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AGRICULTURAL RESEARCH SERVICE

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In Cooperation With

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April 1, 1965 - March 31, 1966

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LINE PROJECT ANNUAL PROGRESS REPORT

U. S. Department of Agriculture
Agricultural Research Service
Agricultural Engineering Research Division
Crop Production Engineering Research Branch
Plant Pest Control Equipment and Practices Investigations
College Station, Texas

in cooperation with

The Texas Agricultural Experiment Station
Texas A&M University

1965

Equipment and Techniques for Applying Herbicides to Vegetation in Puerto Rico and Texas
Line Project No. AE-0-0-2(DOD)

1967.

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Date: April 1, 1966

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INTRODUCTION

This report concerns the second year of activity on the engineering phases of the research program in Texas on the use of herbicides for vegetation defoliation and control which is sponsored by the Advanced Research Projects Agency (ARPA) of the Department of Defense. This program is conducted jointly by the Agricultural Engineering Research Division and the Crops Research Division of the Agricultural Research Service, USDA in cooperation with the Texas Agricultural Experiment Station. Research is designed to discover and evaluate new herbicides and principles for killing trees, brush and other vegetation, develop methods of evaluating herbicides on different species of woody vegetation, develop methods and principles for improved application techniques, and to determine the effects of environment on the behavior and effectiveness of promising herbicides.

Personnel assigned to the engineering phase of the project during the reporting period April 1, 1965 to March 31, 1966 were as follows:

Louis F. Bouse, Agricultural Engineer, Full-time employee

*Harry L. Francis, Laboratory Mechanic, Full-time employee

*Mrs. Wanda Spears, Clerk-Typist, Half-time employee

*James F. Jackson, Technical Assistant,

Part-time employee, 4-1-65 to 9-8-65

*Robert D. Chenoweth, Technical Assistant,

Full-time employee, 5-31-65 to 9-20-65

Part-time employee, 9-20-65 to 1-28-66

*James E. Parker, Technical Assistant,

Part-time employee, 1-18-66 to 3-31-66

*Orvel F. Hill, Jr., Technical Assistant,

Part-time employee, 1-7-66 to 3-31-66

Joint studies are conducted with personnel of the Crops Protection Research Branch, Crops Research Division, ARS-USDA. Professional cooperative personnel of the Crops Protection Research Branch at this location include R. W. Bovey, M. G. Merkle, and H. L. Morton, Research Agronomists; and F. S. Davis and R. E. Meyer, Plant Physiologists. Close cooperation is also maintained with staff personnel of the Agricultural Engineering and Range Science Departments of the Texas A&M University and the Texas Agricultural Experiment Station.

Office and laboratory space have been provided in the Agricultural Engineering Building on the Texas A&M University campus and shop facilities and space for large experimental equipment are located in the Agricultural Engineering Research Buildings at the edge of the main campus. A Texas A&M University owned Grumman Ag-Cat agricultural spray plane has been made available for aerial application studies. Space for aircraft storage and for conducting spray distribution studies is available at the Texas A&M University Annex (formerly Bryan Air Base). Space for studies concerning spray penetration has been provided on the Range Science Departments experimental range area.

Two general areas of investigation have been emphasized during the past year and will continue to receive attention. They are as follows:

1. Evaluation of the characteristics and penetration of sprays through typical sub-tropical foliage.

2. Investigations of spray formation and droplet size regulation in airstreams.

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*Employed through Cooperative Agreement No. 12-14-100-2320(42) between the Agricultural Engineering Research Division, ARS-USDA and the Texas Agricultural Experiment Station.

LINE PROJECT SUMMARY

A. Summary Statement

1. Spray Formation in Airstreams: This study is planned to investigate factors affecting the atomization of aerially applied sprays and to attempt to develop techniques for regulating droplet size. Samples of spray atomization in a low-speed wind tunnel are obtained through the use of high-speed single-flash photography. The effects of airspeed, physical properties of the spray material, physical dimensions and shape of the nozzle or other atomizing device, angle of introduction of spray into the airstream, nozzle pressure, and other factors are being considered. Preliminary photographs have been obtained of several high-viscosity spray materials and water spray. A considerable difference in the method of spray drop formation has been noted from photographs of different viscosity spray materials formed with the same type of pressure nozzle. Evaluation of a series of photographs of water spray formed with two spray pressures has provided drop-size distribution data from sampling zones located 3 different distances from the spray nozzle orifice. Further studies are planned to characterize the drop-size distribution of various spray materials and spray nozzles and to investigate methods for narrowing the drop-size spectrum.

2. Spray Placement and Penetration Studies: Field tests were made to measure the penetration of aerially applied spray through foliage canopies. Quantitative measurements were obtained by collecting dyed spray deposits on 4" x 4" square Mylar plastic sheets supported above and below the canopies of 10 to 12 foot tall mesquite trees.

Approximately 45% of an invert emulsion spray applied at the rate of 7.24 GPA and 60% of a conventional oil-water emulsion spray applied at the rate of 2.09 GPA penetrated the mesquite canopy. In similiar tests with live oak trees which were 10 to 15 feet tall only 12% of a water spray applied at the rate of 2.18 GPA penetrated the foliage canopy. A spray penetration sampling station was constructed to measure and compare the penetration of various type sprays through a dense 40' tall post oak overstory canopy and a dense 15' tall yaupon understory canopy. In initial tests 21% of a water spray applied at the rate of 3.43 GPA penetrated the oak canopy and only 6% penetrated both the oak and yaupon canopies. Samples collected under 20 to 35' tall winged elm trees indicated that approximately 57% of a 3.9 GPA application of particulated spray (Norbak) and approximately 43% of a 3.4 GPA application of conventional water spray penetrated the foliage canopy. Aerial spray distribution measurements indicated that conventional water sprays and oil-water emulsion sprays were more uniformly distributed within the swath than were invert emulsion sprays or particulated sprays.

Studies concerning the distribution or placement of spray on the foliage of woody plants and the penetration of aerially applied spray through brush and tree canopies will be continued. The effect of spray drop-size on penetration and distribution will be investigated.

3. Timed-Interval Photographic Device: An automatic control system for an electric motor driven 35 mm camera and a plant supporting turntable were designed and constructed for making timed-interval color photographs. This equipment will be used to photograph potted woody plants at selected intervals in studies designed to measure the speed of response of woody plants to herbicidal treatments. Intervals between photographs may be easily varied from 1 minute to 21 hours. Use of the turntable permits up to 6 plants to be photographed at the end of each timed-interval.

SPRAY FORMATION IN AIRSTREAMS

I. Introduction and Objectives

The need for controlling spray drift from both aerial and ground applications of agricultural chemicals has created considerable interest in methods and techniques for regulating spray droplet-size. Efforts to eliminate the small drop component of sprays, which is responsible for the major portion of spray drift problems, have led to the use of thickened spray materials. In general, the use of thickened or viscous spray materials results in the production of large diameter droplets which are less susceptible to spray drift than small droplets. However, small driftable spray droplets are not entirely eliminated when using thickened materials with conventional pressure spray nozzles. In addition, the production of extremely large droplets is undesirable because this means a considerable reduction in the number of droplets available per unit area of plant leaf surface from a given rate of spray application. Studies concerning the effect of drop population on plant response to herbicides have shown that the number of droplets per unit area is important. Techniques for producing sprays with more homogenous droplet diameters are therefore needed.

This study is planned to investigate factors affecting the atomization or drop-size distribution of aerially applied sprays and to attempt to develop techniques for regulating droplet-size. Major objectives are to study the effects of airspeed, physical properties of the spray material, physical dimensions and shape of the nozzle or other atomizing device, angle of introduction of spray into the airstream, nozzle pressure and other factors upon spray atomization.

II. Equipment and Techniques

This work is being conducted in a small, low-speed wind tunnel where a single spray nozzle can be observed and aerial spraying speeds simulated. Airspeed, spraying rate, nozzle angle, etc. are easily controlled and varied. Replications of tests under identical conditions are also easily obtained.

(a) Wind tunnel equipment: General specifications for the wind tunnel are listed in the 1964 Line Project Report. The unit consists essentially of a 36"-long horizontal test section which is 12" x 12" square inside. Walls of the test section are made of ½" thick transparent plastic to permit observation of spray formation. Air is drawn through the tunnel with a centrifugal fan powered by a 3600 RPM, 25 HP electric motor (Figures 1 & 2). Air velocity in the test section can be varied from 0 to 125 MPH by regulating the air discharging from the centrifugal fan with a sliding gate. Air velocity in the tunnel is measured indirectly by measuring the static pressure (Figure 3) in the intake air nozzle and converting to velocity by use of the Bernoulli equation. For standard air, the velocity in ft per min is as follows: $V = 4005 \sqrt{VP}$, where VP is the velocity pressure in inches of water. Velocity pressure is assumed equal to static pressure since the nozzle coefficient, for practical purposes, is unity.

(b) Spray system: A single spray nozzle or other atomizing device can be attached to a removable door in the top panel of the test section. Figure 4 shows a diaphram cut-off-type nozzle mounted in the test section. Nozzle angle is varied by means of a swivel connector. Spray liquid is fed to the nozzle from a 10 gallon pressurized paint container. Spraying pressure is varied by regulating the liquid pressure in the spray line above the wind tunnel. The air pressure on the liquid container is also

Figure 1. General view of low-speed wind tunnel used in spray formation studies.

Figure 2. Wind tunnel test section and 5X magnification camera.

Figure 3. Airspeed measurement instrumentation and control panel.

Figure 4. Diaphram-type spray nozzle positioned in wind tunnel test section.

regulated. This pressure system has been used successfully for spraying conventional water and dye solutions; water particulated with "Norbak," which is a particulating agent manufactured by the Dow Chemical Company; water thickened with "Dacagin," which is a pseudoplastic spray gel agent manufactured by the Diamond Alkali Company; and water thickened with "Natrasol" (since renamed "Vistik"), a high viscosity hydroxyethylcellulose manufactured by the Hercules Powder Company.

(c) Sampling equipment: Spray atomization is observed through the transparent sides of the wind tunnel test section. Samples are obtained by means of high-speed silhouette photography. A 4" x 5" press camera (Figure 2) fitted with a specially constructed extension tube to provide 5X magnification photographs is positioned on one side of the test section directly opposite a high-speed light source. A 135mm f/4.5 lens with a between-the-lens shutter is mounted on the extension tube. The length of the extension tube was determined by the degree of magnification needed and the focal length of the lens. The actual size of the area photographed is approximately 0.8" wide x 0.7" high. Image and object distances, which are respectively the distance from the lens to the film and the distance from the lens to the object being photographed, may be readily calculated for a magnification factor of 5 from the following equations:

(1) $1/F = 1/I + 1/O$ where: F = focal length of the lens (135 mm = 5.315" for camera used)

(2) $I/O = M$ I = image distance

O = object distance

M = magnification factor

From these relationships we obtain:

$$O = F(1 + 1/M) = 5.315'' \ (1 + 1/5) = 6.378''$$

$$I + F(1 + M) = 5.315'' \ (1 + 5) = 31.890''$$

Therefore, if the object is in focus at a point 6.378" from the lens, an image distance of 31.890" is required for a magnification of 5X.

The object distance of 6.378" permits the camera lens to be focused on any point from the inside wall of the wind tunnel (on the camera side) to approximately the centerline of the tunnel by moving the camera. In order to assure that photographs could be obtained at points slightly beyond the centerline of the spray pattern, the spray nozzle was mounted so that it can be positioned approximately 5 inches from the wind tunnel wall.

Depth of field calculations were made for the camera following procedures outlined by Roth.* Calculations were made for f-stop values of 4.5 and 16 since focusing is ordinarily done at f/4.5 but exposures are made at f/16. The following relationships were used to calculate the depth of field limits.

$$\text{Near limit} = O - \frac{O^2 \tan \theta}{L + O \tan \theta}$$

$$\text{Far limit} = O + \frac{O^2 \tan \theta}{L - O \tan \theta}$$

where: O = object distance

θ = angular size of the circle of confusion (the blurred image circle that occurs when an object is located outside of the plane focused upon)

L = effective diameter of lens = $\dfrac{\text{focal length of lens}}{\text{f-stop number}}$

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*"Liquid Atomization Related to the Production and Measurement of Spray Particles," Unpublished PhD Thesis, Oklahoma State University, May, 1965.

For the camera used:

$O = 6.378''$

$\theta = 2$ minutes of arc (this is a common value)

$$L_{16} = \frac{5.315''}{16} = 0.3322 \text{ for f-stop of } 16$$

$$L_{4.5} = \frac{5.315''}{4.5} = 1.1811 \text{ for f-stop of } 4.5$$

From the preceding relationships the depth of focus for f/4.5 is found to be:

Near Limit = 6.358"

Far Limit = 6.398"

Depth of Focus = 0.040"

For f/16, the setting at which most exposures are made:

Near Limit = 6.308"

Far Limit = 6.450"

Depth of Focus = 0.142"

A high-speed electronic stroboscope (General Radio Type 1531-A) provides a high-intensity short-duration flash which "stops" spray drop motion and permits single-flash photographs. A 4" diameter condensing lens with a 16" focal length is positioned in a tube 12" from the stroboscope reflector to provide a spot of high-intensity light at the camera lens. Flash duration measured at 1/3 peak-intensity is approximately 0.8, 1.2, and 3.0 microseconds for high; medium; and low-speed ranges respectively. Use of a photo-electric pickoff and time-delay unit permits the light flash to be triggered with the camera shutter. Figure 5 shows relative positions of the camera, tunnel test section, and electronic light unit. A specially designed supporting table provides for crank and screw adjustment of the horizontal, vertical, and lateral positions of

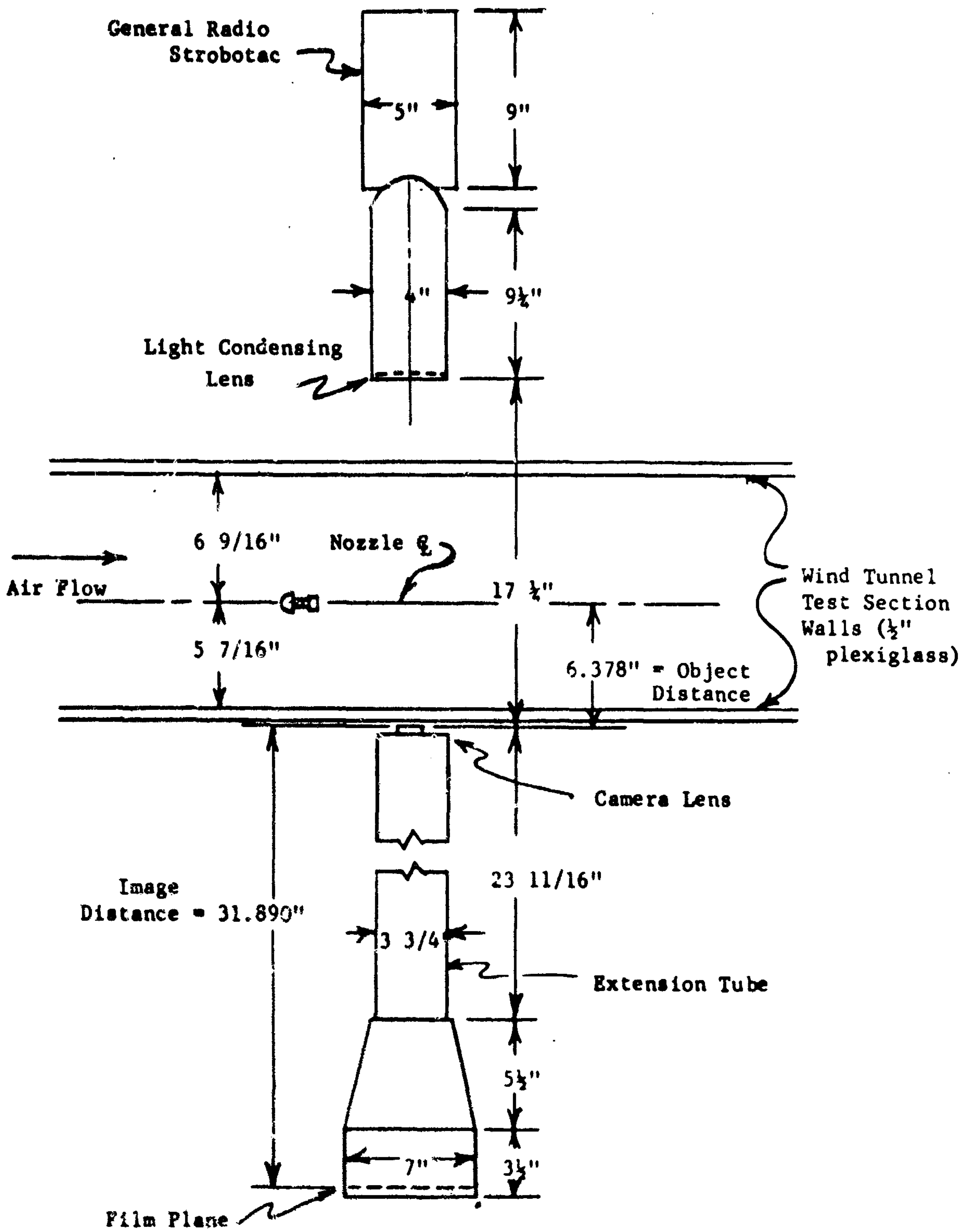


Figure 5. Plan view showing relative positions of camera, wind tunnel test section, nozzle and high-speed light.

the camera and light unit. The adjustable table is shown in Figures 1 and 2.

(d) Test procedures and sampling techniques: After considerable trial and error experimentation and comparison of various fine-grain, high-contrast films, a satisfactory film, shutter speed, f-stop setting, and light intensity were selected. In searching for a suitable film, several comparisons were made between Kodak Tri-X Pan which has an ASA Index of 320 and Kodak Contrast Process Ortho which is a very high contrast fine-grain film with an Exposure Index of 50 for tungsten and 100 for white flame arc. Other films were also tried. Equally satisfactory negatives were obtained using the Tri-X and Contrast Process Ortho films. The addition of nigrosine dye (1% solution) to the spray liquid provided improved drop-edge definition. A shutter speed of 1/60 second is used for all photographs since this reduces extraneous background light to a low level but still provides a sufficient length of time for the strobe to be flashed, while the lens is open, using the photo-electric pickoff and time-delay unit. When using Contrast Process Ortho film, the electronic flash is adjusted for high-intensity and the f-stop is set at 16. Medium-intensity light is used with an f-stop of 16 when exposing the Tri-X film. The Tri-X film in packs is somewhat more convenient than the Contrast Process Ortho which can be obtained only in sheets. Polaroid Type 52 film packets which can be processed immediately have about the same exposure index as Tri-X and have been extremely useful in determining correct exposures, light settings, etc. These packets are used in the 4" x 5" press camera with the aid of a special film-holder. Daylight developing tanks are used for processing the Tri-X and Contrast Process Ortho negatives.

