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AN EVALUATION OF THE SUITABILITY OF
THE PARTICLE RESISTANCE / INERTIA PARAMETER
IN STUDYING THE DEPOSITIONAL BEHAVIOR OF COARSE AEROSOLS
presented by

Alan Robert Hays

has been accepted towards fulfillment
of the requirements for

MASTER OF SCIENCE degree in ENTOMOLOGY

Angus J. Howitt
Major professor

Date Mar. 18, 1982



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**AN EVALUATION OF THE SUITABILITY OF
THE PARTICLE RESISTANCE / INERTIA PARAMETER
IN STUDYING THE DEPOSITIONAL BEHAVIOR OF COURSE AEROSOLS**

BY

Alan Robert Hays

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

MASTER OF SCIENCE

Department of Entomology

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ABSTRACT

AN EVALUATION OF THE SUITABILITY OF THE PARTICLE RESISTANCE / INERTIA PARAMETER IN STUDYING THE DEPOSITIONAL BEHAVIOR OF COARSE AEROSOLS

By

Alan Robert Hays

Several dyes were evaluated for solubility in dioctyl phthalate, a non-volatile liquid carrier used in this study.

An inexpensive wind tunnel was constructed and used to increase control over air movements during testing of aerosol deposition.

Two methods were employed for estimating the distribution of droplet sizes in a non-volatile coarse aerosol. Teflon coated glass slides were compared to Teflon cylinders after each was adjusted by mathematical calculation for differential collection efficiencies, based on the droplet size, air velocity and cylindrical obstacle size.

Experiments were conducted with various sized cylinders, balsam fir branches and cylinders, single balsam fir trees, and a canopy of balsam fir trees in the wind tunnel.

It was found that the particle resistance / inertia parameter is a suitable tool for use in the estimation of coarse aerosol depositional behavior.

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INTRODUCTION

INTRODUCTION

While many factors involved in the application of a pesticide are not under the direct control of the applicator, there are a few factors which can be manipulated. In order to properly manipulate these factors, an understanding of how these factors influence the application is needed. Applications can be divided into two main categories, namely ground applications, and aerial applications.

During a ground application, some of the factors that can be manipulated include, timing, air velocity, droplet size distribution, and application rate. These are not all independent, since the droplet size relates to the application rate in many instances. Timing is dependent on the pest being controlled, but may also be influenced by environmental considerations.

Aerial applications are even more restricted in the number of factors under the applicator's control. To some degree, the applicator may choose a time with reasonably favorable environmental conditions. This choice may be limited by timing of the application for the pest. Additionally, if the application is to cover a large expanse, conditions may vary within the treatment area. While the applicator has some control over droplet size, this is limited due to weight considerations. For reasons of economy a relatively small droplet size distribution and low volume spray release is desirable, but this must be balanced against off target impact considerations. Flying height and speed are under the applicator's control, though influenced by terrain, locality and type of aircraft (Corschee R. G., et al. 1979).

It would be desirable to have an understanding of the interactions between environmental conditions, and the pesticide target. The primary environmental

factor is wind. The primary target factors include the impingement target structure and canopy structure.

Can information on the target and environmental conditions be used in predicting deposition behavior? Physicists early in this century developed a dimensionless behavior parameter, called the particle resistance / inertia parameter (particle parameter) (Richardson, 1960). This parameter allows the behavior of particles of differing size and under differing conditions to be compared. This parameter is related to the efficiency with which a given particle, approaching an obstacle, will collide with that obstacle. The efficiency of collision will be referred to as the collection efficiency, where the value of the collection efficiency must be between zero and one. This relationship states that the log of the particle parameter plotted against the collection efficiency forms a sigmoid curve (Herne, 1960).

The particle parameter is a function of the particles density, the spherical particle diameter, the fluid velocity, the absolute viscosity of the fluid, and the cylindrical or spherical obstacle diameter (Richardson, 1960). The particle parameter can be nearly any positive value. Values less than 0.1 indicate collection efficiencies near, but not equal to, zero. Values greater than 100 indicate collection efficiencies near unity.

The particle parameter is dimensionless, so that it permits universal use, regardless of the dimensions used in the calculation. Hence a particle parameter calculated by the English system is identical to the particle parameter calculated from the metric system for the same conditions. The only need for dimensional care is within a given calculation. That is if velocity is expressed in centimeters per second, then diameters should be expressed in centimeters. A more detailed discussion of the particle parameter will be given later.

The particle parameter is primarily used in calculations involving filters, turbine blades, and other situations in which the impingement of very small particles on various obstacles, is of concern (Richardson, 1960).

The strictly valid limits of the particle parameter are violated with particles larger than about thirty microns in diameter (Davies, 1960). Many such particles exist in pesticide aerosols (Ayers G. et al. 1979). The author suggests that even though the valid limits of the particle parameter are violated some predictive value might be gained through its use.

The use the author considered for the particle parameter in the analysis of pesticide applications was to predict the behavior of a proposed coarse aerosol. If the behavior of an aerosol can be predicted it is possible that the targeting of that aerosol might be feasible. This study was undertaken to demonstrate if the particle parameter is a valid tool in the targeting of a pesticide application.

The study was composed of developing techniques for the field measurement of droplet distributions, measurement of deposit, measurement of air velocities, and record and analyse data by computer. The particle resistance / inertia parameter was used in the adjustment of droplet size distributions for the tendency to collect large droplets more efficiently than small and in the regression of the data for its predictive value.

It was anticipated that conifer trees would be good candidates for the targeting of pesticides, particularly those pesticides applied by air. While the needles of conifers are seldom cylinders, they are small in cross section, being representable by a some mean cylindrical size. The branches and trunks tend to be cylindrical. These characteristics allow for the direct application of the particle parameter with little adjustment to the data. The Balsam Fir was chosen so the data could be of use in the CANUSA cooperative study of the Spruce Budworm.

DEFINITION OF THE PROBLEM

DEFINITION OF THE PROBLEM

Controversy has existed for some time over the optimum droplet size (Mass Median Diameter of a distribution) which should be used in pesticide applications. Professor Himel of the University of Georgia (Himel, 1967) advocated the use of small droplets. Yates and Akesson (1974) tended to advocate the reverse. Research by the Agricultural Aviation Research Unit at the Cranfield Institute of Technology (Lawson and Uk, 1979), tended to support Himel.

The disagreement follows this line; Yates believes that small droplets are less efficient and more prone to drift while Himel indicates the larger drops are not controlling the pest because most are deposited on the ground.

Both groups have points in their favor. It should not be suprising that the smaller the droplet the more likely it is to drift. It is equally clear that the larger a droplet is the steeper its descent to the ground from its release point. Clearly the steeper the descent trajectory the fewer the opportunities for impingement will be afforded to a descending particle. If on its descent through the vicinity of an obstacle a particle fails to impinge on that obstacle, then the particle may approach another obstacle, be lofted to altitudes lacking obstacles, or be deposited on the ground.

If the descent trajectories of two differing particles are considered, the particle with the steeper descent will demonstrate a greater tendency to be deposited on the ground. The particle with the more gradual descent will tend to travel a more horizontal path and thus have increasing numbers of obstacles within its path.

The same forces causing small particles to descend more gradually than large particles cause these smaller particles increasingly to follow air currents around obstacles. These forces are related to the surface area divided by the mass ratio which increases with decreasing spherical particle size. The surface area can be viewed as a measure of the amount of frictional contact between a particle and the air. The mass is directly related to the inertia of the particle so that while a more horizontal trajectory (i.e. high frictional contact with the air, and low inertia) increases the number of opportunities for impingement, the same forces decrease the likelihood of impingement on a given single obstacle.

These offsetting factors must result in an optimum particle size for a given set of conditions and collection of obstacles in an aerosols path. Particles less than the optimum would tend to flow around obstacles resulting in such a low collection efficiency as to offset the increased number of opportunities for impingement. Particles larger than the optimum would tend to have higher collection efficiencies but fewer opportunities for impingement. The optimum size can be considered a combined optimum resulting from the product of the collection efficiency and the number of opportunities for impingement.

The problem was to find a more rigorous way of comparing and predicting depositional behavior. The previously mentioned particle resistance / inertia parameter seemed to be the best available physical parameter for describing the behavior of fluid born particles. This parameter appeared to be easily adaptable to the restricted data available in most field research.

By quantifying the behavior of a pesticide aerosol it might be possible to resolve some of the controversy surrounding pesticide applications.

A series of experiments were proposed to determine if the particle parameter was usefull in discribing a pesticide aerosols behavior. To the authors knowledge no

publications exist on the use of the particle parameter in describing pesticide or coarse aerosol behavior.

A preliminary theoretical model for the gross behavior of a pesticide aerosol descending from an aerial application through a coniferous forest has been worked out at the University of Michigan (Hays, P. B. and A. R. Hays, 1980). The model has been computer tested with reasonable results. The model uses a derivation of the Renold's number, which is nearly identical to the particle parameter. The basic construction of the model is similar to Beer's law of the extinction of light in the atmosphere.

METHODS FOR DEVELOPING TECHNIQUES

METHODS FOR DEVELOPING TECHNIQUES

Introduction

It was anticipated that to rely on natural winds in initial tests would result in an undue variability in air velocity between treatment runs. In order to avoid this various methods of artificially producing wind were considered. The goal in artificially producing wind for the study would be to balance repeatability of air velocity with the cost of attaining that repeatability.

Another consideration in this type of study was to simplify the problem of changing droplet size due to evaporation. It was desired to produce droplets composed of a liquid non-volatile core beyond which no evaporation would occur. Such a material was used by Hogmire (1979). The material was Dioctyl Phthalate, a vacuum pump oil and plasticizer.

Measurements needed during the test process included air velocity, some measure of turbulence, droplet distribution size and flux determinations and dye tracers for a measure of deposition. Additionally the dye needed to be recoverable from the collecting obstacles.

Methods for Wind Production and Measurement

Wind Tunnel Design

The use of a wind machine was considered for the production of repeatable air flow. Any attempt to produce repeatable air flow while exposed to natural air currents would require relatively high air velocities to overcome these natural air

currents. Furthermore the cost of a large wind machine was considered prohibitive.

A turbine fan was available from the Michigan State University Department of Agricultural Engineering. It consisted of a Joy Axivane Fan, belt driven, equipped with an outlet cone with ten degrees of divergence per side. The fan was manufactured by Joy Manufacturing Company, Air Moving Products division, 338 south broadway, New Philadelphia, Ohio 44663.

The design of the turbine was more suitable as a suction device to operate a wind tunnel than to produce direct wind. An open air wind tunnel was a reasonably cost effective compromise when inexpensive construction materials were proposed.

The wind tunnel was designed based on the estimated capacity of the turbine. This capacity was estimated by the manufacturer as 21 cubic meters per second. By constructing the tunnel 2.13 meters wide and 2.44 meters high inside the estimated maximum wind velocity was predicted to be 4 meters per second. The main portion of the tunnel, which was 17 meters long, was constructed to those dimensions.

The tunnel was oriented with the intake drawing air from the north and the discharge to the south. The entrance was expanded to a square 3.66 meters. This was accomplished by smoothly bending the skin material into a sigmoid shape beginning with an opening of 3.66 meters square and reducing the opening to 2.13 by 2.44 meters. This reduction was made using the top and two sides with the ground level remaining linear. This enlarged entrance was attached to a semi-cylindrical quonset building.

The quonset building was 9.1 meters wide by 4.6 meters high, by approximately 18.3 meters long. This building runs north to south with a 3.5 meters wide and 4.0 meters high entrance to the north and the tunnel exiting to the south.

The quonset was used as a flow stabilizing area of large volume. The fluxuations in natural air currents stabilize somewhat due to the low air velocities

in this large area. As the air entered the tunnel mouth it was required to pass through a progressively decreasing cross sectional area so that the air accelerated into the main tunnel area. The flow was again allowed to stabilize through the main tunnel before reaching the test section.

The test section was constructed so the aerosol could be released in the main tunnel or in a drying tunnel (0.52 M deep by 1.22 M wide by 3 M high), oriented vertically out of the top of the main tunnel. The top of the drying tunnel was blocked except for four 7.62 centimeter diameter openings, in which four TX1 nozzles (Spraying Systems Inc.) were located. The pressure differential between the outside and the inside of the tunnel caused the air to enter these openings turbulently resulting in a mixing of the aerosol as it descended the length of the drying tunnel. The drying tunnel will be discussed later. See Figure 1 for an overall external view of the wind tunnel. Figure 2 shows the entrance to the tunnel. Figure 3 shows a cutaway view of the area just upwind of the test section.

Down wind (south) of the vertical tunnel the sample section 4.9 meters long, was followed by the final 2.44 meters of the full size section of the main tunnel. The last section of the tunnel was constructed to reduce the main tunnel to the size of the turbine inlet. This section was constructed 2.3 meters long reducing the tunnel size to 1.22 meters on a side by tapering four sides (top, ground, east and west sides).

The turbine was attached to this last section with the inlet 1.22 meters in diameter. The outlet was 2.44 meters south of the inlet being 1.52 meters in diameter. The turbine was powered by an air cooled four cylinder Wisconsin type G engine.

During the testing process it became obvious that natural pressure



Figure 1. Wind Tunnel (overall view)



Figure 2. Wind Tunnel Entrance

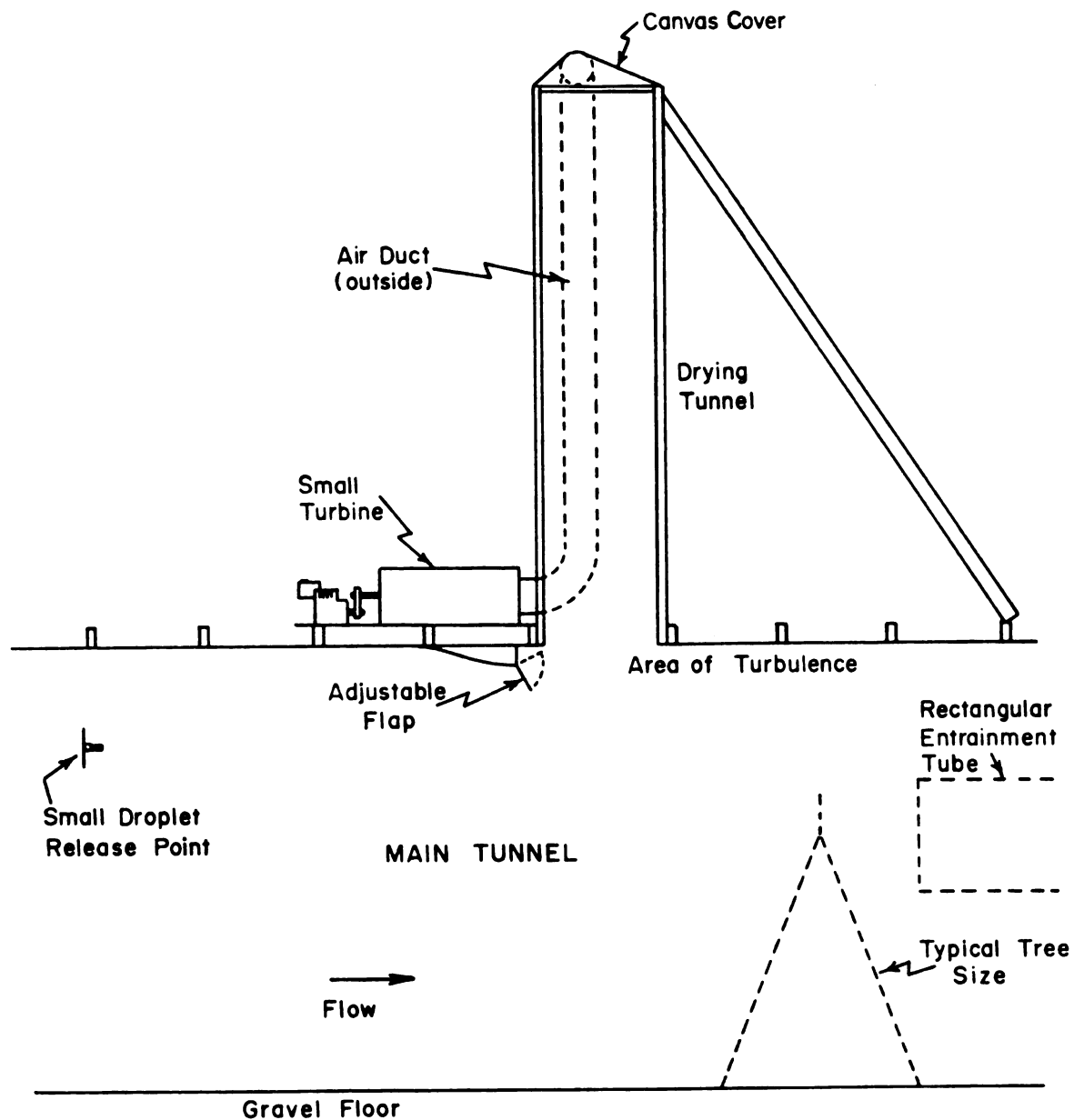


Figure 3. Cutaway View of Drying Tunnel and Main Tunnel Connection

differences were not sufficient to bring the aerosol through the vertical tunnel at high main tunnel velocities. A small turbine was added to the vertical drying tunnel to assist in forcing the the aerosol to the test level in the main tunnel. Additionally a flap was added to the top inside of the main tunnel just upwind of the verticle tunnel entrance. This flap served the purpose of creating an adjustable area of turbulence above the sample area. This turbulence aided in the mixing and dispersion of the aerosol into a more uniform flux throughout the sample areas crossection.

The lowest main tunnel velocity was limited by the engine idle speed. In order to decrease the minimum velocity at engine idle, a partial block was made to restrict the turbine inlet. This restriction caused a greater pressure differential across the turbine blades so that the reduced efficiency in the turbine allowed very low air velocities to be created in the tunnel.

Wind Tunnel Construction

The wind tunnel was constructed similar to a conventional building except the structural material was placed on the outside. High density pressed exterior fiberboard was used for the inside skin. The structural lumber was placed 61 centimeters on center on the outside. The walls were secured in place with buttresses 2.44 meters on center, on the outside. The floor of the tunnel was constructed of raked gravel. The capabilities of the tunnel are summarized in

Table 1.

Table 1. Summary of Wind Tunnel Velocity vs Engine RPM Relationship

	Height Above Floor			Engine RPM	50% Block	Flap Position	Canopy In Place
	136 cm	84 cm	35 cm				
Mean mm/sec	1788	2193	2151				
St. Dev.	248.1	181.6	187.6	610	NO	Lowered	NO
Rel. Int. ^x	0.134	0.046	0.050				
Mean mm/sec	3211	4141	4029				
St. Dev.	499.6	178.5	268.6	1200	NO	Lowered	NO
Rel. Int.	0.156	0.041	0.065				
Mean mm/sec	3742	5046	4930				
St. Dev.	635.9	196.1	326.1	1510	NO	Lowered	NO
Rel. Int.	0.178	0.039	0.066				
Mean mm/sec	2811	1971	1938				
St. Dev.	83.8	92.8	128.7	600	NO	Raised	NO
Rel. Int.	0.042	0.047	0.066				
Mean mm/sec	3526	3505	3347				
St. Dev.	128.3	135.8	257.5	1100	NO	Raised	NO
Rel. Int.	0.036	0.039	0.077				
Mean mm/sec	4753	4620	4383				
St. Dev.	219.4	288.2	324.9	1525	NO	Raised	NO
Rel. Int.	0.046	0.045	0.074				
Mean mm/sec	4298	1142	919				
St. Dev.	339.6	46.4	38.4	590	NO	Raised	YES
Rel. Int.	0.079	0.041	0.041				
Mean mm/sec	2423	713	573				
St. Dev.	97.7	41.9	28.5	845	YES	Raised	YES
Rel. Int.	0.040	0.059	0.050				
Mean mm/sec	3243	1486	1081				
St. Dev.	484.9	73.9	32.0	1060	NO	Raised	YES
Rel. Int.	0.15	0.050	0.030				

^x Rel. Int. = Relative Turbulent Intensity.

Methods for Wind Measurements

Wind Sensors

In the wind tunnel air velocity was measured using three miniature cup anemometers. Miniature cup anemometers were chosen because the electronics in the sensor were relatively well protected from contact with the spray solution. The anemometers chosen were model 011-1 miniature cup anemometers manufactured by Climet Instrument Co., Division of Wehr Corporation, 1320 West Colton Avenue, Redland, California. They were equipped with Teflon wind cups for resistance to the chemicals in the spray solution.

It should be noted here that the Teflon cups were more resistant to the spray solution than to some of the solvents used to rinse the spray solution off. For this reason it was determined that the cups should either not be rinsed or only rinsed with ethanol. Dichloromethane and acetone tended to make the cups brittle after several rinsings.

These anemometers were sensitive to low air velocities with a threshold of approximately 26.8 centimeters per second. The response distance constant is 152 centimeters of flow. Since the anemometer responds to a sudden change in the air flow exponentially, the distance constant is defined as the distance the air flows for the anemometer to reach $1 - e^{-1}$ (~63%) of the true flow (Heldman 1981). The accuracy of the anemometers were the greater of plus or minus 2.64 centimeters per second or one percent of the reading.

The conversion of rotational speed to electronic signal is achieved by optoelectronic means. A light emitting diode-phototransistor pair was used to detect slots in a rotating disk. The disk rotates at the same speed as the cup assembly. There were 100 slots in the circumference of the disk. The output signal

is a square wave with ten volts of change throughout one cycle peak to peak. The frequency of the output wave is proportional to wind speed by the following relation (Climet 1980):

$$\text{mm/sec} = 1000 \times ((10 \times D(i,j) / P(0) + 30.11) / 71.74)$$

Where:

$D(i,j)$ = the raw output pulses per sample interval and i and j are matrix subscripts to distinguish anemometer and time interval respectively.

$P(0)$ = sample interval

Anemometer Data Collection Device

A means of recording the output of the anemometers was needed. Commercially available interface devices generally record data on punched paper tape or in graphic form on a strip chart. Some use electronic data smoothing to produce a collateral graph of smoothed data. Some produce an electronically generated collateral turbulence graph, however equipment with this level of sophistication was very costly. The less sophisticated models would require considerable manual data manipulation. For this study it was desired to directly store the data on magnetic cassette, readable by computer.

An inexpensive counting device was designed by the author that would display by light emitting diode the number of pulses received by counters over adjustable time intervals. The data was to be recorded by photographic means but this still would require considerable manual data analysis. The author then discussed the data collection with Mr. Tim Childs of the MSU Department Computer Sciences, Engineering Technical Services. Mr. Childs was confident he could devise a data collection device, low in cost, operated by computer, and flexible enough to have time

intervals under software control.

Mr. Childs designed and build such a device based on the Intel 8253 Programmable Interval Timer integrated circuit. The device operated as an extension of the computer memory (memory mapped) or by input / output ports. The device operated with hardware timing control, software directed. The schematics for this device, reproduced from schematics provided by Mr. Childs, are reproduced in Appendix F.

The device counted the number of anemometer output pulses received over software predetermined sample intervals. The counting sample interval could be varied from 0.1 seconds to 6.5 seconds in 0.1 second increments. The sample repeat interval could be varied from 1.0 seconds to 9.0 seconds in 1.0 second intervals. The total overall counting interval could be varied from 1.0 minutes to the limit of computer memory as determined by the repeat interval and number of counters being used.

The device is currently being revised by Mr. Childs to increase the potential number of anemometers from four to seven and rework the hardware clock and count inhibit circuits. The existing clock created problems with changing clock speed. The initial hardware clock was operated by a number 555 (National Semiconductor) timer with the clock frequency set by a potentiometer. This timer was excessively sensitive to temperature changes causing a tendency to drift until temperature stability was reached. As a result it required one or more hours for a stable clock frequency to be reached. A crystal clock is being installed to correct this problem.

The count inhibit circuit shown in Appendix F, Figure F3 worked in the first prototype version but subsequent revisions inadvertently disabled it effectiveness. This circuit is also being revised.

The operational software, which was written by Mr. David Zeitler (MSU

Department of Computer Science, Applications Programming) to interface the counting device with the computer, will be discussed under "Computer Programs Employed".

The author believes this device has great potential for many applications. Any application in which discrete pulses or events translatable into pulses, required to be recorded, could be easily recorded by this device and a microcomputer.

Determining a Suitable Dye Tracer

Prospective Dyes

A dye tracer was needed to allow the amount of coarse aerosol deposit to be easily determined. The use of a dye tracer was demonstrated by Hogmire (1979) to be a rapid and efficient method for determining spray deposit. Hogmire used a water carrier for his dye. In this study a non-volatile carrier was desired, so that low volume spray techniques could be evaluated. All non-volatile carriers considered were oils or oil like liquids. This created a problem in locating dyes with suitable solubility in oils.

The Colour Index (1956) and later editions were consulted. The Colour Index lists several hundred dyes indicating many of their uses and solubility properties. Many dyes listed in the "Solvent Dye" section were considered candidate dyes.

A list of prospective dyes was compiled and their respective manufacturers were contacted. The manufacturers were requested to furnish samples and were also asked for suggestions relative to additional or new dyes that might be highly soluble in oils. One additional dye was listed (Automate Red B) in the USDA technical bulletin number 1596 (Barry, J. W., et al. 1978). This last dye led to a family of dyes which had promising properties.

The Dye Carriers

The carriers considered were dioctyl phthalate (DOP) #585 diesel oil and mineral oil. The complete list of dye samples received for testing in these solvents may be found in Table 2. These dyes did not all arrive at the same time and are listed in the order of their arrival.

Two of the three carriers evaluated, DOP and mineral oil, were chosen for their non-volatility. The third # 585 diesel oil was chosen because it is used as a carrier for aerial pesticide applications (Nigham 1979).

Properties of the Dyes

As dyes arrived for evaluation gross solubility tests were conducted with the three chosen carriers. This served to rapidly eliminate those dyes with little potential. A small amount of the dye was placed in a two milliliter portion of the three carriers. The initial results for the first twenty one dyes are shown in Table 3. The resulting eight dyes with good potential were tested further.

These eight dyes were evaluated for their absorption maximum in the visible wavelength range. This was done with a Bausch and Lomb Spectronic 20 colorimeter or a Beckman DB spectrophotometer. The results of those determinations are shown in Table 4. Once the absorption peak was determined the best solvent among acetone, ethanol, benzene, hexane, diethyl ether, and dichloromethane was determined. This information is listed in Table 5.

To evaluate the best solvent each dye tested was dissolved to saturation in each of the test solvents. A one microliter portion of the saturated solution was injected into three milliliters of acetone. The resulting solution was evaluated for absorbance at the dye absorption peak in a colorimeter. When necessary the sample was serially diluted so a reading greater than fifteen percent transmission could be

Table 2. Dyes Evaluated

Dye Number .	Manufacturers Dye Name	Colour Index Dye Name	Manufacturer of Dye
1	Orasol Yellow 2 RLN	# 89 Solvent Yellow	Ciba-Geigy
2	Orasol Yellow 2 GLN	—	Ciba-Geigy
3	Orasol Orange RLN	# 59 Solvent Orange	Ciba-Geigy
4	Orasol Red G	#125 Solvent Red	Ciba-Geigy
5	Orasol Violet RN	# 24 Solvent Violet	Ciba-Geigy
6	Nitro Fast Red B 2094-100-3	—	Sandoz Col. & Chemical
7	Acetosol Fire Red 3 GLS 1040-100-1	—	Sandoz Col. & Chemical
8	Iosol Red	—	Buffalo Color Co.
9	Iosol Red 4B	—	Buffalo Color Co.
10	Iosol Yellow	—	Buffalo Color Co.
11	Iosol Orange	—	Buffalo Color Co.
12	Iosol Black	—	Buffalo Color Co.
13	Du Pont Oil Red	—	E. I. Du Pont
14	Red PL	—	Dyken
15	Blue PF	—	Dyken
16	Luxol Fast Yellow TN	—	E. I. Du Pont
17	Oil Red Flakes	—	E. I. Du Pont
18	Rhodamine B Extra	—	E. I. Du Pont
19	Oil Blue A	—	E. I. Du Pont
20	Luxol Fast Blue ARN	—	E. I. Du Pont
21	Oil Brown N	# 22 Solvent Brown	E. I. Du Pont
22	Automate Red	—	Morton Chemical
23	Orasol Navy Blue 2 RB 90Z	—	Ciba-Geigy
24	Orasol Orange RLN	—	Ciba-Geigy
25	Automate Yellow # 8	—	Morton Chemical
26	Automate Blue # 8	—	Morton Chemical
27	Automate Orange # 3	—	Morton Chemical
28	Automate Purple RS	—	Morton Chemical
29	Morton Yellow	—	Morton Chemical
30	Morton Blue	—	Morton Chemical
31	Perox Yellow	—	Morton Chemical
32	Oil Bronze	—	E. I. Du Pont

Table 3. Gross Solubility Screening of the First Twenty One Dyes

Dye Number	Manufacturers Dye Name	Solvent		
		# 585 Diesel	DOP	Mineral Oil
1	Orasol Yellow 2 RLN	0 ^x	0	0
2	Orasol Yellow 2 GLN	0	0	0
3	Orasol Orange RLN	0	0	0
4	Orasol Red G	0	X ^x	0
5	Orasol Violet RN	X	0	0
6	Nitro Fast Red B 2094-100-3	X	0	0
7	Acetosol Fire Red 3 GLS 1040-100-1	0	0	0
8	Iosol Red	0	0	0
9	Iosol Red 4B	0	0	0
10	Iosol Yellow	0	0	0
11	Iosol Orange	0	0	0
12	Iosol Black	0	0	0
13	Du Pont Oil Red	X	0	0
14	Red PL	X	X	0
15	Blue PF	X	X	0
16	Luxol Fast Yellow TN	0	0	0
17	Oil Red Flakes	0	0	0
18	Rhodamine B Extra	0	0	0
19	Oil Blue A	X	X	X
20	Luxol Fast Blue ARN	0	0	0
21	Oil Brown N	X	X	X

0 Indicates poor solubility testing discontinued.

X Indicates dye shows potential continue with further testing.

Table 4. Absorbance Maxima* for Dyes Passing the Gross Solubility Screening, up to Dye 22. (Numbers in table are % transmission)

Wave Length (nm)	Dye Number								
	4	5	6	13	14	15	19	21	22
420	89	71	57	59	63	88	96	23	67
430	88	72	56	58					
440	88	73	54	56	60	88	97	28	65
450	86	72	52	54					
460	85	69	50	52	55	90	98	32	62
470	85	67	47						
480	85	63	42	44	47	89	97	32	55
490	84	60	38						
500	85	56	34	35	38	87	93	38	46
510	85	52	30	31	35				42
520	86	50	x 29	x 30	x 33	82	89	23	39
530	87	46	29	30	33			22	x 38
540	87	43	31	33	35	78	81	x 21	38
550	83	41	35	37	39	74	76	21	41
560	x 77	40	42	44	47	72	72	22	46
570	80	39	54			71	68	34	
580	88	x 38	68	73	73	70	63	27	66
590	95	38	81			68	56		
600	99	40	89	91	91	x 68	51	38	90
610	100	46	94			69	x 51		
620	100	59	96	95	98	72	55	54	99
630	100	71	96			74	55		
640	100	79	96	95	97	77	51	73	99
650	100	84	95				49	81	

* The percent transmission data in this table cannot be compared between columns.

Table 5. Best Solvents and Absorbance vs. Concentration Slope for Dyes Passing the Gross Solubility Screening up to Dye 21.

Dye Number	Manufacturers Dye Name	Best Solvent	Next Best Solvent	Regression Slope
4	Orasol Red G	Dichloromethane	Acetone	1.05
5	Orasol Violet RN	Acetone	Ethanol	1.69
6	Nitro Fast Red B 2094-100-3	Dichloromethane	Xylene	1.79
13	Du Pont Oil Red	Dichloromethane	Xylene	0.321
14	Red PL	Dichloromethane	Benzene	0.485
15	Blue PF	Dichloromethane	Benzene	0.106
19	Oil Blue A	Dichloromethane	Benzene	0.374
21	Oil Brown N	Dichloromethane	Xylene	0.534

made. Fifteen percent transmission was arbitrarily chosen as lower limit below which accuracy was considered limited. The solvent resulting in the highest absorbance was considered the best tested solvent.

The information on the best solvent and the absorption peak for of each of these eight dyes were used to evaluate the approximate slope of the relationship between dye concentration and absorbance. This determination was sought to aid in determining the dye with the greatest change in absorbance for a given change in concentration. This was only to be used if two dyes with similar properties were available and a best choice was needed. This essentially could be used as an indicator of sensitivity in determining deposit. The slopes of the relations are listed in Table 5.

When dye number 22 arrived it was noted that the dye was predissolved in a solvent. It was considered possible that predissolving the dry dyes in their respective best solvent might improve solubility in the carrier. A series of tests were conducted to evaluate this on 6 of the better dyes. Table 5 indicates the percent increase in solubility due to predissolving the dye in its best solvent. The evaluation applies to # 585 diesel oil.

Of the first twenty one dyes, dye number 21 demonstrated the most promise. Dye number 22 (Automate Red B) was rapidly evaluated and demonstrated such potential (due in part, to its liquid state) that it was immediately placed in the detailed evaluation process. Dyes number 21 and 22 (newly arrived) were evaluated for recovery from balsam fir.

Dye Recovery From Balsam Fir

In order to evaluate the recovery of a dye-carrier solution from foliage it was necessary to determine if a branch of balsam fir could be extracted without excess

background interference from branch organics. From experience with the dye solubility experiments only two solvents acetone and dichloromethane were considered suitable to remove the dyes from foliage.

Six centimeter portions of branch were extracted twenty minutes in twenty milliliters of each solution, with replications, and the resulting absorption spectra examined. Acetone gave the lowest interfering absorption after twenty minutes in solvent. This evaluation was also done on white spruce, with the same result.

Dye tracers (Oil Brown N, and Automate Red B) were used to evaluate the percent recovery of spray solution from the foliage of balsam fir. A solution of dye and the carriers DOP and # 585 diesel oil were prepared using eighty milligrams dye to one milliliter of carrier. The resulting solution was applied to various stem and foliage parts of balsam fir branches. The evaluations were conducted on the upper and lower surfaces of needles and stems of first, second and third year growth. The solutions were applied with a microliter syringe at a rate of four microliters per six centimeter branch part. All tests were replicated three or four times.

The branches, with the dye-carrier solution applied, were extracted in twenty milliliters of acetone. With the diesel oil carrier an immediate loss of dye to the needles was evident, with only 77% recovery hence diesel oil was abandoned as a carrier of the dye. In addition to the poor recovery diesel oil was also too volatile for the purposes of this study. Further testing was conducted with DOP as the carrier.

Oil Brown N at a rate of fifty milligrams per milliliter of DOP was used to evaluate the recovery of a dye-DOP solution. The same procedure was followed as for the dye-diesel solution. It was noted that the under side of second year and older needles gave the lowest recovery. Good recovery was found from all other parts including the stems. In an effort to consider all possibilities, recoveries were

attempted in reduced room light to reduce the photosynthetic rate and possibly improve recovery. Recovery greatly improved so that nearly all the dye was recovered. A series of tests in reduced room light were conducted with the results shown in Table 6.

