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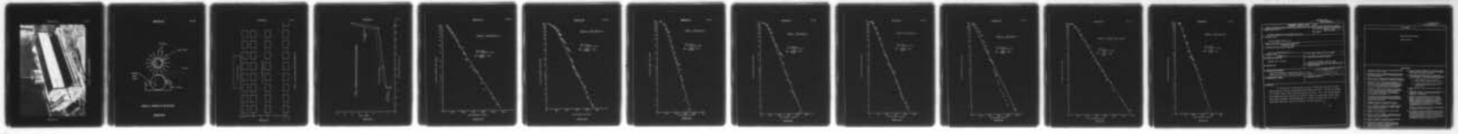

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NO. 382

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by

G.A. Hill and F.L. McCallum

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ABSTRACT

A new type of liquid sprayer called a roller-brush sprayer has been constructed at the Defence Research Establishment Suffield. The device operates by flicking liquid drops with polypropylene bristles. The roller-brush sprayer was tested with high viscosity oil and was found to produce good liquid drops. Mass median diameters were determined for a range of spray rates and it was found that the spray rate did not affect the drop spectrum.

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INTRODUCTION

Liquid sprays are generally formed by forcing liquid through small orifices which causes the stream to break up from shear forces and air resistence. This technique is not suitable for slurries, which tend to plug small orifices, nor for highly viscous liquids, which cannot be sprayed due to friction (pressure) losses.

A new technique has recently been studied by Tripp (1) and Roth (2). Bristles were flicked through a layer of liquid, resulting in the formation and projection of liquid drops. The kinetic energy of the fast moving bristles broke up the layer of liquid. By combining many bristles together (forming a brush) and by providing a continuous feed of liquid spray, a spray of liquid drops resulted. This technique was found to be more suitable for slurries and high viscosity fluids than the conventional technique. Thus it may be a potentially more versatile method of spraying liquids.

The purpose of this work was to construct a field size roller-brush sprayer and to test it with a viscous liquid.

MATERIALS AND PROCEDURES

The roller-brush sprayer, constructed at DRES, is shown in Figure 1. It consists of a metal housing containing two shafts. The lower shaft is knurled and is used for transporting a layer of liquid. The upper shaft contains a spiral of bristles.

The overall dimensions of the housing are 95 cm x 20 cm x 30 cm high. The lower, knurled shaft has a diameter of 8.8 cm and the diameter of the upper, coiled bristle brush is 16.5 cm (mounted on a 5.1 cm shaft). Both shafts are rotated by 1/4 HP electric motors as shown in Figure 2. The motors are connected to the shafts by chains and sprockets through two 26 RPM gear reducers. As constructed, the lower roller can be rotated at both 13 and 26 RPM while the upper brush can be rotated at 30, 61 and 123 RPM. The housing forms a trough 95 cm x 20 cm x 6.4 cm deep, capable of holding 7.2 litres of liquid for spraying. The brush consists of 4.5 cm long, polypropylene bristles measuring 0.27 cm x 0.17 cm in cross-section. They are spirally wound and stretched out along the upper shaft to an average density of approximately 41 for every centimetre of brush length.

SAE-50 oil (a Newtonian liquid) dyed with 1% Williams Red was chosen to test the roller-brush sprayer. It has a viscosity of approximately 5 poise at room temperature. A determination of the spread factor of this material on Printflex* cards was made by placing drops of known sizes on these cards and measuring the resultant stain diameters.

The output rates of the sprayer were determined by weighing the liquid collected in a specially constructed trough over a measured time interval.

The housing was filled with 5 litres of the dyed oil. Printflex cards were positioned in front of the sprayer as shown in Figure 3. With the sprayer parameters fixed at known values, the power was turned on and the spraying begun. When a suitable sample was observed on the Printflex cards, the power was turned off.

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*Printflex is a white, glossy paper purchased from Andrew Paper Co., Washington, D.C.

Data were taken from every card on each spray trial to determine a mass median diameter. Ten drops were randomly chosen from each card. Some cards did not receive this many drops and so all the drops on those cards were sized. The contamination density was determined for spray trial number 2 by sizing drops in a measured area of one card from each row.

After this analytical work was completed, the roller-brush sprayer was qualitatively observed with water and with water and diethyl phthalate thickened with a cellulose thickener. A small field trial was then conducted by towing a military vehicle under the roller-brush sprayer as it was spraying dyed oil.

RESULTS AND DISCUSSION

The operational characteristics of the roller-brush sprayer with dyed SAE-50 oil are listed in Table 1 and shown in Figure 4. For convenience, the term 'relative brush speed' is plotted on the abscissa of Figure 4. The relative brush speed is simply the sum of the circumference times the revolutions per second for both the brush and roller. The data indicates that the liquid spray rate was increased by:

(i) increasing the bristle overlap,
(ii) increasing the brush speed, and
(iii) increasing the roller speed.

It was found that increasing the roller speed had the greatest effect on spray rate. This indicates that the rate of liquid being fed to the bristles was the greatest limiting factor on output rate.

The spread of SAE-50 oil dyed with 1% William's Red on Printflex cards was found to be log-normally distributed according to the equation:

$$\log_{10} (\text{Drop Mass}) = 2.63465 \log_{10} (\text{Stain Diameter}) - 7.58964$$

where: Drop mass is in micrograms
Stain diameter is in microns.

The experimental stain sizes were measured after five days of spreading. The oil continued to spread very slowly beyond five days. All stains in the roller-brush experiment were sized from five to eight days after spraying and the above equation was used to determine drop sizes.

It was observed that the bulk of the liquid was projected only a short distance from the sprayer. The sampling cards were stationed at the same height as the sprayer. The mass distribution for spray trial number 2 is shown in Table 2, based on one second of spray. The bulk of the liquid fell within the range of 76 cm with practically no liquid falling at 127 cm. It was observed that the physical parameters of the sprayer did not noticeably affect this distribution.

The mass median diameters of each spray were determined by plotting the log cumulative number (from the largest drop) versus the drop diameter. This technique gave straight lines (as seen in Figures 5 to 10). Each line represents about 250 data points. Regression analyses were performed on each line yielding the equations shown on the Figures. From the slopes of these lines, the mass median diameters (MMDs) were evaluated according to:

$$\text{MMD} = 1.594/\text{Slope}$$

The resultant MMDs are listed in Table 3 as functions of spray rates. It can be seen that no logical sequence occurred, leading to the conclusion that our experimental techniques could not distinguish any effect of spray rate on drop size. As a final step, all the data were used to calculate an overall MMD. The result is shown in Figure 11. From this analysis, the MMD of the roller-brush atomizer was found to be 1680 μ when spraying SAE-50 oil at any rate.

Shewchuk and Maybank (3) have examined the effect of liquid rheological properties on spray characteristics using water thickened with hydroxyethyl cellulose and the DRES Sprayer. They found that the drop size was affected by viscosity, by the roller-brush parameters, and by the spray rate. In qualitative experiments performed with thickened liquids at DRES, it was observed that the sprayer could not spray certain thickened liquids (e.g., DMHP or Dowanol DPM thickened with an acrylic thickener). This appeared to be due to the elastic properties of these liquids.

