Research on Aerial Spraying

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Some day it may be said that the air age in insect control arrived with the discovery of the unusual values of DDT during the Second World War.

In the two preceding decades, the application of insecticides by airplane had been tried against various pests, but the method was not used extensively except over cotton fields. Its advantages were recognized—large acres could be covered quickly with no mechanical damage to the soil or to plants, and forest and swamps and other inaccessible places could be reached by air. There was one great limitation, though: The large quantity of insecticides that had to be applied for satisfactory control made the cost too high, even when the poisons were applied as undiluted dry powders. Liquid sprays, being less concentrated, required even greater quantities.

DDT changed that situation. In their search for better insecticides for combatting malaria-carrying mosquitoes in the Pacific and other war theaters, entomologists found that DDT in an oil-solution spray gave good results when as little as one-fifth to one-fourth pound per acre was used. Engineers developed spraying apparatus for several types of military planes, and before long entire islands were being sprayed as a routine protective measure against mosquitoes and flies.

The end of the war brought a great demand for adapting aerial spraying to a variety of civil needs. Stimulating influences were the publicity given wartime developments, the availability of war-surplus airplanes at low prices and former military pilots who wanted peacetime occupation in aviation, the discovery of other insecticides, and increasing labor costs. Farmers, owners of timberlands, public health authorities, and we all became air-minded about insect control. Hopes were so high, in fact, that some people got the idea that airplanes and the new insecticides would quickly end all insect problems.

But we soon learned that man’s war with insects was not yet over. More was needed than a mere abundance of planes, pilots, and DDT. Much of the wartime development had been made in haste to meet specific military requirements, to get a job done, regardless of cost; in peacetime the idea is to do a job but to do it effectively and economically. After the war, therefore, it was necessary to do a great deal of research to reconvert wartime developments to peacetime uses.

Several Federal and State agencies and many commercial operators conducted the research or assisted by furnishing equipment for making experimental control tests. The investigations have centered on the development of more efficient distributing apparatus and more effective insecticide formulations and the improvement of aircraft for insect-control operations.

Their methods have included generalized observations or appraisals in the field, trial-and-error experiments of limited scope, and broader studies of the principles governing the dispersal and deposition of insecticides from aircraft. Their objective has been to develop wider uses for aerial application of insecticides and to apply them better, faster, and cheaper. Because sprays are less affected by wind and adhere better to foliage, the greater emphasis has been placed on spraying equipment. In the first year or two after the war a great variety of spray equipment was being used. Experimentation and experience, however, have gradually narrowed the field to three main types, boom and nozzles, rotary devices, and exhaust sprayers.

The boom and nozzle sprayer was most commonly in use in 1952. Originally developed for light planes, it has
been adapted to large transports. The sprayer usually consists of a spray tank carried inside the plane from which the spray liquid flows to a wind-driven pump. The pump forces the liquids into a tubular boom mounted beneath the wing (beneath the lower wing of biplanes), from which it is discharged as a spray through atomizing nozzles. The spray is turned on or off by a quick-opening gate valve, and a constant pressure in the spray lines is maintained by the use of an adjustable pressure regulator installed in the line between the pump and gate valve.

The chief advantages of this sprayer over others are the simplicity of its installation and maintenance; the ease with which the degree of atomization of the spray or its rate of application can be changed (it is necessary only to change the size or the number of the nozzles); the use of a pressure regulator, thereby insuring a constant pressure in the system and a uniform discharge rate; and the fact that any excess flow of liquid from the pump is returned to the tank through the bypass from the pressure regulator, thus providing agitation or stirring action in the tank.

Variations in design have been made for specialized jobs. For example, the boom has been placed inside the wing, and nozzles have been attached to it by short pipe connections that extend vertically beneath the lower surface of the wing. In areas where uniformity of spray coverage has not been a prime requirement, other modifications have been to place the nozzles in clusters near the wing tips, on the rear edge of the wing, and on the tail assembly. Those installations improve the flight performance of the plane by reducing the air resistance, but they do not allow rapid adjustments of flow rate and atomization, which may be necessary for controlling different pests.

