CONSTRUCTION AND OPERATION
OF
GROUND EQUIPMENT
FOR
APPLYING CONCENTRATED SPRAYS

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CONSTRUCTION AND OPERATION OF GROUND EQUIPMENT FOR APPLYING CONCENTRATED SPRAYS

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This bulletin is a progress report on the development by the authors of ground equipment that can apply highly concentrated spray mixtures effectively. These machines avoid the necessity of handling large volumes of water and heavy equipment, increase rate and ease of coverage and reduce the cost of application. The discussion which follows describes (1) the basic requirements of different types and sizes of equipment, (2) equipment constructed by the writers and some adaptations made for existing equipment and (3) methods of operation of concentrate applicators. Certain of the better formulations for use in such equipment have been discussed by S. F. Potts and Philip Garman in a paper entitled, "Concentrated Sprays for Application by Mist Blowers for Control of Forest, Shade and Fruit Tree Pests," published in May, 1950, as Station Circular 177.[3]

I. Basic Requirements and Construction

NON-BLOWER EQUIPMENT

Power machines for applying mechanically atomized concentrated sprays are of several general types. The cheapest and simplest of these does not use a blower to help atomize the spray or to drive it to considerable distances. In machines of this type the spray mixture is pumped through hydraulic atomizing nozzles, such as oil burner and fan (flat) spray nozzles, that deliver 2 to 12 gallons per nozzle per hour at 20 to 75 pounds pressure.[4] The nozzles may project the spray in the form of a cone or in a flat, fan-shaped sheet. In the former case, they are usually spaced 12 to 14 inches apart on a boom; in the latter, they may be spaced about 18 to 24 inches apart.

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[1] U. S. Department of Agriculture, Agricultural Research Administration. Bureau of Entomology and Plant Quarantine.
[2] Connecticut Agricultural Experiment Station.
[3] For the first report on this subject, see S. F. Potts and R. B. Friend, "Mist Blowers for Applying Concentrated Sprays," Connecticut Agricultural Experiment Station Bulletin 501, 1946.
[4] Potts, S. F. 1942. Equipment Available for Applying Concentrated Sprays, pages 4 and 5. Bur. Ent. and Pl. Quar. E574, processed.

This type of machine is limited in use to certain types of low growth and cannot be used to spray entire trees. It is useful for applying certain insecticides and herbicides in solution or emulsion form and is employed for the low gallonage application of 2,4-D concentrates. The system is limited by the fact that with extremely low gallonage it cannot atomize the spray material to a sufficiently fine degree. From 20 to 40 gallons per acre of semi-concentrated spray suspension have been applied successfully to certain row crops for insect control with these machines, using two to three No. B2 or B3 whirljet nozzles,[1] or the equivalent, with 1/16- and 3/32-inch orifices, respectively, per 3- to 4-foot row.

The use of a large orifice and proper screens is required to prevent clogging by suspensions of solids. This results in a high output of fairly coarse spray. Line and nozzle screens of suitable mesh and surface area are important. Nozzle screens finer than 60 mesh may clog with any mixture and screens finer than 20 mesh are not satisfactory for suspensions. This type of application may not provide sufficient coverage for good plant disease control.

A second type of non-blower applicator uses a compressor to atomize the spray with compressed air, with or without the air blast of a fan to carry it. Very fine atomization can be produced with compressed air, but a blower is required for tree application. The compressor makes a more expensive, and sometimes a more complicated, machine.

MIST BLOWER EQUIPMENT

Sizes

Two methods of application characterize mist blowers. These are: (1) the use of a high air velocity of 200 to 300 m.p.h. to atomize and

TABLE 1. HORSE POWER, WEIGHT, AND AIR CAPACITY OF MIST BLOWERS

Horse power requirement	Weight (pounds)	Air velocity (miles per hr.)	Air volume (cu. ft. per min.)	Preferred mounting
1.5	90-100	225	150	Wheelbarrow, pick-up truck, trailer, small tractor
4 to 5	300	180	800	Trailer, truck, tractor
7	500 and 185[1]	175	1,700	Trailer, truck, tractor
15	700	145	4,000	Truck, trailer, big tractor
25 to 30	1,800 to 2,000	135	8,000	Truck, tractor-drawn trailer
40 to 50	3,000	125	12,000 to 15,000	Truck, tractor-drawn trailer
75[2]	4,000 to 5,000	120	24,000 to 30,000	Tractor-drawn trailer

[1] Weight of 185 pounds refers to use with light two-cycle engine.
[2] For discharging from both sides of machines.

[1] See page 35 of this bulletin and page 2, Catalogue No. 22 of Spraying Systems Company, 4021 West Lake St., Chicago, Ill.

distribute the spray; or (2) the use of a combination of medium high air velocity of 90 to 180 m.p.h. and hydraulic pressure nozzles or centrifugal spinner nozzles, to break up the mixture and distribute it.

The specific requirements of blower type applicators vary considerably with the kind of growth and size of areas to be treated. Table 1 indicates seven approximate sizes and capacities for general uses.

Fans and Outlets

There are two general types of fans, the axial flow and the centrifugal. So-called curved blade, squirrel cage or multivane, Sorocco, and multiple stage fans are merely modifications of these two types. No specific type of fan is best for all conditions.

Belt drives, and some direct drives, have been successful. Weakly constructed right angle gear drives always break down. However, a strong, specially constructed right angle drive can be made to work on a strong, steady frame. Fans should be steady and as free of noise as possible.

The principal factors determining the type of fan to use are the air velocity required to break up and deposit the spray, the size of the machine, and whether the outfit is to be operated by one or two men. In general, very small rigs utilize high velocity air to break up the spray by shearing action. Hence, they may use high velocity, low volume, single or double stage fans. Usually the medium to medium large rigs employ a combination of air velocity of 125 to 150 m.p.h. and hydraulic pressure of 150 p.s.i.,[1] or less, through whirl nozzles to atomize the spray. Machines of this type usually have delivered about 4,000 to 10,000 c.f.m.[2] of air by either of the two types of fans. Machines of very high volume and low velocity may require a small, high velocity, low volume auxiliary blower to break up the spray and distribute it into the air stream from a big fan or they may atomize the spray with whirl or fan type nozzles at 200 to 600 p.s.i. For most shade tree work, air velocities of 120 to 150 m.p.h. are required in volumes of at least 8,000 c.f.m. Volumes of 12,000 to 15,000 c.f.m. at velocities of 125 to 135 m.p.h. are preferred for 70- to 120-foot trees, especially where elm bark beetles and certain other pests in the tops of the trees are to be controlled.

There is an optimum ratio between velocity and volume at the orifice to attain the greatest height and distance with a given horse power under operating field conditions. The volume of air delivered is directly proportional to the square of the diameter of the outlet. Thus, a 24-inch outlet delivers four times as much air as one 12 inches in diameter at the same velocity. In shade tree work the optimum velocities for various sized outlets are as given in Table 2. The figures in Table 2 do not correspond

[1] Pounds per square inch.
[2] Cubic feet per minute.

exactly to those of Table 1, due primarily to a slight difference in outlet size, nor do the figures correspond with those of Table 3, since Table 2 represents the optimum conditions, while Table 3 represents the actual machine in use.

TABLE 2. OPTIMUM VELOCITY AND VOLUME FOR ROUND OUTLETS OF GIVEN DIAMETER FOR TREE APPLICATION[1]

Diameter of outlet (inches)	Optimum velocity (m.p.h.)	Volume (c.f.m.)
4	170	1,300
8	150	4,200
10	145	6,300
10.5	140	6,300
12	130	8,000
15	126	.......[2]
18	123	.......[2]
20	120	21,000
24	115	27,000 (approx.)

[1] This is ORIFICE velocity. Deposition velocity is much less.
[2] Figures not available.

In small machines like the wheelbarrow model, a much higher air velocity (200 to 300 m.p.h.) has been employed because air velocity provides the means of atomizing the spray.

The spray delivery for the different sized air outlets will vary as follows:

Outlet diameter (inches)	Spray delivery (gallons per hr.)	
	Range	Efficient for most purposes
1.25	5 to 15	7
2	10 to 25	14
4	15 to 40	20
10	20 to 72	40
12	25 to 120	50
15	30 to 150	60
18	35 to 168	70
20	40 to 180	80
24	45 to 180	90

In the large machines spray delivery should be calibrated to permit regulation of any specified delivery between 20 and 180 gallons per hour (1/3 to 3 gallons per minute).

The size, shape and flexibility of the outlet are important. For the small machines that deliver high velocities a very flexible outlet is essential to obtain even coverage. The round, short outlet is the most efficient shape for shade tree and mosquito work where the fine spray must be driven to

great distances. For the large, one man-operated orchard machines some air and power efficiency must be sacrificed in order to effect sufficient spread close to the machine, as shown in Table 3. This spread may be obtained with slot or fishtail outlets with spreader vanes or spoilers, or with multiple round ones.