The spray trial in the field demonstrated the feasibility of using this unit to disseminate a non-elastic viscous liquid. The drops collected on the target were sized and found to have a MMD of 910 μ (see Figure 12).

CONCLUSIONS

1. A roller-brush sprayer has been built and tested with a viscous Newtonian liquid. It was observed to work well with this liquid.

2. The greatest factor affecting output rate was found to be the rate of feed of liquid to the bristles.

3. The roller-brush parameters and spray rate did not affect the drop spectrum for SAE-50 oil. The overall mass median diameter was found to be 1680 microns.

4. Most of the liquid was sprayed within one meter of the sprayer (if sampled at the same height as the sprayer).

5. There is evidence that the sprayer may not be suitable for non-Newtonian elastic liquids.

REFERENCES

1. Tripp, G.W. "Development of a Roller-Brush Pesticide Applicator", MS Thesis, Oklahoma State University, Stillwater, Oklahoma, 1970.

2. Roth, L.O. and G.W. Tripp "A Roller-Brush Atomizer", Trans. of the ASAE, 16, p. 653-655 & 659. 1973.

3. Shewchuk, S.R. and J. Maybank "An Analysis of a Roller-Brush Spraying System", Saskatchewan Research Council Report P 76-2, Saskatoon, Saskatchewan, 1976.

TABLE 1

ROLLER-BRUSH SPRAY RATES

TRIAL NO.	BRISTLE OVERLAP* (mm)	BRUSH SPEED (RPM)	ROLLER SPEED (RPM)	OUTPUT (g/sec)
1A	3.2	30.0	12.8	2.4
1B	3.2	30.0	12.8	2.4
2	7.2	30.0	12.8	4.8
3	7.2	61.4	12.8	6.7
4	7.2	123	12.8	9.2
5	7.2	123	25.5	24.1

*Difference between length of bristles and distance between roller and shaft.

TABLE 2

CONTAMINATION DENSITIES FOR SPRAY TRIAL NO. 2

DISTANCE IN FRONT OF SPRAYER (cm)	CONTAMINATION DENSITY* ($\mu g/mm^2$)
13	3.56
36	3.65
76	1.35
127	0.02

*Based on 1 second of spray.

TABLE 3

EFFECT OF SPRAY RATE ON MMD

TRIAL NO.	SPRAY RATE (g/sec)	MASS MEDIAN DIAMETER (microns)
1A	2.4	2580
1B	2.4	1840
2	4.8	1150
3	6.7	1500
4	9.2	1600
5	24.1	1890

