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EQUIPMENT FOR THE DISPERSAL OF DDT INSECTICIDES BY MEANS OF AIRCRAFT [1]

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Division of Insects Affecting Man and Animals

The development of equipment for the dispersion of insecticides is a necessary function in connection with investigational work on new insecticidal materials, because in many cases the efficiency of a material is largely dependent on proper methods of application.

The early work with DDT for the control of certain insects of medical importance, which was under way at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine in 1942, required immediate consideration of ways and means to apply this insecticide. Biological tests had fully demonstrated the value of DDT as a mosquito larvicide, and the material was also found to be useful for adult mosquito control when applied under outdoor conditions. The quantity of DDT needed per unit rate of application as a larvicide was shown to be much lower than that required for arsenicals. The possibility that this might be true for the control of adults over large areas prompted investigations on airplane equipment for the dispersion of DDT insecticides, since aircraft provide methods of application not practical or feasible with other types of equipment.

Investigations were started in July 1943 at the Orlando laboratory to develop suitable equipment for the application of DDT insecticides for use by the armed forces. Since that time several types of equipment for the dispersal of sprays and aerosols by aircraft have been designed and tested, and this report discusses in detail some of the equipment developed. Other agencies have also carried out further studies on this problem, and mention is made of the equipment developed by them but tested in cooperation with the Orlando laboratory.

DDT in dust form was first applied from airplanes in August 1943. The physical properties of the insecticide at this time were such that a powder containing 10 percent or more of the material was not suitable for dusting purposes. Because of this condition, and because

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sprays have certain advantages over dust, studies were begun on the development of spray equipment.

Since the most effective particle size of spray to use was not known when this work was started, the first equipment was designed to produce a reasonably fine spray with a wide range of particle sizes. Even late in 1945 the best particle-size range for the various uses had not been determined, although it was known that good results could be obtained with small as well as relatively large particles.

PORTABLE SPRAY UNIT

L-Series Army Airplanes

A portable spray unit for use on the L-4 (Army Cub), J3-65, and NE-1 Navy Cub was developed in October 1943. It was simple in design, with a venturi beneath the fuselage of the airplane. The venturi kept the spray from coming in contact with the fuselage. The first model was small and contained a 17-gallon spray tank. A gear pump (1/2 inch), operated by a 2-bladed, wind-driven propeller, delivered the spray material from the tank to the nozzles under a pressure of 60 pounds per square inch. Two splatter-plate nozzles, each with a 3/32-inch orifice, were mounted on the trailing lower edge of the venturi.

The droplets produced by this equipment were rather large. However, the equipment was used to conduct certain preliminary biological tests on mosquito larvae and adults, and served as a model for the construction of a larger and more practical unit. The tank of the larger unit holds 25 gallons of spray material. The unit is constructed so that it can be installed and removed from an L-4, a J3-65, or an NE-1 Navy Cub airplane. To install this equipment no structural changes are necessary in any of the airplane-fuselage members, nor is the center of gravity of the airplane changed by its installation. As in the original unit, a gear pump (1/2 inch), powered by a 2-bladed, wind-driven propeller, forces the spray material to the nozzles. Six splatter-plate nozzles are attached to the spray boom near the outer and lower edge of the venturi. Each nozzle is provided with a No. 60 wire-gage size orifice, although orifices of several different sizes were tested.

The gear pump operates at a pressure of approximately 50 pounds per square inch and at an air speed of 70 miles per hour. The spray material used in most of the tests with this equipment consisted of 80 parts of fuel oil and 20 parts of lubricating oil.

The delivery rate was 2 3/4 gallons per minute. A view of this spray unit is shown in figure 1. This sprayer was specifically designed for the L-4; however, with slight modifications it can be installed in an Aeronca (L-3), a Taylorcraft (L-2), and an L-5.

When the sprayer was operated at a pressure of 40 pounds, and the splatter-plate nozzles were provided with No. 54 wire-gage size orifices, the droplets ranged in diameter from 10 to 461 microns.

In early tests this equipment was used with various DDT solutions against larvae and adult mosquitoes. The swath width recommended was 40 feet with the planes flying at a height of 15 to 35 feet and at a speed of 70 miles per hour. The dosage was 2 quarts of solution per acre, which was equivalent to 0.2 pound of DDT per acre when a 5 percent concentration of DDT was employed.

Army PT-17 (Stearman) Airplane

The spray unit designed for the PT-17 (Stearman) airplane was a modification of one designed for the L-4 series. Details of this equipment are shown in figures 2 and 3.

The tank, with a capacity of 60 gallons, was designed to fit in the front-seat compartment after removal of the seat and front control stick. The venturi was also similar to that used on the L-4 series but considerably larger. It was held in place beneath the fuselage by clamping it to the lower longerons. A gear pump (1/2 inch) was mounted on a bracket attached to the landing-gear strut. A 4-bladed, 18-inch, wind-driven wooden propeller was mounted on the pump shaft to build up pressure in the lines. The spray boom, situated near the lower trailing edge of the venturi, consisted of 12 nozzles provided with No. 60 wire-gage size orifices.

A brake assembly was designed for the gear pump, the control being mounted in the pilot's compartment so that the plane could be flown to and from the area to be treated without unnecessary wear on the pump.

This equipment was mounted at the center of gravity of the airplane, and its installation required no structural changes in any part of the airplane.

With an operating pressure of 120 pounds per square inch the delivery rate of the spray solution was 7 1/4 gallons per minute. Tests showed that an effective swath width of 80 feet was obtained when the airplane was flown into the wind at an altitude of 40 feet.

The droplets ranged from 3 to 201/ microns in diameter.

The PT-17 spray equipment was used extensively in connection with research at the Orlando laboratory. For these tests a special spray tank was built which contained three separate compartments holding 20 gallons each. A valve system was designed and mounted in the pilot's compartment so that the fluid could be sprayed from any one (or all three) of the tank compartments at will. Smoke equipment, which will be discussed later, was installed on the same plane. It was possible, therefore, to apply three separate spray solutions and to make three smoke applications in one flight.

BREAKER-BAR SPRAYER

Although the original portable spray units produced satisfactory results, there were a number of objections to the equipment and efforts were made to make improvements. It was desirable to decrease the weight and air resistance of the equipment, and to provide for more uniform distribution of the spray. The first opportunity to construct and use the breaker-bar sprayer was afforded while one of the writers, C. N. Husman, was on assignment in the Pacific with Research Unit No. 2 of the U. S. Navy. The equipment was designed for the TBM or TBF airplanes and proved successful against mosquitoes in tests conducted by the Navy. Similar equipment for the smaller planes was then designed at the Orlando laboratory.

L-4 Series Airplanes

The new portable spray unit for the L-4 series airplanes uses the same tank, pump, and wind-driven propeller that were constructed for the original model, and the venturi is replaced by two breaker-bar spray booms, one mounted under each of the wing struts. Details of this equipment are given in plates 1, 2, and 3, and parts of the equipment are shown in figures 4 and 5.

The two spray booms are clamped to the wing struts just outside the slip stream. Each boom is 38 inches long and has 24 orifices of a No. 71 wire-gage diameter; however, the orifices can be made larger if desired. The space between the two booms is 8 feet 6 inches, making a total of 16 feet 6 inches from the tip of one boom to the tip of the other.

The spray booms are constructed of 3/8-inch (i.d.) aircraft tubing, the 24 orifices, equally spaced, being drilled horizontally along the tube. A Duralumin spray-breaker bar, 5/8 by 1/4 inch, with a 5° convex face, is mounted on the tubing with a space of 1/2 inch between the tubing and the bar. The bar is held in place by three 3/16-inch bolts, which are threaded so that adjustments can be made between the breaker bar and the tubing. When a 4-bladed propeller is used, the spray material is forced through the orifices at a pressure of 70 pounds, and the spray particles are broken up by the spray material impinging against the bar. Further break-up results from air stream flowing over the edges of the bar.

As the spray material disperses it is well distributed between the two bars a short distance beyond the rear of the plane. Since the spray is forced out over a total length of 8 feet, it becomes dispersed through air turbulence caused by movement of the plane. With this equipment the effective swath width is 80 feet, as compared with 40 feet for the original equipment.

In the tests with this equipment the spray material consisted of 80 parts of fuel oil and 20 parts of No. 30 lube oil plus dye. When 4 1/8 gallons of solution was applied per minute, the dosage of spray was 1.7 quarts per acre when the plane was flown at 60 m.p.h., as compared with 1.45 quarts per acre when the plane was flown at 70 m.p.h. When 5 3/5 gallons of solution was applied per minute, the dosage was 2.32 quarts per acre at 60 m.p.h. and 1.99 quarts per acre at 70 m.p.h.

The breaker-bar sprayer has advantages over the original sprayer when used on an L-4 airplane, and it is the type now recommended for military use. It is lighter than the original sprayer, and the absence of the venturi reduces the air resistance. A wider swath, smaller droplets, and a more uniform distribution of the spray within the swath is also obtained. The droplet diameters range from 10 to 461/ microns. The delivery rate and size of the droplets can be readily changed by having available several sets of tubing with different sizes and number of orifices.