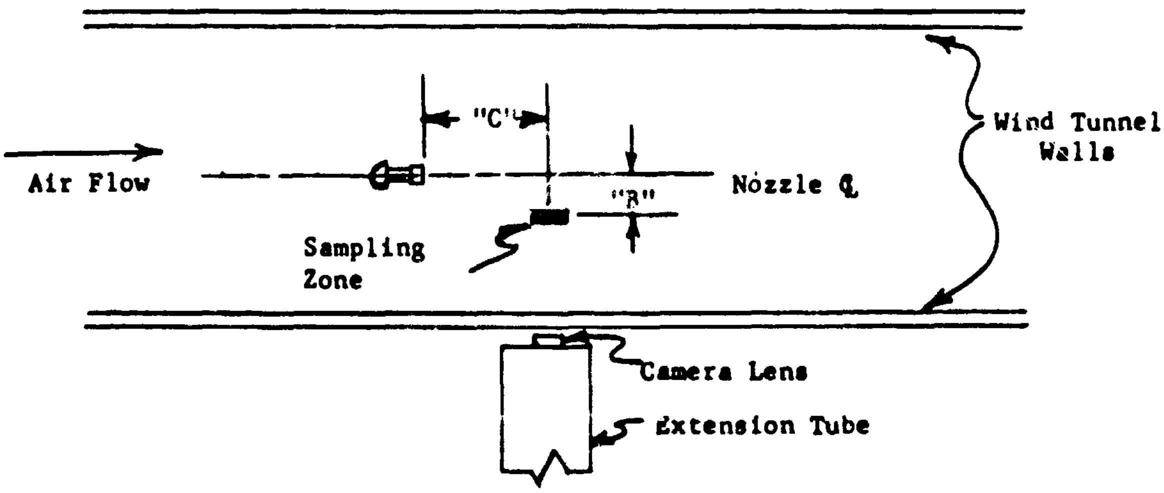
In conducting a test, the camera is focused on some pre-selected sampling zone. In selecting zones for sampling, a visual inspection of the entire spray pattern is first made with the camera shutter open and the strobe flashing at a high rate (approximately 4,000 to 10,000 cycles/minute is satisfactory). This provides an image on the ground glass at the film plane for each flash and gives the effect of continuous scanning of the object area. The supporting table adjustments are then used to "locate" the entire spray pattern. Sampling zones (0.8" x 0.7" x depth of focus) are selected within the spray pattern. The location of the center of the selected sampling zones in relation to the center of the spray-nozzle orifice is determined and recorded by the dimensions "B", "C", and "D" shown in Figure 6. When a sampling zone is selected and the camera positioned to focus at that zone, the shutter is closed and cocked and the strobe light set for single-flash. Film is then inserted in the camera and exposed by tripping the shutter which automatically causes a synchronized single flash of the strobe light.

The 5X magnification negatives thus obtained are evaluated with the aid of drop-and spot-sizing equipment described in detail elsewhere in this report.

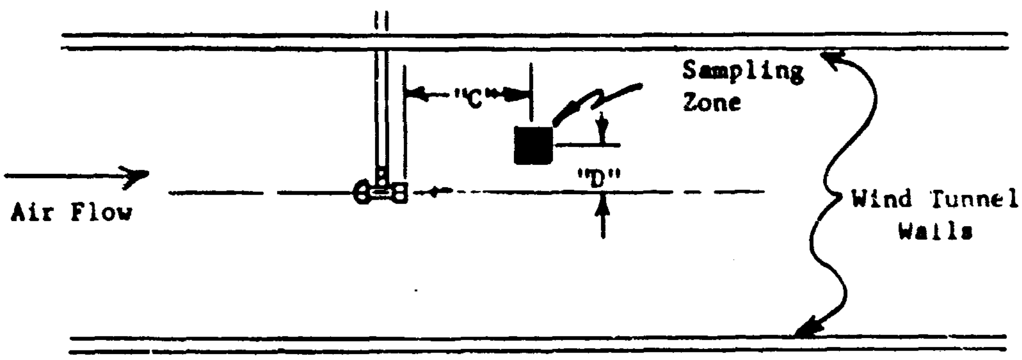
III. Current Status and Data Obtained

Preliminary photographs have been obtained of several types of spray materials. Sample photographs are shown of water (Figure 7), water particulated with Norbak (Figure 8), and water thickened with Dacagin (Figure 9). A considerable difference is noted in the appearance of these sprays. In addition, a series of photographs of water spray from a No. 4664-D10-45 Teejet nozzle aimed directly with the airstream ($\alpha = 0°$) have been obtained and evaluated. A single airspeed (75 MPH) and two pressures (10 and 30 psi) were used.

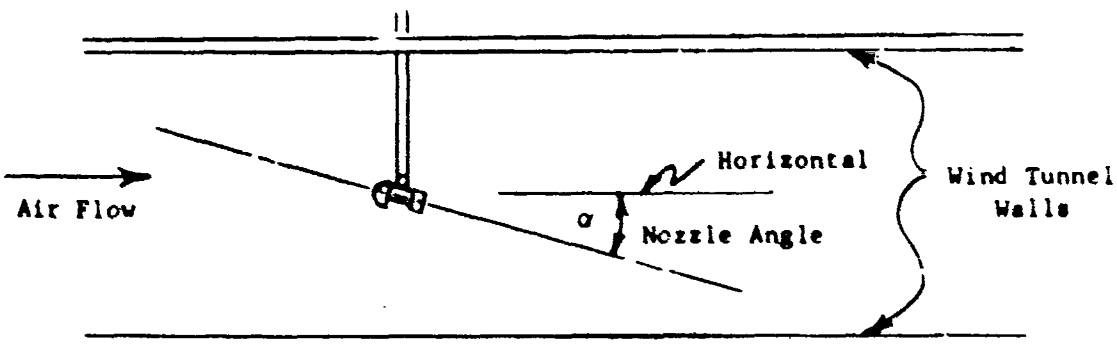
Sampling zones (camera position), pressures used, and resulting



(a) Plan View Showing Dimensions "B" & "C"



(b) Horizontal View Showing Dimensions "C" & "D"



(c) Horizontal View Showing Nozzle Angle, α

Figure 6. Dimensions used to relate sampling zone location to spray nozzle location.

Figure 7. 5X magnification photograph of water spray produced at 30 psi in a 75MPH airstream. (Spraying Systems #4664-D10-45 Teejet nozzle aimed directly with the airstream).

Figure 8. 5X magnification photograph of particulated spray (Norbak) produced at 45 psi in a 120 MPH airstream. (Spraying Systems #4664-D10-45 Teejet nozzle aimed directly with the airstream).

Figure 9. 5X magnification photograph of Dacagin spray produced at 30 psi in a 120 MPH airstream. (Spraying Systems #4664-D10-45 Teejet nozzle aimed directly with the airstream).

drop-size distribution data are presented in Table 1. In addition, % cumulative volume and % cumulative numbers curves for test Nos. 1 & 5 are presented in Figure 10 and frequency-distribution plots for tests No. 1 & 5 are presented in Figure 11. Tests Nos. 1 and 5 were made under the same operating conditions. The sampling zone for Test 1 was centered 2" downstream from the nozzle orifice plate while the sampling zone for Test 5 was centered 8" downstream from the nozzle orifice plate. Figure 11 and Table 2 illustrate the tremendous difference in the number of drops in focus at the two positions. The sampling zone for Test 1 (2" downstream) was selected so that a maximum number of drops were in focus by adjusting camera position "B" to 5/8". Likewise, camera position "B" was adjusted to 2 7/8" for Test 5 to obtain a maximum number of drops in focus at the 8" downstream distance. Adjustment of camera position "B" was necessary as the distance downstream (position "C") was changed because of the cone-shaped spray pattern. The data presented were obtained by counting the number of drops in 20μ size classes. The number of drops per size class is shown in Table 2. An area 8 cm. x 8 cm. on the film (approximately 2.56 sq. cm. or 0.397 sq. inch object area) was counted for each replication.

Table 1. Summarization of Drop Size Distribution Data From Preliminary Wind Tunnel Studies

Note: Air Velocity = 75 MPH; No. 4664-D10-45 Spraying Systems Teejet Nozzle; Spray Angle (α) = 0; Diameters Given are in Microns.

Test No.	No. of Reps.	Camera Position B	Camera Position C	Camera Position D	Press (psi)	Diameters for % Cumulative Volume 16%	50%	84%	Diameters for % Cumulative Numbers 16%	50%	84%	Volume Mean Diam.	Volume Mean Std. Dev.	Length Mean Diam.	Length Mean Std. Dev.
1	3	5/8	2	0	30	280	560	850	54	119	249	272	432	167	136
2	3	1/2	2	0	10	295	470	760	57	135	317	286	413	188	146
3	3	3/4	5	0	10	340	480	750	74	179	389	335	470	234	164
4	3	1 3/4	5	0	30	295	530	720	118	232	368	347	428	267	151
5	3	2 7/8	8	0	30	370	640	830	173	284	492	432	524	341	183
6	3	1 1/4	8	0	10	330	590	810	105	193	350	348	463	247	164
7	3	5/8	2	0	30	340	630	1050	67	126	272	304	345	183	152
8	3	1/2	2	0	10	340	710	970	53	107	249	294	472	165	152
9	3	3/4	5	0	10	310	510	670	62	140	332	301	401	202	153
10	3	1 3/4	5	0	30	235	470	610	74	128	252	254	347	175	120
11	3	2 7/8	8	0	30	305	490	610	143	219	416	341	394	273	144
12	3	1 1/4	8	0	10	395	540	680	89	191	467	368	439	269	179
13	5	0	2	1 1/8	30	475	1020	1450	37	114	327	387	660	193	209
14	5	0	2	3/4	10	330	580	1040	71	142	313	255	482	200	156
15	5	0	5	1 3/4	10	420	780	1030	83	181	431	323	576	256	204
16	5	0	5	2 5/8	30	435	830	1190	44	150	408	404	639	230	218
17	5	0	8	3 1/4	30	280	485	770	67	165	324	300	412	209	146
18	5	0	8	2 5/8	10	340	550	800	90	214	401	365	477	263	175
19	4	0	8	0	10	155	270	395	37	81	179	166	223	95	80
20	3	0	8	0	30	85	150	205	41	70	118	109	56	90	42

Note: Tests No. 1 through 6 were made with ordinary tap water. Tests No. 7 through 20 were made with 1% solution of Nigrosine dye and tap water.

Table 2. Total Number of Drops Measured in Each Size Class For Tests Listed in Table 1.

Size Class No.	Drop Mid-Range Diam.	Test Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	10	6	1					1	6	2	1			54			18				
2	30	71	39					13	57	18	3		1	154	7	4	36	9	5	58	11
3	50	129	77	10			2	87	107	21	11	1		186	110	2[illegible]	40	28	9	105	63
4	70	187	94	14	5		6	162	182	27	30	1	7	165	169	41	48	35	12	89	69
5	90	170	88	19	8	4	7	183	164	32	35	3	13	146	216	49	26	32	11	72	60
6	110	154	75	15	19	2	11	172	133	33	47	1	9	119	171	37	41	33	11	53	29
7	130	124	62	3	18	3	16	151	122	28	40	4	9	125	165	41	25	27	18	41	21
8	150	126	61	11	17	5	12	114	88	37	31	6	7	86	147	51	23	27	14	37	8
9	170	104	54	11	15	4	5	107	57	16	25	16	8	78	132	36	19	23	12	25	13
10	190	73	43	6	18	7	12	70	50	7	21	6	10	57	107	31	18	16	11	26	5
11	210	71	33	10	10	9	6	51	34	15	14	3	7	58	78	33	19	20	11	19	3
12	230	48	30	6	12	6	10	58	34	16	10	7	1	49	69	23	14	30	11	12	3
13	250	40	23	2	20	3	11	32	27	11	4	1	4	32	55	21	22	19	5	9	
14	270	37	35	8	14	11	4	35	21	14	6	4	5	34	42	35	13	11	10	9	
15	290	24	16	3	13	7	6	26	19	6	2	4	5	34	42		14	12	10	5	1
16	310	25	23	8	10	3	5	20	19	7	9	5	5	32	46	16	14	19	6	6	
17	330	22	15	3	8	6	3	20	17	10	4	1		26	30	13	11	13	8	5	
18	350	19	14	3	12	7	5	18	19	6	7	3	2	21	29	16	7	7	9	5	
19	370	15	19	7	10	3		14	9	3	4	2	1	21	33	12	11	13	14	3	
20	390	16	6	5	6	5	2	12	13	8	1	4	2	19	18	9	5	1	3	1	
21	410	9	14	4	3	3	3	18	5	3	3	1	3	17	26	7	9	7	9	1	
22	430	8	13	4		3	2	14	8	3		3	3	13	13	3	9	3	3	1	
23	450	4	16	5	3	1	1	4	5	1	2	1	2	12	18	14	11	5	2	2	
24	470	4	10	4	3	4	2	13	9	2	3	1	5	24	17	10	4	7	2	1	
25	490	10	10	1	3	3	2	10	6	5	1	1		12	15	5	7		3		
26	510	7	2		4	1		10	7	6	1	2	3	15	15	5	5	2	1		
27	530	2	9			1	1	4	3	7	1	1	4	12	12	10	2	1	2		
28	550	4	4	3		5	2	5	4	2	3		2	10	10	5	2	1	4		
29	570	6	2		2			2	1	2			3	14	12	7	7	3	5		
30	590	7	7		2			14	5	3	3	3	1	15	11	4	8	5	3		
31	610	1	1	1	2	1		1	1	1		1		2	5	1	1				
32	630	1		1	1	1	1	4		1	2	1	1	5	1	1					
33	650	1	2	1	1	1		2	1	2	1	1	1	1	2	2	1				
34	670	4			3			1	2	1	1		2	2	1	3	1				
35	690	3		1	1	3		1	2				1	5	5			1	2		
36	710	2	1		1		4	4	5				1	4	2	2	2				
37	730	1	1	1		1		1	1					4		2		1			
38	750	2			2			2	1						2	3	2		1		
39	770							1					1	4	4	2	1	1			
40	790	1	1		1		1		1						2		1	1	1		
41	810				1	1	1	6		1				2	2	1		2			
42	830	2	1			1			1					1	1		2		2		
43	850	4				2	1		1					1		3	3	1			

Continued

Table 2. Continued

Size Class No.	Drop Mid-Range Diam.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
44	870							1						1	1	1	2		1		
45	890	2						4		1				2	2	1	2				
46	910		1						3						1	3					
47	930	1						1	3						1						
48	950								3					2		1	1				
49	970					1			1					4	1	2	1				
50	990								5						3	3	1		1		
51	1010							3						4		1					
52	1030															1					
53	1050													1							
54	1070															1					
55	1090													2			2				
56	1110	1													3						
57	1130																				
58	1150			1											1						
59	1170		1											1		1	1				
60	1190	1												2			1				
61	1210																				
62	1230													2							
63	1250													1							
64	1270																				
65	1290													2	2						
66	1310							1													
67	1330															1					
68	1350																				
69	1370													2							
70	1390																				
71	1410													1							
72	1430							1						1							
73	1450																				
74	1470													2							
75	1490													1							
76	1510													1							
77	1530																				
78	1550																				
79	1570																				
80	1590																				
81	1610																				
82	1630																				
83	1650																				
84	1670																1				
85	1690													1							
TOTAL NO. DROPS		1549	904	171	248	118	144	1474	1262	358	326	88	129	1704	1857	597	514	416	232	585	286

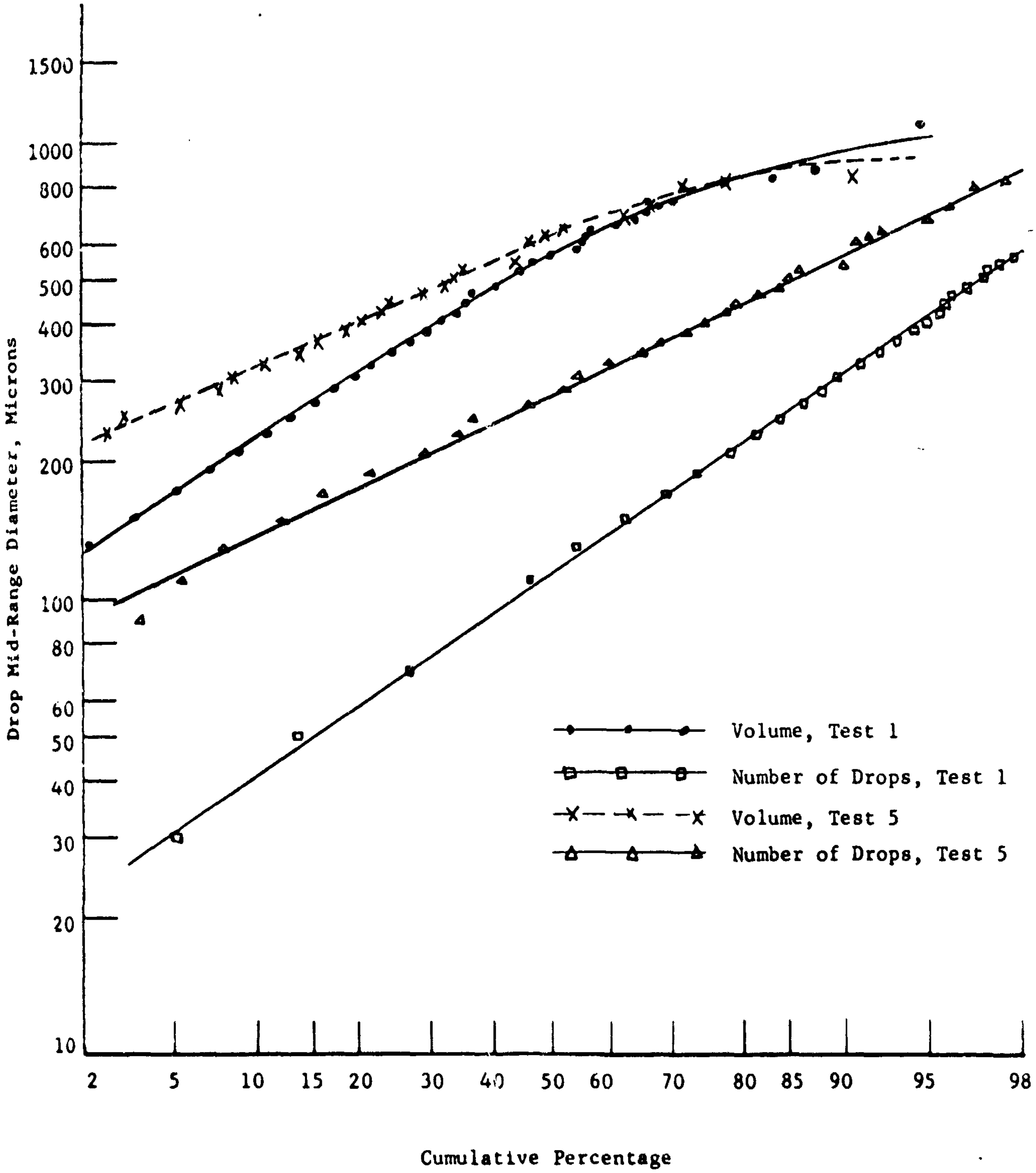


Figure 10. Log - Normal Probability Plot of Volume and Numbers Data from Tests 1 & 5 Listed in Table 1.

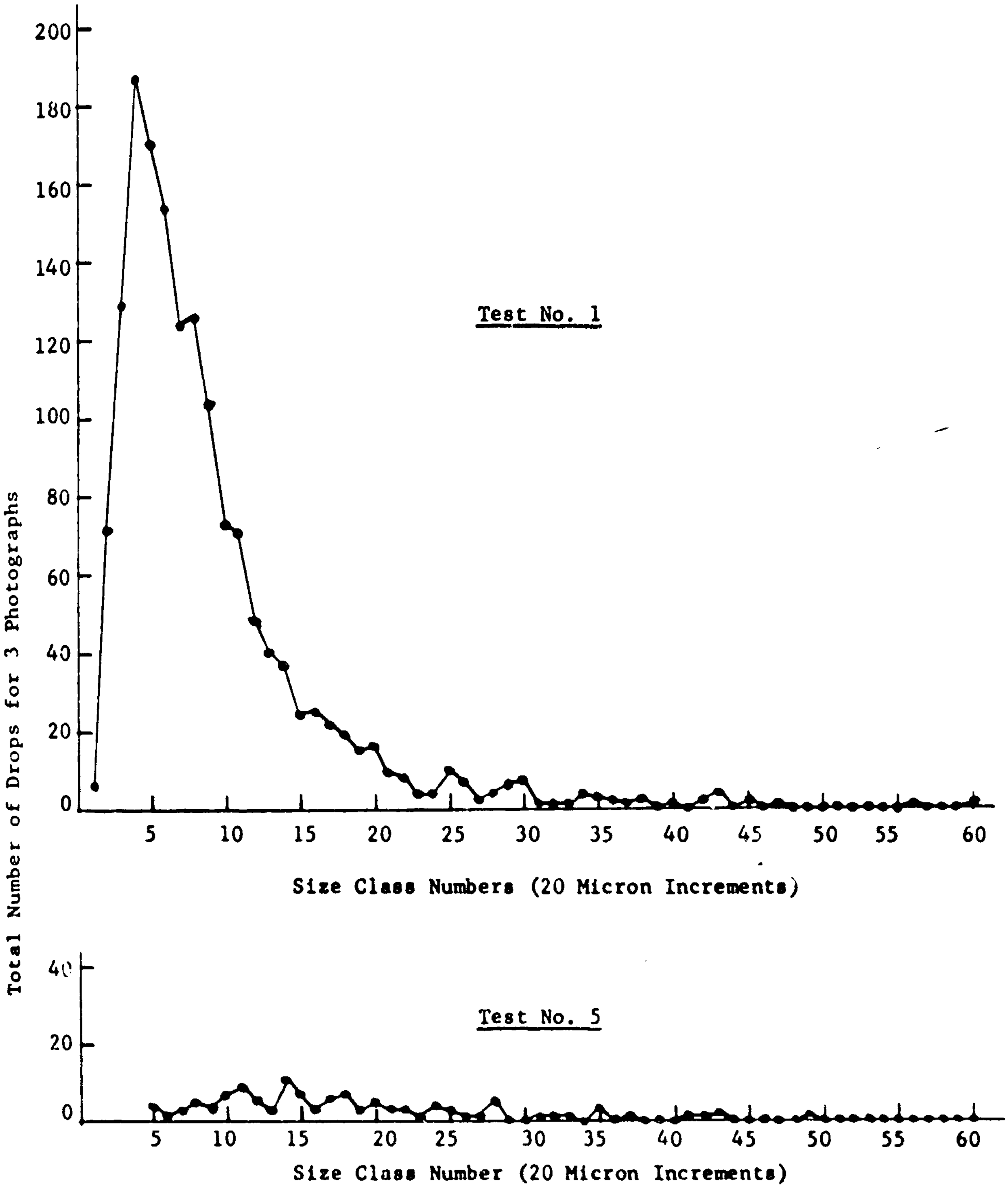


Figure 11. Drop Frequency-Distribution Plot for Tests 1 & 5.

