	160	16.9	27.4	RH 40%.
1049	9.5	12.3	13.6	13.8	120	16.6	27.2	
1119	9.7	12.3	13.4	13.8	140	17.8	28.6	RH 34%.
1149	9.7	12.3	14.1	15.8	190	18.9	33.0	
1219	10.8	13.7	15.7	17.1	150	19.4	35.7	RH 31%.
1249	11.1	14.5	16.0	16.3	180	20.6	37.0	

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-14 - ZERO 1032 MDT - 13 JUNE 1985

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1032				6.0	300	21.4	25.0	RH 58%.
1034	2.5	3.1	3.5	4.0	310	21.1	25.2	
1037	4.8	5.1	5.4	5.8	280	22.3	25.5	RH 56%.
1042	6.7	7.2	8.0	11.6	300	20.7	28.10	Very light rain.
1102	7.1	7.9	8.8	9.0	310	22.7	29.5	RH 51%.
1132	7.6	8.5	9.3	9.4	310	22.8	32.7	RH 45%.
1202	9.4	10.6	11.7	11.9	340	22.8	35.0	RH 43%.
1232	11.8	13.5	14.6	14.9	300	23.3	36.8	RH 41%.
1302	10.2	11.3	12.4	13.0	270	26.0	37.5	RH 39%.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-15 - ZERO 0944 MDT - 17 SEPTEMBER 1985

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
0944					310	10.0	10.0	RH 64%.
0946	9.7	13.4	16.4	18.5	320	10.2	10.2	Light
0949	13.3	15.5	17.2	18.8	330	10.6	10.5	cloud
0954	13.1	15.2	17.1	18.4	350	10.8	11.1	all
								times.
1014	12.9	15.1	16.5	16.6	340	11.1	13.0	RH 62%.
1044	11.6	13.4	14.8	16.6	340	12.0	14.4	
1114	10.9	12.6	13.8	14.7	350	14.0	14.7	RH 58%.

APPENDIX B

METEOROLOGICAL OBSERVATIONS

FP 80-16 - ZERO 1058 MDT - 25 SEPTEMBER 1985

Time	Wind Speed km h^{-1}				DIR°	Temperature °C		Remarks
MDT	0.5 m	1.0 m	1.5 m	2.0 m	2.0 m	Air	Ground	
1058				10.0	280	10.1	8.7	RH 60%.
1100	7.7	9.3	10.9	12.0	260	10.7	9.1	Clear
1103	8.7	9.8	11.1	12.0	270	10.6	9.4	until 1228.
1108	8.5	9.7	10.7	11.3	260	10.8	10.0	
1128	7.2	8.2	9.1	10.1	250	11.7	11.3	RH 57%.
1158	9.5	10.5	11.0	13.4	250	14.6	15.4	RH 54%.
1228	11.9	14.3	16.1	17.0	270	14.7	16.0	RH 48%.
1258	13.0	15.1	17.0	17.8	230	15.4	18.0	RH 48%.
1328	12.6	14.7	16.5	17.3	230	16.1	19.1	RH 45%.

APPENDIX C

DROP SIZE SAMPLING RESULTS

The relationship between liquid drop size and corresponding stain size produced on detector paper by impinging drops was determined by fitting a straight line to a series of stain sizes produced by a series of drops of known various sizes. The data, which was chosen in the most appropriate range of drop sizes, yielded the following drop sizes, D, from the various stain sizes, S, both in units of millimetres.

(1) Neat DMSO on 3 way detector paper

$$D = 0.0567 + 0.184S \qquad (C1)$$

(2) Unthickened 80/20 DMSO/Water

$$D = 0.02789 + 0.183S \qquad (C2)$$

(3) Thickened 80/20 DMSO/Water

$$D = 0.05125 + 0.371S \qquad (C3)$$

The data and fitted lines are shown in Figures C1, C2 and C3. The analysis of drop size sampling results assumes that cumulative number of drops, starting from the largest ones, is an exponential function of drop size, as given by the following equation.

$$N = N_T \exp -bD \qquad (C4)$$

where N_T is the intercept at diameter D = 0, and N is the cumulative number of drops. The mass median diameter, D_o, of each distribution is related to the slope b of a semi-log plot by the following relationship.

$$bD_o = 3.672 \qquad (C5)$$

For pure DMSO, equation C4 is generally followed. Analysis of data from the thickened 80/20 DMSO/water and some of the unthickened 80/20 DMSO/water showed that the plots tend to follow curves which can be synthesized by two straight line distributions on semi-log paper. This indicated a bimodal mass diameter frequency distribution, each component being represented by an equation of the type given by Equation (C4). The total mass, Q, in each of the two exponential distributions is given by

$$Q = \frac{\pi \rho N_T}{b^3} \qquad \text{(C6)}$$

where ρ is the density of the material.

A comparison was made between the total mass calculated from Equation (C6) and the mass measured from the analysis of the data from the sponges. To do this, typical data from FP-80-16 was used in which the detector paper and sponge from card E-3 were analyzed and compared. Also the average values obtained from all eight papers and sponges on line 3 were compared. The drop size data used is shown in Table C5 and plotted in Figures C4 and C5 along with fitted curves. The sponge data is taken from Appendix D, where all the ground contamination results from the sponges is shown. The results of the comparison are shown as follows:

<u>Ground contamination from card E-3</u>:
Detector paper stains - 3.23 g m^{-2}
Material absorbed by sponges - 4.05 g m^{-2}
Ratio: 3.23/4.05 = 0.798

<u>Ground Contamination from line 3</u>:
Detector paper stains - 1.73 g m^{-2}
Material absorbed by sponges - 1.91 g m^{-2}
Ratio: 1.72/1.91 = 0.906

TABLE C1

DROP SIZE SAMPLING RESULTS FOR NEAT DMSO

Stain Size mm	Drop Size mm	Number of Drops in Each Size Class					
		FP80-1	FP80-2	FP80-3	FP80-4	FP80-5	FP80-6
0-0.15	0	0	[illegible]	0	0	0	0
0.15-0.3	0.084	2853	1740	2465	2346	6658	3910
0.3-0.4	0.112	3673	3346	3165	2933	4976	2910
0.4-0.5	0.130	3190	2726	2563	2355	3802	2602
0.5-0.6	0.149	3541	2841	3020	2771	2427	1890
0.6-0.7	0.167	2847	2221	2477	2349	1355	1245
0.7-0.8	0.186	2219	1651	1954	1909	866	799
0.8-0.9	0.204	1528	1244	1297	1274	506	412
0.9-1.0	0.222	1321	1021	1153	1197	319	248
1.0-1.1	0.241	1010	811	917	923	189	158
1.1-1.2	0.259	696	634	665	691	109	107
1.2-1.3	0.278	591	463	557	615	51	59
1.3-1.4	0.296	389	395	437	460	60	31
1.4-1.5	0.317	338	269	308	374	37	24
1.5-1.6	0.333	235	217	247	279	29	22
1.6-1.7	0.351	199	188	186	266	17	11
1.7-1.8	0.370	139	121	141	178	10	10
1.8-1.9	0.388	105	106	113	138	5	6
1.9-2.0	0.406	81	81	77	128	5	3
2.0-2.2	0.425	107	121	110	207	5	10
2.2-2.4	0.462	63	74	80	153	2	1
2.4-2.6	0.498	46	59	43	87	1	7
2.6-2.8	0.535	33	43	33	65	1	0
2.8-3.0	0.572	19	24	18	45	1	0
3.0-3.5	0.609	23	43	14	74	0	0
3.5-4.0	0.701	12	17	8	32	0	0
4.0-4.5	0.799	5	10	1	15	0	0
4.5-5.0	0.885	0	4	1	8	0	0
≥5.0	0.977	3	5	3	11	0	0

TABLE C1 continued

DROP SIZE SAMPLING RESULTS FOR NEAT DMSO

FP 80-7

Stain Size mm	Drop Size mm	Number in Class
0-0.2	0	0
0.2-0.4	0.094	5156
0.4-0.5	0.130	1536
0.5-0.6	0.149	1068
0.6-0.7	0.167	661
0.7-0.8	0.186	516
0.8-0.9	0.204	381
0.9-1.0	0.222	248
1.0-1.1	0.241	295
1.1-1.3	0.278	176
1.3-1.5	0.314	107
1.5-1.7	0.351	42
1.7-1.9	0.388	31
1.9-2.2	0.425	16
2.2-2.4	0.462	9
2.4-2.6	0.488	4
2.6-2.8	0.535	2
2.8-3.0	0.572	6
3.0-3.5	0.609	4
3.5-4.0	0.701	5
4.0-4.5	0.799	0
4.5-5.0	0.885	1
≥5.0	0.977	0