L-5 Series Airplanes

The L-5 airplane was more readily available in combat areas than the L-4. It is also somewhat larger and will carry a heavier pay load. For this reason it was desirable to adapt the same type of sprayer for use in the L-5 as was designed for the L-4. This was done by the Army Air Forces Board, Army Air Forces Center, Orlando, Fla., in cooperation with the Orlando laboratory. The equipment is essentially the same as that for the L-4 but is somewhat larger. The spray tank has a capacity of 40 gallons. The spray is delivered at the rate of 10 gallons per minute, and at a dosage of 2 quarts per acre an effective swath width of 110 feet is obtained at a plane speed of 90 miles per hour. The breaker-bar spray boom is constructed of 3/4-inch tubing, 5 feet long.

PT-17 (Stearman) and N3N3 Airplanes

PT-17 and N3N3 airplanes, which were used by the Army for primary trainers, are suitable for the application of sprays and are available as Government surplus property. A breaker-bar type of sprayer was designed for the PT-17 which was similar in principle to the equipment described for the L-4. The details of construction are given in plates 4, 5, 6, and 6a to 6h, inclusive, and in figures 6 and 7. Figure 8 shows the application of a DDT spray with a PT-17 airplane equipped with the breaker-bar spray unit.

The unit is considerably larger than the L-5 breaker-bar sprayer. The spray tank has a capacity of 60 gallons, and the two spray booms beneath the wings have a total length of 24 feet. Each spray boom can be provided with the number and size of orifices required to give the delivery and approximate droplet spectrum desired. The unit described has a delivery rate of 10/ gallons per minute when the 3/4-inch gear pumps are powered with a 4-bladed, wind-driven propeller on each wing. The spray booms used in the test model were provided with 100 No. 70 wire-gage size orifices (50 in each boom), and the spray was forced through the orifices at a pressure of 100 pounds per square inch. At a dosage of 2 quarts of solution per acre, an effective swath of 120 feet is obtained when the plane is flown at a speed of 90 m.p.h. The droplets produced by this equipment range from 10 to 461/ microns in diameter.

TBM and TBF Airplanes

The breaker-bar spray unit for TBM and TBF airplanes was first constructed for use in the Pacific. The equipment is designed for the application of DDT in fuel oil. It is constructed so that no structural changes in the plane are necessary when the equipment is installed, and the plane can also be used for combat. All parts used in the construction were procured from Naval Aviation Supply in the theater of operations. Photographs of parts of the equipment are shown in figures 9 and 10.

The bomb-bay auxiliary gas tank available for this aircraft is used for the insecticide spray tank. The only modification on the tank is the installation of four outlets to feed the four electric pumps. These outlets are mounted on the top end of the tank, with four standpipes extending to the bottom. All other fittings on the tank, such as transmitter, filler, and breathers, are standard installations.

Four electric auxiliary booster fuel pumps (U. S. Navy Stock No. TFD 9500) (fig. 11) are mounted on a bracket which is the duplicate of the rear bracket supporting the tank. Two pieces of 3/4-inch plywood are bolted to each side of the brackets, to which the pumps are bolted. The brackets and pumps are mounted in the rear of the bomb-bay compartment, leaving working space between the tank and the pumps. The pump capacity is approximately 400 gallons per hour. These pumps are adjusted for a pressure of 27 pounds per square inch, and produce a 25-pound operating pressure at the nozzle.

Power is furnished to the pumps by the 24-volt electrical system of the plane. The wiring is brought to the pumps from the junction box mounted on the rear portside of the bomb bay. The switch, which is mounted on the portside of the cockpit just in front of the throttle, is easily accessible to the pilot.

Each spray nozzle, located on the tip of each wing, is fed by two pumps connected by a Y, and the spray material is delivered to the nozzle by a 1-inch (i.d.) aluminum tubing. A 1 1/4-inch hole is drilled in an inspection plate on the fuselage and rubber grommet is installed. The 1-inch aluminum tubing leads out from the Y joint through this inspection plate. From this point it extends up to the lower part of the wing and then out to the spray nozzles. The tube lies flush against the wing skin, and is held in place by clamps (U. S. Navy Stock No. CSCO 64) that are bolted to the wing by screws (8-36). Two short sections of oil-resistant hose are installed in the line so that it may be uncoupled to allow the wings to fold. The spray nozzles and brackets are constructed of molybdenum steel, with gaskets between the brackets and the wing. These are held in place with 1-inch drilled head screws (8-36) and are safety wired. The bracket plate is constructed of 1/16-inch plate. Hangers for the spray boom are constructed of 1/2-inch (i.d.) 0.035-inch wall-thickness aircraft tubing welded to the plate and also to the clamps that hold the spray nozzle in place. Cross braces are welded in the hanger for additional strength.

The spray nozzle is constructed of 1-inch (i.d.) 0.035-inch wall-thickness aircraft tubing. Nineteen No. 50 wire-gage size orifices, equally spaced, are drilled horizontally along the tube. A breaker-bar spray constructed of 1/4- by 5/8-inch Duralumin is mounted on the tubing. The bar is held in place by bolting it to the tubing with 8-36 drilled head screws, with spacers between the tube and the bar. The screws must be safety wired.

The following is a brief description of a unit built by the Banana River Naval Base, Banana River, Fla., from plans furnished by the Orlando laboratory. This unit is a slight modification of the original type constructed in the Pacific. The bomb-bay auxiliary gas tank is used for the insecticide spray tank. The spray material is pumped by four electric auxiliary booster fuel pumps (U. S. Navy Stock No. TFD 9100). Each pump has a capacity of 700 gallons per hour and is adjusted to give an operating pressure of 25 pounds per square inch at the nozzle.

The spray booms, one under each wing (see fig. 10), are constructed of 1 1/4-inch (i.d.) 0.035-inch side-wall aircraft tubing. Each boom is 12 feet long and provided with 38 orifices of a No. 48 wire-gage size. The size of the orifices can be changed to suit particular needs. A bar constructed of 1/4- by 1-inch Duralumin is attached to each of the booms with a clearance of 1 inch between the orifice outlets and the bar. The face of this bar is flat. The spray material is forced through the orifices in the tubing, and the spray particles are broken up by the spray material impinging against the bar. Further break-up results from air stream flowing over the edges of the bar.

TBF and TBM planes equipped with this sprayer usually fly at a speed of 115 knots (132 miles) per hour. The plane is flown with 15° of flaps under average conditions. At this speed a delivery of 2 quarts of solution per acre is obtained flying swath widths of 250 feet. Droplets ranging in diameter from 10 to 341+ microns were produced by this spray.

A new device for the breaker-bar type of sprayer has been constructed and is being tested. It consists of screen wire 5 inches wide mounted in a frame 4 inches to the rear of the breaker bar. The device runs the full length of the spray boom, and is held in place by brackets which are clamped to the spray boom. Several frames have been constructed of different size screens, ranging from 16 to 40 mesh. The spray produced with this attachment has smaller particles and is more equally distributed.

EXHAUST-GENERATED SPRAYS AND THERMAL AEROSOLS

Because of the promising results obtained with DDT sprays, and because pyrethrum smokes had shown some promise against flies and mosquitoes in early tests made by the workers at the Agricultural Research Center at Beltsville, Md., equipment was designed for testing DDT smokes applied from airplanes. The exhaust was utilized to produce the heat required to generate the DDT smoke. Various types of thermal equipment for generating smokes and aerosols have since been investigated by different agencies. The kinds of equipment developed and tested on various types of airplanes are discussed briefly in the following pages.

Insecticidal Smoke-Spray Equipment

L-4 Series Airplanes.--The first smoke-spray equipment was designed for the L-4 series airplanes, employing the same spray tank, pump assembly, and venturi used with the Husman-Longcoy spray device. Copper pipes, which were attached to the exhaust pipes, joined in a Y beneath the fuselage. A single 4-inch pipe then extended through and to the trailing edge of the venturi, utilizing the venturi as a support. It was originally believed that the venturi would aid in the dispersion of the smoke, but this was later proved incorrect and the pipe alone was used. The copper pipes were covered wholly or partially with asbestos to retain the heat. The spray material was forced through a nozzle located inside of each exhaust pipe, just behind the exhaust blaze from the engine. A stainless-steel exhaust pipe was later employed, because it was found that the copper pipe did not withstand the heat. Figure 12 shows this equipment installed on a Cub airplane.

A number of field and semifield tests were conducted with this apparatus in the fall of 1943. The fuel oil solutions used in these tests contained from 5 to 20 percent of DDT. Cyclohexanone was used as an auxiliary solvent with the higher concentrations of DDT. In some of these tests good results were obtained against adult salt-marsh mosquitoes and Anopheles larvae, although in general results were unsatisfactory. The heat of the exhaust volatilized a portion of the DDT solution, resulting in a rather intense smoke. The equipment did not, however, cause complete conversion of the material into smoke, since some spray was produced. On the basis of studies conducted by workers of the National Defense Research Committee at Columbia University and the Bureau of Entomology and Plant Quarantine at Beltsville, and later confirmed at the Orlando laboratory, it has been concluded that the DDT smoke particles (less than 1 micron in diameter) are relatively nontoxic to insects. The mortality of larvae and adults obtained in some of the tests with the equipment described can, no doubt, be largely attributed to the spray particles. The equipment described does not appear to be of practical value.