SPRAY PLACEMENT AND PENETRATION STUDIES

I. Introduction and Objectives

This work concerns the distribution or placement of chemicals on the foliage of woody plants and the penetration of aerially applied sprays through brush and forest canopies. Although specific information as to the type of spray placement needed for various plant species is not available, it is generally believed that a uniform distribution is desirable. It has also been suggested that an optimum drop-size and drop-population per unit area of foliage may exist for various plant species. The three factors, uniformity of distribution, drop-size, and drop-population were selected as the criteria for evaluating spray placement. In addition to these factors, information is needed concerning the effect of spray drop-size on the penetration of foliage canopies.

In recent years efforts to control spray drift by manipulating the physical properties of the spray liquid have resulted in the development and use of viscous or "thickened" materials such as invert emulsions, particulates, hydroxyethylcellulose, and pseudoplastic gel agents. Although the use of these materials results in the production of larger droplets which are less susceptible to drift than small droplets, all small droplets are not eliminated. Narrower swaths, less uniform distribution in the swath, and fewer drops per unit area for a given application rate are also results of the use of large droplets. Since it has been found that for some plant species there is a definite correlation between the number of drops per unit area and herbicide effectiveness, it is very likely that higher rates of application will be required when using large drops in order to obtain results comparable to those obtained when using small spray drops.

The major objectives of this work are to determine the uniformity of spray distribution, droplet-size-distribution, and droplet population per unit area obtained from various types of spray liquids and to study the factors which affect the penetration of sprays through foliage canopies. The effect of spray nozzle design and other equipment and application variables are also being considered.

II. Equipment and Techniques

Spray distribution and penetration sampling techniques selected for use in this work are discussed in the 1964 Line Project Progress Report. Samples of dyed spray particles are collected on 4" x 4" square Mylar plastic sheets and small Mylar covered labels to obtain quantitative measures of spray deposits. The spray material is washed off of the Mylar sampling surfaces and the dyed solutions thus obtained are analyzed with standard colorimetric procedures. The 4" x 4" square Mylar sampling surfaces are attached to metal plates and used to sample spray distribution in the swath and the penetration of spray through foliage canopies. The small Mylar covered labels are attached directly to plant leaves and used to obtain measures of spray deposits on the foliage.

Samples for estimating drop-size-distribution are obtained by collecting dyed spray deposits on 4" x 4" square Kromekote spot cards. Drop-size-distribution data is obtained from the cards by counting the number of spots in selected size classes. This has been done by enlarging the spots with a micro projector and counting with a manually operated electro-mechanical device described in detail elsewhere in this report. Future drop-size-distribution data will be obtained primarily by photographing the spot cards and analyzing the negatives with the flying spot particle analyzer. Appropriate spread factors relating spray drop diameter to the size of the spots on the cards are used to convert spot-size data to drop-size data.

<u>Spray penetration through the canopies of small trees</u> is measured by supporting sampling surfaces at 2' horizontal intervals on specially designed sampling frames. Samples are obtained both above and below the plant canopy. Samples near the ground are obtained by attaching sampling plates to a long probe which is inserted through the lower branches of the plant or below the low growing branches. Spray penetration through the canopies of mesquite and live oak trees was measured with the sampling frames during test plot applications in 1965. Figure 12 shows a frame supporting 10 sampling surfaces on 2' intervals above the canopy of a mesquite tree (11½' above ground level) and 10 sampling surfaces below the mesquite tree foliage (2½' above ground level) during aerial application tests near Archer City, Texas in July 1965. Figure 13 shows 2 sets of sampling frames erected in live oak trees near Victoria, Texas during aerial spray tests conducted in July 1965. The frame on the left is supporting 10 sample plates at each of two heights (10' and 2') while the frame on the right is supporting sample plates at 15' and 2' heights. The sampling frames were also used during an aerial spray test to support sample plates above a spray distribution sample line in order to measure differences in the spray distribution pattern at 2 heights. Figure 14 shows 20 samples supported on 2' horizontal intervals at a height of 10' directly above a line of samples supported 1' above ground on sampling boards near Benchley, Texas in May 1965. The amount of spray material penetrating through the canopies of tall trees was also measured in field tests at Benchley by placing sample lines on the ground as shown in Figure 15.

Figure 12. Sampling frame supporting sample plates above and below mesquite tree canopies - Archer City, Texas.

Figure 13. Spray penetration sample frames in live oak trees - Victoria, Texas (Texas A&M University spray plane spraying plot in background).

Spray distribution from aerial tests was measured with 100 ft. sample lines located in open areas. Figures 16 and 17 show sample plates supported on specially designed stake-type holders at 3' intervals during aerial spraying tests in mesquite and live oak respectively. Figure 18 shows the method of attaching the sample plates to the holders.

In order to obtain more detailed information about factors which effect the penetration of aerially applied spray through a dense foliage canopy, a sampling station for measuring spray penetration through post oak overstory foliage and yaupon understory foliage was constructed near College Station. Two 45' tall communications towers were erected to support 105' long sampling lines at 3 heights; (1) above the oak trees which are approximately 40' tall; (2) under the oak canopy and above yaupon plants which are approximately 15' tall; and (3) below the yaupon foliage. The sampling lines each consist of 2 parallel 1/8" endless steel cables stretched between the towers with 35 sample holder brackets attached on 3' intervals. A cable traverse system was constructed to aid in sample changing. The cables are placed in the grooves of 2 - 5" diameter "V"-belt pulleys at each tower so that the sample holder brackets can be cranked into position as the sample plates are attached. Actual heights of the sample lines at the towers are 2', 16', and 43' above ground level. The lines are tensioned for tests so the sag between the towers does not exceed 1 foot. The sampling lines are positioned in a north-south direction and aerial applications made in an east-west direction. In tests conducted thus far, seven 33' swaths were flown over the sample area to assure that the entire length of the sampling lines was evenly sprayed. Non-toxic dyed spray liquid is used for all tests so that the foliage is not damaged. This permits replication of tests as well as comparisons of various spray equipment and types of spray liquid

Figure 14. Sampling frames supporting 20 sample plates at 10' height above 100' long spray distribution sample line - Benchley, Texas.

Figure 15. Sample line to measure spray penetration through winged-elm tree - Benchley, Texas.

Figure 16. Spray distribution sample line in mesquite test plot - Archer City, Texas.

Figure 17. Spray distribution sample line in live oak test plots - Victoria, Texas.

Figure 18. Attachment of sample plates to specially designed holder-stakes.

Figure 19. Communication tower used to support spray penetration sampling lines - College Station, Texas.

under identical or at least very similiar foliage conditions.

Figure 19 shows the south supporting tower which is equipped with work platforms for changing samples at the 16' and 43' heights. The north supporting tower and a portion of the upper sample line is shown in Figure 20. The tall post oak trees shown are defoliated due to the winter season. The dense yaupon understory vegetation does not defoliate during the winter. Figure 21 shows the lower work platform and a portion of the south tower. The method of attaching sample plates to the sample holders, sample boxes, a Kromekote card drying rack, and the lower end of the south tower are shown in Figure 22. Two 4" x 4" square sampling surfaces may be attached to each sample holder. One sample on a Mylar plastic sheet and one sample on a Kromekote card are ordinarily obtained at each sampling station. A colorimetric analysis of the spray collected on the plastic surfaces provides quantitative deposit information, while drop-size data is obtained from the Kromekote spot cards.

Figure 20. Spray penetration sampling station - College Station, Texas.

Figure 21. Lower work platform on spray penetration sampling tower - College Station, Texas.

Figure 22. Base of sampling tower, sample holder boxes, card drying rack, and cable sample line - College Station, Texas.

III. Results of Spray Penetration Measurement with Sampling Frames

Measurements were obtained of the penetration of invert emulsion and conventional oil-water emulsion sprays through mesquite tree canopies. These measurements were obtained near Archer City, Texas in July, 1965 during aerial spray applications to experimental test plots by staff members of the Range Sciences Department of Texas A&M University. Applications were made with the Texas A&M University spray plane which was equipped with a bi-fluid spraying system for spraying invert emulsion. The bi-fluid system utilized a trailing-edge spray boom with 30 - 1 gallon per minute nozzles. The nozzle tips were designed especially for invert emulsion and contained 9 - 0.041" diameter holes each which produced 9 jet streams. The conventional oil-water emulsion spray was applied with the conventional single-fluid aircraft spray system which utilizes a leading-edge in-wing boom equipped with 24 spraying systems No. 4664-D10-45 Teejet nozzles. This test consisted of the measurement of spray penetration through three mesquite trees selected from a 5 acre plot which was sprayed with invert emulsion and three mesquite trees in a 5 acre plot sprayed with conventional oil-water emulsion. Figure 12 shows a typical tree with a sampling frame erected. Samples were obtained on 2' lateral spacings both above and below the mesquite foliage. The upper sample lines were supported 11½' above ground and the lower samples 2½' above ground. Table 3 shows quantitative deposit measurements of invert emulsion spray obtained above and below the canopies of the three trees sampled and the "difference" or amount retained on the plant foliage based on the mean "above" and "below" canopy measurements. Table 4 shows the same information for the three trees sampled in the conventional oil-water emulsion spray test plot. Kromekote spot cards were used to obtain samples of drop-size and drop-size distribution during the mesquite canopy penetration studies. These cards have not yet been analyzed.

Table 3. Invert Emulsion Spray Penetration in Mesquite - Archer City, Texas July, 1965. (Deposit Measurements in Gallons per Acre)

Sample	Deposits Above Canopy				Deposits Below Canopy			
No.	Tree A	Tree B	Tree C	Mean	Tree A	Tree B	Tree C	Mean
1	7.2	3.9	2.9	4.7	6.8	1.2	1.1	3.0
2	10.4	6.0	4.0	6.8	3.0	1.9	3.1	2.7
3	6.9	11.8	7.6	8.8	2.9	4.4	3.9	3.7
4	3.8	5.7	10.1	6.5	3.0	2.4	3.1	2.8
5	4.0	8.6	11.2	7.9	2.5	2.0	3.0	2.5
6	4.9	4.6	11.9	7.1	2.3	1.7	2.0	2.0
7	5.7	4.1	8.2	6.0	2.7	3.4	4.6	3.6
8	6.0	10.3	11.1	9.1	1.9	3.4	3.8	3.0
9	7.4	9.8	9.3	8.8	2.7	3.6	4.8	3.7
10	6.5	5.6	8.0	6.7	3.4	5.3	9.4	6.0

Above Canopy Mean = 7.24 GPA   Below Canopy Mean = 3.30 GPA

Amount of Spray Intercepted by Canopy - 7.24 - 3.30 = 3.94 GPA

Percent Intercepted = $\frac{3.94}{7.24} \times 100 = 54\%$

Table 4. Conventional Oil-Water Emulsion Spray Penetration in Mesquite - Archer City, Texas, July, 1965. (Deposit Measurements in Gallons per Acre)

Sample No.	Deposits Above Canopy				Deposits Below Canopy			
	Tree A	Tree B	Tree C	Mean	Tree A	Tree B	Tree C	Mean
1	.5	2.9	4.5	2.6	1.0	1.3	1.5	1.3
2	.6	2.5	3.7	2.3	.2	.7	1.5	.8
3	.4	2.5	2.7	1.9	.1	1.0	1.1	.7
4	.5	2.1	2.8	1.8	.2	.8	1.8	.9
5	.9	2.0	2.5	1.8	.5	.6	1.6	.9
6	1.6	2.3	2.8	2.2	.3	1.0	1.5	.9
7	1.6	1.8	1.4	1.6	.6	1.5	1.2	1.1
8	3.3	1.9	2.0	2.4	.9	1.3	2.3	1.5
9	1.8	1.9	2.8	2.2	2.0	1.4	2.4	1.9
10	2.0	2.1	2.3	2.1	2.2	1.3	3.9	2.5

Above Canopy Mean = 2.09 GPA　　　　Below Canopy Mean = 1.25 GPA

Amount of Spray Intercepted by Canopy = 2.09 - 1.25 = 0.84 GPA

Percent Intercepted = $\frac{0.84}{2.09} \times 100 = 40\%$

Measurements of the penetration of conventional water spray through live oak tree canopies were also obtained in July, 1965. This test was conducted during experimental aerial spray applications near Victoria, Texas by USDA Crops Research Division personnel and staff members of the Range Sciences Department of Texas A&M University. The University spray plane equipped with the conventional leading-edge in-wing boom was used for the applications. Three clusters of small live oak trees approximately 10' tall and three single trees approximately 15' tall were selected for sampling spray deposits both above and below the foliage canopies. Figure 13 shows typical trees used in the test with sampling frames erected. Samples were collected on 2' lateral intervals above and below the canopies. In order to find a sufficient number of trees suitable for sampling in the selected 4 acre plot, the two sizes of trees were used. Quantitative deposit measurements were obtained on Mylar sampling surfaces from two 10' tall tree clusters and one 15' tall single tree while drop-size samples were obtained on Kromekote spot cards from two 15' tall single trees and one 10' tall cluster. In general, the taller trees were separated from surrounding vegetation by at least a few feet while the smaller trees grew in extremely dense clusters. Drop-size measurements have not yet been obtained from the Kromekote sampling cards. Quantitative measurements of spray deposits obtained from the Mylar samples are presented in Table 5. Samples above the single trees were obtained at a height of 15' while samples above the dense clusters were obtained at a height of 10'. Samples below the canopies of all trees were obtained at a height of 2'.

IV. Results of Spray Penetration Measurement with Tower Supported Sampling Lines

The initial spray penetration test using the cable sampling lines supported by communications towers as shown in Figures 19 and 20 was

Table 5. Water Spray Penetration in Live Oak - Victoria, Texas - July, 1965. (Deposit Measurements in Gallons per Acre).

Sample No.	Deposits Above Canopy				Deposits Below Canopy			
	Tree A (10')	Tree B (15')	Tree C (10')	Mean	Tree A (10')	Tree B (15')	Tree C (10')	Mean
1	2.3	5.0	1.6	3.0	0.3	1.3	.7	.8
2	1.5	4.2	1.6	2.4	1.8	0	.4	.7
3	.7	5.0	2.0	2.6	.2	0	.5	.2
4	1.0	6.2	2.1	3.1	0	0	.3	.1
5	.8	4.1	2.4	2.4	0	0	.1	.03
6	.8	2.3	2.1	1.7	0	0	.2	.06
7	.5	2.8	2.8	2.0	0	0	0	0
8	.3	2.5	2.3	1.7	0	.6	.2	.3
9	.7	1.9	2.2	1.6	0	.2	.6	.3
10	.5	1.1	2.3	1.3	.5	.7	.6	.06

Above Canopy Mean = 2.18 GPA   Below Canopy Mean = 0.26 GPA

Amount of Spray Intercepted by Canopy = 2.18 - 0.26 = 1.92 GPA

Percent Intercepted = $\frac{1.92}{2.18} \times 100 = 88\%$

conducted in late October, 1965. As previously mentioned, the sample station was erected to measure spray penetration through a dense post oak overstory canopy and a dense yaupon understory canopy. The test consisted of three replications of conventional water spray with ½% Carmine 2-B dye applied with the Texas A&M University spray plane. The aircraft was equipped with a conventional leading-edge in-wing boom having 24 No. 4664-D10-45 Spraying Systems Company diaphram Teejet nozzles. Seven 33' swaths covering a theoretical total width of 231' were flown over the sample station at a 90° angle to the sample lines for each replication. Swath marking flag stations were located approximately 400 feet to either side of the sample station. Spraying was started as the plane passed over the first swath marking flag and continued to the second flag to make certain the entire sampling area was sprayed. The height of spray release was approximately 10' above the upper sample line and the airspeed approximately 75 MPH. The wind was calm for replications 1 and 2 and varied from 2 to 4 MPH from a 45° angle for replication number 3.

Samples obtained during the test included quantitative deposit measurements on 4" x 4" Mylar plastic sheets and drop-size distribution measurements on 4" x 4" Kromekote spot cards. One Mylar sheet and one Kromekote card was clipped to each of the previously mentioned sample holder brackets on the sampling lines. This provided 35 Mylar and 35 Kromekote samples spaced on 3' intervals at each sampling height for each replication. Table 6 presents results of the quantitative deposit measurements obtained from the Mylar sheets. The data from Table 6 is presented graphically in Figure 23. Although drop-size data from the Kromekote spot cards is not yet analyzed a portion of these cards have been photographed and the negatives scanned with the electronic flying

Table 6. Spray Penetration Through Post Oak and Yaupon, College Station, Texas, October 1965. (Deposit Measurements in Gallons per Acre).