Field evaluations were conducted on live balsam fir in various levels of light. The same losses occurred during high light levels but at low light levels recovery was excellent. Light level measurements were not taken due to a lack of equipment. The level of light encountered after 7:00 PM in late september was sufficiently reduced to yield excellent recovery. The author believes the low angle of the sun during this time period resulted in a sufficiently reduced radiant flux so that photosynthetic activity was reduced. This reduced plant activity resulted in a closing of the stomata on the under sides of the needles. With the stomata closed dye was less likely to enter the needles via these structures.

As mentioned earlier, the Automate Red dye had excellent solubility properties. Four new Automate dyes were available near the conclusion of these evaluations. Two of these Automate Yellow #8 and Automate Blue # 8 were highly soluble in DOP and resolvable spectrophotometrically. These two dyes were recoverable from fir foliage under reduced light levels. These two dyes were the most satisfactory for this study and were selected for the tracers used in later wind tunnel tests. Table 7 gives a summary of the recoveries of the Automate dyes.

Dye Recovery From Filters

The dyes were recoverable from the foliage but some obstacles used in the tunnel were covered with filter paper. In addition, the flux filter, (discussed later), was a high density glass fiber filter media. Recoveries were evaluated on these by placing four microliters of dye-DOP solution on aluminum foil then placing the foil in

Table 6. Comparison of Dye Recovery in High vs. Low Light Levels From Balsam Fir.

Location	High Light Level			Low Light Level		
	Mean Absorbance	St. Dev.	Mean % Recovery	Mean Absorbance	St. Dev.	Mean % Recovery
Top 1st year needles	0.528	0.026	103	0.482	0.011	94
Bottom 1st year needles	—	—	—	0.523	0.0	102
Top 2nd year needles	0.478	0.033	93	0.496	0.027	96
Bottom 2nd year needles	0.364	0.114	71	0.496	0.027	95
Stems	0.505	0.031	98	0.467	0.036	91
Standards	0.514	0.018	—	0.514	0.018	—

Table 7. Recovery Determination of Automate Yellow and Blue From Balsam Fir in Low Light.

(Figures in the table are microliters/milliliter wash, all washes 20 milliliters)

	Needles					
	Top 1st year	Bottom 1st year	Top 2nd year	Bottom 2nd year	Stems	Standards
Yellow						
Rep 1	0.02931	0.02836	0.02980	0.02836	0.02661	0.02956
Rep 2	0.02931	0.02931	0.02931	0.02791	0.02931	0.02956
Rep 3	0.03031	0.02931	0.02931	0.02747	0.02931	0.02861
Rep 4	0.02931	0.02980	0.02931	0.02791	0.02931	—
Mean	0.02956 a ^x	0.02920 ab	0.02943 a	0.02791 b	0.02864 ab	0.02924
ab						
St. Dev.	0.00050	0.00060	0.00025	0.00036	0.00135	0.0054
% Recovery	101	95	97	101	100	
Blue						
Rep 1	0.02692	0.02627		0.02660		0.02615
Rep 2	0.02660	0.02660		0.02627		0.02746
Rep 3	0.02660	0.02595		0.02595		0.02680
Rep 4	0.02692	0.02660		—		0.02680
Mean	0.02676 a	0.02636 a		0.02627 a		0.02680
a						
St. Dev.	0.00018	0.00031		0.00033		0.00053
% Recovery	100	98		98		

^x Means followed by the same letter are not significantly different, as determined by the SNKRT. Alpha = 0.10.

contact with the media to be tested. The dye-DOP solution was allowed to soak into the media for several minutes then the media and foil were then extracted in acetone. A visible stain was evident on the media in all cases. Dichloromethane was then tried with complete recovery of the dye. Dichloromethane was chosen as the extraction solvent for the filter paper and flux filters.

Dye Standard Curves

Standard curves of absorbance versus concentration were determined for the yellow and blue Automate dyes. These data are presented in tables 8 and 9. These data were regressed for use in a computer with the regression statistics indicated in tables 8 and 9 also. The yellow dye data were regressed by linear regression and the blue by curvilinear regression. In both cases the regressions resulted in a good fit.

Once a dye-DOP solution, standard curves and the recovery techniques had been developed, a system to produce differing aerosols in the wind tunnel was needed. It was desirable to produce two aerosols, each with a different dye tracer, that could be released in the wind tunnel.

Tunnel-Dye Solution Interaction

The Spray System

The system developed for pressurizing the spray was composed of two tanks with a regulated air pressure inlet in the top and piping to conduct the solution to their respective nozzle sets exiting the bottom of the tanks.

The blue solution was always sprayed from the south tank and the yellow solution from the north tank. Pressure was applied to the top of these tanks by compressed air passing through an adjustable pressure regulator. The pressure was maintained at a constant 8440 grams per square centimeter (~120 psi).

Table 8. Standard Curve of Absorbance vs Concentration for Automate Yellow # 8 Dye

Dilution number	Dye ul/ml	Resultant total volume	420 nm absorbance	650 nm absorbance
1	0.4	10 ml	--	0.0177
2	0.2	10	--	0.0101
3	0.1	10	--	0.0531
4	0.05	10	1.237	0.0044
5	0.025	10	0.648	0.00218
6	0.0125	10	0.328	0.0
7	6.25 E-3	10	0.167	0.0
8	3.125 E-3	10	0.0888	0.0
9	1.563 E-3	10	0.0458	0.0
10	7.813 E-4	20	0.02	0.0
11	0.0364	6	0.921	0.0044
12	0.0121	10	0.314	0.00435
13	4.05 E-3	15	0.109	0.0

Regression Results : $r = 0.9998$

Regression Function : $\text{ul Dye} = 0.04029 \times (\text{Absorbance @ 420 nm}) - 4.49 \text{ E-4}$

Table 9. Standard Curve of Absorbance vs Concentration for Automate Blue # 8 Dye

Dilution number	Dye ul/ml	Resultant total volume	420 nm absorbance	650 nm absorbance
1	0.395	10 ml	0.644	--
2	0.1975	10	0.284	2.301
3	0.09875	10	0.149	1.466
4	0.04938	10	0.0757	0.921
5	0.02469	10	0.0362	0.393
6	0.01234	10	0.0186	0.190
7	6.172 E-3	10	0.011	0.102
8	3.086 E-3	10	0.0066	0.053
9	1.543 E-3	10	0.0022	0.0269
10	7.772 E-3	20	0.0	0.0132
11	0.01197	10	0.0177	0.1972
12	0.00399	10	0.0044	0.0680
13	4.05 E-3	15	0.109	0.0

Regression Results : $R = 0.99993$

Regression Function : $\text{Abs} = \text{Absorbance}$

$\text{ul Dye} = 2.9803 + (4.2895 \text{ E-2} \times (\text{Abs @ 650})) + (8.2642 \text{ E-3} \times \text{Abs}^2) + (4.2909 \text{ E-3} \times \text{Abs}^3)$

Early in the operation of the spray system a problem of plugged nozzles caused a non-uniform spray flux to be produced. This problem was corrected by installing screen traps at the pressure tank outlets. The screens were thirty nine mesh to the centimeter (100 to the inch). Thirty nine mesh screens were also used at the nozzles. Apparently the double screening was sufficient to reduce clogging although occasional clogging still occurred later causing the need for rejection of some runs.

Another problem encountered was difficulty in rapidly shutting off the spray. It was impossible to remove all the air from the spray lines. The trapped air was compressed during the time pressure was actively applied to the nozzles. When the outlet of the pressure tanks were shut off this pressurized air expanded resulting in a gradually reducing spray pressure at the nozzles. This caused a continued dribble lasting for several minutes in some cases. The very large droplets produced occasionally found their way to the sample locations resulting in unreliable data.

To solve this problem vents were installed at the lowest points in the spray piping. These vents were separately valved so that when the pressure tanks were shut off these valves could be opened to relieve pressure. The vented solution was conveyed to glass containers for re-use. The result was a very rapid cessation of spraying.

Separation of the Droplet Distributions

The basic goal in producing two aerosols in the tunnel was to compare deposit on an obstacle under two droplet distributions. By evaluating the deposit from both large and small droplet distribution on the same obstacle under the same wind conditions it was hoped to reduce the variance in the observations.

The production of a relatively narrow droplet distribution by the TX1 nozzle

was noted in a study by Ayers et al. (1979). This nozzle was chosen due to its low cost, small size, and simple operation. The nozzle operates on simple hydraulic pressure and produces few very large droplets (droplets greater 300 microns), although the distribution was not as narrow as desired. The problem of producing two different droplet distributions in the test area had to be resolved.

The carrier containing the dye was DOP, essentially non-volatile, and very soluble in acetone and dichloromethane. Since the largest droplet desired was not larger than 300 microns the droplet surface was at most 150 microns from any portion of the droplet volume. This is comparable to a very thin film of solution. If a volatile solvent such as acetone was used to dissolve the dye-DOP solution the solvent was anticipated to be lost due to volatility within seconds of spraying (Himel 1980).

In order to test this hypothesis, a highly dilute solution of the dye-DOP-acetone solution was sprayed on five micron wires. The resulting droplets were observed at 430 magnifications with an ocular micrometer in a microscope within four seconds. The drops were observed for any change in size. In all cases the solvent had volatilized before reaching the microscope and no change was observed. It was concluded that the droplet distribution could be altered by changing the amount of volatile solvent used to dilute the spray solution. A stipulation was then made that the spray be released a sufficient distance upwind to require at least four seconds of travel for the spray to reach the test area. Due to a fire hazard with the acetone the solvent was changed to dichloromethane. Since dichloromethane was much more volatile than acetone the four second stipulation was considered adequate.

DOP is not sprayable from a TX1 nozzle without some dilution due to its viscosity. If equal parts of DOP and a dichloromethane were used the solution was sprayable. The minimum dilution was set at 50% dye-DOP to dichloromethane. This

solution was sprayed from the vertical tunnel and allowed to dry throughout its descent and by choice was marked with the yellow dye tracer in all cases. The time required to descend the distance of the vertical tunnel was estimated to be greater than four seconds based on the calculated flow through the vertical tunnel.

A dilution of twelve to one was chosen for the smaller droplet distribution. By choice the blue dye tracer was used in all cases with the small droplet distribution. Although these selections of dilution begin to separate the two distributions of droplet size, the separation was not complete. Wind-gravitational separation was responsible for the final separation. Large droplets tended to descend from the drying tunnel in a steeper descent than the small droplets due to the greater ratio of surface area divided by mass for the smaller droplets which allowed for more wind deflection.

By releasing the large droplet distribution from the vertical drying tunnel and the small droplet distribution from upwind in the main tunnel, the small drops in the large distribution tended to be swept above the sample area. Similarly the small droplets of the smaller distribution were swept into the sample area while the large drops tended to "rain out" before the sample area. The resulting separation in the droplet spectra was nearly complete.

One complication was the sensitivity of this separation system to changes in air velocity. This sensitivity resulted in making duplication of a droplet distribution difficult after a change in air velocity was made. The air velocity was changed after each pair of droplet distributions had been tested through three runs of the tunnel. This is evident in the data of droplet distributions reported in the results and discussion of the experiments. This difficulty in controlling the droplet distribution made use of the particle parameter essential for treatment comparisons.

Droplet Distribution Measurement

Three Methods Employed

Three methods of measuring droplet distributions were in place during testing. These were Himel's Droplet Impingement Harp (Hogmire 1979), Teflon[™] coated glass slides, and Teflon laboratory tubing. All of these required the capture of non-volatile droplets on the collection devices, which could later be evaluated to determine the droplet distribution. The Droplet Impingement Harps have not been evaluated due to time constraints. Photographic records of the harps are available for future comparisons.

The reason the harps were not used solely was the result of a previous study (Ayers et al. 1979). In this study the harps were compared with laser optical size determinations. The results indicated the harps were very sensitive to air velocity particularly with large droplets.

The Teflon coated slides were used as a commonly used standard method. The Teflon tubes were used as a standard of comparison since their cylindrical shape was directly compatible with the physical theory used to adjust droplet count frequency. This theory has been mentioned and involves the particle resistance / inertia parameter and collection efficiency, as detailed by Richardson (1960).

The glass slides were 2.54 centimeters wide by 7.62 centimeters long. Of this 2.54 centimeters by 5.72 centimeters were covered with clear Teflon. The remainder was frosted for a label area. These slides were also mathmatically adjusted for collection efficiency. This was done by treating them as cylinders 2.54 centimeters in diameter.

The Teflon cylinders were of two sizes, 1.077 centimeters outside diameter by 7.62 centimeters long and 0.96 centimeters outside diameter by 7.62 centimeters

long. Both the cylinders and the slides were placed in the tunnel normal to the air flow in the vicinity of the collecting obstacles. The droplet distribution was determined by counting the first 250 droplets observed on the cylinders. These droplets were measured using an ocular micrometer in an American Optical binocular compound microscope equipped with a mechanical stage, and tube holding device.

The diameters were recorded in microscope units and later the data were converted to microns diameter and categorized into thirty, ten micron size categories. The conversion to microns diameter was done by multiplying the number of microscope units by the number of microns per unit and by the spread factor of 0.797 (see "Adjusting the Measured Distribution").

Adjusting the Measured Distribution

The frequencies were adjusted to account for the effect of droplets tending to flow around the cylinder and not impinging by calculating the particle parameter and then using Herne's (1960) empirical relationship to calculate the collection efficiency for each size category. The unadjusted frequency for each size category was divided by the calculated collection efficiency for that category to arrive at an adjusted frequency distribution. The adjusted frequency distribution was considered more representative of the true distribution than the unadjusted distribution.

In order to adjust for the tendency for droplets to spread on a slide or tube a spread factor had to be determined. This has been previously done by Anderson and Schulte (1971) for technical malathion on teflon slides. The equipment used by Anderson and Schulte was not available for this study. The following method was devised to determine an overall spread factor on slides. The assumption was made that the same spread factor could be used for Teflon cylinders as well as Teflon slides.

An area of four slides were masked so that only the open area (approximately one square centimeter) would contain droplets after the mask was removed. The slides were then exposed to a relatively wide droplet distribution of dye-DOP solution. The mask was then removed and the slide carefully cleaned to remove any dye not within the masked area.

The slides were photo-enlarged on Kodalyth Orthoth film then washed in three milliliters of acetone and read in a spectrophotometer. This reading was used to determine the volume of dye solution removed. The Kodalyth prints were then examined and the diameters of all the droplet images found were recorded. This information was used to calculate a predicted cumulative volume, treating the measured diameter as though it was from a spherical drop.

The predicted volume and the measured volumes were then compared. The predicted volumes, being larger, were divided by the measured volumes, giving a percent volume change. The cube root of the percent was a spread factor. Table 10 gives the results of these measurements. The mean spread factor was found to be 0.797. The spread factor determined by Anderson and Schulte for technical malathion was 0.69, not an unreasonable difference considering different fluids were evaluated.

The computer program DROPDIST/BAS is listed in Appendix D. This program converts the data as previously mentioned from microscope units to microns and adjusts the frequency distribution by the following relations:

The particle parameter

$$P_i = \frac{\text{Drop Density} \times \text{Drop Diameter}_i^2 \times \text{Air Velocity}}{9 \times \text{Obstacle Diameter} \times \text{Absolute Viscosity of Air}}$$

Where: P_i = The particle parameter of the i^{th} size category.

Table 10. Spread Factor Evaluation of DOP-Dye Solution on Teflon Slides

Replicate number	Measured sum of volume	Predicted sum of volume	% volume change	Resultant spread factor
1	0.0588	0.10864	54.1	0.815
2	0.0706	0.1499	47.1	0.778
3	0.09519	0.1839	51.8	0.803
4	0.05511	0.1111	49.6	0.792
.				
.			Mean	= 0.797
.			St. Dev	= 0.0158

Table 11. Teflon Slide and Cylinder Comparison as Droplet Collection Devices

Discription	Slide Volume Weighted Mean	Cylinder Volume Weighted Mean	Shift Cylinder - Slide
R3BT4 [*]	38	31	-7
R2YT3	90	85	-5
R1YT5	54	58	4
R1BT6	32	31	-1
R3YT5	67	53	-14
R2BT6	30	30	0
R1YT7	76	67	-9
R1BT8	46	37	-9
R2YT7	67	76	9
R2BT8	31	30	-1
R3YT7	99	104	5
R3BT8	37	42	5
R1YT9	89	113	24
R1BT10	39	40	1
R2YT9	73	66	-7
R2BT10	33	38	5
R3YT9	70	75	5
R3BT10	40	45	5
R1YT11	165	187	22
R1BT12	47	47	0
R2BT12	51	41	-10
R2YT11	155	169	14
R3YT11	165	170	5
R3BT12	43	53	10
.	X	Y	--

Regression Results : $r = 0.9833$ Regression Function: $Y = 1.105 X - 5.06$

* R3BT4 = Run 3, Blue Dye, Treatment 4; Y = Yellow Dye.

Drop Diameter_i = The midpoint diameter of the ith size category.

The collection efficiency

$$E_i = b_0 + b_1 \times \log_{10} P_i + b_2 \times (\log_{10} P_i)^2$$

Where: E_i = The collection efficiency of the ith size category.

The constants b are dependent on the value of P (see program DROPDIST/BAS in Appendix D).

Comparison of Slides and Cylinders

After the droplet distributions of the slides and the cylinders had been adjusted the slides and cylinders were compared. The calculated volume weighted mean diameter (~MMD) of the slides were compared with the volume weighted mean diameter of the cylinders. Only slides and cylinders counted by the same individual were compared. The results indicated that the slides did not behave as cylindrical obstacles. The slides apparent cylindrical behavior diameter tended to change with the air velocity in a predictable way. The regression function at the bottom of Table 11 will adjust a volume weighted mean diameter from a Teflon cylinder to approximate that of a Teflon coated slide. A rearrangement of the function can perform the reverse approximation which is the correct approach.

The cylinders were more difficult to handle, store and count, due to their shape. The slides were easily handled by their edges, labeled on the free end, stored in standard slide boxes, and counted with a microscope equipped with a standard mechanical stage. By using the proper regression function a reasonable estimate of the volume weighted mean diameter of a non-volatile droplet distribution can be made from Teflon coated glass slides. Unfortunately there was no established inexpensive standard to which a measuring method could be compared.

Dye Flux Determination

Anisokinetic Sampling

The flux of dye passing through an area of the tunnel was determined by placing a high efficiency air pollution sampler in the air stream. The sampler was a model 086-004 air pollution sampler by Atomic Products Corporation, Atomlab Division, Center Moriches, New York. The device was operated with number 091-110 (10.2 centimeter in diameter) glass fiber filters. The effective filter area was reduced to 8.9 centimeters in diameter by the retaining ring. The sampler was equipped with a flow rate indicator which indicated a 2.83×10^5 cubic centimeters per minute flow rate with the filters used. This is equivalent to a flow of 75.8 centimeters per second through the effective filter area.

The sampling rate for this filter is fixed and thus anisokenitic sampling was used except for approaching air velocities equivalent to the fixed sampling rate. Since no adjustment is made in this study for anisokinetic sampling there was therefore a sampling bias to the filter data. The filter data has been used in a very sparing way so this error does not have great influence on the analysis of data.

The filter was operated throughout the time that dye solution was being released in the tunnel. Operation of the filter was begun one half to one minute before dye was released and terminated three to four minutes following the cessation of dye release. By this procedure the sampler was operating throughout the time any dye solution was passing the target area.

Isokinetic Sampling

For future research an effort should be made to develop an inexpensive isokinetic air sampler. The device should be small enough to be inconspicuous to the

air flow. Several such devices should be used in a matrix throughout the sample area in a effort to track non-uniformities in the spray flux.

Preliminary consideration has been given such a device with the following general design properties suggested:

The sample air inlet should be approximately one half to one centimeter in diameter. The filter media should be recessed from the inlet. The glass fiber media referred to above could be easily cut to size for use in such a smaller device. An outlet from the side of the forward extension could serve as an indicator of isokinetic flow.

To accomplish this a U-shaped tube could be attached to this outlet. The tube should connect to the sampler normal to the approaching air flow. The other end of the tube should also be normal to the air flow exiting in the same direction and as free of nearby obstructions as possible. The U-shaped tube could be constructed of glass and a small plastic bead placed inside at the bottom of the U. The tops of the U should be indented to prevent escape of the bead. The bead should have as little mass as possible and move freely in the tube. The bead should be only slightly smaller than the inside of the tube.

As air flows through this tube the bead will move in the direction of flow. The air movement in the tube will be created by the pressure differences between the inside and outside of the sampler inlet upwind of the filter. When the bead indicates no flow (tending to rest at bottom center) the sampler would be drawing air in at the same rate as air is approaching and thus be sampling isokinetically.

The sampler could be driven by a vacuum tube at the sampler outlet. This vacuum tube could have a bleeder valve to regulate the pressure difference. The valve could be adjusted until the bead indicated the flow is approximately isokinetic.

This device has not been constructed and these suggestions are offered as a

possible design for future work. Clearly the design is only preliminary and will need to be refined once a prototype has been constructed.

Sampling Procedures

During experiments many samples were taken. These included six centimeter branch parts, filter paper coverings of cylinders, Teflon cylinders, Teflon slides, harps, and flux filters. Each required handling in such a way as to prevent contamination from dye that covered non-sample obstacles.

The storage life of the dyes used was indefinite so this was not a consideration. Samples of dye-DOP solution after more than one year in storage were not detectably different in dye content than when originally mixed.

Branch parts, flux filters and filter paper samples were handled by stainless steel forceps. The samples were removed from the sample location and immediately inserted into laboratory culture tubes equipped with Teflon lined screw caps. The branches required cutting to a length of six centimeters. This was done at the time of sampling with minimal handling. The cut was made with surgical scissors in contact with the stems only. The branches were inserted onto the culture tubes and any dye rubbed onto the lip of the tube was wiped off with aluminum foil. The foil was then inserted into the tube. Flux filters and filter paper samples were folded with forceps and inserted into culture tubes. All tubes were marked with labels to indicate treatment, run, and sample type.

Branch parts were extracted in twenty milliliters of acetone for one minute. The branch part was then removed and stored in standard labeled four dram vials. The branch parts were later dried at sixty degrees centigrade for one week and then weighed. The needles were removed and the stems weighed. These data were

recorded as a measure of the variation in branch structure.

The flux filters were washed in twenty milliliters of dichloromethane for fifteen minutes. The filter paper samples were washed in five milliliters of dichloromethane. A three milliliter portion of the washings was removed and read in a Beckman DB spectrophotometer. If the percent transmission was less than fifteen the sample was serially diluted. Records on all such dilutions were kept.

The droplet impingement harps were removed from the sample area, stored in their cases, and then taken to the dark room. In the dark room the harps were photo enlarged with a 1.27 centimeter aluminum foil standard in the enlargement field. The foil served to give a means of determining the enlargement factor. After being recorded on Kodalyth film and the film marked with the information on the harp label, the harps were cleaned for re-use.

The Teflon cylinders were removed from the sample area and stored vertically in wooden dowels held by holes in the wood. The cylinders were vulnerable to damage through contact with the exposed sample droplets and were therefore stored in a locked cabinet until counting.

The counting was done with a standard compound microscope equipped with a special tube holder. The tube holder consisted of a slide sized base (2.54 cm by 7.62 cm), with a U-shaped bracket fastened above. The tubes were secured in the holder with four insect pins, two in each end. The insect pins were inserted through the end of the bracket into small corks in the end of the tubes. The tube holder was placed in the mechanical stage and the counting was done along the length of the tubes. By shifting the pins in the ends of the tubes the tubes could be rotated to count different sections.

The Teflon slides were removed from the sample area and stored in standard slide boxes. The boxes were stored with the slides flat and the drops hanging below

the slides. Counting of the slides was done on the same microscope used for the Teflon tubes. The slides were fastened in the machanical stage directly with both stage adjustments usable in this case. This method greatly reduced the time spent in counting.

Computer Methods Employed

The Microcomputer

A microcomputer was purchased to control the anemometer data collection device. This computer was a TRS-80[™] model I by Tandy Corporation. It was initially purchased with 32,767 bytes of memory, 12,288 of which were the level II Microsoft BASIC interperter in read only memory. The programs written for this machine were in Microsoft BASIC or Z-80[™] assembly language. The programs written for this machine are readily convertible to other machines using Microsoft BASIC with the exception of the assembly language routine.

Computer Programs Employed

Five computer programs were written for data collection and conversion. One was written by David Zeitler formerly of Applications Programing, MSU department of Computer Science. This program was written in BASIC with an assembly language data collection subroutine which controlled the anemometer counters and recorded the counts in random access memory. The speed of assembly language was required in order to capture the data while the counters were running. Upon completion of data collection control returned to the BASIC program which printed the data on magnetic tape. This program is listed in Appendix E.

The other four programs were written by the author of this document. ANEMCONV/BAS was used to read the tapes of raw anemometer data, convert the

data to millimeters per second form and calculate the means, standard deviations, and measures of turbulence.

DROPDIST/BAS used keyboard input of droplet measurements, air velocity, collecting obstacle size, microscope conversion, and spread factor, to calculate and correct the droplet frequency distribution of Teflon slides and cylinders.

ABSORCON/BAS used keyboard input of sample percent transmission and background percent transmission (if branch data was being converted) for both yellow and blue dye. The effect of the blue dye absorption spectra to overlap on the absorption peak of the yellow dye is removed as well as any background interference from branches. The output printed absorbance and microliters dye per milliliter of final wash. The program does not convert to total microliters because the dilutions were not always the same (some samples were serially diluted).

DATA CONV/BAS was a short program to convert the microliters per milliliter result from ABSORCON/BAS, obstacle intercept size and dilution amount to print total microliters and microliters per square millimeter. These programs are listed in appendix D.

CANOPY EXPERIMENTS

CANOPY EXPERIMENT

Introduction

The goal of this study was to spray a canopy of trees with differing droplet distributions, one composed of relatively large droplets and the other composed of small droplets. The larger of the distributions would contain primarily droplet sizes found in the larger half of a typical spray distribution. The smaller would contain droplet sizes found in the smaller half of a typical spray distribution. By separating a typical distribution it was anticipated that information on how each portion contributes to spray deposition in a canopy of trees could be obtained.

Methods and Materials

The canopy consisted of seventeen balsam fir trees placed in the wind tunnel. The canopy was composed of trees approximately 1.37 meters high from the ground to the top whorl of branches. The trees were approximately 1.0 meter in diameter at the base tapering to the terminal branch above the top whorl. The trees were grown for Christmas trees. Christmas trees are often trimmed to improve their shape and thicken growth. For this study the grower reserved trees that had not been trimmed.

The canopy was structured, beginning approximately 4.4 meters north of the vertical tunnel inlet, and extending approximately 10 meters south from the start. The canopy was composed of eleven rows of trees. The first (north) row was composed of two trees, the next row one tree and so on for the eleven rows. The rows were placed 0.91 meter center to center. The south nine trees were down wind

of the vertical tunnel and thus the droplet outlet. The north eight trees were upwind of the droplet outlet and served to assure a fully developed wind shear upwind of the test area.

The trees were cut to have a trunk extension fifteen to twenty centimeters long extending below the bottom whorl of branches. This trunk extension was placed in a small bucket inserted flush in the tunnel floor. The bottom whorl of branches was in contact with the floor. The buckets were kept filled with water to keep the trees fresh.

The trees were supported by wires extending horizontally across the tunnel 0.8 meters above the floor. The trees were attached to the wires with cable clamps securing wire loops wrapped around the tree trunk.

Four sample trees were within the canopy. These were the second, third and fourth rows from the south. The second and fourth rows contained one tree each and the third row contained two trees. The whole single trees in rows two and four were sample trees. The west half of the east tree and east half of the west tree in the third row were considered a single tree.

Three anemometers were placed in the tunnel within the sample area of the canopy. The anemometers were adjusted to be at 35 centimeters, 86 centimeters and 137 centimeters above the floor. Their position was adjusted so they did not contact any obstacles. An effort was made to assure they were not measuring different flows from one side to the other. However, this was difficult to determine, given that the anemometers were of the miniature cup type. Hot wire anemometers were not considered due to the exposure to spray during readings.

Droplet sizing devices were placed at the three anemometer levels. The flux filter was placed at the middle anemometer level for the entire run. Originally flux determinations were planned at each of the three anemometer heights for one third

of the total run time. This did not prove to be feasible due to the difficulty in changing filters in mid run without contaminating the sample trees by physical contact. The flux filter would have needed changing six times for each replication, resulting in six opportunities for contamination.

Samples were to be taken at each of the three anemometer heights on the north , south and east sides, on the outside and inside half way between the perimeter and trunk. Two six centimeter portions of the current years growth were to be sampled. The method of choosing the branch was based on the two branches nearest to the geometric sample location.

Yellow dye solution was released from the vertical tunnel for a given time interval then the droplet sizing devices were changed before the blue dye solution was released.

Results and Discussion

No data were collected for these trials other than wind data. Of three canopies placed in the wind tunnel all were rejected for problems in the spray delivery system. The main difficulty involved plugged nozzles. The second difficulty involved the blue dye solution which tended to be swept above the canopy due to the smaller droplet distribution. The result was to have non-uniform spray fluxes. The runs were considered useless due to this flux bias. Samples were not taken for any of the canopy tests.

The turbine on the vertical tower and the movable flap on the inside tunnel roof were added to aid in correcting these problems. In addition a set of nozzles were installed in the main tunnel three meters north of the vertical tunnel outlet. These additions greatly improved the spray distribution within the main tunnel test area.

Further canopy tests were not made after these modifications were made. The full canopy trials tended to consume trees at a very rapid rate. It was considered more important to concentrate on techniques which consumed fewer resources. No further canopy trials have been attempted. It is probable that successful canopy tests could now be designed with the benefit of the experience gained from the following experiments.

SINGLE TREE EXPERIMENTS

SINGLE TREE EXPERIMENTS

Introduction

A single tree in a forest of trees in all probability will not be effected by the wind in the same way as a single tree, standing alone. If only a single horizontal level of a tree is considered at a time then it is not necessary to have the tree under a fully developed wind shear. This is not completely valid since the level of turbulence will differ due to the lack of wind shear. It is reasonable to expect to gain information on the relative effect of the wind on droplets as it passes through the foliage of a tree. Later the effects of turbulence could be evaluated in subsequent studies.

An experiment was designed in which single trees were placed in the tunnel and exposed to two spray distributions. The first two treatments (~1320 mm/sec air velocity) were replicated four times and the third and fourth (~2500 mm/sec) were replicated only once.

Methods and Materials

Single trees 1.0 meter in diameter at the base and 1.37 meters high from the ground to the top whorl of branches were used. These trees were placed 4.9 meters down wind (south) of the vertical tunnel. The trees were held in place by the horizontal wires used in the canopy tests. The bottom whorl of branches were in contact with the ground.

Droplet sampling devices were placed slightly off-center and upwind of the

tree at three heights. The heights were 35 , 86 and 137 centimeters above the floor. Teflon coated slides, Teflon tubes and droplet impingement harps were included.

After the dye solution was released for thirty seconds the spray was stopped and the droplet samplers examined. If the samplers had a sufficient number of droplets for a determination of the distribution they were removed. In some cases they remained for the entire spray run lasting 1.5 minutes with insufficient numbers. This occurred with the blue (smallest droplets) at the lowest low level.

The anemometers were placed upwind of the tree 2.5 meters. The upwind positioning of the anemometers measured the approach velocity of the air. By placing the anemometers upwind the approaching wind and droplets were disturbed. The assumption was made that this disturbance would be minimal after the 2.5 meter travel. The alternative was to take wind measurements upwind of the droplet release or down wind of the trees. In the first case the effects of the vertical tunnel and adjustable turbulence flap would be missed. In the second the velocity following the tree would be measured. The down wind velocity would be useful in addition to the upwind velocity but of less use alone.

Wind samples were taken at five second repeat intervals with a sample interval of 0.5 seconds, at 35, 86 and 137 centimeters from the ground. Counting was started at the same time as the dye solution was released and terminated approximately thirty seconds after the dye solution was halted.

Branch samples were taken at each of the three anemometer heights on the north, south, and east sides of the tree, on the outside (N, S, E) and inside (NI, SI, EI) of the tree half way between the perimeter and trunk. Two six centimeter portions of the current years growth were taken. The method of choosing the branch was based on the two branches nearest to the described sample location. Samples were collected and handled as indicated in the "Sampling Procedures" section of the

"METHODS FOR DEVELOPING TECHNIQUES" portion of this document.

The flux filter was used down wind of the tree only at the eighty six centimeter height. The data from this filter are not reported. Since the dye flux in the tunnel varied considerable with position this filter sampling down wind of the tree at only one location could only be used for comparison with the deposit immediately upwind of that location.

Filter data for a flux determination would be desirable but a matrix of several isokinetic flux samplers would be much more usefull than the single anisokinetic sampler.

Results and Discussion

The data are divided into two categories based on the air velocity. The first category includes replicates one through four of the first two treatments at approximately 1320 millimeters per second of flow. The second category includes replicate one of treatments three and four at approximately 2500 millimeters per second of flow.

The data are summarized in Appendix A. The data for the low air velocity are divided by replicates. The first table for each replicate gives the specific mean velocities for three heights and two treatments and the volume weighted mean diameters of the droplet distributions.

The secondtable for each replicate gives the apparent dye flux as estimated from the dye deposit and the branch intercept area, for each height and position. The branch intercept area was estimated based on the mean branch width multiplied by the six centimeter sample length. Columns three and six give the ratio of the estimated flux at the sample location divided by the flux estimated at the first upwind sample (N).

Figures 4 through 7 are graphs of these ratios plotted on the Y axis and the distance from the most upwind sample location (N) in centimeters on the X axis. Samples on the east are not included because it is likely local flux variations would invalidate the comparisons. The samples taken on the north, north inside, south inside and south all are positioned on a line parallel to the flow of the air and tend to be exposed to the same flux entering the tree to the north. This flux does change as particles are removed by impingement while passing through the tree and by sedimentation however this is part of the problem being evaluated.

All graph lines originate from the coordinate 0,1, since by definition the north deposit divided by the north deposit is one. In general all the ratios tend to decrease with distance from the north. There seems to be a tendency for the deposit to increase slightly on the down wind perimeter. This tendency is possibly due to the increased number of obstacles near the perimeter as compared to the relatively more open center of the tree. The greater the number of obstacles per unit volume the more probable it is that a particle flowing around one obstacle will be forced into another close obstacle. An additional factor, which could account for this increased deposit, is that droplets may flow around the whole tree and be swept into the back of the tree by turbulence.

This trend for increased deposit on the down wind side tends to decrease the lower the sample height. This may be due to the increased number of total obstacles previously encountered by the flux of droplets. The reduction in volume of flux is more likely at these lower sample heights since there is a longer path length of obstacles previously passed. This is due to the trees conical shape and also accounts for the longer length of the graph along the X axis with decreased height.