PT-17 (Stearman) Airplane.--Smoke-spray equipment similar to that on the L-4 series airplanes was installed by the Tennessee Valley Authority (drawings used were furnished by Orlando laboratory) on a PT-17 airplane (450 hp.), and a similar device was designed for the PT-17 (220 hp.) at the Orlando laboratory. The equipment consisted of the same spray tank, pump assembly, valve, and spray line systems used with the original L-4 spray unit. A 19-foot stainless-steel pipe, 5 inches in diameter, made of two sections of equal length, and mounted along the side of the fuselage, was connected with the exhaust pipe of the airplane by means of a 2 3/4-inch (i.d.) elbow and a piece of 2 3/4-inch (i.d.) flexible tubing 8 inches long. The discharge end of the extension of the exhaust pipe was located beneath the tail of the plane. Figure 13 shows this equipment on a PT-17 airplane, and figure 14 shows an insecticidal smoke being dispersed from the same plane.

The nozzles used inside the pipe were of various types of L-shaped jets, and were placed so that the spray was forced in the direction of the air stream within the pipe and the nozzles could be placed at different distances from the end of the exhaust pipe. When the nozzles were placed near the engine a high percentage of the DDT solution was of screening-smoke size (1 micron or less), whereas when they were placed near the end of the exhaust-pipe extension a large portion of the solution did not volatilize but broke up into spray particles.

Extensive experiments were conducted with this type of equipment by the Tennessee Valley Authority. Excellent results were reported against *Anopheles* larvae and promising results against adults of *Anopheles quadrimaculatus* Say. Some success was also obtained with this equipment in a few tests conducted at Orlando. As with the L-4 smoke equipment, however, the spray fraction was probably responsible for most of the toxic action.

Thermal Aerosol-Spray Equipment

The results of tests with the insecticidal smoke-spray or thermal aerosol-spray equipment discussed in connection with the L-4 and PT-17 airplanes were of sufficient promise to warrant further study of the method for dispersing insecticides with exhaust-generated spray equipment. The National Defense Research Committee at the University of Illinois therefore designed equipment for the dispersion of DDT solutions as aerosols or fine sprays. Tests with this equipment were carried on in cooperation with the Tennessee Valley Authority, the U. S. Navy, the Army Air Forces, and the Bureau of Entomology and Plant Quarantine. The exhaust-generated spray equipment has been designed for several types of airplanes and brief mention will be made of each.

PT-17 Airplane.-- The first exhaust-generated spray unit for the PT-17 airplane was built by the Tennessee Valley Authority. These planes are powered by 450-hp. engines.

The equipment consists of a venturi within the extension of the exhaust pipe. The spray solution is injected through several small orifices placed at or near the constriction of the venturi. The rapid flow of the hot exhaust gases at the point of constriction of the venturi atomizes the solution into fine droplets. A portion of the solvent volatilizes and the insecticide is discharged as a screening smoke, although this is thought to represent only a small portion of the total material.

Extensive experimental and practical control tests were conducted by the Tennessee Valley Authority in 1944 and 1945, and satisfactory results have been reported against both larvae and adults of mosquitoes. Solutions containing as much as 20 percent of DDT in Velsicol NR-70 (chiefly tetramethylnaphthalene) were used in these tests.

The same type of equipment was also installed on a PT-17 airplane from plans furnished by the National Defense Research Committee at the University of Illinois. In tests conducted against adult salt-marsh mosquitoes satisfactory results were obtained in only one test. These results were comparable with those obtained with spray apparatus tested at the same time.

Details of the exhaust-generated aerosol equipment for the PT-17 airplane and its performance may be obtained from the National Defense Research Committee, Department of Physical Chemistry, University of Illinois, Urbana, Ill.; and from the Health and Safety Department, Tennessee Valley Authority, Wilson Dam, Ala.

Navy TBM Airplane.--The same type of exhaust spray equipment as was used on the PT-17 airplane has been designed by the National Defense Research Committee at the University of Illinois and installed in a Navy TBM airplane. Tests conducted in Florida, Panama, and elsewhere indicated satisfactory biological results against *Anopheles* larvae and also against adults of *A. albimanus* Wied., *triannulatus* Neiva and Pinto, and *punctimacula* D. and K. The agencies cooperating in these tests were the U. S. Navy, the National Defense Research Committee, the U. S. Army in Panama, the Tennessee Valley Authority, and the Bureau of Entomology and Plant Quarantine.

C-47 Airplane.--Rather extensive tests with the exhaust-generated aerosol equipment installed on a C-47 transport plane have recently been conducted by the Army Air Forces Board, Army Air Forces Center, Orlando, in cooperation with the Orlando laboratory of this Bureau, and the National Defense Research Committee. Results of these tests will be discussed in a special report.

OTHER TYPES OF EQUIPMENT FOR THE DISPERSAL OF INSECTICIDES FROM AIRPLANES

Other types of spray equipment have been investigated by various agencies, principally the Army Air Forces Board at Orlando. Some of these are in practical use by the armed services at the present time, while others are in the experimental stage. The various types of equipment known to have been tested will only be mentioned here, and reference will be made to known sources that may be consulted for more detailed information.

Chemical Warfare Service Tanks

Soon after initial tests were made which demonstrated that adult mosquitoes and larvae could be controlled with DDT sprays applied from small aircraft, preliminary tests were made by the Orlando laboratory, in cooperation with the Army Air Forces Board at Orlando, to determine whether DDT sprays could be applied from the M-10 and M-33 tanks used by the Chemical Warfare Service.

Fairly satisfactory results have been reported and, since the equipment was already available in combat areas, it was serving a useful purpose because it could be employed in the absence of equipment designed specifically for dispersion of insecticides. The limitations on the use of the equipment were the rather low pay load and the lack of suitable methods of controlling the delivery of the spray material.

Since sufficiently good results were obtained with these tests, no further practical tests were conducted by the Army Air Forces Board at Orlando. This method of dispersing DDT sprays was then explored further by the Army and Navy and also by the British.

Details of the equipment and its performance may be obtained through the Office of the Air Surgeon, Army Air Forces, and from the Chemical Warfare Service, Washington, D. C.

Gravity Feed Spray Equipment for Use on C-47 and B-25 Airplanes

One of the most promising types of spraying equipment for use on large airplanes is the gravity feed equipment designed by the Army Air Forces Board at Wright Field, Dayton, Ohio, and the National Defense Research Committee at the University of Illinois. This equipment, installed on a C-47 or B-25 plane, gave excellent results in tests conducted in Florida and Panama by various cooperating agencies.

Details of the equipment and its performance may also be obtained from the Office of the Air Surgeon, Army Air Forces, Washington, D. C.

Spray Equipment for Use on Helicopters

Several types of spray equipment have been tested on a Sikorsky R-4 helicopter, including ordinary spray nozzles mounted on spray booms, exhaust generated smoke-sprayers, and the breaker-bar type nozzles. This work was done by the U. S. Coast Guard, the Bureau of Medicine and Surgery of the U. S. Navy, and the Orlando laboratory. Satisfactory spraying equipment has been developed, and preliminary tests indicate satisfactory biological results. The use of a helicopter for dispensing insecticides is in the experimental stage, however, and its place in this field has not yet been determined.

Details regarding equipment for this type of helicopter may be obtained through the Bureau of Medicine and Surgery of the U. S. Navy, Washington, D. C.

DUSTING EQUIPMENT

Although sprays have a number of advantages over dusts when applied from airplanes, insecticidal dusts have been widely used for the control of mosquitoes as well as agricultural pests. Since DDT can also be applied in dust form for the control of anopheline larvae, it seems appropriate to mention dusting equipment. For use by the armed services DDT dusts have the following disadvantages: (1) The physical properties of DDT dusts are such that uniform dosages are difficult to apply; (2) the problem of obtaining satisfactory diluents for dusts in combat theaters is usually more difficult than for liquid insecticides; (3) mixing DDT dusts in the field is generally more difficult than mixing liquid preparations; (4) although effective against surface-feeding larvae, such as the anophelines, DDT dusts are not highly effective against culicine larvae; and (5) DDT in dust form is less effective against adult mosquitoes than it is in a spray.

Dusting equipment was used in some of the early work done at the Orlando laboratory. A portable dusting unit, which was designed by the Bureau of Entomology and Plant Quarantine for use on a small plane, such as the L-4 series and similar airplanes, is described below. Plans for the unit are shown in plates 7 and 8. The equipment installed on a J3-65 is shown in figure 15.

The portable unit is designed so that it can be readily removed and installed on the airplane. No structural changes or alterations of any of the aircraft members are required to install the unit, and the airplane can be used for other purposes when the equipment is removed.

The hopper has a capacity of 6 1/2 cubic feet. It is mounted in the rear-seat compartment and is equipped with a dust-sealed cover and adjustable cabin ventilators to protect the pilot from dust while in flight. The various controls and valves are also shown in plates 7 and 8. As with the spray, the venturi attached beneath the fuselage (pl. 7 and fig. 15) prevents the dust from entering the plane and also aids in forcing the dust downward away from the fuselage. The dust agitator is powered by a wind-driven propeller. By means of the feed-control valve located beneath the agitator, the pilot can change the rate of delivery of the dust while in flight. The dust flow can be quickly cut on and off by means of butterfly valves mounted in the two throats which extend from the hopper to the venturi. The equipment is designed for applying arsenical dusts, and is made so that the rate of delivery can be changed to put out dusts at the rate of 1 to 20 pounds per acre while flying a 50-foot swath.