Considerable work has been done on adapting standard pumps and developing special pumps for the sprayers. Both centrifugal and positive-displacement types have given satisfactory performance. The latter develop higher pressures but often are subject to excessive wear when they are used with certain wettable powders that contain abrasive materials.

Other developments include devices for driving pumps directly from the airplane engine, by hydraulic systems, or by electric motors; the substitution of aluminum for brass or iron to reduce weight; special pump bearings; and pump packing and rubber parts resistant to the solvent action of sprays. Some attempts have been made to eliminate the pump entirely and to depend on gravity flow of the spray liquid from the tank to the boom. It has been found, however, that gravity systems do not deliver at a uniform rate unless some means is provided to compensate for the decreasing hydrostatic pressure as the tank empties.

Many atomizing devices, such as nozzles, jets, slotted orifices, and small venturi tubes, have been tested with varying success. None has been developed which will break up the liquid into drops of a uniform size. In general, though, nozzles that discharge the spray either in a hollow-cone pattern (similar to that of the common sprinkling nozzle) or in a flat fanlike sheet have been the most satisfactory and are the ones most commonly used.

Rotary sprayers were originally developed for applying oils and concentrated slurries of the older type of insecticides, which were too thick to go through pumps. Later they were used for other materials. Some mechanical improvements have been made in post-war models for distributing the newer insecticides, but those sprayers have been less popular than the boom and nozzle type.

The distinctive part of a rotary sprayer is the atomizing unit. It has a shaft with suitable housing and bearings; in front is a small, wind-driven propeller, and on the other end is a series of concave disks or circular wire brushes. The units may be placed on
the wings or on outriggers on the sides of the fuselage. Either way, the shaft is parallel to the fuselage. In flight the liquid flows by gravity from the tank to the center of the disks or brushes. It is then thrown outward by centrifugal force to the periphery of the rotating units, where the passing air shears the liquid into drops. One can change the output by regulating the rate of flow of the material to the units. The speed of rotation, the number and spacing of disks or brushes, and, in the latter, the size of the individual bristles govern the atomization.

Exhaust sprayers, first made for mosquito control, were designed to produce a cloud of spray like the mist sometimes applied inside buildings. The spray liquid is atomized by injecting it into the exhaust of the airplane engine. Usually the exhaust pipe is extended somewhat beyond the engine, and the liquid is introduced into the throat of a venturi or into a special atomizing head on the end of the pipe. The apparatus must be carefully designed for each engine because any restriction in the flow of the exhaust gases may create a dangerous back pressure against the engine. Since the war a few exhaust sprayers have been used in combatting some species of mosquitoes and other biting pests, but they have not come into general use for two reasons: The application rate is too low to kill many kinds of insects, and the spray is so fine that much of it may be carried away by wind or may evaporate before reaching the ground.

Work with dusting equipment has been directed mainly toward getting a wider and more uniform distribution of the materials beneath the plane. The materials usually are discharged from a spreader, like a venturi, on the under side of the fuselage. Consequently a heavy deposit frequently forms along the flight lines and the lateral spread is limited. Efforts have been made to correct the condition, chiefly by changing the design of the spreaders. Some redesigned spreaders have wide openings at the discharge ends or longitudinal deflecting vanes so arranged that the dust is thrown outward on a diagonal. Other spreaders are bifurcated, each branch being curved outward for the same effect. In the project for development of an agricultural airplane, described later, plans have been made to try building streamlined dusting units into the wings.

One advance in a special field is the development of equipment to distribute grasshopper bait from a multi-engine plane. Such poisoned baits have been applied by small aircraft, but the planes cover only limited areas. In order to combat extensive outbreaks, therefore, a bait spreader was designed for a C-47 transport plane. A large hopper holding 8,000 pounds of dry bait was built into the cargo space. A large air duct on each side of the fuselage extends from an opening near the leading edge of the wing, along the floor of the cargo space, and opens to the outside again near the rear of the fuselage. In operation, vaned rollers feed the bait from the hopper into the ducts. The flow of air carries it to the outside. Such a plane can treat 10,000 acres in a day, compared to 1,000 acres for the biplanes commonly used in crop work. The equipment has been modified to permit its use for applying sprays as well as baits by installing removable tanks inside the bait hopper.