Sample Loc.	Above Post Oak Canopy				Below Post Oak Canopy & Above Yaupon Canopy				Below Yaupon Canopy			
	Rep. 1	Rep. 2	Rep. 3	Mean	Rep. 1	Rep. 2	Rep. 3	Mean	Rep. 1	Rep. 2	Rep. 3	Mean
1	2.45	2.94	1.70	2.36	.17	.32	.14	.21	.09	.23	.06	.13
2	1.61	4.00	2.42	2.68	.23	.23	.20	.22	.12	.09	.06	.09
3	3.28	4.61	3.37	3.75	.55	.69	.32	.52	.09	.03	0	.04
4	4.32	2.97	4.67	3.99	.78	1.30	.78	.95	.17	.20	.17	.18
5	5.90	2.85	4.03	4.26	.26	.17	.40	.28	.09	.03	.03	.05
6	3.54	2.94	2.79	3.09	.29	.17	.29	.25	.20	.23	.17	.20
7	4.55	6.62	2.36	4.51	.92	.86	1.12	.97	.14	0	0	.05
8	5.76	5.82	2.48	4.69	1.87	1.12	1.24	1.41	1.07	.46	.09	.54
9	4.12	4.03	2.13	3.43	.26	.69	.98	.64	.49	.58	.58	.55
10	3.72	3.02	2.62	3.12	1.01	2.19	1.07	1.42	.17	.23	.26	.22
11	2.82	2.51	2.53	2.62	.92	1.07	.43	.81	.46	.35	.06	.29
12	3.08	1.81	2.85	2.58	.95	1.58	.69	1.07	.26	.17	0	.14
13	3.34	2.16	4.18	3.23	.75	2.51	1.21	1.49	.29	.35	.37	.34
14	4.03	2.71	4.09	3.61	.60	1.56	1.07	1.08	.40	.29	.75	.48
15	2.76	3.89	2.59	3.08	.26	.20	.32	.26	.26	.23	.23	.24
16	3.00	3.54	3.74	3.43	.89	.32	.69	.63	.20	.23	.14	.19
17	4.20	3.66	5.67	4.51	.95	.69	.66	.77	.14	.20	0	.11
18	5.93	4.46	4.32	4.90	1.76	1.32	1.50	1.53	.49	1.79	.23	.84
19	4.35	3.74	3.63	3.91	.26	.60	.06	.31	.43	.43	.09	.32
20	3.37	3.51	3.46	3.45	1.38	.75	1.53	1.22	.26	.06	.12	.15
21	3.17	2.71	4.12	3.33	.40	.32	.84	.52	.14	.03	.09	.09
22	1.99	1.87	6.11	3.32	.17	.23	1.35	.58	.09	.03	.06	.06
23	1.96	1.87	7.52	3.78	.32	.26	.09	.22	.14	.03	.03	.07
24	2.74	2.79	2.25	2.59	.60	1.61	.55	.92	.17	.12	0	.10
25	3.92	2.82	3.86	3.53	.98	.35	1.07	.80	.17	.14	.06	.12
26	4.92	3.23	3.86	4.00	.95	1.21	.63	.93	.23	.23	.14	.20
27	4.75	4.69	2.45	3.96	.32	.43	1.09	.61	.17	.12	.06	.12
28	2.51	2.62	1.61	2.25	.14	.17	.20	.17	.06	.09	.14	.10
29	5.07	3.66	1.18	3.30	.14	.14	.20	.16	.09	.09	.12	.10
30	3.37	4.38	1.76	3.17	.32	.58	.29	.40	.23	.17	.09	.16
31	3.43	4.20	1.01	2.88	.49	.63	.49	.54	.09	.09	0	.06
32	3.20	3.77	1.09	2.69	.89	1.27	.35	.84	.12	.20	.03	.12
33	3.46	3.31	1.58	2.78	2.30	1.73	.55	1.53	.23	.17	.03	.14
34	5.07	4.61	1.96	3.88	1.67	2.02	.52	1.40	.75	.55	.12	.47
35	3.34	4.69	2.39	3.47	0	.17	0	.06	.29	.12	.06	.16
Mean	3.69	3.51	3.10	3.43	.71	.84	.65	.73	.25	.24	.13	.21

Note: Sample location No. 1 is at the south end of the sample lines and No. 35 is at the north end.

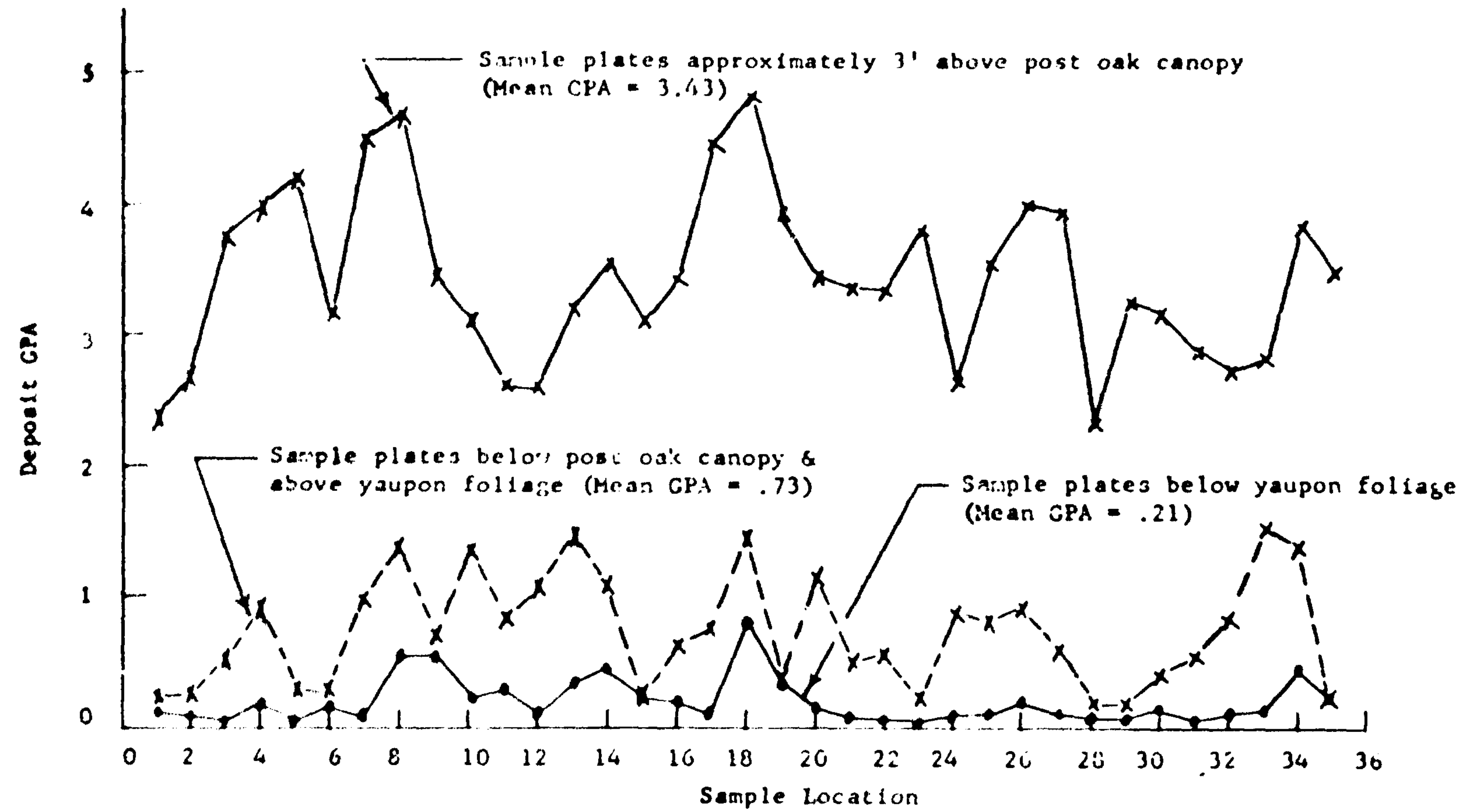


Figure 23. Spray Penetration through Post Oak and Yaupon - College Station, Texas, October 28-29, 1965.

Spray Material: Water + ½% Carmine 2B Dye

Aircraft: Texas A&M University Ag-Cat

Height above foliage: Approximately 10 feet spot particle analyzer. Spot-size data from the scanned negatives was automatically recorded on punched cards so that computations and analysis can be performed with a digital computer.

V. Results of Aerial Spray Distribution Measurements

Spray distribution samples were collected during aerial applications of herbicides to experimental winged elm test plots near Benchley, Texas in May, 1965 in order to obtain comparisons between distribution patterns from conventional water spray and Norbak particulated spray. The experimental test plot applications were a portion of a study on the control of winged elm being conducted by staff members of the Range Sciences Department at Texas A&M University. The applications were made with a commercially operated Snow aircraft equipped with Spraying Systems Whirljet nozzles and a positive displacement pump. The same equipment was used for both the conventional and particulated spray applications.

Distribution samples were collected in two 5 acre test plots sprayed with particulated material and one 5 test plot sprayed with conventional water spray. Two 100' long sample lines were located in open areas within each test plot. Fifty 4" x 6" Mylar sheets and 50 - 4" x 6" Kromekote spot cards were supported 1' above ground either on sampling boards or specially designed sample-holder stakes. The samples were spaced on 2' intervals along the lines. In addition, the sampling frames previously described were used to support 20 - 4" x 4" Mylar sample plates on 2' intervals at a height of 10' directly above the center 40' section of the 100' sample lines in the conventional water spray plot and in one of the particulated spray plots. The purpose of this test was to compare the spray distribution pattern at the 10' height with that obtained 1' above ground level. Both plots where samples were collected at the 10' height were sprayed at a rate of 4 GPA using a 40' swath width. The particulated spray plot where samples were not collected at the 10' height was sprayed at the rate of 6½ GPA using a 25' swath width.

Figure 24 shows the distribution patterns obtained with water spray at the 10' and 1' heights and Figure 25 shows the same information for Norbak particulated spray. Replications 1 and 2 for each spray are plotted separately since the sampling lines were a considerable distance apart and the spray swath centers occurred at slightly different locations within each sample line. Figure 26 shows the distribution patterns obtained at a height of 1' from the 6½ GPA Norbak spray. Again, replication 1 and 2 are plotted separately since the spray swath centers occurred at different locations within each sample line.

Aerial spray distribution samples were also collected during the spray penetration studies in mesquite trees near Archer City, Texas in July 1965. The purpose of the distribution measurements which were made in cooperation with Range Sciences Department of Texas A&M University was to compare the distribution patterns obtained from invert emulsion with that obtained from conventional oil-water emulsion. Three 100' sample lines consisting of 33 sample-holder stakes each were located in open areas within an invert emulsion plot. Three similar sample lines were located in a conventional oil-water emulsion plot. Sample-holder stakes were spaced on 3' intervals within each line and used to support 1 - 4" x 6" Mylar sheet and 1 - 4" x 4" Kromekote spot card each. Data from the quantitative measurements obtained from samples collected on the Mylar sheets in the invert emulsion plot are presented in Figure 27 and date from the conventional emulsion plot is presented in Figure 28. Drop count data was obtained from the Kromekote spot cards by Range Sciences Department personnel. The average number of drops per square inch per GPA was 61 with the conventional oil-water emulsion and 18 with the invert emulsion.

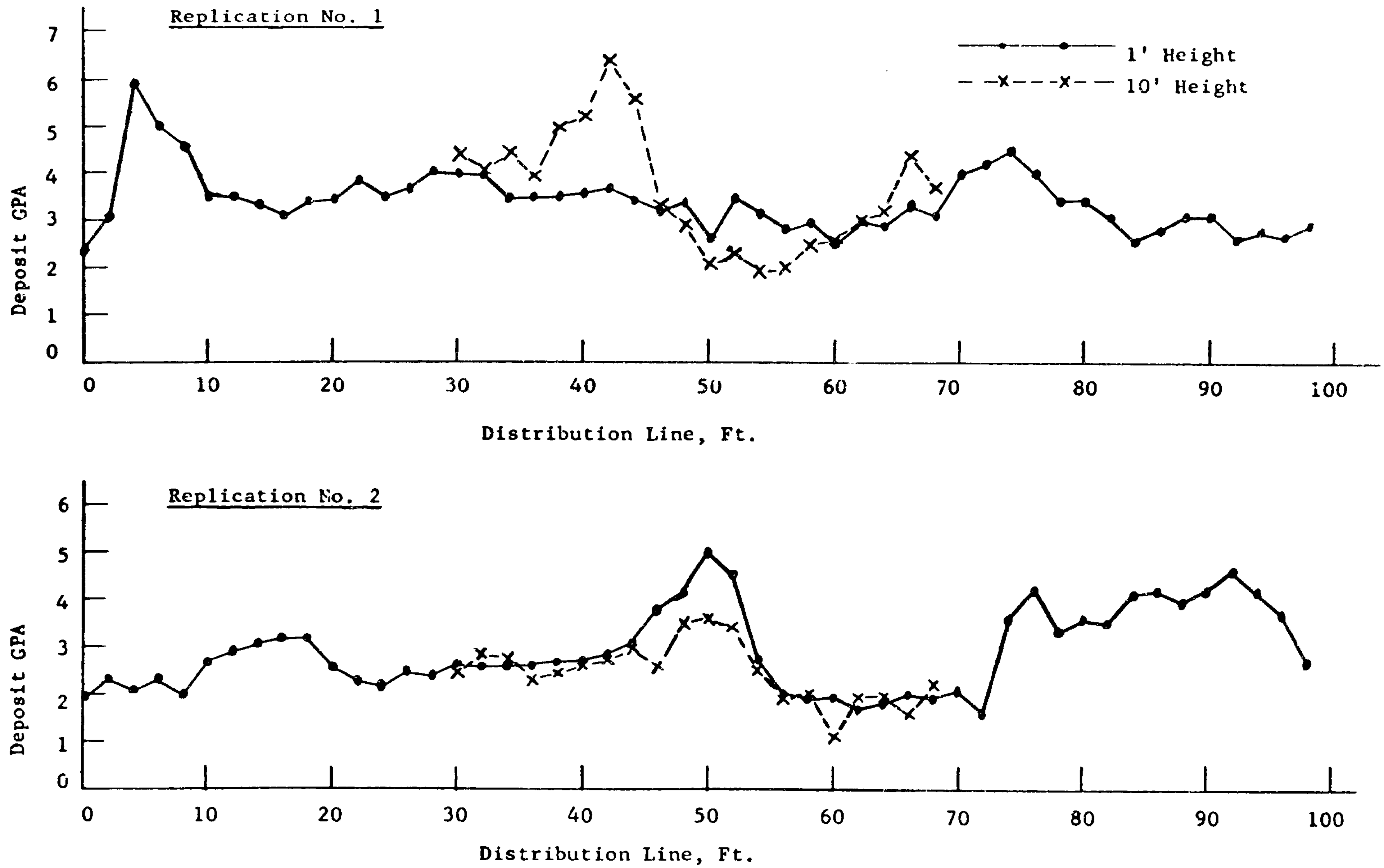


Figure 24. Water Spray Distribution Patterns at 10' & 1' Heights Above Ground for 4 GPA Rate and 40' Swath Width.

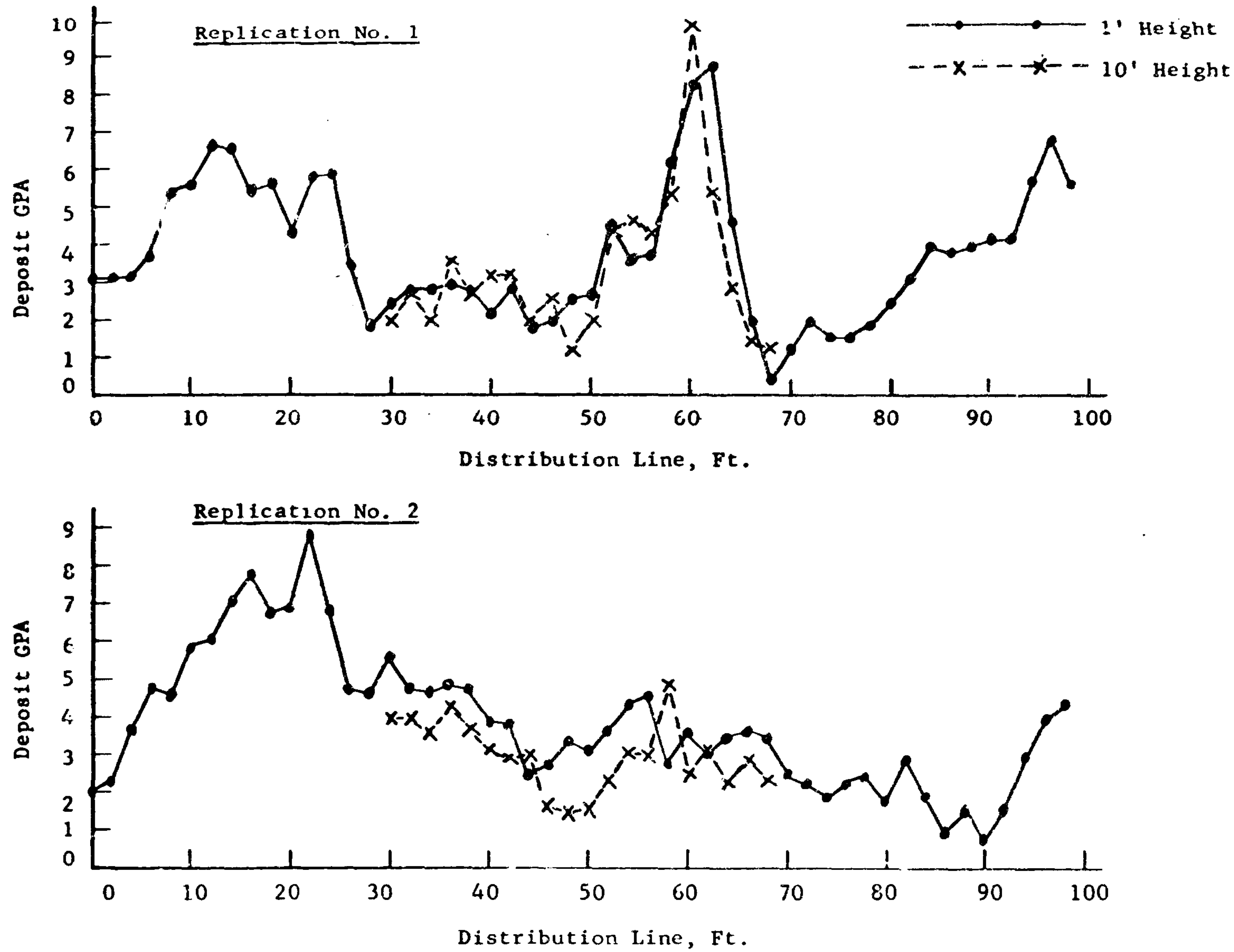


Figure 25. Norbak Spray Distribution Patterns at 0' & 1' Heights Above Ground Level for 4 GPA and 40' Swath Width.

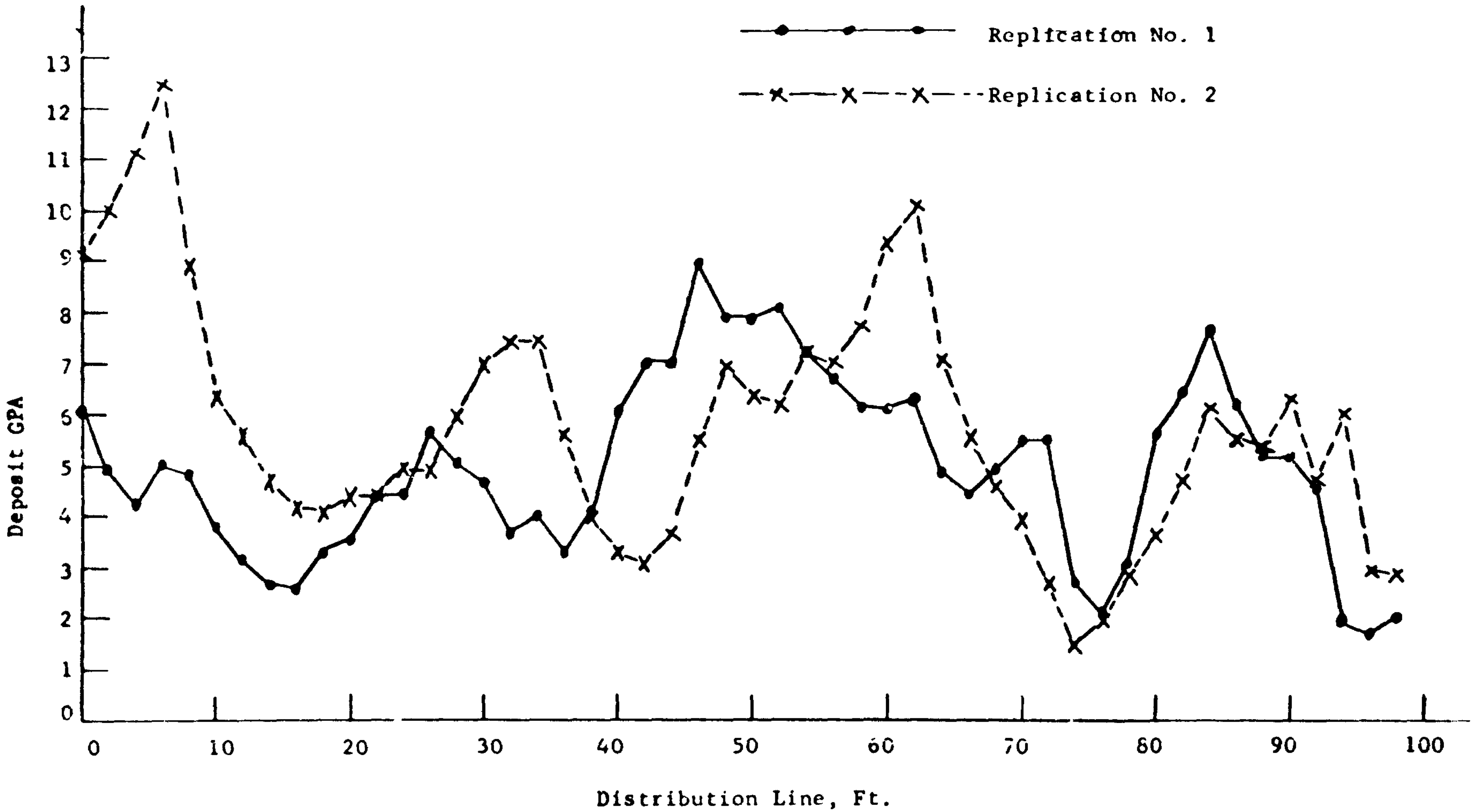


Figure 26. Norbak Spray Distribution Patterns at 1' Height Above Ground Level for 6½ GPA Rate and 25' Swath Width.

