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Aerial Application Equipment for Herbicidal Drift Reduction

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PORTLAND, OREGON



Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

Abstract

This publication provides silviculturists and managers of utility rights-of-way with a description and evaluation of available helicopter spray application equipment. Modified conventional equipment will reduce drift of sprays in normal carriers and apply various high viscosity sprays. Specialized spray systems have found limited use in forestry; they are more commonly used on utility rights-of-way. Most of the available spray systems or spray adjuvants reduce but do not completely eliminate drift. Maximum drift reduction with present equipment and adjuvants is obtained with the Microfoil Boom®.

Keywords: Herbicide applications, spraying (-brush control, application equipment, helicopters, silviculture.

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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Introduction

Herbicides have been successfully used as aerial sprays to release conifers and prepare planting sites in the Pacific Northwest for more than 20 years. During this time, techniques have been developed and used to reduce spray loss and insure maximum deposition on target areas. Increased public concern about use of pesticides suggests that measures designed to reduce herbicidal drift will be more necessary in the future. Therefore, silviculturists who prescribe and use herbicides on forest lands must become more familiar with factors influencing spray drift and methods available for keeping herbicidal losses at acceptable levels.

Drift hazard from aerial sprays is related to weather conditions during spraying, distance that droplets must fall, and drop size. Spray drift can be reduced by spraying under ideal weather conditions: air temperatures below 75° F, slightly unstable air temperature gradient, relative humidity above 50 percent, windspeed less than 6 miles per hour, and wind direction away from sensitive areas (Gratkowski 1974, Yates et al. 1967). 'As flying height increases, spray droplets remain suspended longer and are more subject to evaporation and drift. Therefore, flying height should be as low as safety permits, usually 30 to 50 feet above the vegetation.

A major factor influencing amount and distance of drift is spray droplet size. The greatest potential for reducing drift hazard is through reduction or elimination of small (less than 100-micrometer diameter) drift-susceptible droplets. Whenever possible, this should be done by reducing the range of sizes produced rather than by increasing average drop size, since large droplets result in poor plant coverage (fig. 1).

Liquids must be broken into small drops by a complex process called atomization to obtain good coverage and distribution of the spray. Atomization, and the

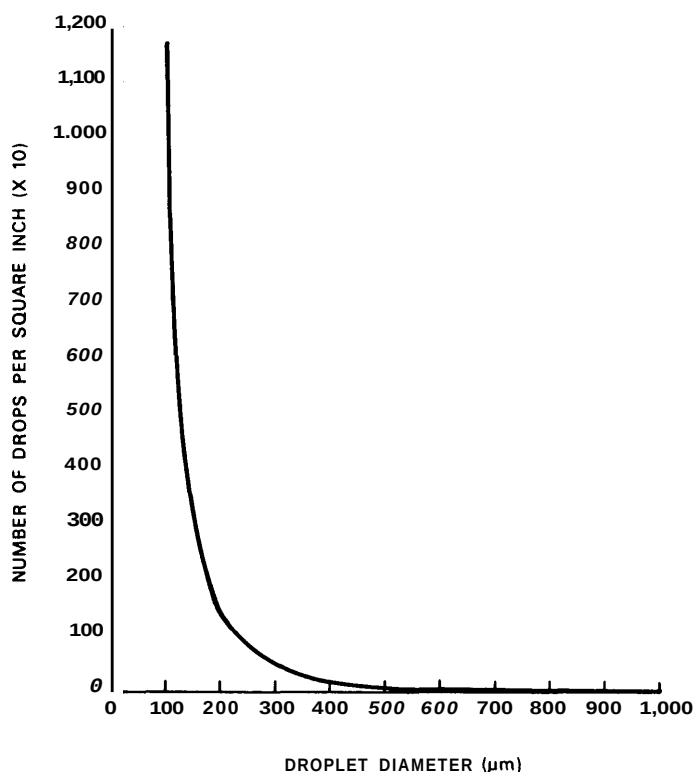


Figure 1.--Relation of droplet size to number of droplets per square inch in 10 gallons of spray.

resulting droplet size distribution, is controlled by physical properties of the spray solution and type and arrangement of the application equipment. Silviculturists can improve spray deposition by selecting herbicidal formulations and adjuvants that reduce volatility and increase spray viscosity and surface tension (Butler et al. 1969, Gratkowski and Stewart 1973).

Selection of proper aerial application equipment is as important as selecting herbicidal formulation. In fact, significant improvements can be made in reducing drift of normal formulations through use of well-designed spray delivery systems. Modifications of conventional application equipment or specialized systems may be necessary for applying high viscosity sprays for maximum drift reduction. This

report describes and evaluates helicopter spray delivery systems for applying normal sprays or high viscosity sprays on forest lands and utility rights-of-way.

Aerial Application Equipment

All conventional and most specialized spray application systems have the following parts: spray tank, pump, shutoff valve, pressure gage, spray boom, and nozzles (fig. 2). There are only five factors related to application equipment that can be altered to affect drop-let breakup. These are: (1) flying speed, (2) pump pressure, (3) nozzle orifice diameter, (4) nozzle type, and (5) nozzle orientation with respect to the airstream. All modifications of conventional systems and specialized systems designed for application of normal sprays rely on these factors. Additional modifications are necessary to pump and apply high viscosity invert emulsions, particulated sprays, or thickened sprays.

Each application system is designed for use with specific formulations or spray adjuvants (table 1). When drift reduction is not

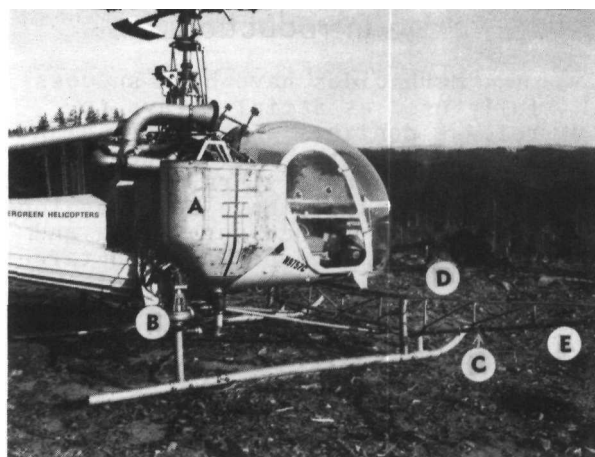


Figure 2.--Conventional aerial spray system: (A) spray tank, (B) pump, (C) pressure gage, (D) spray boom, and (E) nozzles.

needed for every application, conventional spray systems and tank mix visco-elastic adjuvants like Amchem Products' Lo-Drift® or Nalco's Nalco-Trol® should be used. Such systems are more flexible, readily available, and cost less than specialized application equipment.

Table 1.--Suitability of aerial spray systems for applying different herbicidal formulations and adjuvants

Aerial spray system	Normal spray	Foam spray	Invert emulsion		Particulated sprays	Thickened sprays
			Tank mix	Flash mix		
Conventional	X	X	X		X	X
Microfoil Boom®	X					
Transducer ^{1/}	X					
Electrostatic ^{1/}	X					
Dow R-511® and modified R-511			X		X	X
Bifluid® and Visko-Rhap®				X		
Spra-Disk® ^{1/}			X			

^{1/} Not presently recommended for forestry use.

When maximum drift reduction is needed on every acre treated, specialized systems and spray formulations should be considered. For example, Amchem's Microfoil Boom®, experimental transducer systems, or electrostatic systems are designed to reduce drift of normal sprays. The Dow R-511 spray system®, modified R-511, Stull Bifluid®, Rhodia Visko-Rhap®, and Amchem Spra-Disk® are used with thickened sprays, particulated sprays, or invert emulsions (Gratkowski 1974). The Spra-Disk® is not used for forestry, and transducer and electrostatic sprayers are experimental and not presently recommended. These systems are included for information only.