TABLE 3. AIR VELOCITIES AT GIVEN HORIZONTAL DISTANCES FROM BLOWERS, DELIVERY THROUGH ROUND OUTLETS OF GIVEN DIAMETER[1]

Diameter of outlet (inches)	Approximate volume (c.f.m.)	Velocity (m.p.h.) at the following distances from blower							
		At blower outlet	10 feet	25 feet	50 feet	75 feet	100 feet	150 feet	200 feet
1	140	300	15	2	0				
1.25	200	225	20	3	0				
2	370	200	30	5	1	0			
4	1,300	170	40	8	2	0.2	0		
8	3,800	125	40	10	3	1	0		
10	6,100	140	70	35	6	3	1.8	0	
10.50	6,300	140	75	40	7	3	2	0 to 1	0
12	7,500	125	60	30	7	4	2.5	1	0
24	20,000	90	50	25	7	5	3	2	0
24	28,000	120	75	40	17	10	7	5 to 7	3
54[2]	27,000	50	35	30	8	4	3	2	0

[1] Air gauges used were: (1) a gauge for measuring air velocity in terms of inches of water pressure, (2) an airplane air pressure gauge for registering air velocity in miles per hour, (3) a special low velocity air speed gauge, and (4) a hand anemometer.
[2] Not an enclosure outlet.

The relative distances to which air is driven from slot type outlets that compare to round outlets is indicated by the data in Table 4.

The flexibility of the outlet may determine the type of fan to use for highest operational efficiency. For example, certain axial flow fans are more efficient in moving air straight away from the fan than the paddle or centrifugal type fans. However, to use axial flow fans in shade tree work, it is necessary to expend some horse power in forcing a directional change in the air stream. On the other hand, some of the paddle or centrifugal fan cases with straight, short outlets can be rotated or easily swung up and down in a 180 to 230 degree arc with no loss of air efficiency. This feature covers about 90 per cent of the situations to be met in general operation, and a 180 degree (half turn) turntable is sufficient to take care of the others. This provision also permits making the rig shorter, more flexible, simpler, and more efficient of operation.

The large machines, at least, should be designed for changing the shape and width of the air stream quickly while the machine is moving. Moreover, it is now possible to change the velocity of the air stream without changing the drop size, and to apply a wide, "soft" air-spray stream close

TABLE 4. DIMENSIONS OF SLOT TYPE OUTLETS AND ROUND OUTLETS REQUIRED TO DRIVE AIR SAME DISTANCE[1] AT GIVEN VELOCITY

Slot Outlet		Round Outlet	
Dimensions of slot outlet (inches)	Square area of slot outlet (sq. in.)	Diameter of round outlet (inches)	Area of round outlet (sq. in.)
3 x 24	72	5.1	20.5
3 x 36	108	5.4	23.0
3 x 50	150	5.7	25.5
3 x 70	210	6.0	28.3
3 x 96	288	6.4	32.2
3 x 100	300	6.4	32.2
4 x 20	80	6.3	31.2
4 x 30	120	6.6	34.1
4 x 36	144	6.7	35.1
5 x 40	200	8.1	51.3
6 x 30	180	9.2	66.5
6 x 60	360	9.7	73.5
6 x 70	420	9.9	78.0
7 x 70	490	11.2	98.0
7½ x 70	513	11.6	105.7

[1] Formula: To determine the diameter of round outlet required to give the same distance as a slot outlet of given dimensions:

$$W \times 1.3 + \frac{\sqrt{L}}{4} = D$$, where W = width of slot, and L = length of slot, D = diameter of round outlet

to the machine and suddenly change to a narrower, higher velocity stream to attain greater height and distance.

Nozzles

Nozzles must be capable of delivering any kind of mixture at appropriate rates. It should be possible to regulate the mass average drop diameter from 28 to 75 microns. This is ordinarily equivalent to a numerical average diameter of approximately 23 to 65 microns.

Large droplets carried in air at low velocities are deposited more readily than small droplets. Since air velocity from mist blowers reduces rapidly as distance from the blowers increases, it is advantageous to apply droplets of 41 to 65 microns for coverage at distances greater than 50 feet from the machine. A greater proportion of small droplets will deposit per unit area on small objects, such as insect antennae and pine needles, than on large objects such as oak leaves, because of the greater air "cushion" and eddies around the large objects. According to Yeomans and Rogers,[1] the minimum air velocity for efficient deposition with elevation or distance

[1] Yeomans and Rogers. 1950. Special Rept. ‡IN 2-22. Bur. Ent. and P.Q., U.S.D.A.

is 2.2 m.p.h. for 50-micron droplets when the sprayed objects are ¼ inch in diameter and 16.2 m.p.h. when the objects are 2 inches in diameter. For 100-micron droplets the optimum air velocity was calculated to be 1.1 m.p.h. for ¼-inch wide objects, and 4.6 m.p.h. for 2-inch wide objects.

Rate of fall and drift are other factors concerned in degree of atomization. For example, in still air droplets of 200, 100, 50 and 20 microns in diameter will fall 50 feet in 13, 51, 204 and 1,260 seconds, respectively. Droplets 200, 100, 50 and 25 microns in diameter will drift 43, 175, 700 and 2,800 feet, respectively, while falling 50 feet in a 2 m.p.h. wind.

Clogging must be avoided or reduced to a minimum. Clean tanks and suitable strainers in the line immediately back of the nozzles, the absence of whirl grooves in the nozzles and the use of nozzle orifices of at least 1/16 inch in diameter when applying abrasive suspensions and viscous oils and emulsions help prevent clogging. At pressures greater than 15 p.s.i. it is necessary to use hardened steel nozzles when applying concentrates containing abrasives like sulfur and wettable DDT. At pressures greater than 30 pounds, hardened, rust-proof nozzles should be employed regardless of the mixture dispersed. The whirljet type nozzles with ⅛-inch female pipe connection have been fairly satisfactory at pressures of 30 to 100 p.s.i. The direct pressure nozzles must be placed inside of the air blast to obtain maximum atomization by the air and should be spaced in such a way that the mist is distributed throughout the air stream with as few nozzles as possible. This permits using larger orifices. Oil burner nozzles with fine screens and small (.01 to .03 inch) orifices are satisfactory for applying thin, light oils and emulsions but will clog with suspensions. Heavy oils can be applied in emulsions containing up to 30 per cent oil.

The optimum number of direct pressure nozzles on air-liquid nozzle manifolds varies with the diameter and number of air outlets and the nozzle output (g.p.m.[1]). For single air outlets less than 7 inches in diameter, a single nozzle is usually pointed against the air blast or at right angles to it. In the case of multiple small outlets, one direct pressure nozzle per outlet may be installed. For a single 12-inch diameter outlet, the use of four nozzles at right angles to the air blast is satisfactory.

For applying some of the heavy, viscous suspensions and straight, heavy oils at low temperatures, a pressure of at least 40 pounds is used and a nozzle with 3/32- or ⅛-inch orifice is pointed against the air blast and placed in the center of the outlet. Placing the nozzles in the same direction as the air stream results in too coarse atomization. At pressures varying from 12 to 700 p.s.i., the speed of water ejected from the orifices ranges from 28 to 220 m.p.h.[2] The atomization depends upon the relative speed of the air past the nozzle. Hence, a stream from the nozzle directly against the air blast increases the shearing effect as the speed of the drops is added to the speed of the air.

The hollow jet or shear type of nozzle requires higher air velocity for atomization than direct pressure nozzles, and a low liquid pressure of approximately 3 to 6 p.s.i. Larger air volumes also aid in atomization.

[1] Gallons per minute.

[2] $V = 8.3 \sqrt{\text{gage pressure at nozzle}}$

For air outlets 1, 2, 4 and 12 inches or greater in diameter, air velocities of 250, 225, 180 and 150 miles per hour, respectively, are needed for fine atomization with these air velocity, shear type nozzles. Particle size can be changed by changing the direction of the jets in relation to the direction of the air blast. Two sizes of tube orifices (1/16" and 3/32") are usually used. They are sharpened at their free ends to increase shearing action. For outlets 1, 1.5, 2, 4 and 12 inches in diameter, approximately 3, 4, 5, 6 and 8 tubes, respectively, should be used. The number of hollow jets can be reduced somewhat as the size of their orifice is increased. Provision can be made to reduce output by shutting off any number of tubes of the nozzle manifold.

On large machines, an auxiliary high velocity blower to atomize the spray into the stream of high volume, low velocity air coming from a large fan offers possibilities of improvement. This arrangement permits a greater control of particle size range since in our experience the low velocity air (30 to 80 m.p.h.) will not change materially the size of droplets smaller than 80 microns in diameter unless they are injected against the air blast. Moreover, this system generally permits a conservation of horse power since it requires about twice the horse power to double the velocity at a given air output. The system has a disadvantage in that it adds another item, the small, auxiliary high velocity blower.