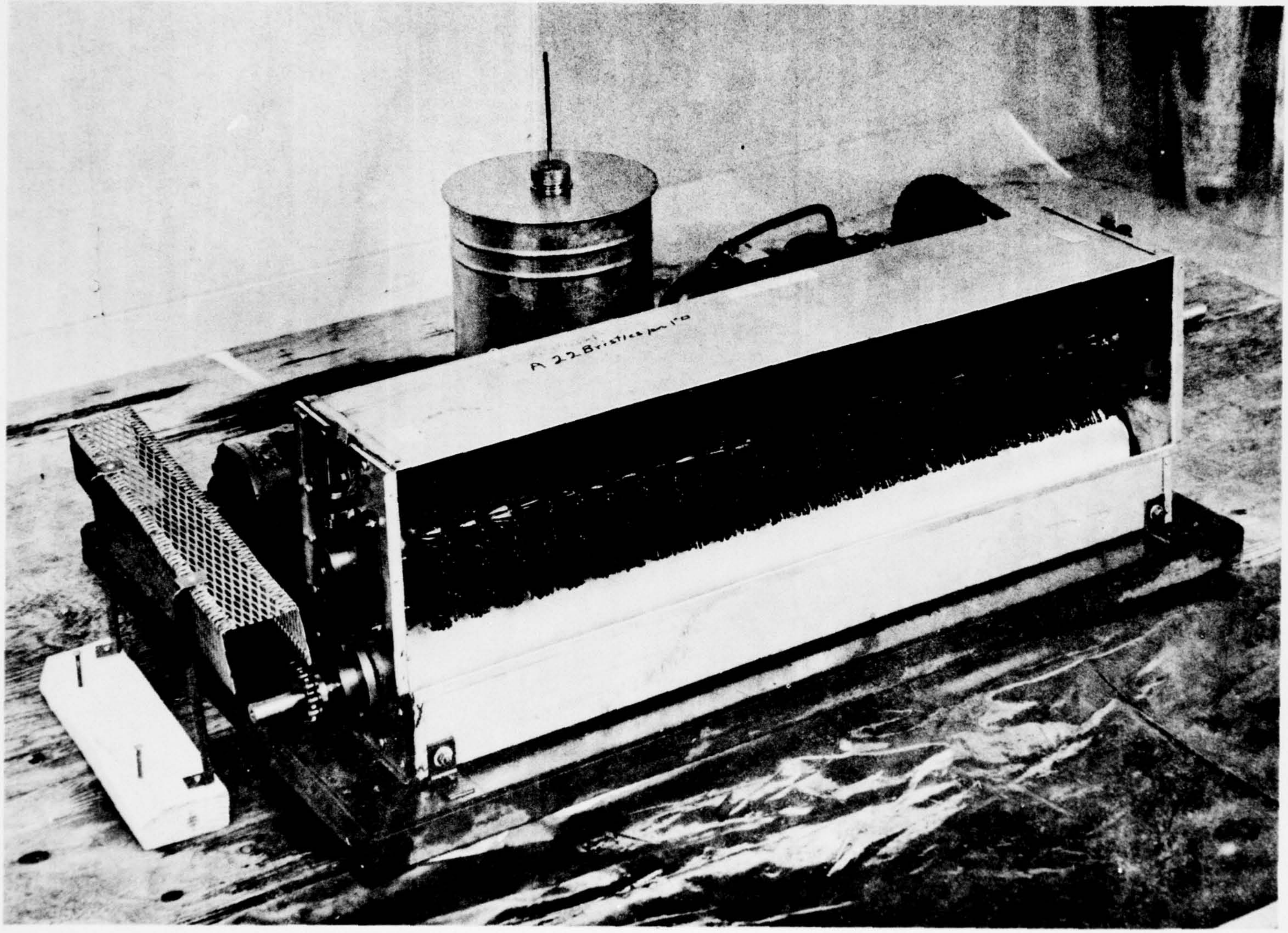


FIGURE 1: ROLLER-BRUSH SPRAYER

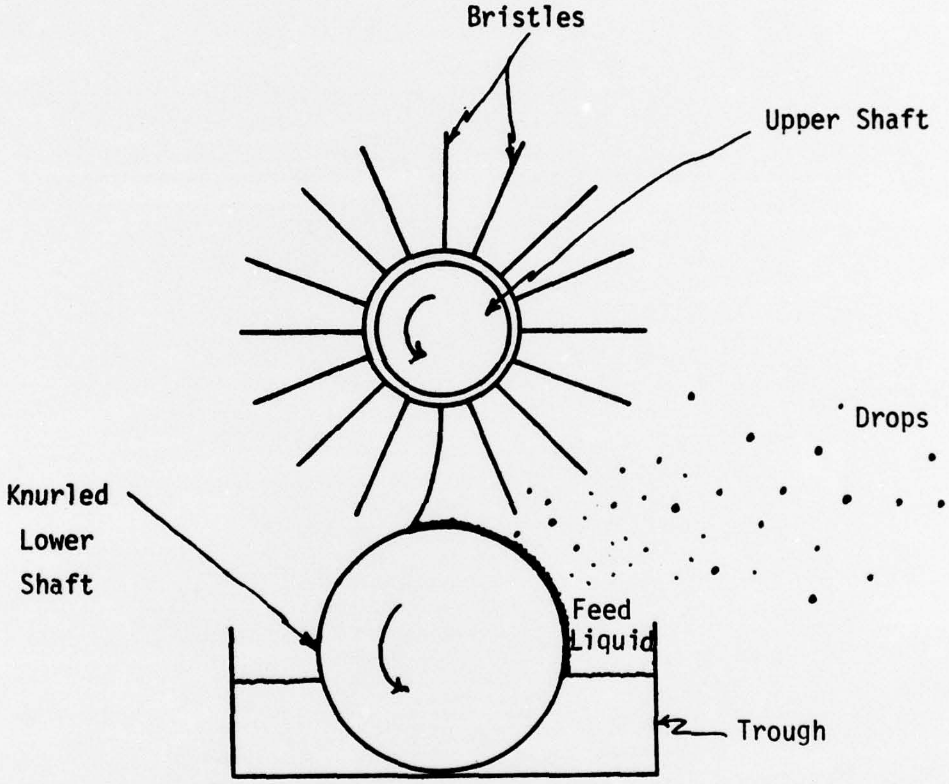


FIGURE 2: SCHEMATIC OF ROLLER-BRUSH