CONVENTIONAL SPRAY SYSTEMS

Normal Sprays

Normal water- or oil-based sprays can be applied with conventional spray tanks, pumps, distribution lines, and spray booms. To reduce drift, it is necessary to reduce the amount of spray in small, drift-susceptible droplets. Conventional hydraulic pressure nozzles shape the spray pattern and produce the initial formation of droplets. A wide range of droplet sizes is formed as a result of droplet-shearing forces produced by turbulence in the nozzle and in the airstream. These are counteracted by droplet-forming forces of viscosity and surface tension of the spray. To reduce droplet breakup, it is necessary to minimize turbulence within the nozzle and airstream.

Shear forces within the nozzle can be reduced by using large orifice nozzles with straight flow internal design and by lowering spray pressures. Six types of hydraulic pressure nozzles are used for aerial spraying: hollow cone with whirl plate, hollow cone with offset entrance (whirl chamber), fan, full cone, cylindrical jet, and flooding nozzles (Akeson and Burgoyne 1967, Bintner 1974). Of these, fan, hollow cone with whirl plate, and cylindrical jet nozzle patterns are most commonly used in forestry (fig. 3).

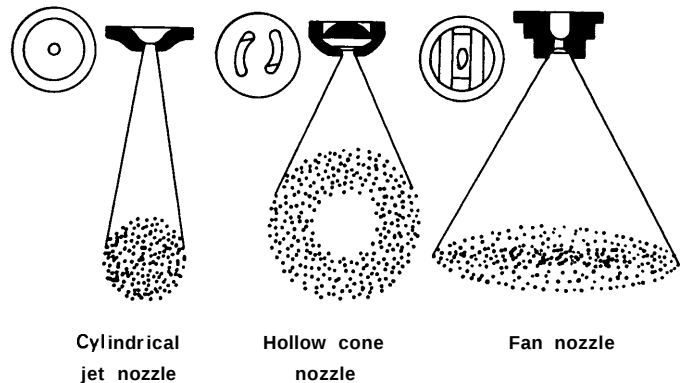


Figure 3.--Design and spray pattern of cylindrical jet, hollow cone, and fan nozzles.

Nozzles producing narrow, cylindrical patterns form fewer small drops and are better for reducing drift. Hollow cone nozzles with whirl plates are especially versatile because both the whirl plate number and disc orifice size can be varied to obtain desired median droplet sizes. It is possible to increase droplet size by using whirl plates that produce narrow cone angles. For example, spray drift can be reduced with Spraying Systems Company hollow cone nozzles by using whirl plate numbers greater than 45 (Akeson et al. 1970, 1971). Maximum reduction is possible by using cylindrical jet nozzles or hollow cone nozzles without the whirl plate that discharge the spray as a narrow solid stream.

Several foam spray systems have been developed for aerial spraying (Gratkowski and Stewart 1973). These systems require an air-aspirating nozzle to inject air into the spray (fig. 4) and special adjuvants to stabilize the air-in-water emulsion formed by the nozzles. Foam-generating nozzles should be operated at a minimum of 40 pounds per square inch (psi) pressure measured at the nozzle. Nozzles should discharge straight back along the airstream or no more than 30° from horizontal to obtain best drift reduction. Because the adjuvants do not increase spray viscosity, only the nozzles

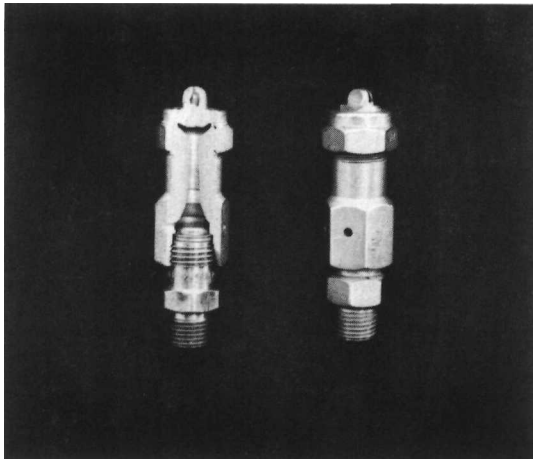


Figure 4.--A foam-generating nozzle.

of a conventional spray system need to be changed to apply foam sprays. Foam-generating nozzles inject a fixed amount of air into the spray depending on individual design. Moreover, each adjuvant will stabilize only a narrow ratio of air to water. Therefore, it is important to use only the nozzle specified by the manufacturer of the foam adjuvant (table 2).

Recent studies strongly suggest that drift-reducing benefits claimed for foam sprays are due to the coarse atomizing nozzles used rather than the foam itself (Akeson et al. 1972, Bouse and Leerskov 1973). In fact, addition of the foaming agent reduces surface tension of the spray and may form drift-susceptible clusters of air bubbles. Foam adjuvants expand spray volume two to seven times. This expansion, plus improved sticking and spreading due to surfactant properties of the foam adjuvants, may compensate for reduced plant coverage caused by the coarse spray. This possible effect is the only justification for using foam sprays.

The Delavan Manufacturing Company recently developed a new nozzle for reducing drift of normal sprays applied at usual operating pressures of 35 to 40 pounds per square inch. The Raindrop® nozzle produces a hollow cone pattern with droplets that are significantly larger than those produced by conventional nozzles at comparable pressures and flow rates (fig. 5). Furthermore, the amount of spray under 100 micrometers is sharply reduced. For example, the mass

Table 2--Characteristics of foam-generating nozzles used in aerial spraying.

Nozzle name		Spray pattern	Recommended foam agent	Range of nozzle outputs at 40 pounds per square inch
				<u>Gallons per minute</u>
Accutrol®	aerial coarse	Multiple jet	Accutrol	0.75-1.50
Foamspray®	aerial w ^{1/}	Single jet	Foamspray	.23-1.39
Foamspray®	Row Crop ^{2/}	Flat fan	Foamspray	.77-1.39
DFA Dela-Foam®		Single jet	Fomex	.77-7.10
Foamjet®		Single jet	None	.60-3.00

^{1/} Used at airspeeds above 60 miles per hour.

^{2/} Used at airspeeds below 60 miles per hour.



Figure 5.--Comparison of spray pattern from Raindrop[®] (left) and hollow cone (right) nozzles (4m/h crosswind).

median diameter^{1/} (MMD) of droplets produced by a Delavan hollow cone DC4-25 nozzle is 195 micrometers at 40 pounds per square inch with 16 percent of the spray volume in droplets under 100 micrometers (Delavan Manufacturing Company n.d.). In contrast, a Raindrop[®] 4-25 nozzle produces droplets with a MMD of 410 micrometers and less than 1 percent of the volume under 100 micrometers.

By lowering spray pressure, it is possible to further reduce droplet breakup. However, pressure must be reduced as much as four times to double the average droplet size produced by fan and hollow cone nozzles (Akesson 1952, Akesson and Burgoyne 1967). Since flow rates also decrease with reduced pressure, reducing spray pressure probably

^{1/} Mass median diameter (MMD) or volume median diameter (VMD) is the drop diameter that divides the spray volume into two equal parts. In other words, 50 percent of the spray volume is in droplets larger or smaller than the MMD.

has little significance for standard spray nozzles within the operating limits imposed by desired application volume and other conditions. This may change in the future with additional development of special low pressure (10 pounds per square inch or less), high flow rate nozzles such as made by Spraying Systems Company (Bouse et al. 1976).

Droplet breakup occurs after the spray is discharged from the nozzle and subjected to additional shear forces in the airstream. These forces are reduced as discharge velocity and direction approach that of the airstream itself. Therefore, flying speed and nozzle orientation are major factors affecting droplet breakup outside the nozzle (Isler and Carlton 1965, Brandes 1966). However, the effect of reduced flying speed on droplet breakup is insignificant within the narrow range, 45 to 60 miles per hour, necessary for the small helicopters used in forestry. More variation is possible with larger helicopters operating above

60 miles per hour or with fixed-wing aircraft operating above 90 miles per hour.