Pumps

There are three general kinds of liquid pumps which may be used: plunger, centrifugal and gear. Plunger pumps can deliver any kind of mixture at any pressure. They are heavier and more expensive, but if kept in repair are more durable than gear types. Metal centrifugal pumps can deliver any kind of mixture at low pressures (below 40 p.s.i.). Spur type gear pumps can deliver up to 150 pounds pressure at 1,200 to 2,000 r.p.m.[1] Ordinarily, abrasives like sulfur and cryolite will wear off the gears at such high speeds and pressures. Present types of gear pumps do not last long when applying such abrasive substances at high speeds with pressures above 15 to 20 pounds. However, at pressures of 2 to 15 pounds and at speeds of 350 to 700 r.p.m., good ones may last one to three years. They are usually more satisfactory than centrifugal pumps for most mist blowers. For the small machines a 1/4" gear pump is adequate; however, large rigs may require a 3/8" or 3/4" gear, or a 2 to 4 gallon per minute plunger pump.

The pumping systems require oiling, suitable liquid by-pass arrangements, relief valves, and pressure gauges with diaphragms to keep the liquid from entering the gauges. Gear pumps without "built in" pressure relief regulators are preferable for general use. To pump at specified low pressures, a suitable relief valve and large capacity by-pass are essential. Steady pressure without pulsations is essential in all spray systems.

Washers, Gaskets, Hose

All washers, gaskets and hose must be resistant to oil solvents. Disintegrating rubber parts in the line can plague the operator continuously by repeatedly plugging the nozzles. Leather washers and neoprene hose (such as Weatherhead hose) are more resistant than natural rubber products. It is expected that some of the new plastic materials may replace rubber materials.

[1] Revolutions per minute.

Tanks and Agitators

Supply tanks should be of the proper size and shape. This depends on the capacity of the machine and the nature of application. On big machines 40- to 75-gallon tanks are suitable for shade tree spraying, but 75- to 300-gallon tanks may be desirable for fruit trees. A round or trough-shaped bottom with a mechanical agitator is desirable for mixing any kind of material, and for agitation. By-pass agitation is insufficient. Paddle type agitators should move slowly, sweep the bottom, and be provided with a disengaging mechanism. For filling purposes tanks should have a wide mouth provided with 12- to 16-mesh removable strainer. It is helpful to have a quantity gauge for reading the volume of mixture in the tank. The tank metal should be non-corrosive, and any paints applied to it should be able to withstand oil solvents and ordinary spray chemicals.

The construction must enable the operator to drain the tank and spray line quickly and completely. Hence, a large tank drain plug should be located conveniently. Sometimes it is handy to be able to connect a hose to the drain plug connection to convey the waste solution to a disposal spot. It is important to avoid strainer wells in the tank's bottom. It is also important to be able to shut off the tank from the spray line at a point immediately below the tank to prevent spray material from settling down into the spray line, strainers and nozzles.

The installation of an auxiliary 1 to 3 gallons graduated flush tank is helpful. This facilitates quick flushings of the spray line at the end of each spraying job or between change of mixtures. This small tank can be used as a material tank for small jobs or when treating individual trees. It should be connected to the main supply tank and provided with a shut-off between it and the supply tank.

As few corners, turns and restrictions as possible should be made in the spray line between tank and nozzles. The pipe or hose line should be as short as practicable and of sufficient size (usually 1/4 to 3/4 inch inside diameter) to maintain a rapid flow and thus prevent stoppage by sludge.[1]

Other Construction Details

Screw type valves should not be installed except for regulating pressure or liquid to be by-passed. A quick acting shut-off valve operated by a foot or hand lever is absolutely essential. It must be conveniently located so that the operator can use both hands simultaneously for "finger touch" manipulation of outlet and liquid and dust shut-off levers. It should also permit him to observe the spray operation continually without changing his line of vision.

One large surface area strainer of approximately 16 mesh should be located between tank and pump. A 20-mesh strainer of smaller size should

[1] See Groves, Johnson and Walker. Washington Agr. Expt. Sta. Bul. 515. 1950.

be placed in the line between pump and nozzles. All coarse mixtures prepared outside of the machine should be poured through a strainer in the top of the spray tank. Many modern spray materials of small particle size, however, do not require it.

Some means of measuring and regulating the quantity of spray material delivered per minute, per tree, per given area, or per given distance of travel is helpful. Hence, there is a definite need for at least one of three types of meters: a flow meter, a time (dial) meter, and a distance or low speed speedometer to measure rates of travel between 0 and 6 miles per hour.

The turntable may be power driven by hydraulic motor or electric motor equipped with generator; or the machine may be turned with a wheel and cable. The latter is the cheapest and simplest method. The turntable should be provided with a good hand or foot brake.

For shade tree and mosquito spraying, the machine is usually mounted on a truck with wide tires to reduce damage to lawns. For treating orchards, it is usually drawn on a trailer.

For night work a good spot light can be mounted on the rotating outlet head or heads.

A throat microphone, or preferably a two-way chest microphone, is useful for communication between operator and driver. The throat microphone costs less than 10 dollars, and consists of ear phones, four 1½ volt dry batteries, a rubber covered, two-strand wire, and throat microphone.

MIST BLOWERS FOR SPECIAL USES

Orchard Equipment

Some variations in adaptations, design and method of operation are necessary for orchard equipment. The size of the machine depends somewhat on the size of the orchard. The small orchard machines are similar to small shade tree machines, in that they may be operated by two men and may be provided with rotating, flexible single or multiple outlets. In general, they deliver higher air velocities than large rigs. The rate of travel and rate of coverage increase as the capacity and size of the machines increase.

The big machines may be operated by one man and should be able to cover simultaneously all parts of the tree, including lower leaf surfaces, when spraying from one or both sides of the machine. Hence, a wide spread of spray must be produced at the machine and there must be enough drive to carry the mist to the top centers of the trees, while delivering a "soft" air stream to the lower portions.

Air velocities of at least 120 miles per hour are desirable and up to 150 or 175 have given satisfactory results. Both slot and circular outlets have been provided by manufacturers. For large trees either movable vanes or a flexible rubber collar or other means to permit direction of the

spray are important. The revolving spray delivery outlet devised by Dr. Brann (page 24) has apparently worked well. The latter stirs up the air effectively and turns over the leaves allowing them to be sprayed on the undersides. Some provision for greater amounts of spray to be delivered to the tops of orchard trees, in comparison with the sides, is important and is a feature of several newer model mist blowers. For the shorter length slot deliveries, promising mechanically operated oscillating mechanisms have been invented.

For any of the various machines the angle of delivery should be adequate for large trees (about 110°) or adjustable to take care of both large and small trees.

The use of slot or fishtail outlets with vanes is the most familiar way of spreading the air, although it is wasteful of air and power. The outlets may be held in a fixed position or oscillated up and down when held in a horizontal position by a cam eccentric. One spreader method that has worked successfully employs two separate fans on the same shaft to deliver 125 m.p.h. or more of air through two 4- by 24-inch adjustable fishtail outlets. One of the outlets drives the air from a low position on the machine to the lower two-thirds of the tree, while the other delivers from a higher position to the top center of the tree. The top outlet should be shorter and wider than the bottom one. It may develop that this upper outlet should be an adjustable single outlet, or a double round outlet which would give a vertical angle of spread of between 0 and 25 degrees.

In any case, the atomizing system should fill the air stream without delivering too much spray mixture. Moreover, it is advantageous if the operator can change at will the velocity, volume and spread of the air without changing drop size. For the large machines, this feature may require the use of a small auxiliary high velocity (250 to 300 m.p.h.) blower with one or more outlets to atomize the spray to a given drop size, irrespective of the air velocity from the big, low velocity (50 to 80 m.p.h.) high volume fan.

Tanks should hold 100 to 300 gallons of mixtures, depending on size desired. Orchard rigs should be streamlined so that they can pass freely through close tree plantings. Usually, they should be trailer-mounted, and flexible, to reduce wastage of material.

Row Crop Equipment

Development of row crop equipment is in the initial stage. The conventional use of two or three spray nozzles per row is not practical for applying concentrate suspensions because, if the orifices are sufficiently large (1/16 to 3/32 inch) to avoid clogging, at least 50 gallons of mixture may be applied per acre. If the size of the orifices and the pressures are reduced to lower the spray delivery, clogging will result. A remedy for this problem would seem to be the distribution of the output of each liquid nozzle over more than one row, using air from the spreader outlets. The machines should travel 2.5 to 5 miles per hour, the rate of mixture applied per acre being in inverse ratio to rate of travel.