The new distributing apparatus has given reasonably good performance in the control of a number of insect pests, but there is need for improvement. Some progress can be made by refinements in existing equipment, but in the long run the maximum efficiency can be had only by developing equipment on the basis of the fundamental factors that govern distribution of insecticides from the air.

Research projects have been started to study those factors, particularly the effect of the aerodynamic forces created by the plane, the size of the spray drops or dust particles, and weather conditions.

We have evidence that, aside from the effect of wind, the aerodynamic
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forces created by the airplane, particularly in the wake behind the plane, are largely responsible for the way the insecticide is finally distributed on the ground. This conclusion is based on results from several investigations, which we summarize here:

1. When a plane with a full-span spray boom is flown 3 to 10 feet from the ground, the spray swath laid down has about the same width as the wing span. When the altitude approximately equals the wing span, however, the swath width is increased four or five times. A further increase in altitude does not further increase the swath.

2. At the low altitude, the spray is driven downward, as evidenced by its reaching the less exposed parts of the plants, but in the higher-altitude flights the spray has very little downward force when it reaches the ground and does not penetrate a dense ground cover. The same effect has been observed in the application of dusts.

3. Increasing the discharge rate of the spray does not increase the swath width but merely deposits a greater amount within the swath.

4. In either the low- or high-altitude flight, the swath width is greater when the outlets are spaced over half or more of the wing span. Releasing the spray from a short boom or single outlet directly beneath the fuselage gives a very narrow swath, but extending the boom beyond the wing tips has not given any greater swath than the full-span boom.

5. When repeated tests are made under carefully selected weather conditions, certain random variations always occur in the amount of spray deposited that cannot be accounted for by weather conditions alone.

Aeronautical engineers have long known that the flow of air created by an airplane in flight is turbulent and spreads backward, outward, and downward. The paths of this airflow are complex and have not been completely worked out, but it seems certain that their general direction governs the differences in swath width we described and that the turbulence of the air flow causes the random irregularities in deposit.

Some research has been done to find out how the size of spray drops or dust particles affects the deposition of the insecticides. The aim is to determine the most effective size. None of the practical atomizing devices known today, whether used on the ground or in the air, will produce uniform spray drops. The average size of the drops can be made large or small, of course, but there is always a range of sizes above and below the average; the larger the average size the greater is the range. Therefore the terms coarse, medium, or fine, when applied to sprays, are only relative expressions.

Flight tests have shown that the degree of spray atomization markedly affects the width of the spray swath and the distribution of the deposit within the swath, especially when the plane is flown at an altitude equal to or greater than the wing span. A very fine spray of an average drop size of about 50 microns (1 micron equals about 0.00004 inch) gives a wider swath and a more uniform deposit than a coarse spray in which the drops average about 200 microns. Because the larger, heavier drops in the latter are less affected by the outward forces in the wake of the plane, they fall more nearly vertically and hence tend to concentrate the spray in the center of the swath. On the other hand, very fine sprays have much greater loss of drops by wind and evaporation.

There may also be a difference in the insecticidal efficiency in the deposits of coarse and fine sprays. The loss of the fine sprays is much greater, but field observations indicate that they penetrate crop or forest foliage better than do coarse sprays. Therefore it would seem that they should be more effective in reaching insects at the base of crop plants or those living beneath a forest canopy. As a matter of fact, in laboratory tests on certain species of insects, deposits of fine sprays have given somewhat higher mortality than
equal deposits of coarse sprays. On the other hand, the coarse sprays have had a longer residual effect. Similar tests of residual effectiveness with aerial applications in the field have not given conclusive results on this point.