In contrast, nozzle orientation has a major influence on droplet breakup. Changing nozzle orientation from straight down to directly back along the airstream can increase median droplet size by 150 percent (fig. 6).

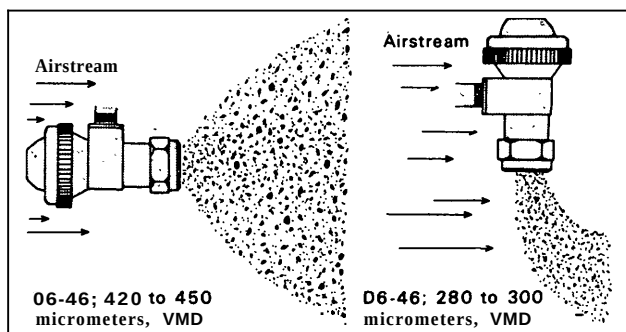


Figure 6.--Variation in droplet size resulting from change in nozzle orientation. (Adapted from Brazelton (1971); used with permission of University of California Division of Agricultural Sciences.

Intermediate degrees of droplet breakup and drift reduction can be obtained by adjusting the nozzles to discharge back at 30° or 45° from horizontal. Nozzle orientation can be easily changed by using fixed-angle elbow connectors, streamlined booms, or round spray booms. Streamlined booms are designed so that nozzles may be located on the top, bottom, and low-turbulence trailing edge of the boom (fig. 7). Round spray booms

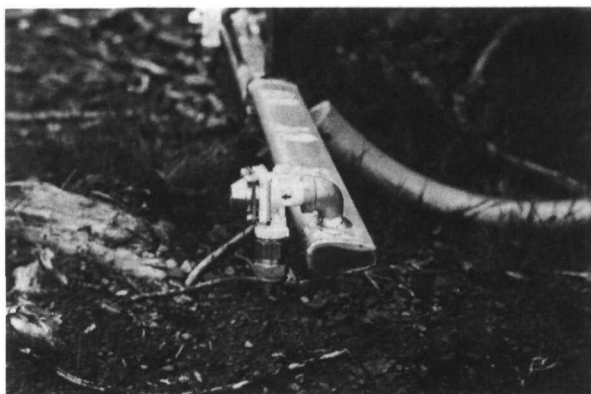


Figure 7.--Nozzles can be attached on the top, bottom, or trailing edge of a Simplex Manufacturing Company streamlined boom.

can be clamped to the helicopter skid toes and then rotated to change nozzle orientation by loosening the clamps. Fixed-angle spray bodies, swivel connectors, or variable spacing nozzles are available but not recommended.

There are several advantages in using conventional rather than specialized spray equipment. Commercial applicators usually have the necessary parts in stock. Spray tanks, pumps, distribution lines, and spray booms do not have to be modified for applying herbicides in normal water, oil-in-water emulsion, or oil carriers. By selecting nozzle type, nozzle orientation, and flying speed, foresters can obtain a suitable droplet size distribution for desired degree of drift control and plant coverage. Therefore, conventional spray systems are less expensive, more flexible, and more readily available than specialized systems or adjuvants. Furthermore, at airspeeds below 65 miles per hour, drift control with D8 jet nozzles (8/64-inch diameter orifice) directed back along the airstream using normal sprays is similar to that obtained with thickened sprays (Butler et al. 1969).

Foresters can obtain maximum drift reduction with normal spray formulations and conventional application equipment by using D8 jet nozzles directed back along the airstream at minimum safe flying height. Additional reductions may be possible with Delavan Raindrop® nozzles operated at standard pressure or Spraying Systems LP® nozzles operated at low pressure. More droplet breakup and better plant coverage but less drift reduction are obtained from hollow cone nozzles with whirl plates that produce narrow cones which are oriented between 45° and straight back along the airstream.

Even with these modifications, a wide range of droplet sizes will still be produced. The smaller drops result in better plant coverage but drift will occur; 2 to 15 percent of the spray volume may be deposited beyond 1,000 feet downwind

from the application (Akeson et al. 1972). However, close adherence to weather, flying height, and flying speed restrictions can minimize these losses.

High Viscosity Sprays

Thin tank mix invert emulsions and other low to moderate viscosity sprays can be applied with conventional spray systems. For most applications, jet nozzles directed straight back or no more than 45° from horizontal should be used to minimize droplet breakup. Minimizing shear forces is especially important with viscosity-elastic polyvinyl polymers such as Amchem Products' Lo-Drift® or Nalco's Nalco-Trol®. Adjuvant rates as low as 8 to 16 ounces per 100 gallons may be possible if Lo-Drift® or Nalco-Trol® sprays in water carriers are applied through jet nozzles directed back along the airstream; rates up to 32 ounces per 100 gallons may be necessary with other nozzles or nozzle orientation or with emulsion carriers.

Thick tank mix invert emulsions and other high viscosity sprays can be applied through modified conventional spray systems. All modifications are the result of the increased viscosity and are similar for invert emulsions, thickened sprays, or particulated sprays.

Thick sprays flow more slowly than normal sprays. Therefore, the spray distribution system must have a larger capacity to produce the same flow rates as normal sprays. Crossover lines between helicopter saddle tanks should be about 4 inches in diameter. Pump suction lines should have a diameter at least as large as the pump inlet port and should draw from the center of the crossover line between tanks. Delivery lines to the boom and the boom itself should be 1-1/2 to 2 inches in diameter, and enough lines must be provided from pump to boom to maintain even pressure at all nozzles. Suction and supply lines must be as short as possible, with a minimum number of turns.

Standard centrifugal pumps cannot produce sufficient flow rates with viscous sprays. Therefore, gear (1-1/2 inches or larger), piston, or vane positive displacement pumps should be used. Pump capacity must be at least 30 percent greater than for normal sprays. High capacity centrifugal pumps can be used, but they must be operated in a flooded condition. **With most invert emulsions, pumps must move the required volume without creating additional shear, or the emulsion will become thicker. Pump output must be matched to nozzle output to minimize recycling and additional shearing of the emulsion.**

As with normal formulations, droplet size distribution of thickened sprays is affected by spray pressure, nozzle tip design, orifice size, nozzle orientation, and flight speed. Nozzles with simple internal design and large orifice diameters are necessary for application of highly viscous sprays. If nozzle strainers are used, they should be coarse-meshed--generally 50 mesh or larger. For most forest spraying with viscous sprays, D8 (8/64-inch diameter orifice) or D10 (10/64-inch orifice) jet nozzles directed 45° or straight back will produce adequate flow rates and good drift control. With Norbak® particulated sprays, it may be necessary to use lower rates of adjuvant and nozzles directed downward or 45° back to obtain some breakup and reasonable spray coverage (Butler et al. 1969).

High viscosity sprays will produce volume median diameters between 800 and 5 000 micrometers when applied through D8 jet or other straight stream nozzles directed down at airspeeds less than 60 miles per hour or back along the airstream at higher speeds (Akeson et al. 1972). However, the range of droplet sizes produced is still relatively large, with 1 or 2 percent of the spray volume in small, drift-susceptible droplets.

As with normal sprays, maximum drift reduction with invert emulsions, Vistik®, Dacagin®, Lo-Drift®,

Nalco-Trol[®], and Norbak[®] applied through modified conventional equipment will be obtained if: (1) jet nozzles are used, (2) nozzles are directed back along the airstream, (3) aircraft speed is reduced, and (4) pump pressures are reduced. A lower flying height will further reduce drift, but swath coverage will also be reduced. Therefore, normal flying heights of 30 to 50 feet above the vegetation should be used in applying high viscosity sprays.