Rapid coverage with low gallonage should be possible in two ways. First, by using a round outlet containing one or more liquid nozzles to deliver spray at right angles to the line of travel. For instance, machines delivering air at 3,000 c.f.m. or more are mounted at least 3 feet above the ground so that sprays will be delivered to a considerable distance. With this arrangement, 15- to 75-foot strips (5 to 25 three-foot rows) are treated from two opposite sides. The width of the strips covered depends on the size and capacity of the machine. The larger outfits may over-shoot three to five rows nearest to the machine. However, this can be remedied by using a deflector or spoiler to deflect downward at least a portion of the mist from one nozzle onto the rows close to the blower. Thus far, this method has been promising for insect and disease control when delivering as little as 4 to 7 gallons of concentrate per acre.

The second method of obtaining rapid coverage with low gallonage attempts to cover a narrower strip with a smaller machine by directing the spray and air blast rearward or forward of the carriage vehicle. To accomplish this, the air may be delivered through one of three types of outlets: (1) a manifold of three to five round outlets, (2) one large slot or fishtail outlet with spreader vanes, or (3) three to five smaller fishtail or slot (fan) outlets. In the multiple outlet manifolds, the outside outlets point at an angle of about 45 degrees to the line of travel, while the outlet or outlets in the center point along the line of travel. Thus, each air-liquid nozzle, properly directed, can cover more than one row. The nozzles should be at least two feet above the plants in order to direct the blast slightly downward towards them at an angle of 15 to 20 degrees from the horizontal. Directing the air blast at this angle causes considerable rebounding of the mist onto the undersides of the leaves.

Preliminary work indicates that machines of 5, 7 and 15 h.p. could cover approximately four, six and eight rows (3 to 5 feet apart), respectively, at about 3 miles per hour travel.

II. New Machines and Adaptations

The foregoing discussion was concerned with the construction and basic requirements of mist blowers, and with methods of operation. The discussion which follows is concerned with new machines developed by the writers, and with adaptations made by them for existing equipment.

NEW EQUIPMENT

Electric Hand Blower

Previously, two serious weaknesses of most electrical units have been (1) inability to apply suspensions, and (2) lack of sufficient air velocity or pressure to feed the liquid properly and atomize it finely. The smallest power unit developed by the authors weighs 12 pounds (Figures 1 and 2) and consists of a multibladed centrifugal fan, a 1/3 to 1/2 h.p. high speed electric motor, and a removable outlet having a screw top to fit 1-, 2- and 4-pint jars. The nozzle tip is a hollow tube, 3/32 inch in diameter, placed at the center of the outlet for applying any kind of concentrate. A needle valve on the feed line just above the jar top regulates the spray output. Within limits, the drop size can be increased with increase of liquid output.

Figure 1. One-third h.p. electric mist blower with screw-top for jars of one to four pints capacity, for indoor, greenhouse and garden treatments. Side view. Weight: 12 lbs.

Figure 2. Front view of electric mist blower to show nozzle position in outlet and needle valve to regulate spray output.

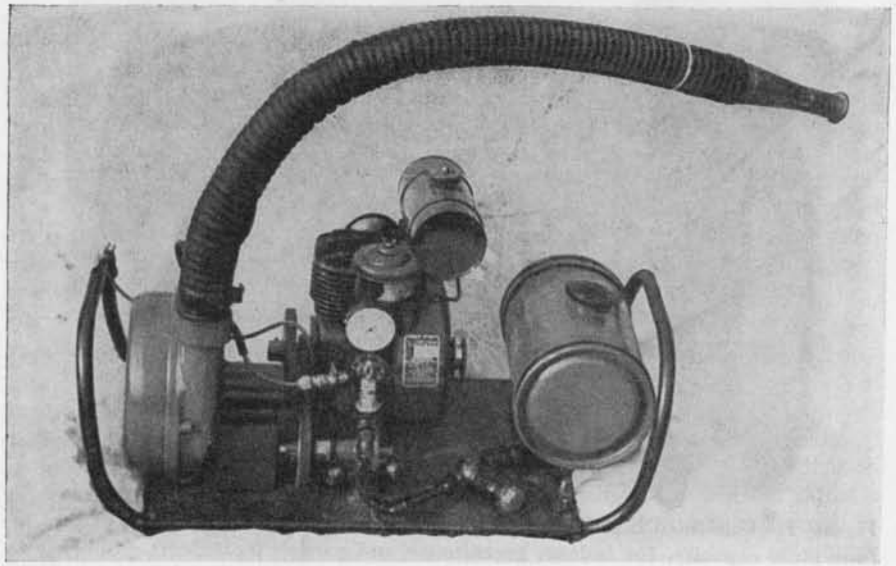

Figure 3. Skid model mist blower for mounting on a cart, small tractor, truck or wheelbarrow. Dry weight 88 lbs.

The liquid is fed partly by suction and partly by air pressure. The air outlet is ¾ inch in diameter. Approximately 50 c.f.m. of air is delivered through it at about 200 m.p.h. This is sufficient air to atomize a maximum of 3 gallons of concentrate solution, emulsion or suspension per hour.

Small Skid and Wheelbarrow Models[1]

A small skid model mist blower weighing 88 pounds (Figure 3) has been developed for applying solutions, emulsions and suspensions. This unit can be mounted on a horse, cart, trailer, tractor, truck or wheelbarrow. It can be regulated for applying ½ to 12 gallons of mixture per acre, using an operating pressure of 4 to 8 pounds per square inch. The tops of 30-foot trees can be reached, and the spray can be drifted horizontally for 200 feet or more. It consists essentially of a small tank of 1 to 3 gallons capacity, a strainer in the spray pipe line, a gear pump, a pressure gauge, a needle valve for regulating spray delivery, a quickly operated shut-off valve, an atomizing nozzle and aluminum pressure blower, such as Allen Billmyre Model 10HR12, and a 1 to 2 h.p. gasoline engine, such as the 1.3 h.p. Lauson engine (Model R.S.C.). The blower on the units shown in Figures 3, 4 and 5 weighs 15 pounds. It delivers 160 c.f.m. at 225 m.p.h. through a 1¼-inch diameter air outlet attached to a 3-foot flexible 2¼-inch auto hose. The best operating speed for the blower fan is 8,000 to 10,000 r.p.m. Gear pumps (¼ inch size) are satisfactory when turning at 300 to 700 r.p.m. A maximum of 2 gallons of mixture per minute can be applied, but 4 to 8 gallons per hour is usually the best delivery for optimum drop size and coverage.

[1] **Patent No. 2,454,339.**

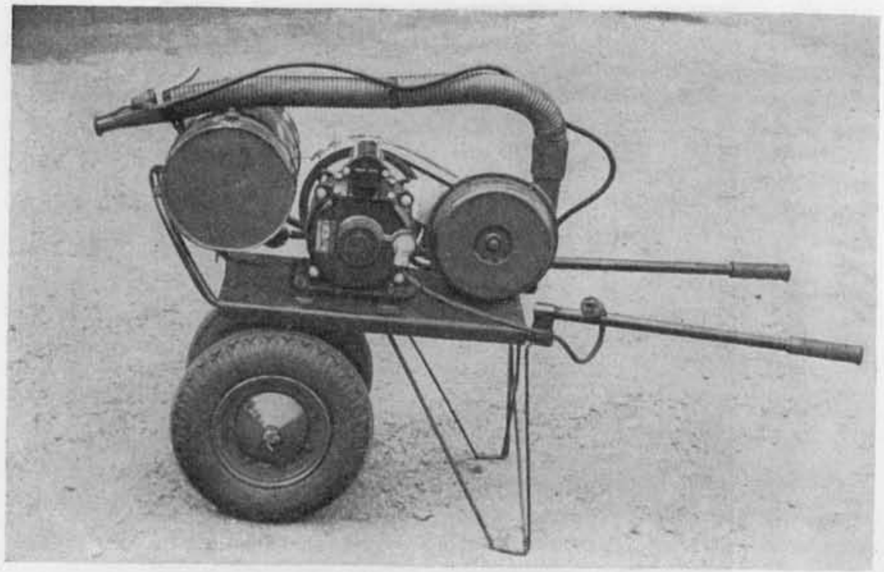

Figure 4. Side view of wheelbarrow mounted mist blower powered with an electric motor, flexible air hose and hand shut-off near nozzle.

Figure 5. Small mist blower weighing 140 lbs., powered with gasoline engine, mounted on a wheelbarrow chassis. Quick acting spray shut-off, fan speed and direction of spray are controlled at the two handles.

Figure 6. Showing operation of wheelbarrow model mist blower by one man in spraying 30-foot apple trees. One rig treated 12 trees per hour at ½ gallon of mixture per tree.