Some studies on the effect of particle size on distribution have been made with dusts, but the extent of the work has been limited because the particles, being irregular in shape and considerably smaller than spray drops, are much harder to collect and measure. As with spray drops, fine dust particles give a wider swath and cover foliage better than coarse ones. They are more subject to the effects of wind, however. In the case of diluted dusts, if the carrier or diluent (usually a clay, lime, or talc) is made up of particles different in size from those in the active ingredient, the two components may separate in the air and give a very irregular deposit of poison on the plants.

The least controllable factors that limit the effectiveness of aerial applications are air movement (wind and convection), temperature, and humidity—factors that may change greatly within seconds and over only a few hundred feet.

Wind is surely the most important. It may cause irregular coverage of the treated plants and may cause the spray or dust to drift beyond the treated area. The amount of loss by drift will not depend on the wind velocity alone, however. Size of the drops and altitude of flight also affect the loss. For example, in a wind of 1 mile an hour, a 200-micron drop released 10 feet above the ground will drift about 6 feet. But if the drop is released in a 10-mile-an-hour wind from an altitude of 50 feet it will be carried about 300 feet. Under the same conditions, a 20-micron drop will travel some 3.5 miles. Aside from reducing the amount of insecticide reaching the insects, drift may cause most of the material to strike the plant horizontally. That may result in an uneven distribution on the foliage of plants or trees.

The effect of the wind on spray distribution from planes is especially important when the more potent new insecticides are used. It may cause the spray or dust to drift from the area being treated, thereby contaminating nearby crops sufficiently to be a hazard to people and livestock. The maximum permissible wind velocity when treating crops or spraying for mosquito control generally should not exceed 10 to 15 miles an hour, and when treating forest it should not be greater than 8 miles an hour. Local conditions, of course, may be such that even those velocities are too high.

Convection is another factor. It is an upward flow of air that takes place when the ground temperature is higher than the air temperature. Convection currents usually become noticeable as the sun warms the ground during the morning. They may develop considerable force by afternoon. They affect sprays and dusts much as wind does. They are more variable than wind but, unlike wind, they carry the drops of particles upward instead of horizontally. We have no simple way to determine the amount of convection in an area during spraying or dusting operations. A fairly workable rule of thumb is that the operations should be stopped when the pilot finds the air is becoming bumpy, or when the lighter parts of the spray or dust cloud show a tendency to rise.

Temperature and humidity affect spray distribution indirectly. Increasing temperature promotes convection and increases evaporation rate. The latter may be particularly important when finely atomized, highly volatile materials are being applied. Humidity is chiefly important for its effect on the evaporation of water spray. We know of at least one instance in which a finely atomized water spray, applied on a hot, dry morning, evaporated before it reached the ground.

The best time to apply insecticides from the air is usually from daylight to 9 or 10 o'clock in the morning. Air movement and temperature then are at their lowest and humidity at the
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highest. In some localities the short time just before sunset also is satisfac-
tory.

The fundamental factors interact closely. No one can be isolated and studied by itself. Furthermore, when the control of an insect is being studied the effects of all factors must be con-
sidered in respect to its habits and en-
vironment, and the insecticide to be used.

Many of the new organic insecti-
cides, primarily the chlorinated hydro-
carbons and hydrocarbons containing phosphorus, are highly effective in small amounts. Their development has advanced all methods, air and ground, that employ low volumes of concen-
trated insecticides. The discovery of each has made it necessary to work out spray or dust formulas for each pest by testing the new compound in com-
bination with other compounds, with different solvents or dust carriers, and at different concentrations.

Some research has been directed toward finding how the physical prop-
erties of spray liquids affect dispersal and the efficiency in killing insects. An example is the finding that liquids of high viscosity are more coarsely atomized than less viscous ones and therefore give a narrower spray swath. The more volatile the spray, however, the more rapidly it evaporates; there-
fore a smaller amount reaches the in-
ssects.