SPECIALIZED SPRAY SYSTEMS

The Microfoil Boom[®] and various transducer spray systems were designed to reduce drift of normal sprays. The Microfoil Boom[®] reduces drift by increasing median drop size and decreasing the range of droplet sizes produced; while transducers decrease only the range of drop sizes. The electrostatic system seeks to reduce drift by electrically charging the spray stream and using the electrical potential of the earth's surface to attract the spray droplets. Although theoretically possible, this system has failed to demonstrate reduction in drift.

The R-511[®] and modified R-511 spray systems were designed to overcome problems in pumping and applying high viscosity spray mixtures. The Bifluid[®] and Visko-Rhap[®] systems were designed to mix and apply flash mix invert emulsions (Gratkowski 1974, Gratkowski and Stewart 1973). The Spra-Disk[®] was developed to apply tank mix invert emulsions with minimum droplet breakup when flying high above powerline rights-of-way.

Microfoil Boom[®]

The Microfoil Boom[®], developed by Amchem products, Inc., combines the advantages of low pressure, straight flow jet nozzles, and proper nozzle orientation to obtain large, nearly uniform size droplets (Kirch 1968). Spray is circulated through two parallel booms which help to equalize pressure and flow to each nozzle (fig. 8). To reduce droplet breakup, a 40-pounds per square inch spray pressure in the

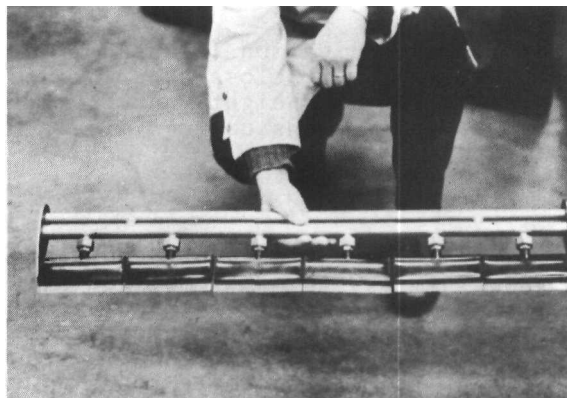


Figure 8.--The Microfoil Boom[®] circulates spray through two parallel booms to equalize pressure and flow to each nozzle.

boom is reduced to only 2 pounds per square inch at the nozzle orifices.

Microfoil nozzles are shaped like an airfoil to produce laminar or smooth airflow and minimum turbulence at the point where spray droplets form (fig. 9). Each nozzle is 6 inches long and contains

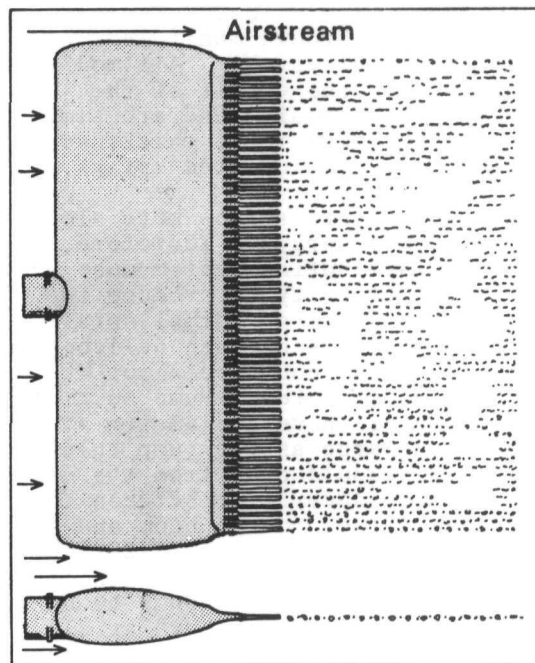


Figure 9.--Microfoil nozzles have an airfoil-shaped body with needlelike orifices protruding from the trailing edge. (Adapted from Brazelton (1971); used with permission of University of California Division of Agricultural Sciences.)

a row of sixty 0.013- or 0.028-inch diameter needlelike orifices along the trailing edge of the airfoil. Two other special nozzles are available for the Microfoil Boom®. The first was developed for forestry use and consists of three rows of 0.013-inch orifices delivering 10 gallons of spray per acre at 60 miles per hour. The second, termed a "hay-rake" nozzle, was developed for application of sprays at heights of up to 400 feet above powerlines. Each nozzle contains a single row of 0.060-inch orifices that produce very large diameter droplets (fig. 10).

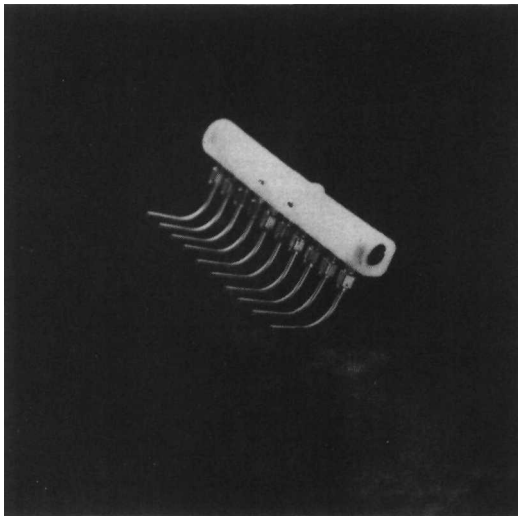


Figure 10. -- A Microfoil® "hay-rake" nozzle with 0.060-inch orifices.

Microfoil nozzles produce droplets of two distinct sizes, primarily as a result of a process called Rayleigh breakup (Wilce et al. 1974). Primary droplets are about twice the size of the orifice diameter. Smaller satellite droplets are formed from thin filaments of spray between the primary droplets. If the nozzles are properly oriented with the airstream, these smaller droplets are recaptured by the larger ones in the smooth air flow behind each nozzle. **For maximum drift reduction, the boom must be continually leveled with the airstream by means of a pilot-oriented control unit as a helicopter changes flight attitude. When properly**

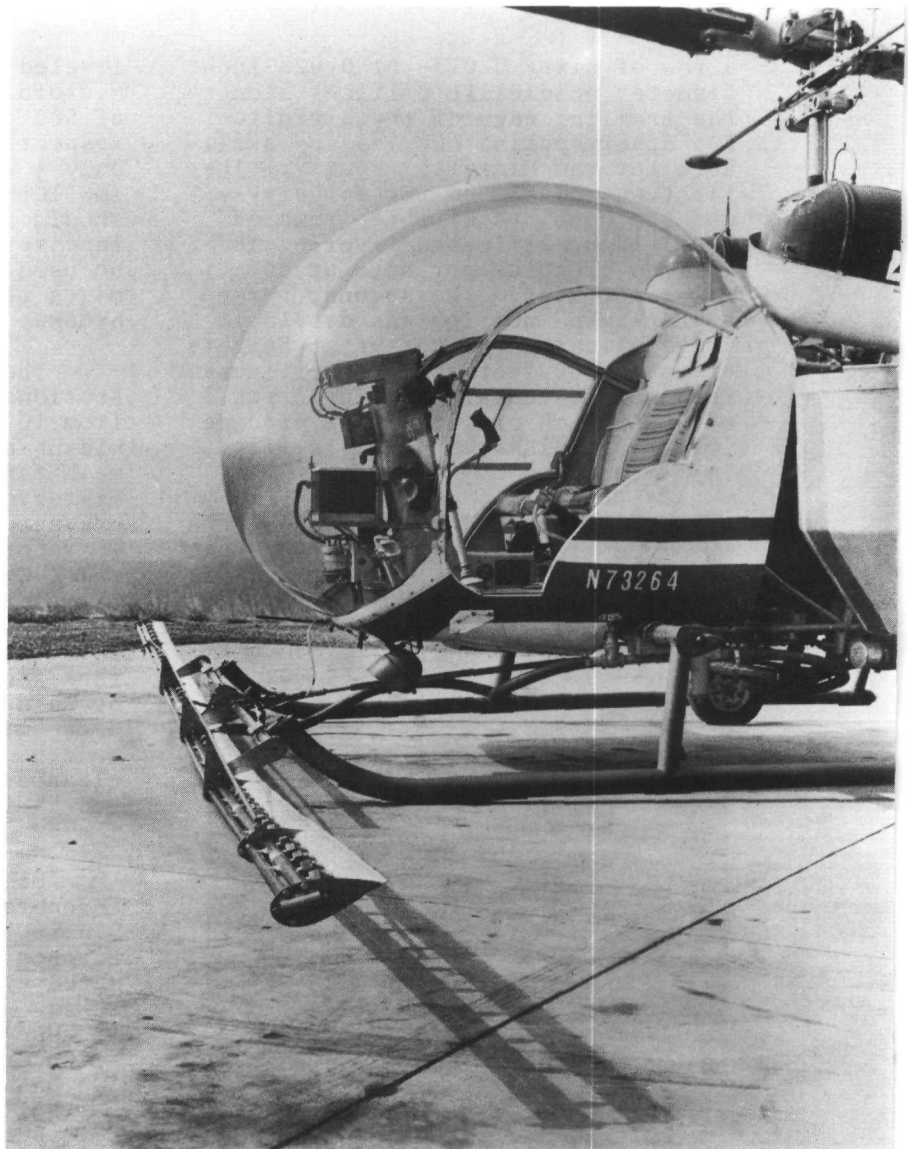
leveled, the 0.013- and 0.028-inch Microfoil nozzles produce droplets of 800 and 1 700 micrometers, respectively, with a variation of only ± 200 micrometers. Only the smaller 0.013-inch diameter orifice should be used for forest or range-land spraying. The Microfoil should be used only at airspeeds below 60 miles per hour; excessive droplet breakup occurs at greater airspeeds.