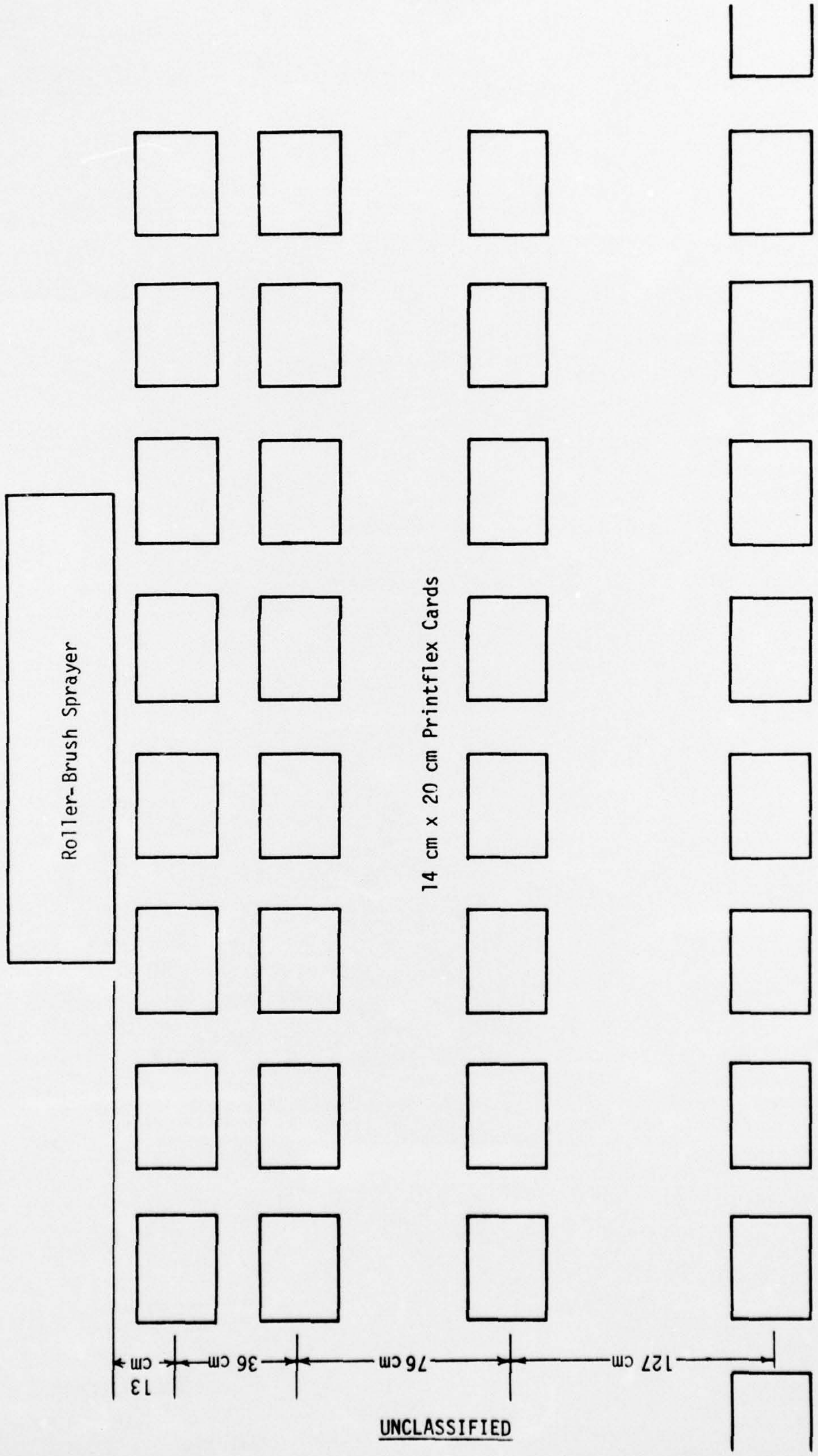


FIGURE 3: SAMPLING CARD LAYOUT FOR DROP ANALYSIS

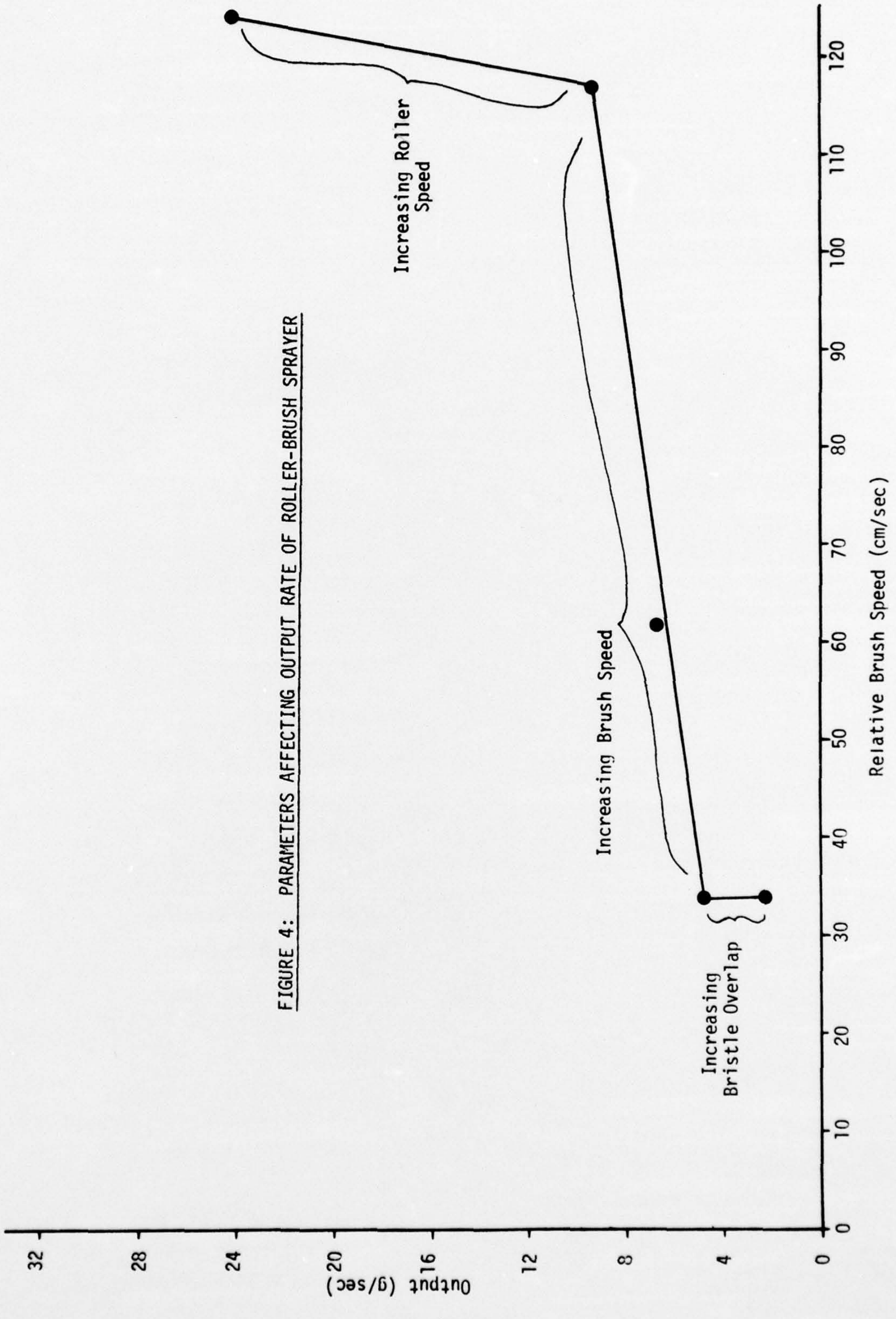