Compared to the amount of research on distributing apparatus and insecti-
cides for use in aircraft, the research on developing aircraft especially for spraying and dusting has been very limited. Most of the need for planes immediately after the war was met by adapting war-surplus biplane trainers because they were cheap and sturdy and could carry up to 1,200 pounds of insecticide. Many an operator, how-
ever, has preferred small, two-place, high-wing monoplanes, particularly for treating small acreages. Their per-
formance has been improved. Some spray and dust equipment has been designed so it can be removed easily and the plane can be used for other purposes.

One builder of aircraft dispensing equipment has designed a spray tank in the shape of a seat, the back and bot-
tom having a capacity of about 30 gal-
lons. Such tanks need not be removed.

The helicopter was designed for general-purpose uses, but its ability to fly low and slow has been of particular advantage in spraying and dusting. It is well suited for treating small, in-
accessible areas. It can be landed near or in the field being treated, and con-
siderable ferry time is saved. The heli-
copter is said to be more effective than fixed-wing aircraft in giving thorough coverage to plants, but its first cost and operating costs are quite high.

In order to fill the need for a fixed-
wing aircraft which would be more suitable for agricultural purposes than war-surplus trainers, the National Fly-
ing Farmers Association, Texas Agri-
cultural and Mechanical College, the Civil Aeronautics Administration, and the United States Department of Agri-
culture sponsored the development of such a plane. The prototype model was constructed at the Personal Aircraft Research Center of the Texas Agricul-
tural and Mechanical College. The de-
sign was based on findings in a survey among commercial operators and re-
search organizations to determine the essential characteristics that it should have.

SAFETY was given special considera-
tion. The cockpit is located so as to give the pilot excellent visibility. For protection in a forced landing, all loads and heavy masses are located in the wings or forward of the cockpit, and the pilot has a special seat, safety belt, and shoulder harness. The leading edge of the landing gear is sharp so it can cut wires it might accidentally touch in flight. Two structural members and a crash tripod over the cockpit give ad-
ditional protection. The all-metal, low-
wing monoplane can carry 1,200 pounds of insecticide. It operates at
Machines for Applying Insecticides

Howard Ingerson, Frank Irons

Machines for applying insecticides are available in many makes, models, types, and sizes. They offer a wide range of selection for different conditions and uses. They save labor and provide more efficient ways to combat pests.

Power equipment is of six types—high-pressure sprayers, low-pressure sprayers, air-type sprayers, mist sprayers, dusters, and fog applicators.

The power source usually has been gasoline engines, either by separate engine or through power take-off from a tractor. The trend during the past few years has been toward air-cooled engines for the engine-powered units because they weigh less and are more compact than the water-cooled types. Water-cooled engines are used particularly for the higher horsepower requirements, however, because suitable air-cooled engines have not been available for the larger machines. The engines in use range from one-horsepower, air-cooled types to the large industrial water-cooled engines of 75 horsepower or more.

Tractors, besides hauling the equipment, furnish power to operate the machine. A standard power take-off attachment extends from the rear of the tractor through a power shaft and is connected with the drive shaft of the sprayer or duster.

The vehicles and mountings for carrying the application equipment are: Trailer type, tractor-mounted, motor-truck-mounted, self-propelled, and wheelbarrow and pushcart types.

Trailer-type and tractor-drawn machines commonly are used in orchards and on row crops, especially when heavy machines are required.

 speeds up to 100 miles an hour. Special designed flaps and ailerons give excellent slow-flight characteristics and slow landing speeds, less than 40 miles an hour.

Special types of distributing apparatus were developed. Space for the equipment is in the fuselage and the wing, which was made extra thick for the purpose. The sprayer has tanks and a boom in the wing and an engine-driven pump in the fuselage. The fuselage has a dust hopper with a conventional spreader underneath. On the drawing boards were plans for other types of distributing apparatus, particularly duster units mounted in the wing to give a wider and more uniform swath and equipment for distributing seeds and fertilizers. The plane was flown successfully in 1950.

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