Overall there is little difference between the deposit with the large versus

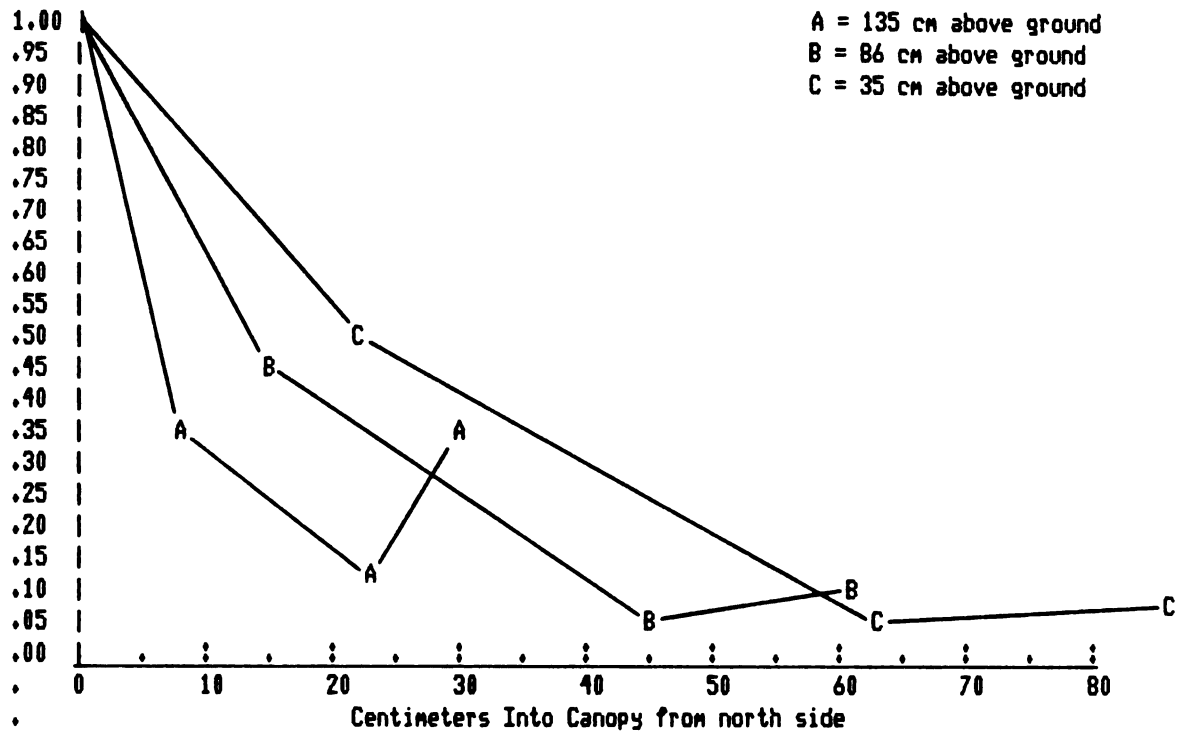


Figure 4. Plot of the Ratio of Yellow Deposit at various Distances into the Tree / Deposit on Upwind Side (distance = zero), Low Velocity Air Flow (~ 130 cm/sec).

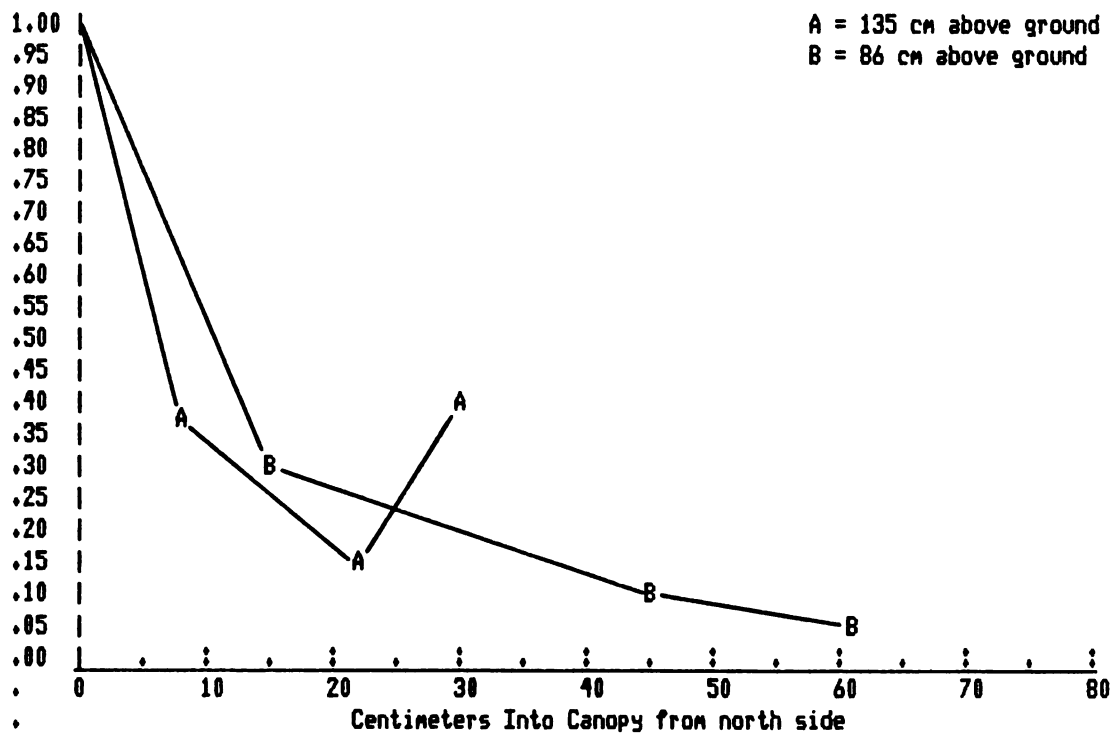


Figure 5. Plot of the Ratio of Blue Deposit at various Distances into the Tree / Deposit on Upwind Side (distance = zero), Low Velocity Air Flow (~ 130 cm/sec).

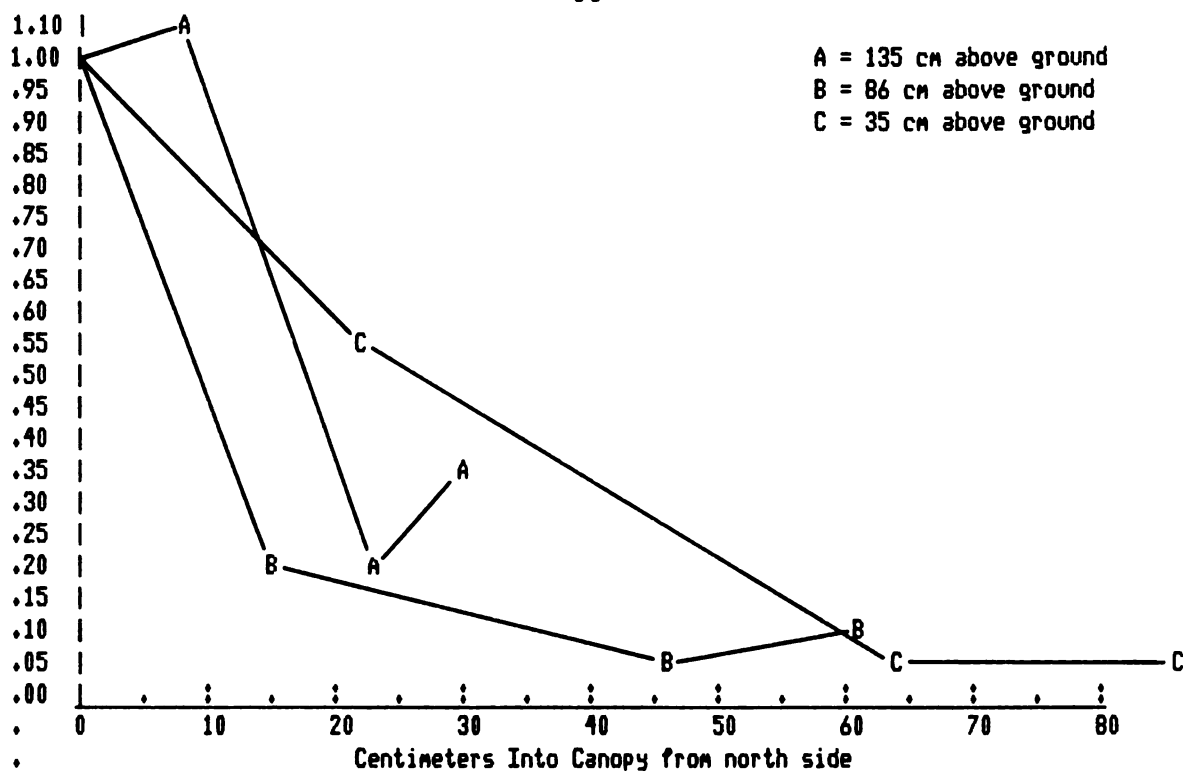


Figure 6. Plot of the Ratio of Yellow Deposit at various Distances into the Tree / Deposit on Upwind Side (distance = zero), High Velocity Air Flow (~ 250 cm/sec).

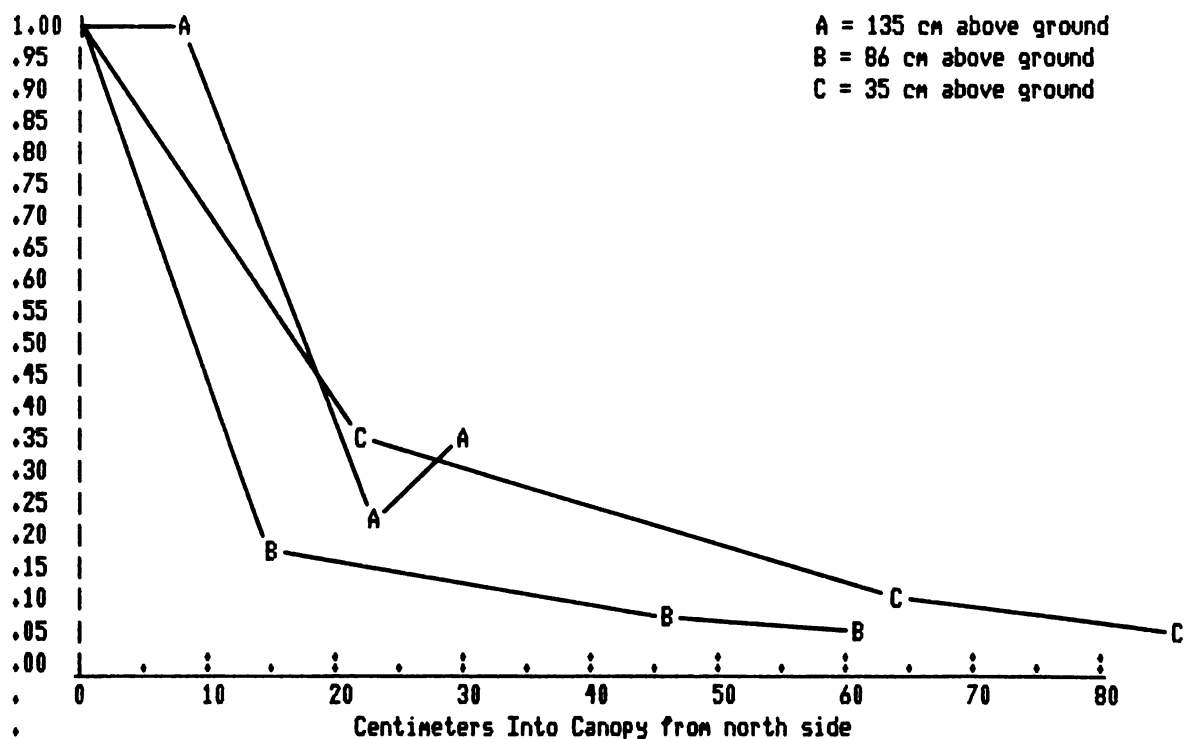


Figure 7. Plot of the Ratio of Blue Deposit at various Distances into the Tree / Deposit on Upwind Side (distance = zero), High Velocity Air Flow (~ 250 cm/sec).

small droplet distributions at the two air speeds. This at first may seem to indicate the relation proposed by the theory of particle parameter is incorrect. This is not a valid conclusion since all the obstacles observed were composed of similar composites of small obstacles. The composite is a branch composed of a twig center with small needles extending out from this center. It is reasonable to expect these small obstacles to be relatively efficient collectors of the passing flux. If efficient enough then the effect of air velocity and droplet size would be small.

Differential deposition might be more evident if differing obstacle sizes were studied. The next set of experiments begins to examine differing obstacle sizes.

CYLINDER EXPERIMENT

CYLINDER EXPERIMENTS

Introduction

As stated previously the basic objective of the study was to evaluate the potential for using the particle resistance / inertia parameter in predicting pesticide aerosol behavior. To accomplish this data must be available about the cylindrical obstacle size, droplet size approaching the obstacle, and air velocity approaching the obstacle. In addition some measure of the true dye flux passing the obstacle would be desirable.

Various sized cylinders were placed in the tunnel to evaluate the deposition of dye-DOP aerosols. The study was used primarily to refine techniques for a more rigorous study of cylinders and branches of balsam fir.

In order to make air velocity and flux measurements that were closely related to the local conditions around the sample devices some additional equipment was installed in the tunnel. The additions included an air entrainment structure, to prevent gross changes in conditions within the sample area.

Methods and Materials

An air entrainment structure was constructed 61 centimeters wide by 53 centimeters high by 244 centimeters long inside. The structure was constructed of structural lumber and 6.4 millimeter thick exterior pressed fiber board as the interior skin. The general form was that of a rectangular tube which was approximately one meter above the tunnel floor. This structure was centrally placed

in the tunnel down wind of the vertical tunnel. The structure was oriented parallel to the main tunnel so that the wind entered from the north and exited to the south.

Various sized sampling cylindrical obstacles were placed in this structure. Cylinders of 1.16, 1.66, 2.22, and 3.94 centimeters in diameter were included. The smaller three sizes of these cylinders were glass vials inverted on a linear array of pegs, in a vertical position. The largest size was a graduated cylinder horizontally positioned above and slightly to the rear of the vertical cylinders. The samplers were 2.54 centimeter wide strips of filter paper wrapped around the cylindrical portion of the cylinders and joined at the back with double faced tape. The cylinders were arranged in a linear row alternating cylinder sizes. The first cylinder on the east was 1.16 centimeters followed by the 2.22 centimeter and 1.66 centimeter sizes. This pattern was repeated for nine cylinders or three blocks of the three sizes in the linear array.

The sample holding device was composed of two vertical steel rods one on each side of the structure approximately twelve centimeters from the inside vertical wall. Standard laboratory test tube clamps were attached to these rods which in turn supported the linear array of cylinders, the graduated cylinder, and the droplet sizing samplers (Harps, Teflon slides and Teflon cylinders). The linear array of the smaller cylinders was composed of a horizontal wooden support 46 centimeters long with nine vertical wooden dowels 7.6 centimeters long placed five centimeters on center along its length. The nine dowels were treated as three blocks of three cylinders. Random placement was not used because relative comparisons were desired between adjacent cylinders.

A single anemometer was placed in the entrainment structure 1.23 meters down wind behind the samplers twenty five centimeters from the west wall. The flux filter was placed approximately eighteen centimeters from the east wall, also 1.23

meters down wind from the samplers. This orientation caused the flux filter to be sampling downwind of the first block of cylinders.

The cylinders were exposed initially to the large droplet distribution from the vertical tunnel for fifteen seconds then the smaller droplet distribution from the lower release point upwind of the vertical tunnel outlet for forty five seconds. This process was repeated for three tunnel runs which resulted in nine replications of each cylinder size. Since the data was used to compare the efficiency of collection on one size cylinder with another adjacent size, each pair of compared cylinders were considered independent from another pair the of the same sizes.

The droplet measuring devices were removed between each dye change. The flux filter was changed between each tunnel run. Wind data were collected at five second repeat intervals with one half second sample intervals.

Results and Discussion

The data collected are summerized in tables 12 through 15. Theses tables list the ratios of relative collection effeciency between three of the tested cylinder sizes. These data are included for the yellow (large droplet distribution), blue (smaller droplet distribution), the mean air velocity in millimeters per second, and the volume weighted mean diameters (approximately the mass median diameter).

The ratios in tables 12-15 result from dividing the estimated dye flux per millimeter squared on the smaller cylinder into the estimated flux per millimeter squared on the larger cylinder. The data indicates smaller cylinders are more efficient collectors than the larger cylinders.

A more complete data file was included in Appendix B. The data from the filter flux were not analysed for reasons previously discussed in the "Dye

Table 12. Comparison of the Relative Collection Efficiencies of Three Cylinder Sizes for Treatments One and Two.

YELLOW Treatment One				BLUE Treatment Two		
MEAN POSITION	RATIO	VELOCITY	APPROX MHD	RATIO	VELOCITY	APPROX MHD
Sizes 2.22 cm vs. 1.16 cm						
1.5	.669	744	129	—	741	28
4.5	.688	"	"	—	"	"
7.5	.724	"	"	.520	"	"
1.5	.633	747	147	—	714	20
4.5	.459	"	"	—	"	"
7.5	.585	"	"	—	"	"
1.5	.636	741	134	.196	719	37
4.5	.663	"	"	.240	"	"
7.5	.798	"	"	1.13	"	"
.						
.	Mean	.642		Mean	.522	
Sizes 2.22 cm vs. 1.66 cm						
2.5	.658	744	129	—	741	28
5.5	.738	"	"	—	"	"
8.5	.715	"	"	.749	"	"
2.5	.837	747	147	—	714	20
5.5	.718	"	"	—	"	"
8.5	.687	"	"	—	"	"
2.5	.915	741	134	.749	719	37
5.5	.771	"	"	.749	"	"
8.5	.818	"	"	.487	"	"
.						
.	Mean	.761		Mean	.684	
Sizes 1.66 cm vs. 1.16 cm						
3.5	.812	744	129	—	741	28
6.5	.868	"	"	.695	"	"
3.5	.648	747	147	—	714	20
6.5	.667	"	"	—	"	"
3.5	.915	741	134	.749	719	37
6.5	.975	"	"	.695	"	"
.						
.	Mean	.813		Mean	.713	

Table 13. Comparison of the Relative Collection Efficiencies of Three Cylinder Sizes for Treatments Three and Four.

YELLOW Treatment Three				BLUE Treatment Four		
MEAN POSITION	RATIO	VELOCITY	APPROX HND	RATIO	VELOCITY	APPROX HND
Sizes 2.22 cm vs. 1.16 cm						
1.5	.771	787	81	.749	782	42
4.5	.680	"	"	.361	"	"
7.5	.784	"	"	.388	"	"
1.5	.623	770	98	.161	782	33
4.5	.462	"	"	—	"	"
7.5	.570	"	"	—	"	"
1.5	.568	785	99	.246	798	33
4.5	.536	"	"	—	"	"
7.5	.543	"	"	—	"	"
.						
.	Mean	.615		Mean	.381	
Sizes 2.22 cm vs. 1.66 cm						
2.5	.569	787	81	.240	782	42
5.5	.656	"	"	.520	"	"
8.5	.642	"	"	.706	"	"
2.5	.750	770	98	.354	782	33
5.5	.665	"	"	—	"	"
8.5	.719	"	"	—	"	"
2.5	.552	785	99	.135	798	33
5.5	.771	"	"	—	"	"
8.5	.738	"	"	—	"	"
.						
.	Mean	.674		Mean	.391	
Sizes 1.66 cm vs. 1.16 cm						
3.5	1.008	787	81	.328	782	42
6.5	.971	"	"	.360	"	"
3.5	.757	770	98	—	782	33
6.5	.807	"	"	—	"	"
3.5	.754	785	99	—	798	33
6.5	.856	"	"	—	"	"
.						
.	Mean	.859		Mean	.344	

Table 14. Comparison of the Relative Collection Efficiencies of Three Cylinder Sizes for Treatments Five and Six.

YELLOW Treatment Seven				BLUE Treatment Eight		
MEAN POSITION	RATIO	VELOCITY	APPROX MMD	RATIO	VELOCITY	APPROX MMD
Sizes 2.22 cm vs. 1.16 cm						
1.5	.813	1427	163	.384	1462	44
4.5	.758	"	"	.421	"	"
7.5	.791	"	"	.494	"	"
1.5	.727	1490	188	.402	1453	40
4.5	.749	"	"	.443	"	"
7.5	.789	"	"	.424	"	"
1.5	.774	1495	148	.438	1484	36
4.5	.757	"	"	.353	"	"
7.5	.809	"	"	.353	"	"
.						
Mean	.774			Mean	.412	
Sizes 2.22 cm vs. 1.66 cm						
2.5	.829	1427	163	.606	1462	44
5.5	.977	"	"	.637	"	"
8.5	1.074	"	"	.645	"	"
2.5	.978	1490	188	.671	1453	40
5.5	.856	"	"	.606	"	"
8.5	.906	"	"	.610	"	"
2.5	.827	1495	148	.631	1484	36
5.5	.891	"	"	.533	"	"
8.5	.921	"	"	.590	"	"
.						
Mean	.918			Mean	.614	
Sizes 1.66 cm vs. 1.16 cm						
3.5	1.015	1427	163	.695	1462	44
6.5	1.063	"	"	.695	"	"
3.5	.817	1490	188	.660	1453	40
6.5	.903	"	"	.663	"	"
3.5	.823	1490	148	.599	1484	36
6.5	1.009	"	"	.663	"	"
.						
Mean	.938			Mean	.663	

Table 15. Comparison of the Relative Collection Efficiencies of Three Cylinder Sizes for Treatments Seven and Eight.

YELLOW Treatment Nine				BLUE Treatment Ten		
MEAN POSITION	RATIO	VELOCITY	APPROX HMD	RATIO	VELOCITY	APPROX HMD
Sizes 2.22 cm vs. 1.16 cm						
1.5	.155	2134	213	.561	2090	60
4.5	.999	"	"	.588	"	"
7.5	1.014	"	"	.582	"	"
1.5	.886	2210	194	.548	2264	80
4.5	1.047	"	"	.571	"	"
7.5	.953	"	"	.568	"	"
1.5	.819	2013	217	.744	2045	44
4.5	.899	"	"	.537	"	"
7.5	.730	"	"	.630	"	"
.						
.	Mean	.942		Mean	.592	
Sizes 2.22 cm vs. 1.66 cm						
2.5	.729	2134	213	.698	2098	28
5.5	.762	"	"	.795	"	"
8.5	.838	"	"	.729	"	"
2.5	.777	2210	194	.713	2264	80
5.5	.857	"	"	.749	"	"
8.5	1.009	"	"	.727	"	"
2.5	.875	2013	217	.658	2045	44
5.5	1.09	"	"	.725	"	"
8.5	1.22	"	"	.788	"	"
.						
.	Mean	.906		Mean	.731	
Sizes 1.66 cm vs. 1.16 cm						
3.5	.780	2134	213	.672	2090	66
6.5	.912	"	"	.674	"	"
3.5	1.027	2210	194	.695	2264	80
6.5	1.009	"	"	.727	"	"
3.5	1.085	2013	217	.717	2045	44
6.5	.994	"	"	.675	"	"
.						
.	Mean	.960		Mean	.693	

Flux Determination" section.

As the air velocity was increased (i.e. the particle parameter increases) the tendency for the ratios to approach unity and for the cylinders to behave similarly is more evident with the large droplet distribution than with the small. This tendency is evident with the smaller droplets as well though not as distinctly.

The larger the droplet size or the higher the air velocity the closer the collection efficiency of a cylinder approaches unity. Then it is reasonable to expect the collection efficiencies of two different sized cylinders to converge at unity with very large droplets and or very high velocities (see the functional relationship of the particle parameter in "Adjusting the Measured Distribution"). Then by extension the relative collection efficiency of two cylinders will also converge at unity for very large droplets and or very high velocities.

The relative collection efficiency was lower with the smaller droplets distributions and tended to increase as the velocity was increased. The same tendency for the relative collection efficiencies to increase existed for the larger droplet distributions but is displaced closer to unity.

To place this in perspective with the particle parameter, as droplet size or air velocity are increased, holding other factors constant, the particle parameter is increased. As previously mentioned high particle parameters imply high collection efficiencies. If all factors are held constant except the collecting obstacle size then as the obstacle size is increased the collection efficiency is decreased. This means that the ratio of the deposits per millimeter squared for a large cylinder divided by a small cylinder will be less than one.

This tendency was not violated for the largest cylinder as indicted in the data in Appendix B. The predicted flux for the this cylinder (3.94 centimeter in diameter not included in tables 12-15) indicated on the second page of each table in Appendix

B, is lower than those for smaller cylinders.

These data do not give any information on the relative behavior of the balsam fir branch as compared the various cylinders. In addition the particle resistance / inertia parameter has not yet been used in these evaluations. A series of experiments were undertaken to evaluate the particle parameter and the relative collection of fir branches. These experiments were similar to this one with only small modifications as indicated in the following section.

BRANCH AND CYLINDER EXPERIMENT

BRANCH AND CYLINDER EXPERIMENTS

Introduction

The purpose of this experiment was to establish if any general relationships exist between small peripheral branches of the balsam fir and the various cylinders examined. It was of particular interest to determine the relative collection efficiencies between the cylinders and the branches. It was hoped that these relations would be of use in predicting aerosol depositional behavior.

There was little difference from the cylinder tests though only two cylinders were compared with the branches. A multiple linear regression file was constructed to determine constants for regression models in which the branches were compared to the cylinders and the cylinders to one another. The particle parameter was employed to enter air velocity and droplet distribution differences into the analysis in a single factor (see the functional relationship of the particle parameter in "Adjusting the Measured Distribution").

Methods and Materials

The basic methods were identical to the methods used in the cylinder tests with the following differences:

The three treatment blocks used with the cylinder tests were modified so that twelve centimeter lengths of first or second year growth peripheral branches occupied one of the three positions in each block. The array of obstacles were numbered so that the first position to the east was numbered one, the second two and so on to the last position, to the west, which was numbered nine.

For the first run of each treatment pair (after the first pair), position one was occupied by a branch, position two by a 1.16 centimeter diameter cylinder, position three by a 2.22 centimeter diameter cylinder and position four a branch again and so on to position nine. For the second run the first position had the 2.22 centimeter cylinder, position two the branch and position three the 1.16 centimeter cylinder and so on to position nine. For the third run position one had a 1.16 centimeter cylinder, followed by the 2.22 centimeter cylinder and branch and so on to position nine.

This systematic shift resulted in each position in the array being occupied by each target type once during the three runs. The probability of any target type occupying any given position was precisely one third. This effectively preserved the basic purpose of randomization which in this case is to eliminate positional bias to the data while allowing comparisons of differing adjacent targets. With true randomization no realistic number of comparisons could be assured.

The 1.66 and 3.94 centimeter in diameter cylinder were not placed in the tunnel during these tests. The addition of these sizes could have over crowded the sample area and caused unreliable wind or droplet data to be collected.

Wind velocities were varied from 672 millimeters per second to 1813 millimeters per second. Each general wind velocity group was exposed to two droplet distributions. The flux filter, droplet sampling devices and anemometer were positioned as in the "CYLINDER EXPERIMENT". The large droplet flux was released from the vertical tunnel and the smaller from upwind in the main tunnel.

Results and Discussion

The data are summarized for each treatment in Appendix C. The ratios of relative collection efficiency are summarized in tables 16 through 21. These tables

Table 16. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments One and Two.

YELLOW Treatment One					BLUE Treatment Two			
MEAN POSITION, RUN	RECIPROCAL RATIO		VELOCITY	Δ HMD	RECIPROCAL RATIO		VELOCITY	Δ HMD
Branch vs. vs Large Cyl.	L/B	B/L			L/B	B/L		
2.5, R1	.829 B	1.21	763	122	.121 B	8.26	728	38
5.5, R1	1.13 L	.888	"	"	.214 B	4.67	"	"
8.5, R1	1.22 L	.823	"	"	.223 B	4.48	"	"
2.5, R2	.838 B	1.20	672	109	—	—	717	30
5.5, R2	.696 B	1.44	"	"	.249 B	4.02	"	"
8.5, R2	.647 B	1.55	"	"	.211 B	4.74	"	"
2.5, R3	.568 B	1.76	761	107	—	—	700	28
5.5, R3	.675 B	1.48	"	"	—	—	"	"
8.5, R3	.865 B	1.16	"	"	—	—	"	"
.	Mean	1.28 times as much on branch			Mean	5.24 times as much on branch		
.	S.D.	0.31 as on LG cylinder.			S.D.	1.72 as on LG cylinder.		
Branch vs Small Cyl.	B/S	S/B			B/S	S/B		
2.5, R1	.940 S	1.06	763	122	—	—	728	38
5.5, R1	.657 S	1.52	"	"	—	—	"	"
8.5, R1	.525 S	1.90	"	"	—	—	"	"
2.5, R2	.867 S	1.15	672	109	—	—	717	30
5.5, R2	.820 S	1.22	"	"	—	—	"	"
8.5, R2	.983 S	1.02	"	"	—	—	"	"
2.5, R3	.629 S	1.59	761	107	—	—	700	28
5.5, R3	.675 S	1.48	"	"	—	—	"	"
8.5, R3	.953 S	1.05	"	"	—	—	"	"
.	Mean	1.33 times as much on small cyls.			Mean	—		
.	S.D.	0.31 as on branches.			S.D.	—		
Large vs Small Cyl.	S/L	L/S			S/L	L/S		
2.5, R1	.407 S	2.46	763	122	—	—	728	38
5.5, R1	.695 S	1.44	"	"	—	—	"	"
8.5, R1	—	—	"	"	—	—	"	"
2.5, R2	.702 S	1.42	672	109	—	—	717	30
5.5, R2	.618 S	1.62	"	"	—	—	"	"
8.5, R2	—	—	"	"	—	—	"	"
2.5, R3	.659 S	1.52	761	107	—	—	700	28
5.5, R3	.579 S	1.73	"	"	—	—	"	"
.	Mean	1.70 times as much on small cyl.			Mean	—		
.	S.D.	0.389 as on large cyl.			S.D.	—		

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
 The letter following the ratio indicates the obstacle with the greater deposit.

Table 17. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments Three and Four.

MEAN POSITION, RUN	YELLOW Treatment Three				BLUE Treatment Four			
	RATIO	RECIPROCAL RATIO	VELOCITY	^ MMD	RATIO	RECIPROCAL RATIO	VELOCITY	^ MMD
Branch vs Large Cyl.	L/B	B/L			L/B	B/L		
3.5, R1	.611 B	1.64	750	74	.033 B	30.3	783	32
6.5, R1	.729 B	1.37	"	"	—	—	"	"
1.5, R2	.760 B	1.32	726	79	.017 B	58.8	779	33
4.5, R2	.735 B	1.36	"	"	.018 B	55.6	"	"
7.5, R2	.588 B	1.70	"	"	—	—	"	"
2.5, R3	.684 B	1.46	796	85	—	—	790	31
5.5, R3	1.14 L	.875	"	"	—	—	"	"
8.5, R3	1.22 L	.820	"	"	—	—	"	"
.								
.	Mean	1.32 times as much on branch			Mean	48.2 times as much on branch		
.	S.D.	0.32 as on LG cylinder.			S.D.	15.6 as on LG cylinder.		
Branch vs Small Cyl.	S/B	B/S			S/B	B/S		
1.5, R1	1.05 S	.951	750	74	.054 B	18.5	783	32
4.5, R1	.969 B	1.03	"	"	—	—	"	"
7.5, R1	.872 B	1.15	"	"	.102 B	9.80	"	"
2.5, R2	1.08 S	.924	726	79	.072 B	13.9	779	33
5.5, R2	1.14 S	.879	"	"	.115 B	8.70	"	"
8.5, R2	.897 B	1.11	"	"	.119 B	8.40	"	"
3.5, R3	.893 B	1.12	796	85	—	—	790	31
6.5, R3	1.74 S	.575	"	"	—	—	"	"
.								
.	Mean	1.02 times as much on small cyl.			Mean	11.86 times as much on branch		
.	S.D.	0.187 as on branches.			S.D.	4.31 as on small cylinders.		
Large vs Small Cyl.	L/S	S/L			L/S	S/L		
2.5, R1	.534 S	1.87	750	74	—	—	779	33
5.5, R1	.520 S	1.92	"	"	—	—	"	"
8.5, R1	.700 S	1.43	"	"	—	—	"	"
3.5, R2	.538 S	1.86	726	79	—	—	790	31
6.5, R2	.525 S	1.90	"	"	—	—	"	"
1.5, R3	.626 S	1.60	796	85	—	—	785	32
4.5, R3	.679 S	1.47	"	"	—	—	"	"
7.5, R3	.572 S	1.75	"	"	—	—	"	"
.								
.	Mean	1.24 times as much on small cyl.			Mean	—		
.	S.D.	0.11 as on large cyl.			S.D.	—		

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
The letter following the ratio indicates the obstacle with the greater deposit.

Table 18. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments Five and Six.

YELLOW Treatment Five					BLUE Treatment Six			
MEAN POSITION, RUN	RECIPROCAL RATIO		VELOCITY	Δ HMD	RECIPROCAL RATIO		VELOCITY	Δ HMD
Branch vs Large Cyl.	S/B	B/S			S/B	B/S		
3.5, R1	.519 B	1.93	1007	58	.136 B	7.35	943	31
6.5, R1	.406 B	2.43	"	"	.083 B	12.0	"	"
1.5, R2	.347 B	2.88	991	53	.068 B	14.7	930	30
4.5, R2	.303 B	3.30	"	"	.056 B	17.9	"	"
7.5, R2	.411 B	2.43	"	"	.062 B	16.1	"	"
2.5, R3	.712 B	1.40	928	53	.108 B	9.26	919	29
5.5, R3	.479 B	2.09	"	"	.058 B	17.2	"	"
8.5, R3	.442 B	2.26	"	"	.068 B	14.7	"	"
.	Mean	2.34 times as much branch as on LG cylinder.			Mean	13.66 times as much on branch as on LG cylinder.		
.	S.D.	1.28			S.D.	3.79		
Branch vs Small Cyl.	S/B	B/S			S/B	B/S		
1.5, R1	1.06 S	.944	1007	58	.354 B	2.82	943	31
4.5, R1	1.02 S	.980	"	"	.317 B	3.15	"	"
7.5, R1	.916 B	1.09	"	"	.331 B	3.02	"	"
2.5, R2	.778 B	1.29	991	53	.199 B	5.03	930	30
5.5, R2	.623 B	1.61	"	"	.225 B	4.44	"	"
8.5, R2	.793 B	1.26	"	"	.276 B	3.62	"	"
3.5, R3	1.02 S	.979	928	53	.093 B	10.8	919	29
6.5, R3	.767 B	1.30	"	"	.137 B	7.30	"	"
.	Mean	0.85 times as much on small cyls. as on branches.			Mean	5.02 times as much on branch as on small cylinders.		
.	S.D.	0.226			S.D.	2.74		
Large vs Small Cyl.	L/S	S/L			L/S	S/L		
2.5, R1	.437 S	2.29	1007	58	.365 S	2.74	943	31
5.5, R1	.429 S	2.33	"	"	.281 S	3.56	"	"
8.5, R1	.406 S	2.06	"	"	.304 S	3.29	"	"
3.5, R2	.423 S	2.36	991	53	.251 S	3.98	930	30
6.5, R2	.471 S	2.12	"	"	.251 S	3.98	"	"
1.5, R3	.613 S	1.63	928	53	.746 S	1.31	919	29
4.5, R3	.654 S	1.53	"	"	.793 S	1.26	"	"
7.5, R3	.520 S	1.92	"	"	.523 S	1.91	"	"
.	Mean	2.03 times as much on small cyl. as on large cyl.			Mean	2.75 times as much on sm. cyl as on large cyl		
.	S.D.	0.32			S.D.	1.13		

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
 The letter following the ratio indicates the obstacle with the greater deposit.