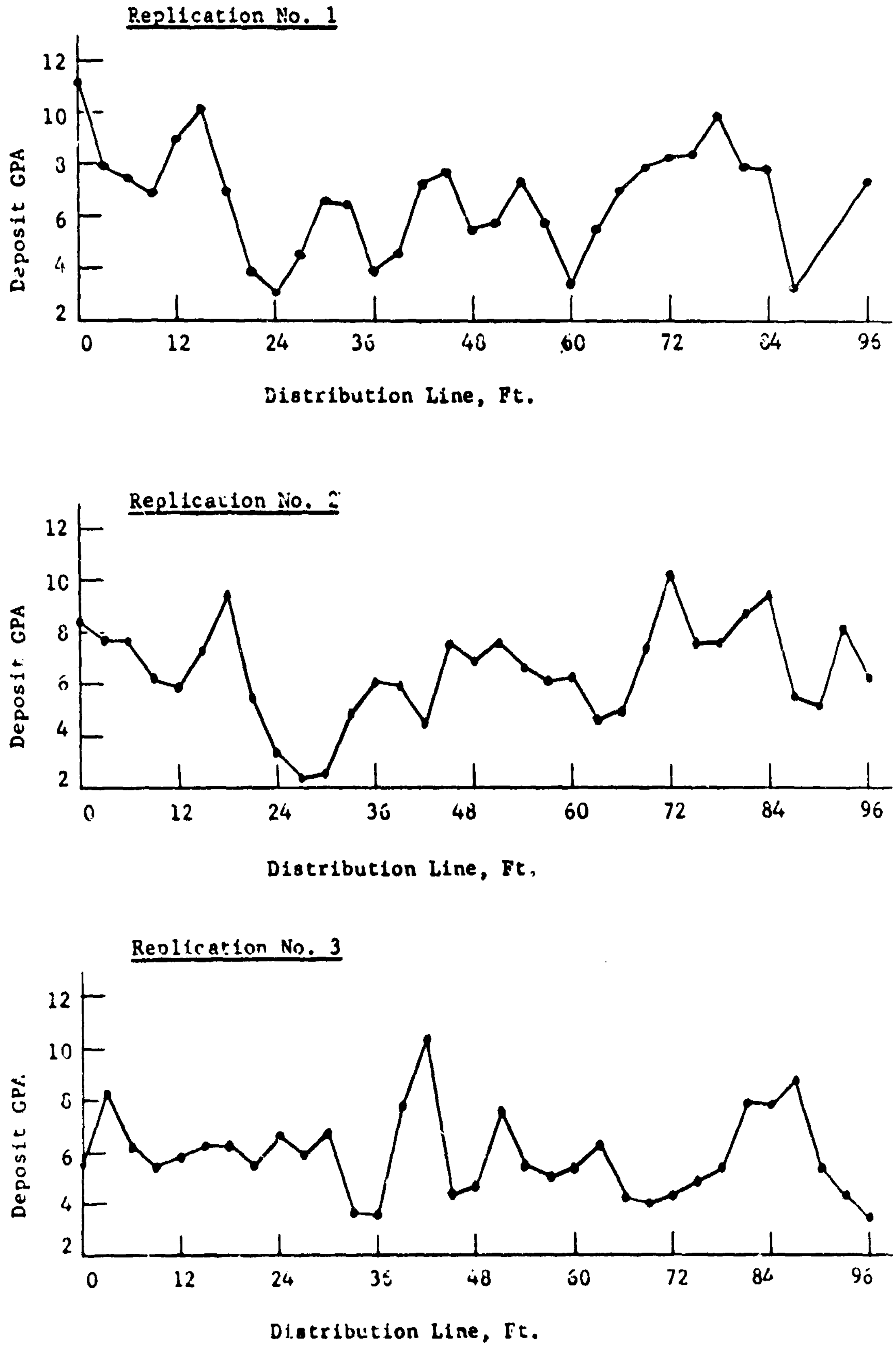


Figure 27. Invert Emulsion Spray Distribution Patterns, Archer City, Texas, July, 1965 - 33' Swath Width.

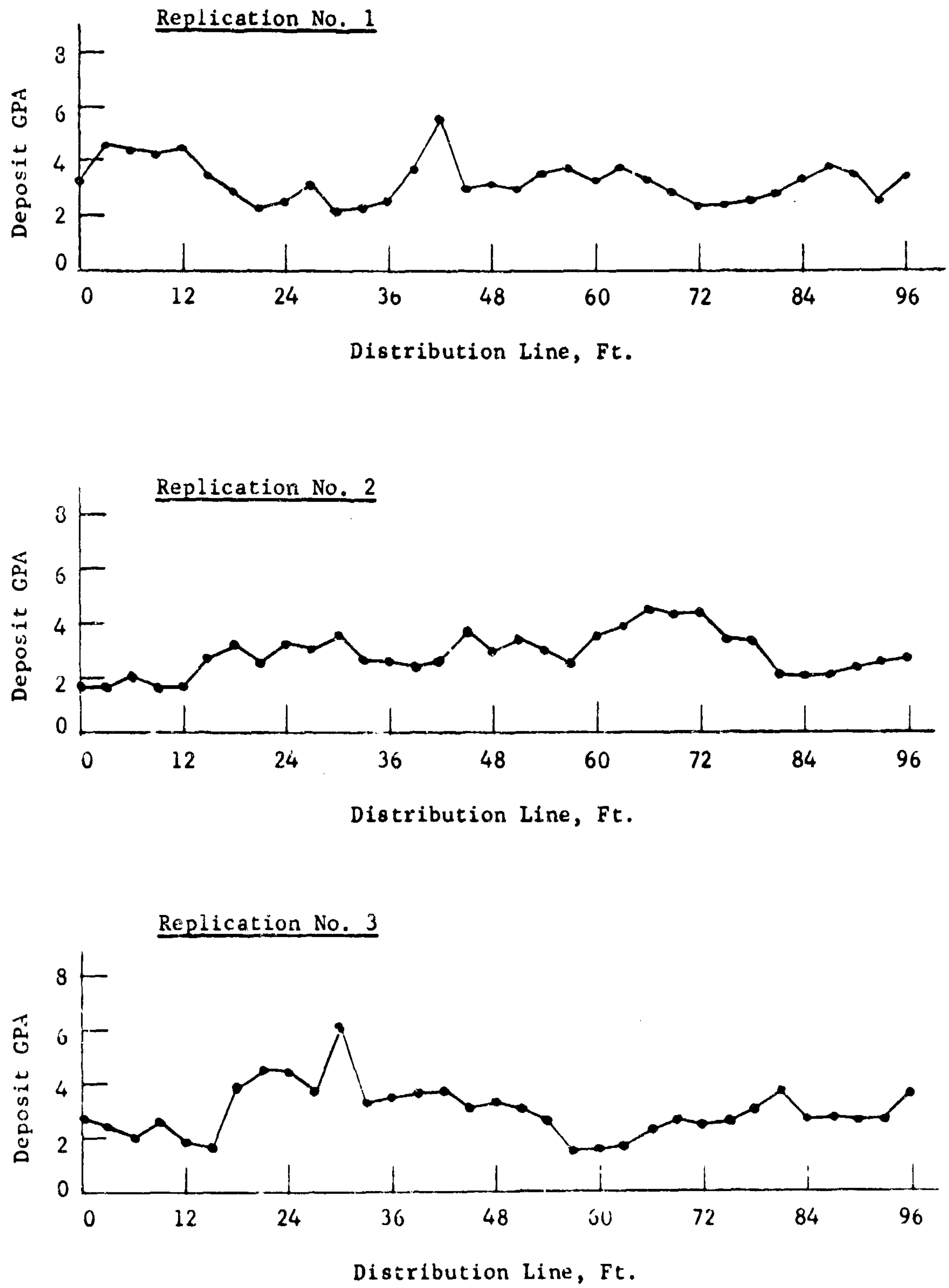


Figure 28. Conventional Oil-water Emulsion Spray Distribution Patterns Archer City, Texas - July, 1965 - 33' Swath Width.

Aerial distribution pattern measurements were also made in conjunction with the penetration studies near Victoria, Texas in July, 1965. For this test 3 - 100' sample lines were spaced 10' apart in an open area within a 5 acre spray plot (Figure 17). Each sample line consisted of 33 sample-holder stakes spaced on 3' intervals. Two 4" x 4" Mylar sheets were attached to each sample-holder stake to obtain quantitative spray deposit measurements. The Texas A&M University spray plane equipped with the conventional leading-edge in-wing boom having 24 Spraying Systems Company No. 4664-D10-45 Teejet nozzles was used for the applications. Swath widths were 33 feet. One purpose of this test was to determine the effect of leaving the Mylar sample sheets exposed to sunlight for a period of time after the dyed spray was deposited. There was reason to suspect that the Carmine 2-B dye might fade, thus resulting in erroneous measurements, if the samples were not recovered and placed in light-proof boxes immediately after the spray drops had settled. It was considered that this may have been the cause of lower than expected deposit measurements in some previous studies. In order to investigate this possibility one of the Mylar samples attached to each sample-holder stake was retrieved as soon as the spray from all swaths was deposited. The remaining sample on each stake was left exposed to a bright sun and approximately 85° F temperature for an additional 45 minutes. Data from this study is presented in Figure 29 and Table 7. The results indicated that dye deterioration is not a problem when the Mylar sample sheets are retrieved within 45 minutes. Longer exposure times have not been studied.

VI. Results of Measurements of the Penetration of Particulated Spray and Conventional Water Spray Through Overstory Vegetation.

Spray penetration measurements through overstory vegetation were

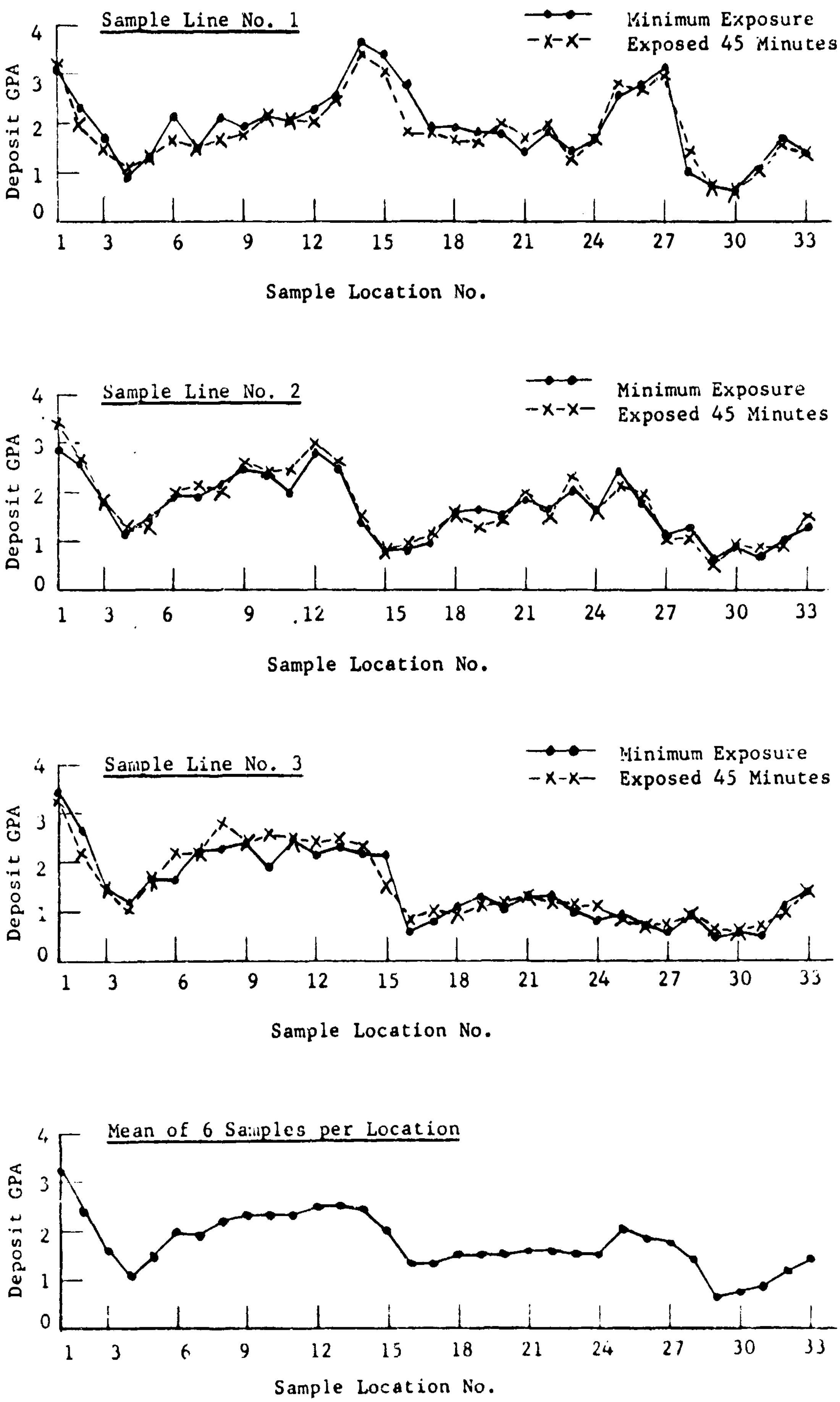


Figure 29. Water Spray Distribution Patterns, Victoria, Texas, July, 1965.

Table 7. Water Spray Distribution Data - Victoria, Texas - July, 1965

Sample Loc.	Line #1 Minimum Exp.	Line #1 Exp. 45 Min.	Line 1 Mean	Line #2 Minimum Exp.	Line #2 Exp. 45 Min.	Line 2 Mean	Line #3 Minimum Exp.	Line #3 Exp. 45 Min.	Line 3 Mean	Grand Mean
1	3.1	3.2	3.15	2.9	3.4	3.15	3.4	3.3	3.35	3.2
2	2.3	2.0	2.15	2.6	2.7	2.65	2.7	2.2	2.45	2.4
3	1.7	1.5	1.6	1.8	1.8	1.8	1.5	1.5	1.5	1.6
4	0.9	1.1	1.0	1.2	1.3	1.25	1.2	1.1	1.15	1.1
5	1.3	1.3	1.3	1.5	1.3	1.4	1.7	1.7	1.7	1.[illegible]
6	2.2	1.7	1.95	1.9	2.0	1.95	1.7	2.2	1.95	2.0
7	1.5	1.5	1.5	1.9	2.2	2.1	2.2	2.2	2.2	1.9
8	2.2	1.7	1.95	2.2	2.1	2.15	2.3	2.8	2.55	2.2
9	1.9	1.8	1.85	2.5	2.6	2.55	2.4	2.4	2.4	2.3
10	2.2	2.2	2.2	2.4	2.4	2.4	1.9	2.6	2.25	2.3
11	2.1	2.1	2.1	2.0	2.5	2.25	2.5	2.5	2.5	2.3
12	2.3	2.0	2.15	2.8	3.0	2.9	2.2	2.4	2.3	2.5
13	2.6	2.5	2.55	2.5	2.6	2.55	2.4	2.5	2.45	2.5
14	3.7	3.4	3.55	1.4	1.5	1.45	2.2	2.3	2.25	2.4
15	3.4	3.1	3.25	0.8	0.8	0.8	2.2	1.5	1.85	2.0
16	2.8	1.8	2.3	0.8	0.9	0.85	0.6	0.8	0.7	1.3
17	1.9	1.8	1.85	1.0	1.2	1.1	0.8	1.0	0.9	1.3
18	1.9	1.7	1.8	1.7	1.6	1.65	1.1	1.0	1.05	1.5
19	1.8	1.7	1.75	1.7	1.3	1.5	1.3	1.2	1.25	1.5
20	1.8	2.0	1.9	1.6	1.5	1.55	1.1	1.1	1.1	1.5
21	1.4	1.7	1.55	1.9	2.0	1.95	1.3	1.3	1.3	1.6
22	1.8	1.9	1.85	1.7	1.5	1.6	1.3	1.2	1.25	1.6
23	1.4	1.3	1.35	2.1	2.3	2.2	1.0	1.1	1.05	1.5
24	1.7	1.7	1.7	1.7	1.7	1.7	0.8	1.1	0.95	1.5
25	2.6	2.8	2.7	2.4	2.2	2.3	0.9	0.8	0.85	2.0
26	[illegible].8	2.7	2.75	1.8	1.9	1.85	0.7	0.7	0.7	1.8
27	3.2	3.1	3.15	1.2	1.1	1.15	0.6	0.7	0.65	1.7
28	1.0	1.4	2.2	1.3	1.1	1.2	0.9	0.9	0.9	1.4
29	0.7	0.7	0.7	0.7	0.6	0.65	0.5	0.6	0.55	0.6
30	0.6	0.6	0.6	0.9	0.9	0.9	0.6	0.6	0.6	0.7
31	1.1	1.0	1.05	0.7	0.8	0.75	0.5	0.7	0.6	0.8
32	1.7	1.6	1.65	1.1	0.9	1.0	1.1	1.0	1.05	1.2
33	1.4	1.4	1.4	1.3	1.5	1.4	1.4	1.4	1.4	1.4

Note: "Minimum Exposure" indicates that plates were retrieved as soon as spray drops had settled. "Exp. 45 Min" indicates plates which were left exposed to bright sun and approximately 85° F temperature for additional 45 minute period.

obtained during the previously mentioned aerial spray studies conducted with Norbak particulated spray and conventional water spray near Benchley, Texas in May, 1965. Conditions were not considered ideal for this type of study as the overstory vegetation, which consisted primarily of scattered winged elm trees, was extremely variable. Two sample lines were established in separate locations for measuring the amount of water spray penetrating through overstory vegetation from a 4 GPA application rate. One of these sample lines and the overstory vegetation is shown in Figure 15. Two sample lines were also established for the same purpose in a 4 GPA Norbak particulated spray plot. In each penetration sampling location selected, sample stations were located 2' apart in 40' lines. The sample plates were placed directly on the ground. Two 4" x 4" Mylar plates and one 4" x 4" Kromekote spot card were placed at each sample station. Spray penetration quantitative deposit data from the 4 GPA water spray application is presented in Table 8 and data from the 4 GPA Norbak particulated spray penetration is presented in Table 9. The mean spray deposit for all water spray samples collected was 1.46 GPA while the mean spray deposit for all particulated spray samples collected was 2.23 GPA. The extremely variable nature of the overstory vegetation could probably have accounted for this difference.