TABLE C2

DROP SIZE SAMPLING RESULTS FOR UNTHICKENED 80/20 DMSO/WATER

FP 80-8

Stain Size mm	Drop Size mm	Number in Class
0-0.2	0	2327
0.2-0.4	0.064	14020
0.4-0.5	0.101	5493
0.5-0.6	0.119	3518
0.6-0.7	0.138	2649
0.7-0.8	0.156	1966
0.8-0.9	0.174	1368
0.9-1.0	0.193	1048
1.0-1.2	0.211	1309
1.2-1.4	0.248	754
1.4-1.6	0.284	442
1.6-1.8	0.321	233
1.8-2.0	0.357	177
2.0-2.2	0.394	112
2.2-2.4	0.431	63
2.4-2.6	0.467	39
2.6-2.8	0.504	36
2.8-3.0	0.541	30
3.0-3.5	0.577	36
3.5-4.0	0.669	19
4.0-4.5	0.760	14
4.5-5.0	0.851	2
≥5	0.943	12

TABLE C2 continued

DROP SIZE SAMPLING RESULTS FOR UNTHICKENED 80/20 DMSO/WATER

Stain Size mm	Drop Size mm	Number in Class	
		FP80-9	FP80-10
0-0.15	0	48	123
0.15-0.30	0.055	8371	10392
0.30-0.45	0.083	8630	10584
0.45-0.60	0.110	5175	6472
0.60-0.75	0.138	3001	4036
0.75-0.90	0.165	1735	2435
0.90-1.05	0.193	1096	1460
1.05-1.20	0.220	720	896
1.20-1.50	0.247	755	959
1.50-1.80	0.302	416	374
1.80-2.10	0.357	212	185
2.10-2.40	0.412	145	83
2.40-2.70	0.467	107	48
2.70-3.00	0.522	49	19
3.00-3.50	0.577	51	27
3.50-4.00	0.669	31	10
4.00-4.50	0.760	15	8
4.50-5.00	0.852	16	2
≥5.00	0.943	29	6

TABLE C2 continued

DROP SIZE SAMPLING RESULTS FOR UNTHICKENED 80/20 DMSO/WATER

Stain Size mm	Diameter mm	Number in Class		
		FP80-11	FP80-12	FP80-13
0-0.05	0	0	0	0
0.05-0.10	0.037	4203	12344	13262
0.10-0.15	0.046	2329	9532	10404
0.15-0.20	0.055	1852	7532	8296
0.20-0.30	0.064	2891	5837	6427
0.30-0.40	0.083	2069	3546	3594
0.40-0.50	0.101	1514	2061	2034
0.50-0.60	0.119	1007	1163	1065
0.60-0.70	0.138	651	631	539
0.70-0.80	0.156	455	366	270
0.80-0.90	0.174	296	207	135
0.90-1.00	0.193	173	116	66
1.00-1.10	0.211	147	62	31
1.10-1.20	0.229	70	30	17
1.20-1.30	0.249	58	14	11
1.30-1.40	0.266	40	8	5
1.40-1.50	0.284	28	3	4
1.50-2.00	0.302	80	1	1
2.00-2.50	0.394	23	0	0
2.50-3.00	0.486	13	0	0
3.00-4.00	0.577	6	0	0
4.00-5.00	0.760	1	0	0
≥5.00	0.943	1	0	0

TABLE C3

DROP SIZE SAMPLING RESULTS FOR THICKENED 80/20 DMSO/WATER

Stain Size mm	Diameter mm	Number in Class FP80-14	FP80-15	FP80-16
0.0.05	0	3	0	0
0.05-0.10	0.070	443	4	6857
0.10-0.15	0.088	483	23	6749
0.15-0.20	0.106	483	123	6539
0.20-0.30	0.126	736	761	6031
0.30-0.40	0.163	487	512	3891
0.40-0.50	0.20	321	333	2551
0.50-0.60	0.237	201	190	1773
0.60-0.70	0.274	141	131	1273
0.70-0.80	0.311	83	91	960
0.80-0.90	0.348	66	56	745
0.90-1.00	0.385	52	43	588
1.00-1.10	0.423	41	33	482
1.10-1.20	0.460	30	16	400
1.20-1.30	0.497	15	19	335
1.30-1.40	0.534	9	9	282
1.40-1.50	0.571	14	8	239
1.50-2.00	0.608	32	20	213
2.00-2.50	0.794	13	10	108
2.50-3.00	0.980	7	5	68
3.00-4.00	1.165	6	3	38
4.00-5.00	1.537	0	0	15
≥5.00	1.908	1	2	8

TABLE C4

MASS MEDIAN DIAMETERS FROM DROP SIZING DATA

Trial Number	Charge grams Primacord	D_0 (1) mm	D_1 (2) mm	D_2 (2) mm
FP80-1	100	0.29		
2	100	0.35		
3	100	0.28		
4	100	0.41		
5	100	0.16		
6	100	0.17		
7	100	0.27		
8	100	0.31	0.70	0.24
9	100	0.47	0.84	0.25
10	100	0.25	0.57	0.20
11	100	0.22	0.34	0.13
12	100	0.12		
13	100	0.11		
14	100	0.72	0.95	0.28
15	200	0.68	1.13	0.30
16	200	1.11	1.37	0.35

1 Overall mass median diameter

2 Mass median diameter of each distribution

TABLE C5

DROP SIZE SAMPLING RESULTS FROM ROW 3 FP 80-16

Stain Size	Diameter	Number in Class	
mm	mm	Card E 3	Row 3
0-0.05	0	0	0
0.05-0.10	0.070	17	18
0.10-0.15	0.088	19	60
0.15-0.20	0.106	94	181
0.20-0.30	0.126	345	625
0.30-0.40	0.163	114	300
0.40-0.50	0.200	56	156
0.50-0.60	0.237	42	85
0.60-0.70	0.274	28	59
0.70-0.80	0.311	11	26
0.80-0.90	0.348	8	31
0.90-1.00	0.385	2	23
1.00-1.10	0.423	5	15
1.10-1.20	0.460	3	5
1.20-1.30	0.497	1	10
1.30-1.40	0.534	0	4
1.40-1.50	0.571	1	4
1.50-2.00	0.608	3	18
2.00-2.50	0.794	3	4
2.50-3.00	0.980	3	6
3.00-4.00	1.165	1	4
4.00-5.00	1.537	2	3
≥5.00	1.908	0	6