Table 19. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments Seven and Eight.

MEAN POSITION, RUN	YELLOW Treatment Seven				BLUE Treatment Eight			
	RECIPROCAL		VELOCITY	^ MMD	RECIPROCAL		VELOCITY	^ MMD
	RATIO	RATIO			RATIO	RATIO		
Branch vs Large Cyl.	L/B	B/L			L/B	B/L		
3.5, R1	.625 B	1.60	1098	67	.092 B	10.9	1057	37
6.5, R1	.676 B	1.48	"	"	.133 B	7.52	"	"
1.5, R2	.595 B	1.68	1118	76	.089 B	11.2	1093	30
4.5, R2	.558 B	1.79	"	"	.105 B	9.52	"	"
7.5, R2	.511 B	1.96	"	"	.100 B	10.0	"	"
2.5, R3	1.09 L	.914	1163	104	.103 B	9.71	1109	42
4.5, R3	1.16 L	.860	"	"	.137 B	7.30	"	"
8.5, R3	1.13 L	.888	"	"	.149 B	6.71	"	"
.								
.	Mean	1.40 times as much branch as			Mean	9.11 times as much on branch		
.	S.D.	0.44	on LG cylinder.		S.D.	1.71	as on LG cylinder.	
Branch vs Small Cyl.	S/B	B/S			S/B	B/S		
1.5, R1	.953 B	1.05	1098	67	.360 B	2.78	1057	37
4.5, R1	1.16 S	.862	"	"	.374 B	2.67	"	"
7.5, R1	.897 B	1.11	"	"	.403 B	2.48	"	"
2.5, R2	1.33 S	.754	1118	76	.358 B	2.79	1093	30
5.5, R2	.859 B	1.16	"	"	.286 B	3.50	"	"
8.5, R2	.958 B	1.04	"	"	.341 B	2.93	"	"
3.5, R3	1.67 S	.599	1163	104	.252 B	3.97	1109	42
6.5, R3	1.61 S	.622	"	"	.415 B	2.41	"	"
.								
.	Mean	0.90 times as much small cyls.			Mean	2.94 times as much on branch		
.	S.D.	0.22	as on branches.		S.D.	0.53	as on small cylinders.	
Large vs Small Cyl.	L/S	S/L			L/S	S/L		
2.5, R1	.556 S	1.80	1098	67	.239 S	4.18	1057	37
5.5, R1	.557 S	1.73	"	"	.309 S	3.24	"	"
8.5, R1	.636 S	1.57	"	"	.330 S	3.03	"	"
3.5, R2	.690 S	1.45	1118	76	.354 S	2.82	1093	30
6.5, R2	.594 S	1.68	"	"	.293 S	3.41	"	"
1.5, R3	.716 S	1.40	1163	104	.340 S	2.94	1109	42
4.5, R3	.763 S	1.31	"	"	.447 S	2.24	"	"
8.5, R3	.746 S	1.34	"	"	.411 S	2.43	"	"
.								
.	Mean	1.54 times as much on small cyl.			Mean	3.04 times as much on sm. cyl		
.	S.D.	0.188	as on large cyl.		S.D.	0.604	as on large cyl	

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
The letter following the ratio indicates the obstacle with the greater deposit.

Table 20. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments Nine and Ten.

YELLOW Treatment Nine					BLUE Treatment Ten			
MEAN POSITION, RUN	RECIPROCAL RATIO		VELOCITY	Δ PHD	RATIO	RECIPROCAL RATIO	VELOCITY	Δ PHD
	L/B	B/L			L/B	B/L		
Branch vs Large Cyl.								
3.5, R1	1.23 L	.816	1343	89	.145 B	6.90	1286	39
6.5, R1	1.14 L	.882	"	"	.177 B	5.65	"	"
1.5, R2	.864 B	1.16	1335	70	.201 B	4.98	1281	36
4.5, R2	.927 B	1.08	"	"	.153 B	6.54	"	"
7.5, R2	.936 B	1.07	"	"	.172 B	5.81	"	"
2.5, R3	.723 B	1.38	1342	73	.152 B	6.58	1263	43
5.5, R3	.700 B	1.43	"	"	.155 B	6.45	"	"
8.5, R3	.599 B	1.67	"	"	.103 B	9.71	"	"
.	Mean	1.19 times as much on branch			Mean	6.58 times as much on branch		
.	S.D.	0.29 as on LG cylinder.			S.D.	1.41 as on large cyl.		
Branch vs Small Cyl.	B/S	S/B			B/S	S/B		
1.5, R1	.600 S	1.67	1343	89	.344 B	2.91	1286	39
4.5, R1	.565 S	1.78	"	"	.531 B	1.88	"	"
7.5, R1	.652 S	1.53	"	"	.404 B	2.07	"	"
2.5, R2	.790 S	1.27	1335	70	.406 B	2.46	1281	36
5.5, R2	.687 S	1.46	"	"	.473 B	2.11	"	"
8.5, R2	.715 S	1.40	"	"	.414 B	2.42	"	"
3.5, R3	.766 S	1.31	1341	73	.825 B	1.21	1263	43
6.5, R3	.628 S	1.59	"	"	.649 B	1.54	"	"
.	Mean	1.50 times as much small cyls.			Mean	2.08 times as much on branch		
.	S.D.	0.18 as on branches.			S.D.	0.54 as on small cylinders		
Large vs Small Cyl.	L/S	S/L			L/S	S/L		
2.5, R1	.703 S	1.42	1343	89	.293 S	3.41	1286	39
5.5, R1	.673 S	1.49	"	"	.238 S	4.20	"	"
8.5, R1	.696 S	1.44	"	"	.367 S	2.72	"	"
3.5, R2	.753 S	1.33	1335	70	.354 S	2.82	1281	36
6.5, R2	.660 S	1.52	"	"	.345 S	2.90	"	"
1.5, R3	.702 S	1.42	1342	73	.318 S	3.14	1263	43
4.5, R3	.555 S	1.80	"	"	.172 S	5.81	"	"
7.5, R3	.546 S	1.83	"	"	.192 S	5.21	"	"
.	Mean	1.53 times as much on small cyl.			Mean	3.78 times as much on sm. cyl		
.	S.D.	0.18 as on large cyl.			S.D.	1.18 as on large cyl		

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
The letter following the ratio indicates the obstacle with the greater deposit.

Table 21. Relative Comparison of the Efficiency of Droplet Collection for Branches and Cylinders for Large and Small Droplet Distributions Used in Branch and Cylinder Treatments Eleven and Twelve.

YELLOW Treatment Eleven					BLUE Treatment Twelve			
MEAN POSITION, RUN	RECIPROCAL RATIO		VELOCITY	Δ MPD	RECIPROCAL RATIO		VELOCITY	Δ MPD
Branch vs Large Cyl.	B/L	L/B			B/L	L/B		
3.5, R1	.586 L	1.98	1797	176	.066 B	15.2	1813	47
6.5, R1	.579 L	1.73	"	"	.315 B	3.17	"	"
1.5, R2	.486 L	2.06	1646	169	.028 B	35.7	1702	46
4.5, R2	.183 L	5.46	"	"	.061 B	16.4	"	"
7.5, R2	.518 L	1.93	"	"	.053 B	18.9	"	"
2.5, R3	.672 L	1.49	1590	163	.369 B	2.71	1602	48
5.5, R3	.327 L	3.06	"	"	.396 B	2.53	"	"
8.5, R3	.402 L	2.49	"	"	.291 B	3.44	"	"
.	Mean	0.40 times as much on branch.			Mean	12.25 times as much on branch		
.	S.D.	1.28	as on LG cylinder.		S.D.	11.74	as on LG cylinder.	
Branch vs Small Cyl.	B/S	S/B			B/S	S/B		
1.5, R1	.392 S	2.55	1797	176	.300 B	3.33	1813	47
4.5, R1	.413 S	2.42	"	"	.092 B	10.87	"	"
7.5, R1	.604 S	1.66	"	"	1.04 S	.958	"	"
2.5, R2	.395 S	2.53	1646	169	.249 B	4.02	1702	46
5.5, R2	.166 S	6.02	"	"	.246 B	4.07	"	"
8.5, R2	.450 S	2.22	"	"	.251 B	3.98	"	"
3.5, R3	.398 S	2.51	1590	163	.729 B	1.37	1602	48
6.5, R3	.318 S	3.14	"	"	.087 B	1.13	"	"
.	Mean	2.08 times as much on small cyl.			Mean	4.54 times as much on branch		
.	S.D.	1.33	as on Branches.		S.D.	3.32	as on small cylinders.	
Large vs Small Cyl.	L/S	S/L			L/S	S/L		
2.5, R1	.855 S	1.17	1797	176	.289 S	3.46	1813	47
5.5, R1	.828 S	1.21	"	"	.520 S	2.65	"	"
8.5, R1	.855 S	1.17	"	"	.520 S	1.92	"	"
3.5, R2	.678 S	1.47	1646	169	.378 S	2.65	1702	46
6.5, R2	.849 S	1.18	"	"	.248 S	4.03	"	"
1.5, R3	.860 S	1.16	1590	163	.423 S	2.36	1602	48
4.5, R3	—	—	"	"	—	—	"	"
7.5, R3	.773 S	1.29	"	"	.361 S	2.77	"	"
.	Mean	1.24 times as much on small cyl.			Mean	2.69 times as much on sm. cyl		
.	S.D.	0.11	as on large cyl.		S.D.	0.74	as on large cyl	

S.D. = Standard Deviation B = Branch L = Large cylinder S = Small cylinder
 The letter following the ratio indicates the obstacle with the greater deposit.

are similar to those for the cylinder tests. They differ in that the branches do not behave as a known fixed cylinder. The relationship between the cylinders and branches changes with droplet distribution. This change occurs in such a way as to indicate that the representative apparent branch size changes with changing droplet size and thus particle parameter.

The cylinders tended to collect more of the aerosol than the branches when the large droplet distribution was applied. The reverse was true for the smaller droplet distribution. A possible explanation for this tendency involves the way the air moves through a branch. It is not unreasonable to expect small scale turbulences to exist as the air moves around needles and the stem of a branch. These turbulences would be induced by the composit of small obstacles. The turbulence induced by a single large cylinder standing along would be expected to occur following the cylinder with respect to air flow.

Droplets approaching a composit of cylinders would encounter these turbulences and their path would be altered. The path of small droplets would tend to more closely follow the air path than the path of large droplets. The tendency then would be for the large droplets to take a more direct path through this composit of cylinders than the small droplets. The more direct path may result in a depositional pattern more similar to the deposit approaching a single cylinder. The path of the small droplets would tend to be less direct and the path length longer. The small droplets approaching a single cylinder would tend to flow around. Small droplets approaching a composit flowing around one obstacle may tend to be thrown into another nearby obstacle. This buffeting of the smaller droplets may account for the greater relative collection efficiency of the branches than the cylinders with the smaller droplets.

This does not imply a greater true collection efficiency of small droplets

versus large droplets. In the data tables in Appendix C are indicated the collection efficiencies with respect to the filter flux (column denoted "Rel. to Filter" in the tables). These ratios should more closely approximate the true collection efficiency than the relative efficiency between obstacles. These ratios indicate collection efficiencies much higher for the larger droplets.

Multiple linear regression files were prepared from the data. These files are listed in Appendix C. The file in Listing 1 was constructed from the relative collection efficiencies of the cylinders versus the filter. This file includes the relative collection efficiency of the two cylinder sizes as the dependent variable. Since the relationship of the particle parameter to the collection efficiency (CE) tends to be more linear using a logarithmic transformation the independent variables are the logarithm to the base ten of the particle parameter ($\log P$) for the cylinder, the quantity the $\log P$ squared and The quantity the $\log P$ cubed. The proposed relationship was the $CE = f(P)$. These data were regressed by the following curvalinear model:

$$Y_j = \text{Sum}(B_i X_{i,j}) + E_j$$

Where $\{i \mid 1 \leq i \leq 4\}$

E_j = the error term

B_i = the respective coefficients

$X_1 = 1$

$X_{2,j}$ = the respective $\log P$

$X_{3,j}$ = the respective $(\log P)^2$

$X_{4,j}$ = the respective $(\log P)^3$

$Y_j = CE = f(P)$

The regression results indicate a reasonable multiple linear fit to the data. The following is a summary of the regression results:

Regression Statistics

Coefficient of Determination (R^2)	= .8428
Coefficient of Multiple Correlation	= .9180
Standard Error of the Estimate	= .1379
Regression Sum of Squares	= 5.507
Residual Sum of Squares	= 1.027
F-Ratio (Regression)	= 96.51
Degrees of Freedom	= 1 & 54
Probability of Chance	= 1.11×10^{-9}
Number of Subjects	= 58

Coefficients

$$B_1 = .1455$$

$$B_2 = .6580$$

$$B_3 = .5003$$

$$B_4 = -.3893$$

A complete multiple linear regression data file was constructed for the relative collection efficiencies between obstacles including the branches. This file contains 223 elements and was listed in Appendix C, Listing 2. The file was constructed so the dependent variable was the relative collection efficiency between the two compared obstacles. The first independent variable was the logarithm of the particle parameter. The second was a binary indicator variable (0 or 1) for a branch versus small cylinder comparison. The third was an indicator variable (0 or 1) for a branch versus large cylinder comparison. When variables two and three respectively equal 1,0 branch versus small cylinder are indicated. When variables two and three equal 0,1 branch versus large cylinder are indicated. When variables two and three equal 0,0 small versus large cylinder are indicated. The combination 1,1 was not

used. The fourth was the relative turbulent intensity as determined by the mean wind velocity divided by the standard deviation of the wind velocity. The fifth was the branch needle weight in grams. The sixth was the sample position in the tunnel midway between the two obstacles.

The entire file was regressed with an R equal to 0.337. To evaluate the weakness in this regression portions of the file were regressed separately. First the file was regressed for all file independent variables number two and three equal to zero (cylinders only compared). The first independent variable ($\log P$) was squared to replace independent variable two and cubed to replace independent variable three. The R improved to 0.666

The next regression utilized all data to compare deposits on branch and large cylinder. The $\log P$ was again squared and cubed for variables two and three. The R for this regression was equal to 0.769. These regressions do indicate a relation exists, but that the regression model does not fit properly.

As mentioned earlier the relationship of the particle parameter to the collection efficiency is based on the ratio of the deposit to the true flux approaching the obstacle. The relative efficiency in these files does not change in the same way with a changing particle parameter as the collection efficiency would. This differing behavior for these ratios may in part account for the poor regression results.

A smaller data file was constructed of the collection efficiency relative to the filter for the branch data. This file was constructed with an arbitrary particle parameter calculated using the small cylinder diameter (1.16 cm). This was necessary since the apparent cylindrical size of the branches was not known. The data of treatments one and two were excluded because they were not taken under the sample position shifting procedure described in the preceding "Methods and Materials" section. Only the data for the branches located directly upwind of the flux filter

were included. The purpose of excluding the other branch data was an attempt to restrict the data to branches exposed to the same flux as the filter. This resulted in six of the previously mentioned replications being rejected leaving three for each treatment.

The file was regressed by linear regression for treatments three through twelve. The regression was repeated excluding the data for treatment eleven. As stated earlier the valid limits of the particle parameter include particles less than thirty microns. The data of treatment eleven include very large droplets and may exceed the valid limits of the particle parameter by too much. The results of these regressions follow:

Model: same as multiple linear regression model.

where $B_3 = 0$; $B_4 = 0$

Total file: $r = .7638$; $a = .2390$; $b = .3065$; $n = 50$

Function: Collection efficiency = $.2390 + .3065 \times \text{Log } P$

Excluding treatment 11: $r = .8488$; $a = .2376$; $b = .4651$; $n = 46$

Probability of chance = 6.45×10^{-8}

Function: Collection efficiency = $.2376 + .4651 \times \text{Log } P$

From these regression statistics it is evident that the particle parameter can be extended beyond the theoretically valid limit with reasonable results. The extension may begin to fail to produce reasonable results, if the droplet distribution being considered contains too many large droplets.

SUMMARY AND CONCLUSION

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Several techniques have been developed for the evaluation of coarse aerosol deposition of non-volatile liquids. Several dyes were evaluated for solubility and absorption characteristics in dioctyl phthalate. Two dyes in liquid form were found that can be evaluated for deposit from a single sample extraction and another dye was found that could be used alone.

An inexpensive wind tunnel was constructed and used to increase control over air movement during testing of aerosol deposition. Modifications to the tunnel improved the performance but flux variations within the tunnel continued as a problem.

Two methods were compared for the measurement of non-volatile aerosol size distributions. The use of Teflon tubes as a standard method when the data were adjusted for differential collection, as determined by the particle parameter, was compared to Teflon coated glass slides. The slides did not behave as a true cylinder but the deviation was predictable. The slides were easier to use and store. With proper adjustment of the droplet distribution and correction of the apparent obstacle size these slides can reasonably estimate a droplet distribution. For either obstacle to be used air velocity determinations are necessary.

Both canopy and single tree experiments were conducted. The results of these experiments were limited due to the flux variations within the tunnel. Because of flux problems an air entrainment tube was installed within the tunnel. The single tree data demonstrated a clear tendency for preferential deposition on

the upwind side of the tree. The deposit pattern throughout the tree indicated decreased deposit on the interior of the tree followed by a slight increase on the downwind perimeter. Smaller scale experiments with cylinders and branches were subsequently conducted.

Branches of balsam fir were compared with various sized cylinders. The indications were that the apparent cylindrical size of the branches tends to change as the particle parameter changes which in this study was most obviously different with the smaller droplet distributions.

The particle resistance / inertia parameter does not offer a satisfactory tool for directly predicting the relative collection efficiency of two obstacles. The particle parameter does offer potential as a tool in estimating the true collection efficiency of an obstacle. By extension it could be used to estimate the relative collection efficiency of two obstacles whose true collection efficiency have been estimated.

In order to perform a more meaningful study in the area of whole trees and miniature canopies better control or measurement of the aerosol flux is needed. This may be attainable through the use of a matrix of isokinetic air samplers. Once precise flux determinations can be made the relationship of the particle parameter to the collection efficiency for particles exceeding the theoretical limits appear attainable. With this relationship clearly defined depositional behavior on true cylinders directly follows. Obstacles other than cylinders will require analyses to determine the apparent obstacle size under various conditions.

It has been demonstrated that the particle parameter offers potential as a useful tool in coarse aerosol behavior. The study performed was only preliminary. Techniques developed and the data gathered will be useful in the future to design new more definitive research. The data gathered still has potential for further

analysis as relationships are more clearly defined. The future of this line of research offers great potential for determining constants and coefficients needed in the modeling of pesticide aerosol behavior. It is the author's hope that this type of research will continue.

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APPENDICIES

APPENDIX A

SINGLE TREE TEST DATA

APPENDIX A

SINGLE TREE TEST DATA

These data are arranged into five tables one for each replicate. The first part of each table is a summary of the mean air velocities and volume weighted mean diameters of the droplet distributions for the three sample heights. The second part of each table is a summary of the estimated dye flux per millimeter squared for each sample location.

Column one of the second part of the tables give the sample location. The labels include a letter indicating the direction in the tunnel from which the sample was taken (N = North, S = South, E = East). The second letter in some cases indicate the sample was not taken on the tree periphery but inside midway between the periphery and trunk. Columns two and four include the flux reported based on the air intercept area of a branch normal to the air flow and assuming the branch forms a solid cylinder. Columns three and five include the ratio of the estimated flux at the sample location divided by the estimated flux on the north side (upwind) at the same height.

Table A1. Data for Single Tree Test, Low Velocity, Replicate One

Height cm	Dye Tracer	Air Velocity mm/sec	Volume Weighted Mean Diameter (u)
137	Yellow	1380	—
"	Blue	1385	—
86	Yellow	1382	—
"	Blue	1385	—
35	Yellow	1311	—
"	Blue	1308	—

Sample Location	Flux Predicted From Intercept Area and Deposit			
	Yellow Flux ul/mm ²	Flux/N Flux at same level	Blue Flux ul/mm ²	Flux/N Flux at same level
N 137	4.357 E-4		3.38 E-4	
N 137	3.764 E-4	1	2.825 E-4	1
N 86	1.356 E-4		3.455 E-5	
N 86	1.646 E-4	1	4.299 E-5	1
N 35	3.892 E-5		0.0	
N 35	9.146 E-5	1	4.37 E-6	1
NI 137	3.008 E-5		2.957 E-5	
NI 137	5.854 E-5	.109	6.077 E-5	.146
NI 86	6.382 E-5		1.667 E-5	
NI 86	5.874 E-5	.408	8.841 E-6	.329
NI 35	1.138 E-5		0.0	
NI 35	2.957 E-5	.314	0.0	0.0
S 137	2.673 E-4		2.135 E-4	
S 137	3.181 E-4	.721	2.623 E-4	.767
S 86	1.819 E-5		4.37 E-6	
S 86	9.451 E-6	.092	4.37 E-6	.113
S 35	0.0		0.0	
S 35	1.321 E-6	.010	0.0	0.0
SI 137	2.5 E-5		1.667 E-6	
SI 137	4.238 E-5	.083	4.644 E-5	.102
SI 86	1.128 E-5		1.321 E-6	
SI 86	2.134 E-6	.045	0.0	.017
SI 35	3.76 E-6		0.0	
SI 35	2.051 E-6	.045	0.0	0.0
E 86	4.624 E-5		7.317 E-6	
E 86	3.415 E-5	.268	0.0	.094
E 35	3.415 E-5		0.0	
E 35	1.657 E-5	.524	0.0	0.0
EI 86	1.373 E-4		4.37 E-6	
EI 86	8.211 E-5	.731	1.321 E-6	.074
EI 35	2.957 E-5		0.0	
EI 35	1.047 E-5	.302	0.0	0.0

Table A2. Data for Single Tree Test, Low Velocity, Replicate Two

Height cm	Dye Tracer	Air Velocity mm/sec	Volume Weighted Mean Diameter (μ)
137	Yellow	1299	—
"	Blue	1276	—
86	Yellow	1263	—
"	Blue	1264	—
35	Yellow	1198	—
"	Blue	1192	—

Flux Predicted From Intercept Area and Deposit				
Sample Location	Yellow Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level	Blue Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level
N 137	4.508 E-4		2.945 E-4	
N 137	4.941 E-4	1	3.400 E-4	1
N 86	1.554 E-4		5.203 E-5	
N 86	1.509 E-4	1	4.846 E-5	1
N 35	2.459 E-5		0.0	
N 35	2.266 E-5	1	0.0	1
NI 137	3.355 E-4		1.841 E-4	
NI 137	2.278 E-4	.596	1.666 E-4	.553
NI 86	7.815 E-5		1.972 E-5	
NI 86	8.222 E-5	.523	2.541 E-6	.223
NI 35	1.900 E-5		0.0	
NI 35	1.362 E-5	.690	0.0	0.0
S 137	1.202 E-4		1.105 E-4	
S 137	8.333 E-6	.136	2.541 E-6	.178
S 86	8.435 E-6		0.0	
S 86	1.829 E-6	.033	0.0	0.0
S 35	1.016 E-6		0.0	
S 35	5.691 E-6	.142	4.065 E-6	—
SI 137	9.045 E-6		5.589 E-6	
SI 137	5.945 E-5	.072	4.319 E-5	.077
SI 86	5.081 E-6		0.0	
SI 86	2.419 E-5	.096	8.638 E-6	.086
SI 35	2.459 E-5		0.0	
SI 35	7.622 E-6	.682	0.0	0.0
E 86	4.482 E-5		2.297 E-5	
E 86	4.177 E-5	.283	1.016 E-5	.330
E 35	1.270 E-5		0.0	
E 35	3.455 E-6	.342	0.0	0.0
EI 86	2.642 E-5		1.016 E-6	
EI 86	2.429 E-5	.166	5.589 E-6	.066
EI 35	3.455 E-6		0.0	
EI 35	1.016 E-6	.095	0.0	0.0

Table A3. Data for Single Tree Test, Low Velocity, Replicate Three

Height cm	Dye Tracer	Air Velocity mm/sec	Volume Weighted Mean Diameter (μ)	
137	Yellow	1353	81	
"	Blue	1348	29	
86	Yellow	1347	92	
"	Blue	1353	—	
35	Yellow	1319	—	
"	Blue	1313	—	

Sample Location	Flux Predicted From Intercept Area and Deposit			
	Yellow Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level	Blue Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level
N 137	4.152 E-4		3.881 E-4	
N 137	4.765 E-4	1	3.887 E-4	1
N 86	2.733 E-4		1.464 E-4	
N 86	1.949 E-4	1	9.614 E-5	1
N 35	2.195 E-5		0.0	
N 35	4.228 E-5	1	0.0	—
NI 137	1.177 E-4		1.583 E-4	
NI 137	1.434 E-4	.293	1.427 E-4	.425
NI 86	7.866 E-5		2.581 E-5	
NI 86	5.091 E-5	.277	1.220 E-6	.111
NI 35	1.128 E-5		0.0	
NI 35	1.847 E-5	.339	0.0	—
S 137	3.699 E-5		5.891 E-5	
S 137	2.164 E-4	.284	2.564 E-4	.446
S 86	1.453 E-5		4.167 E-6	
S 86	1.118 E-5	.055	0.0	.017
S 35	3.760 E-6		0.0	
S 35	0.0	.059	0.0	—
SI 137	6.870 E-5		7.873 E-5	
SI 137	1.138 E-5	.090	3.394 E-5	.152
SI 86	0.0		0.0	
SI 86	3.760 E-6	.088	0.0	—
SI 35	0.0		0.0	
SI 35	0.0	—	0.0	—
E 86	1.888 E-4		1.179 E-5	
E 86	1.398 E-4	.531	1.331 E-4	.597
E 35	7.276 E-5		0.0	
E 35	4.228 E-5	1.79	0.0	—
EI 86	2.632 E-5		5.691 E-6	
EI 86	4.573 E-6	.066	0.0	.023
EI 35	7.927 E-6		0.0	
EI 35	2.134 E-6	.157	0.0	—

Table A4. Data for Single Tree Test, Low Velocity, Replicate Four

Height cm	Dye Tracer	Air Velocity mm/sec	Volume Weighted Mean Diameter (μ)
137	Yellow	1351	65
"	Blue	1343	35
86	Yellow	1361	101
"	Blue	1372	40
35	Yellow	1323	98
"	Blue	1338	—

Sample Location	Flux Predicted From Intercept Area and Deposit			
	Yellow Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level	Blue Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level
N 137	4.046 E-4		3.780 E-4	
N 137	4.694 E-4	1	3.702 E-4	1
N 86	2.558 E-4		6.697 E-5	
N 86	2.503 E-4	1	5.620 E-5	1
N 35	1.298 E-4		8.740 E-6	
N 35	1.220 E-4	1	8.740 E-6	1
NI 137	1.911 E-4		1.801 E-4	
NI 137	1.140 E-4	.349	1.214 E-4	.403
NI 86	2.405 E-4		5.793 E-5	
NI 86	4.014 E-5	.554	1.636 E-5	.603
NI 35	5.742 E-5		1.220 E-6	
NI 35	1.140 E-4	.684	2.744 E-6	.227
S 137	9.919 E-5		9.004 E-5	
S 137	9.888 E-5	.227	9.614 E-5	.249
S 86	7.388 E-5		3.069 E-5	
S 86	2.368 E-5	.193	1.220 E-6	.259
S 35	6.199 E-6		0.0	
S 35	1.047 E-5	.066	0.0	—
SI 137	8.171 E-5		8.028 E-5	
SI 137	1.474 E-4	.262	1.198 E-4	.267
SI 86	1.392 E-5		4.167 E-6	
SI 86	6.199 E-6	.040	1.220 E-6	.044
SI 35	1.392 E-5		0.0	
SI 35	7.114 E-6	.084	0.0	—
E 86	1.271 E-4		2.104 E-5	
E 86	1.570 E-4	.561	3.982 E-5	.494
E 35	1.082 E-4		1.179 E-5	
E 35	1.536 E-4	1.36	2.744 E-6	.273
EI 86	9.421 E-5		2.907 E-5	
EI 86	5.539 E-5	.296	1.404 E-5	.356
EI 35	5.742 E-5		1.220 E-6	
EI 35	5.102 E-5	.431	0.0	.168

Table A5. Data for Single Tree Test, High Velocity, Replicate One

Height cm	Dye Tracer	Air Velocity mm/sec	Volume Weighted Mean Diameter (μ)
137	Yellow	2547	93
"	Blue	2562	53
86	Yellow	2421	110
"	Blue	2441	60
35	Yellow	2531	121
"	Blue	2473	—

Sample Location	Flux Predicted From Intercept Area and Deposit			Flux/N Flux at same level
	Yellow Flux $\mu\text{l}/\text{mm}^2$	Flux/N Flux at same level	Blue Flux $\mu\text{l}/\text{mm}^2$	
N 137	3.713 E-4		4.957 E-4	
N 137	4.652 E-4	1	4.616 E-4	1
N 86	1.125 E-3		5.305 E-4	
N 86	1.170 E-3	1	6.799 E-4	1
N 35	1.262 E-3		2.390 E-4	
N 35	1.146 E-3	1	1.616 E-4	1
NI 137	6.726 E-4		7.287 E-4	
NI 137	2.501 E-4	1.10	2.308 E-4	1.00
NI 86	4.793 E-4		2.098 E-4	
NI 86	3.404 E-5	.224	1.911 E-5	.189
NI 35	7.396 E-4		8.720 E-5	
NI 35	5.695 E-4	.544	5.122 E-5	.346
S 137	5.783 E-5		6.230 E-5	
S 137	2.309 E-4	.345	2.824 E-4	.360
S 86	6.250 E-5		2.693 E-5	
S 86	1.859 E-4	.188	7.134 E-5	.081
S 35	3.892 E-5		1.148 E-5	
S 35	1.311 E-5	.022	2.439 E-5	.090
SI 137	5.203 E-5		7.500 E-5	
SI 137	1.108 E-4	.195	1.405 E-4	.225
SI 86	1.230 E-4		3.496 E-5	
SI 86	2.479 E-5	.064	7.012 E-6	.035
SI 35	3.516 E-5		1.910 E-5	
SI 35	1.311 E-5	.020	1.220 E-6	.051
E 86	7.470 E-4		1.518 E-4	
E 86	1.120 E-3	.813	3.415 E-4	.408
E 35	4.793 E-4		2.439 E-5	
E 35	8.232 E-4	.541	2.439 E-5	.122
EI 86	9.104 E-4		2.390 E-4	
EI 86	9.213 E-4	.798	2.695 E-4	.420
EI 35	2.591 E-5		2.642 E-6	
EI 35	7.154 E-5	.040	8.537 E-6	.028

APPENDIX B

CYLINDER TEST DATA

APPENDIX B

CYLINDER TEST DATA

These data are arranged into four tables each includes data for a different air velocity range. The mean air velocities and volume weighted mean diameters are reported in the first part of each table. The second part of each includes: The tunnel run number, the cylinder size, and the tunnel position (1 being far east through to 9 far to the far west) are in column one. The estimated dye flux in microliters per square millimeter are in columns two and four. The ratio of the estimated dye flux predicted from the larger of two adjacent cylinders divided by the flux from the smaller cylinder are reported in columns three and five. Columns two and three report data for the large droplet distribution while columns four and five report data for the small droplet distribution.