The spray boom is assembled in sections and can be varied in length from 10 to 26 feet to obtain swath widths between 10 and 70 feet. Fine mesh tank truck and saddle tank filter systems are necessary to prevent clogging of the orifices. Therefore, **high viscosity sprays and wettable powders cannot be applied through the Microfoil.** Furthermore, extra care must be taken to prevent debris from entering spray tanks. This can be done by covering nurse tank and saddle tank openings and by using fine mesh screens in water draw hoses, pump lines, and nozzles. Nozzles should be removed and cleaned frequently with a spray-pik tooth cleaner or similar device.

Other problems that developed in operational spray tests on the Siuslaw and Siskiyou National Forests can be minimized or eliminated by the following actions:

1. Use high-volume electric or hydraulic pumps and manifolds on Hiller helicopters. On Bell helicopters, use Amchem's special hydraulic pump supplied with the Microfoil.
2. Because the boom is mounted near the ground (fig. 11), use a raised landing pad (e.g., railroad ties) and a level helispot to prevent damage to the boom.
3. Use nozzle bodies made from polypropylene plastic that are less subject to cracking than the original plastic nozzles.
4. Use negative pressure or suck-back devices to prevent draining of the nozzle bodies after shut-off in flight.

Figure 11 -- The Microfoil Boom[®] is mounted in front of and below the skid toes where it is subject to damage.



The Microfoil Boom[®] is expensive to buy and maintain. Therefore, few applicators have access to one. The spray swath is well defined and falls directly below the helicopter and behind the pilot in a sheetlike pattern (fig. 12). Skips and poor coverage are common unless the pilot is experienced and can maintain at least a 5-foot swath overlap. Because of poor coverage produced by even the smallest diameter orifices, experience on two National Forests suggests that the Microfoil Boom[®] should not be used to apply bud-break sprays on deciduous species. Too little spray is intercepted by

the leafless stems and branches to obtain good brush control. For foliage sprays, degree of brush control with the Microfoil can be equivalent to or somewhat less than that obtained with conventional booms.

The Microfoil Boom[®] provides the best drift control possible at this time. In aerial spray tests, 98 to 99 percent of the spray volume was deposited within the desired swath width (Akesson et al. 1971). If maximum drift reduction is a primary concern, the increased costs and difficulties with the Microfoil Boom[®] may have to be accepted.



Figure 12.--If the Microfoil Boom[®] is maintained in proper trim, the spray falls in a characteristic sheetlike pattern.

Transducer Spray Systems

Transducer spray systems use conventional spray equipment except for specially designed nozzles. Within each nozzle, a cyclic pulse is applied to the pressurized stream

of spray ahead of the orifice by means of a vibrating magnetized rod or piezoelectric crystal (fig. 13) (Bouse et al. 1974, Roth 1971, Wilce et al. 1974). This vibration causes droplets to form at the applied frequency. For example, 6,000 drops per second are formed at a vibration rate of 6,000 times per second. As long as external vibrations from pumps or other equipment do not cause the vibrations to become out of phase, the resulting drops are uniform in size due to the regularity of the applied pulse. Droplet formation becomes irregular if secondary pulses occur.

Drop size is determined by the size of the orifice used, pump pressure, and applied frequency. Since small diameter jet orifices are used, droplet size is about twice the orifice diameter. An increase in pressure will increase droplet diameter by increasing the volume of liquid flowing between pulses. To minimize shear forces

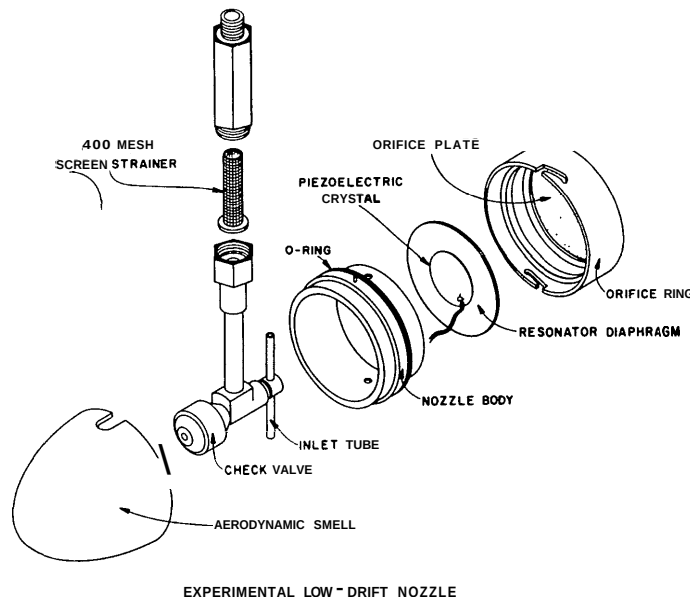


Figure 13.--Transducer nozzles using vibration of a piezoelectric crystal to pulse the stream (Wilce et al. 1974, reproduced with permission).

the nozzles are oriented to discharge along the airstream (fig. 14). By varying orifice diameter, pulse frequency, and pump pressure, droplet sizes suitable for application of different herbicides can be produced.

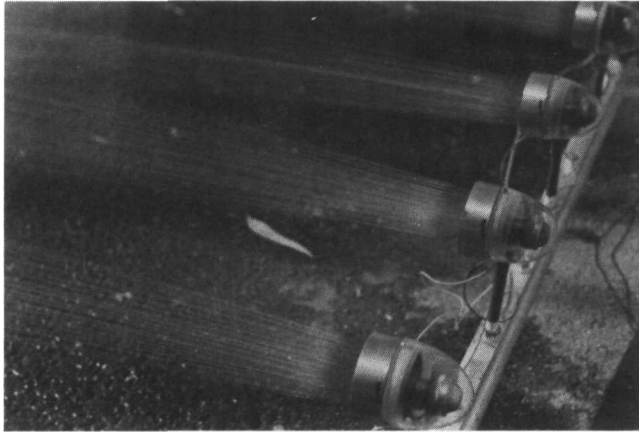


Figure 14.--Multiple orifice transducer nozzles are directed with the airstream to reduce droplet breakup (Wilce et al. 1974, reproduced with permission).