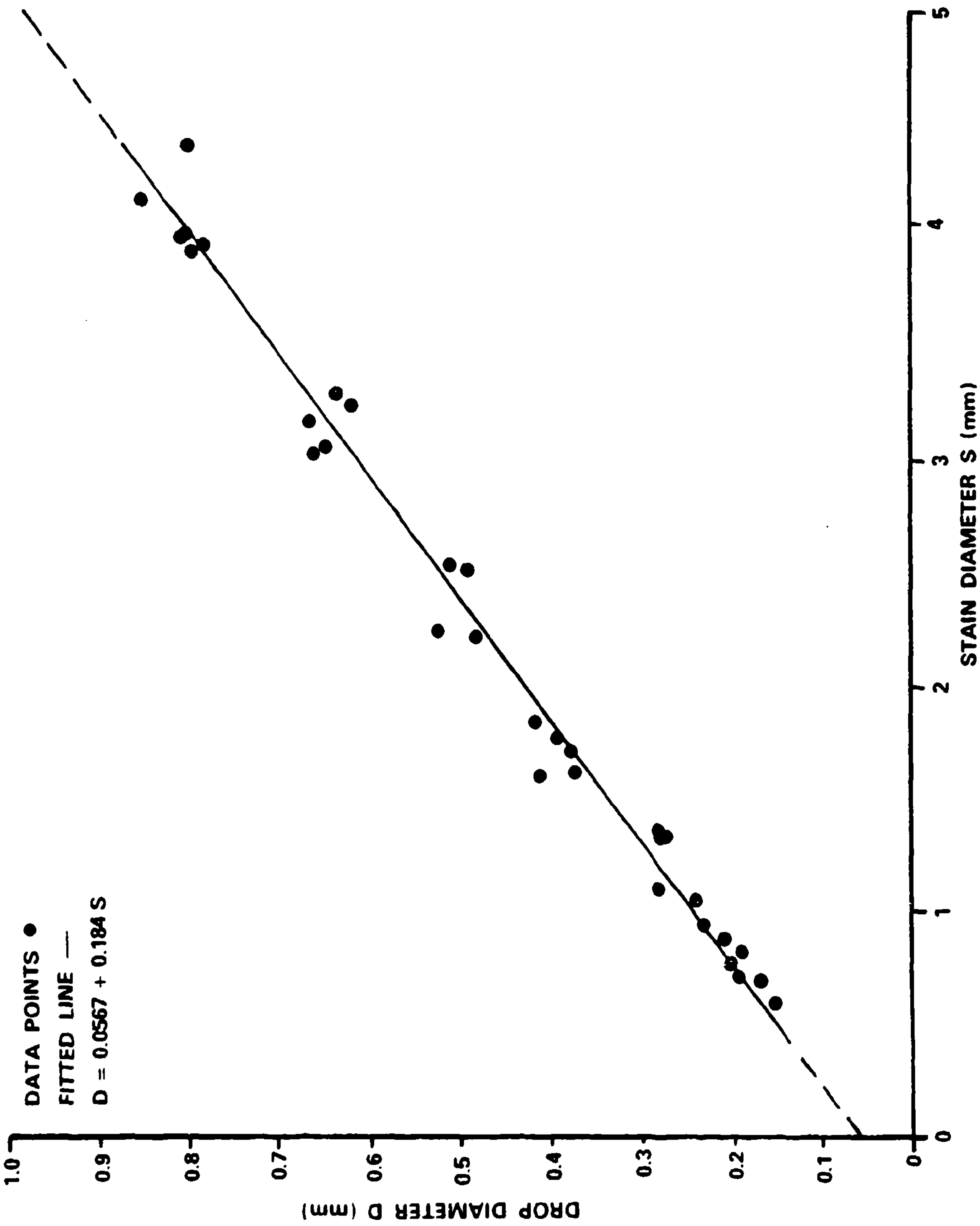

Figure C1

SPREAD OF DMSO DROPS ON THREE-WAY DETECTOR PAPER

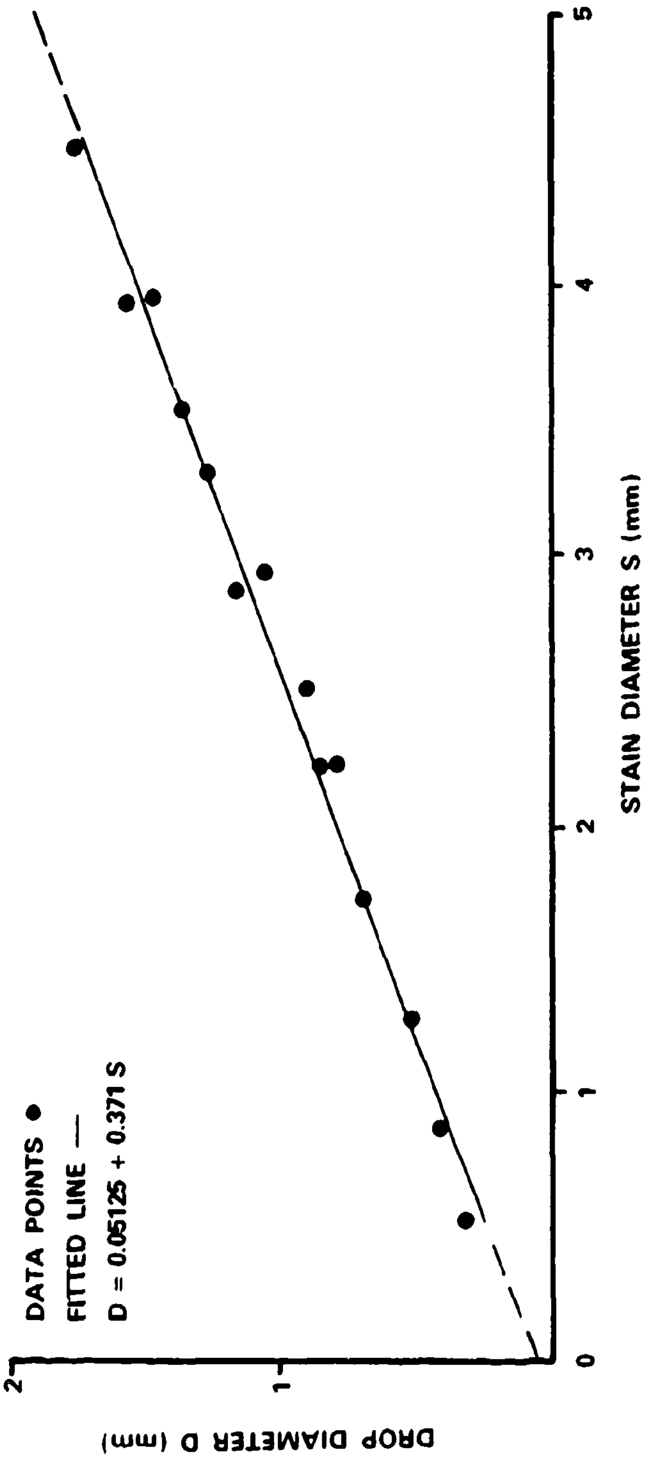

Figure C2

SPREAD OF 80% DMSO 20% WATER (V) DROPS ON 3-WAY DETECTOR PAPER

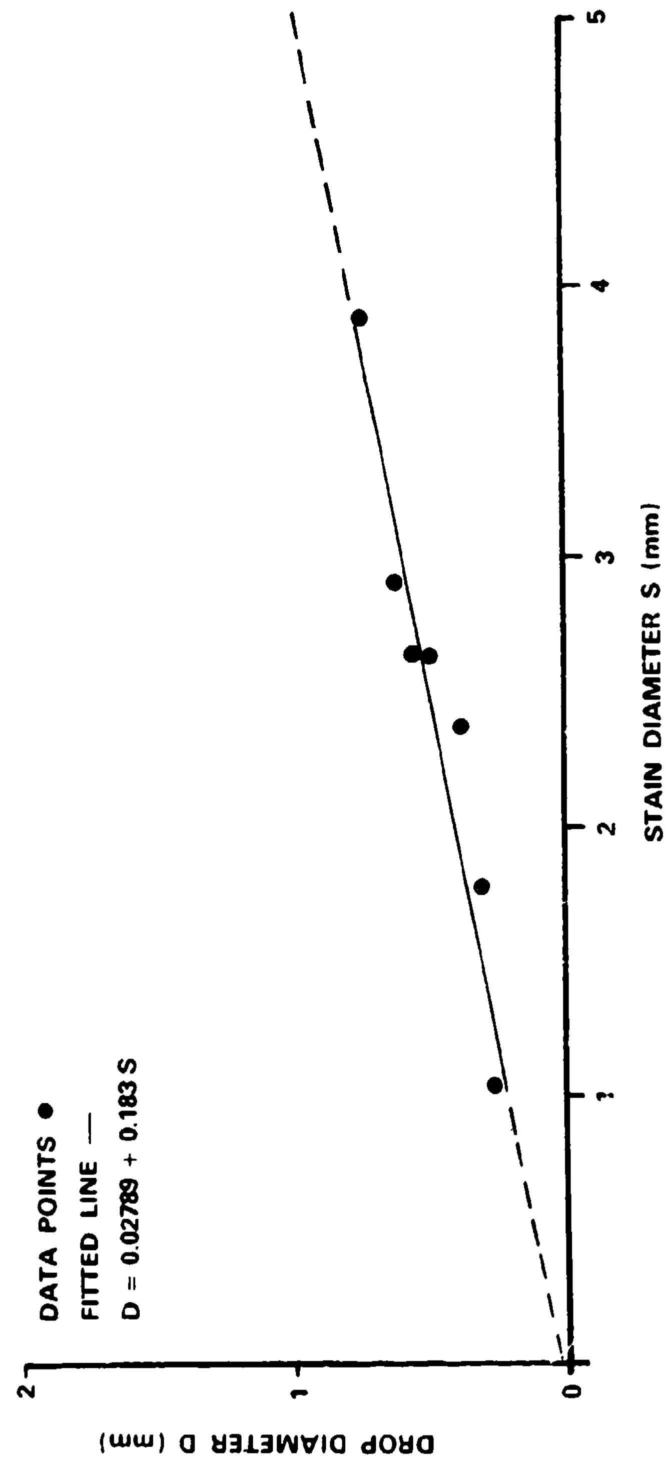

Figure C3

SPREAD OF 80% DMSO 20% WATER DROPS ON 3-WAY DETECTOR PAPER

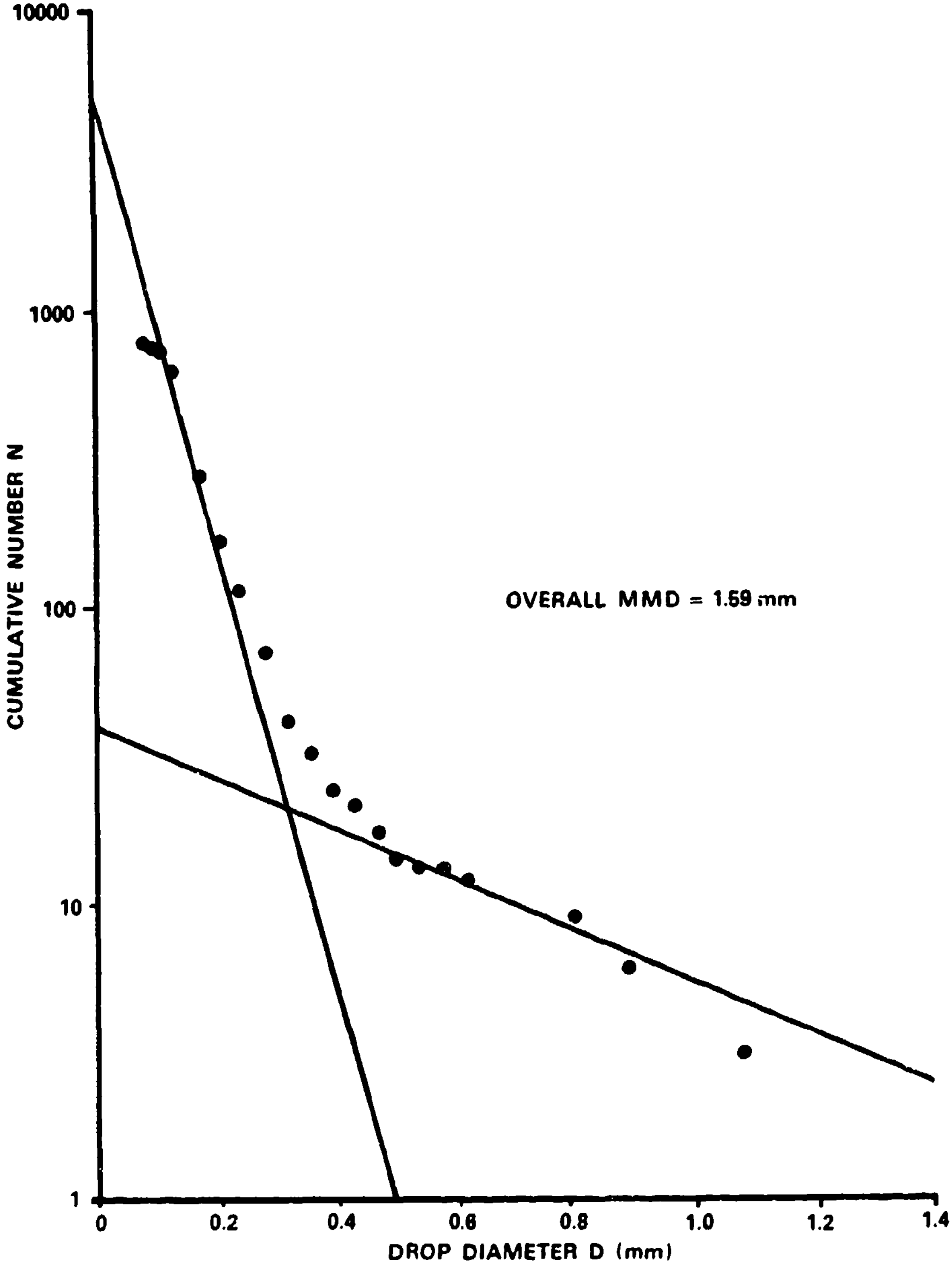

Figure C4

DROP DIAMETER NUMBER DISTRIBUTION FPP 80 – 16

CARD E-3 3-WAY

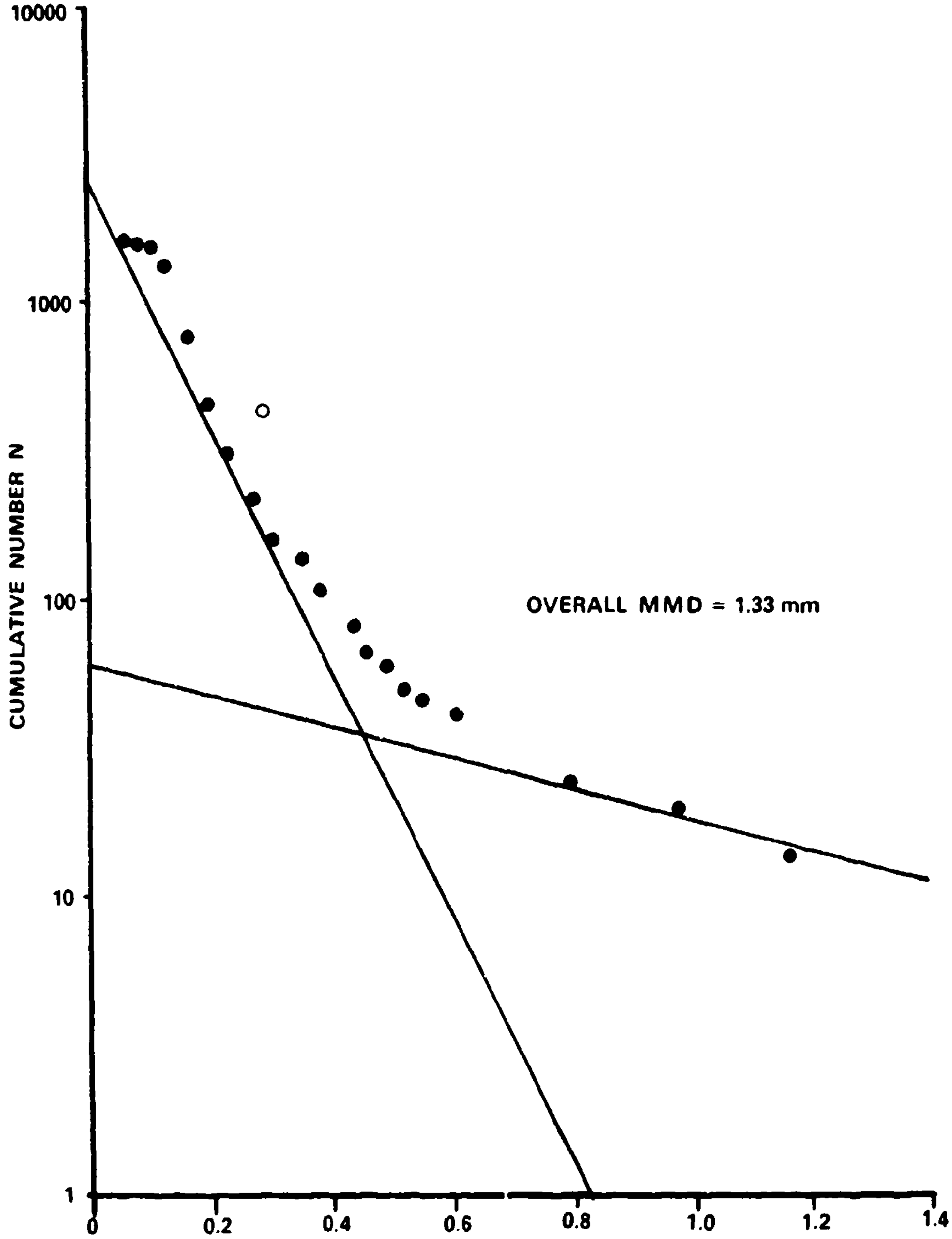

Figure C5

DROP DIAMETER NUMBER DISTRIBUTION FPP 80 – 16

ROW 3 3-WAY

APPENDIX D

TABLE D1

CONTAMINATION DENSITY SAMPLES

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO

$g\ m^{-2}$

FP80-1 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1661 g

Line / Row	1	2	3	4	5	6
H	0.03	0.03	1.07	0.14	0.08	0.33
G	0.67	0.83	1.81	1.15	1.89	0.69
F	1.68	2.05	2.88	3.93	5.83	1.99
E	1.71	1.46	3.40	2.40	4.21	2.16
D	0.72	2.24	1.42	2.73	2.13	4.60
C	0.45	1.05	0.74	1.55	1.08	3.42
B	0.25	0.99	0.32	1.50	1.36	1.48
A	0.10	0.67	0.27	1.37	0.89	0.52