Table B1. Cylinder Test Data for Treatments One and Two

RUN NO.	DYE TRACER	AIR VELOCITY MM/SEC	VOLUME WEIGHTED MEAN DAIOMETER (U)
ONE	YELLOW	744	129
	BLUE	741	28
TWO	YELLOW	747	147
	BLUE	714	20
THREE	YELLOW	741	134
	BLUE	719	37

Flux Predicted From Intercept Area and Deposit

CYLINDER SIZE : POSITION		YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 1					
1.16	1	2.577E-04		0	
			.669		0
2.22	2	1.725E-04		0	
			.65		0
1.66	3	2.655E-04		0	
			.812		0
1.16	4	3.269E-04		0	
			.688		0
2.22	5	1.987E-04		0	
			.738		0
1.66	6	2.693E-04		1.418E-06	
			.86		.695
1.16	7	3.133E-04		2.041E-06	
			.724		.52
2.22	8	2.269E-04		1.062E-06	
			.715		.749
1.66	9	3.174E-04		1.418E-06	
RUN 2					
1.16	1	2.724E-04		2.041E-06	
			.633		0
2.22	2	1.725E-04		0	
			.837		0
1.66	3	2.06E-04		0	
			.648		0
1.16	4	3.177E-04		2.041E-06	
			.459		0
2.22	5	1.458E-04		0	
			.718		0
1.66	6	2.032E-04		0	
			.667		0
1.16	7	3.048E-04		0	
			.582		0
2.22	8	1.773E-04		0	
			.687		0
1.66	9	2.579E-04		1.418E-06	

Table B1. Continued

CYLINDER SIZE : POSITION	YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 3				
1.16 1	4.043E-04		1.173E-05	
		.636		.196
2.22 2	2.572E-04		2.301E-06	
		.915		.749
1.66 3	2.812E-04		3.073E-06	
		.886		.695
1.16 4	3.175E-04		4.422E-06	
		.663		.24
2.22 5	2.106E-04		1.061E-06	
		.771		.748
1.66 6	2.732E-04		1.418E-06	
		.975		.695
1.16 7	2.801E-04		2.041E-06	
		.798		1.127
2.22 8	2.235E-04		2.301E-06	
		.818		.487
1.66 9	2.731E-04		4.728E-06	
LARGE CYLINDERS				
3.94	1.527E-04		1.3E-06	
3.94	1.58E-04		1.3E-06	
3.94	1.527E-04		1.3E-06	
3.94	1.155E-04		2.7E-06	
3.94	1.244E-04		1.3E-06	
3.94	1.244E-04		1.3E-06	
3.94	1.406E-04		2.7E-06	
3.94	1.173E-04		1.3E-06	
3.94	1.091E-04		1.3E-06	

Table B2. Cylinder Test Data for Treatments Three and Four

RUN NO.	DYE TRACER	AIR VELOCITY MM/SEC	VOLUME WEIGHTED MEAN DIAMETER (U)
ONE	YELLOW	787	81
	BLUE	782	42
TWO	YELLOW	770	98
	BLUE	782	33
THREE	YELLOW	785	99
	BLUE	798	33

Flux Predicted From Intercept Area and Deposit

CYLINDER SIZE : POSITION	YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 1				
1.16 1	2.929E-04		2.837E-06	
		.771		.749
2.22 2	2.257E-04		2.124E-06	
		.569		.24
1.66 3	3.966E-04		8.844E-06	
		1.008		.328
1.16 4	3.936E-04		2.695E-05	
		.68		.361
2.22 5	2.676E-04		9.735E-06	
		.656		.52
1.66 6	4.082E-04		1.871E-05	
		.971		.36
1.16 7	4.206E-04		5.201E-05	
		.784		.388
2.22 8	3.296E-04		2.018E-05	
		.642		.706
1.66 9	5.136E-04		2.857E-05	
RUN 2				
1.16 1	3.837E-04		2.857E-05	
		.623		.161
2.22 2	2.391E-04		4.602E-06	
		.75		.354
1.66 3	3.189E-04		1.3E-05	
		.757		3.185
1.16 4	4.214E-04		4.082E-06	
		.462		0
2.22 5	1.945E-04		0	
		.665		0
1.66 6	2.927E-04		6.147E-06	
		.807		0
1.16 7	3.626E-04		0	
		.57		0
2.22 8	2.0673E-04		0	
		.719		0
1.66 9	2.877E-04		1.655E-05	

Table B2. Continued

CYLINDER SIZE : POSITION	YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 3				
1.16 1	4.588E-04		1.871E-05	
		.568		.246
2.22 2	2.604E-04		4.602E-06	
		.552		.135
1.66 3	4.719E-04		3.404E-05	
		.754		3.849
1.16 4	6.262E-04		8.844E-06	
		.536		0
2.22 5	3.354E-04		0	
		.771		0
1.66 6	4.35E-04		9.693E-06	
		.856		0
1.16 7	5.0816E-04		0	
		.543		0
2.22 8	2.758E-04		2.124E-06	
		.738		0
1.66 9	3.735E-04		0	
LARGE CYLINDERS				
3.94	1.893E-04		2.6E-06	
3.94	2.003E-04		2.6E-06	
3.94	1.92E-04		2.6E-06	
3.94	1.719E-04		0	
3.94	1.472E-04		1.2E-06	
3.94	1.492E-04		4.1E-06	
3.94	-1		-1	
3.94	-1		-1	
3.94	-1		-1	

Table B3. Cylinder Test Data for Treatments Five and Six

RUN NO.	DYE TRACER	AIR VELOCITY MM/SEC	VOLUME WEIGHTED MEAN DIAMETER (U)
ONE	YELLOW	1427	163
	BLUE	1462	44
TWO	YELLOW	1490	188
	BLUE	1453	48
THREE	YELLOW	1495	148
	BLUE	1484	36

Flux Predicted From Intercept Area and Deposit

CYLINDER SIZE : POSITION		YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 1					
1.16	1	1.107E-03		1.231E-04	
			.813		.384
2.22	2	8.995E-04		4.726E-05	
			.829		.686
1.66	3	1.085E-03		7.881E-05	
			1.815		.695
1.16	4	1.069E-03		1.122E-04	
			.758		.421
2.22	5	8.899E-04		4.725E-05	
			.977		.637
1.66	6	8.291E-04		7.423E-05	
			1.863		.695
1.16	7	7.883E-04		1.068E-04	
			.791		.494
2.22	8	6.172E-04		5.274E-05	
			1.874		.645
1.66	9	5.749E-04		8.18E-05	
RUN 2					
1.16	1	9.663E-04		1.177E-04	
			.727		.482
2.22	2	7.825E-04		4.726E-05	
			.978		.671
1.66	3	7.184E-04		7.845E-05	
			.817		.66
1.16	4	8.796E-04		1.068E-04	
			.749		.443
2.22	5	6.591E-04		4.726E-05	
			.856		.686
1.66	6	7.697E-04		7.881E-05	
			.983		.663
1.16	7	8.527E-04		1.177E-04	
			.789		.424
2.22	8	6.727E-04		4.991E-05	
			.986		.61
1.66	9	7.428E-04		8.18E-05	

Table B3. Continued

CYLINDER SIZE : POSITION		YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 3					
1.16	1	6.956E-04		1.014E-04	
			.774		.438
2.22	2	5.382E-04		4.442E-05	
			.827		.631
1.66	3	6.511E-04		7.045E-05	
			.823		.599
1.16	4	7.912E-04		1.177E-04	
			.757		.353
2.22	5	5.986E-04		4.159E-05	
			.891		.533
1.66	6	6.719E-04		7.801E-05	
			1.009		.663
1.16	7	6.656E-04		1.177E-04	
			.809		.353
2.22	8	5.384E-04		4.159E-05	
			.921		.59
1.66	9	5.844E-04		7.045E-05	
LARGE CYLINDERS					
3.94		5.576E-04		1.89E-05	
3.94		6.082E-04		1.59E-05	
3.94		6.401E-04		1.44E-05	
3.94		5.577E-04		1.74E-05	
3.94		5.578E-04		1.59E-05	
3.94		5.811E-04		1.74E-05	
3.94		4.065E-04		1.59E-05	
3.94		4.365E-04		1.59E-05	
3.94		4.6E-04		1.44E-05	

Table B4. Cylinder Test Data for Treatments Seven and Eight

RUN NO.	DYE TRACER	AIR VELOCITY MM/SEC	VOLUME WEIGHTED MEAN DAINETER (U)
ONE	YELLOW	2134	213
	BLUE	2090	66
TWO	YELLOW	2210	194
	BLUE	2264	80
THREE	YELLOW	2013	217
	BLUE	2045	44

Flux Predicted From Intercept Area and Deposit

CYLINDER SIZE : POSITION		YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
RUN 1					
1.16	1	6.959E-04		2.881E-04	
			1.155		.561
2.22	2	8.0407E-04		1.6159E-04	
			.729		.698
1.66	3	1.103E-03		2.314E-04	
			.78		.672
1.16	4	1.414E-03		3.442E-04	
			.999		.588
2.22	5	1.413E-03		2.025E-04	
			.762		.795
1.66	6	1.854E-03		2.548E-04	
			.912		.674
1.16	7	2.032E-03		3.779E-04	
			1.014		.582
2.22	8	2.06E-03		2.2E-04	
			.838		.729
1.66	9	2.457E-03		3.017E-04	
RUN 2					
1.16	1	5.425E-04		2.095E-04	
			.886		.548
2.22	2	4.809E-04		1.149E-04	
			.777		.713
1.66	3	6.189E-04		1.612E-04	
			1.027		.695
1.16	4	6.024E-04		2.32E-04	
			1.047		.571
2.22	5	6.308E-04		1.324E-04	
			.857		.749
1.66	6	7.359E-04		1.768E-04	
			1.009		.727
1.16	7	7.296E-04		2.432E-04	
			.953		.568
2.22	8	6.95E-04		1.382E-04	
			.918		.69
1.66	9	7.567E-04		2.002E-04	

Table B4. Continued

CYLINDER SIZE : POSITION		YELLOW FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL	BLUE FLUX UL/MM SQ	LARGER CYL/ SMALLER CYL
<hr/>					
RUN 3					
1.16	1	3.573E-04		5.85E-05	
			.819		.744
2.22	2	2.926E-04		4.354E-05	
			.875		.658
1.66	3	3.344E-04		6.619E-05	
			1.085		.717
1.16	4	3.082E-04		9.235E-05	
			.899		.537
2.22	5	2.77E-04		4.956E-05	
			1.09		.725
1.66	6	2.541E-04		6.832E-05	
			.994		.675
1.16	7	2.556E-04		1.012E-04	
			.73		.63
2.22	8	1.867E-04		6.372E-05	
			1.22		.788
1.66	9	1.53E-04		8.085E-05	
LARGE CYLINDERS					
3.94		2.001E-03		1.144E-04	
3.94		1.839E-03		1.078E-04	
3.94		1.572E-03		1.012E-04	
3.94		1.404E-03		9.79E-05	
3.94		1.261E-03		9.13E-05	
3.94		1.077E-03		8.8E-05	
3.94		3.344E-04		6.619E-05	
3.94		2.541E-04		6.832E-05	
3.94		1.53E-04		8.085E-05	

APPENDIX C

BRANCH AND CYLINDER TEST DATA

APPENDIX C

BRANCH AND CYLINDER TEST DATA

These data are arranged into six tables one for each air velocity range. Each table is broken into four groups. The first group includes a summary of the mean air velocities and droplet distributions volume weighted mean diameters. The balance of each table is divided by tunnel run number into three groups. The first column reports obstacle type (TP Branch = Top 6 cm of 12 cm branch, Small = 1.16 cm diameter cylinder and Large = 2.22 cm diameter cylinder). Columns two and five report the estimated dye flux in microliters per millimeter squared. Columns three and six report the ratio of the estimated deposits on two adjacent objects with the direction of division being the larger flux divided into the smaller flux. Columns four and seven report the ratio of the estimated deposit on the object divided by the estimate flux from the air filter. The air filter flux is reported as the last line in each data group.

Tables C7 and C8 follow the above data tables. Table C7 includes the multiple linear regression file for the data in tables C1 through C6. The dependent variable (DV) is the relative collection efficiency of the two compared obstacles. The first independent variable (IV#1) is the logarithm of the particle parameter for the small cylinder as a reference to bring in air velocity and droplet size. The second and third independent variables are the indicator variables discussed in the text (see "Results and Discussion" of "BRANCH AND CYLINDER EXPERIMENTS"). The fourth is the relative turbulent intensity of the air. The fifth are the grams dry weight for the

branch. The sixth is the mean tunnel position.

Table C8 includes the multiple linear (in this case curvilinear regression) regression file for the branch versus the air filter. The dependent variable (DV) is the estimated collection efficiency of the branches. Independent variable one (IV#1) is the logarithm of the particle parameter for the small cylinder as a reference to include the air velocity and droplet size. Independent variables two and three are the logarithm of the particle parameter squared and cubed respectively.

Table C1. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 672 and 763 mm/sec (No Position Shifting).

		Yellow	Blue
Run 1 Air Velocity (mm/sec)		763	728
Run 1 Vol. Weighted Mean		122	38
Run 2 Air Velocity		672	717
Run 2 Vol. Weighted Mean		189	38
Run 3 Air Velocity		761	780
Run 3 Vol. Weighted Mean		187	28

Summary for Run One							
Type/Pos.		Flux Yellow	Smaller/ Larger	Rel. to Filter	Flux Blue	Smaller/ Larger	Rel. to Filter
Small	1	1.95238E-4		.472	trace		—
			.948			—	
TP Branch	2	1.8354 E-4		.444	1.7581 E-5		.014
			.829			.121	
Large	3	1.5221 E-4		.368	2.124 E-6		.0017
			.487			—	
Small	4	3.7381 E-4		.984	trace		—
			.657			—	
TP Branch	5	2.4543 E-4		.594	1.9186 E-5		.015
			.888			.214	
Large	6	2.7628 E-4		.668	4.682 E-6		.0036
			.695			—	
Small	7	3.9728 E-4		.961	trace		—
			.525			—	
TP Branch	8	2.8864 E-4		.584	2.8638 E-5		.016
			.823			.223	
Large	9	2.5362 E-4		.613	4.682 E-6		.0036
FILTER	1	4.1344 E-4			1.2789 E-3		

Table C1. Continued

Summary for Run Two

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Small	1	3.5868 E-4		1.82	4.08163 E-6		.0039
,			.867			—	
TP Branch	2	3.0142 E-4		.875	trace		—
,			.838			—	
Large	3	2.5827 E-4		.727	trace		—
,			.702			—	
Small	4	3.5646 E-4		1.83	trace		—
,			.828			—	
TP Branch	5	2.9228 E-4		.849	8.5366 E-6		.0081
,			.696			.249	
Large	6	2.8354 E-4		.591	2.1239 E-6		.002
,			.618			—	
Small	7	3.2925 E-4		.956	trace		—
,			.983			—	
TP Branch	8	3.2368 E-4		.948	1.8861 E-5		.0096
,			.647			.211	
Large	9	2.8354 E-4		.591	2.1239 E-6		.002
,							
FILTER	#	3.4442 E-4			1.0488 E-3		

Summary for Run Three

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Small	1	2.8435 E-4		.727	trace		—
,			.629			—	
TP Branch	2	1.7896 E-4		.458	8.5366 E-6		.0096
,			.568			—	
Large	3	1.8159 E-4		.268	trace		—
,			.659			—	
Small	4	1.5488 E-4		.394	trace		—
,			.695			—	
TP Branch	5	2.2174 E-4		.567	1.8861 E-5		.011
,			.675			—	
Large	6	1.4974 E-4		.383	trace		—
,			.579			—	
Small	7	2.5858 E-4		.661	trace		—
,			.953			—	
TP Branch	8	2.4624 E-4		.638	5.5894 E-6		.0063
,			.865			—	
Large	9	2.1318 E-4		.545	trace		—
,							
FILTER	#	3.9111 E-4			8.8845 E-4		

\times Flux is in μl liquid dye / mm^2 squared.

Table C2. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 726 and 796 mm/sec.

	Yellow	Blue
Run 1 Air Velocity (mm/sec)	750	783
Run 1 Vol. Weighted Mean	74	32
Run 2 Air Velocity	726	779
Run 2 Vol. Weighted Mean	79	33
Run 3 Air Velocity	796	790
Run 3 Vol. Weighted Mean	85	31

Summary for Run One

Type/Pos.	Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
TP Branch 1	1.4065 E-4		.310	7.5 E-5		.047
Small		.951			.054	
Large		.534			.520	
TP Branch 2	1.4796 E-4		.326	4.0016 E-6		.0025
Small		.611			.033	
Large		.969			—	
TP Branch 3	1.2917 E-4		.284	6.4024 E-5		.040
Small		.520		trace	—	
Large		.729		trace	—	
TP Branch 4	6.5133 E-5		.143			
Small		.872		8.6404 E-5	.102	.054
Large		.700		8.0435 E-6	.0035	
TP Branch 5	7.7891 E-5		.172			
Small			.120	7.0797 E-6	.0044	
Large						
FILTER	4.5404 E-4			1.6037 E-3		

Table C2. Continued

Summary for Run Two

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Large	1	6.3889 E-5		.281	2.1239 E-6		.0011
,			.768			.817	
TP Branch	2	8.2927 E-5		.264	1.2317 E-4		.062
,			.924			.872	
Small	3	8.9796 E-5		.286	8.8435 E-6		.0045
,			.538			.240	
Large	4	4.8318 E-5		.154	2.1238 E-6		.0011
,			.735			.557	
TP Branch	5	6.5752 E-5		.289	1.1819 E-4		.068
,			.879			.115	
Small	6	7.4838 E-5		.238	1.3685 E-5		.0069
,			.525			—	
Large	7	3.9292 E-5		.125	trace		—
,			.588			—	
TP Branch	8	6.6768 E-5		.213	1.9715 E-4		.100
,			.897			.840	
Small	9	5.9864 E-5		.175	2.3469 E-5		.011
,							
FILTER	2	3.1397 E-4			1.9813 E-3		

Summary for Run Three

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Small	1	1.1828 E-4		.273	trace		—
,			.626			—	
Large	2	6.9827 E-5		.171	trace		—
,			.684			—	
TP Branch	3	1.8892 E-4		.258	1.4238 E-4		.088
,			.893			—	
Small	4	9.8136 E-5		.223	trace		—
,			.679			—	
Large	5	6.1239 E-5		.152	trace		—
,			.875			—	
TP Branch	6	5.3557 E-5		.132	1.1982 E-4		.067
,			.575			—	
Small	7	9.3197 E-5		.231	trace		—
,			.572			—	
Large	8	5.3274 E-5		.132	trace		—
,			.828			—	
TP Branch	9	4.3699 E-5		.188	1.3344 E-4		.075
,							
FILTER	3	4.8396 E-4			1.7864 E-3		

\times Flux is in ul liquid dye / mm squared.

Table C3. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 919 and 1007 mm/sec.

	Yellow	Blue
Run 1 Air Velocity (mm/sec)	1007	943
Run 1 Vol. Weighted Mean	58	31
Run 2 Air Velocity	991	969
Run 2 Vol. Weighted Mean	53	30
Run 3 Air Velocity	928	919
Run 3 Vol. Weighted Mean	53	29

Summary for Run One

Type/Pos.	Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
TP Branch 1	7.6423 E-5		.326	1.4980 E-4		.102
Small		.944			.354	
Large		.437			.365	
TP Branch 2	8.0952 E-5		.346	5.3061 E-5		.036
Small		.519			.136	
Large		.980			.317	
TP Branch 3	3.5398 E-5		.151	1.9381 E-5		.013
Small		.429			.281	
Large		.486			.083	
TP Branch 4	6.8191 E-5		.291	1.4238 E-4		.097
Small		.916			.332	
Large		.287			.304	
TP Branch 5	6.9558 E-5		.297	4.5068 E-5		.031
Small		.486				
Large		.139				
TP Branch 6	2.9823 E-5		.127	1.2655 E-5		.0086
Small		.313				
Large		.517				
TP Branch 7	7.3374 E-5		.313	1.5173 E-4		.103
Small		.287				
Large		.486				
TP Branch 8	6.7177 E-5		.287	5.0340 E-5		.034
Small		.139				
Large		.139				
FILTER ONE	2.3412 E-4			1.4663 E-3		

Table C3. Continued

Summary for Run Two

Type/Pos. '		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Large	1	2.6726 E-5		.087	1.5310 E-5		.0082
'			.347			.068	
TP Branch	2	7.6931 E-5		.252	2.2602 E-4		.122
'			.778			.199	
Small	3	5.9864 E-5		.196	4.5068 E-5		.024
'			.423			.251	
Large	4	2.5310 E-5		.083	1.1327 E-5		.0061
'			.303			.056	
TP Branch	5	8.3537 E-5		.273	2.0051 E-4		.108
'			.623			.225	
Small	6	5.2041 E-5		.170	4.5068 E-5		.024
'			.471			.251	
Large	7	2.4513 E-5		.080	1.1327 E-5		.0061
'			.411			.062	
TP Branch	8	5.9655 E-5		.195	1.8232 E-4		.098
'			.793			.276	
Small	9	4.7279 E-5		.155	5.0340 E-5		.027
'							
FILTER TWO		3.0585 E-4			1.8574 E-3		

Summary for Run Three

Type/Pos. '		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Small	1	7.6701 E-5		.355	2.1769 E-5		.014
'			.613			.764	
Large	2	4.6992 E-5		.218	1.6637 E-5		.010
'			.712			.108	
TP Branch	3	6.5955 E-5		.306	1.5366 E-4		.095
'			.979			.093	
Small	4	6.7347 E-5		.312	1.4286 E-5		.0089
'			.654			.793	
Large	5	4.4071 E-5		.204	1.1327 E-5		.0070
'			.479			.058	
TP Branch	6	9.1972 E-5		.426	1.9583 E-4		.122
'			.767			.137	
Small	7	7.0578 E-5		.327	2.6871 E-5		.017
'			.520			.523	
Large	8	3.6726 E-5		.170	1.3982 E-5		.0087
'			.442			.068	
TP Branch	9	8.3130 E-5		.385	2.0529 E-4		.127
'							
FILTER THREE		2.1585 E-4			1.6111 E-3		

x Flux is in ul liquid dye / mm squared.

Table C4. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 1057 and 1163 mm/sec.

	Yellow	Blue
Run 1 Air Velocity (mm/sec)	1098	1057
Run 1 Vol. Weighted Mean	67	37
Run 2 Air Velocity	1118	1093
Run 2 Vol. Weighted Mean	76	30
Run 3 Air Velocity	1163	1109
Run 3 Vol. Weighted Mean	104	42

Summary for Run One

Type/Pos.	Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
TP Branch 1	6.9207 E-5		.538	2.5661 E-4		.135
Small		.953			.360	
2	7.2618 E-5		.565	9.2347 E-5		.049
Large		.556			.239	
3	4.0354 E-5		.314	2.2035 E-5		.012
TP Branch 4	6.4533 E-5		.502	2.3913 E-4		.126
Small		.862			.374	
5	7.4830 E-5		.582	8.9456 E-5		.047
Large		.577			.309	
6	4.3186 E-5		.336	2.7611 E-5		.015
TP Branch 7	6.3923 E-5		.497	2.0772 E-4		.109
Small		.676			.133	
8	7.1259 E-5		.554	8.3674 E-5		.044
Large		.897			.403	
9	4.5310 E-5		.352	2.7611 E-5		.015
FILTER ONE	1.2857 E-4			1.9028 E-3		

Table C4. Continued

Summary for Run Two

Type/Pos.		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Large	1	2.9469 E-5		.220	1.9381 E-5		.011
'			.595			.089	
TP Branch	2	4.9492 E-5		.369	2.1768 E-4		.127
'			.754			.358	
Small	3	6.5646 E-5		.490	7.7891 E-5		.046
'			.690			.354	
Large	4	4.5310 E-5		.338	2.7611 E-5		.016
'			.558			.105	
TP Branch	5	8.1199 E-5		.606	2.6281 E-4		.154
'			.859			.286	
Small	6	6.9728 E-5		.520	7.5170 E-5		.044
'			.594			.293	
Large	7	4.1416 E-5		.309	2.2035 E-5		.013
'			.511			.100	
TP Branch	8	8.1098 E-5		.605	2.2022 E-4		.129
'			.958			.341	
Small	9	7.7721 E-5		.580	7.5170 E-5		.044
'							
FILTER TWO		1.3398 E-4			1.7086 E-3		

Summary for Run Three

Type/Pos.		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Small	1	1.0017 E-4		.679	4.5068 E-5		.046
'			.716			.340	
Large	2	7.1681 E-5		.406	1.5310 E-5		.016
'			.914			.103	
TP Branch	3	6.5549 E-5		.444	1.4797 E-4		.150
'			.599			.252	
Small	4	1.0935 E-4		.741	3.7245 E-5		.038
'			.763			.447	
Large	5	8.3451 E-5		.566	1.6637 E-5		.017
'			.860			.137	
TP Branch	6	7.1740 E-5		.406	1.2144 E-4		.123
'			.622			.415	
Small	7	1.1531 E-4		.782	5.0340 E-5		.051
'			.746			.411	
Large	8	8.6018 E-5		.583	2.0708 E-5		.021
'			.887			.149	
TP Branch	9	9.6951 E-5		.657	1.3872 E-4		.141
'							
FILTER THREE		1.4751 E-4			9.8521 E-4		

x Flux is in ul liquid dye / mm squared.

Table C5. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 1263 and 1343 mm/sec.

	Yellow	Blue
Run 1 Air Velocity (mm/sec)	1343	1286
Run 1 Vol. Weighted Mean	89	39
Run 2 Air Velocity	1335	1281
Run 2 Vol. Weighted Mean	70	36
Run 3 Air Velocity	1342	1263
Run 3 Vol. Weighted Mean	73	43

Summary for Run One

Type/Pos.	Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
TP Branch 1	9.5732 E-5		.617	1.3872 E-4		.216
Small 2	1.5952 E-4	.600	1.03	4.7789 E-5	.344	.074
Large 3	1.1212 E-4	.703	.724	1.3982 E-5	.293	.022
TP Branch 4	9.1464 E-5	.816	.590	9.6342 E-5	.145	.150
Small 5	1.6191 E-4	.565	1.04	5.3061 E-5	.531	.083
Large 6	1.0894 E-4	.673	.703	1.2655 E-5	.238	.020
TP Branch 7	9.6138 E-5	.082	.620	7.1342 E-5	.177	.111
Small 8	1.4745 E-4	.652	.952	3.4524 E-5	.404	.054
Large 9	1.0266 E-5	.070	.066	1.2655 E-5	.367	.020
FILTER ONE	1.5495 E-4			6.4147 E-4		

Table C5. Continued

Summary for Run Two

Type/Pos. '		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Large	1	6.3451 E-5		.634	2.9027 E-5		.040
'			.864			.201	
TP Branch	2	7.3476 E-5		.734	1.4421 E-4		.200
'			.790			.406	
Small	3	9.3027 E-5		.929	5.8503 E-5		.081
'			.753			.354	
Large	4	7.0089 E-5		.700	2.0708 E-5		.029
'			.927			.153	
TP Branch	5	7.5610 E-5		.755	1.3516 E-4		.187
'			.687			.473	
Small	6	1.1003 E-4		1.10	6.3946 E-5		.088
'			.660			.345	
Large	7	7.2566 E-5		.725	2.2035 E-5		.030
'			.936			.172	
TP Branch	8	7.7541 E-5		.774	1.2825 E-4		.177
'			.715			.414	
Small	9	1.0850 E-4		1.08	5.3061 E-5		.073
'							
FILTER TWO		1.0015 E-4			7.2267 E-4		

Summary for Run Three

Type/Pos. '		Flux x Yellow	Smaller/ Larger	Rel. to Filter	Flux x Blue	Smaller/ Larger	Rel. to Filter
Small	1	6.8027 E-5		.708	6.9558 E-5		.111
'			.702			.318	
Large	2	4.7708 E-5		.497	2.2135 E-5		.035
'			.723			.152	
TP Branch	3	6.6057 E-5		.687	1.4604 E-4		.232
'			.766			.825	
Small	4	8.6225 E-5		.897	1.2058 E-4		.192
'			.555			.172	
Large	5	4.7876 E-5		.498	2.0708 E-5		.033
'			.700			.155	
TP Branch	6	6.8394 E-5		.712	1.3344 E-4		.212
'			.628			.649	
Small	7	1.0804 E-4		1.13	8.6565 E-5		.138
'			.546			.192	
Large	8	5.9381 E-5		.618	1.6637 E-5		.026
'			.599			.103	
TP Branch	9	9.9085 E-5		1.03	1.6148 E-4		.257
'							
FILTER THREE		9.6085 E-5			6.2861 E-4		

x Flux is in ul liquid dye / mm squared.

Table C6. Branch and Cylinder Data Summary for Two Droplet Distributions Exposed to Air Velocities Between 1590 and 1813 mm/sec.

	Yellow	Blue
Run 1 Air Velocity (mm/sec)	1797	1813
Run 1 Vol. Weighted Mean	176	47
Run 2 Air Velocity	1646	1702
Run 2 Vol. Weighted Mean	169	46
Run 3 Air Velocity	1590	1602
Run 3 Vol. Weighted Mean	163	48

Summary for Run One

Type/Pos.	Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
TP Branch 1	5.0107 E-5		.501	5.6200 E-5		.404
Small		.392			.300	
Large		.855	1.28	1.6837 E-5	.289	.121
TP Branch 2	1.2789 E-4					
Small		.586	1.09	4.8673 E-6	.066	.035
Large		.413				
TP Branch 3	1.0939 E-4		.554	7.4289 E-5		.535
Small		.828			.092	
Large		.579	1.34	6.8027 E-6	.520	.049
TP Branch 4	5.5386 E-5					
Small		.604	1.11	3.5398 E-6	.315	.026
Large		.855				
TP Branch 5	1.3418 E-4		.643	1.1240 E-5		.081
Small		.958			.958	
Large		.520	1.07	1.1735 E-5	.520	.084
TP Branch 6	1.0646 E-4					
Small		.911				
Large		.044	.911	6.1062 E-6		.044
FILTER ONE	9.9952 E-5			1.3894 E-4		

Table C6. Continued

Summary for Run Two

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Large	1	1.1283 E-4		.816	1.8620 E-6		.816
,			.486			.828	
TP Branch	2	5.4878 E-5		.397	3.7500 E-5		.563
,			.395			.249	
Small	3	1.3895 E-4		1.81	9.3537 E-6		.140
,			.678			.378	
Large	4	9.4159 E-5		.681	3.5399 E-6		.853
,			.183			.861	
TP Branch	5	1.7276 E-5		.125	5.8029 E-5		.871
,			.166			.246	
Small	6	1.8488 E-4		.753	1.4286 E-5		.214
,			.849			.248	
Large	7	8.8487 E-5		.648	3.5398 E-6		.853
,			.518			.853	
TP Branch	8	4.5833 E-5		.332	6.6972 E-5		1.81
,			.458			.251	
Small	9	1.8187 E-4		.737	1.6837 E-5		.253
,							
FILTER TWO		1.3823 E-4			6.6634 E-5		

Summary for Run Three

Type/Pos. ,		Flux \times Yellow	Smaller/ Larger	Rel. to Filter	Flux \times Blue	Smaller/ Larger	Rel. to Filter
Small	1	6.6497 E-5		.841	1.3180 E-4		.329
,			.868			.423	
Large	2	5.7168 E-5		.723	5.5752 E-5		.139
,			.672			.369	
TP Branch	3	3.8415 E-5		.486	1.5112 E-4		.377
,			.398			.729	
Small	4	9.6429 E-5		1.22	1.1828 E-4		.275
,			.981			.422	
Large	5	1.8699 E-4		1.35	4.6549 E-5		.166
,			.327			.396	
TP Branch	6	3.4959 E-5		.442	1.1758 E-4		.293
,			.318			.887	
Small	7	1.1883 E-4		1.39	1.8425 E-4		.268
,			.773			.361	
Large	8	8.5844 E-5		1.88	3.7611 E-5		.894
,			.482			.291	
TP Branch	9	3.4146 E-5		.432	1.2937 E-4		.323
,							
FILTER THREE		7.9848 E-5			4.8887 E-4		

\times Flux is in ul liquid dye / mm squared.

TABLE C7 DATA FILE: UPDMLR/DTA

	DV	IV#1	IV#2	IV#3	IV#4	IV#5	IV#6
ELEMENT # 1	.534	.315	0	0	.081	0	2.5
ELEMENT # 2	.52	.315	0	0	.081	0	5.5
ELEMENT # 3	.7	.315	0	0	.081	0	8.5
ELEMENT # 4	.538	.368	0	0	.08	0	3.5
ELEMENT # 5	.525	.368	0	0	.08	0	6.5
ELEMENT # 6	.626	.503	0	0	.062	0	1.5
ELEMENT # 7	.679	.503	0	0	.062	0	4.5
ELEMENT # 8	.572	.503	0	0	.062	0	7.5
ELEMENT # 9	.437	.232	0	0	.053	0	2.5
ELEMENT # 10	.429	.232	0	0	.053	0	5.5
ELEMENT # 11	.486	.232	0	0	.053	0	8.5
ELEMENT # 12	.423	.159	0	0	.082	0	3.5
ELEMENT # 13	.471	.159	0	0	.082	0	6.5
ELEMENT # 14	.613	.13	0	0	.073	0	1.5
ELEMENT # 15	.654	.130	0	0	.073	0	4.5
ELEMENT # 16	.365	-.342	0	0	.066	0	2.5
ELEMENT # 17	.281	-.342	0	0	.066	0	5.5
ELEMENT # 18	.304	-.342	0	0	.066	0	8.5
ELEMENT # 19	.251	-.366	0	0	.05	0	3.5
ELEMENT # 20	.764	-.757	0	0	.059	0	1.5
ELEMENT # 21	.793	-.757	0	0	.059	0	4.5
ELEMENT # 22	.523	-.757	0	0	.059	0	7.5
ELEMENT # 23	.556	.407	0	0	.074	0	2.5
ELEMENT # 24	.577	.407	0	0	.074	0	5.5
ELEMENT # 25	.636	.407	0	0	.074	0	8.5
ELEMENT # 26	.69	.524	0	0	.061	0	3.5
ELEMENT # 27	.594	.524	0	0	.061	0	6.5
ELEMENT # 28	.763	.812	0	0	.054	0	4.5
ELEMENT # 29	.746	.812	0	0	.054	0	7.5
ELEMENT # 30	.239	-.121	0	0	.066	0	2.5
ELEMENT # 31	.309	-.121	0	0	.066	0	5.5
ELEMENT # 32	.33	-.121	0	0	.066	0	8.5
ELEMENT # 33	.354	-.297	0	0	.082	0	3.5
ELEMENT # 34	.293	-.297	0	0	.082	0	6.5
ELEMENT # 35	.34	-.297	0	0	.048	0	1.5
ELEMENT # 36	.447	.069	0	0	.048	0	4.5
ELEMENT # 37	.411	.069	0	0	.048	0	7.5
ELEMENT # 38	.703	.748	0	0	.054	0	2.5
ELEMENT # 39	.673	.748	0	0	.054	0	5.5
ELEMENT # 40	.696	.748	0	0	.054	0	8.5
ELEMENT # 41	.753	.527	0	0	.045	0	3.5
ELEMENT # 42	.66	.527	0	0	.045	0	6.5
ELEMENT # 43	.702	.567	0	0	.059	0	1.5
ELEMENT # 44	.555	.567	0	0	.059	0	4.5
ELEMENT # 45	.546	.567	0	0	.059	0	7.5
ELEMENT # 46	.293	.0245	0	0	.048	0	2.5
ELEMENT # 47	.238	.0245	0	0	.048	0	5.5
ELEMENT # 48	.367	.0245	0	0	.048	0	8.5

TABLE C7 CONTINUED

ELEMENT # 49	.354	-.0607	0	0	.093	0	3.5
ELEMENT # 50	.318	.0844	0	0	.087	0	1.5
ELEMENT # 51	.172	.0844	0	0	.087	0	4.5
ELEMENT # 52	.192	.0844	0	0	.087	0	7.5
ELEMENT # 53	.855	1.546	0	0	.061	0	2.5
ELEMENT # 54	.828	1.546	0	0	.061	0	5.5
ELEMENT # 55	.855	1.546	0	0	.061	0	8.5
ELEMENT # 56	.849	1.478	0	0	.092	0	6.5
ELEMENT # 57	.86	1.016	0	0	.073	0	1.5
ELEMENT # 58	.773	1.016	0	0	.073	0	7.5
ELEMENT # 59	.289	1.546	0	0	.061	0	2.5
ELEMENT # 60	.52	1.546	0	0	.061	0	5.5
ELEMENT # 61	.52	1.546	0	0	.061	0	8.5
ELEMENT # 62	.378	1.478	0	0	.092	0	3.5
ELEMENT # 63	.248	1.478	0	0	.092	0	6.5
ELEMENT # 64	.423	1.016	0	0	.073	0	1.5
ELEMENT # 65	.422	1.016	0	0	.073	0	4.5
ELEMENT # 66	.361	1.016	0	0	.073	0	7.5
ELEMENT # 67	.76	.368	0	1	.080	.24	1.5
ELEMENT # 68	.735	.368	0	1	.08	.339	4.5
ELEMENT # 69	.588	.368	0	1	.08	.34	7.5
ELEMENT # 70	.684	.503	0	1	.062	.039	2.5
ELEMENT # 71	1.14	.503	0	1	.062	.214	5.5
ELEMENT # 72	1.22	.503	0	1	.062	.33	8.5
ELEMENT # 73	.611	.315	0	1	.081	.292	3.5
ELEMENT # 74	.729	.315	0	1	.081	.297	6.5
ELEMENT # 75	1.05	.315	1	0	.081	.205	1.5
ELEMENT # 76	.969	.315	1	0	.081	.292	4.5
ELEMENT # 77	.872	.315	1	0	.081	.297	7.5
ELEMENT # 78	.924	.368	1	0	.08	.244	2.5
ELEMENT # 79	1.14	.368	1	0	.08	.339	5.5
ELEMENT # 80	.897	.368	1	0	.08	.34	8.5
ELEMENT # 81	.893	.503	1	0	.062	.039	3.5
ELEMENT # 82	1.74	.503	1	0	.062	.214	6.5
ELEMENT # 83	.017	-.352	0	1	.084	.244	1.5
ELEMENT # 84	.018	-.352	0	1	.084	.339	4.5
ELEMENT # 85	.033	-.378	0	1	.071	.292	3.5
ELEMENT # 86	.054	-.378	1	0	.07	.205	1.5
ELEMENT # 87	.102	-.378	1	0	.07	.292	4.5
ELEMENT # 88	.072	-.352	1	0	.084	.244	2.5
ELEMENT # 89	.115	-.352	1	0	.084	.339	5.5
ELEMENT # 90	.119	-.352	1	0	.084	.34	8.5
ELEMENT # 91	.519	.232	0	1	.053	.27	3.5
ELEMENT # 92	.406	.232	0	1	.053	.239	6.5
ELEMENT # 93	.347	.159	0	1	.082	.247	1.5
ELEMENT # 94	.251	-.366	0	0	.05	0	6.5
ELEMENT # 95	.092	-.121	0	1	.066	.302	3.5
ELEMENT # 96	.383	.159	0	1	.082	.361	4.5
ELEMENT # 97	.411	.159	0	1	.082	.399	7.5
ELEMENT # 98	.712	.13	0	1	.073	.24	2.5
ELEMENT # 99	.479	.13	0	1	.073	.264	5.5