Two kinds of nozzles have been used: (1) a direct-pressure type requiring 40 to 60 pounds pressure, and (2) a capillary-tube (air velocity) nozzle with four 1/16- or one 3/32-inch hollow brass tubes projecting from the periphery of a circular feed pipe for a distance of ¼ inch into the mouth of the outlet. The brass tubes are sharpened at their free ends to increase the shearing action of the air blast that passes over them at right angles. Some of the uses for the machine are given by Potts and Spencer.[1]

The wheelbarrow model (Figure 5) weighs 140 pounds and was described in its early stage of development.[1] Later, the machine was

[1] **Potts, S. F. and Spencer, R. A., 1947. A small portable mist blower for applying concentrated sprays. ET-234. USDA., BEPQ., processed.**

converted to a one man-operated outfit by making three important installations at the handles. The spray shut-off valve is opened or closed by turning the left handle grip sleeve. The engine throttle is also located at this handle. The grip sleeve of the right handle is similarly turned to rotate the blower cases and nozzle outlet. This permits the direction of the spray to any angle up or down from the machine while it is being pushed by the operator (Figures 5 and 6). A convenient means of tightening belts is arranged. A kick stand is provided to prevent the machine from overturning when standing on a steep slope.

A four-row Potts-Spencer skid model machine mounted on a farm tractor is described by Rowell and Howard.[1] In this unit the liquid is discharged through liquid fan spray nozzles near the mouth of fan-shaped air outlets equipped with spreader vanes. One outlet is used per 2- to 4-foot row.

An electric model (Figure 4) has been developed for use where a gasoline engine is not acceptable. It is essentially the same as the skid model except for the electric motor and two-wheel wheelbarrow chassis

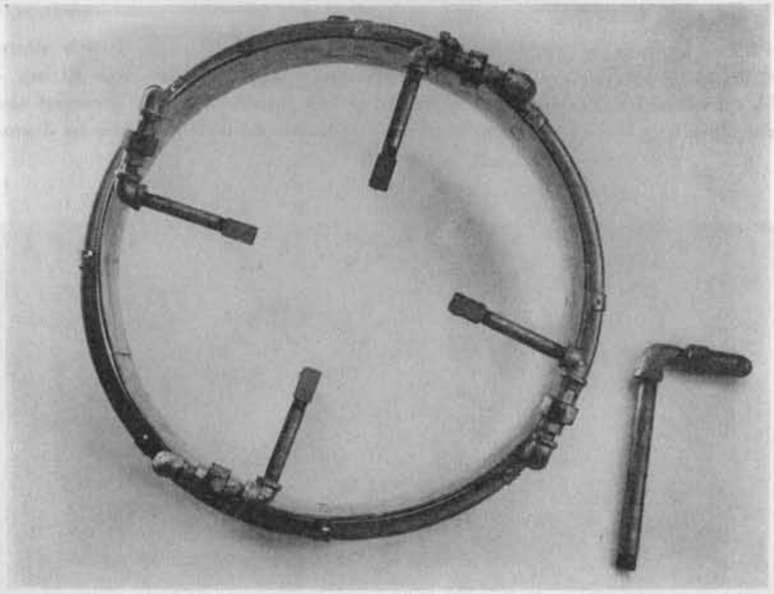

Figure 7. Nozzle manifold and assembly for 12-inch diameter round air outlet. Adjustable for setting given numbers of direct pressure nozzles of various sizes and types at given positions inside or outside of the outlet. Nozzles may be turned at any angle in relation to direction of air blast.

[1] **Rowell, J. B. and Howard, F. L. "Mist blower" fungicidal concentrates for row crops. (Abs.) Phytopathology 39 (1): 21, 1949.**

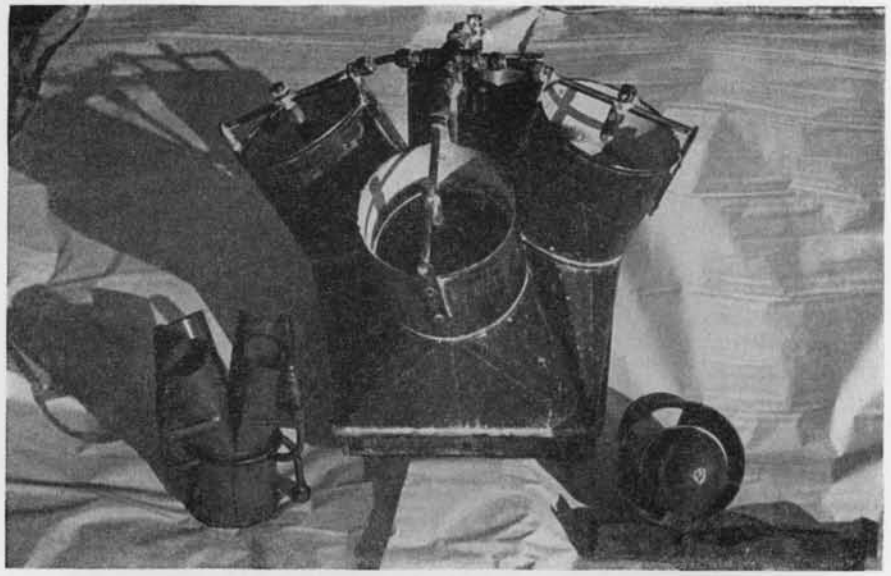

Figure 8. Quadruple spreader outlets. Assembly for small 4-inch diameter outlet is at lower left. At upper center is a large outlet for fitting onto the 14 x 14-inch outlet of a 25 h. p. machine. A liquid nozzle is reversed against the air blast in each of the four outlets which are each 7¼ inches in diameter.

Figure 9. Quadruple spreader outlet with 50 degree included angle.

Outlets and Nozzles

Round air outlets. A very useful 12-inch diameter nozzle manifold is shown in Figure 7. With this assembly, which includes a set of short and long nipples, plugs, and reducer couplings, from one to four nozzles of ¼-inch or ⅛-inch connection can be attached. For most work four nozzles are placed at the mouth of the outlet in the air blast, usually at right angles to it. This fills the air stream with spray. Two or three makes of nozzles have been satisfactory, including the whirljet types B1, B2 and B3.

With this manifold it is possible to place the nozzles at any point between the center of the outlet and a position outside of the outlet. Moreover, the nozzles can be pointed at any angle, so as to spray in any direction in relation to the direction of the air blast. In all of our work with round outlets, however, we have found it best to place the nozzles inside the air blast.

Spreader outlets. Spreader outlets developed have been of two general types: (1) multiple round outlets, and (2) fan or fishtail shaped ones, with and without spreader partitions, fins or vanes. Multiple round outlets are shown in Figures 8, 9 and 10. One conventional liquid whirljet (B1, B2 or B3) or Monarch nozzle is reversed against the air blast in each

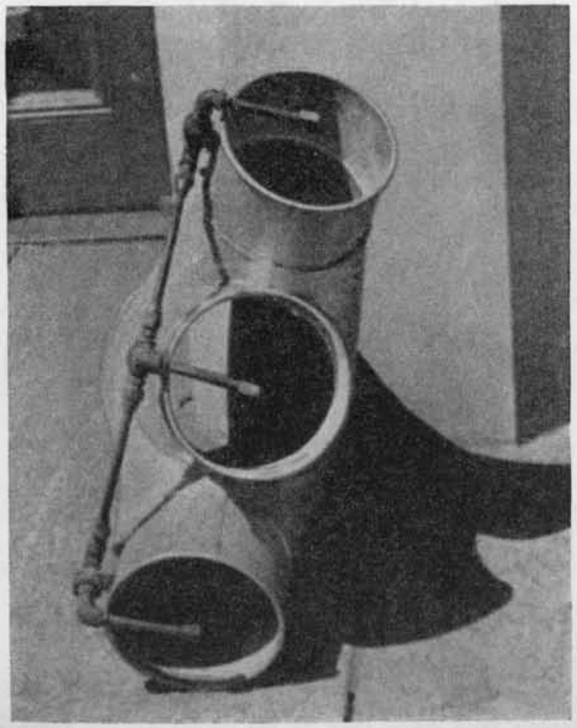

Figure 10. Triple outlet manifold with outlets forming a 70 degree included angle. The outlets are each 7 inches in diameter and have a No. 2 or No. 3 whirljet nozzle reversed against the air blast at the center of each outlet.