Mean C.D. 1.55 $g\ m^{-2}$

TABLE D2

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO

$g\ m^{-2}$

FP80-2 (100 grains primacord, bottles at 2 m)
Total liquid disseminated 1670 g

Line / Row	1	2	3	4	5	6
H	0.68	1.87	0.44	0.22	0.08	0.06
G	2.35	10.95	3.92	4.60	0.69	0.32
F	2.49	8.88	6.99	7.63	4.89	1.82
E	1.83	3.13	3.65	6.51	4.55	5.42
D	1.26	1.40	2.38	1.86	9.01	1.34
C	0.04	0.43	0.40	1.11	4.21	3.12
B	0	0.32	0.21	0.17	0.57	4.21
A	0.01	0.06	0.19	0.08	0.19	0.91

Mean C.D. 2.45 $g\ m^{-2}$

APPENDIX D

TABLE D3

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO
$g\ m^{-2}$

FP80-3 (100 grains primacord, bottles at 2 m)
Total liquid disseminated 1682 g

Line / Row	1	2	3	4	5	6
H	0	0	0	0	0	0
G	0.34	0.09	1.72	8.78	0	0.59
F	1.86	0.56	1.60	1.81	0.62	3.80
E	4.65	2.33	2.57	7.08	0.98	4.32
D	4.85	1.29	4.14	7.45	2.22	2.60
C	3.25	0.64	2.56	4.89	1.97	1.36
B	3.14	0.67	1.74	4.20	1.21	0.75
A	2.77	0.26	0.65	1.38	0.46	0.50

Mean C.D. 1.71 $g\ m^{-2}$

TABLE D4

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO
$g\ m^{-2}$

FP80-4 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1683 g

Line / Row	1	2	3	4	5	6
H	0	0.01	0	0.02	0	0
G	0.24	0.15	0.60	7.29	0.54	1.41
F	1.80	1.57	3.87	2.52	1.72	2.55
E	4.37	2.70	4.20	5.06	2.73	3.57
D	4.17	5.26	3.47	1.86	3.28	0.94
C	1.96	2.09	0.13	0.90	3.26	0.80
B	1.71	0.85	1.22	0.57	2.15	0.28
A	2.91	0.73	0.47	0.12	0.92	0.10

Mean C.D. 1.81 $g\ m^{-2}$

APPENDIX D

TABLE D5

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO
$g\ m^{-2}$

FP80-5 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1710 g

Line Row	1	2	3	4	5	6
H	0	0	0.06	0.05	0	0
G	0.11	0.31	0.27	2.57	0.83	0.27
F	2.65	1.19	3.27	1.37	2.12	1.61
E	4.22	4.09	3.91	2.51	1.74	4.14
D	2.88	3.73	1.98	2.07	2.74	4.82
C	1.72	3.08	0.87	1.04	1.69	4.89
B	1.09	3.25	0.91	1.02	1.34	2.98
A	0.94	3.08	0.43	0.39	1.03	2.32

Mean C.D. 1.83 $g\ m^{-2}$

TABLE D6

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO
$g\ m^{-2}$

FP80-6 (100 grains primacord, bottles at 2 m)
Total liquid disseminated 1728 g

Line Row	1	2	3	4	5	6
H	0	0	0	0	0	0
G	0.10	0.06	0	1.44	0.16	0.30
F	4.14	0.49	1.61	2.13	0.76	0.83
E	3.03	2.00	2.43	6.41	7.05	0.41
D	2.50	4.75	4.85	4.58	1.21	0.14
C	1.77	3.93	8.96	2.72	0.50	0.07
B	-	1.75	1.70	0.06	0.07	0
A	1.05	4.92	1.25	0.13	0.06	0

Mean C.D. 1.54 $g\ m^{-2}$

APPENDIX D

TABLE D7

CONTAMINATION DENSITY SAMPLES FOR NEAT DMSO
g m^{-2}

FP80-7 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1641 g

Line / Row	1	2	3	4	5	6
H	0.41	0.53	0	0.24	0.24	0
G	1.88	1.03	0.78	1.63	2.66	1.20
F	2.43	4.37	2.38	4.22	4.56	3.20
E	2.08	4.36	3.64	2.67	5.39	4.17
D	1.18	2.39	2.51	2.55	4.34	4.19
C	0.95	1.18	1.37	1.27	2.61	2.62
B	0.69	0.66	0.81	0.71	1.83	2.30
A	0	0.72	0.33	1.42	1.77	0.38

Mean C.D. 1.94 g m^{-2}

TABLE D8

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
g m^{-2}

FP80-8 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1668 g

Line / Row	1	2	3	4	5	6
H	0	0	0.15	0	0	0
G	2.03	0.31	1.63	2.25	0.37	0.70
F	1.58	0.66	3.94	1.98	1.95	7.20
E	3.33	3.10	1.76	2.68	1.98	5.54
D	2.40	8.02	2.76	1.42	3.83	2.00
C	2.39	2.48	2.94	1.06	5.53	1.59
B	1.63	0.43	1.20	0.44	2.88	1.07
A	0.97	0.45	0.79	0.20	2.92	0.68

Mean C.D. 1.96 g m^{-2}

APPENDIX D

TABLE D9

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-9 (100 grains primacord, bottles at 2 m)
Total liquid disseminated 1669 g

Line / Row	1	2	3	4	5	6
H	0.97	0.06	0.01	0.07	0.01	0.01
G	0.71	0.16	0.56	1.84	0.72	1.74
F	0.70	6.38	1.00	0.62	1.67	1.70
E	0.48	1.28	2.24	3.73	3.40	2.47
D	0.16	0.82	2.40	4.66	4.07	0.91
C	0.19	0.38	1.21	3.62	3.62	0.13
B	0.11	0.69	1.33	1.99	1.05	0.14
A	0.08	0.33	1.24	1.45	0.58	0.05

Mean C.D. 1.35 $g\ m^{-2}$

TABLE D10

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-10 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1665 g

Line / Row	1	2	3	4	5	6
H	0	0.01	0.03	0.01	0.01	0.04
G	0.29	0.94	0.19	0.83	0.30	0.11
F	1.45	2.39	2.67	3.84	1.64	2.84
E	1.86	3.51	2.40	4.21	1.89	2.84
D	1.12	1.61	2.79	3.32	1.74	1.06
C	0.53	1.03	1.29	1.56	0.74	1.03
B	0.26	0.58	0.80	0.90	0.71	0.74
A	0.23	0.82	0.50	1.14	0.56	0.72

Mean C.D. 1.31 $g\ m^{-2}$

APPENDIX D

TABLE D11

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-11 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1635 g

Line / Row	1	2	3	4	5	6
H	4.51	1.17	2.69	0.03	0.01	0.04
G	6.85	5.90	4.21	1.68	2.99	2.04
F	3.79	6.60	6.75	0.74	3.79	6.70
E	2.83	5.45	2.61	5.20	4.95	0.71
D	3.53	3.67	0.60	3.27	4.07	0.40
C	1.62	2.04	0.34	1.48	3.23	0.26
B	0.82	1.28	0.12	0.86	1.77	0.21
A	0.44	0.79	0.14	0.39	1.27	0.22

Mean C.D. 2.41 $g\ m^{-2}$

TABLE D12

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-12 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1677 g

Line / Row	1	2	3	4	5	6
H	0.00	0.04	0.26	0.01	0.01	0.02
G	0.63	0.59	2.60	4.97	0.46	3.92
F	5.50	2.79	4.16	4.89	7.10	3.21
E	4.96	4.86	2.07	5.20	5.80	2.13
D	2.04	2.43	3.22	2.85	2.53	1.45
C	0.93	1.71	1.95	1.33	1.32	2.20
B	0.48	0.94	0.54	0.83	1.42	3.55
A	0.11	0.42	0.61	0.93	0.59	1.03

Mean C.D. 2.12 $g\ m^{-2}$

APPENDIX D

TABLE D13

CONTAMINATION DENSITY SAMPLES FOR UNTHICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-13 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1664 g