No doubt many other types of dusting equipment have been designed, and further information may be obtained from the Health and Safety Department of the Tennessee Valley Authority.

GENERAL CONSIDERATIONS IN THE APPLICATION OF INSECTICIDES FROM AIRCRAFT

Detailed instructions cannot be given for the application of sprays by aircraft, as several different types of planes will be used. The directions suggested here are general, and outline principles that should be followed in applying sprays with any type of slow-moving aircraft. In routine applications the plane is flown back and forth over the area to be treated (pl.9). The distance between successive flights, or swath width, will depend on the type of airplane used, the quantity of spray to be applied, the droplet size of the spray, the rate of spray delivery, and the velocity and direction of the wind. The most effective swath width must be determined for each type of aircraft and equipment. To assist in calculating the interval required between swath widths in relation to the dosage of insecticide, spray delivery, and speed of plane, a chart (pl. 10) has been prepared.

Droplet Size

The optimum droplet size for use in aircraft spraying for mosquito control has not been determined. No doubt for use against larvae it will be different from that required for adult mosquitoes. However, good results have been obtained against both larvae and adults of mosquitoes with DDT sprays producing particle sizes ranging from 10-460 microns in diameter. Until more is known on this subject it seems well to employ this range of droplet sizes. By using nozzles with orifices of different sizes, the spray can be broken up into a wide range of droplet sizes, some of which will be in the so-called aerosol range (less than 25 microns) and others in the range of 300 to 400 microns. This range of droplet size assures thorough and uniform coverage under a wide range of conditions. The small droplets are carried by the air currents, thereby giving a more uniform distribution over a wider swath, and the large droplets generally fall downward beneath the path of flight of the plane.

Swath Width

The delivery rate of the solution should be set according to speed and desired swath width to obtain the amount needed per acre of a given concentration of spray. At present 2 to 3 quarts per acre of a 5-percent solution or emulsion is generally recommended. The flights to determine swath width should be made at altitudes of 35 to 150 feet flying into or downwind. The original TBM, equipped with the breaker-bar unit, was flown at 115 knots, using 15 degrees of wing flaps, and at 2 quarts of solution per acre an effective swath of 150 feet was indicated. The newer model, which was designed by the Orlando laboratory and recently installed on this plane by the Banana River Naval Air Station, produces a wider, more effective swath at the same rate of application per acre. The breaker-bar type of spray unit installed on an L-4 will give an effective swath of 80 feet, whereas 120 feet has proved satisfactory for the L-5, both applying the insecticide at a rate of 2 quarts per acre. The PT-17 can be flown at swath widths of 110 to 120 feet. The Tennessee Valley Authority reports that the exhaust-generator type of equipment produces a wide swath. With the larger planes, such as the C-47 and B-25,equipped with gravity-feed spray equipment, an effective swath of 300 to 600 feet is obtained.

In applying sprays in open areas where there are no obstructions, it may be desirable to fly light aircraft, such as the L-4 series, at 35 feet or lower, the height depending upon the wind velocity. In a strong wind it is necessary to fly as low as safety permits to prevent excessive drift. With light planes sprays should not be applied when the wind exceeds 15 miles per hour. A breeze of about 5 miles per hour is an advantage in air applications, as the drift causes the spray from successive swaths to overlap and insures more even and complete coverage.

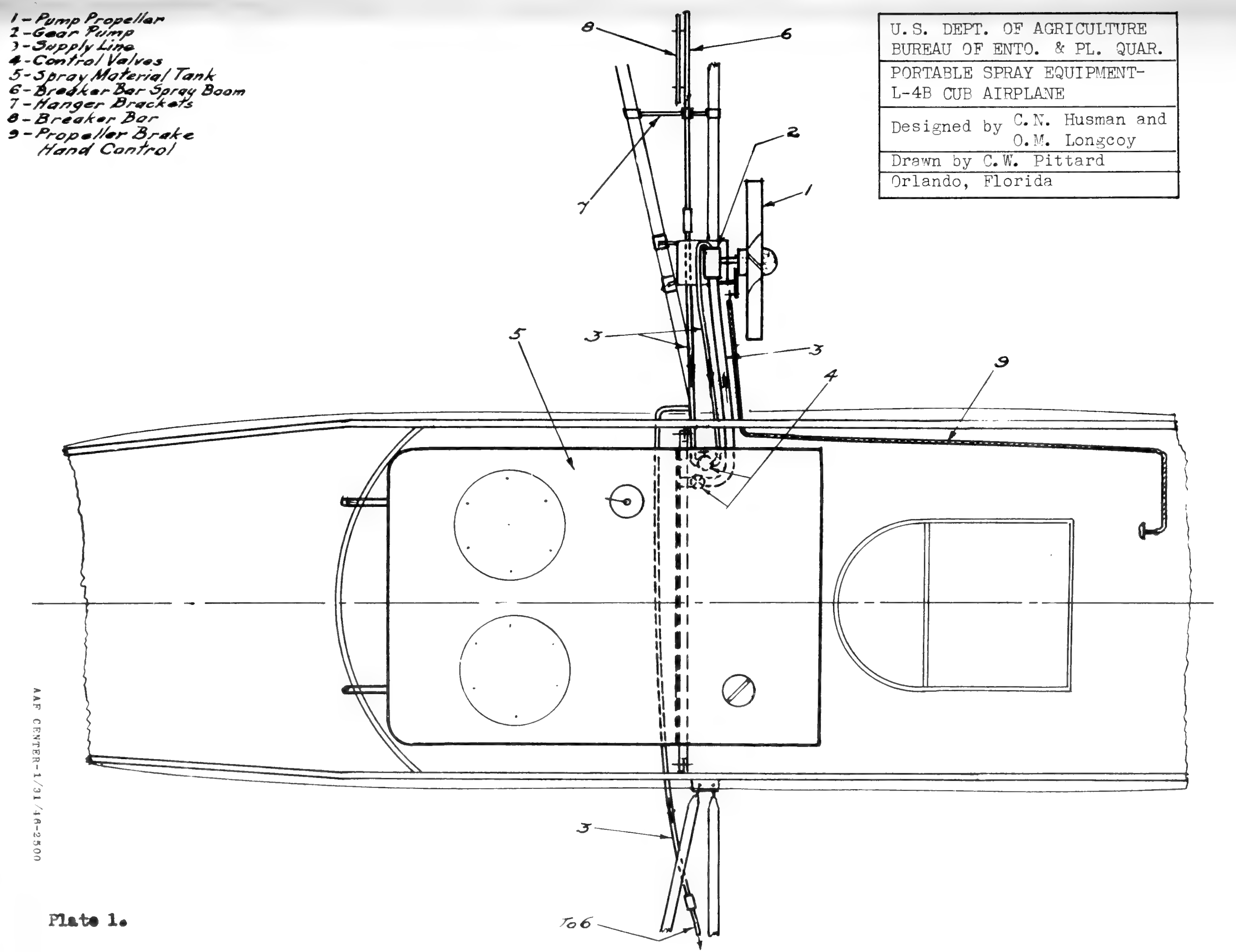
Under the same conditions, larger planes are flown at heights of 50 and 150 feet. The kind of spray, the nature of the terrain, and the heights of the obstructions usually determine the height of flight. This is particularly true of small planes. The recommended height at which the C-47 and B-25 should be flown (150 feet, as determined by the Army Air Forces Board) is usually high enough to clear obstructions. In areas with high obstructions it is suggested that small planes be flown as low as conditions of safety permit. An extra swath or two should be applied on the windward side, and ground observers should direct the pilot so that these first swaths will fall just outside the area to be treated. If care is not taken, the drift may leave an untreated strip on the windward side.

When possible, sprays should be applied early in the morning. Wind conditions are usually most favorable at that time of day and there is less air turbulence. The importance of time of day has not been fully determined, but for the present early morning spraying is suggested as being most satisfactory.

Pilots who have not applied dusts or sprays should be trained before they are assigned to airplane spraying. It is of primary importance that they be guided for the swath width until they have demonstrated that they can fly even swaths without assistance. The degree of control obtained from airplane treatments depends very largely upon how uniformly the pilot maintains his flight or swath lines. In open areas a simple method of directing the pilot is to place flagmen at each end of the area to be treated; in wooded areas meteorological balloons may be used. Each time the pilot flies over the markers the men move over the required number of feet to mark the next swath. Many pilots soon learn to judge this distance and do not require flagmen except in difficult terrain or in critical control situations. Where possible, a light two-way radio would be of advantage in directing the pilot, especially for spot spraying. A 40-pound transmitter and receiver is available for communication with the TBF or SB2C and other aircraft where the pay load permits. Plate 11 shows the flight pattern suggested by the Army Air Forces Board when C-47 or B-25 aircraft are employed on small areas. Large aircraft are difficult to maneuver, and should be used only for large areas where the course is quite long. The large aircraft, such as TBM, B-25, SB2C, or C-47, carry larger loads and thus reduce the amount of time lost in the refilling operations. Also, their greater speed and flight range allow them to be used considerable distances from the base of operations. Small areas requiring short runs should be treated with small aircraft or by hand.