TABLE C7 CONTINUED

ELEMENT # 100	.442	.13	0	1	.073	.283	8.5
ELEMENT # 101	1.02	.232	1	0	.053	.27	4.5
ELEMENT # 102	.916	.232	1	0	.053	.239	7.5
ELEMENT # 103	.778	.159	1	0	.082	.247	2.5
ELEMENT # 104	.623	.159	1	0	.082	.361	5.5
ELEMENT # 105	.793	.159	1	0	.082	.399	8.5
ELEMENT # 106	1.02	.13	1	0	.073	.24	3.5
ELEMENT # 107	.767	.13	1	0	.073	.264	6.5
ELEMENT # 108	.083	-.342	0	1	.066	.239	6.5
ELEMENT # 109	.068	-.366	0	1	.05	.247	1.5
ELEMENT # 110	.056	-.366	0	1	.05	.361	4.5
ELEMENT # 111	.062	-.366	0	1	.05	.299	7.5
ELEMENT # 112	.108	-.757	0	1	.059	.24	2.5
ELEMENT # 113	.058	-.757	0	1	.059	.264	5.5
ELEMENT # 114	.068	-.757	0	1	.059	.283	8.5
ELEMENT # 115	.345	-.342	1	0	.066	.293	1.5
ELEMENT # 116	.331	-.342	1	0	.066	.239	7.5
ELEMENT # 117	.317	-.342	1	0	.066	.27	4.5
ELEMENT # 118	.199	-.366	1	0	.05	.247	2.5
ELEMENT # 119	.255	-.366	1	0	.05	.361	5.5
ELEMENT # 120	.276	-.366	1	0	.05	.399	8.5
ELEMENT # 121	.093	-.757	1	0	.059	.24	3.5
ELEMENT # 122	.137	-.757	1	0	.059	.264	6.5
ELEMENT # 123	.625	.407	0	1	.074	.302	3.5
ELEMENT # 124	.595	.524	0	1	.061	.284	1.5
ELEMENT # 125	.558	.524	0	1	.061	.391	4.5
ELEMENT # 126	.511	.524	0	1	.061	.331	7.5
ELEMENT # 127	1.09	.812	0	1	.054	.249	2.5
ELEMENT # 128	1.16	.812	0	1	.054	.298	5.5
ELEMENT # 129	1.13	.812	0	1	.054	.35	8.5
ELEMENT # 130	.953	.407	1	0	.74	.36	1.5
ELEMENT # 131	1.16	.407	1	0	.74	.302	4.5
ELEMENT # 132	.897	.407	1	0	.74	.224	7.5
ELEMENT # 133	1.33	.524	1	0	.061	.284	2.5
ELEMENT # 134	.859	.524	1	0	.061	.391	5.5
ELEMENT # 135	1.67	.812	1	0	.054	.249	3.5
ELEMENT # 136	1.61	.812	1	0	.054	.298	6.5
ELEMENT # 137	.133	-.121	0	1	.066	.224	6.5
ELEMENT # 138	.089	-.297	0	1	.082	.284	1.5
ELEMENT # 139	.105	-.297	0	1	.082	.391	4.5
ELEMENT # 140	.1	-.297	0	1	.082	.331	7.5
ELEMENT # 141	.103	.0069	0	1	.048	.249	2.5
ELEMENT # 142	.137	.0069	0	1	.048	.298	5.5
ELEMENT # 143	.149	.0069	0	1	.048	.35	8.5
ELEMENT # 144	.36	-.121	1	0	.066	.36	1.5
ELEMENT # 145	.374	-.121	1	0	.066	.302	4.5
ELEMENT # 146	.403	-.121	1	0	.066	.224	7.5
ELEMENT # 147	.358	-.297	1	0	.082	.284	2.5
ELEMENT # 148	.286	-.297	1	0	.082	.391	5.5
ELEMENT # 149	.341	-.297	1	0	.082	.331	8.5
ELEMENT # 150	.252	.069	1	0	.048	.249	3.5

TABLE C7 CONTINUED

ELEMENT # 151	.415	.869	1	0	.048	.298	6.5
ELEMENT # 152	1.23	.748	1	0	.054	.323	3.5
ELEMENT # 153	1.14	.748	1	0	.054	.293	6.5
ELEMENT # 154	.864	.527	1	0	.045	.305	1.5
ELEMENT # 155	.927	.527	1	0	.045	.331	4.5
ELEMENT # 156	.936	.527	1	0	.045	.296	7.5
ELEMENT # 157	.723	.567	1	0	.059	.301	2.5
ELEMENT # 158	.7	.567	1	0	.059	.19	5.5
ELEMENT # 159	.599	.567	1	0	.059	.302	8.5
ELEMENT # 160	.6	.748	0	1	.054	.314	1.5
ELEMENT # 161	.565	.748	0	1	.054	.323	4.5
ELEMENT # 162	.652	.748	0	1	.054	.293	7.5
ELEMENT # 163	.79	.527	0	1	.045	.305	2.5
ELEMENT # 164	.687	.527	0	1	.045	.331	5.5
ELEMENT # 165	.715	.527	0	1	.045	.296	8.5
ELEMENT # 166	.766	.567	0	1	.059	.301	3.5
ELEMENT # 167	.628	.567	0	1	.059	.19	6.5
ELEMENT # 168	.145	.0245	1	0	.048	.323	3.5
ELEMENT # 169	.177	.0245	1	0	.048	.293	6.5
ELEMENT # 170	.201	-.0607	1	0	.093	.305	1.5
ELEMENT # 171	.153	-.0607	1	0	.093	.331	4.5
ELEMENT # 172	.172	-.0607	1	0	.093	.296	7.5
ELEMENT # 173	.152	.0844	1	0	.087	.301	2.5
ELEMENT # 174	.155	.0844	1	0	.087	.19	5.5
ELEMENT # 175	.103	.0844	1	0	.087	.302	8.5
ELEMENT # 176	.344	.0245	0	1	.048	.314	1.5
ELEMENT # 177	.531	.0245	0	1	.048	.323	4.5
ELEMENT # 178	.404	.0245	0	1	.048	.293	7.5
ELEMENT # 179	.406	-.0607	0	1	.093	.305	2.5
ELEMENT # 180	.414	-.0607	0	1	.093	.296	8.5
ELEMENT # 181	.825	.0844	0	1	.087	.301	3.5
ELEMENT # 182	.649	.0844	0	1	.087	.19	6.5
ELEMENT # 183	.506	1.546	1	0	.061	.255	3.5
ELEMENT # 184	.579	1.546	1	0	.061	.26	6.5
ELEMENT # 185	.406	1.478	1	0	.092	.314	1.5
ELEMENT # 186	.183	1.478	1	0	.092	.207	4.5
ELEMENT # 187	.518	1.478	1	0	.092	.234	7.5
ELEMENT # 188	.672	1.016	1	0	.073	.272	2.5
ELEMENT # 189	.327	1.016	1	0	.073	.261	5.5
ELEMENT # 190	.402	1.016	1	0	.073	.316	8.5
ELEMENT # 191	.392	1.546	0	1	.061	.247	1.5
ELEMENT # 192	.413	1.546	0	1	.061	.255	4.5
ELEMENT # 193	.604	1.546	0	1	.061	.26	7.5
ELEMENT # 194	.395	1.478	0	1	.092	.314	2.5
ELEMENT # 195	.166	1.478	0	1	.092	.207	5.5
ELEMENT # 196	.45	1.478	0	1	.092	.234	8.5
ELEMENT # 197	.398	1.016	0	1	.073	.272	3.5
ELEMENT # 198	.318	1.016	0	1	.073	.261	6.5
ELEMENT # 199	.066	1.546	1	0	.061	.255	3.5
ELEMENT # 200	.315	1.546	1	0	.061	.26	6.5
ELEMENT # 201	.028	1.478	1	0	.092	.314	1.5

TABLE C7 CONTINUED

ELEMENT # 202	.061	1.478	1	0	.092	.207	4.5
ELEMENT # 203	.053	1.478	1	0	.092	.234	7.5
ELEMENT # 204	.369	1.016	1	0	.073	.272	2.5
ELEMENT # 205	.396	1.016	1	0	.073	.261	5.5
ELEMENT # 206	.291	1.016	1	0	.073	.316	8.5
ELEMENT # 207	.3	1.546	0	1	.061	.247	1.5
ELEMENT # 208	.092	1.546	0	1	.061	.255	4.5
ELEMENT # 209	1.04	1.546	0	1	.061	.26	7.5
ELEMENT # 210	.249	1.478	0	1	.092	.314	2.5
ELEMENT # 211	.246	1.478	0	1	.092	.207	5.5
ELEMENT # 212	.251	1.478	0	1	.092	.234	8.5
ELEMENT # 213	.729	1.016	0	1	.073	.272	3.5
ELEMENT # 214	.887	1.016	0	1	.073	.261	6.5
ELEMENT # 215	.52	.13	0	0	.073	0	7.5
ELEMENT # 216	.716	.812	0	0	.054	0	1.5
ELEMENT # 217	.354	-.0607	0	0	.093	0	6.5
ELEMENT # 218	.678	1.478	0	0	.092	0	3.5
ELEMENT # 219	.136	-.342	0	1	.066	.27	3.5
ELEMENT # 220	.676	.407	0	1	.074	.224	6.5
ELEMENT # 221	.958	.524	1	0	.061	.331	8.5
ELEMENT # 222	.473	-.0607	0	1	.093	.331	5.5
ELEMENT # 223	1.06	.232	1	0	.053	.293	1.5

TABLE C8 DATA FILE: BRANFIL/DTA

	DV	IV#1	IV#2	IV#3
ELEMENT # 1	.31	.323	.184329	.8336983
ELEMENT # 2	.847	-.386	.148996	-.8575125
ELEMENT # 3	.284	.323	.184329	.8336983
ELEMENT # 4	.84	-.386	.148996	-.8575125
ELEMENT # 5	.264	.366	.133956	.8498279
ELEMENT # 6	.862	-.362	.131844	-.8474379
ELEMENT # 7	.289	.366	.133956	.8498279
ELEMENT # 8	.86	-.362	.131844	-.8474379
ELEMENT # 9	.273	.469	.219961	.183162
ELEMENT # 10	.88	-.41	.1681	-.868921
ELEMENT # 11	.25	.469	.219961	.183162
ELEMENT # 12	.867	-.41	.1681	-.868921
ELEMENT # 13	.326	.239	.857121	.8136519
ELEMENT # 14	.182	-.333	.118889	-.836926
ELEMENT # 15	.291	.239	.857121	.8136519
ELEMENT # 16	.897	-.333	.118889	-.836926
ELEMENT # 17	.252	.154	.823716	3.65226E-03
ELEMENT # 18	.122	-.35	.1225	-.842875
ELEMENT # 19	.273	.154	.823716	3.65226E-03
ELEMENT # 20	.188	-.35	.1225	-.842875
ELEMENT # 21	.386	.126	.815876	2.88838E-03
ELEMENT # 22	.895	-.482	.161684	-.8649649
ELEMENT # 23	.538	.482	.161684	.8649649
ELEMENT # 24	.135	-.13	.8169	-2.197E-03
ELEMENT # 25	.582	.482	.161684	.8649649
ELEMENT # 26	.126	-.13	.8169	-2.197E-03
ELEMENT # 27	.369	.52	.2784	.148688
ELEMENT # 28	.127	-.298	.888884	-.8264636
ELEMENT # 29	.686	.52	.2784	.148688
ELEMENT # 30	.154	-.298	.888884	-.8264636
ELEMENT # 31	.444	.889	.654481	.529476
ELEMENT # 32	.15	.88182	1.8484E-06	1.86121E-09
ELEMENT # 33	.617	.736	.541696	.398688
ELEMENT # 34	.216	.88896	9.21681E-07	8.84737E-10
ELEMENT # 35	.59	.736	.541696	.398688
ELEMENT # 36	.15	.88896	9.21681E-07	8.84737E-10
ELEMENT # 37	.734	.525	.275625	.144783
ELEMENT # 38	.2	-.87	4.9E-03	-3.43E-04
ELEMENT # 39	.755	.525	.275625	.144783
ELEMENT # 40	.187	-.87	4.9E-03	-3.43E-04
ELEMENT # 41	.687	.564	.318896	.179486
ELEMENT # 42	.232	.878	6.884E-03	4.74552E-04
ELEMENT # 43	.484	.312	.897344	.8383713
ELEMENT # 44	.535	.312	.897344	.8383713
ELEMENT # 45	.563	.266	.878756	.8188211
ELEMENT # 46	.377	.277	.876729	.8212539

APPENDIX D

DATA CONVERSION PROGRAMS

APPENDIX D

DATA CONVERSION PROGRAMS

Listing D1. Program <ANEMCONV/BAS>

This program has a tape input from the anemometer collection routine, written by Dave Zeitler of MSU. This program converts the raw data from frequency to millimeters per second. The statistics are calculated and the results printed on the CRT (a routine for line printer output is available though not listed here). A graph of the turbulent fluxuations is optionally plotted on the CRT. An optional converted data tape is possible.

The statistical information includes:

The means, standard deviations, turbulent intensities, and relative intensities, for each anemometer.

Each area of the program is set off by non-program comments. The program lines have been spaced and modified for readability. These changes will require correction before the programs can be run. Contact the author if an unmodified program listing is desired.

This program can be run on a 16K RAM level II TRS-80 Microcomputer, without disk or line printer.

```
***** Initializing variables and preliminaries *****
1 ON ERROR GOTO 2 :CMD"T" :CLOSE :GOTO 5 '*** Disable interrupts
2 RESUME 5 '*** Begin at line 5 if non disk basic
5 CLEAR 750 :BB=45 :MM=0 :CLS :PRINT "          DATA CONVERSION ROUTINE
FOR ANEMOMETER DATA                                BY A.R.HAYS"
```

```

:PRINT
6 PRINT" TO RECEIVE ADDITIONAL DETAILS ABOUT THE PROGRAM, ENTER
'HELP' AT ANY PAUSE, SUCH AS 'WHEN READY HIT ENTER'." :PRINT'
***** Tape input routine *****
7 INPUT "INSERT RAW DATA TAPE, SET TO PLAY AND HIT ENTER" ;A$ :IF
A$="HELP" THEN MM=1 :GOSUB 2000 :GOTO 7 :ELSE :CLS :PRINT " DATA
BEING ENTERED"
10 :DEFDBL C ,S ,X :DEFINT D ,I-N ,P :DIM P(2) ,P0(27) :*** Dimension arrays and
define variable types ***
20 INPUT#-1 , P(0) ,P(1) ,P(2) ,N$ :*** Enter timing and discription ***
30 Z=P(2)*60/P(1) :N1=Z-1 :IF INT(Z/9) <> Z/9 THEN Z=Z+9 : Dimension data array
based on input timing ***
35 DIM D(2,Z) :CLS :PRINTN$ :PRINT USING "SAMPLE INTERVAL = ## SECOND(S)"
;P(0)/10
36 PRINT USING "REPEAT INTERVAL = ## SECOND(S)" ;P(1) :PRINT USING "TOTAL
INTERVAL = ## MINUTE(S)" ;P(2)
40 FOR I=0 TO N1 STEP 9 :*** Input data in blocks of 27 elements ***
50 INPUT#-1 ,D(0,I) ,D(1,I) ,D(2,I) ,D(0,I+1) ,D(1,I+1) ,D(2,I+1) ,D(0,I+2) ,D(1,I+2)
,D(2,I+2) ,D(0,I+3) ,D(1,I+3) ,D(2,I+3) ,D(0,I+4) ,D(1,I+4) ,D(2,I+4) ,D(0,I+5) ,D(1,I+5)
,D(2,I+5) ,D(0,I+6) ,D(1,I+6) ,D(2,I+6) ,D(0,I+7) ,D(1,I+7) ,D(2,I+7) ,D(0,I+8) ,D(1,I+8)
,D(2,I+8) :NEXT I
***** Print raw data on CRT *****
60 CC=1 :FOR J=0 TO N1 STEP 3 :PRINT TAB(0) J ;D(0,J) ;D(1,J) ;D(2,J) ;TAB(21) J+1
;D(0,J+1) ;D(1,J+1) ;D(2,J+1) ;TAB(42) J+2 ;D(0,J+2) ;D(1,J+2) ;D(2,J+2)
65 IF CC>=15 :GOTO 75 :*** Stop if screen full ***
70 CC=CC+1 :NEXT J :CC=1
***** Convert data & calculate statistics *****
73 S(0)=0 :S(1)=0 :S(2)=0 :SS(0)=0 :SS(1)=0 :SS(2)=0 :GOTO 79 :*** Zero double precision
variables ***
75 INPUT "HIT ENTER TO CONTINUE LIST" ;A$ :CC=0 :IF A$="HELP" THEN MM=0
:GOSUB 2000 :GOTO 60 :ELSE :GOTO 70
79 PRINT " CONVERSIONS BEING CALCULATED" ;P2=420
80 FOR I=0 TO 2 :FOR J=0 TO N1 :CD=1000*((10*D(I,J)/P(0)+30.11)/71.74)
:IFCD>P2 THEN :D(I,J)=INT(CD+.5) :S(I)=S(I)+CD :SS(I)=SS(I)+CD :NEXT J
:XB(I)=S(I)/(N1+1) :SX(I)=(SS(I)-S(I)*(2/(N1+1)))/N1 :NEXT I :GOTO 90 :*** Convert to
mm/sec and sum squares ***
81 D(I,J)=0 :NEXT J,I
90 FOR K=0 TO 2 :*** Calculate standard deviations ***
100 IF SX(K) < 0 THEN NEXT ELSE SD(K)=SQR(SX(K)) :SY(K)=SD(K)/XB(K) :NEXT K
:GOTO 200
110 NEXT K
200 CLS :INPUT "CREATE A NEW TAPE FILE (CONVERTED)" ;A$ :MM=2 :IF
A$="HELP" THEN GOSUB 2000 :GOTO 200
210 CLS :IF A$="YES" OR A$="Y" GOSUB 500 :*** Call converted tape routine ***
220 INPUT "DO YOU WISH TO SEE THE CONVERTED DATA LIST" ;A$ :MM=0
:IFA$="HELP" THEN GOSUB 2000 :GOTO 220
230 IF A$="YES" OR A$="Y" GOSUB 900 :GOTO 220 :*** Call routine to print the
converted data listing on CRT ***
235 CLS :INPUT "DO YOU WISH TO SEE TURBULENCE GRAPH" ;A$ :IF A$="Y" OR
A$="YES" :GOSUB 3000 :GOTO 220 :*** Call graph routine ***
240 CLS :PRINT@540, "END" :PRINT :PRINT :PRINT :END :*** Terminate program
***
***** Coverted data tape preparation routine *****
500 INPUT "INSERT CLEAN TAPE SET TO RECORD AND HIT ENTER" ;A$ :IF

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A$="HELP" THEN MM=3 :GOSUB 2000 :GOTO 500 :ELSE :N0$=""
510 PRINT#-1, P(0), P(1), P(2), N$
512 PRINT#-1, XB(0), XB(1), XB(2), SD(0), SD(1), SD(2)
514 PRINT#-1, S(0), S(1), S(2), SS(0), SS(1), SS(2)
516 PRINT#-1, SX(0), SX(1), SX(2), SY(0), SY(1), SY(2)
520 FOR I=0 TO N1 STEP 9
530 PRINT#-1, D(0,I), D(1,I), D(2,I), D(0,I+1), D(1,I+1), D(2,I+1), D(0,I+2), D(1,I+2),
, D(2,I+2), D(0,I+3), D(1,I+3), D(2,I+3), D(0,I+4), D(1,I+4), D(2,I+4), D(0,I+5), D(1,I+5),
, D(2,I+5), D(0,I+6), D(1,I+6), D(2,I+6), D(0,I+7), D(1,I+7), D(2,I+7), D(0,I+8), D(1,I+8),
, D(2,I+8) :NEXT I
540 CLS :INPUT "REWIND TAPE, SET TO PLAY AND HIT ENTER" :A$ :IF A$="HELP"
THEN MM=4 :GOSUB 2000 :GOTO 540 :ELSE :M=0
***** Verify tape *****
545 CLS :PRINT#545, "VERIFICATION"
550 INPUT#-1, P0(0), P0(1), P0(2), N0$
560 FOR I=0 TO 2 :IF P(I) <> P0(I) :PRINT P(I), P0(I), "P(I) ERROR" :M=1 :GOTO 800
570 NEXT I :IF N$ <> N0$ :PRINT N$, N0$, "N$ ERROR" :M=2 :GOTO 800
575 INPUT#-1, X(0), X(1), X(2), SA(0), SA(1), SA(2)
580 FOR I=0 TO 2 :A=XB(I) :AA=X(I) :IF A <> AA :PRINT XB(I), X(I), "XB(I) ERROR"
:M=3 :GOTO 800
590 NEXT I :FOR I=0 TO 2 :A=SD(I) :AA=SA(I) :IF A <> AA :PRINT SD(I), SA(I), "SD(I)
ERROR" :M=4 :GOTO 800
595 NEXT I :INPUT#-1, SA(0), SA(1), SA(2), SB(0), SB(1), SB(2)
600 FOR I=0 TO 2 :A=S(I) :AA=SA(I) :IF A <> AA :PRINT S(I), SA(I), "S(I) ERROR"
:M=5 :GOTO 800
610 NEXT I :FOR I=0 TO 2 :A=SS(I) :AA=SB(I) :IF A <> AA :PRINT SS(I), SB(I), "SS(I)
ERROR" :M=6 :GOTO 800
612 NEXT I :INPUT#-1, SA(0), SA(1), SA(2), SB(0), SB(1), SB(2)
614 FOR I=0 TO 2 :A=SX(I) :AA=SA(I) :IF A <> AA :PRINT SX(I), SA(I), "SX(I) ERROR"
:M=7 :GOTO 800
616 NEXT I :FOR I=0 TO 2 :A=SY(I) :AA=SB(I) :IF A <> AA :PRINT SY(I), SB(I), "SY(I)
ERROR" :M=8 :GOTO 800
620 NEXT I :FOR I1=0 TO N1 STEP 9 :INPUT#-1, P0(1), P0(2), P0(3), P0(4), P0(5), P0(6),
P0(7), P0(8), P0(9), P0(10), P0(11), P0(12), P0(13), P0(14), P0(15), P0(16), P0(17), P0(18),
P0(19), P0(20), P0(21), P0(22), P0(23), P0(24), P0(25), P0(26), P0(27) :K=0
630 FOR J=I1 TO (I1+8) :FOR J1=0 TO 2 :K=K+1
640 IF P0(K) <> D(J1,J) :PRINT D(J1,J), P0(K), "DATA ERROR" :M=9 :GOTO 800
650 NEXT J1, J, I1
660 INPUT "GOOD TAPE, MAKE A COPY" :A$ :IF A$="HELP" THEN MM=5 :GOSUB
2000 :GOTO 660
670 CLS :IF A$="YES" OR A$="Y" :GOTO 500
700 RETURN
***** Tape error trapping and identification *****
800 INPUT "DATA ERROR, REMAKE TAPE, (Y/N)" :A$ :IF A$="HELP" THEN MM=6
:GOSUB 2000 :GOTO 800
810 IF A$="YES" OR A$="Y" GOTO 500
820 ON M GOTO 570, 575, 590, 595, 610, 612, 616, 620, 650
830 END
***** Print results on CRT *****
900 CLS :PRINT N$ :PRINT USING "SAMPLE INTERVAL = ## SECOND(S)" :P(0)/10
910 PRINT USING "REPEAT INTERVAL = ## SECOND(S)" :P(1) :PRINT USING
"TOTAL INTERVAL = ## MINUTE(S)" :P(2) :PRINT
915 INPUT "HIT ENTER TO CONTINUE" :A$ :IF A$="HELP" THEN MM=0 :GOSUB
2000 :GOTO 915

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920 CLS :PRINT"                ANEMOMETER"
930 PRINT STRING$(62,"-") :PRINT TAB(18) "0" ;TAB(38) "1" ;TAB(58) "2"
940 PRINT STRING$(62,"-") :PRINT TAB(0) "MEAN" ;TAB(12) INT(XB(0)) ;TAB(32)
INT(XB(1)) ;TAB(52) INT(XB(2)) :PRINT
950 PRINT TAB(0) "ST. DEV." ;TAB(12) CSNG(SD(0)) ;TAB(32) CSNG(SD(1)) ;TAB(52)
CSNG(SD(2)) :PRINT
960 PRINT TAB(0) "TURBULENT" :PRINT TAB(0) "INTENSITY" ;TAB(12) CSNG(SX(0))
;TAB(32) CSNG(SX(1)) ;TAB(52) CSNG(SX(2)) :PRINT
970 PRINT TAB(0) "RELATIVE" :PRINT TAB(0) "INTENSITY" ;TAB(12) CSNG(SY(0))
;TAB(32) CSNG(SY(1)) ;TAB(52) CSNG(SY(2)) :PRINT
980 CC=1 :INPUT "HIT ENTER , TO LIST DATA" ;A$ :IF A$="HELP" THEN MM=0
:GOSUB 2000
990 CLS :FOR J=0 TO N1 STEP 2:PRINT TAB(3)J;D(0,J) ;D(1,J) ;D(2,J) ;TAB(31) J+1
;D(0,J+1) ;D(1,J+1) ;D(2,J+1)
1000 IF CC >= 15 :INPUT "HIT ENTER TO CONTINUE LIST" ;A$ :CC=0 :IF A$="HELP"
GOSUB 2000 :GOTO 990
1010 CC=CC+1 :NEXTJ :INPUT "NEED AN EXPLANATION OF UNITS" ;A$ :IF A$="Y"
OR A$="YES" THEN MM=0 :GOSUB 2000 :RETURN
1011 CLS :INPUT "WANT TO SEE GRAPH" ;A$ :IF A$="Y" OR A$="YES" :GOSUB 3000
1020 RETURN
***** Help routine to explain the program *****
2000 A$="" :IF MM>0 :ON MM GOTO 2190 ,2200 ,2210 ,2220 ,2230
2020 CLS :PRINT "WHAT TYPE OF INFORMATION DO YOU WISH?" :PRINT
"AVAILABLE FILES INCLUDE:" :PRINT "      1. UNITS OF MEASURE" :PRINT"
2. CONVERSION EQUATIONS" :PRINT"      3. REGRESSION EQUATION":PRINT"
4. RATIONALE" :PRINT"      5. RETURN TO PROGRAM
2030 PRINT :PRINT :INPUT "ENTER YOUR NUMBER CHOICE" ;Z! :ONZ! GOTO 2040
,2050 ,2060 ,2070 ,2080 :RETURN
2040 CLS :PRINT TAB(10) "UNITS OF MEASURE" :PRINT STRING$(40,"-") :PRINT"
SAMPLE INTERVAL      TENTHS OF SEC" :PRINT" REPEAT INTERVAL
SECONDS" :PRINT" TOTAL INTERVAL      MINUTES" :PRINT" INPUT DATA
NO. LIGHT CHOPS/SAMPLE INTERVAL"
2042 PRINT" CONVERTED DATA      MM/SEC" :PRINT" MEANS
MM/SEC" :PRINT" STANDARD DEVIATION      MM/SEC" :PRINT" TURBULENT
INTENSITY      MEAN SQUARE VELOCITY" :PRINT" RELATIVE INTENSITY
DIMENSIONLESS"
2043 PRINT :FOR L=6 TO 31 :SET(46,L) :NEXT :INPUT "WHEN READY HIT ENTER"
;A$ :GOTO 2020
2050 CLS :FOR L=1 TO 4 :READ A$ :NEXT :FOR L=1 TO 3 :READ A$ :PRINT A$ :NEXT
:RESTORE :PRINT :PRINT :INPUT "WHEN READY HIT ENTER" ;A$ :GOTO 2020
2060 CLS :FOR L=1 TO 7 :READ A$ :NEXT :FOR L=1 TO 2 :READ A$ :PRINT A$
:NEXT :RESTORE :PRINT :PRINT :INPUT "WHEN READY HIT ENTER" ;A$ :GOTO
2020
2070 CLS :FOR L=1 TO 4 :READ A$ :PRINT A$ :NEXT :PRINT :RESTORE :INPUT "HIT
ENTER WHEN READY" ;A$ :GOTO 2020
2080 RETURN
2100 DATA" THE INITIAL DATA IS INPUT AS AN INTEGER. THIS INTEGER
REPRESENTS THE NUMBER OF LIGHT CHOPS OVER THE SAMPLE INTERVAL."
2110 DATA"THE CONVERTED DATA REPRESENTS AN AIR SPEED IN MILLIMETERS
PER SECOND. THIS CHOICE OF UNITS ALLOWS INTEGER DATA STORAGE WITH A
MINIMUM ACCURACY OF 0.05 METERS PER SECOND."
2120 DATA" THE CHOICE OF TURBULENT INTENSITY, AND RELATIVE
INTENSITY ARE BASED ON REPORTING THE MOST COMMONLY USED MEASURES
OF TURBULENCE, AVAILABLE WITH THE DATA COLLECTED. THIS OF COURSE

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IMPLIES BETTER MEASURES ARE POSSIBLE, WITH ADDED DATA "

2130 DATA "INPUTS. THIS IS TRUE. HOWEVER, THE PRESENT PROJECT DOES NOT JUSTIFY THE ADDED COSTS. FUTURE PROJECTS SHOULD CONSIDER THE USE OF BETTER MEASURES."

2140 DATA "THE EQUATION TO CONVERT THE RAW DATA TO MM/SEC DATA IS: $CD = 1000 * ((10 * D(i,j)) / P(0) + 30.11) / 71.74$ WHERE $D(i,j)$ = RAW DATA $P(0)$ = SAMPLE INTERVAL"

2150 DATA " THE FACTOR OF TEN CONVERTS THE SAMPLE INTERVAL TO SECONDS. THE FACTOR OF ONE THOUSAND CONVERTS THE RESULT TO MM/SEC. THE CONSTANTS ARE FROM INSTRUMENT CALIBRATION REGRESSION."

2160 DATA "THE TURBLUENT INTENSITY IS ACTUALLY THE VARIANCE OF THE VELOCITY FLUXUATIONS. THE RELATIVE INTENSITY IS MEARLY THE STANDARD DEVIATION OVER THE MEAN VELOCITY."

2170 DATA " THE REGRESSION EQUATION ORIGINATED FROM THE MANUFACTURER OF THE MINIATURE CUP ANEMOMETERS. THIS FOLLOWS: $METERS/SEC = (FREQUENCY/SEC + 30.11) / 71.74$ WHERE THE 31.11 IS" 2180 DATA "THE TRESHOLD OF 0.42 m/s"

2190 CLS:PRINT "PLACE RAW DATA TAPE, FROM DATA COLLECTION ROUTINE, IN THE TAPE RECORDER, SET VOLUME TO 5, PRESS PLAY BUTTON, AND HIT THE ENTER KEY.":RETURN

2200 CLS :PRINT "ENTER 'YES' IF YOU WANT A PERMANENT, TAPE RECORD OF THE CONVERTED DATA. THIS WILL INCLUDE DESCRIPTIVE STATISTICS." :RETURN

2210 CLS :PRINT "PLACE A NEW OR BULK ERASED TAPE IN THE RECORDER. SET THE RECORDER TO RECORD, AND HIT THE ENTER KEY." :RETURN

2220 CLS :PRINT "THIS PROCESS VERIFIES THAT THE TAPE WAS RECORDED WITHOUT ERRORS. ONE ERROR CAN MAKE THE TAPE USELESS." :RETURN

2230 CLS :PRINT "THIS TAPE IS GOOD. IF THE DATA IS VERY IMPORTANT IT IS ADVISABLE TO HAVE A SPARE. TAPES ARE EASILY DAMAGED, BY DUST, STATIC CHARGE AND WRINKLES." :RETURN

***** Graphical plot *****

3000 FOR II=0 TO 2 :C=7 :A=22 :GOSUB 3010 :GOTO 3020

3010 CLS :PRINT TAB(0) "990" ;TAB(20) "ANEMOMETER" ;TAB(31) II :PRINT@64 , "-" :PRINT@448 , "0" :PRINT@832 , "+" :PRINT@896 , "990" :FOR I=0 TO 43 STEP 2 :SET(6,I) :NEXT :FOR I=6 TO 127 STEP 5 :SET(I,22) :NEXT :RETURN

3020 FOR J=1 TO N1 :F=D(II,J)-XB(II) :B=INT(F+.5)/BB :IF A+B > 44 THEN B=22 :ELSE IF A+B < 0 THEN B=-22

3030 IF B > 0 THEN :FOR K=A TO A+B :SET(C,K) :NEXT K :ELSE :FOR K=A+B TO A :SET(C,K) :NEXT K

3040 C=C+1 :IF C > 127 THEN C=7 :INPUT "HIT ENTER TO CONTINUE THIS GRAPH" :A\$:GOSUB 3010

3050 NEXT J :INPUT "HIT ENTER TO SEE NEXT GRAPH" :A\$:IF A\$="HELP" :GOTO 4000

3060 NEXT II :RETURN

***** Continued help routine for graph *****

4000 CLS :PRINT "THE GRAPH PLOTS DEVIATIONS FORM THE MEAN VELOCITY. THE MEAN IS REPRESENTED BY ZERO. POSITIVE DEVIATIONS ARE BELOW THE ZERO LINE, AND NEGATIVE DEVIATIONS ARE ABOVE THE LINE. UNITS ARE IN MM/SEC FROM THE MEAN."

4010 A\$="" :INPUT "HIT ENTER TO CONTINUE GRAPHS" :A\$:NEXT II :RETURN

Listing D2. Program <DROPDIST/BAS>

This program converts droplet counts, from Teflon coated glass slides, Teflon cylinders, or other cylindrical obstacles, recorded in microscope units, to a distribution. The distribution contains 30 size categories from 10 microns to 300 microns. In addition the program calculates the effect of wind on the collection efficiency of each droplet size category, then adjusts the distribution to reflect a more meaningful distribution.

The results are printed giving a description of the data, various means, standard deviations, coefficients of variation, frequency counts, maximum values, minimum values, number counted, cumulative volume for each category, percent volume for each category, particle inertial impingement parameters and collection efficiencies for each category and cylinder size, and input constants are printed for reference.