FIGURE 4: PARAMETERS AFFECTING OUTPUT RATE OF ROLLER-BRUSH SPRAYER

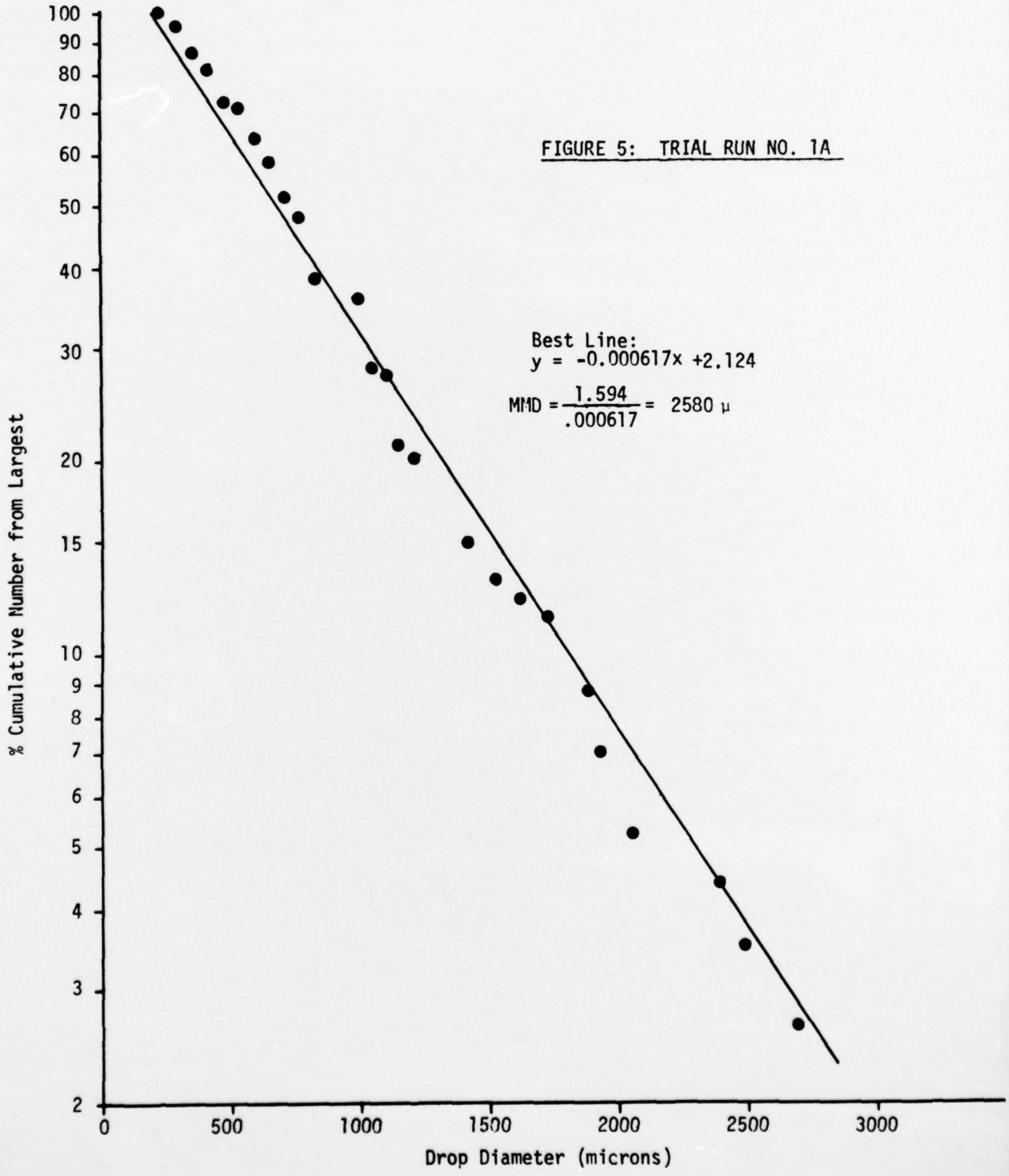
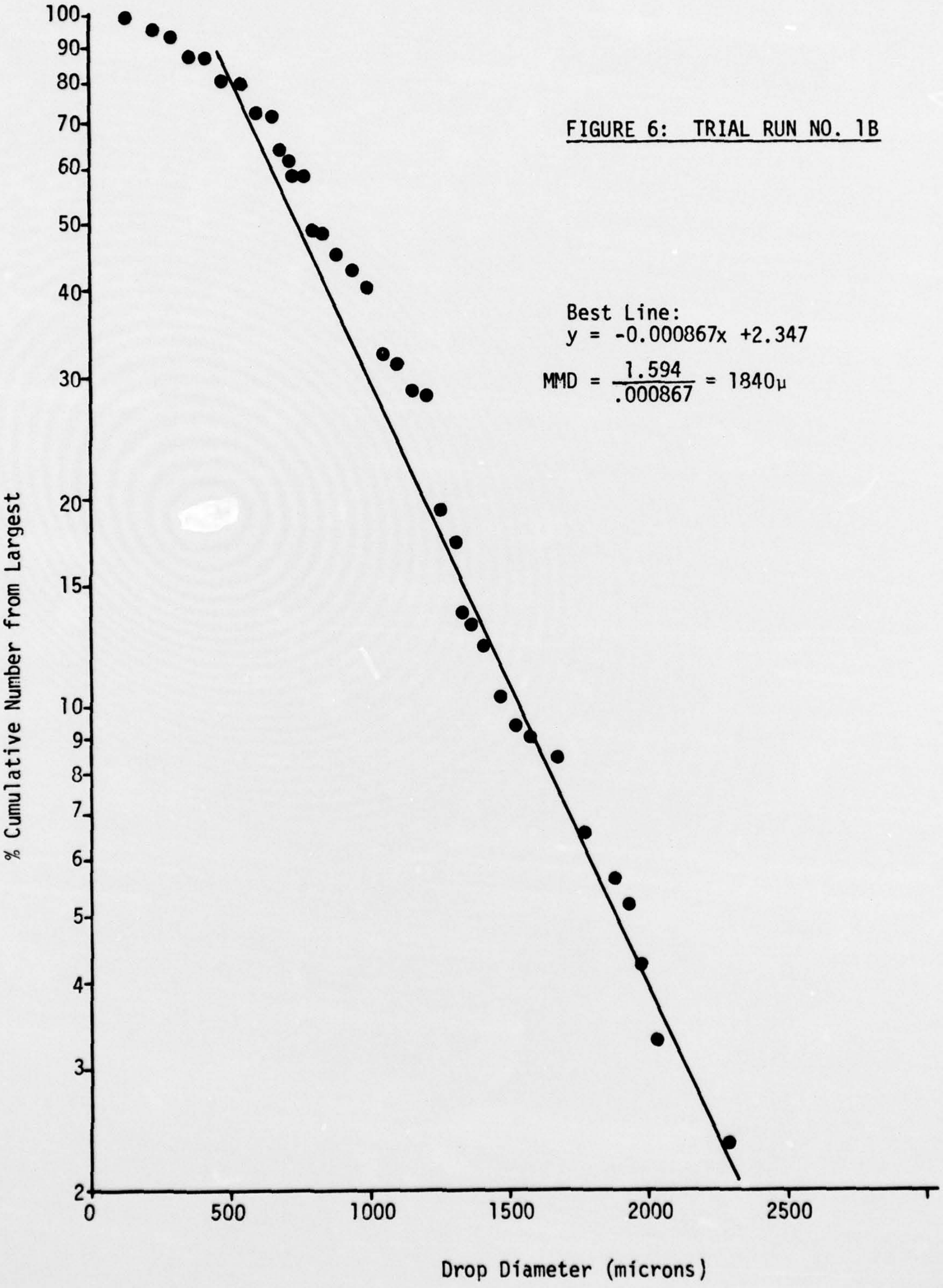