Table 8. Water Spray Penetration Measurements Under Winged Elm Trees - Benchley, Texas, May, 1965. Mean Application Rate = 3.4 GPA

Penetration Location E					Penetration Location W				
Replication #1		Replication #2			Replication #1		Replication #2		
Sample No.	Deposit GPA	Sample No.	Deposit GPA	Mean GPA	Sample No.	Deposit GPA	Sample No.	Deposit GPA	Mean GPA
81	1.1	101	1.0	1.05	41	3.1	61	3.1	3.1
82	.6	102	.6	.6	42	3.3	62	3.6	3.45
83	.9	103	1.2	1.05	43	4.0	63	3.6	3.8
84	1.6	104	2.1	1.8	44	4.5	64	4.4	4.45
85	3.5	105	2.7	3.1	45	4.8	65	3.9	4.3
86	3.0	106	2.0	2.5	46	3.4	66	2.9	3.15
87	.8	107	.6	.7	47	1.9	67	1.5	1.7
88	.2	108	.05	.1	48	1.3	68	1.2	1.25
89	.2	109	.2	.2	49	.8	69	.7	.75
90	.5	110	.5	.5	50	.8	70	.8	.8
91	.7	111	.7	.7	51	.7	71	.9	.8
92	1.1	112	.6	.85	52	1.0	72	.7	.85
93	.4	113	.4	.4	53	.7	73	.4	.55
94	.6	114	.6	.6	54	.5	74	.5	.5
95	.4	115	.3	.35	55	.7	75	.5	.6
96	.3	116	.4	.35	56	.7	76	.7	.7
97	.5	117	.5	.5	57	1.2	77	1.2	1.2
98	1.3	118	1.3	1.3	58	1.5	78	1.4	1.45
99	1.5	119	1.8	1.65	59	1.9	79	2.3	2.1
100	1.9	120	1.9	1.9	60	2.3	80	2.6	2.45

Grand Mean for Water Spray,= 1.46 GPA

Table 9. Norbak Spray Penetration Measurements Under Winged Elm Trees - Benchley, Texas - May, 1965. Mean Application Rate = 3.9 GPA

Penetration Location E					Penetration Location W				
Replication 1		Replication 2			Replication 1		Replication 2		
Sample No.	Dep. GPA	Sample No.	Dep. GPA	Mean GPA	Sample No.	Dep. GPA	Sample No.	Dep. GPA	Mean GPA
341	0	361	0	0	301	1.4	321	1.8	1.6
342	0	362	0	0	302	1.4	322	2.5	1.9
343	0	363	0	0	303	2.7	323	2.0	2.3
344	2.3	364	0	1.1	304	2.1	324	2.4	2.25
345	.3	365	.3	.3	305	1.1	325	.7	.8
346	1.5	366	1.6	1.55	306	0	326	0	0
347	4.1	367	4.2	4.15	307	0	327	0	0
348	3.9	368	4.8	4.3	308	0	328	0	0
349	2.2	369	1.6	1.9	309	0	329	0	0
350	.8	370	2.6	1.7	310	0	330	0	0
351	3.4	371	3.0	3.2	311	0	331	0	0
352	2.9	372	2.9	2.9	312	0	332	0	0
353	2.9	373	3.9	3.4	313	0	333	.5	.2
354	6.2	374	5.4	5.8	314	.4	334	.8	.6
355	9.1	375	9.0	9.05	315	1.8	335	2.4	2.1
356	8.0	376	5.8	6.9	316	2.5	336	1.1	1.8
357	5.7	377	2.9	4.3	317	2.8	337	3.6	3.2
358	3.4	378	1.9	2.6	318	4.9	338	6.1	5.5
359	4.0	379	3.8	3.9	319	4.6	339	4.1	4.35
360	2.1	380	1.6	1.8	320	3.7	340	3.9	3.8

Grand Mean for Norbak Spray = 2.23 GPA

LABORATORY SPRAYER FOR POTTED PLANTS

I. Introduction and Summarization

Work on the laboratory sprayer was initiated during the fall of 1964. The 1964 Line Project Annual Progress Report contains several photographs, a list of design requirements, and considerable design information. During the 1965 reporting year, the sprayer has been completed and placed in use. The sides of the spray booth were enclosed with 3/16" transparent plastic and an activated charcoal filter system was installed for removing herbicidal fumes from the air. An automatic-reset interval timer was provided for control of the exhaust fan on the air filter system to assure that sufficient air movement occurs between spray treatments to completely replace contaminated air with clean air. The performance of the filter system was checked by placing susceptible plants near the air exhaust area during spraying operations. No plant damage was detected. The sprayer has operated satisfactorily since being placed in operation and has been used to make uniform a ications of herbicides to potted plants on numerous occasions.

A brief manuscript entitled, "A Laboratory Spray for Potted Plants" by L. F. Bouse (AERD) and R. W. Bovey (CRD) has been prepared for submission to the Journal of Weeds for publication. The text and figures (renumbered for this report) submitted for publication are presented in the following pages.

A Laboratory Sprayer for Potted Plants[1]

L. F. Bouse and R. W. Bovey[2]

Abstract. A laboratory sprayer designed to make herbicide applications to potted plants and to study spray distribution patterns with different nozzles is described. An activated charcoal air filter was installed to minimize herbicide contamination to adjoining greenhouse-laboratory facilities during the spraying operation.

A laboratory sprayer was required for rapid and precise treatment of a large number of greenhouse and growth-chamber grown plants. The use of knapsack sprayers has been unsatisfactory because of non-uniform application rates and contamination of the laboratory-greenhouse areas with herbicides. Consequently, a laboratory spray was designed which has the following features: (1) A spray chamber and drain pan to confine and remove herbicide spray, (2) an activated charcoal air filter system, (3) a variable-speed spray cart (0-5 mph) mounted on an overhead track, and (4) a variable height plant supporting tray. One or

[1]Received for publication___________, 1966. This research is sponsored by the Advance Research Projects Agency, Department of Defense. Cooperative investigation of the Crops Research Division and Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture and the Texas A&M University, College Station, Texas.

[2]Agricultural Engineer and Research Agronomist, Agricultural Engineering Research Division and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

several potted plants up to 4 ft in height can be treated at one time with single or repeated applications. The rate of application is controlled by nozzle speed, nozzle size, and spray pressure. Operation and cleaning procedures are easily performed.

General Design. An enclosed spray booth 4 ft wide, 9 ft high and 16 ft long was constructed (Figure 30). The frame consists primarily of 2 x 2 in ornamental steel tubing. A drain pan slopes from the ends of the spray booth toward the center. The center section of the drain pan (4 x 6 ft) is recessed for a plant supporting tray consisting of a steel tubing frame covered with expanded metal. The plant support tray can be raised and lowered by a cable lift to adjust the distance below the spray nozzle from 2 to 6 ft.

A spray cart carries the spray nozzle and herbicide container the length of the spray booth (Figure 31). The spray cart carriage system is similar to that described by Hare and Harrell (1). The cart frame is constructed of a 5/16 in thick aluminum plate and 1 x 1 in lightweight steel tubing. Four 3 in diameter nylon rollers carry the plate on an overhead track. The spray cart is propelled along the track by a mechanical linkage to a No. 50 steel roller chain carried on two 60-tooth sprockets located at either end of the track. The mechanical linkage consists of a 1 ½ diameter roller bearing fastened to an attachment link in the chain. The bearing operates in a vertical groove on the spray cart and carries the cart back and forth across the spray booth as the roller chain is driven continuously in one direction. The chain is driven by a ½ horsepower variable speed drive unit. The speed of the cart is controlled by a small hand wheel located on the front of the spray booth. A mechanical counter attached to the hand wheel shaft has been calibrated to indicate cart speed in mph and ft/sec. All exposed

Figure 30. Enclosed Laboratory Sprayer for Potted Plants.

Figure 31. Spray Cart Assembly Mounted on Overhead Track.

steel surfaces were painted with a chemically resistant epoxy resin.

Spray Unit Design. The sprayer consists of a 1 qt pressurized spray can, an electric solenoid operated valve, a pressure gauge, and a nozzle. Air pressure is supplied through a flexible rubber hose. A small glass bottle containing the herbicide solution is placed inside the pressurized spray can (Figure 32). The liquid inlet tube extends to the bottom of the bottle, permitting nearly all of the material in the bottle to be sprayed. The entire spray system can be flushed with clean water or solvent by attaching a hose to the end of the liquid inlet tube after the pressurized and herbicide containers are removed. Subsequently, the cleaning solution can be removed from the spray system by an air hose attached to the same liquid inlet tube. The entire spray unit on the cart can be raised or lowered by adjustable brackets. Rate of application can be readily calculated from the nozzle delivery rate and cart speed. Potted plants can also be sprayed when the spray cart is stationary.

Air Filter System. The spray booth sides are enclosed with 3/16 in thick transparent plastic panels to confine the spray particles. Two 5 ft high by 3 ft wide sliding doors provide access to the plant supporting tray, sprayer unit, and interior of the booth. In addition, two 3 ft wide by 2 ft high doors below the larger doors may be opened to provide a large opening for placing large plants into the booth. An exhaust fan was installed under one end of the drain pan to draw air containing herbicide particles out of the booth through a louvered opening in the drain pan and force it through an activated charcoal filter system. Clean air enters the booth from the top. This fan is operated as soon as spray droplets are deposited after each spraying operation. An automatic-reset interval timer is used to assure that adequate time is allowed for air in the booth to be replaced with clean air. This system has been very effective in preventing herbicide contamination.

Figure 32. Replacement of Pressurized Can Containing Glass Herbicide Bottle.

Control System. Manual or automatic control of the spray cart and solenoid valve was provided on a control panel on the front of the booth. Trip blocks attached to the drive chain activate a snap switch to provide automatic cart and spray valve operation. The automatic spraying distance may be varied by repositioning the trip blocks. Air pressure for spraying is adjusted with a pressure regulator at the control panel. An air valve for turning air into the pressurized spray container also releases air pressure from the container when in the off position.

Estimated cost of the materials for the sprayer is $1,850.00. Additional information on the design of the sprayer may be obtained from either the Agricultural Engineering Research Division or Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland, or by writing to the authors.

LITERATURE CITED

1. Hare, W. W., and E. A. Harrell. 1964. An experimental laboratory sprayer for simulating field conditions. U. S. Dept. Agr., ARS 42-100. 7 p.

SPREAD FACTOR DETERMINATION FOR SAMPLE PAPERS

I. Introduction and Objectives

Spray deposits are often collected on paper sampling surfaces for the purpose of determining the drop-size distribution of the spray. Dye is ordinarily added to the spray solution so that drop stains are formed which can be readily measured and counted. A "spread factor," which is the ratio of spot or stain size to actual drop-size, must be applied to the data to correct for the spreading of the spray liquid on the sampling surface. Before estimates of the actual drop-size distribution can be obtained, appropriate spread factors must therefore be available for the spray liquid and sampling surfaces used in the test. The objective of this work was to determine spread factors for several sampling surfaces and spray liquids which are under study on this project.

II. Equipment and Techniques

Techniques for producing uniformly sized water droplets with both vibratory and rotating devices are discussed in the 1964 Line Project Annual Report. Techniques and equipment for obtaining 5X magnification photographs of streams of uniform size drops produced with these devices are also described in the 1964 report. During the 1965 reporting year the same equipment and techniques were used with the exception that a small variable-speed drive unit and supporting stand replaced the ½" variable-speed drill press used with the rotary droplet production device (Figure 33). Figure 34 is a close-up photograph of the rotating spindle, stainless steel blade, and liquid holding apparatus.

The technique used to obtain spread factors has been to adjust the

Figure 33. Variable Speed Rotary Droplet Device.

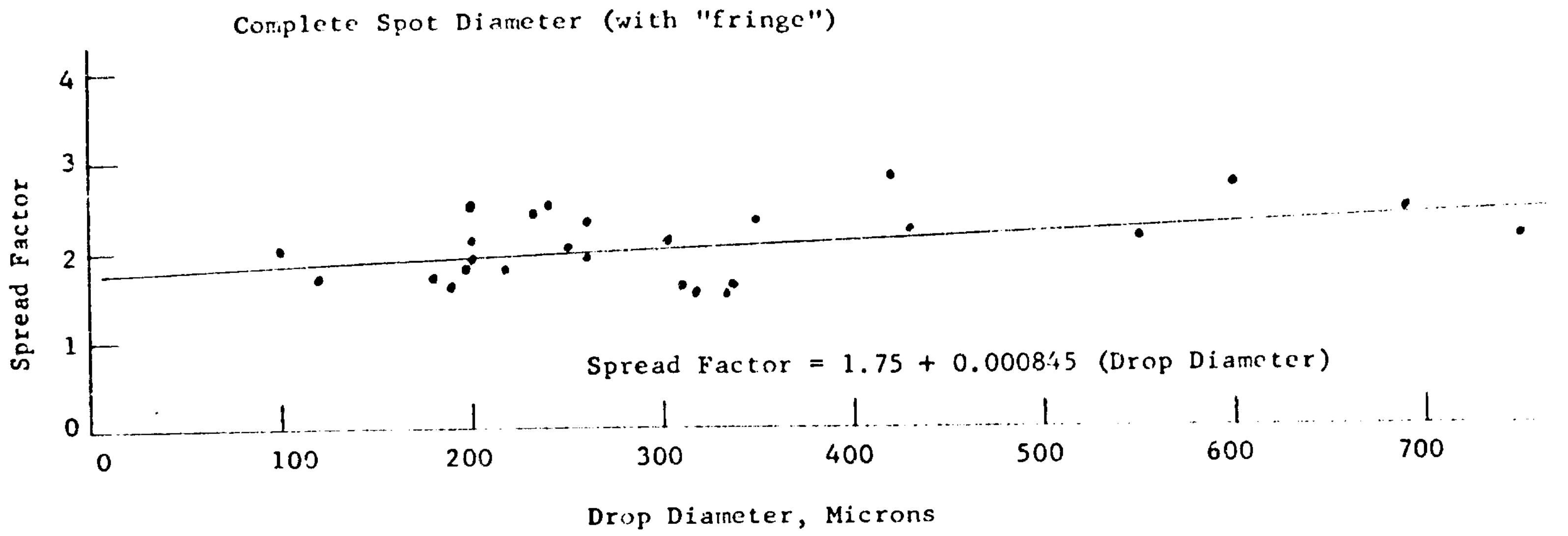
Figure 34. Close-up of Rotating Shaft and Blade, Syringe Barrel, and Liquid Holder.

drop producing apparatus and liquid flow rate so that a steady stream of uniform diameter drops is being produced and then obtain a high-speed photograph of the drops in free flight while simultaneously collecting the drops on selected sampling materials. The high-speed photographs are obtained with an electronic stroboscope and a 5X magnification camera. Actual drop diameters are obtained by measuring the drop images on the photograph and spot diameters are obtained by measuring the drop stains on the sampling surfaces.

Water and two types of dye have been used in spread factor determinations. Pontacyl Carmine 2-B dye (red) and water soluble Nigrosine dye (black) have been used as ½ percent solutions in water. Brief attempts to produce streams of uniform diameter drops of thickened spray material have been unsuccessful although large drops of thickened material can be dislodged from a hypodermic needle with a small jet of air. Streams of uniform diameter water drops have also been produced with a small vibratory pump and a hypodermic needle. Sampling surfaces used in tests have included 0.012" thick, short-grain, white Kromekote cover paper which is coated on one side, adding machine tape, and type 480 Kodak Linagraph paper. The Linagraph paper is sensitive to water and light and does not require the use of dye to provide drop stains; however, spread factors without dye have not been obtained.

III. Spread Factor Data Obtained

Figure 35 shows the relationship between actual drop size and spread factor for Carmine 2-B dye in water on Kromekote cover paper. Each data point shown was obtained from the mean of 5 spot diameters and from 1 to 5 drop diameters depending on the number of drops in sharp focus on each photograph. A least-squares-fit straight line is shown on each graph. The "inner spot diameter" shown on Figure 35 refers to the diameter of a



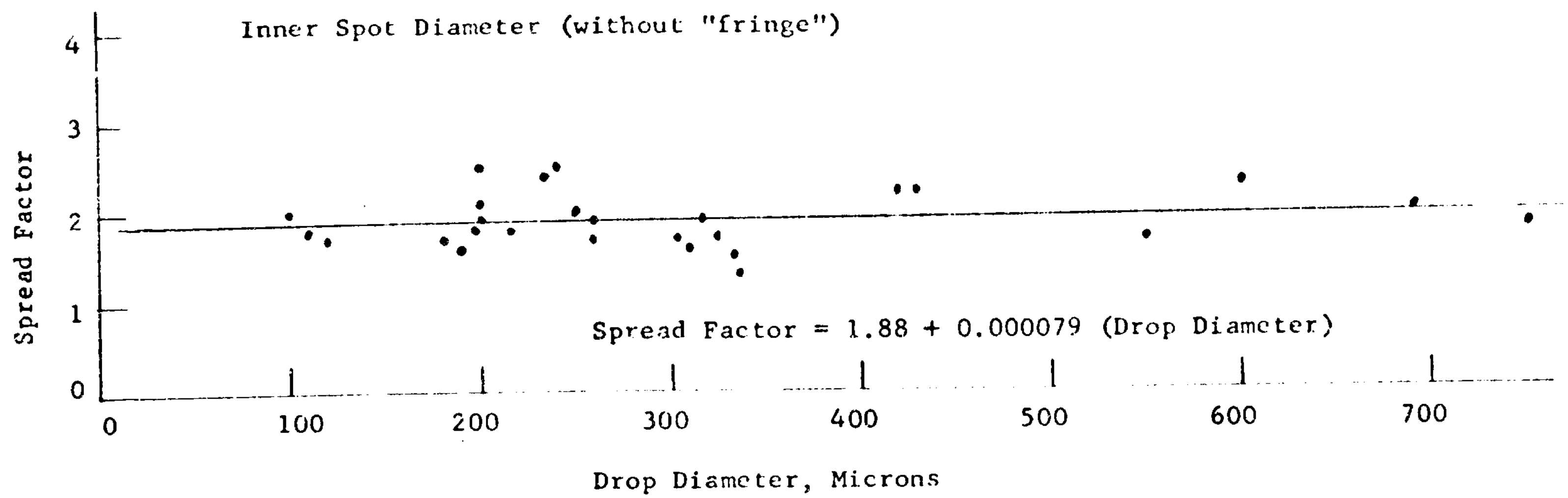


Figure 35. Spread Factors for ½% Carmine Dye in Water on Kromekote Paper

dark inner spot which was surrounded by a lighter "halo" or fringe. The complete spot diameter refers to the outside diameter of the outer circle or fringe. A sharp change in color intensity separated the inner spot from the outer fringe. This "halo" effect was obtained only with the Kromekote sampling paper. Figure 36 shows the relationship of spread factor to drop diameter for Carmine 2-B dye on adding machine tape and Linagraph paper. Figures 37 and 38 show the relationship of spread factor to drop diameter for Nigrosine dye in water on the three sampling papers. The "halo" effect was also present for Nigrosine dye and water on Kromekote paper.

There was some question as to whether the method of drying the spray on the spot cards affected the spread factor. In order to study this possibility two different sizes of uniform diameter drops were collected on each of the sampling papers. Three samples with large drops and three samples with small drops were dried in the sun on a warm bench while three samples with large drops and three samples with small drops were dried in the shade at a somewhat lower temperature. Ten spots were measured on each sampling surface. Table No. 10 shows the mean diameters of the ten spots measured on each sample. This data shows that the difference in the mean diameters from three samples dried in the sun and the mean diameters from three samples dried in the shade is less than the variation among the three means of a single drying condition and drop size.