```
***** Initializing variables & preliminaries *****
20 CLS :PRINT "INITIALIZING" :ON ERROR GO TO 25 :CMD"T" :CLOSE :GO TO 30
25 RESUME 30
30 CLEAR 500: DEFINT I-K,M,N: DEFDBLX-Z: DEFSNG A-D,L: DEFSTR E-F: DIM C(12)
,CV(30),E!(4,30),L(34),L1(34),M(30),OB(5),P(4,30),PV(30):POKE 16425,1:POKE
16424,66: A2=5' *** Dimension arrays & define variables ***
35 CO=1.6479E-3 :DEN=.979540 : FOR I=1 TO 12: READ C(I) :NEXT I :RESTORE
:OB(2)=1.156 :OB(3)=1.664 :OB(4)=2.223 :OB(5)=3.937' *** Define constants used in the
particle parameter *** DEN = droplet density, OB(i) = obstacle sizes, CO = constant of
particle parameter factor held fixed for this study
40 FOR II=0 TO 30: M(II)=II*10: NEXT II'*** Load array of midpoints ***
60 CLS :PRINT TAB(18) "PROGRAM DROPLET DISTRIBUTION :PRINT TAB(27)"BY A. R.
HAYS"
70 PRINT: PRINT: INPUT "HOW WILL DATA BE ENTERED, (T)APE OR (K)EYBOARD"; E
:IF E="T" THEN GOSUB 2000
75 CLS: INPUT "OUTPUT RESULTS TO A LINE PRINTER, Y/N"; EB
80 IF E="T": GOSUB 1000: END'*** Call tape input routine ***
***** Keyboard input routine *****
90 CLS :INPUT "ENTER A DISCRPTION OF THE TREATMENT, UP TO 200
CHARACTERS"; EF
100 CLS :INPUT "CREATE A TAPE FILE Y/N"; EA
110 CLS: INPUT "ENTER MICROSCOPE CONVERSION IN MICRONS,
COLLECTING OBSTACLE SIZE IN CM,
AIR VELOCITY IN CM/SEC, AND
SPREAD FACTOR (DEC FRACTION)
"; A, OBS(1), VEL ,B :A1=A*B
120 CLS :PRINT "THESE ARE YOUR ENTRIES, CHECK THEM FOR ACCURACY." :PRINT
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130 PRINT "MICROSCOPE CONVERSION      " ;A ;" MICRONS/UNIT"
140 PRINT "COLLECTING OBSTACLE SIZE    " ;OBS(1) ;" CM"
150 PRINT "AIR VELOCITY                " ;VE ;" CM/SEC"
160 PRINT "SPREAD FACTOR               " ;B
170 PRINT :INPUT "IF CORRECT HIT (ENTER), OTHERWISE ENTER 'NO'" ;A$ :IF
A$="NO" OR A$="N" :A$="" :GO TO 110
180 ED=""
***** Data entry, conversion and sort routine *****
200 L(34)= 300
210 CLS: PRINT "BEGIN ENTERING YOUR DATA SIGNAL THE END OF YOUR DATA
WITH AN (@) SYMBOL" : PRINT
220 FOR II=1 TO 12 :EE="" :INPUT EE '*** Enter data in string form ***
230 IF EE="@" OR EE="Q" THEN 265 '*** Check for end of data ***
232 IF VAL(EE)=0 :II=12 :INPUT "DID YOU MEAN TO ENTER ZERO, Y/N" ;ED :IF ED="N"
OR ED="NO" THEN INPUT "ENTER THE CORRECT VALUE" ;EE :GOTO 232 ELSE IF ED
<>"Y" GOTO 232 '*** Trap accidental zero entry ***
235 I=VAL(EE)*A1+A2: IF I<L(34) THEN L(34)=I '*** Convert data to numeric form, and
save smallest size ***
237 IF I>L(33) THEN L(33)=I '*** Save largest size ***
240 I=I/10: IF I>=31 THEN L(31)=L(31)+1: GOTO 260 '*** Count number over 305 microns
***
250 L(I)=L(I)+10 :L(32)=L(32)+1'*** Increment correct category by 10 for better inter
accuracy ***
260 NEXT II: GOTO 210
** Use particle parameter to adjust frequency distribution & calculate statistics **
265 CLS :PRINT "CALCULATING THE PARTICLE PARAMETERS, COLLECTION
EFFICIENCIES  AND ADJUSTING THE FREQUENCY DISTRIBUTION." :PRINT :PRINT
"BE PATIENT" :GOSUB 5000' *** Call subroutine to calculate particle parameters ***
270 'DISC STATS ROUTINE GIVING ARITHMETIC MEAN (N1), DIAMETER WGTED MEAN
(N2), SURFACE WGTED MEAN (N3), VOLUME OR DE BROUCKERE MEAN (N4), AND THE
MEAN VOLUME VMD (N5)
280 ' *** THE STANDARD DEVIATIONS RESPECTIVELY ARE (Y1,...,Y4) NO STANDARD
DEV IS CALCULATED FOR THE MEAN VOLUME ***
285 PRINT "CALCULATING STATISTICS"
290 FOR I=1 TO 30: D=D+L(I)*M(I): X2=X2+L(I)*M(I)[2]: X3=X3+L(I)*M(I)[3]:
X4=X4+L(I)*M(I)[4]: X5=X5+L(I)*M(I)[5]: NEXT I '*** Calculate statistics for categories
10-300 microns ***
300 N1=D/L(32): N2=X2/D: N3=X3/X2: N4=X4/X3: N5=(X3/L(32))[1]/3
310 Y1=SQR((X2-(D[2]/L(32)))/(L(32)-1)): Y2=SQR(X3/D-(X2/D)[2])
:Y3=SQR(X4/X2-(X3/X2)[2]): Y4=SQR(X5/X3-(X4/X3)[2])
320 GOSUB 1000
330 IF EB="YES" OR EB="Y" GOSUB 6000
335 IF EA="Y" OR EA="YES" THEN GOSUB 500
340 END
***** Converted data tape routine *****
499 'TAPE FILE SUBROUTINE
500 INPUT "READY TAPE FOR RECORDING DATA, AND HIT ENTER" ; ED
510 PRINT#-1, EF, OB, VE, L
520 PRINT#-1, L(0), L(1), L(2), L(3), L(4), L(5), L(6), L(7), L(8), L(9), L(10), L(11), L(12),
L(13), L(14), L(15), L(16), L(17), L(18), L(19), L(20), L(21), L(22), L(23), L(24), L(25), L(26),
L(27), L(28), L(29), L(30), L(31), L(32), L(33), L(34)
530 PRINT #-1, N1, N2, N3, N4, N5, Y1, Y2, Y3, Y4
***** Verify the tape *****
540 CLS :INPUT "REWIND TAPE SET TO PLAY, HIT ENTER" ;ED

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550 INPUT #-1,EF$,O1,V1,L1
555 K=INT(O1*100):K1=INT(OB*100):K2=INT(V1*100):K3=INT(VE*100)
560 IF EF$<>EF OR K<>K1 OR K2<>K3 OR L<>L1 THEN CLS:PRINT "TAPE BAD REDO":
GOTO 500
570 INPUT #-1, L1(0), L1(1), L1(2), L1(3), L1(4), L1(5), L1(6), L1(7), L1(8), L1(9), L1(10),
L1(11), L1(12), L1(13), L1(14), L1(15), L1(16), L1(17), L1(18), L1(19), L1(20), L1(21), L1(22),
L1(23), L1(24), L1(25), L1(26), L1(27), L1(28), L1(29), L1(30), L1(31), L1(32), L1(33), L1(34)
580 FOR KK=0 TO 34: IF (INT(L1(KK)*10)/10) <> (INT(L(KK)*10)/10) THEN CLS:PRINT
"TAPE BAD REDO":GOTO 500
590 NEXT KK: INPUT #-1, M1, M2, M3, M4, M5, Z1, Z2, Z3, Z4
600 K=INT(M1*10):K1=INT(N1*10):K2=INT(M2*10):K3=INT(N2*10):K4=INT(M3*10)
:K5=INT(N3*10):K6=INT(M4*10):K7=INT(N4*10):K8=INT(M5*10):K9=INT(N5*10)
610 IF K<>K1 OR K2<>K3 OR K4<>K5 OR K6<>K7 OR K8<>K9 THEN CLS:PRINT "TAPE
BAD REDO":GOTO 500
620 K=INT(Z1*100):K1=INT(Y1*100):K2=INT(Z2*100):K3=INT(Y2*100):K4=INT(Z3*100)
:K5=INT(Y3*100):K6=INT(Z4*100):K7=INT(Y4*100)
630 IF K<>K1 OR K2<>K3 OR K4<>K5 OR K6<>K7 THEN CLS:PRINT "TAPE BAD REDO":
GOTO 500
640 CLS:INPUT "TAPE GOOD, COPY Y/N";ED:IF ED="Y" OR ED="YES":GOTO 500
650 RETURN
***** Print results *****
1000 'SUBROUTINE FOR PRINTING RESULTS
1010 CLS:PRINT EF '*** Print discription on CRT ***
1015 C=Y1:PRINT TAB(28)"MEAN";TAB(34)"ST. DEV.";TAB(46)"COEF OF VARIATION"
1020 PRINT TAB(8);"ARITMETIC ";TAB(28)N1;TAB(34)C;TAB(46)(C/N1):C=Y2
1030 PRINT TAB(8)"DIAMETER WEIGHTED";TAB(28)N2;TAB(34)C;TAB(46)(C/N4):C=Y3
1040 PRINT TAB(8)"SURFACE WEIGHTED";TAB(28)N3;TAB(34)C;TAB(46)(C/N3):C=Y4
1050 PRINT TAB(8)"VOL WEIGHTED (VMD)";TAB(28)N4;TAB(34)C;TAB(46)(C/N4)
1060 PRINT TAB(8)"MEAN VOLUME";TAB(28)N5
1070 IF EB="Y" OR EB="YES" THEN 1080 ELSE 1150 '*** Check for line printer ***
1080 LPRINT :LPRINT :LPRINT"
":LPRINTTAB(10)EF:LPRINT :LPRINT TAB(36)"MEAN";TAB(46)"ST.DEV.";TAB(56)
"COEF. OF VARIATION":C=Y1 '*** Apply tension to ribbon, print discription on line
printer & table headings ***
1100 LPRINT :LPRINT TAB(10)"ARITHMETIC";TAB(36)N1;TAB(46)C;TAB(56)(C/N1)
:C=Y2
1110 LPRINT TAB(10)"DIAMETER WEIGHTED";TAB(36)N2;TAB(46)C;TAB(56)(C/N2)
:C=Y3
1120 LPRINT TAB(10)"SURFACE WEIGHTED";TAB(36)N3;TAB(46)C;TAB(56)(C/N3)
:C=Y4
1130 LPRINT TAB(10)"VOLUME WEIGHTED (VMD)";TAB(36)N5;TAB(46)C
;TAB(56)(C/N3)
1140 LPRINT TAB(10)"MEAN VOLUME";TAB(36)N5 '*** Go back to CRT ***
1150 INPUT "HIT (ENTER) TO CONTINUE LIST";ED
1160 CLS:PRINT "SIZE";TAB(8)"FREQUENCY";TAB(23)"SIZE";TAB(30)"FREQUENCY"
;TAB(45)"SIZE";TAB(53)"FREQUENCY"
1170 FOR I=1 TO 30 STEP 3:PRINT TAB(1)I*10;TAB(9)L(I);TAB(24)I*10+10;TAB(31)
L(I+1);TAB(46)I*10+20;TAB(54)L(I+2)
1180 NEXT I
1190 IF EB="Y" OR EB="YES" THEN 1200 ELSE 1240
1200 LPRINT :LPRINT
1210 LPRINT TAB(10)"SIZE";TAB(16)"FREQUENCY";TAB(30)"SIZE"
;TAB(36)"FREQUENCY";TAB(50)"SIZE";TAB(56)"FREQUENCY"
1220 FOR I=1 TO 30 STEP 3:LPRINT TAB(11)I*10;TAB(19)L(I);TAB(31)I*10+10

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;TAB(39) L(I+1) ;TAB(51) I*10+20 ;TAB(59) L(I+2)
1230 NEXT I
1240 GOSUB 3000 '*** Call subroutine to calculate percent volume for categories ***
1250 CLS :PRINT "MAXIMUM VALUE      : " ;L(33)-5
1260 PRINT "MINIMUM VALUE          : " ;L(34)-5
1270 PRINT "NUMBER OFER 300 MICRONS : " ;L(31)
1280 PRINT "NUMBER COUNTED         : " ;L
1290 IF EB="YES" OR EB="Y" THEN 1300 ELSE 1380 '*** Line printer ? ***
1300 LPRINT :LPRINT TAB(10) "MAXIMUM VALUE      : " ;L(33)-5 ;TAB(50) "MICRO
CONVER      : " ;A
1310 LPRINT TAB(10) "MINIMUM VALUE          : " ;L(34)-5 ;TAB(50) "COL OBS SIZE      :
" ;OB(1)
1320 LPRINT TAB(10) "NUMBER OVER 300 MICRONS : " ;L(31) ;TAB(50) "AIR VELOCITY
: " ;VE
1330 LPRINT TAB(10) "NUMBER COUNTED         : " ;L ;TAB(50) "SPREAD FACTOR      : "
;B
1340 LPRINT CHR$(12)
1380 RETURN '*** Back where called from ***
***** Tape input routine *****
1990 'SUBROUTINE TO INPUT FROM TAPE
2000 CLS :INPUT "PLACE TAPE IN RECORDER, SET TO PLAY AND HIT ENTER" ; ED
2010 INPUT #-1 ,EF ,OB ,VE
2020 CLS: PRINT EF
2030 INPUT #-1 , L(0) ,L(1) ,L(2), L(3), L(4), L(5), L(6), L(7), L(8), L(9), L(10), L(11), L(12),
L(13), L(14), L(15), L(16), L(17), L(18), L(19), L(20), L(21), L(22), L(23), L(24), L(25), L(26),
L(27), L(28), L(29), L(30), L(31), L(32), L(33), L(34)
2040 INPUT #-1 ,N1 ,N2 ,N3 ,N4 ,N5 ,Y1 ,Y2 ,Y3 ,Y4
2050 RETURN
***** Percent volume calculation & print routine *****
2990 'SUBROUTINE TO CALCULATE AND OUTPUT % VOL AND CUM VOL
3000 RESTORE: FORI=1 TO 12 :READ A$ :NEXT I
3010 CV(0)=0 :FOR I=1 TO 30 :READ AV :CV(I)=AV*L(I) :CV(0)=CV(0)+CV(I) : NEXT I
3015 FOR I=1 TO 30 :PV(I)=(INT((CV(I)/CV(0))*1E6)/1E4) :NEXTI
3020 CLS: PRINT TAB(15)"CUMULATIVE VOLUME IN CUBIC MICRONS"
3030 PRINT "SIZE"; TAB(7)"CUM. VOLUME"; TAB(20)"SIZE" ;TAB(27)"CUM. VOLUME";
TAB(40)"SIZE"; TAB(47)"CUM. VOLUME"
3040 A1=0 :A2=0 :A3=0 :FOR I=1 TO 30 STEP 3: A1=A1+CV(I): A2=A1+CV(I+1):
A3=A2+CV(I+2): PRINT I*10; TAB(6) A1; TAB(20) I*10+10; TAB(26) A2; TAB(39) I*10+20;
TAB(46) A3 :A1=A3 :A2=0 :A3=0 :NEXT I
3050 INPUT"HIT (ENTER) TO CONTINUE" ;ED :IF EB="Y" OR EB="YES" THEN 3060 ELSE
3120
3060 LPRINT :LPRINT TAB(23) "CUMULATIVE VOLUME IN CUBIC MICRONS" :LPRINT
3070 LPRINT TAB(10) "SIZE" ;TAB(17) "CUM. VOLUME" ;TAB(31) "SIZE" ;TAB(38) "CUM.
VOLUME" ;TAB(52) "SIZE" ;TAB(59) "CUM. VOLUME"
***** Cumulative volume printout *****
3080 A1=0 :A2=0 :A3=0 :FOR I=1 TO 30 STEP 3: A1=A1+CV(I) : A2=A1+CV(I+1):
A3=A2+CV(I+2) : LPRINTTAB(11) I*10; TAB(18) A1 ;TAB(32) I*10+10; TAB(39) A2;
TAB(53)I*10+20; TAB(60) A3 :A1=A3 :A2=0 :A3=0 :NEXT I
3090 LPRINT :LPRINT TAB(24) "PERCENT VOLUME TABLE"
3100 LPRINT :LPRINT TAB(10) "SIZE" ;TAB(17) "PERCENT VOL." ;TAB(31)"SIZE" ;TAB(38)
"PERCENT VOL." ;TAB(52) "SIZE" ;TAB(59) "PERCENT VOL."
3110 FOR I=1 TO 30 STEP 3 :LPRINT TAB(11) I*10; TAB(18) FV(I); TAB(32) I*10+10;
TAB(39) FV(I+1);TAB(53) I*10+20; TAB(60) FV(I+2); NEXT I
3120 CLS: PRINT "SIZE" ;TAB(10) "% VOL." ;TAB(20) "SIZE" ;TAB(30) "% VOL." ;TAB(40)

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"SIZE" ;TAB(50) "% VOL."
3130 FOR I=1 TO 30 STEP 3 :PRINT TAB(2) I*10; TAB(13) IV(I); TAB(23) I*10+10; TAB(33)
PV(I+1); TAB(43) I*10+20; TAB(53) PV(I+2) :NEXT I
3140 INPUT "HIT (ENTER) TO CONTINUE" ;ED :RETURN
**** Subroutine to calculate particle parameters ****
***** and collection efficiencies *****
5000 FOR I=1 TO 4 :PRINTUSING" #/4 CALCULATION IN PROCESS " ;I : FOR K=1 TO 30
: P(I,K)=(DEN*(M(K)/1E4)/[2*VEL]/(CO*OBS(I))
5010 IF P(I,K) <.1 THEN J=1 :GOTO 5060
5020 IF P(I,K) <1 THEN J=4 :GOTO 5060
5030 IF P(I,K) <20 THEN J=7 :GOTO 5060
5040 IF P(I,K) <100 THEN J=10 :GOTO 5060
5050 E(I,K)=1 :NEXT K,I :GOTO 5070
5060 E(I,K)=C(J)+C(J+1)*LOG(P(I,K))+C(J+2)*(LOG(P(I,K)))^2 :NEXT K,I
5070 PRINT :PRINT "ADJUSTING FREQUENCY" :L=L(32) :L(32)=0 :FOR I=1 TO 30
:L(I)=(INT((L(I)/E(I)*100))/100 :L(32)=L(32)+L(I) :NEXT I
5080 RETURN
***** Print particle parameters *****
***** and collection efficiencies *****
6000 ' SUBROUTINE TO PRINT THE PARTICLE PARAMETERS AND COLLECTION
EFFICIENCIES FOR GIVEN CYLINDERS
6020 FOR I=1 TO 3 :LPRINT :NEXT I :LPRINT " " :LPRINT TAB(20) "PARTICLE
INERTIAL IMPINGEMENT PARAMETERS (P)" :LPRINT TAB(26) "AND COLLECTION
EFFICIENCIES (E)"
6030 LPRINT :LPRINT TAB(2) " SIZE" ;TAB(38) "CYLINDER SIZE (CM)"
6040 LPRINT TAB(2) "CATEGORY" ;TAB(16) OB(2) ;TAB(40) OB(3) ;TAB(64)OB(4)
:FOR J=13 TO 61 STEP 24 : LPRINT TAB(J) "P" ;TAB(J+12) "E" ;;NEXTJ :LPRINT
:LPRINT TAB(4) STRING$(73,"-")
6050 FOR I=1 TO 30 :LPRINT TAB(3) I*10 ;TAB(8) P(2,I) ;TAB(19) E(2,I) ;TAB(32) P(3,I)
;TAB(43) E(3,I) ;TAB(56) P(4,I) ;TAB(67) E(4,I) :NEXT I
6055 LPRINT :LPRINT :LPRINT TAB(3) "AIR VEL =" ;VE ;"CM/S" ;TAB(28) "DENSITY OF
DROP =" ;DE ;TAB(56) "CONSTANT =" ;CO
6060 LPRINT CHR$(12) :RETURN
***** Data for calculations *****
***** Volume in cubic microns *****
7000 DATA .0125 ,.00108 ,0 ,.479 ,.437 ,.101 ,.475 ,.295 ,-.0456 ,.773 ,.0865 ,-.00858
7010 DATA 523.6 ,4188.8 ,14137 ,33510 ,65449 ,113097 ,179594 ,268082 ,381704 ,523599
,696910 ,904779 ,1.15035E6 ,1.43676E6 ,1.76715E6 ,2.14466E6 ,2.57244E6 ,3.05363E6
,3.59136E6 ,4.18879E6 ,4.84905E6 ,5.57528E6 ,6.37063E6 ,7.23823E6 ,8.18123E6 ,9.20277E6
,1.0306E7 ,1.1494E7
7020 DATA 1.27701E7 ,1.41372E7

```

Listing D3. Program <ABSORCON/BAS>

This program converts percent transmission data to absorbance, and then to microliters per milliliter of wash. The program also removes the effect of the blue dye interference on the yellow absorbance peak. In addition it corrects for instrumentation bias. The factors needed for these corrections are called for during the program initiation.

```
***** Initialize and define variables *****
100 CLS : CLEAR 500 : DEFINT I-N : DEFSNG A-H,Y
110 PRINTTAB(15) " PROGRAM <ABSORCON/BAS>
                                BY ALAN R. HAYS"
120 PRINT : INPUT "LINE PRINTER ATTACHED";A$
130 POKE 16424,67 : POKE 16425,1 ' *** SET UP LINE PRINTER DRIVER ***
140 IF A$="Y" OR A$="YES" : CLS : PRINT "TURN ON LINE PRINTER ADJUST TO
THE TOP OF THE PAPER, AND SET TO < ON LINE >" : LPRINT CHR$(27);CHR$(20) :
ELSE : GOTO 160 '*** Signal line printer to print 16.7 characters per inch ***
145 LPRINT "      "; FOR IC=1 TO 3 : LPRINT " " : NEXT IC
150 PRINT : INPUT "ENTER A BRIEF DISCRPTION OF THE DATA" ;A1$ : LPRINT
TAB(8) A1$ : LPRINT : LPRINT '*** Print discription on line printer ***
160 C$(0)="YELLOW" : C$(1)="BLUE" : C$(2)=" BACKGROUND " : C$(3)=" REFERENCE
" : BASE=2.30259 '*** Base is a constant to convert log base e to log base 10 ***
170 K=-1 : FOR I=0 TO 1 : FOR J=0 TO 1 : PRINT "ENTER " ; C$(J) ; C$(I+2) ; "%
TRANSMISSION"
180 K=K+1 : INPUT BK(K) : NEXT J,I
190 FOR IA = 0 TO 3 : BK(IA)=LOG(100/BK(IA))/BASE : NEXT IA : IF A$="Y" OR
A$="YES" THEN LPRINT TAB(8) C$(0) ; C$(2) ; " = " ; BK(0) : LPRINT TAB(8) C$(1) ; C$(2)
; " = " ; BK(1) : LPRINT TAB(8) C$(0) ; C$(3) ; " = " ; BK(2) : LPRINT TAB(8) C$(1) ; C$(3) ; " =
" ; BK(3) : ELSE 200
192 LPRINT : LPRINT TAB(14)"% TRANSMISSION" ; TAB(48)"ABSORBANCE" ; TAB(75)
"YELLOW      BLUE"
195 LPRINT TAB(8) " YELLOW      BLUE      YELLOW 1   BLUE 1   YELLOW 2
MICRO L/ML   MICRO L/ML   ENTRY #" : LPRINTTAB(8) ; : LPRINTSTRING$
(105,"-")
200 FOR IB= 0 TO 1000 : CLS
***** Enter, convert and print data *****
250 PRINT " ENTER THE YELLOW AND BLUE % TRANSMISSIONS FOR ENTRY ";IB :
INPUT YE$ , BL$ :IF YE$<>"Q" THEN YE=VAL(YE$) : BL=VAL(BL$) :
Y1=LOG(100/YE)/BASE-BK(0) : B1=LOG(100/BL)/BASE-BK(1) : ELSE 650
300 IF B1>.0045 THEN Y2=Y1-(-4.0021E-4+9.2704E-2*B1) ELSE Y2=Y1 ' *** THIS
LINE REMOVES THE EFFECT OF THE BLUE ON THE 420 NM READING ***
350 IF Y2>0.0888 THEN Y3=4.029E-2*Y2-4.49E-4 ELSE
Y3=5.55433E-5+3.4298E-2*Y2
400 IF B1>.15 THEN B2=2.9254E-3+5.0948E-2*B1 ELSE B2=6.5651E-2*B1-3.07328E-4
425 IF PEEK (16425) =>60 THEN LPRINT CHR$(11) : LPRINT "      " : LPRINT :
```

```

LPRINT : LPRINT : LPRINT' *** Check for end of page ***
435 IF Y3<0 OR Y1<=0 THEN Y3=0
440 IF B2<0 THEN B2=0
450 PRINTC$(0);" MICROLITERS DEPOSIT = ";Y3 : PRINT C$(1);" MICROLITERS
DEPOSIT = ";B2
500 IF A$="Y" OR A$="YES" THEN 550 ELSE INPUT"HIT <ENTER> TO
CONTINUE";B$ : NEXT IB '*** If no line printer stop to view screen ***
550 LPRINTTAB(8); LPRINTUSING" ###.## ###.## ##### #.#####
#.##### #.##### #.##### ##" ; YE; BL; Y1; B1; Y2; Y3; B2; IB
600 NEXT IB '*** Format output ***
650 CLS : IF A$="Y" OR A$="YES" THEN LPRINT CHR$(11) ELSE PRINT C$(0);C$(2);"
= ";BK(0) : PRINT C$(1);C$(2);" = ";BK(1) : PRINT C$(0);C$(3);" = ";BK(2) : PRINT
C$(1);C$(3);" = ";BK(3)
700 PRINT : PRINT " ENTER NEW DATA" : INPUT B$ : IF B$="Y" OR B$="YES" THEN
145 ELSE END

```


Listing D4. Program <DATA CONV/BAS>

This program simply allows groups of data, previously converted by <ABSORCON/BAS>, with the same dilution factor, to be converted to microliters per square millimeter (flux). The data are entered by keyboard in the form of microliters per milliliter of final wash. The program requires input of both yellow and blue dye data and the input of the total dilution factor for the group being entered. There is an allowance for labeling the output through a keyboard entered description of the data. The program requires Disk BASIC due to line 150 "LINEINPUT", to run under Level II BASIC will require some modification.

```

***** Initialize & define variables *****
100 CLS : CLEAR 500 : DEFSNG A-H , O-Z : DEFINT I-N : DIM B(50) , B1(50) , B2(50) ,
Y(50) , Y1(50) , Y2(50)
125 POKE16424,67 : POKE16425,1 '*** Set up line printer driver ***
150 PRINT "    PROGRAM CONVERSION microliters/ml to microliters deposit to
microliters/mm squared"
200 PRINT "                                by Alan R. Hays"
***** Data entry by keyboard *****
225 PRINT : PRINT : PRINT "BEGIN ENTERING DATA PAIRS (ALL SHOULD HAVE
SAME CONVERSIONS)" : PRINT "SIGNAL END WITH AN '-9' SYMBOL"
250 PRINT : FOR I=0 TO 50 : PRINT "ENTRY # "; I ; : INPUT Y(I) , B(I) : IF Y(I) < 0
THEN I=I-1 : GOTO 300 ELSE NEXT I ' Enter data into an array ***
***** Conversoin entry *****
300 CLS : PRINT "ENTER CONVERSIONS FOR ABOVE DATA"
350 INPUT "TOTAL DILUTION FACTOR FOR THE YELLOW AND BLUE" : YD , BD
400 INPUT "AREA IN SQUARE MILLIMETERS FOR YELLOW AND BLUE
INTERCEPTS" : YA , BA
***** Line printout routine *****
405 FOR L=1 TO 6 : LPRINT : NEXT L
410 LPRINT CHR$(27);CHR$(20);"      " : LINEINPUT "ENTER DISCRPTION OF
DATA ? " : A$ : LPRINT TAB(10) A$ '*** Select 16.7 chr/inch print on line printer
***
420 LPRINT : LPRINT TAB(10) "CONSTANTS " ; YD, BD, YA, BA : FOR L=1 TO 2 :
LPRINT : NEXT L
425 LPRINT TAB(25) "YELLOW" ; TAB(40) "TOTAL" ; TAB(55) "ul/mm" ; TAB(70) "BLUE"
; TAB(85) "TOTAL" ; TAB(100) "ul/mm"
430 LPRINT TAB(10) "ENTRY #" ; TAB(25) "ul/ml" ; TAB(40) " ul" ; TAB(55) "squared"
; TAB(70) " ul/ml" ; TAB(85) " ul" ; TAB(100) "squared"
***** Convert data and print results on line printer *****
450 FOR J=0 TO I : Y1(J)=Y(J)*YD : Y2(J)=Y1(J)/YA : B1(J)=B(J)*BD :
B2(J)=B1(J)/BA : LPRINT TAB(12) J ; TAB(22) Y(J) ; TAB(37) Y1(J) ; TAB(52) Y2(J)
; TAB(67) B(J) ; TAB(82) B1(J) ; TAB(97) B2(J) : NEXT J
500 LPRINT CHR$(11)
550 CLS : INPUT "ENTER NEW DATA" : B$ : IF B$="Y" OR B$="YES" THEN RUN ELSE
END

```

APPENDIX E

DATA COLLECTION PROGRAMS

Listing E1. Program <SYSCALL/BAS>

This program was written by Mr. David Zeitler to control the anemometer interfacing hardware detailed in Appendix F. The program calls the system subroutine <MACH>, prints the data on magnetic tape, and checks the tape for errors. Subroutine <MACH> follows in Listing E2. Note Mr. Zeitler was formerly of the Department of Computer Science, Applications Programming, Michigan State University.

The raw data resulting from this program must be converted using <ANEMCONV/BAS> listed in Appendix D.

```
100 CLS : CLEAR 470
110 DEFINT A-Z : DIM P(4) , P(27) : MS = INT( 32250/16[2 ] ) : LS = INT( 32250 - MSB *
16 [ 2 ] ) '*** Entry ***
130 INPUT "SAMPLE INTERVAL (1/10 S) :" ; P(1)
140 INPUT "REPEAT INTERVAL ( S )   :" ; P(2)
150 INPUT "TOTAL INTERVAL ( MIN )  :" ; P(3)
160 IF P(1) > P(2) * 10 THEN PRINT "CANNOT REPEAT THIS FAST" : STOP
170 P(3) = P(3) * 360 / P(2) : P(1) = P(1) * 1000 : IF P(2) > 3 THEN P(2) = (P(2) * 10000) -
65536 ELSE P(2) = P(2) * 10000
175 Z = P(3) / 6 : N1 = Z - 1 : IF INT( Z / 9 ) <> Z / 9 THEN Z = Z + 9 '*** Determine
minimum array size for tape write output ***
180 DIM D(2,Z-1) : Z = VARPTR (P(1)) : P(4) = VARPTR (D(0,0))
190 REM *** Z = Base of params ; P(4)=Base of data array ***
195 POKE 16526 ,LS : POKE 16527 ,MS '*** Set up for <MACH> subroutine ***
200 Z = USR( Z ) '*** Call <MACH> routine to collect data ***
220 P(1) = P(1) / 1000 : IF P(2) < 0 THEN P(2) = (P(2) + 65536) / 10000 ELSE P(2) = P(2) /
10000
225 P(3) = P(3) * P(2) / 360
230 PRINT : INPUT "COMMENTS FOR FILE ( < 231 CHARS )" ; N$
240 IF LEN (N$) > 230 THEN N$ = LEFT$ (N$ , 230) : PRINT "TRUNCATED TO" ; N$
```

APPENDIX E

DATA COLLECTION PROGRAMS

```

250 PRINT "READY CASSETTE FOR RECORD" : NO$=""
270 INPUT "HIT RETURN WHEN SET" : Z$ : PRINT#-1, P(1), P(2), P(3), N$
280 FOR I = 0 TO N1 STEP 9
285 FOR J=I TO I+8 : PRINT J ; D(0,J) ; D(1,J) ; D(2,J) : NEXT J
290 PRINT#-1, D(0,I), D(1,I), D(2,I), D(0,I+1), D(1,I+1), D(2,I+1), D(0,I+2), D(1,I+2),
D(2,I+2), D(0,I+3), D(1,I+3), D(2,I+3), D(0,I+4), D(1,I+4), D(2,I+4), D(0,I+5), D(1,I+5),
D(2,I+5), D(0,I+6), D(1,I+6), D(2,I+6), D(0,I+7), D(1,I+7), D(2,I+7), D(0,I+8), D(1,I+8),
D(2,I+8)
300 NEXT I
310 PRINT "STORE COMPLETE - REWIND TAPE AND PLAYBACK FOR VERIFY"
320 PRINT "HIT RETURN WHEN READY" ;; INPUT Z$
330 INPUT#-1, P0(1), P0(2), P0(3), N0$
340 IF N0$ <> N$ THEN 500
350 FOR I=1 TO 3 : IF P(I) <> P0(I) THEN 430
360 NEXT I : FOR I=0 TO N1 STEP 9
370 INPUT#-1, P0(1), P0(2), P0(3), P0(4), P0(5), P0(6), P0(7), P0(8), P0(9), P0(10),
P0(11), P0(12), P0(13), P0(14), P0(15), P0(16), P0(17), P0(18), P0(19), P0(20), P0(21),
P0(22), P0(23), P0(24), P0(25), P0(26), P0(27)
380 FOR J=1 TO 27 STEP 3 : FOR K=0 TO 2: IF D(K,I+INT(J/3)) <> P0(J+K) THEN 430
390 NEXT K, J, I : INPUT "DATA OK - COPY(Y/N)" : Z$
400 IF Z$ = "Y" THEN 250 ELSE END
420 REM *** Error condition processing for data verify ***
430 PRINT "D(" ; K ; "," ; I+INT(J/3) ; ")=" ; D(K,I+INT(J/3)) ; "P0(" ; J ; ")=" ; P0(J) ; :
INPUT "CONTINUE/REWRITE/STOP(C/R/S)" : Z$
440 IF Z$ = "C" THEN 390
450 IF Z$ = "S" THEN STOP
460 IF Z$ = "R" THEN 250
470 END
500 PRINT N$ : PRINT N0$ : INPUT "CONTINUE/REWRITE/STOP(C/R/S)" : Z$
510 IF Z$ = "S" THEN STOP
520 IF Z$ = "C" THEN 350
530 IF Z$ = "R" THEN 250
540 END

```

Listing E2. Assembly Language Subroutine to Control Anemometer Data Collection

Device.