Line / Row	1	2	3	4	5	6
H	0.04	0.01	1.32	0.03	1.27	0.34
G	2.61	4.99	4.75	2.13	6.67	6.44
F	3.94	4.26	7.12	2.53	2.40	4.55
E	2.46	3.33	1.35	3.11	0.94	1.75
D	1.04	1.86	0.81	0.53	0.41	1.11
C	0.71	0.54	0.40	0.12	0.11	0.40
B	0.66	0.26	0.26	0.09	0.11	0.14
A	0.28	0.12	0.22	0.12	0.06	0.10

Mean C.D. 1.64 $g\ m^{-2}$

TABLE D14

CONTAMINATION DENSITY SAMPLES FOR THICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-14 (100 grains primacord, bottles at 1 m)
Total liquid disseminated 1385 g

Line / Row	1	2	3	4	5	6
H	4.08	2.13	5.48	3.18	2.99	0
G	3.07	5.00	2.26	4.12	6.10	0
F	6.42	3.54	4.27	5.16	3.55	-
E	2.80	3.01	2.59	2.86	2.27	3.83
D	0.88	0.67	0.63	0.90	0.44	0.81
C	0.16	0.20	0.29	0.23	0.24	0.15
B	0.06	0.18	0.28	0.06	0.23	0.12
A	0.06	0.07	0.11	0.03	0.17	0.05

Mean C.D. 1.84 $g\ m^{-2}$

APPENDIX D

TABLE D15

CONTAMINATION DENSITY SAMPLES FOR THICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-15 (200 grains primacord, bottles at 1 m)
Total liquid disseminated 1438 g

Line Row	1	2	3	4	5	6
H	3.69	3.65	3.51	3.71	5.00	4.00
G	3.42	5.79	3.24	4.48	4.44	5.35
F	3.24	4.28	2.85	4.35	4.04	3.20
E	3.86	3.51	3.75	4.77	4.38	3.91
D	1.93	2.78	2.50	2.45	1.75	2.65
C	0.55	0.31	0.72	0.77	0.51	1.15
B	0.07	0.14	0.38	0.31	0.25	0.52
A	0.03	0.12	0.14	0.17	0.26	0.24

Mean C.D. 2.44 $g\ m^{-2}$

TABLE D16

CONTAMINATION DENSITY SAMPLES FOR THICKENED 80/20 DMSO/WATER
$g\ m^{-2}$

FP80-14 (200 grains primacord, bottles at 1 m)
Total liquid disseminated 1437 g

Line Row	1	2	3	4	5	6
H	2.40	2.31	1.99	2.98	4.96	3.03
G	3.93	5.24	3.09	4.37	3.57	5.55
F	5.91	4.36	3.46	3.23	5.25	5.82
E	5.66	5.30	4.05	2.56	3.62	4.16
D	1.21	1.70	1.81	1.08	1.08	1.30
C	0.35	1.04	0.69	0.85	0.49	0.49
B	0.25	0.55	0.12	0.23	0.46	0.23
A	0.08	0.16	0.08	0.05	0.07	0.16

Mean C.D. 2.28 $g\ m^{-2}$

APPENDIX E

TABLE E1

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-1

Position	Height m	Sampling Interval (minutes)					
		Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+180
S1	0.3	115.7	39.1	17.7	0	0	0
	0.5	89.6	27.6	27.6	0	0	0
	1.0	30.7	0	0	0	0	0
	1.5	20.0	0	0	0	0	0
S2	0.3	80.4	36.8	26.2	19.8	15.0	0
	0.5	53.0	29.6	19.8	15.6	0	0
	1.0	22.6	13.1	0	0	0	0
	1.5	0	0	0	0	0	0
S3	0.3	98.5	40.4	16.6	12.1	0	0
	0.5	77.7	31.8	12.4	10.3	0	0
	1.0	23.8	13.2	0	0	0	0
	1.5	8.9	0	0	0	0	0

APPENDIX E

TABLE E2

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-2

Position	Height m	Sampling Interval (minutes)					
		Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+180
S1	0.3	0	0	0	12.4	10.2	0
	0.5	0	0	0	0	0	0
	1.0	0	0	0	22.5	9.3	0
	1.5	0	0	19.8	0	0	0
S2	0.3	0	0	0	18.3	14.7	0
	0.5	0	0	0	10.3	11.9	0
	1.0	0	0	0	0	0	0
	1.5	0	0	0	0	11.1	0
S3	0.3	12.4	13.4	13.5	33.1	32.4	13.7
	0.5	12.8	0	0	27.6	27.7	0
	1.0	0	0	0	9.7	9.2	0
	1.5	0	0	0	0	0	0

APPENDIX E

TABLE E3

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-3

Position	Height m	Sampling Interval (minutes)					
		Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+180
S1	0.3	12.6	8.3	11.6	15.1	0.4	0
	0.5	16.1	15.8	12.9	13.9	0	0
	1.0	0	0	0	0	0	0
	1.5	0	0	0	0	0	0
S2	0.3	60.1	35.2	37.4	33.3	13.6	0
	0.5	41.0	17.1	23.1	20.6	0	0
	1.0	4.6	2.3	1.7	0.2	0	0
	1.5	0	0	0	0	0	0
S3	0.3	49.2	24.2	27.4	22.7	9.5	3.6
	0.5	24.5	16.2	17.9	12.5	2.3	0
	1.0	0	0	0	0	0	0
	1.5	0	0	0	0	0	0

APPENDIX E

TABLE E4

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-4

Position	Height m	Sampling Interval (minutes)					
		Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	0	19.8	23.0	11.5	11.2	0
	0.5	6.0	20.5	24.7	1.6	4.8	0
	1.0	0	4.0	0	0	0	0
	1.5	0	0	0	0	0	0
S2	0.3	2.1	8.9	7.7	0	0	0
	0.5	0	0	0	0	0	0
	1.0	0	0	1.5	0	0	0
	1.5	0	0	0	0	0	0
S3	0.3	0	14.[illegible]	20.9	6.9	5.4	0
	0.5	[illegible]	9.3	7.7	2.6	1.1	0
	1.0	0	0	0	0.9	0	0
	1.5	0	0	0	0	0	0

APPENDIX E

TABLE E5

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-5

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	30.6	17.0	42.8	58.5	100.4	23.8	7.9
	0.5	30.0	11.9	30.2	59.7	75.8	16.9	4.6
	1.0	15.9	9.8	20.2	30.0	59.8	6.3	1.5
	1.5	10.5	6.1	14.5	16.7	20.6	1.9	0.3
S2	0.3	0	1.5	36.8	57.1	72.7	15.9	6.2
	0.5	23.4	9.9	33.4	38.9	80.3	11.8	9.6
	1.0	15.6	6.7	18.6	17.9	20.7	4.5	1.6
	1.5	8.0	4.0	11.8	14.1	9.2	2.0	0
S3	0.3	24.2	11.45	37.0	48.7	50.0	17.2	5.4
	0.5	18.0	10.32	33.2	47.6	56.4	12.7	3.6
	1.0	11.4	3.94	18.1	16.7	32.5	4.6	1.2
	1.5	9.6	5.50	11.3	15.7	22.6	1.8	0.5

APPENDIX E

TABLE E6

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-6

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	40.9	21.7	73.8	97.9	103.0	28.5	4.8
	0.5	35.4	0.3	50.0	60.2	62.1	19.4	3.5
	1.0	0	37.3	17.5	44.4	53.0	51.1	10.7
	1.5	0.9	27.5	11.8	22.8	33.8	50.1	5.4
S2	0.3	11.6	14.0	42.7	43.4	36.7	12.3	1.5
	0.5	12.4	11.2	28.0	33.0	32.6	9.0	1.5
	1.0	9.4	8.9	20.8	22.2	17.9	4.1	0.2
	1.5	7.4	7.0	14.7	12.1	7.6	1.7	0
S3	0.3	0	1.5	12.9	24.3	16.4	4.1	1.0
	0.5	0	1.1	8.2	20.8	10.6	3.5	1.7
	1.0	0.3	0.9	6.6	9.8	4.5	1.2	0.6
	1.5	3.0	2.3	6.7	7.8	4.3	0.9	0