FIGURE 5: TRIAL RUN NO. 1A

Best Line:
$y = -0.000617x + 2.124$

$$\text{MMD} = \frac{1.594}{.000617} = 2580\ \mu$$

FIGURE 6: TRIAL RUN NO. 1B



Best Line:
y = -0.000867x +2.347

$$MMD = \frac{1.594}{.000867} = 1840\mu$$

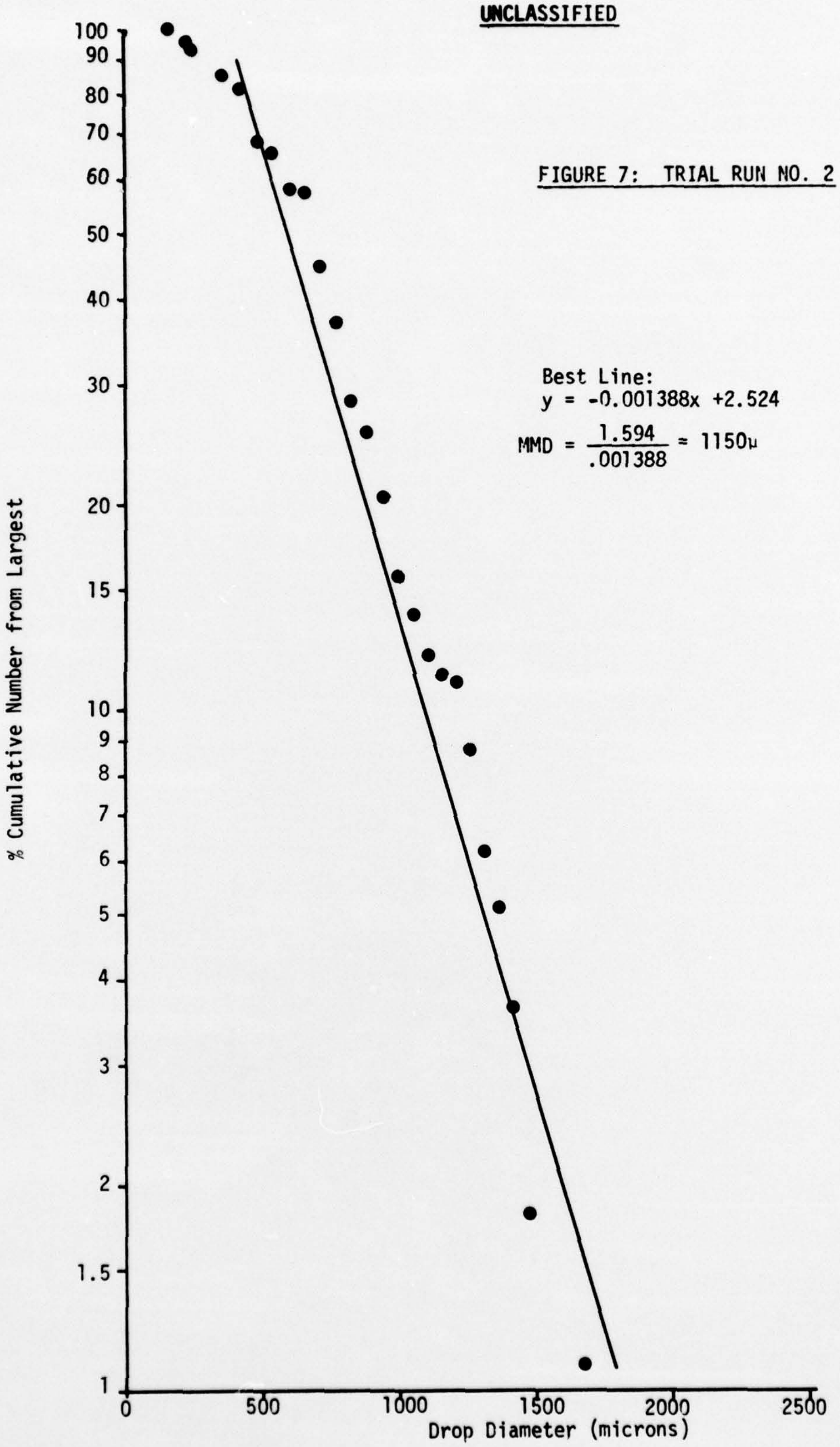


FIGURE 7: TRIAL RUN NO. 2

Best Line:

$y = -0.001388x + 2.524$

$$\text{MMD} = \frac{1.594}{.001388} = 1150\mu$$

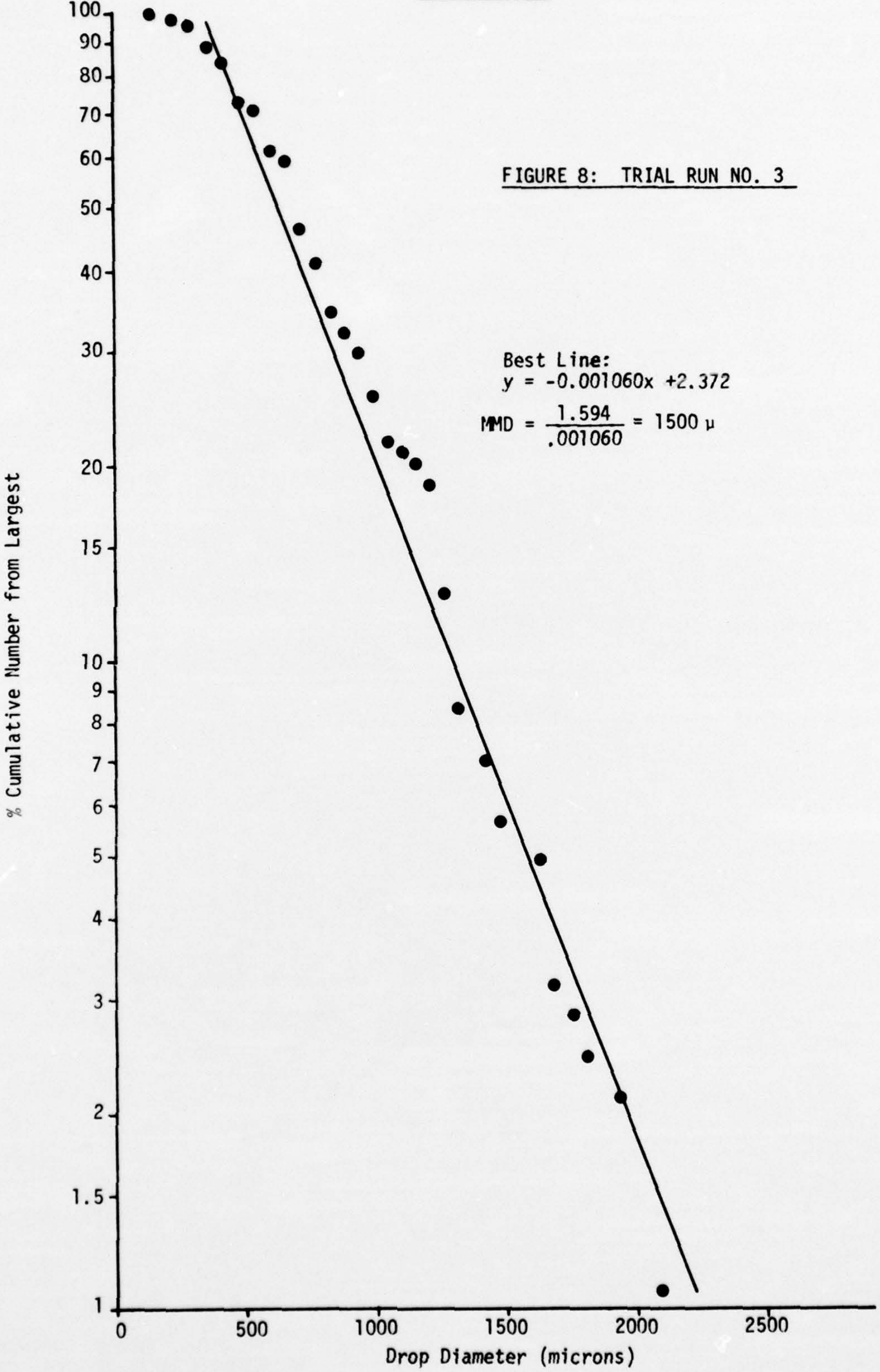


FIGURE 8: TRIAL RUN NO. 3

Best Line:
$y = -0.001060x + 2.372$

$$MMD = \frac{1.594}{.001060} = 1500\ \mu$$

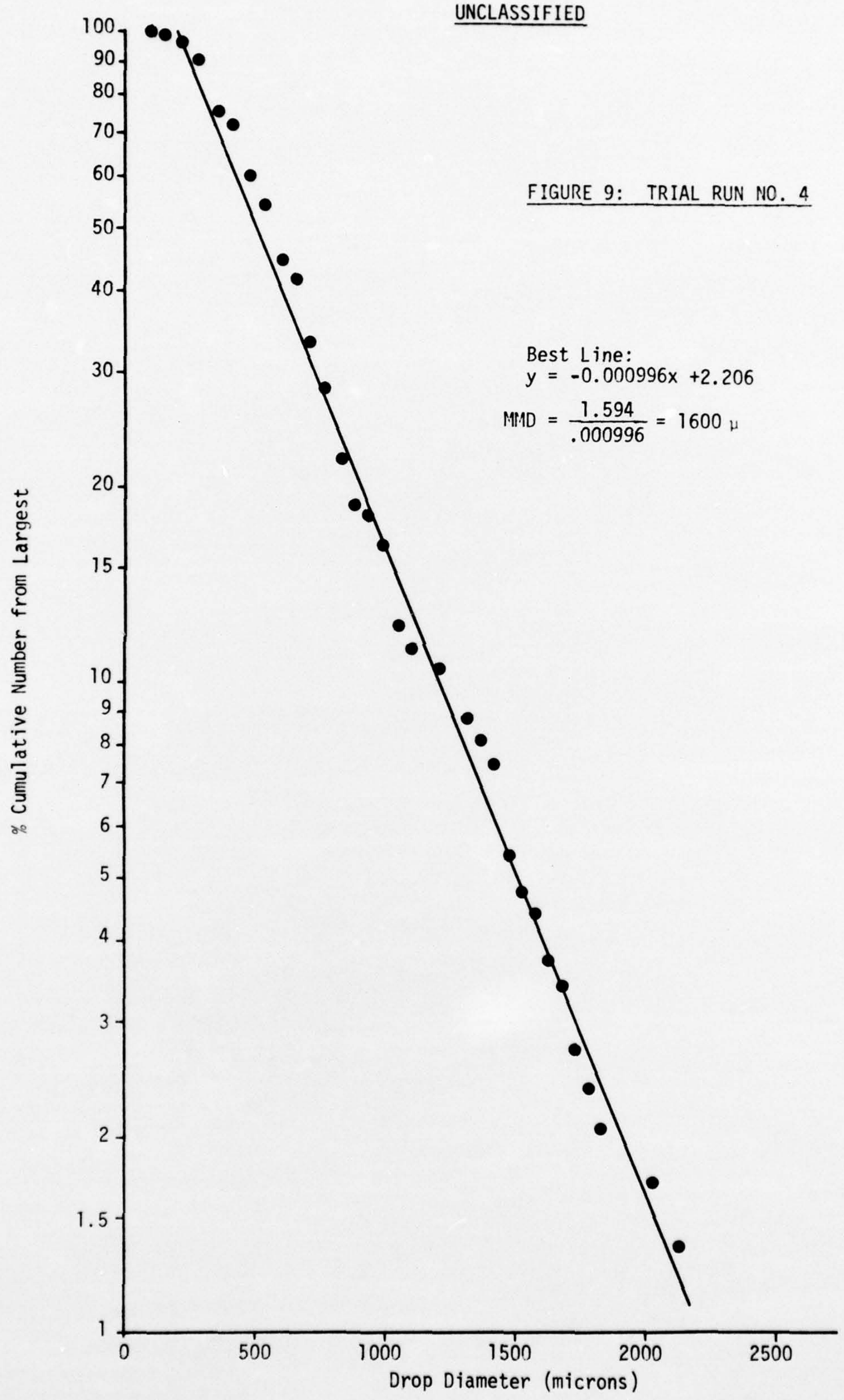


FIGURE 9: TRIAL RUN NO. 4

Best Line:
$y = -0.000996x + 2.206$

$$\mathrm{MMD} = \frac{1.594}{.000996} = 1600\ \mu$$

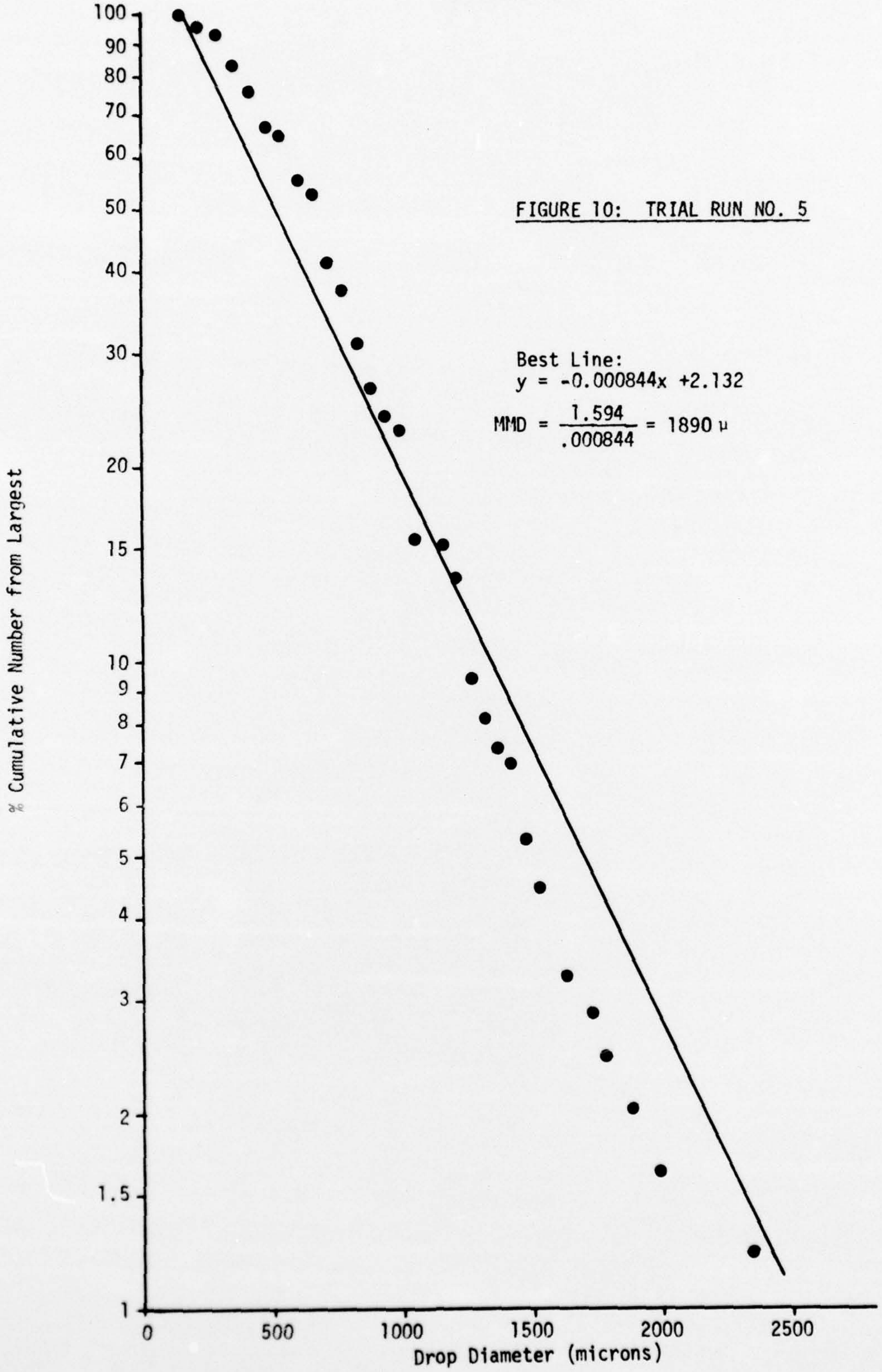


FIGURE 10: TRIAL RUN NO. 5