```

00100 ;***** Z-80 SOURCE FOR ENTOMOLGY DATA COLLECTION
00110 ;          11/80 MSUAP DAVE ZEITLER 355-4684
00120 ;
00130 ; ***** SET MACH CODE AT 32240 ENTRY AT 32250
00140 ;
00160          ORG          7DF0H
00170 ;
00180 ;***** LABEL DEFINITION AREA *****
00190 CLK1      EQU          0          ;OFFSET FOR CLOCK 1
00200 CLK2      EQU          1          ;OFFSET FOR CLOCK 2
00210 CTR1      EQU          2          ;OFFSET FOR COUNTER 1
00220 CTR2      EQU          4          ;OFFSET FOR COUNTER 2
00230 CTR3      EQU          5          ;OFFSET FOR COUNTER 3
00240 CW1       EQU          3          ;OFFSET FOR CONTROL CHIP 1
00250 CW2       EQU          7          ;OFFSET FOR CONTROL CHIP 2
00260 SELCT0    EQU         48          ;SEL MODE0 L/R LSB/MSB CNTR0
00270 SELCT1    EQU        112          ;SEL MODE0 L/R LSB/MSB CNTR1
00280 SELCT2    EQU        176          ;SEL MODE0 L/R LSB/MSB CNTR2
00290 LATCH0    EQU          00          ;LATCH VALUE IN COUNTER 0
00300 LATCH1    EQU         40H          ;LATCH VALUE IN COUNTER 1
00310 LATCH2    EQU         80H          ;LATCH VALUE IN COUNTER 2
00320 ;
00330 ;***** PARAMETER STORAGE AREA
00340 ;
00350 DBASE      DEFW          0          ;BASE OF BASIC ARRAY
00360 TIME1      DEFW          0          ;TIME INTERVAL 1 (SHORT)
00370 TIME2      DEFW          0          ;TIME INTERVAL 2 (LONG)
00380 BYTCNT     DEFW          0          ;BYTE COUNT-CONTROLS RUN LENGTH
00390 BASTK      DEFW          0          ;BASIC STACK ON ENTRY
00400 ;
00410 ;***** BEGIN EXECUTABLE CODE WITH PARAMETER RETREIVE
00420 ;
00430 ENTRY      CALL         0A7FH          ; GET USR(X) PARM
00440             LD           (BASTK),SP      ;SAVE STACK FOR RETURN
00450             LD           E,(HL)          ;LSB TIME1
00460             INC          HL
00470             LD           D,(HL)          ;MSB TIME1
00480             LD           (TIME1),DE      ;SAVE IT
00490             INC          HL
00500             LD           E,(HL)          ;LSB TIME2
00510             INC          HL
00520             LD           D,(HL)          ;MSB TIME2
00530             LD           (TIME2),DE      ;SAVE IT
00540             INC          HL
00550             LD           E,(HL)          ;LSB BYTE COUNT

```

Listing E2. Continued

```

00560      INC      HL
00570      LD       D,(HL)          ;MSB BYTE COUNT
00580      PUSH    DE              ;SAVE FOR BANK 1
00590      LD       (BYTCNT),DE    ;SAVE FOR CLEAN
00610      INC      HL
00620      LD       E,(HL)          ;LSB DATA ARRAY BASE
00630      INC      HL
00640      LD       D,(HL)          ;MSB DATA ARRAY BASE
00650      PUSH    DE              ;FOR BANK 1
00660      LD       (DBASE),DE     ;FOR CLEAN
00670      EXX
00680      POP      DE              ;GOTO BANK 1
00690      POP      BC              ;SET BASE
00700      LD       HL,0FFFFH      ;SET COUNT
00710      EXX                    ;USED FOR LONG WAIT
00720      ;                      ;BACK TO BANK 0
00730      ; ***** SET MODE FOR 2 CLOCKS AND 3 COUNTERS
00740      ; MODE 0 AND LOAD/READ LSB THEN MSB SET FOR EACH
00750      ;
00760      LD       IX,0FFF0H        ;BASE OF DEVICE
00770      LD       A,SELCT0         ;MODE WORD COUNTER0
00780      LD       (IX+CW1),A      ;SET TIMER 1
00790      LD       (IX+CW2),A      ;COUNTER 2
00800      LD       A,SELCT1        ;MODE WORD COUNTER1
00810      LD       (IX+CW1),A      ;SET TIMER 2
00820      LD       (IX+CW2),A      ;COUNTER 3
00830      LD       A,SELCT2        ;MODE WORD COUNTER2
00840      LD       (IX+CW1),A      ;COUNTER1
00850      ; ***** GOT PARAMS AND BANK 0 SET UP FOR RUN
00860      ; SET CLOCK 2 RUNING FOR 1 CYCLE TO HAVE BIT 1
00870      ; OF STATUS WORD SET ON ENTRY
00880      LD       A,1              ;LSB FOR DUMMY COUNT
00890      LD       (0FFF1H),A
00900      LD       A,0              ;MSB FOR DUMMY COUNT
00910      LD       (0FFF1H),A      ;DUMMY COUNT SET UP
00920      ; ***** CLOCK 2 SHOULD READ DONE BY END OF FOLLOWING
00930      ; NOW WAIT FOR USER SIGNAL TO START
00940      ;
00950      LD       HL,(4020H)        ;POINT TO CURSOR POSITION
00960      WAIT    LD       A,'R'     ;FLASH AN R WHILE POLLING
00970      LD       (HL),A           ;THE KEYBOARD
00980      CALL    ZBH               ;FOR RESPONSE
00990      OR      A                 ;TEST FOR ANY BUT NULL
01000      JR      NZ,MAIN          ;HE'S READY
01010      LD       A,' '          ;FLASH THE R
01020      LD       (HL),A
01030      LD       B,0FFH           ;TIMING LOOP FOR FLASH

```

Listing E2. Continued

```

01040 FLASH    DJNZ    FLASH
01050          JR      WAIT                ;AND TRY AGAIN
01060 ; ***** FLASH '*' AT CURSOR FOR RUN SIGNAL
01070 ;
01080 MAIN      PUSH    DE                ;PUT ANOTHER '*' ON VIDEO
01090          PUSH    IY
01100          LD      A,'*'
01110          CALL    33H                ;BASIC DISPLAY ROUTINE
01120          POP     IY
01130          POP     DE
01140 ; ***** DISPLAY DONE NOW GO ON
01150 ;
01160          LD      HL,0FFFFH            ;SET UP BANK 0 FOR LONG
01170          LD      DE,0FFF0H            ;WAIT AND CLOCK TRIGGER
01180          LD      BC,(TIME2)           ;GET TIME 2 FOR STACK
01190          PUSH    BC
01200          LD      BC,(TIME1)           ;SAVE TIME 1 IN BC
01210 LWAIT     LD      A,(HL)             ;NOW WAIT FOR LONG
01220          BIT     1,A                 ;TEST STATUS BIT FOR CLK2
01230          JR     Z,LWAIT             ;NOT DONE YET
01240 ; ***** NOTE USING DE AND TRANSFERING TO HL ALLOWS
01250 ; SHARPER DETECTION OF CLOCK ON WAIT LOOP WITH
01260 ; FASTER TRIGGERING THAN LOADING HL AFTER CLOCK
01270 ; DETECTION
01280 ;
01290          LD      H,D                 ;MOVE DE-->HL
01300          LD      L,E
01310          POP     DE                 ;GET TIME2 IN DE
01320          LD      (HL),C             ;LSB TIME1
01330          LD      (HL),B             ;MSB TIME1
01340          INC     HL                 ;HL := FFF1 (CLK2)
01350          LD      (HL),E             ;LSB TIME2
01360          LD      (HL),D             ;MSB TIME2
01370          INC     HL                 ;NOW = FFF2
01380          LD      (HL),H             ;COUNTER 1 LSB OUT
01390          LD      (HL),H             ;COUNTER 1 MSB OUT
01400          INC     HL                 ;NOW HL=FFF3 (CW1)
01410          INC     HL                 ;HL=FFF4 (CNTR2)
01420          LD      (HL),H             ;FF --> CTR2
01430          LD      (HL),H
01440          INC     HL                 ;HL=FFF5 (CNTR3)
01450          LD      (HL),H             ;FF --> CTR3
01460          LD      (HL),H
01470          LD      HL,0FFF7H           ;SET UP FOR FAST FREEZE
01480          LD      DE,0FFF3H           ;OF COUNTERS
01490          LD      A,LATCH2            ;A=MODE WORD CHIP CNTR2
01500          LD      B,LATCH0            ;MODE FOR COUNTER 2

```

Listing E2. Continued

```

01510      LD      C,LATCH1      ;COUNTER 3
01520      EXX      ;SWITCH COMPLETELY TO
01530      EX      AF,AF'      ;BANK 1 FOR WAIT
01540  SWAIT  LD      A,(HL)      ;GET STATUS
01550      BIT      0,A      ;TEST CLOCK 1
01560      JR      Z,SWAIT      ;NOT YET
01570      EXX      ;BACK TO BANK 0
01580      EX      AF,AF'
01590      LD      (DE),A      ;SEND FREEZE MODE WORDS
01600      LD      (HL),B      ;COUNTERS 1,2,3
01610      LD      (HL),C      ;VALUES FROZE IN CHIP
01620      EXX      ;BACK TO BANK 1 FOR
01630      LD      A,(IX+CTR1)    ;LSB COUNTER 1
01640      CALL    STORIT
01650      LD      A,(IX+CTR1)    ;MSB COUNTER 1
01660      CALL    STORIT
01670      LD      A,(IX+CTR2)    ;LSB COUNTER 2
01680      CALL    STORIT
01690      LD      A,(IX+CTR2)    ;MSB COUNTER 2
01700      CALL    STORIT
01710      LD      A,(IX+CTR3)    ;LSB COUNTER 3
01720      CALL    STORIT
01730      LD      A,(IX+CTR3)    ;MSB COUNTER 3
01740      CALL    STORIT      ;GOT 6 BYTES STORED
01820      LD      A,B      ;CHECK FOR LAST BYTE
01830      OR      C
01840      EXX      ;GOTO BANK 0
01850      JF      NZ,MAIN      ;LOOP IF NOT DONE
01860  ; ***** DATA COLLECTED NOW CLEAN UP FOR BASIC
01870  ; AND THEN RETURN
01880  ;
01890      LD      HL,(DBASE)      ;RESET CPU FOR RUN
01900      LD      BC,(BYTCNT)      ;THRU DATA ARRAY
01910  CLOOP  LD      E,(HL)      ;PULL IN DATA
01920      INC     HL      ;TO DE
01930      LD      D,(HL)
01940      PUSH    HL      ;SAVE DATA POINTER
01950      LD      HL,0FFFFH      ;SET FOR SUBTRACT
01960      SBC     HL,DE      ;HL=HL-BC (TRUE COUNT)
01970      EX      DE,HL      ;SET FOR RESAVE
01980      POP     HL      ;GET LOC BACK
01990      DEC     HL      ;POINT BACK TO LSB
02000      LD      (HL),E      ;AND SAVE DE AGAIN
02010      INC     HL
02020      LD      (HL),D
02030      INC     HL      ;POINT TO NEXT DATA
02040      DEC     BC      ;DEC BYTE COUNT

```


Listing E2. Continued

```

02050      DEC      BC          ;TWO BYTES
02060      LD       A,B        ;AND CHECK FOR DONE
02070      OR       C
02080      JF       NZ,CLOOP    ;MORE DATA YET
02090      LD       SP,(BASTK)  ;RESET BASTK FOR SURE
02100      RET                ;BACK TO BASIC
02110 ;
02120 ; ***** SUBROUTINE STORIT
02130 ;      EXPECTS DATA TO STORE IN A, LOC TO STORE IN DE
02140 ;      AUTO INCREMENTS DE, DECREMENTS BC
02150 ;
02160 STORIT LD       (DE),A
02170      INC      DE
02180      DEC      BC
02190      RET
02200      END

```

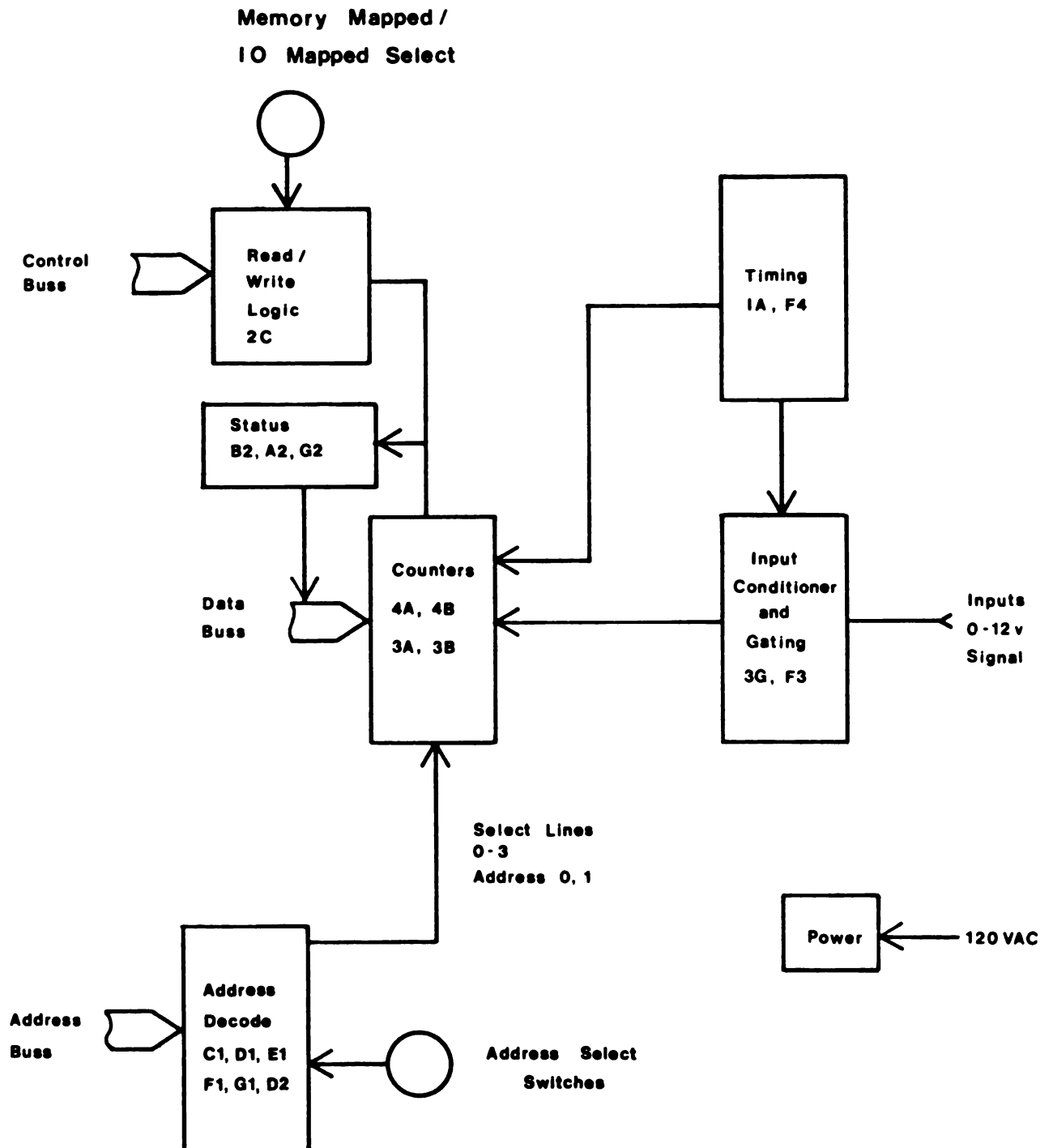
APPENDIX F

ANEMOMETER DATA COLLECTION DEVICE SCHEMATICS

Note: Figures F1 through F9 are the schematics for the anemometer data collection device actually used in this study. The device as shown is not without problems (see text "Anemometer Data Collection Device"). Minor changes have been made in the devices hardware clock, inhibit circuit, and the number of counters have been expanded two nine (two reserved for timing operations leaving seven for data collection). These changes have not been tested at the time of this writing and are therefore not shown on these schematics. For further information on the progress of these revisions contact Mr. Tim Childs of the Michigan State University, Department of Computer Science, Engineering Technical Services, East Lansing, Michigan 48824, or the author.

APPENDIX F

ANEMOMETER DATA COLLECTION DEVICE SCHEMATICS

**Figure F1. System Block Diagram**

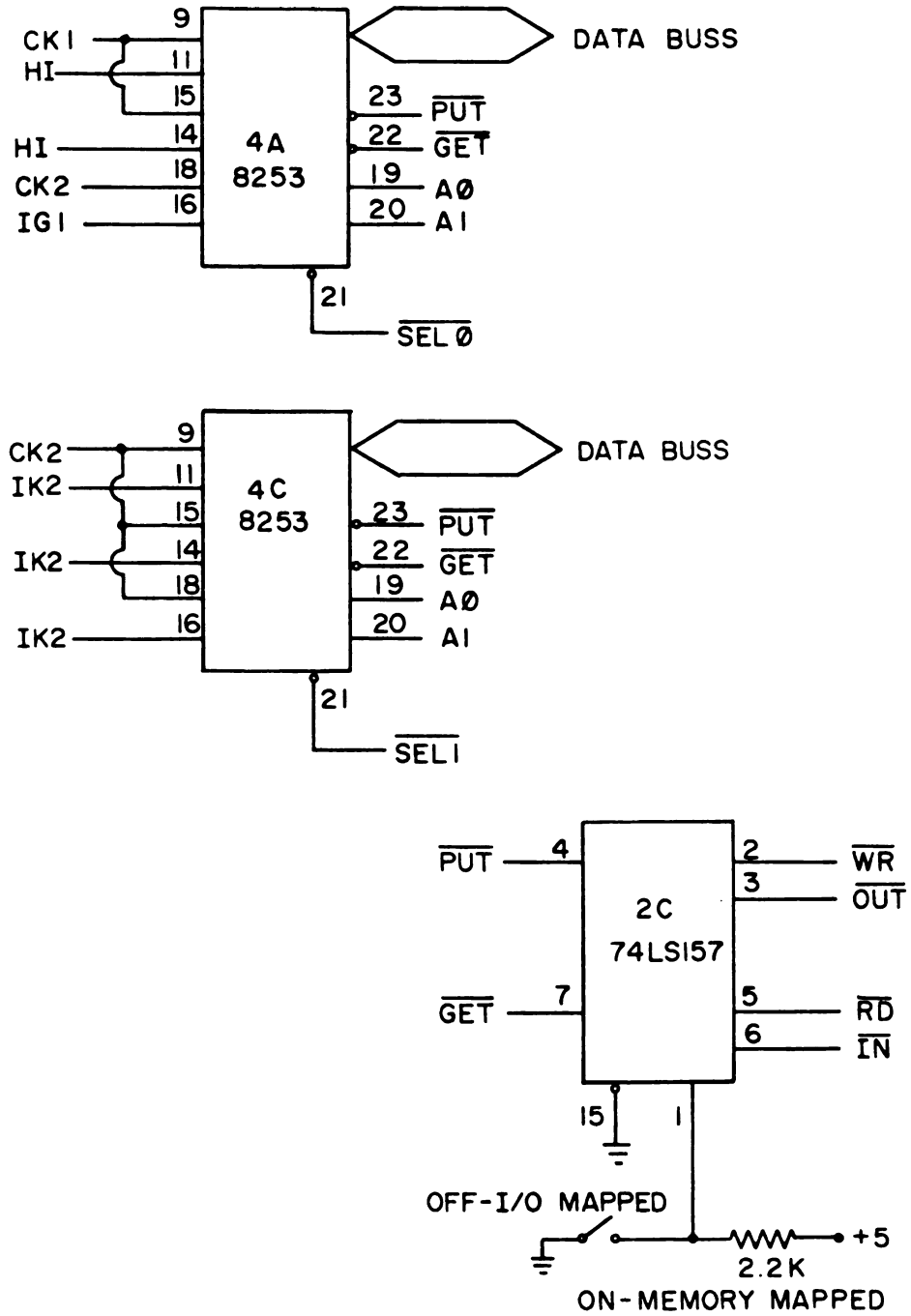


Figure F2. Counters and Interface

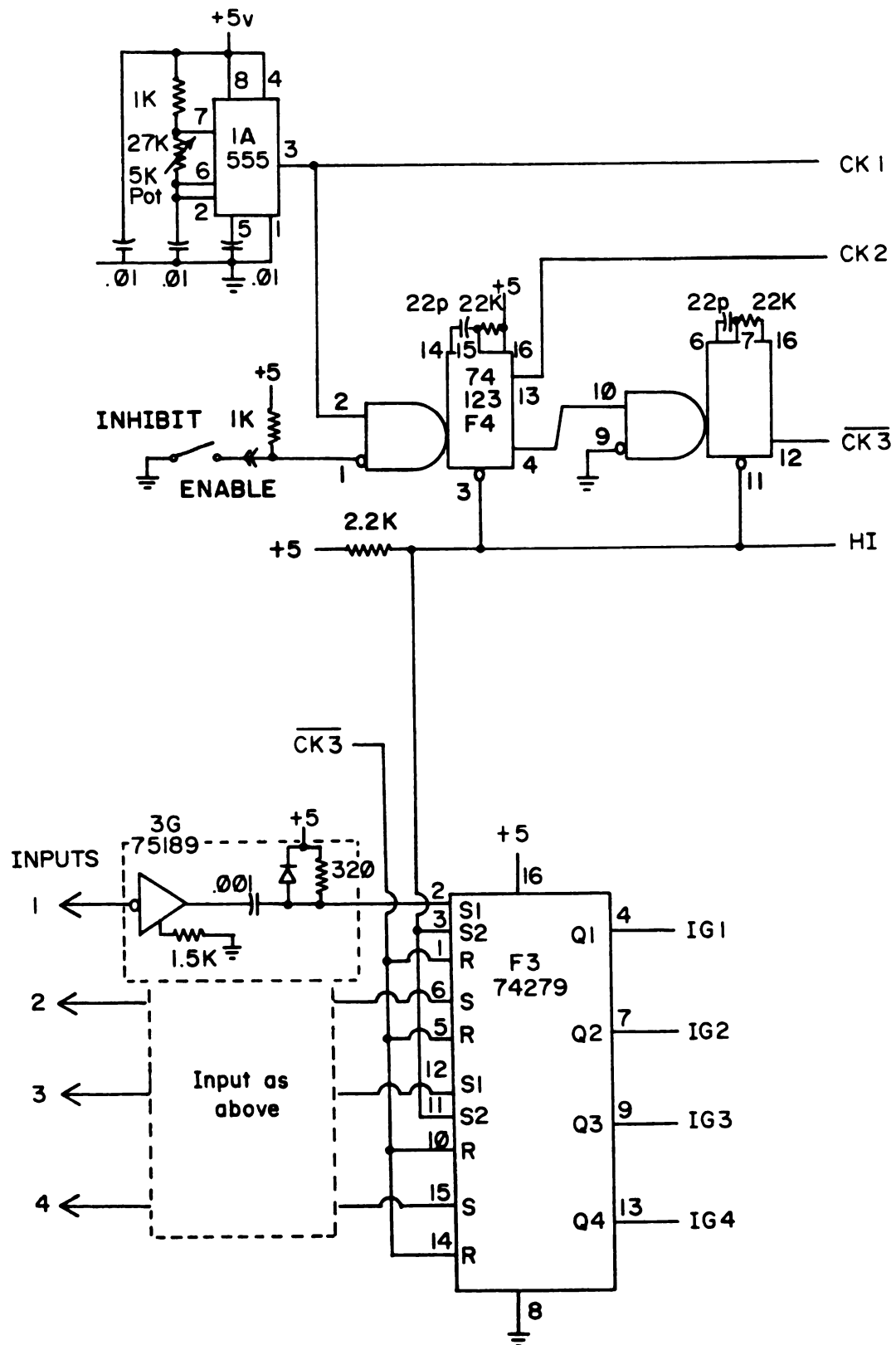


Figure F3. Input Conditioners and Timing

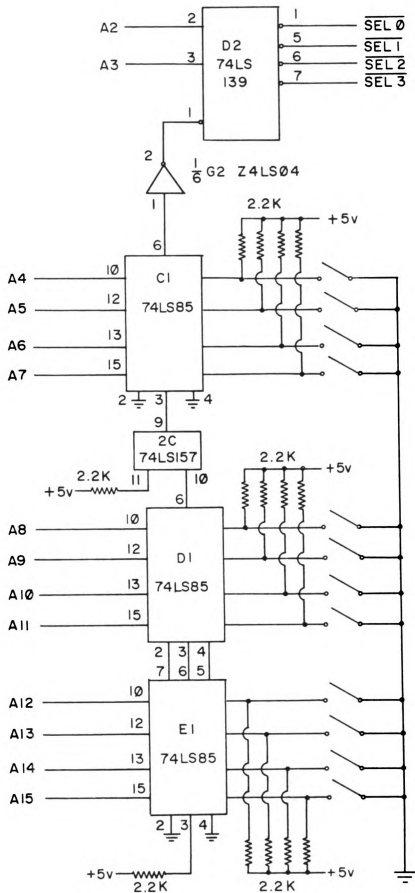


Figure F4. Addressing Logic

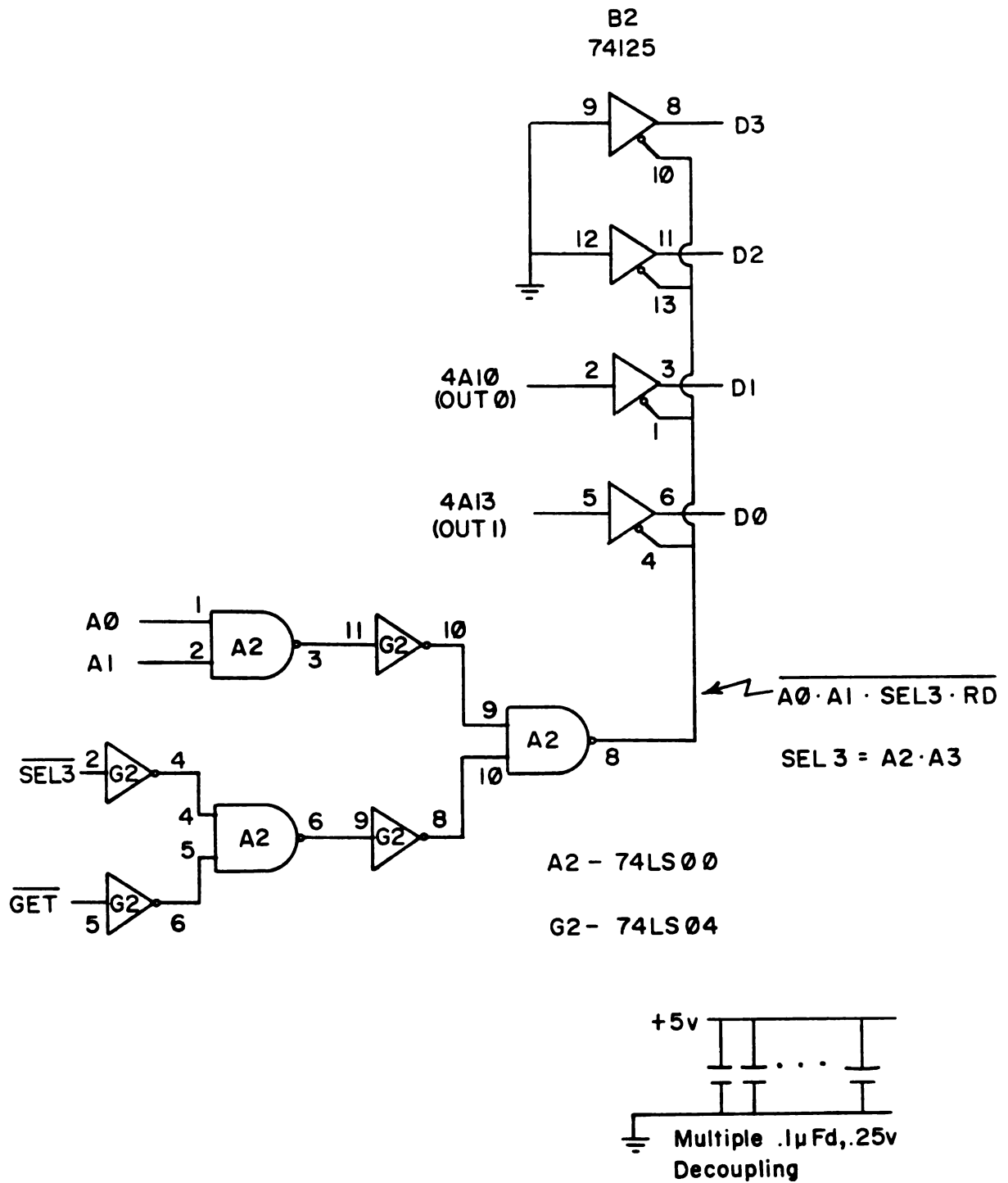


Figure F5. Status Logic

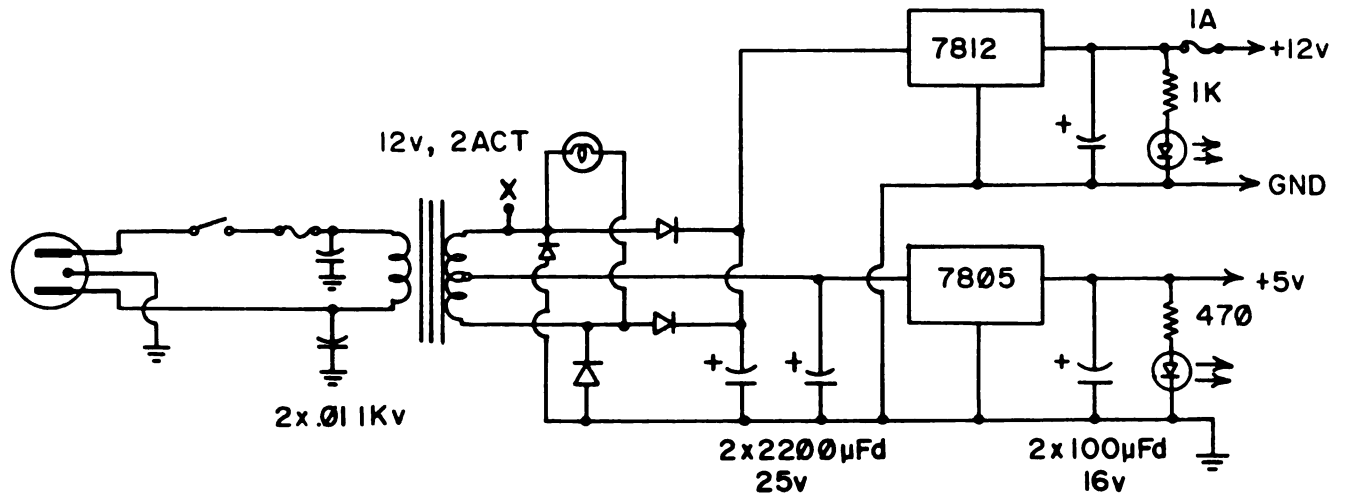


Figure F6. Power Supply

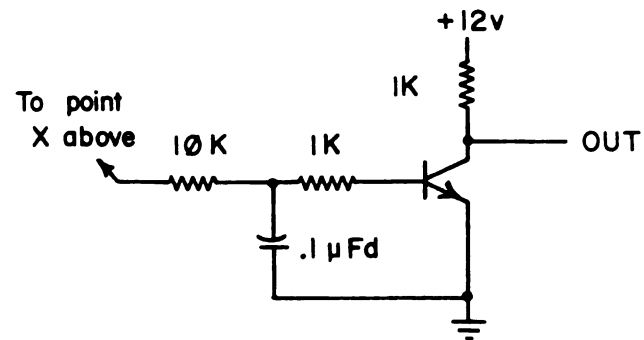


Figure F7. Line Time Reference

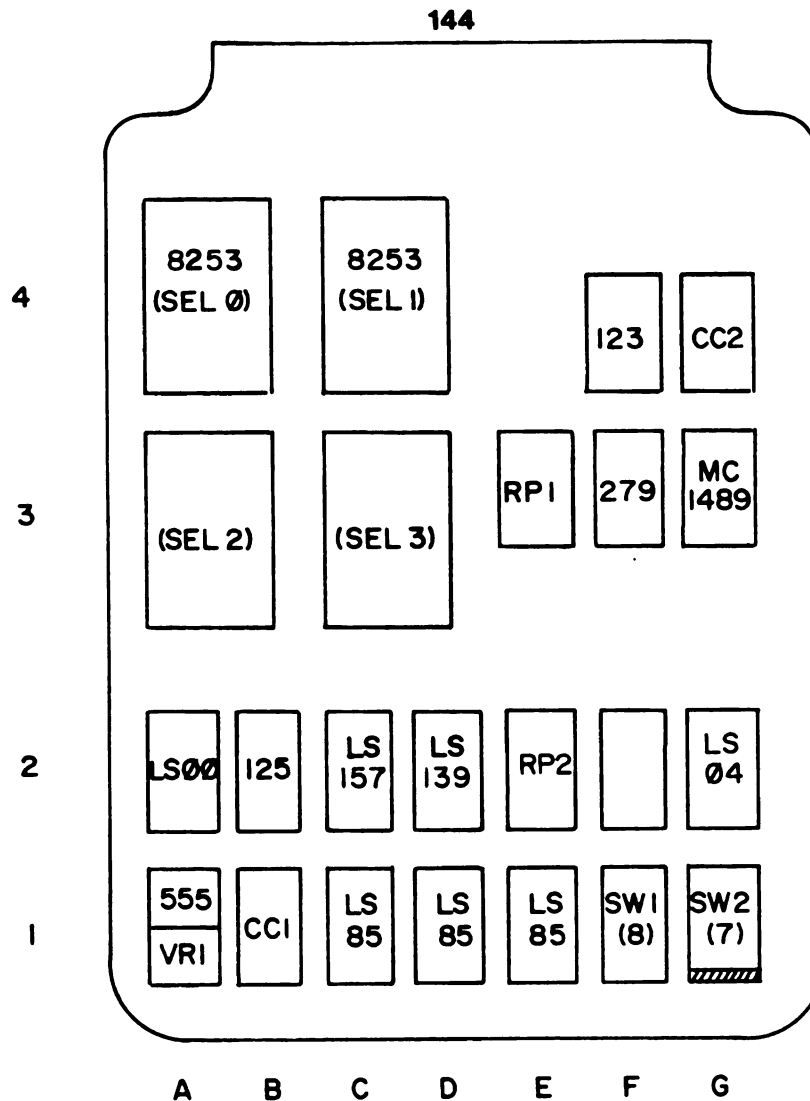


Figure F8. Board Layout (top view)

Mode: This device may be accessed by either I/O Port or Memory access. If switch X1 of SW2 is on, Memory Mapped operation is selected and the base memory address is selected by switches A5 through A15.

If X1 is set to OFF, I/O Port access is selected, and only switches A4 through A7 are used.

Note: When setting the address switches, the ON position is logic 0 and OFF is logic 1.

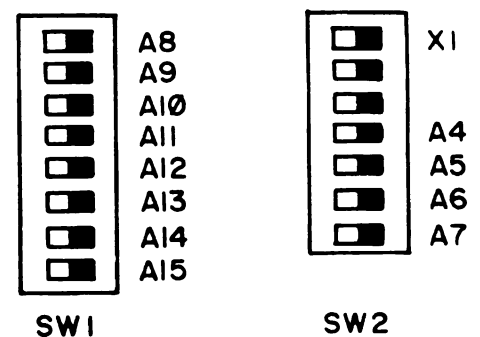


Figure F9. Addressing Selection

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