The pilot is the key man in applications of insecticide from the air, although the over-all operation should be under the direction of an entomologist. The success of the control operations depends on how well the pilot "flies" the area to be treated. He not only should be thoroughly briefed on the problem, but he should work closely enough with those directing the control operations to be familiar with the problem. He should completely understand the object of the control program and its importance. He can better appreciate what is being attempted if he can be shown the problem on the ground.

The difficulty of filling the spray tank on aircraft can be largely overcome by using a trailer tank equipped with a power pump. Such a piece of equipment can be made easily by using a small air-cooled gasoline engine to operate a fuel pump. This pump arrangement can be mounted on a trailer tank having a capacity of 300 gallons or more. The hoses should be oil resistant and sufficiently long so that they can be used to fill the tank from barrels if necessary. The Chemical Warfare Service tank trucks have also been found useful for this purpose.



AAF CENTER-1/31/46-2500

Plate 1.

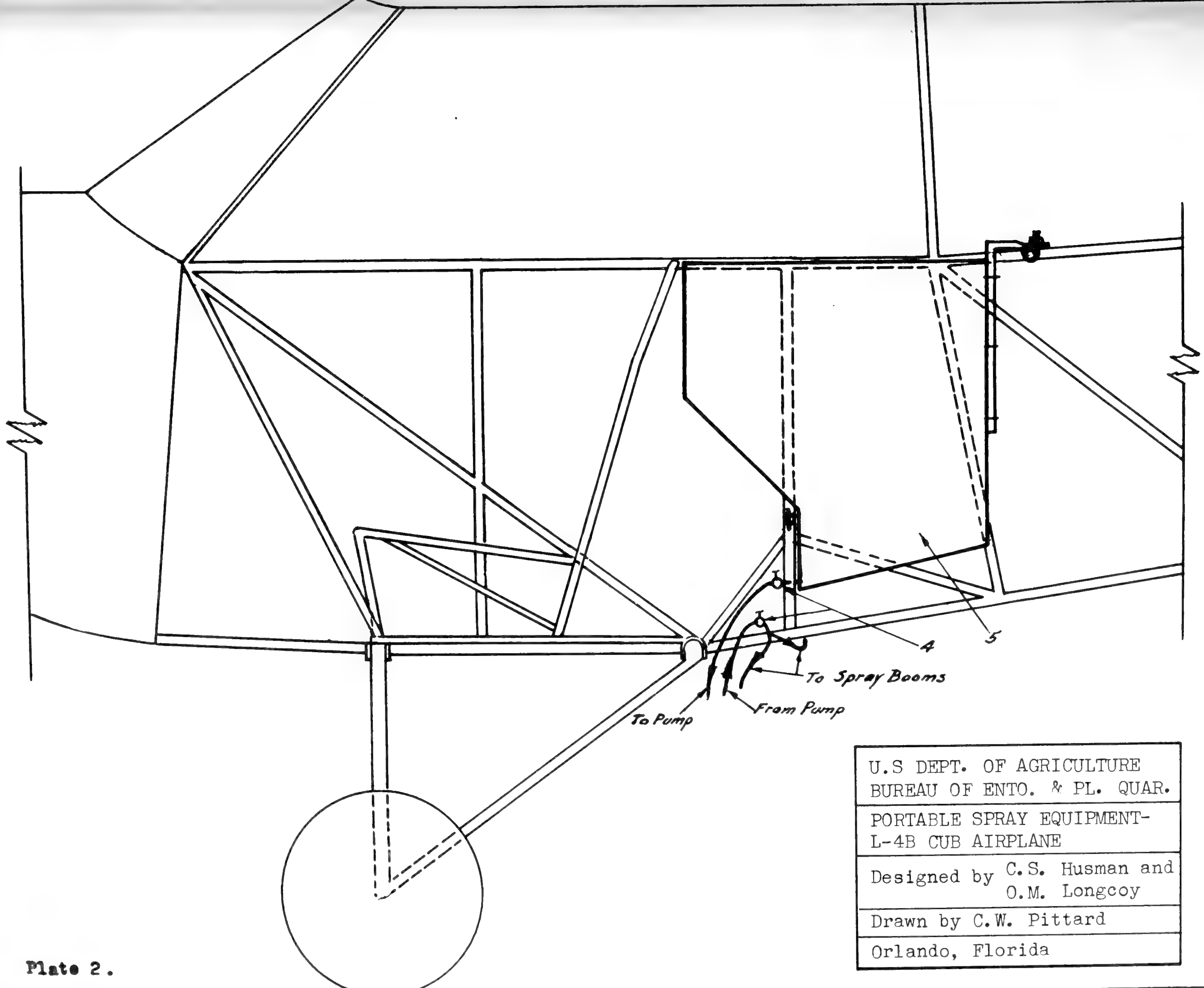
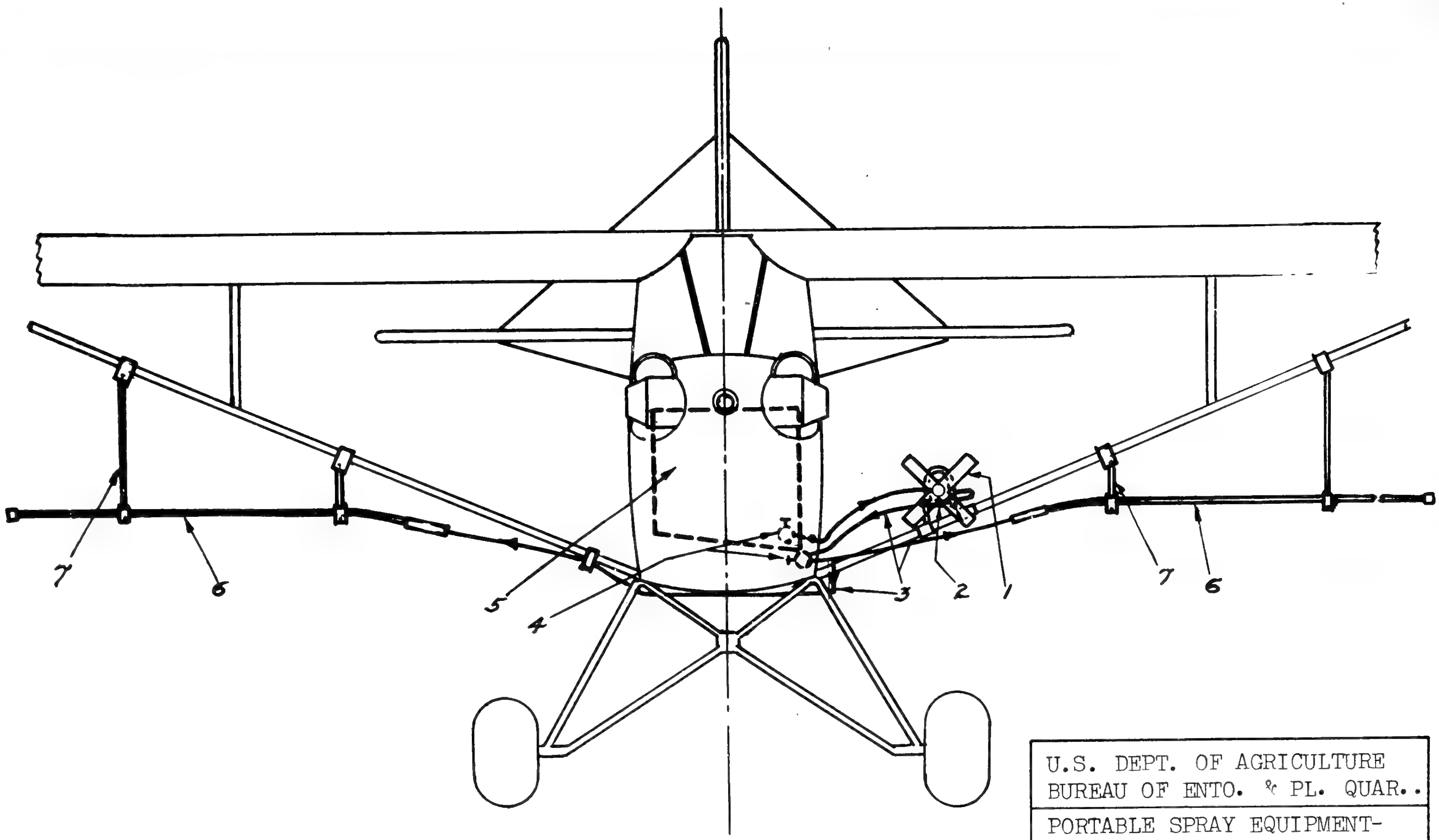
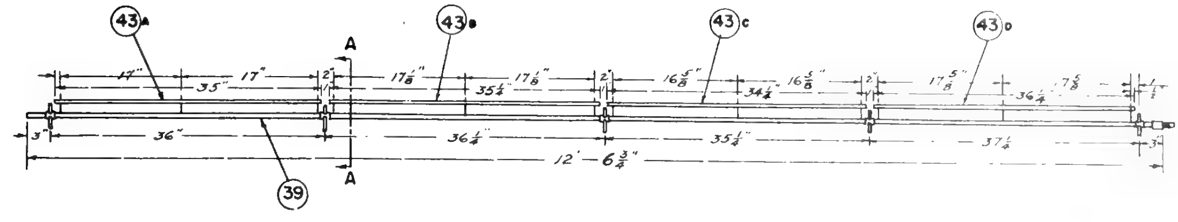

4
5
To Spray Booms
From Pump
To Pump
U.S DEPT. OF AGRICULTURE
BUREAU OF ENTO. & PL. QUAR.
PORTABLE SPRAY EQUIPMENT-
L-4B CUB AIRPLANE
Designed by C.S. Husman and
O.M. Longcoy
Drawn by C.W. Pittard
Orlando, Florida

Plate 2.