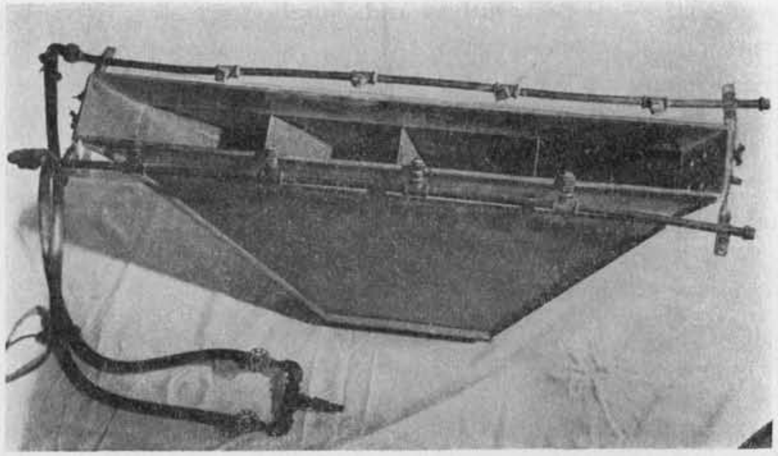

Figure 11. Fan-shaped outlet, 4 x 36 inches, with spreader vanes and nozzle assembly of eight staggered fan spray nozzles directed at a 35 degree angle against the air blast. Two shut-off valves and plugs enable operator to use from one to eight nozzles.

outlet. The included angle of the round outlet manifold ranges from 50 to 90 degrees. In the triple outlet (Figure 10) this can be set between 0 and 70 degrees by turning it from the horizontal towards the vertical position.[1]

The stationary triple and quadruple outlets may not cover sufficiently the tops of 30-foot apple trees. When the outlet manifold is oscillated up and down, coverage is effective. When oscillated, the triple outlet is slightly more effective in a horizontal position than when in a vertical position.

The ordinary, single fishtail type outlets without spreader vanes have been unsatisfactory for big trees[2] in that (1) their outlets are too narrow (1 to 3.5 inches) to obtain distance and penetration (pages 9 and 10) when traveling more than 1.5 miles per hour, (2) they do not provide sufficient angle of air spread, and (3) the highest velocity is in the center of the outlet.

Figure 11 shows an outlet, 4 x 36 inches, with spreader vanes, and with four nozzles on each side. The nozzles are staggered so that no two are opposite each other. Moreover, there is a shut-off valve for each side so that, if desired, the nozzles of one side can be shut off while the others are spraying. Usually the nozzles are reversed against the air blast in the mouth of the outlet.

[1] J. L. Brann of Cornell University has devised a means of rotating these multiple round outlets by power from the motor at 10 to 20 r.p.m. This gives a wider angle of coverage than when they or the single fishtail types are held in a fixed position.

[2] An effective slot type outlet 3.5 inches wide x 7 feet long has been developed by Cornell University entomologists and engineers and is now in commercial production. This is not what we consider a true fishtail type.

ADAPTATIONS OF EXISTING EQUIPMENT

Conversion of Orchard Duster

Many growers have orchard dusters of the type which can be converted for concentrate application. One outfit used delivers about 1,300 c.f.m. of air at 175 m.p.h. through a 4-inch diameter outlet (Figures 12 and 13). The high air velocity provides a good break-up of spray.

A converted machine is shown in Figure 12. It consists of a 30-gallon tank with mechanical agitator to turn at 100 r.p.m.; a 2 to 5 gallons per minute (2 g.p.m. is sufficient) plunger pump; one line strainer of 16 mesh between pump and tank, and another line strainer of 20 mesh between pump and lever operated shut-off valve. A 20-mesh monel metal strainer should be placed just back of the nozzle. A nozzle with orifice of 1/16 or 3/32 inch (as whirljets ⅛ B1, B2 or B3) is reversed against the air blast near the mouth of the air discharge pipe. In Figure 12 the unit is shown mounted on a trailer with spring seat. In Figure 13 it is in a ½-ton covered truck. This converted machine has been used as a duster, a concentrate applicator, and for combination spray-dust applications. The triple, quadruple and fan spreader outlets shown in Figures 9, 10 and 11 have been used. They have certain advantages for trees under 15 feet in height, but do not cover tall fruit trees from a fixed position.

Mechanically Produced Aerosol

A mechanically produced aerosol of 5 to 20 microns diameter droplets has been applied by delivering 10 to 30 gallons per hour of liquid through compressed air nozzles at 5 p.s.i. liquid pressure; and compressed air at 35 to 50 p.s.i. The compressed air nozzle was placed at the mouth of the

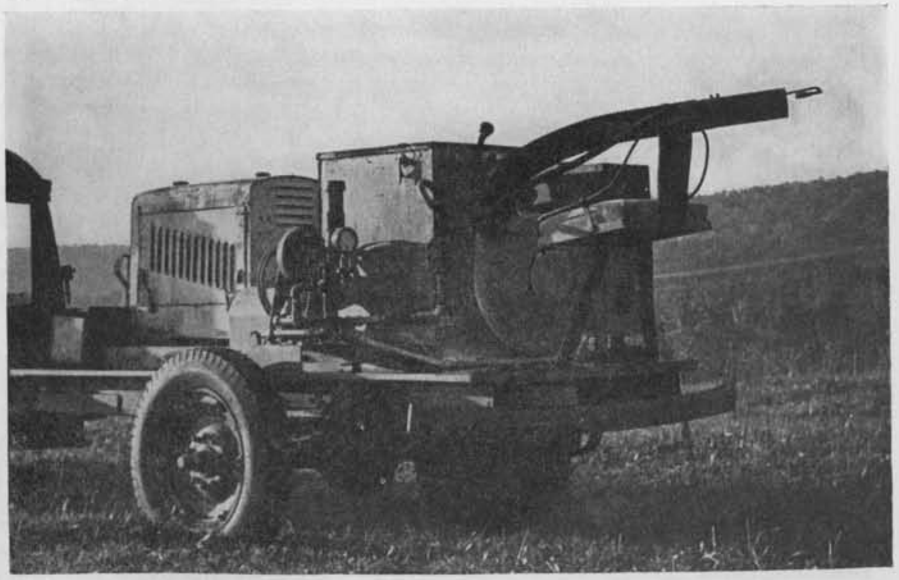

Figure 12. Cyclone duster converted to a concentrate sprayer and sprayer-duster. Mounted on a two-wheel trailer, with spring seat, and with a nozzle reversed against the air blast in front of outlet.

outlet, or at right angles to the air blast of the blower. This system required the installation of a compressor. Its use seems to be limited to indoor treatment.

Modification of Mist-Duster

Figure 14 shows a trailer-mounted, 25 h.p. modified single outlet machine. It delivers about 8,000 c.f.m. of air at about 124 m.p.h. The original unit was modified by removing the 3 x 38 inch fishtail outlet and replacing it with a short cylindrical discharge pipe, 12 inches in diameter. The fan case and outlet can be rotated in a 180-degree arc.

For applying small quantities of mixture, a 15-gallon tank and a ½-gallon tank were installed. The ½-gallon tank was graduated into ounces on a glass water gauge tube. The 115-gallon flat bottom tank which came on the machine was replaced with a round bottom, 50-gallon tank with an improved mechanical agitator. A four g.p.m. plunger pump was attached which could develop a maximum of 400 pounds pressure. A special by-pass system was installed to permit an even flow of liquid with as low as 2 pounds pressure for testing air-velocity type nozzles (see page 10). This machine is shown treating an 80-foot red oak while mounted on a 1½-ton truck (Figure 15). In Figure 16 it is shown treating the Yale Bowl for mosquito control.

Figure 13. Twelve-horsepower high-velocity blower-atomizer treating orchards, using flexible 4-inch diameter discharge tube.

Figure 14. Twenty-five horsepower blower-atomizer on trailer showing large and small tank, dust hopper, hand-operated spray shut-off lever, and ring of eight oil-burner nozzles mounted in discharge outlet at a 45 degree angle to air blast.

Conversion of Speed Sprayer

To make this conversion, remove all speed sprayer nozzles and the several short feed pipes to which they are attached. Replace this assembly with four to ten ¼- or ⅜-inch threaded short feed pipes, on each side of the machine. Screw one end of each of the pipes into a reducer bushing of the spray head manifold. Onto the other end screw a hardened steel or whirljet nozzle, a B1, B2 or B3, depending on whether a solution or a suspension is to be applied (see Table 11). The number of nozzles and their vertical spacing should provide maximum deposit and coverage of the entire tree with special reference to the top center of its crown. Four to six nozzles should be used on each side for peach trees and small apple trees; seven to ten or more for large apple trees.

The nozzle orifice is usually turned against the airblast at the point of highest velocity. This is ¼ inch back of the bell-shaped divide or baffle in the outlet, on the end towards the fan. However, in order to fill the air stream adequately we have found it desirable to place nozzles ahead of the baffle and to put more nozzles at the top of the machine than along its sides. None of the nozzle assemblies tried so far has worked well above four times normal concentration, possibly because of low pump pressure.

A slight increase in velocity (the speed sprayer delivers 100-110 m.p.h.) may be had by operating only one side and closing the opposite, or by partly closing the shutters on both sides.

The B1 whirljet nozzles are efficient for oil emulsions, miscible oils, lime-sulfur, Puratized and other solutions, but may clog with suspensions.