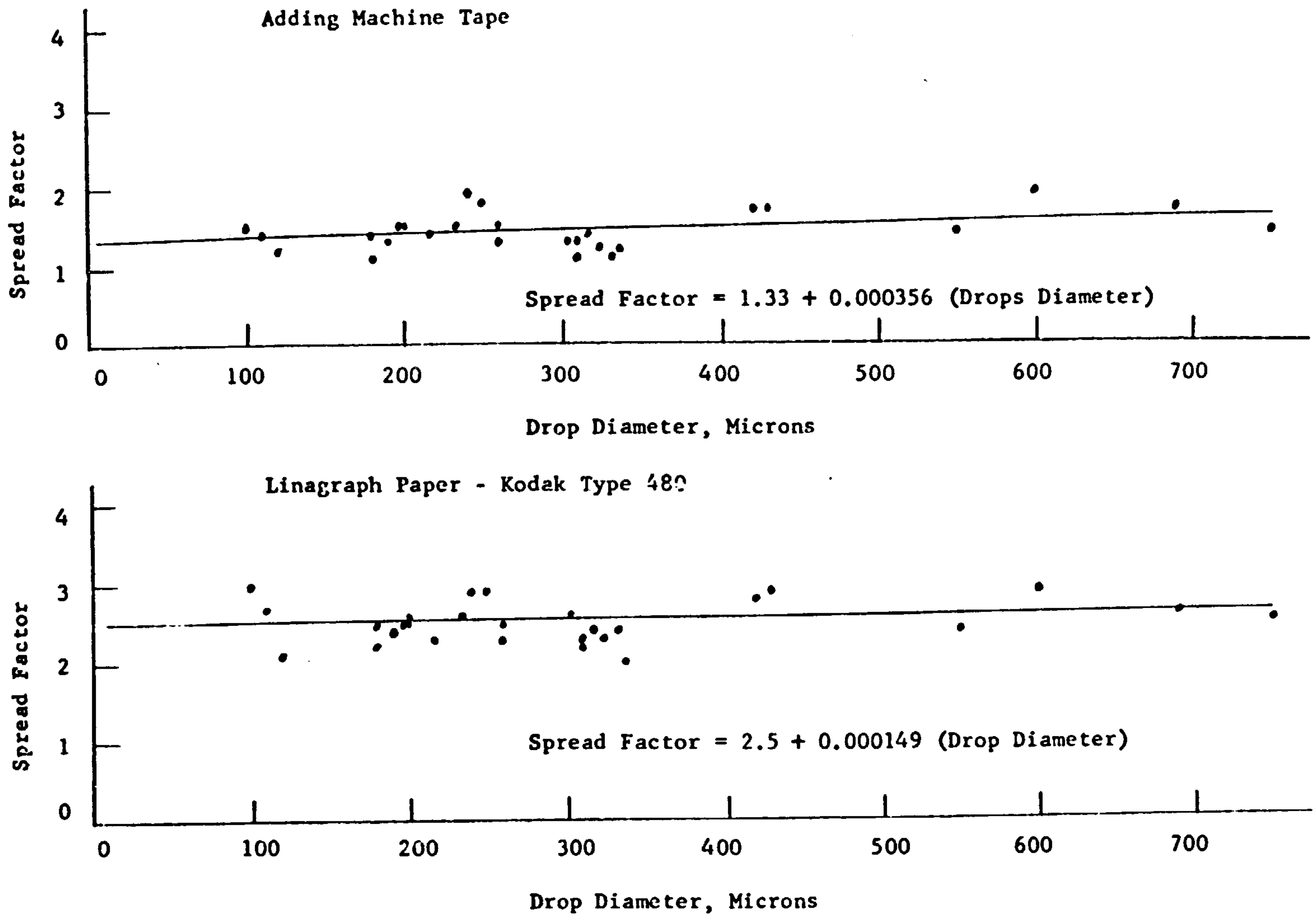


Figure 36. Spread Factors for ½% Carmine Dye in Water on Adding Tape and Linagraph Paper

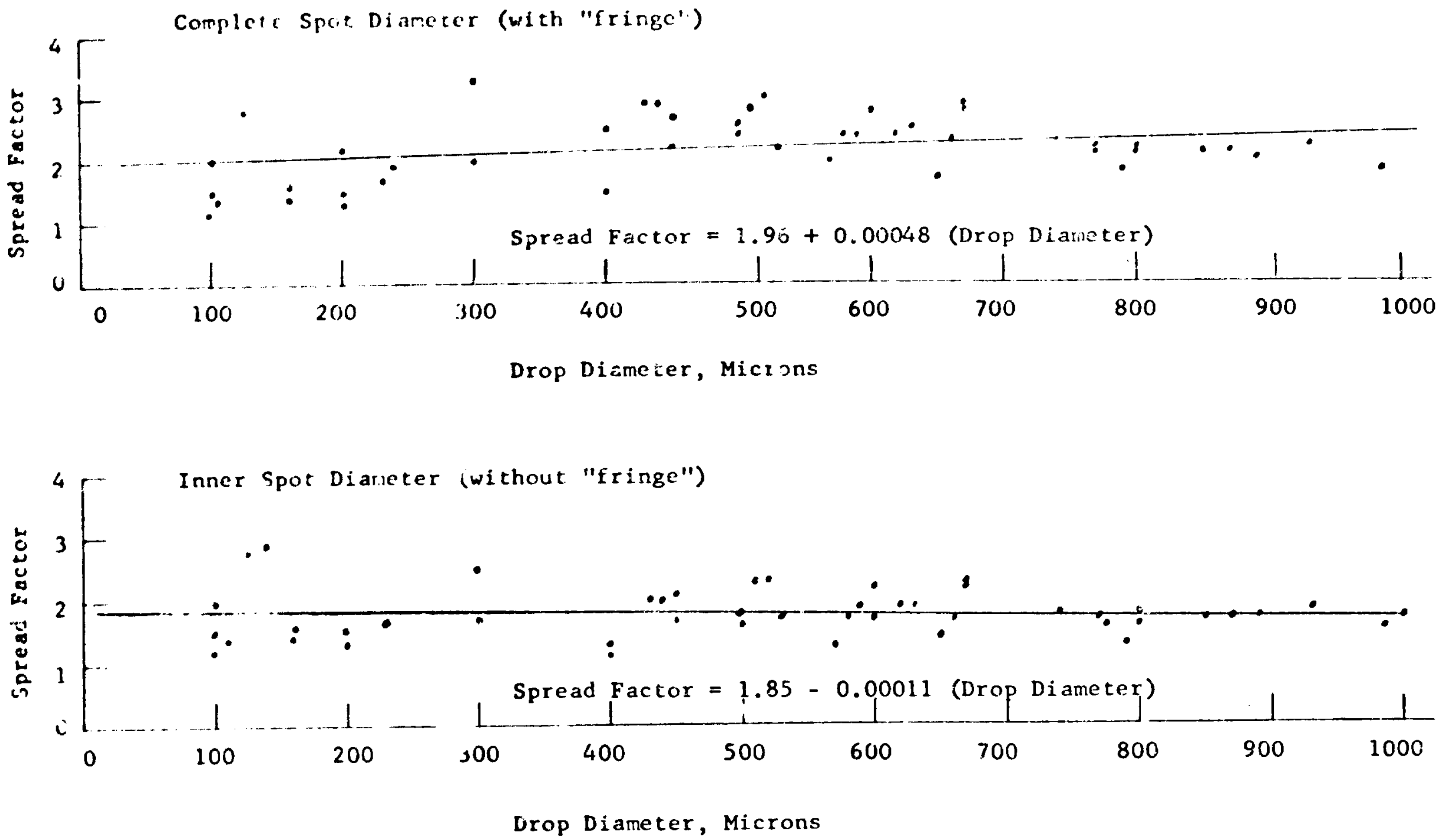


Figure 37. Spread Factors for ½% Nigrosine Dye in Water on Kromekote Paper

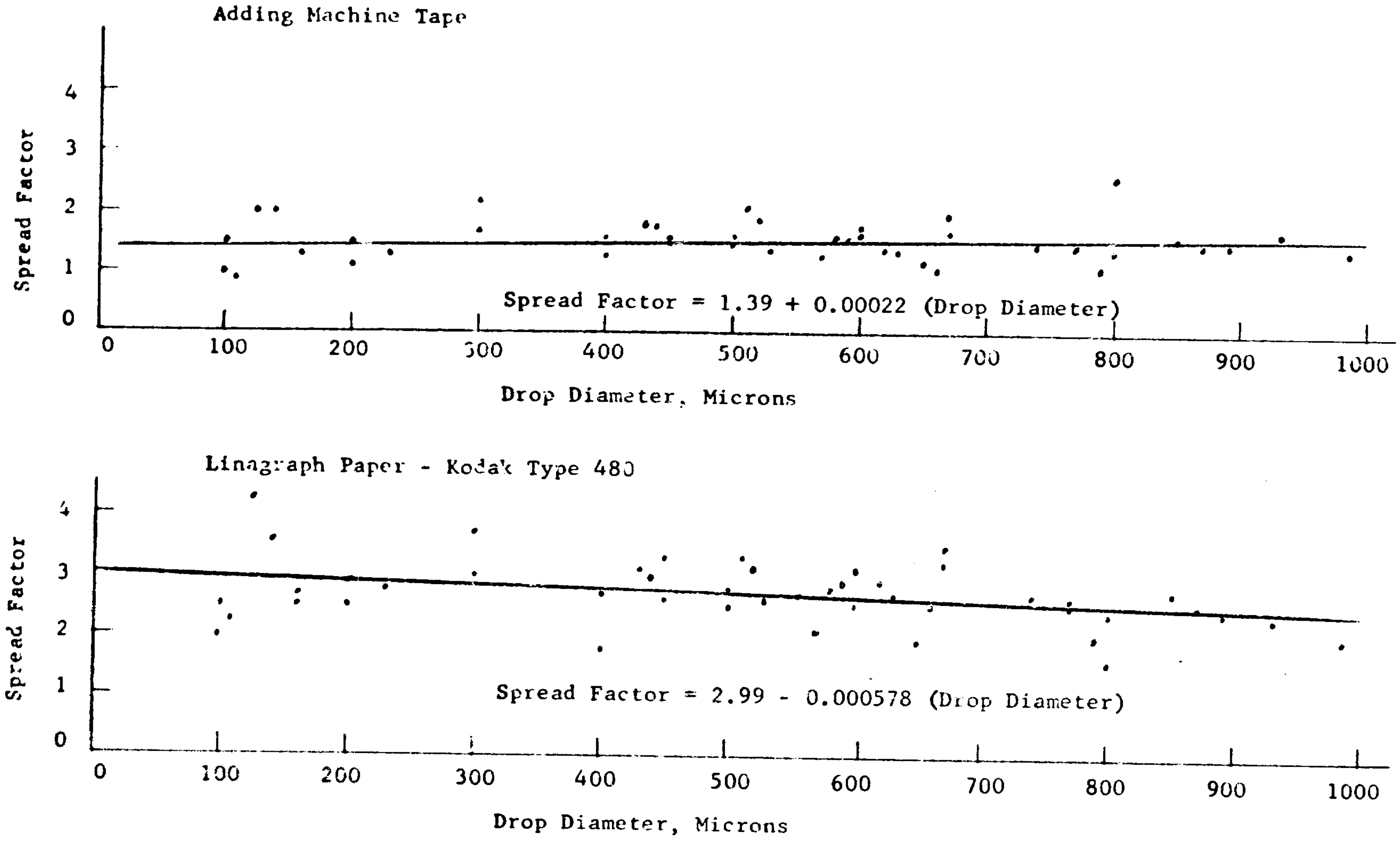


Figure 36. Spread Factors for ½% Nigrosine Dye in Water on Adding Tape and Linagraph Paper

Table 10. A comparison of two drying conditions for large and small drops on 3 sampling papers.

Note: The spot diameters shown are the mean of 10 measurements.

			Spot Diameters, Microns			
Sample No.	Drying Condition	Drop Size	Linagraph Paper	Kromekote (Inner)	Kromekote (Outer)	Adding Tape
905	Dark	Large	755	555	665	405
906	Dark	Large	708	520	588	380
908	Dark	Large	698	533	620	365
Mean	Dark	Large	720	536	624	383
903	Sun	Large	710	520	603	377
904	Sun	Large	733	583	653	400
907	Sun	Large	718	545	618	420
Mean	Sun	Large	720	549	625	399
900	Dark	Small	553	403	465	278
901	Dark	Small	498	360	418	280
902	Dark	Small	453	333	385	270
Mean	Dark	Small	501	365	423	276
897	Sun	Small	513	320	378	270
898	Sun	Small	483	360	418	273
899	Sun	Small	488	350	400	278
Mean	Sun	Small	495	343	399	274

MANUAL DROP MEASURING AND COUNTING INSTRUMENT

I. Introduction

One technique for obtaining drop-size distributions from photographs and spot cards is to count and record the number of drops or spots in size "classes" or increments of a selected width. Frequency-distribution graphs may then be plotted and various median and mean diameters obtained. Methods of measuring and counting drops or spots have ranged from slow laborious measurements with low-power microscopes equipped with measuring reticles to high-speed electronic scanning devices such as the flying-spot particle-analyzer. Samples analyzed with the flying-spot particle-analyzer must be in the form of 35mm transparancies which provide a high degree of contrast between the spot being measured and the background. The drop or spot images must also have well defined edges.

Negatives of spray drops in free flight in the low-speed wind tunnel do not provide sufficient contrast or sharply defined drop edges required for analysis with the flying-spot particle-analyzer. A technique for measuring and counting drops from wind tunnel studies was therefore needed. Also, since the flying-spot particle-analyzer was not readily available for use at this location, equipment was needed for analyzing spot cards where the number of samples involved was limited. Therefore, a manually operated drop measuring and counting instrument was constructed.

II. Equipment and Techniques

The instrument constructed was briefly discussed in the 1964 Line Project Report. Several changes and improvements have been made during the last year to make the device more convenient and to speed up the

Figure 39. Micro-Projector, Electric Counters, and Drop Measurement Apparatus.

counting operation. Figure 39 shows the general arrangement of the equipment. Droplet photographs and spot cards are magnified with the micro-projector shown to obtain either 10X or 20X magnification images on the ground glass screen. Transmitted light is used for transparencies (negatives) and reflected light for spot cards. The images are placed in size classes by adjusting a set of specially constructed calipers mounted on a switch box to the image diameters and pressing a pushbutton switch. This process is repeated for each drop or spot counted. Adjustment of the spacing between the arms of the caliper causes a rotary selector switch to make contact with one of 30 poles which are in turn wired to 30 four-digit, manual-reset, electric counters. Pressing the pushbutton switch completes the circuit to a single counter causing a count to be registered. The rotary switch is connected to the caliper arms through small spur gears and a rack and pinion system (Figures 40 and 41). The gear sizes were selected so that changing the rotary switch position one increment caused a caliper arm movement of exactly 1 mm. In addition to the rotary switch and caliper measuring and counting system, 10 separate pushbutton switches were provided to register counts on the 10 counters corresponding to the 10 smallest size classes. This permits direct registering of drops or spots measured visually with the aid of grid lines on the ground glass screen. Figure 42 shows the switching circuit used in the instrument.

III. Results of Usage

The drop measuring [illegible] unting instrument has been used by members of the Range Science Department of Texas A&M University to obtain drop-size distributions from several hundred spot cards. It has also been used to obtain drop-size distributions from approximately 100 negatives

Figure 40. Top View of Rotary Switch and Adjustable Caliper Apparatus.

Figure 41. Bottom View of D p Measuring Apparatus Showing Spur Gear Drive for Rotary .witch and Caliper Arm.

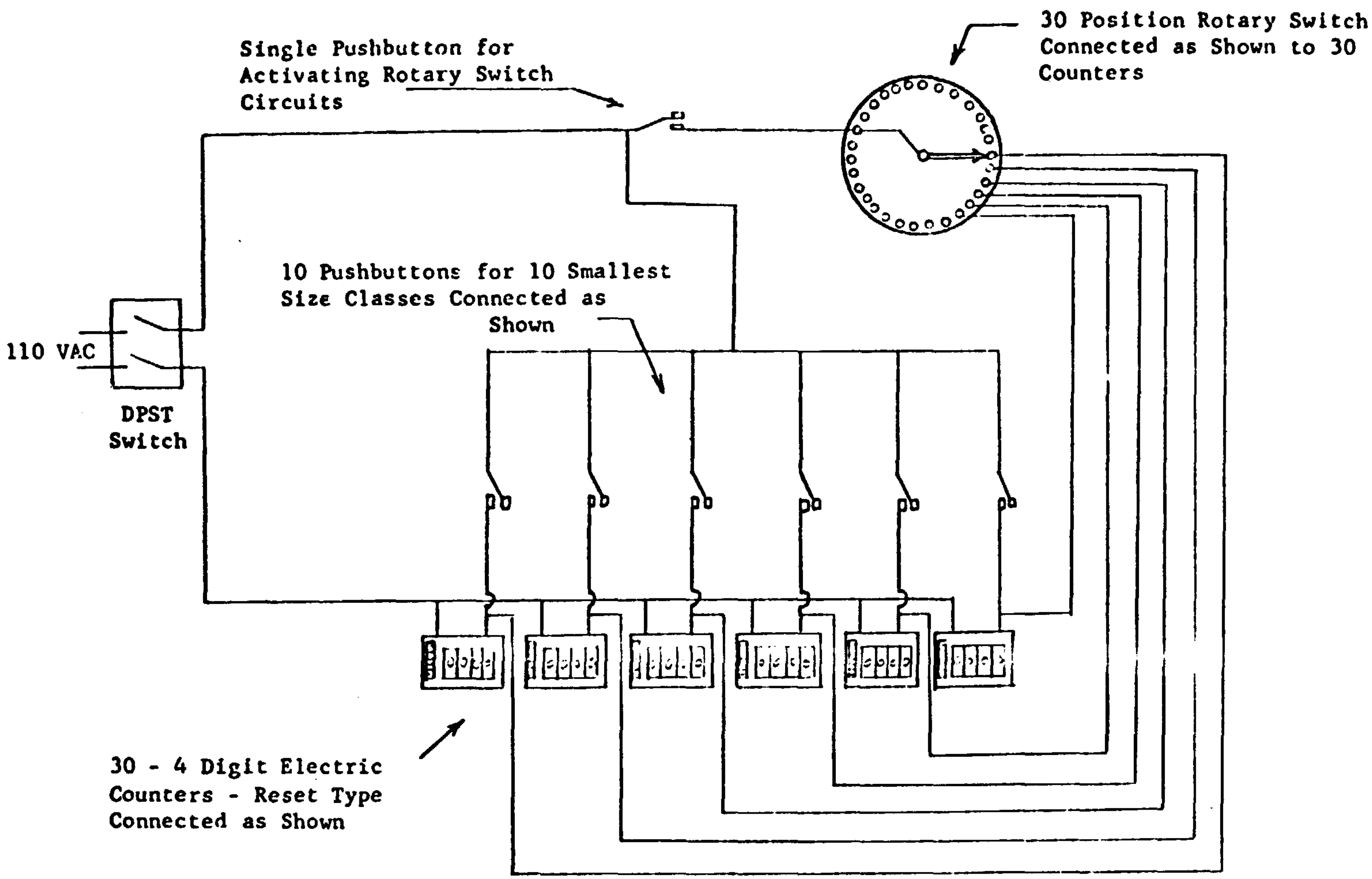


Figure 42. Switching Circuit for Drop Measuring and Counting Instrument

of spray drop formation in the low-speed wind tunnel. Although manual drop measurement with this device is still time consuming, it is much faster than many other manual methods. It at least partially satisfies the need for a measuring technique for those samples which cannot be analyzed with the flying-spot particle-analyzer.

TIMED-INTERVAL PHOTOGRAPHIC EQUIPMENT

I. Introduction

One important criteria in selecting a herbicide and its time of application could be the length of time required to obtain plant response. In order to better study the speed of response of potted plants to various herbicidal treatments, a photographic apparatus for making close-up color photographs of plants at pre-selected timed-intervals was needed. The requirements of such a device included that it be capable of making photographs of either one or more than one plant at a time so that either single or multiple treatments could be studied. Additional requirements were that operation be automatic and that the timed-interval between photographs be easily varied from a few minutes to several hours.

II. Equipment Design

A personal communication with Mr. W. H. Henson, Jr. USDA-AERD at Lexington, Kentucky provided information on a technique for making time-lapse photographs of curing tobacco leaves. Borrowing Mr. Henson's idea for using a turntable to provide photographs of more than one plant at a time, a timed-interval photographic device was designed and constructed.

A 35mm camera with an electric motor drive for advancing the film was available on the project and was used to provide automatic camera operation. Several close-up attachments were also available for obtaining reproduction ratios greater than those possible with the 50mm f2.0 lens alone. Two close-up attachment lenses and two extension rings can be used individually or in combinations to provide reproduction ratios up to approximately 1:1.2. An extension bellows is also available and provides reproduction ratios of 1:1 to approximately 3.5:1 (3.5X magnification). The camera could also be used to provide timed-interval photomicrographs if necessary. An electronic flash unit with a 1/1000 sec. flash duration (Ultrablitz) provides light for the photographs. This unit may be recharged on 110 VAC and is kept in a fully charged state by leaving it plugged-in while a series of exposures is made. After a flash occurs, the unit again reaches its fully charged state in approximately 10 seconds.