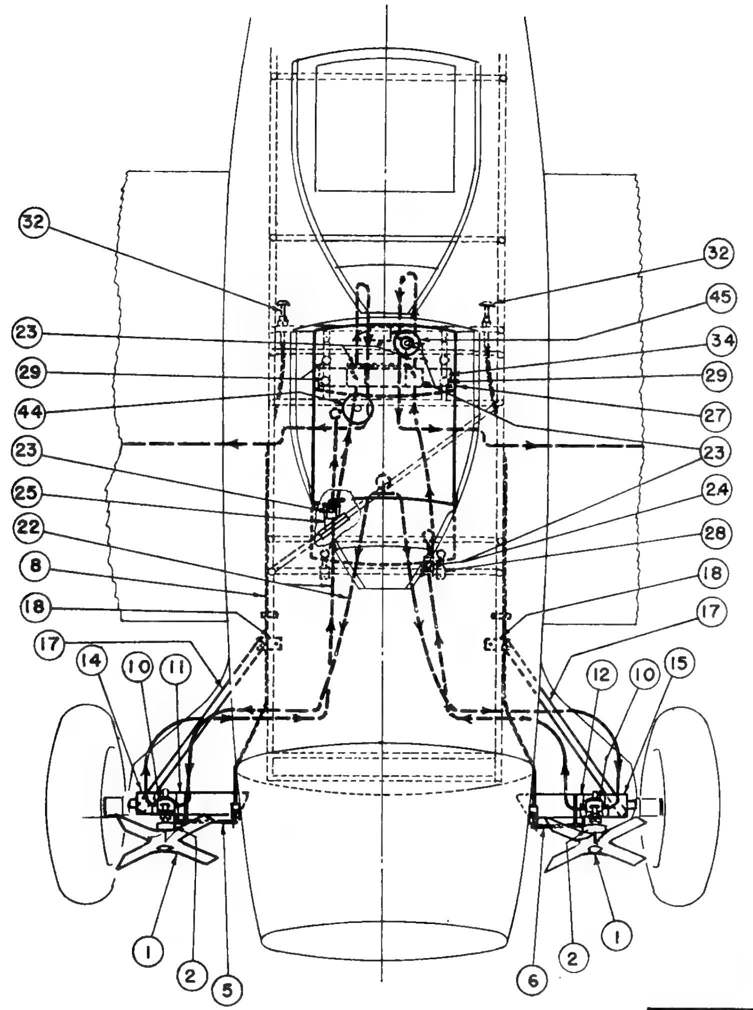


U.S. DEPT. OF AGRICULTURE BUREAU OF ENTO. & PL. QUAR..
PORTABLE SPRAY EQUIPMENT- L-4B CUB AIRPLANE
Designed by C.N. Husman and O.M. Longcoy
Drawn by C.W. Pittard
Orlando, Florida

Plate 3.



BREAKER BAR SPRAY BOOM ASSEMBLY
(REVERSE FOR RIGHT SIDE)



45	FILLER CAP FOR 27	1	ALUMINUM
44	FLOAT GAUGE FOR 27	1	3/32" ALUMINUM ROD 2" D. CORK
43	IMPINGING BARS	8	DURALUMINUM
42	SCREWS FOR 39	24	3/16" STEEL BOLTS
41	SUPPORTS FOR 40	20	3/8" AIRCRAFT STEEL TUBING
40	HANGER BRACKETS FOR 39	10	3/8" " "
39	BREAKER BAR SPRAY BOOM	2	PIN. AIRCRAFT STEEL TUBING
38	HANGER FOR 37	1	STEEL
37	VALVE CONTROL ROD	1	STEEL
36	DUAL VALVE CONTROL	1	STEEL
35	CLAMPS FOR 34	2	STEEL
34	VALVE SUPPORT PLATE	1	ALUMINUM
33	CLAMPS FOR 32	2	STEEL
32	BRAKE HAND CONTROL	2	LOCK TYPE STEEL
31	BAFFLE PLATE, B, FOR 27	1	ALUMINUM
30	BAFFLE PLATE, A, FOR 27	1	ALUMINUM
29	REAR CLAMPS FOR 27	4	STEEL
28	FRONT SUPPORTS FOR 27	2	STEEL
27	SPRAY MATERIAL TANK	1	ALUMINUM
26	PIPE HANGER	2	STEEL
25	VALVE CLAMP	1	STEEL
24	VALVE CLAMP	1	1/4" STEEL ROD
23	VALVES	6	3/4", ALUMINUM
22	SUPPLY LINE	1	ALUMINUM TUBING OIL RES. RUB HOSE 3/4" INLET TO PUMP 1/2" OUTLET FR "
21	CLAMPS FOR 8	2	STEEL
20	SUPPORT FOR 8	2	STEEL
19	CLAMPS FOR 14 & 15	2	1/4" STEEL ROD
18	CLAMPS FOR 17	2	STEEL
17	SIDE BRACKETS FOR 14 & 15	2	STEEL
16	UPRIGHT BRACKETS FOR 14, 15-2		STEEL
15	PUMP SUPPORT, LFT.	1	STEEL
14	PUMP SUPPORT, RT.	1	STEEL
13	BEVELED PLATE FOR 12	2	DURALUMINUM
12	PUMP PLATFORM, LFT.	1	STEEL
11	PUMP PLATFORM, RT.	1	STEEL
10	GEAR PUMP	2	3/4" ROTARY
9	CLAMPS FOR 8	2	FIBRE OR ALUMINUM
8	FLEXIBLE CABLE FOR 7	2	STEEL, 6 LIN. FT.
7	BRAKE WIRE FOR 1	2	STEEL, 6 LIN. FT.
6	CONTROL ARM FOR 2, LFT	1	MOLYB. STEEL
5	CONTROL ARM FOR 2, RT.	1	MOLYB. STEEL
4	BRAKE DRUM FOR 1	2	STEEL
3	BRAKE LINING FOR 1.	2	1/8"
2	BRAKE BAND FOR 1	2	STEEL
1	PUMP PROPELLER	2	LAMINATED SPRUCE
NO.	ITEM	REQ	MATERIAL

U.S.D.A. AG. RES. ADM. BUR. ENT. & PL. QUAR.
DIV. OF INSECTS AFFECTING MAN AND ANIMALS
RESEARCH LABORATORY, ORLANDO, FLORIDA

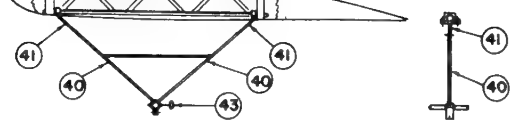
SPRAY UNIT MOUNTED ON U.S.A. PT-17 PLANE — ASSEMBLY

SCALE, 1 IN. = 12 IN. | DR. BY GWP 6-29-45 | CK. BY C.N.H. 6-30-45

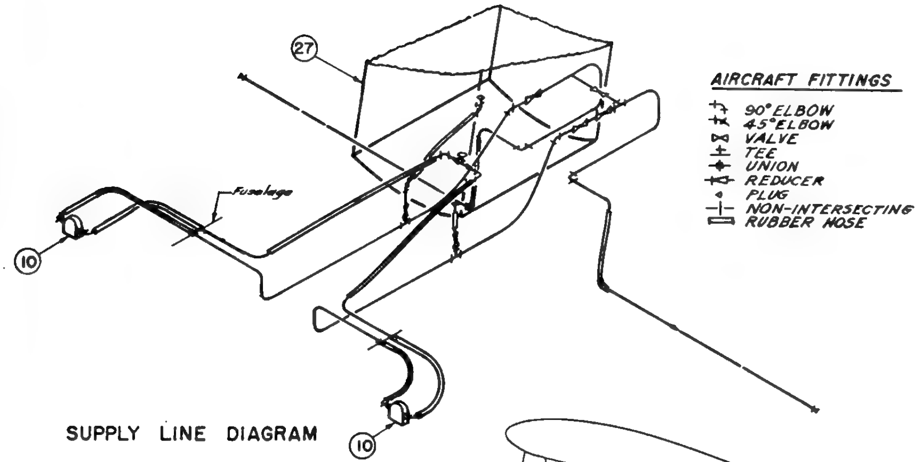
DESIGNED BY C.N. HUSMAN A-100

Plate 4.