III. Coverage

The mist from a blower rises best on calm, warm, dry, sunny days, when there is some upward air current. Height is most difficult to attain on cold, damp, cloudy, windy days. High wind is the most important deterrent to mist blower application, and complete coverage of tall shade trees should not be attempted with winds greater than 5 miles per hour. On the other hand, certain types of application, such as mosquito control, are favored by light winds which carry the tiny droplets to great distances (often 500 to 1,000 feet) from the applicator. In the latter type of applica-

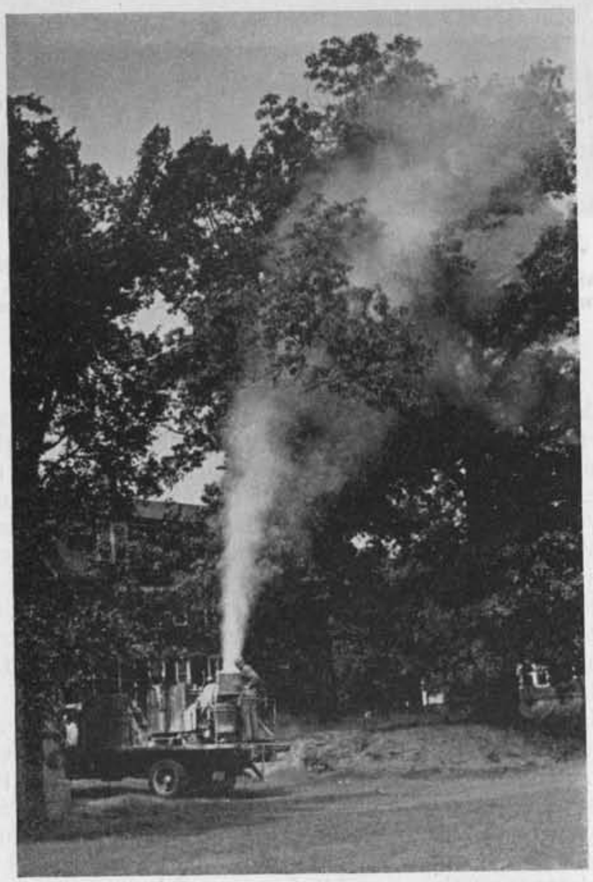

Figure 15. Twenty-five horsepower blower-atomizer treating an 80-foot red oak at Yale Bowl, New Haven, Conn. Machine was equipped to apply dust, aerosol, spray-dust, and atomized concentrates. Nozzle assembly is such as to fill the air stream. The large outlet and velocity control makes possible a wide spray stream. A small amount of dust was added to facilitate photographing.

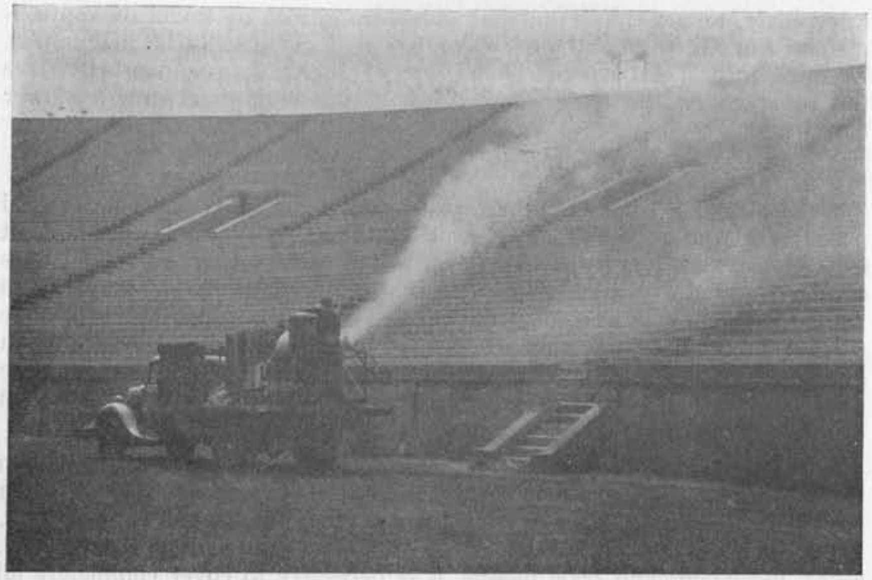

Figure 16. Twenty-five horsepower blower-atomizer treating interior of Yale Bowl for control of mosquitoes. The blower and outlet can be turned in a 180 degree arc for spraying up or down.

tion, most of the spray is directed practically straight up into the air to increase the distance that some of it will drift before falling to the ground. The possible drift of small drops is indicated by the data given by Potts.[1] A droplet 100 microns in diameter and having a specific gravity of 1.0 will drift while falling 50 feet in air moving parallel to the ground at various speeds as follows:

Miles per hour	Feet
0.25	22
0.5	45
1	87
2	175
3	265
4	348
5	435
10	765

It should be realized, of course, that a drop of water will evaporate fairly rapidly, but this may mean it will drift farther if it gets much smaller. Any change in specific gravity would modify this somewhat.

Rate of travel affects coverage. In treating for mosquitoes, flea beetles, leaf hoppers, and gross feeders like the gypsy moth, cankerworms, tent

[1] S. F. Potts. 1946. Particle Size of Insecticides and Its Relation to Application, Distribution, and Deposit. Journal of Economic Entomology 39 (6):716-720.

caterpillars, tussock moth and fall webworm, a rate of travel of approximately 2 m.p.h. for swaths of 50 to 100 feet can usually be maintained. Treating for the elm leaf beetle and certain other pests requires better tree top coverage on the undersides of the leaves and, therefore, a slower travel rate.

TREE COVERAGE

To cover tall trees and other areas rapidly, and to dispense and spread properly a large output of spray, while traveling 1.5 to 3 miles per hour, it is necessary to deliver a large volume of air at optimum velocity. Machines can be designed to change quickly the shape and width of the spray stream while the machine is in operation. Moreover, it is now possible to change the velocity of the air stream without changing the drop size by use of an auxiliary fan and outlet, and to apply a wide, "soft" air-spray stream close to the machine and suddenly change to a narrower, higher velocity stream to attain greater height or distance.

It is important to give special attention to the tree tops. Even though the top of a 70-foot tree may appear to be well covered, the deposit often is three to six times as great 30 to 40 feet from the ground as at 70 feet. To cover properly small, relatively fixed disease spores, aphids, lace bugs, mites, mealybugs and scale insects, it is necessary to cover completely all parts of the tree, particularly its top. This often requires a slow rate of travel and frequent stopping and starting. Since the spray rises to greater heights when released under the canopy of trees or woodlands than when released in the open, open grown trees may require more time and spray material per given ground or foliage area than closed stands.

TABLE 5. RELATIVE DDT DEPOSIT ON 1 X 3-INCH GLASS SLIDES SUSPENDED IN A 70-FOOT ELM AT GIVEN HEIGHTS FROM GROUND WITH MIST BLOWER DELIVERING 8,000 C.F.M. OF AIR AT 125 M.P.H. THROUGH A 12-INCH DIAMETER OUTLET[1]

Feet from ground	Average relative deposit[2] of 16 experiments with winds of 0.5 to 8 m.p.h. (40 feet = 100)	Average relative deposit of 5 experiments with no wind movement (conditions ideal)
20	153	150
25	188	175
30	173	184
35	128	136
40	*100*	*125*
45	75	110
50	49	76
55	28	56
60	14	34
65	11	28
70	6	17

[1] Analysis by R. D. Chisholm and Louis Koblitsky.
[2] To find the deposit in micrograms per square inch of surface, multiply the figures in columns 2 and 3 by 4.379.

Tests were made to determine the relative DDT deposit on 1 x 3-inch glass slides suspended in a vertical position at 5-foot intervals along a rope from the top of a 70-foot elm tree to a distance of 20 feet from the ground (Table 5). Deposits obtained in these tests may be compared with those obtained on twigs of elms sprayed with a mist blower and with a hydraulic sprayer. Due to the vertical position of the glass slides (Table 5) and to their greater surface area, the deposit on them was not as great per given area as on small twigs at the tree top (Table 6). The wind conditions for Table 6 approximate those for column 2 of Table 5. With favorable conditions, the mist blower gives a higher deposit than the hydraulic sprayers used in shade tree work.

TABLE 6. DDT DEPOSIT RELATIONSHIP ON ELM TWIGS ⅛ TO ⅜ INCH IN DIAMETER FROM TREES 50 TO 80 FEET TALL, TOP AND LOWER CROWN, USING EQUIVALENT DOSAGES

Method of application	No. of trees sampled	Top crown p.p.m.[1]	Lower crown p.p.m.[1]	X Lower/top
Hydraulic sprayer	127	139.6	470.4	3.4
Mist blower	97	239.5	589.9	2.5

[1] Parts by weight of DDT deposited per million parts by weight of twigs.

Greatest height is attained by allowing the machine to stand under the tree for a few seconds with the air directed to the tree top at full blast (Table 7). As soon as the air stream reaches the tree top in sufficient force to move the branches or foliage noticeably, spray is released by opening a conveniently located, quick acting shut-off valve. After closing this valve, the air from the fan is allowed to continue to the spot that has just been sprayed for several seconds before changing direction of the outlet (air blast). This prevents the mist from falling back. This procedure requires more time and often more spray volume than continuous travel. Injecting dust in the air stream is often a useful means of determining visually wind direction and velocity, and its effect on distance or height attained by the air stream.