Experimental transducer systems have been built by Cotton, Inc., part of the United States Cotton Council, Texas A & M (Bouse et al. 1974), and University of California at Davis (Wilce et al. 1974). All of these produce drops of about 200- to 300-micrometer diameter, with none below 75 to 100 micrometers and few above 300 micrometers. This smaller droplet diameter provides better plant coverage at normal application volumes while also providing drift reduction similar to that obtained with the Microfoil Boom® (Wilce et al. 1974). Because of the very small orifice diameter, prefiltering and fine mesh line and nozzle filters must be used to prevent clogging. As with the Microfoil, high viscosity sprays and wettable powders cannot be applied through transducer nozzles. Flow rates through small orifices are very low so multiple-orifice nozzles may be necessary to obtain adequate flow rates.

Based on limited tests, transducer systems may prove the most effective means to reduce drift and still obtain good pest control (Wilce et al. 1974). However, they are not commercially available and must be evaluated more thoroughly before they can be recommended for operational spraying.

Electrostatic Systems

Electrostatic spray systems are based on the principle that positively charged spray particles will be attracted to the negatively charged surface of the earth and to image-negative plants. One experimental system uses an electrostatic spinner mounted on the wing in place of a spray boom and nozzles to impart a negative charge to the spray droplets as they leave the aircraft (Agricultural Research 1966).

A second electrostatic system, developed by ElectroGasDynamics, Inc., uses a standard spray boom and nozzles and spray gun-type induction generators mounted on the tail of fixed-wing aircraft (Agricultural Chemistry 1971). The generators impart a negative charge to a fine stream of water injected into the airstream behind the aircraft, leaving the airframe positively charged. This positive charge on the airframe is then transmitted to spray droplets as they leave the nozzles.

Benefits claimed for electrostatic systems include reduced drift, increased plant coverage, and lower application rates. However, these claims have not yet been substantiated in objective spray tests (Threadgill 1973). Therefore, the ElectroGasDynamics system or other electrostatic sprayers are still experimental and cannot be recommended for forestry use at present.

R-511® and Modified R-511 Spray Systems

In 1966, the Dow Chemical Company introduced the R-511 Spray System® for helicopter application of high viscosity Norbak sprays on

rights-of-way (Reimer et al. 1966). Although it is no longer commercially available as a complete unit, many applicators use either the R-511 or a locally modified version of it. Either system can apply any high viscosity spray except flash mix invert emulsions. However, only modified R-511 systems have proved useful for forest spraying (fig. 15).



Figure 15.--Modified R-511 system applying Vistik-thickened sprays on the Siuslaw National Forest.

The R-511 Spray System[®] uses a cluster of five nozzles at the center of an 8-foot support boom (fig. 16). Thickened sprays are drawn from the bottom of the saddle tanks through a suction filter and 2-inch suction line to a positive displacement vane or gear pump. The spray then flows through a series of pilot-operated spray control units and separate 1-inch supply lines to each nozzle. By selecting nozzle pairs, adjusting spray pressure, and changing discharge angle of the nozzle cluster, the pilot can vary swath width from 25 to 50 feet while in flight and still maintain a constant application rate per acre (Reimer et al. 1966).

The Dow Chemical Company also developed a modified R-511 Spray System for applying thick tank mix

invert emulsions. This system is similar to the R-511, except that the nozzle cluster is replaced by three nozzles evenly spaced along the 8-foot boom. All three nozzles are angled back to reduce breakup of the spray by the airstream. However, the two outside nozzles are also angled outward to increase swath width. This partially offsets the benefits of directing the nozzles back.

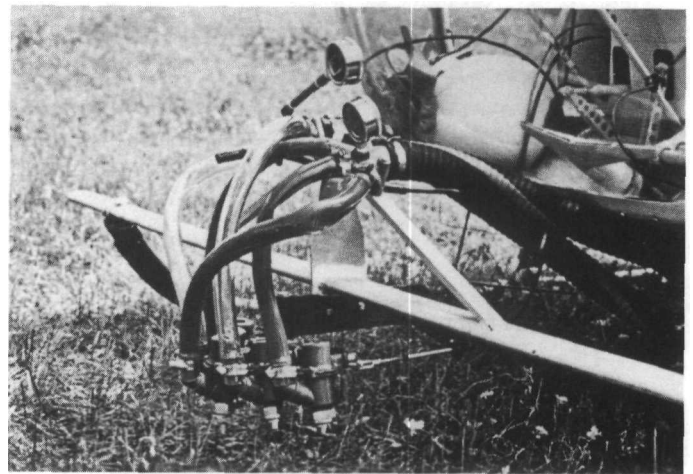


Figure 16.--The Dow R-511[®] Spray System.

The Dow Chemical Company is now testing a boomless sprayer for rights-of-way.^{2/} A Spraying Systems Company cylinder manifold is mounted on an R-511 nozzle body attached to each skid toe (fig. 17). Each manifold is 6-1/2 inches long with seven outlets at 10° spacings around the perimeter along its length. Jet nozzles, usually with 00-30 tips, are used in each outlet. Guide vanes in each nozzle reduce turbulence created as the spray turns the corner between the manifold and nozzle. Diaphragm check valves may be used on each nozzle to provide more positive spray shutoff. Manifolds are mounted facing forward

^{2/} Personal communication from C. A. Reimer, the Dow Chemical Company, Midland, Mich.



Figure 17.--A boomless sprayer **uses** cylinder manifolds mounted on the helicopter skid toes.

with nozzles directed outward to produce a 50-foot swath. Some recent versions include a three-nozzle manifold between the skids to obtain better coverage under the helicopter and permit wider swaths. The boomless spray unit results in better spray breakup and more uniform pattern than the R-511 or three-nozzle modified R-511 systems. However, its usefulness has not yet been demonstrated in forest spraying.

Local modified versions of the R-511 Spray System® have been developed. For example, typical units consist of a 2-inch diameter streamline 8-foot boom mounted on the helicopter skid toes.^{3/} Five nozzles are equally spaced along the boom with a flat fan nozzle at the center and two offcenter^{4/} nozzles to either side (fig. 18). A positive displacement vane or gear pump is used to move high

^{3/} Personal communication from Norm Parker, Western Helicopter Services, Inc., Newberg, Oreg.

^{4/} Offcenter nozzles produce a fan-shaped pattern that is directed down and to the side to obtain maximum swath width.



Figure 18.--A modified **R-511** system with, five **nozzles** arranged on a **short spray boom**.

viscosity sprays through two separate large diameter supply lines to the boom.

To obtain reasonable swath widths with all versions of the R-511 Spray System®, offcenter nozzles are used. These nozzles broadcast the spray over a greater area than conventional nozzles. Therefore, plant coverage and drop-let size may be less uniform near the swath edge than directly under the helicopter.

Bifluid Spray Systems

Bifluid-spray systems are used with special herbicidal formulations to both mix and apply flash mix invert emulsions (Gratkowski and Stewart 1973). Only two systems are commercially available: the Stull Chemical Company Bifluid Spray System®, available as individual parts from Stull, and the Rhodia Visko-Rhap Spray System®, available as a complete unit from the Simplex Manufacturing Company. Both systems have the same essential features. They differ mainly in the location where the invert is formed