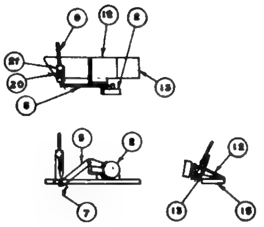
See also Plates 5 & 6



SPRAY BOOM HANGER BRACKET ASSEMBLY



SUPPLY LINE DIAGRAM



PROPELLER BRAKE ASSEMBLY

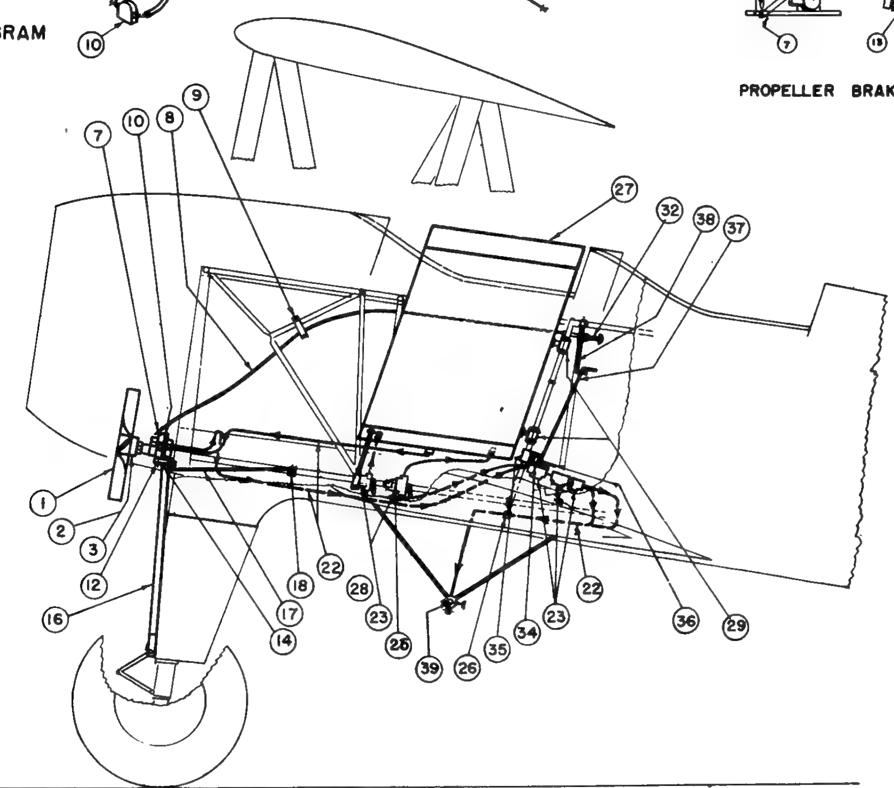


Plate 5.

(See also Plates 4 & 6)

SPRAY UNIT MOUNTED ON U.S.A. PT-17 PLANE—ASSEMBLY

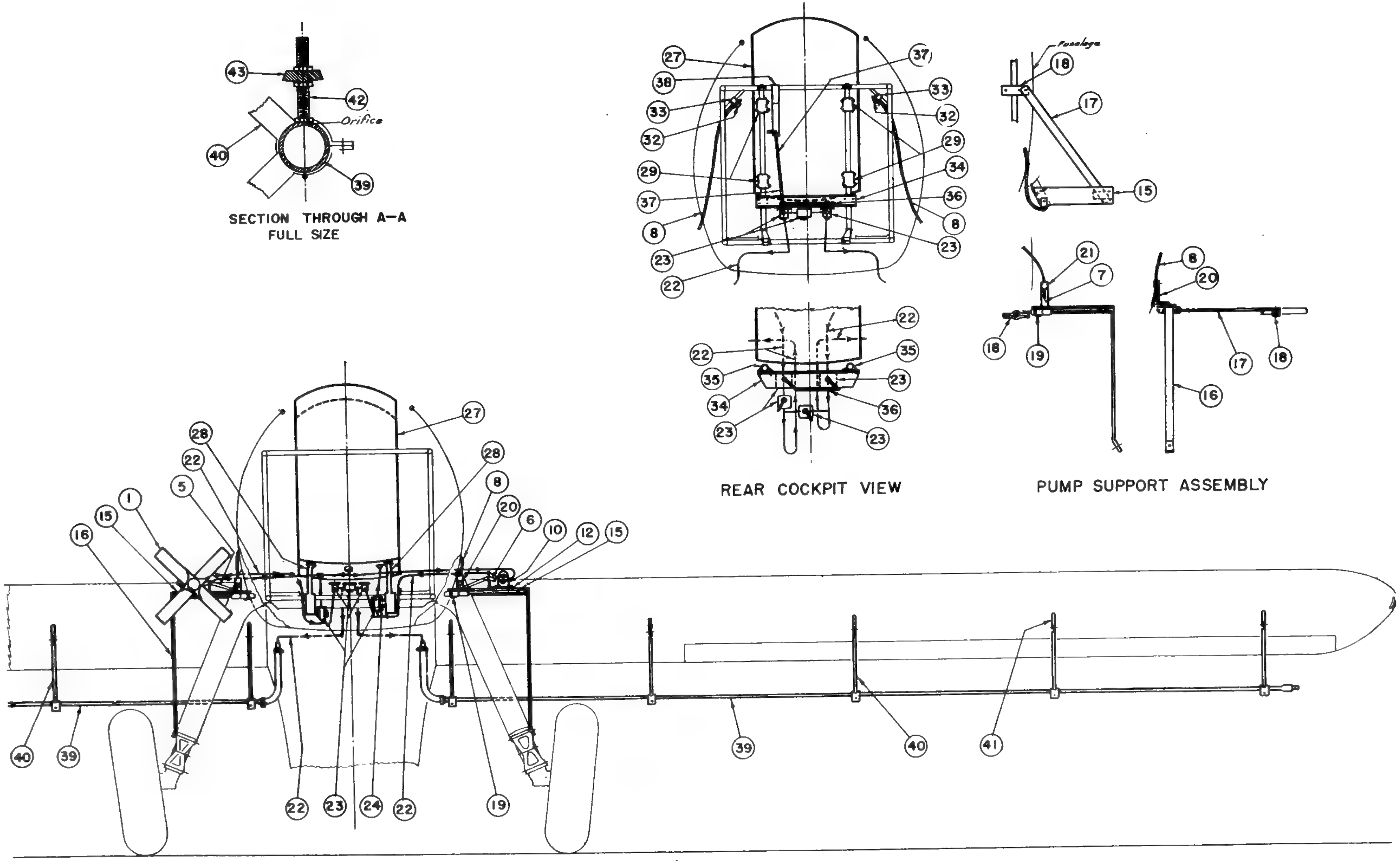


Plate 6.
(See also Plates 4 & 5)