APPENDIX E

TABLE E7

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-7

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	32.0	26.4	28.5	39.0	33.0	13.9	7.8
	0.5	26.1	18.9	33.0	54.0	8.4	85.8	5.4
	1.0	14.1	7.2	9.9	17.1	12.3	5.1	2.3
	1.5	6.6	4.5	6.3	8.4	5.4	2.6	0
S2	0.3	36.0	24.1	33.0	90.0	42.0	23.4	9.9
	0.5	29.4	3.9	23.4	60.0	39.0	14.4	6.6
	1.0	22.8	9.6	24.0	57.0	24.6	7.5	2.7
	1.5	1.7	6.9	11.4	18.0	8.7	3.9	0
S3	0.3	33.0	22.4	45.0	87.0	51.0	23.1	12.0
	0.5	33.0	23.4	30.0	75.0	84.0	36.0	11.1
	1.0	18.0	18.3	19.2	45.0	51.0	27.0	5.1
	1.5	9.9	8.4	9.9	15.3	11.4	6.0	4.5

APPENDIX E

TABLE E8

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-8

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	12.9	4.5	18.9	29.9	22.7	81.8	-
	0.5	11.0	4.1	9.0	22.4	17.7	49.6	8.74
	1.0	8.4	3.8	3.6	11.3	8.1	30.0	17.74
	1.5	5.5	3.6	3.8	5.8	3.5	2.9	0
S2	0.3	11.0	5.1	10.6	23.0	12.2	77.0	20.5
	0.5	10.0	3.6	9.3	22.8	12.0	129.7	34.7
	1.0	8.3	2.8	6.0	7.6	5.5	9.6	3.6
	1.5	3.4	-	4.5	-	14.3	4.3	3.7
S3	0.3	11.8	4.1	13.3	11.4	12.9	54.8	8.4
	0.5	11.2	3.7	12.9	17.7	13.7	58.3	23.2
	1.0	11.7	3.7	10.0	20.3	9.6	53.9	26.2
	1.5	11.1	6.1	16.4	16.8	[illegible].6	9.1	3.0

APPENDIX E

TABLE E9

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-9

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	18.4	13.4	37.6	17.9	22.1	16.9	7.2
	0.5	7.8	6.1	28.8	10.8	18.5	11.3	3.6
	1.0	2.9	4.8	13.8	5.6	8.2	8.3	2.9
	1.5	0	0	2.0	5.1	6.0	7.8	3.8
S2	0.3	34.7	24.7	45.8	31.2	40.9	24.8	7.0
	0.5	12.6	14.8	29.6	16.7	28.1	14.7	4.5
	1.0	3.8	7.8	13.9	5.5	11.1	6.8	1.4
	1.5	0	2.8	7.5	2.9	6.5	4.0	0
S3	0.3	28.0	20.2	31.4	39.4	46.3	21.4	5.2
	0.5	17.0	10.4	22.0	27.2	30.9	13.7	3.6
	1.0	3.1	3.7	11.8	10.7	16.4	7.1	0
	1.5	0	2.6	10.1	5.6	8.4	3.9	0

APPENDIX E

TABLE E10

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-10

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	60.0	40.2	45.0	20.0	18.6	13.3	4.0
	0.5	33.6	28.4	29.9	11.5	11.6	7.7	2.2
	1.0	14.6	10.7	13.6	5.0	5.9	3.5	0
	1.5	2.0	4.5	3.3	1.0	1.1	0	0
S2	0.3	50.5	37.6	47.2	22.0	20.0	11.9	5.1
	0.5	24.6	19.3	27.4	13.4	8.4	12.4	2.2
	1.0	10.2	7.5	13.2	5.0	6.1	2.7	0
	1.5	1.5	3.1	3.4	0.3	0.9	0.9	0
S3	0.3	54.0	27.0	44.6	19.3	15.5	11.6	5.4
	0.5	40.9	13.8	29.7	10.5	11.4	7.2	2.6
	1.0	23.4	4.6	9.0	3.3	2.9	2.2	0
	1.5	3.5	0.5	2.5	3.4	3.9	2.4	0.1

APPENDIX E

TABLE E11

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-11

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	14.7	19.6	25.4	24.2	13.5	3.7	2.6
	0.5	8.9	23.3	20.5	15.2	9.2	9.5	5.6
	1.0	5.6	6.4	7.4	8.5	4.5	1.1	1.4
	1.5	2.1	3.0	3.3	3.5	2.2	0.3	0.7
S2	0.3	32.0	18.8	19.7	29.1	22.9	9.6	3.0
	0.5	11.9	13.5	13.8	19.8	16.4	6.9	2.2
	1.0	6.1	5.6	5.9	8.0	7.6	3.5	1.1
	1.5	2.2	3.3	3.0	3.4	3.7	2.0	0.4
S3	0.3	40.1	27.3	299	45.3	33.7	9.8	2.2
	0.5	22.1	18.8	20.0	28.7	23.3	7.1	15.8
	1.0	6.0	7.8	6.8	11.8	9.6	3.2	0.6
	1.5	2.7	2.8	3.0	4.0	3.9	1.3	0.2

APPENDIX E

TABLE E12

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-12

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	36.5	17.5	38.5	33.3	20.3	4.9	-
	0.5	23.9	13.4	29.8	25.4	15.3	3.7	
	1.0	6.8	6.8	13.4	7.8	7.5	1.6	-
	1.5	1.8	3.8	6.3	4.1	2.9	0.6	-
S2	0.3	31.5	15.9	0	25.2	31.2	26.9	-
	0.5	27.6	9.6	24.1	22.7	16.3	4.7	-
	1.0	11.9	4.8	9.8	10.5	7.5	2.2	-
	1.5	4.3	1.6	4.9	6.0	3.5	1.1	-
S3	0.3	31.0	17.5	35.2	41.1	20.6	7.8	-
	0.5	28.2	14.6	30.0	34.7	18.3	7.0	-
	1.0	12.8	4.2	9.7	9.7	4.8	2.1	-
	1.5	7.3	5.8	5.8	7.2	3.9	1.6	-

APPENDIX E

TABLE E13

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-13

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	16.8	29.1	33.4	27.0	23.8	7.9	2.2
	0.5	12.8	24.3	26.9	24.3	21.9	6.5	1.8
	1.0	0.3	8.1	12.5	12.6	11.5	3.1	0.9
	1.5	0	3.9	6.1	7.1	7.7	2.3	0.1
S2	0.3	15.4	23.5	28.7	24.5	19.5	6.7	2.0
	0.5	8.3	17.4	21.4	20.6	16.1	5.9	1.7
	1.0	5.8	8.1	1.4	13.1	9.5	3.3	0.8
	1.5	0.7	3.5	7.1	9.0	5.1	2.4	0.6
S3	0.3	6.3	20.8	27.8	2.6	18.3	6.7	1.9
	0.5	1.0	15.5	22.7	23.5	16.0	5.8	1.6
	1.0	0.7	10.6	13.3	24.0	9.0	4.1	1.0
	1.5	0	5.1	6.5	8.7	5.5	1.9	0.6

APPENDIX E

TABLE E14

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-14

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	12.6	7.0	17.0	23.7	38.7	30.8	3.4
	0.5	7.4	5.3	15.2	20.0	36.5	26.6	2.7
	1.0	3.1	2.7	9.6	12.4	24.8	19.0	2.0
	1.5	1.4	1.5	6.5	6.8	15.0	12.1	1.1
S2	0.3	2.8	2.1	4.4	6.2	13.6	10.3	1.3
	0.5	3.9	4.7	10.2	16.3	37.1	289	3.2
	1.0	1.0	1.9	7.8	20.5	20.8	17.2	1.6
	1.5	0.5	07	4.1	4.7	15.3	12.1	1.3
S3	0.3	7.1	14.0	5.4	17.9	42.6	31.4	4.0
	0.5	6.4	5.2	12.9	16.0	38.3	33.4	3.7
	1.0	4.5	3.1	7.1	9.2	24.5	23.2	2.5
	1.5	0.6	1.5	4.7	5.3	16.7	15.4	1.6

APPENDIX E

TABLE E15

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-15

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	0.2	1.3	2.1	6.2	21.7	32.7	-
	0.5	0.2	0.7	1.5	4.0	14.1	25.6	-
	1.0	0.2	0.5	0.8	2.0	7.0	14.6	-
	1.5	0	0.3	0.4	1.1	3.3	7.5	-
S2	0.3	3.9	1.8	4.2	7.4	32.2	39.7	-
	0.5	0.7	0.8	1.7	4.1	15.1	28.1	-
	1.0	4.8	0.3	0.9	2.0	7.7	15.9	-
	1.5	3.7	0.2	0.3	1.0	3.5	7.6	-
S3	0.3	4.2	2.0	3.3	9.0	30.0	37.9	-
	0.5	2.0	1.0	1.8	4.7	17.4	31.0	-
	1.0	1.8	0.5	1.0	2.1	8.3	12.8	-
	1.5	0.8	0.2	1.1	0.5	4.6	9.8	-