Best Line:
$y = -0.000844x + 2.132$

$$\text{MMD} = \frac{1.594}{.000844} = 1890\,\mu$$

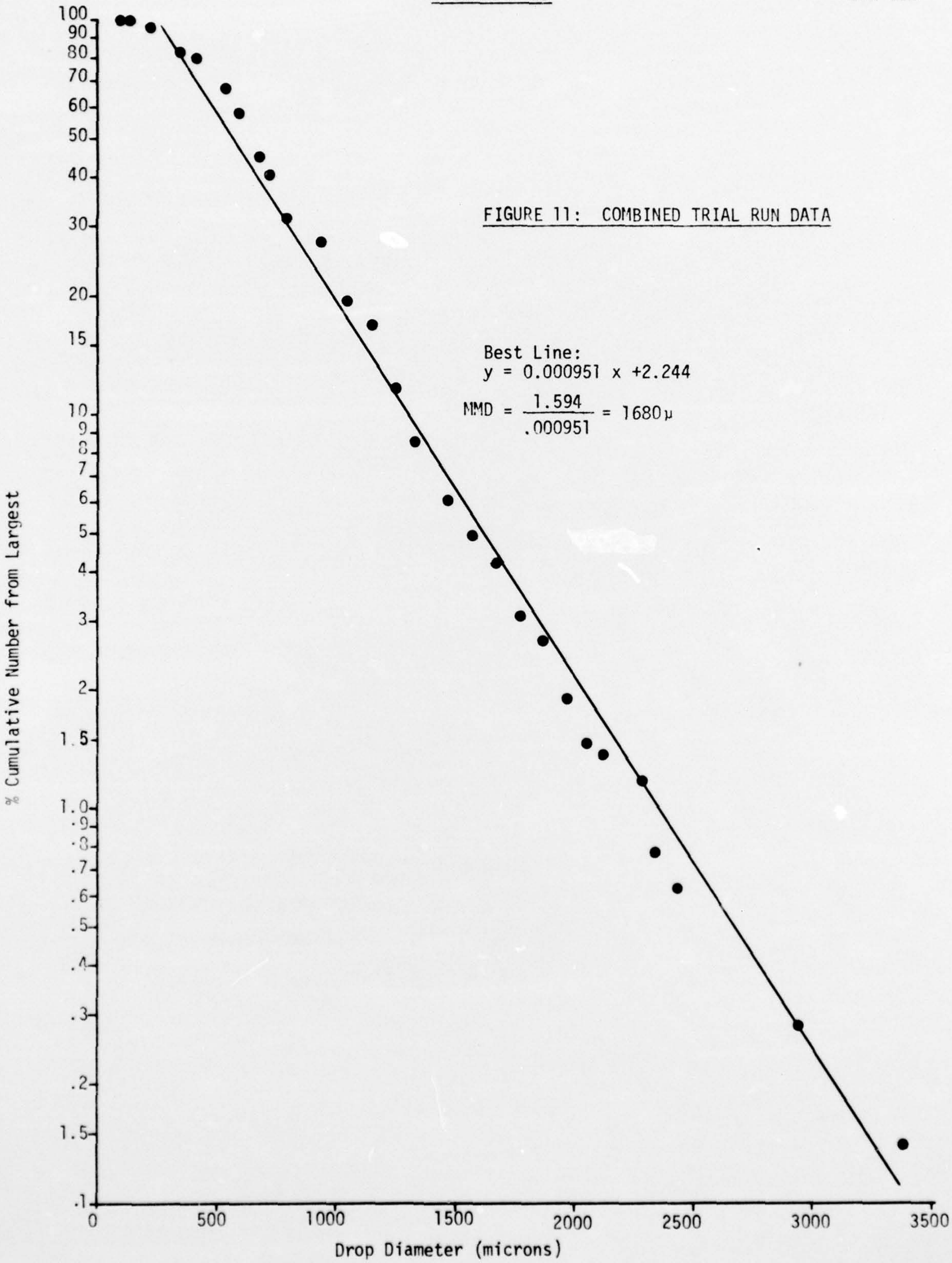


FIGURE 11: COMBINED TRIAL RUN DATA

Best Line:
$y = 0.000951\ x + 2.244$

$$MMD = \frac{1.594}{.000951} = 1680\mu$$

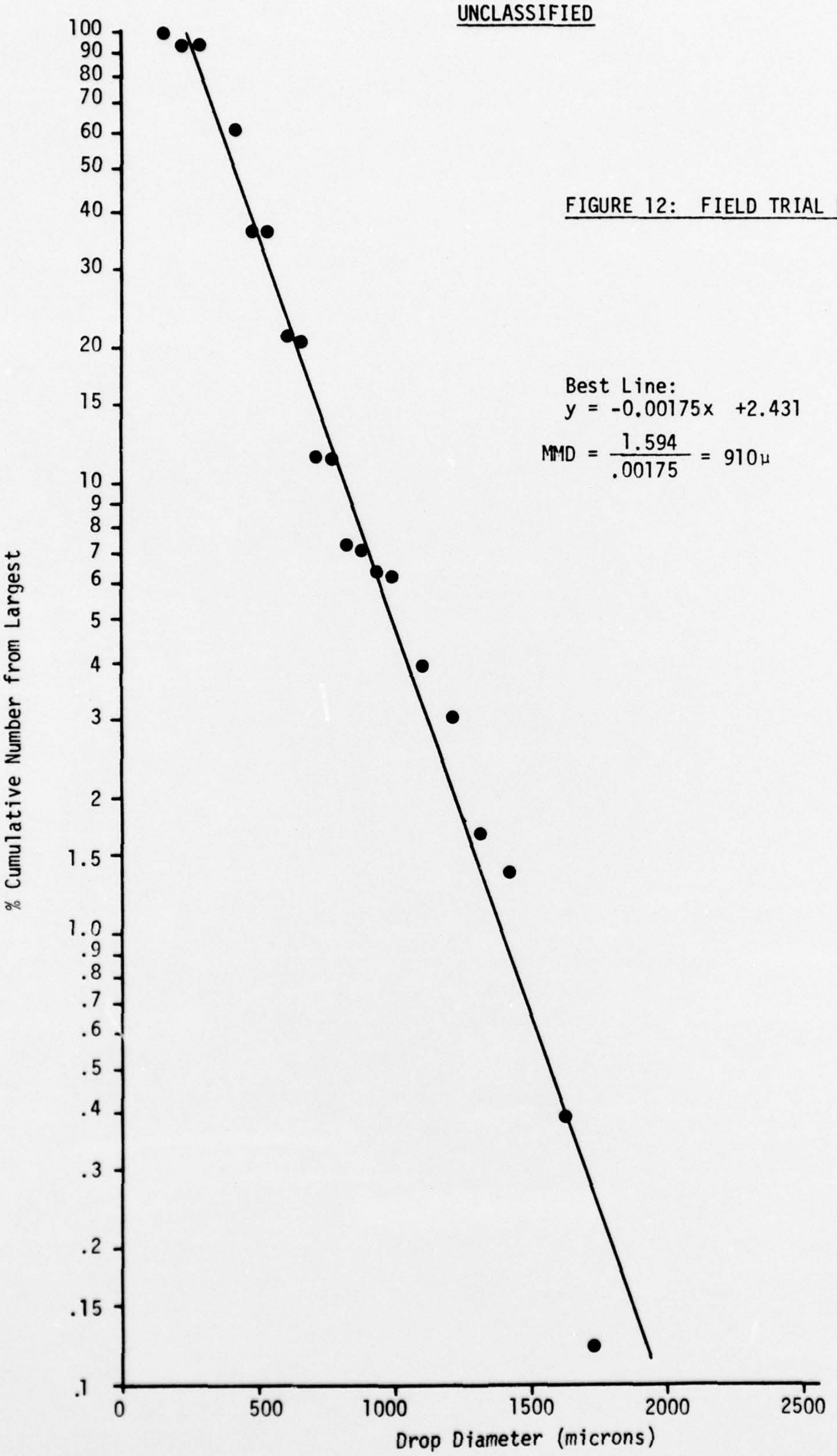


FIGURE 12: FIELD TRIAL DATA

Best Line:
$y = -0.00175x + 2.431$

$$\text{MMD} = \frac{1.594}{.00175} = 910\mu$$

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