A 36" diameter turntable was constructed to support from one to six potted plants and permit photographs of more than one plant within a short period of time. In operation, the camera is mounted on a tripod and adjusted to focus on a single plant on the turntable (Figure 43). A time-clock causes the turntable to rotate one complete revolution at pre-selected timed-intervals. As the turntable rotates, 6 trip blocks located on the turntable shaft operate a micro-switch once for each 60 degrees of table rotation. The micro-switch controls the motor driven camera causing 6 exposures to be taken. The 6 plants are positioned at approximately 60 degree intervals around the turntable so that they are in focus and properly framed as the exposures are made. If less than 6 plants are to be photographed, part of the trip blocks are removed so that the micro-switch is operated and exposures made only for turntable positions containing plants. The turntable is driven with a 2 RPM motor through a set of spur gears which reduces the turntable speed to approximately 0.62 RPM (Figure 44).

When only one plant is to be photographed, the turntable is not used. Reproduction ratios are limited when using the turntable since increasing

Figure 43. Timed-Interval Photographic Equipment and Turntable.

Figure 44. Drive Unit, Snap Switch and Trip Blocks for Actuating Camera, and Snap Switchs for Stopping Table.

the reproduction ratio decreases the depth of focus and focusing becomes very critical. A slight movement of the object toward or away from the camera results in the object being blurred or perhaps completely out of focus. Reproduction ratios of 1:1.23 have been used when photographing leaves of single plants, although normal plant movement such as drooping or closing of the leaves necessitates periodic refocusing of the camera. A reproduction ratio of 1:5.5 has been used successfully with the turntable.

The control circuit for providing timed-interval photographs is shown in Figure 45. A series-repeating timer with a 60 minute dial-cycle which provides a minimum on or off interval of 60 seconds through the use of 60 tilting trippers is used to increment a 21 pole stepping switch. The poles on the stepping switch are wired to the contacts of a 21 position selector switch. This combination provides numerous timed-interval possibilities ranging from 1 minute to 21 hours for single plant photographs and from 2 minutes to 21 hours for turntable photographs. One minute turntable intervals are not possible since the turntable speed is only 0.62 RPM. A normally-open, 2-second delay, time-delay relay is used to reset the stepping switch for single plant photographs and a cam operated snap switch is used for resetting after one complete revolution when taking photographs of plants on the turntable. Another snap switch operated on a slightly longer cam is used to move the turntable an additional short distance to assure that the resetting snap switch opens before the table stops.

III. Results of Usage

Initial photographs recently made with the timed-interval apparatus indicate that operation is satisfactory provided proper care is exercised in adjustment and operation. Periodic refocusing is necessary due to

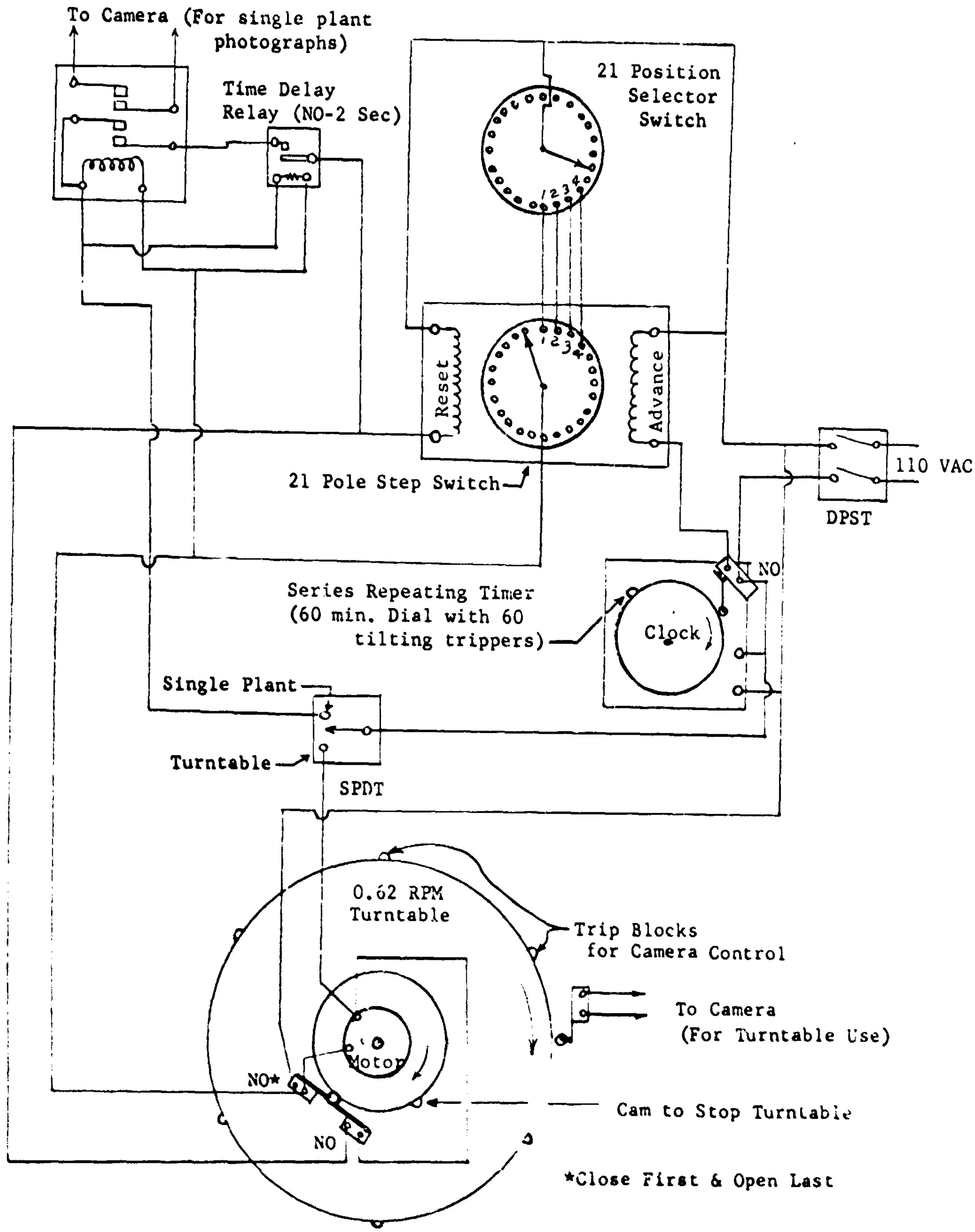


Figure 45. Timed-Interval Photography Control Circuit

normal plant movement when high reproduction ratios (short depth of focus) are used. Figure 46 is a black and white print which was made from a colored slide of mesquite tertiary leaflets immediately after treatment with 100 ppm paraquat herbicide solution. Figure 47 shows the same leaflets 18 hours later.

Figure 46. Mesquite Tertiary Leaflets Photographed with the Timed-Interval Device Immediately after Treatment with 100 ppm Paraquat.

Figure 47. Mesquite Tertiary Leaflets (Shown in Figure 46) Photographed 18 Hours after Treatment with 100 ppm Paraquat.

AERIAL APPLICATION EQUIPMENT

I. Introduction

An agricultural spray plane owned by the Texas Engineering Experiment Station has been made available to Texas Agricultural Experiment Station and USDA research projects for use in research programs on the aerial application of pesticides. The aircraft is a Model G-164 Grumman Ag-Cat manufactured by the Grumman Aircraft Engineering Corporation. This particular plane has the serial number X-1 and is the first experimental agricultural spray plane manufactured by Grumman.

Current and planned research studies by USDA and Texas Agricultural Experiment Station Projects involving the use of the Ag-Cat include; (1) development, testing, and improvement of aerial application equipment and techniques; (2) methods and techniques for controlling pesticide placement; (3) the effectiveness of thickened sprays as compared to conventional sprays for obtaining uniform placement of pesticide materials; (4) the effectiveness of thickened sprays as compared to conventional sprays for obtaining satisfactory plant control with herbicides; and (5) testing and evaluating various herbicides under field conditions.

During the past reporting year the USDA-AERD project on brush control participated in renovation of the aircraft and modification of the aircraft spraying system. The AERD project also cooperated with Texas Agricultural Experiment Station Projects on several studies involving the aerial application of herbicides to field plots and used the aircraft in studies to measure the penetration of sprays through foliage canopies.

II. Spray Equipment

The conventional spraying system for the Ag-Cat utilizes a 220 gallon capacity aluminum alloy hopper, a wind driven centrifugal pump and 2" outside diameter stainless steel piping and booms. The conventional boom is mounted inside the lower wing near the leading edge. Nozzle drops made of 1/8 inch alloy tubing extend below the wing. In order to add flexibility to the aircraft spraying system, a bi-fluid system for spraying invert emulsion was installed. This modification involved mounting a 20 gallon fiberglass tank inside the conventional Ag-Cat hopper for the oil phase of the invert, replacing the conventional centrifugal pump with a bi-fluid pumping system manufactured by the Transland Aircraft Company, and mounting a trailing-edge 2-in-1 bi-fluid boom equipped with diaphram cutoff bi-fluid nozzles on the aircraft. The conventional in-wing boom was left in place and piping provided so that it can be used when needed.

The bi-fluid pumping system consists of two centrifugal pumps driven from a single fan through a special gearbox. The water pump is mounted directly to the bottom hopper plate with the impeller in a horizontal position. Liquid flows directly from the hopper into the water pump through the 2½" inside diameter pump inlet port. The pump outlet connects directly to a 2" ball-type control valve. The oil pump is mounted on the back of a special strut-gearbox assembly with the impeller in a vertical position. Oil flows to the pump inlet through 1" outside diameter tubing. The pump outlet connects to a 1" inside diameter hose which leads to a 1" ball-type control valve. From the ball-type control valves the water and oil are either recirculated to their respective tanks or directed to the trailing-edge 2-in-1 boom where they flow through separate boom compartments to the diaphram cutoff bi-fluid nozzles. In the bi-fluid nozzles the two fluids pass through metering orifices and into a mixing chamber where the "flash" inversion process takes place. Several different sizes of metering orifices are available to vary the oil-water ratio. An oil to water ratio of 1:7 was used for 1965 studies. The invert emulsion formed in the mixing chamber then passes through the nozzle tip which contains 9 0.041" diameter orifices. Nine jet streams of flow are thus formed by each nozzle. At a fluid pressure of 30 psi each nozzle delivers approximately 1 GPM.

Figures 48 and 49 are respectively photographs of the bi-fluid pump system and bi-fluid boom and nozzles. Figure 50 shows the locations of the conventional interior mounted boom and the bi-fluid trailing-edge boom. Figure 51 is a schematic diagram of the 2-in-1 bi-fluid boom showing the separate oil and water compartments. The nozzle arrangement used for the conventional in-wing boom was developed at Texas A&M by the Engineering Experiment Station several years ago and is shown in Figure 52. The bi-fluid nozzle arrangement (Figure 53) was arrived at by making distribution pattern measurements after the bi-fluid system was installed.

III. Pumping and Calibration Tests

Brief calibration and pumping tests were made in cooperation with Range Science Department personnel to determine the suitability of the bi-fluid system water pump for pumping thickened spray materials through the conventional leading-edge boom equipped with #4664-D10-45 Spraying Systems Company nozzles. These tests were conducted on the ground by driving the bi-fluid pump system with a 10 HP gasoline engine and "V"-belts. Diesel fuel was circulated in the oil pump system while the water pump operated the conventional boom. The pump speed approximating actual application was determined by adjusting the ground-drive engine speed until the boom pressure when spraying water was the same as that during actual flying applications (30 psi) when the pump system is wind driven. The control valve settings were the same in each case. In this manner the pump speed was found to be approximately 3445 RPM when spraying water at 30 psi. Calibration tests were then made with both water spray and particulated spray (Norbak). Spray from all nozzles was collected for a measured length of time to determine the rate of flow. The mean flow rate from two replications with water spray was 20 7/8 GPM and the mean flow rate from four replications with particulated spray (4# Norbak/50 gallons water + 3/4% table salt added to water) was 21 3/8 GPM. The liquid pressure at the spray boom was approximately 30 psi for the water spray and 32 psi for the particulated spray. The boom pressure reached equilibrium rapidly (approximately three second lag) for the water spray but was slow for the particulated spray requiring approximately 20 seconds.

Figure 48. Bi-fluid Spray System on Texas A&M Ag-Cat.

Figure 49. Bi-fluid 2-in-1 Spray Boom and Nozzles.

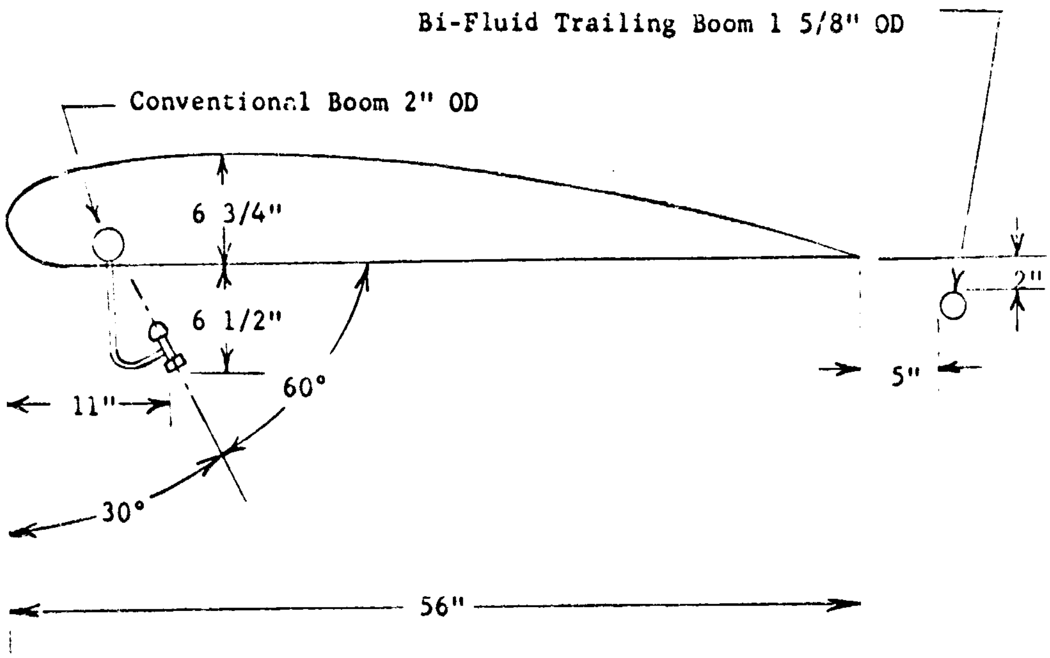


Figure 50. Schematic of Lower-Wing Showing Location of Conventional and Bi-fluid Booms.

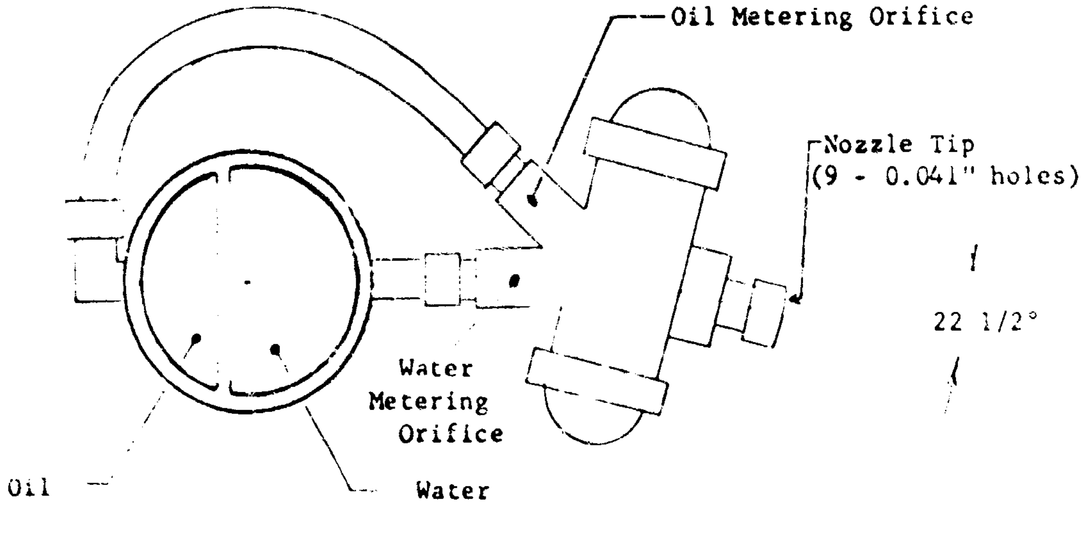
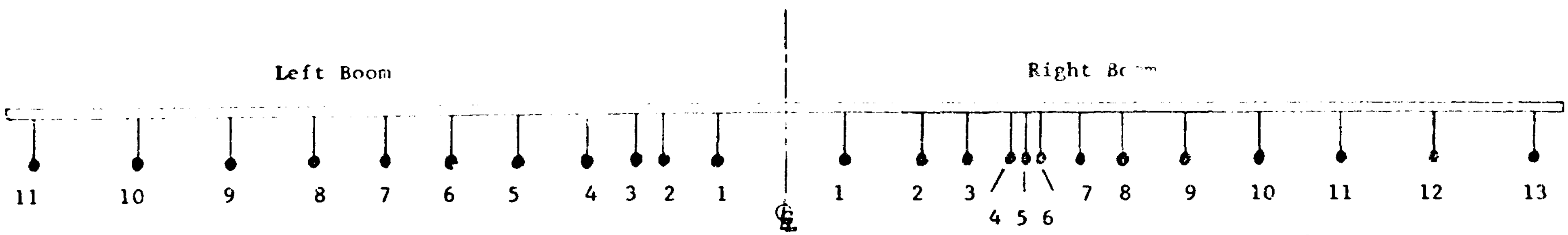


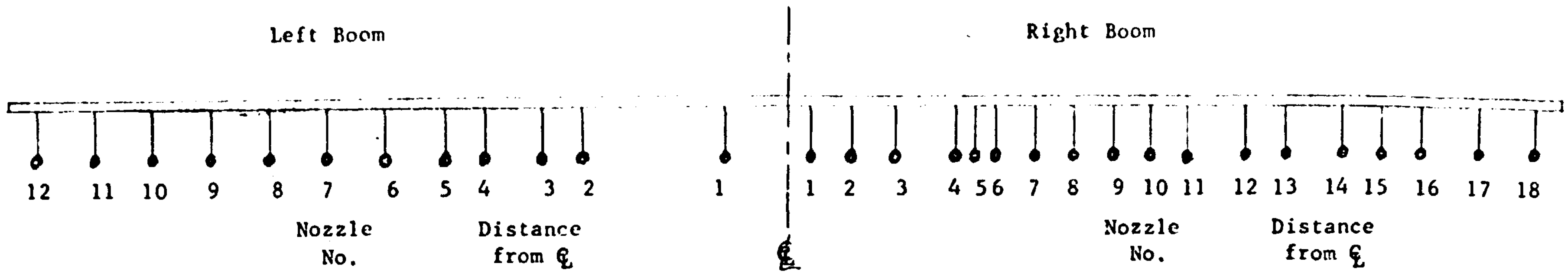
Figure 51. Schematic of 2-in-1 Bi-fluid Boom and Diaphram Cutoff Bi-fluid Nozzle.



Nozzle No.	Distance from ℄
1L	14"
2L	25"
3L	31"
4L	41"
5L	55"
6L	69"
7L	82"
8L	97"
9L	114"
10L	133"
11L	154"

Nozzle No.	Distance from ℄
1R	12"
2R	28"
3R	37"
4R	46"
5R	49"
6R	52"
7R	50"
8R	69"
9R	82"
10R	97"
11R	114"
12R	133"
13R	154"

Figure 52. Nozzle Arrangement of Conventional Leading-Edge Spray Boom Mounted Inside the Lower Wing



Left Boom

Nozzle No.	Distance from ℄
1L	13"
2L	42"
3L	50"
4L	62"
5L	70"
6L	82"
7L	94"
8L	106"
9L	118"
10L	130"
11L	142"
12L	154"

Right Boom

Nozzle No.	Distance from ℄
1R	5"
2R	13"
3R	22"
4R	34"
5R	38"
6R	42"
7R	50"
8R	58"
9R	66"
10R	74"
11R	82"
12R	94"
13R	102"
14R	114"
15R	122"
16R	130"
17R	142"
18R	154"

Figure 53. Nozzle Arrangement of 2-in-1 Bi-fluid Trailing-Edge Spray Boom.