TABLE 7. SECONDS REQUIRED FOR AIR STREAM TO REACH GIVEN HEIGHTS WHEN DELIVERED AT 125 M.P.H. THROUGH A 12-INCH DIAMETER OUTLET POINTED VERTICALLY

Height from outlet (feet)	Diameter of air stream (approximate)	Seconds to reach given height in calm air	Seconds to reach given height in 5 m.p.h. wind at 5-foot level
25	11	1	1.5
50	18	3	5
75	23	8	25 (max. hgt.)
100	35	14	....

SWATH OR STRIP COVERAGE

The width of the swath that can be covered depends on the kind of pest to be controlled, the insecticide, size of drops, the wind direction and velocity, the terrain, the air volume and velocity of the machine and its rate of travel (Table 8).

TABLE 8. RATE OF COVERAGE FOR GIVEN RATES OF TRAVEL AND FOR GIVEN WIDTHS OF SWATH[1]

Rate of travel of machine (m.p.h.)	Feet traveled per hour	Feet traveled per min.	Acreage covered per hour for strips of: 12.5′	25′	50′	100′	200′	300′	500′
0.5	2,640	44	0.75	1.5	3	6	12	18	30
1.0	5,280	88	1.5	3.0	6	12	24	36	60
1.5	7,920	132	2.3	4.5	9	18	36	54	90
2.0	10,560	176	3.0	6.0	12	24	48	72	120
3.0	15,840	264	4.5	9.0	18	36	72	109	180
4.0	21,120	352	6.0	12.0	24	48	96	145	240
5.0	26,400	440	7.5	15.0	30	60	121	181	302
10.0	52.800	880	15.0	30.0	60	120	242	362	604

[1] To calculate the combined nozzle output required per hour, multiply the acres covered per hour by the number of gallons to be applied per acre.

In swath or strip coverage, by far the greatest portion of the spray must be directed towards the border of the strip farthest from the blower, since the largest drops and the greatest number of drops have a tendency to deposit near the machine.

RATE OF COVERAGE

The rates of coverage (acres per hour) for given rates of travel when treating swaths of given widths are given in Table 8. Table 9 shows the rate of coverage and gallons delivery required per hour when treating rows of trees or crops from two opposite sides. Tables 10, 11 and 12 list the time required to discharge given volumes of spray mixture through nozzles or nozzle assemblies delivering given quantities of water per hour. Thus, from these tables the actual spraying time required to deliver specified volumes of spray liquid per tree, per unit area, or per acre can be found.

TABLE 9. RATE OF COVERAGE OF TREES WITH MACHINE TRAVELLING AT GIVEN SPEEDS TREATING BOTH SIDES OF EACH ROW[1]

Travel of machine (m.p.h.)	Distance between rows in feet	Acres per hour	Gallons per hour at 2.5 gals. per acre	5 gals. per acre	10 gals. per acre	15 gals. per acre	30 gals. per acre
1	20	1.2	3.0	6.1	12.1	18.2	36.4
	30	1.8	4.5	9.1	18.2	27.3	54.5
	40	2.4	6.1	12.1	24.2	36.4	72.7
	50	3.0	7.6	15.2	30.3	45.5	90.9
1.5	20	1.8	4.5	9.1	18.2	27.3	54.5
	30	2.7	6.8	13.6	27.3	40.9	81.8
	40	3.6	9.1	18.2	36.4	54.5	109.1
	50	4.5	11.4	22.7	45.5	68.2	136.4
2	20	2.4	6.1	12.1	24.2	36.4	72.7
	30	3.6	9.1	18.2	36.4	54.5	109.1
	40	4.8	12.1	24.2	48.5	72.7	145.4
	50	6.1	15.2	30.3	60.6	90.9	181.8
3	20	3.6	9.1	18.2	36.4	54.5	109.1
	30	5.5	13.6	27.3	54.5	81.8	163.6
	40	7.3	18.2	36.4	72.7	109.1	218.2
	50	9.1	22.7	45.5	90.9	136.4	272.7
5	20	6.1	15.2	30.3	60.6	90.9	181.8
	30	9.1	22.7	45.5	90.9	136.4	272.7
	40	12.1	30.3	60.6	121.2	181.8	363.6
	50	15.2	37.9	75.8	151.5	227.3	454.6

[1] When treating each row from each of two sides (as above), the width of swath is half the distance between rows of trees. If one side of a row is treated on each side of the machine, the rate of coverage and rate of output would be twice that given in the table.

TABLE 10. ACTUAL SPRAYING TIME REQUIRED TO APPLY GIVEN QUANTITIES OF SPRAY CONCENTRATE AT GIVEN RATES OF DELIVERY

Quantity of solution	Time required to spray the quantity listed in Column 1 at the following delivery in gallons per hour										
	5	10	15	20	30	45	60	90	120	180	240
2 ozs.	11.3 sec.	5.6 sec.	3.8 sec.	2.8 sec.	1.9 sec.	1.3 sec.	0.9 sec.	0.6 sec.	0.5 sec.	0.3 sec.	0.2 sec.
4	22.5	11.2	7.5	5.6	3.8	2.5	1.9	1.3	0.9	0.6	0.5
8	45.0	22.5	15.0	11.3	7.5	5.0	3.8	2.5	1.9	1.3	0.9
1 pint	1.5 min.	45.0	30.0	22.5	15.0	10.0	7.5	5.0	3.8	2.5	1.9
2	3.0	1.5 min.	1.0 min.	45.0	30.0	20.0	15.0	10.0	7.5	5.0	3.8
3	4.5	2.3	1.5	1.1 min.	45.0	30.0	22.5	15.0	11.3	7.5	5.6
4	6.0	3.0	2.0	1.5	1.0 min.	40.0	30.0	20.0	15.0	10.0	7.5
6	9.0	4.5	3.0	2.3	1.5	1.0 min.	45.0	30.0	23.0	15.0	11.5
1 gal.	12.0	6.0	4.0	3.0	2.0	1.3	1.0 min.	40.0	30.0	20.0	15.0
1.5	18.0	9.0	6.0	4.5	3.0	2.0	1.5	1.0 min.	45.0	30.0	22.5
2.0	24.0	12.0	8.0	6.0	4.0	2.7	2.0	1.3	1.0 min.	40.0	30.0
3.0	36.0	18.0	12.0	9.0	6.0	4.0	3.0	2.0	1.5	1.0 min.	45.0
5.0	60.0	30.0	20.0	15.0	10.0	6.7	5.0	3.3	2.5	1.7	1.3 min.
10.0	120.0	60.0	40.0	30.0	20.0	13.3	10.0	6.7	5.0	3.3	2.5
15.0	180.0	90.0	60.0	45.0	30.0	20.0	15.0	10.0	7.5	5.0	3.8
30.0	360.0	180.0	120.0	90.0	60.0	40.0	30.0	20.0	15.0	10.0	7.5

TABLE 11. GALLONS OF WATER DELIVERED PER NOZZLE PER HOUR WITH SEVERAL WHIRLJET NOZZLE SIZES[1]

Nozzle No.[2] ♀ Conn.	Nozzle No.[2] ♂ Conn.	Diameter of orifice (inch)	Gallons delivered per hour at the following pressures (pounds):						
			10	20	30	40	60	80	100
A1	B1	1/16	6.0	8.4	10.0	12.0	14.4	16.8	18.6
A2	B2	5/64	12.0	16.8	20.0	24.0	28.8	33.6	37.8
A3	B3	3/32	18.0	25.0	30.0	36.0	43.2	50.4	56.4
A5	B5	1/8	30.0	42.0	51.6	60.0	72.0	84.0	96.0

[1] Data of Spraying Systems Co., 4021 West Lake St., Chicago, Ill.
[2] Nozzles can be obtained for ⅛ inch or ¼ inch pipe connections. Specify hardened steel nozzles instead of brass. In the whirljet nozzles the inlet port hole is slightly smaller than the nozzle orifice.

TABLE 12. GALLONS OF WATER DELIVERED PER MINUTE THROUGH ORIFICES, TUBES OR JETS OF GIVEN DIAMETER AT GIVEN PRESSURES PER SQUARE INCH

P.S.I.	Diameter of orifice or jet (inches)						
	⅜	¼	⅛	3/32	1/16	1/32	1/64
700	67.5	30.0	7.5	4.7	2.0	0.5	0.12
175	33.7	15.0	3.7	2.3	1.0	0.25	0.06
44	16.8	7.5	1.8	1.2	0.5	0.12	0.03
11	8.4	3.7	0.9	0.6	0.25	0.06	0.01
3	4.3	2.0	0.5	0.3	0.1	0.02	No flow