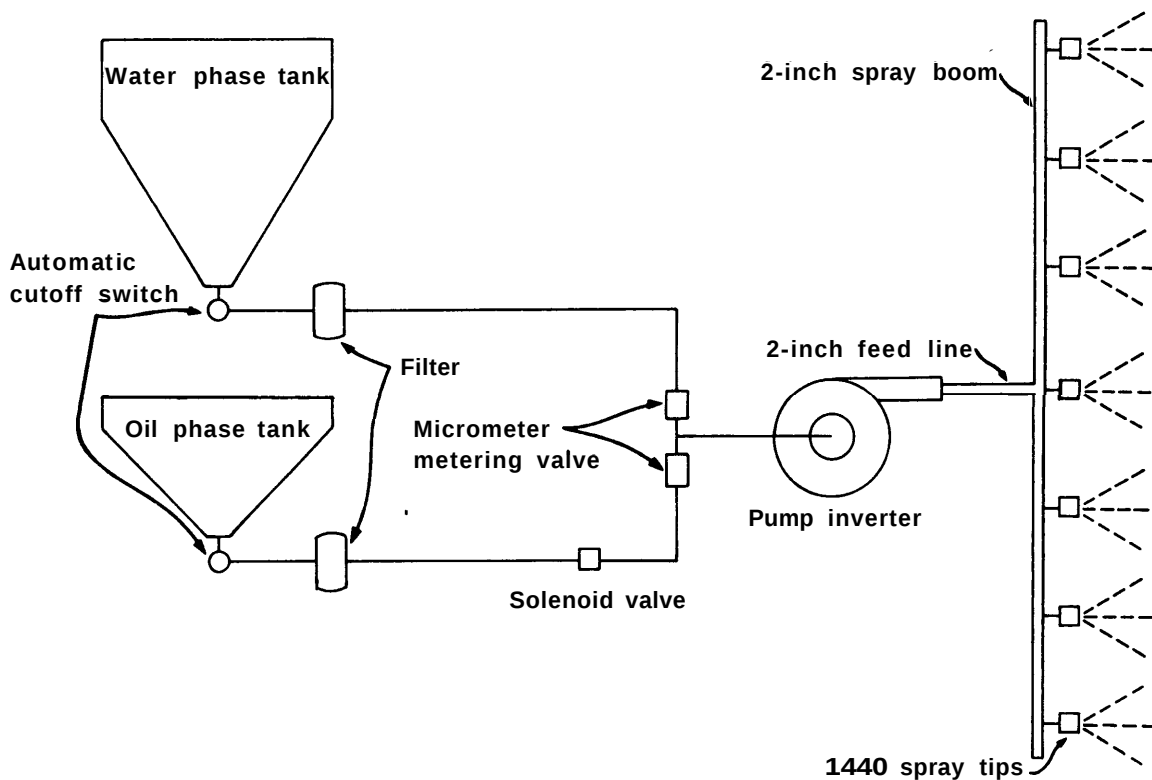


Figure 19.--Diagram of Rhodia Visko-Rhap® Spray System.

and on the method for adjusting flow rate from each tank (fig. 19).

Separate spray tanks are required for the water phase and the oil-herbicide mixture. Because more water is used than oil-herbicide mixture, the water tank should be two to four times larger than the oil-herbicide tank. Formation of the invert emulsion occurs in the centrifugal pump of the Visko-Rhap System® and in a separate mixing chamber on the suction side of a gear pump in the Bifluid System®. Since thickened sprays cannot be returned to the spray tanks, a loop bypass around the pump is used to equalize pressure. Automatic valves shut off the flow from both tanks if either one is empty. Large mesh screens are used to prevent blockage of orifices or

valves used to meter the output from each tank.

The Stull Bifluid Spray System® uses special metering orifices to regulate the flow from each tank. Because viscosity of invert emulsions depends on the water-to-oil ratio, viscosity and sprayer output are varied by changing the metering orifices. Any aerial spray nozzle with sufficient output and simple internal design, such as D8 or D10 jet nozzles, can be used.

The centrifugal pump inverter of the Visko-Rhap Spray System® has an output of 20 to 65 gallons per minute controlled by micrometer valves in the supply lines from each tank. Viscosity is easily adjusted by changing the valve settings. The boom is equipped with 40 special

1440 spray tips; each tip has fourteen 0.040-inch jet orifices. For lower application volumes or smaller droplet sizes, 1040 (ten 0.040-inch orifices) or 1432 (fourteen 0.032-inch orifices) spray tips are available. The Visko-Rhap System® is designed for use on fixed-wing aircraft or on helicopters with Lycoming engines; the Simplex Manufacturing Company also builds special bifluid kits for other aircraft.

Bifluid systems have several advantages: (1) formation of the invert emulsion occurs automatically in flight, eliminating premixing and handling of thickened sprays; (2) herbicide, oil, and water are metered directly into the mixing chamber, assuring a known constant viscosity; and (3) viscosities can be varied for different spraying conditions by changing metering orifices or micrometer valve settings. However, bifluid systems still allow some drift; 1 percent of the spray volume may be in droplets below 200 micrometers in diameter (Hoffman and Haas 1970, Phillips 1963). Distribution of sprays across the swath can also vary greatly, and plant coverage is reduced (Hoffman and Haas 1970, Lehman et al. 1964). Further, final viscosity of the invert emulsion is somewhat dependent on pH of the water used.

Spra-Disk®

In the late 1950's, Amchem Products, Inc., developed the Spra-Disk® for helicopter application of thick tank mix invert emulsions (Kirch et al. 1960). With this system, inverts flow by a combination of gravity and pump suction through large diameter hoses from the spray tanks to the center of a hollow spinning disc mounted between the helicopter skids (fig. 20). As spray enters the disc, it is forced through 12 jet nozzles around the disc perimeter by centrifugal force. A rheostat operated by the pilot controls disc speed. By varying disc speed, flying height, and air-speed, the pilot can obtain swath widths between 20 and 50 feet.

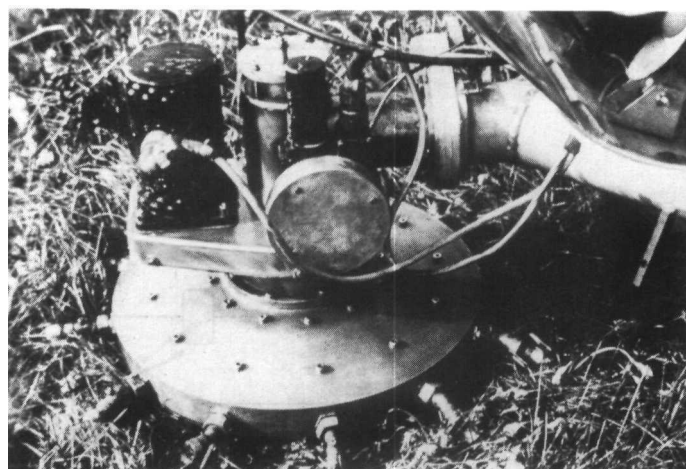


Figure 20.--Amchem's Spray-Disk®.

A long-bodied nozzle is used at the higher disc speeds required to produce 30- to 50-foot spray swaths. A shorter nozzle is used for swath widths between 20 and 35 feet. With the shorter nozzle, disc speed must be increased to obtain the same velocity attained at the tip of the longer nozzle. This increased speed produces desired droplet breakup and sufficient centrifugal force in the disc to maintain constant flow.

The Spra-Disk® is designed for use at airspeeds between 20 and 30 miles per hour. Sprays have been applied on utility rights-of-way at heights up to 300 feet above the vegetation. At normal flying speed and height, application volume can be varied from 18 to 25 gallons per acre by increasing disc speed. Lower volumes are obtained by decreasing the number of nozzles.

Amchem Products, Inc., leases the Spra-Disk® to aerial applicators that use Amchem's invert emulsion formulations. Because Amchem Products, Inc., services and periodically calibrates the equipment and produces the specific formulations used, calibration data supplied with the Spra-Disk are very accurate and require only occasional

field checks by the applicator. Unfortunately, the Spra-Disk® produces a wide range of droplet sizes, but very few are less than 1 000 micrometers in diameter. ^{5/} This is much too large for good vegetation control on forest lands.

Availability of Spray Equipment

Availability of spray equipment from commercial applicators who responded to a February 1973 questionnaire is shown in table 3. This information should help foresters, public utility managers, and others using herbicidal sprays in locating commercial aerial applicators familiar with specific types of equipment. However, the applicator must know what types of equipment or changes in equipment are anticipated prior to the start of spraying. Most do not bring extra equipment into the field unless arrangements have been made.