APPENDIX E

TABLE E16

VAPOUR DOSAGE SAMPLES mg min m^{-3}

FP 80-16

Position	Height m	Sampling Interval (minutes)						
		Z- Z+1	Z- Z+2	Z+2- Z+5	Z+5- Z+10	Z+10- Z+30	Z+30- Z+90	Z+90- Z+150
S1	0.3	2.5	1.5	4.3	8.3	30.8	33.9	16.0
	0.5	10	1.4	4.0	6.0	22.9	25.0	10.6
	1.0	0.3	0.4	2.0	3.1	12.4	12.5	5.2
	1.5	0.1	0.2	1.2	7.1	1.5	5.2	2.6
S2	0.3	1.0	1.5	4.3	5.8	28.1	29.8	11.5
	0.5	0	1.8	3.2	4.5	22.3	23.2	10.7
	1.0	0	0.4	0.5	1.8	2.2	13.3	11.9
	1.5	0.3	0.2	1.0	1.1	6.7	5.5	2.4
S3	0.3	3.6	2.0	4.7	6.2	29.1	31.9	14.0
	0.5	1.5	1.7	4.1	4.7	24.8	27.4	11.5
	1.0	0.7	0.9	2.1	2.4	11.8	12.9	5.6
	1.5	0.3	0.4	1.2	1.2	6.9	6.5	2.7

APPENDIX F

TABLE F1

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-6

Trial Time Minutes	Concentration mg m^{-3} from IR Analyzer	Average Cumulative Dosage mg min m^{-3}	
		IR	Nearest two Bubblers at 1 m
Z	0		
Z+0.2	47.7		
0.4	17.0		
0.5	12.8		
1	5.5	18.8	4.8
1.5	11.9		
2	13.6	29.5	27.8
2.5	9.4		
3	10.2		
3.5	6.0		
4	7.7		
4.5	5.5		
5	6.0	53.8	47.0
6	7.7		
7	10.6		
8	3.4		
9	6.0		
10	4.3	86.6	80.2
12	3.0		

APPENDIX F

TABLE F2

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-8

Trial Time Minutes	Concentration mg m^{-3}		Average Cumulative Dosage mg min m^{-3}	
	IR No. 4	IR No. 5	IR Analyzers	All 3 Bubblers at 1 mm
Z	0	0		
Z+1	3.9	2.5	3.2	9.4
2	5.1	4.9	7.3	12.9
3	4.7	4.9		
4	4.5	4.5		
5	4.3	4.3	19.3	21.3
10	2.7	2.7	33.1	38.8
15	1.2	1.0		
20	0.4	1.3		
25	0.2	0.8		
30	0	0.8	42.1	58.8
35	0	0.4		
40	0.2	0.7		
45	0.4	0.8		
50	0.6	0.8		
55	1.2	0.8		
60	-	1.2		
65	-	1.9		

APPENDIX F

TABLE F3

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-9 & FP 80-10

Trial Time Minutes	Concentration mg m^{-3} From IR Analyzer		Average Cumulative Dosage mg min m^{-3}			
			IR Analyzers		Bubblers	
	FP 80-9	FP 80-10	FP 80-9	FP 80-10	FP 80-9	FP 80-10
Z	0	0	0	0	0	0
2	9.29	23.23	22.6	48.3	9.7	21.5
4	5.07	8.45	42.3	76.9		
5			47.4	81.2	23.5	34.9
6	6.76	3.17	52.5	85.5		
8	2.83	0.84	60.0	89.5		
10	0.84	0.84	63.9	91.6	29.0	39.9
12	1.69	0.84	67.5	93.7		
14	1.27	0.74	70.5	95.3		
16	1.77	0.84	72.2	96.6		
18	0.74	0.63	74.2	98.0		
20	0.21	0.84	74.9	99.5		
30	0.84	0.84	79.0	108.0	38.7	45.9
40	1.69		96.7			
50	1.64		110.6			
60	1.37		127.9			

APPENDIX F

TABLE F4

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-11

Trial Time Minutes	Concentration mg m^{-3}		Average Cumulative Dosage mg min m^{-3}			
	IR No 1	IR No 2	IR No 1	Nearest Two Bubblers @ 1 m	IR No 2	Nearest Two Bubblers @ 1 m
0	0	0	0	0	0	
Z+1	5.28	14.61	2.64	5.8	7.31	6.0
2	[illegible]	10.59	7.71	11.9	17.9	12.8
3	1.7	6.78				
4	3.4	6.78				
5	17	4.66	16.20	18.5	39.9	19.2
6	1.27	4.24				
8	2.11	3.18				
10	2.1	2.5	25.28	26.8	56.6	29.1
12	1.7	2.1				
14	1.7	1.7				
16	1.7	1.7				
18	2.1	2.1				
20	2.1	1.9				
25	1.6	1.7				
30	17	1.3	61.38	32.8	92.7	37.7
40	2.3	1.7				
50	1.7	0.9				
60	2.5	1.7				

APPENDIX F

TABLE F5

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-12

Trial Time Minutes	Concentration mg m^{-3}	Average Cumulative Dosage mg min m^{-3}	
	IR	IR	Nearest 2 Bubblers @ 1 m
Z	0		
0.5	33.8		
1	16.0	20.9	9.4
2	11.8	34.9	15.2
3	8.0		
4	7.2		
5	7.6	43.1	26.8
6	5.5		
8	4.2		
10	3.0	66.6	35.9
12	2.5		
14	2.1		
16	2.1		
18	2.1		
20	2.1		
25	2.5		
30	1.7	88.6	43.4

APPENDIX F

TABLE F6

INFRARED ANALYZER RESULTS

DMSO CONCENTRATION MEASURED BY IR ANALYZERS WITH COMPARISON TO CUMULATIVE DOSAGES FROM BUBBLERS IN FP 80-14

Trial Time Minutes	Concentration mg m^{-3}		Average Cumulative Dosage mg min m^{-3}			
	IR No 1	IR No 2	IR No 1	Nearest 2 Bubblers @ 1 m	IR No 2	Nearest 2 Bubblers @ 1 m
Z	0	0	0		0	
Z+1			0.9	2.0	1.4	2.7
2	1.7	2.8	2.6	4.3	4.2	5.2
4	1.7	2.5				
5			7.7	13.0	12.0	12.7
6	1.7	2.5				
8	1.7	1.5				
10	2.3	2.3	16.8	29.4	22.3	27.6
12	3.0	2.1				
14	3.4	1.7				
16	3.4	2.1				
18	2.7	1.7				
20	3.4	2.1				
30	3.8	1.5	83.5	52.2	59.9	50.2
40	4.2	1.3				
50	5.1	1.5				
60	5.3	1.7				
80	5.5	1.7				
100	5.1	2.1				
120	5.1	2.1				
140	4.6	1.5				

APPENDIX G

TABLE G1

COMPARISON OF MEASURED TOTAL VAPOUR RECOVERY

TO TOTAL LIQUID DISPERSED

Trial	Material	Charge Strength Primacord	Source Strength q g m⁻¹	Recovery Layout			
				Ground		Vapour	
				g m⁻¹	% q	g m⁻¹	% q
1		100	70	25	36	13	19
2	NEAT	100	70	39	56	5	7
3	DMSO	100	70	33	47	12	17
4		100	70	29	41	4	6
5		100	71	30	42	49	69
6		100	72	25	35	34	47
7		100	68	30	44	48	71
8	Unthickened	100	56	31	55	39	70
9	80/20	100	70	22	31	11	16
10	DMSO/	100	69	21	30	27	39
11	Water	100	54	39	72	28	52
12		100	56	34	61	30	54
13		100	56	26	46	20	36
14	Thickened	100	46	29	63	16	35
15	80/20	200	50	39	78	14	28
16	Water	200	48	36	75	15	31

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A series of sixteen trials, seven with neat DMSO and six with 80% DMSO and 20% water to reduce the freezing point temperature, and three with polyvinyl alcohol added to the latter solution to thicken the solution to a zero-shear viscosity of seven poise were conducted on prairie terrain. Explosive dissemination was used on all trials. Vapour sampling and drop sizing results were obtained. The persistence of DMSO and 80/20 DMSO/water on prairie terrain was found directly proportional to the mass median diameter of the drops and the recovery rate of the vapour from prairie terrain agrees favourably with the predictions of an existing DRES mathematical model.

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