Because of increased interest in drift control, types of equipment and numbers of applicators using specialized equipment will probably change in the future. Most applicators will use more flexible spray systems because of the high cost and limited use of specialized systems.

Conclusions and Recommendations

All available drift control methods reduce the volume of spray in small, drift-susceptible droplets. However, none of them completely eliminate drift. Moreover, the advantages of more accurate spray placement are not without cost. As droplet size increases, spray coverage decreases. Therefore, efforts to reduce drift may result in decreased herbicidal effectiveness unless herbicidal dosage or spray volume are increased (Behrens 1957, Buehring et al. 1973, Ennis and Williamson 1963, McKinlay et al. 1972).

^{5/} Personal communication from J. Waldrum, Amchem Products, Inc., Ambler, Pa.

Drift reduction is desirable near streams and other ecologically sensitive areas. However, the use of specialized application equipment and herbicidal formulations or adjuvants will increase the cost of treatment. Because swaths are narrower and well defined, skips will be more likely and the pilot will have to make more passes to obtain good coverage. Use of specialized spray equipment and adjuvants does not reduce the need for good supervision of the spray operation. Nor does it allow relaxing of weather restrictions during spray application.

Fortunately, maximum drift reduction is rarely necessary in the remote areas typically treated in forestry. Drift reduction is generally needed intermittently near specially sensitive areas. Therefore, more flexible spray systems and adjuvants are desirable. Based on present technology and information, the following types of herbicidal application equipment are recommended:

1. For maximum flexibility where good vegetation control and good spray placement are desired, use conventional spray equipment with D8-46 hollow cone or D8 jet nozzles or equivalent directed 30° to 45° back and airspeeds below 50 miles per hour.

2. For increased drift reduction with little sacrifice in flexibility or spray coverage, use D8 or equivalent jet nozzles directed straight back with the airstream. Future research may show that Delavan Raindrop® or Spraying Systems LP® nozzles will be more useful (Bouse et al. 1976).

3. For good drift reduction and flexibility but some reduction in coverage, use D8 jet nozzles directed back with the airstream and 16 to 32 ounces of Lo-Drift® or Nalco-Trol® per 100 gallons of spray. If drift reduction is only required intermittently, the adjuvant may be added to individual spray loads in the saddle tanks.

Table 3--Availability of specialized spray equipment from commercial aerial applicators as of February 1973

Applicator and location	Normal sprays		High viscosity sprays						Foam sprays
	Conventional boom	Microfoil boom [®]	Modified conventional boom	Spra-Disk [®]	Bifluid ^{1/} Systems	Dow R-511 [®]	Modified R-511	Mixing equipment	Foam nozzles
Arizona Helicopters, Inc., Scottsdale, Ariz.	X	X	X	-	SP			-	
Cascade Helicopters, Inc., Cashmere, Wash.	X		X	-	S	-	X	X	X
Coastal Ag Chem, Oxnard, Calif.	X	X	X	X	-			X	X
Coombs West-Air Company, Yakima, Wash.	X							-	X
Evergreen Helicopters, Inc., McMinnville, Oreg.	X	X	X	X	SP	X	X	X	X
Farm and Forest Service, Napavine, Wash.	X				-	X	X	X	X
Helicopter Services, Yakima, Wash.	X		X	X	P			X	X
Inter-Mountain Helicopters, Inc., Boise, Idaho	X		X	-	S	X	X	X	
Mid-Valley Helicopters, Inc., Jefferson, Oreg.	X		X			-	X	-	X
Omniflight Helicopters, Inc., Janesville, Wis.	X	X	X	X	-	X	X	X	X
Rambling Rotors, La Grande, Oreg.	X		X	X	-			-	X
Reforestation Services, Inc., Salem, Oreg.	X		X			X	X	X	X
Rocky Mountain Helicopters, Provo, Utah ^{1/}	X		X	-	P	X	X	-	
Sky Choppers of Utah, Inc., Provo, Utah	X							-	
Western Helicopter Services, Inc., Newberg, Oreg.	X	X	X	-	-	-	X	X	X

^{1/} S = Stull Chemical Company Bifluid[®] Spray System; P = Visko-Rhap[®] (Rhodia, Inc.) Pump Invert System.

4. For maximum drift reduction where flexibility and coverage are less important, use a Microfoil Boom® with 0.013-inch diameter orifices. The Microfoil can only be used for foliage sprays. Further, it may be necessary to

increase spray volumes from the normal 8 to 10 gallons per acre to 15 to 20 gallons. Additional research may show transducer systems provide adequate drift reduction and better coverage than the Microfoil (fig. 21).

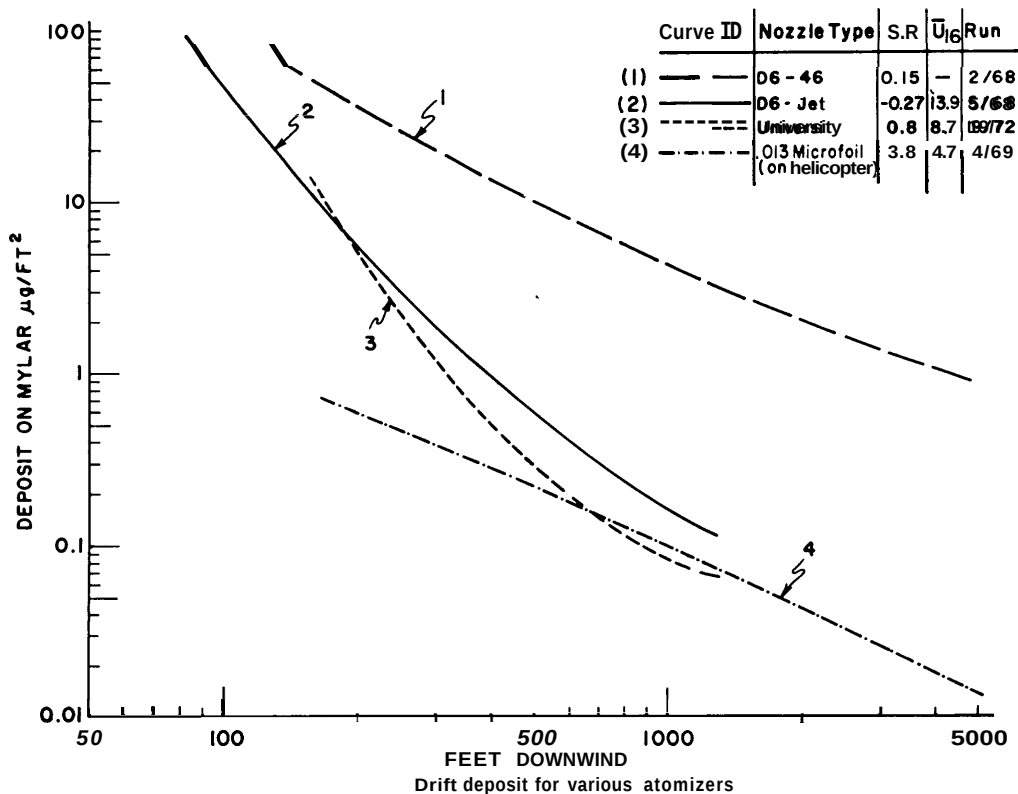


Figure 21.--Comparison of drift downwind from aerial sprays applied through D6-46 nozzles, D6 jet nozzles, transducer system of the University of California at Davis, and a Microfoil Boom® (Wilce et al. 1974, reproduced with permission) .

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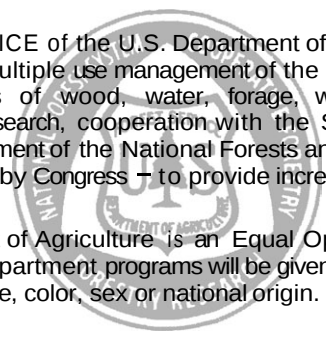
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