SPRAY UNIT MOUNTED ON U.S.A. PT–17 PLANE–ASSEMBLY

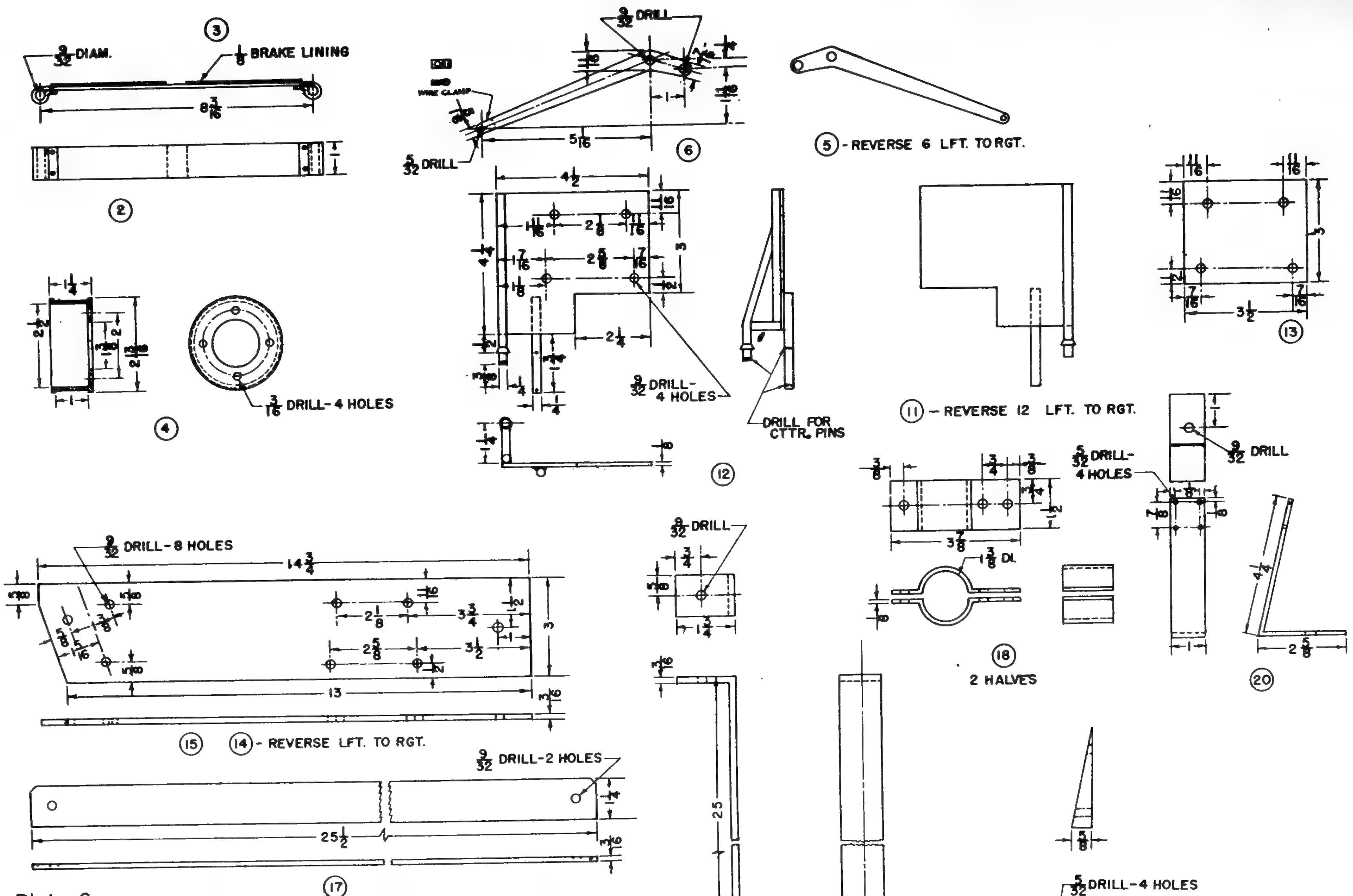


Plate 6a.

DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED.

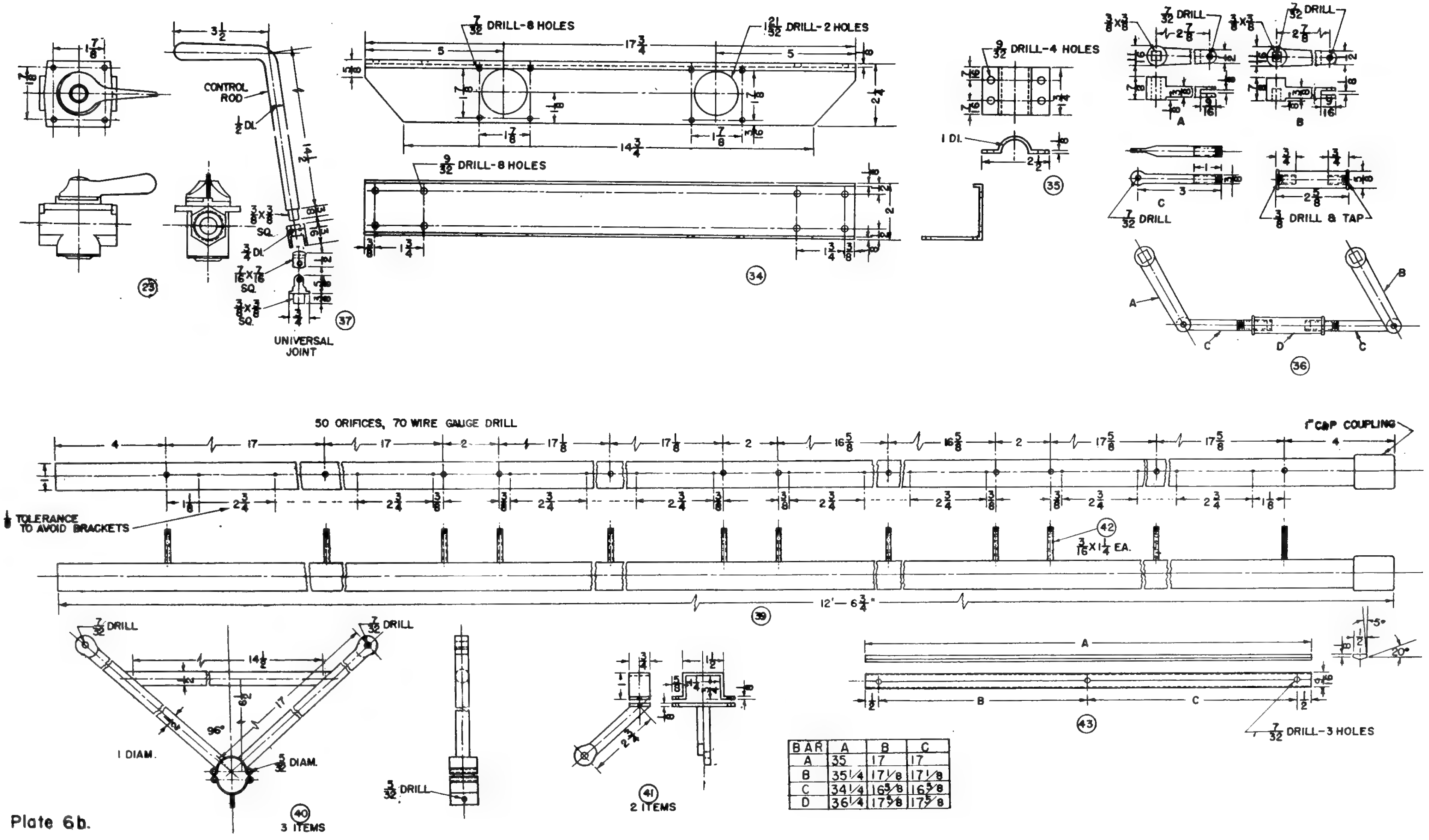
U.S.D.A. AG. RES. ADM. BUR. ENT. & PL. QUAR.
DIV. OF INSECTS AFFECTING MAN AND ANIMALS
RESEARCH LABORATORY, ORLANDO, FLORIDA.

SPRAY UNIT MOUNTED ON U.S.A. PT-17 PLANE—DETAILS

Dr. & Tr. by Cwp	7-12-45	Ch. by C.N.H.	7-15-45

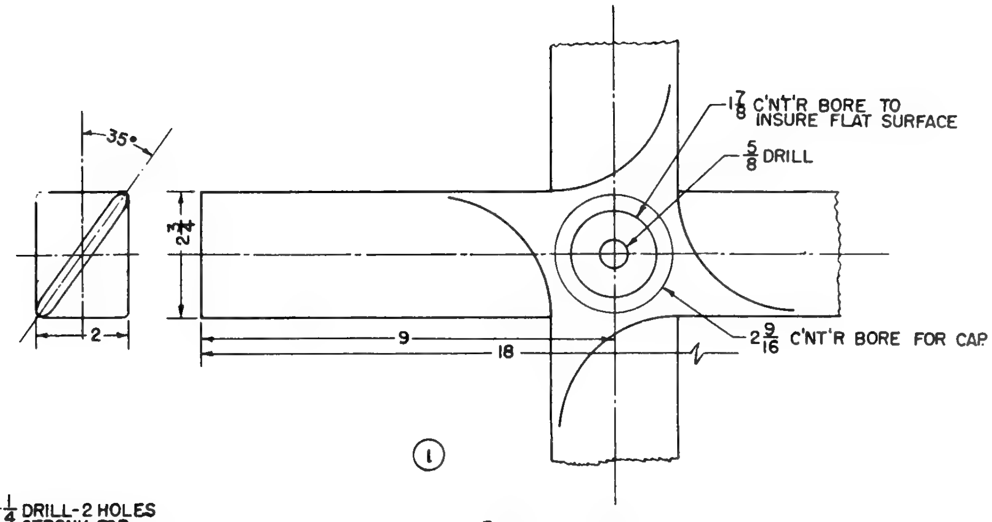
Designed by C.N. Husman — A-101

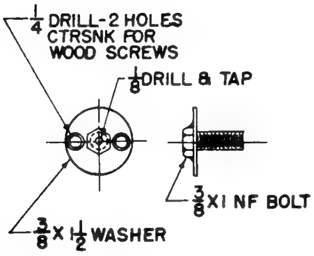
(REF: A-100)

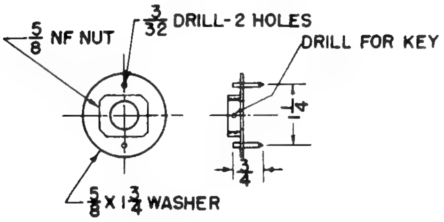


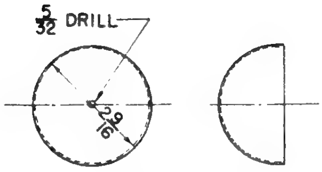
BAR	A	B	C
A	35	17	17
B	35 1/4	17 1/8	17 1/8
C	34 1/4	16 5/8	16 5/8
D	36 1/4	17 5/8	17 5/8

Plate 6b.

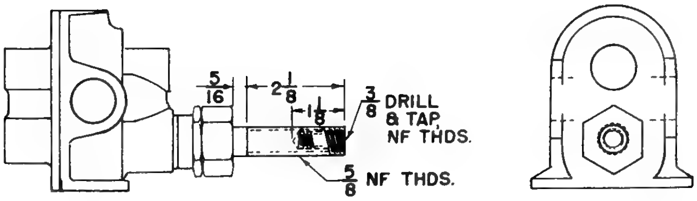


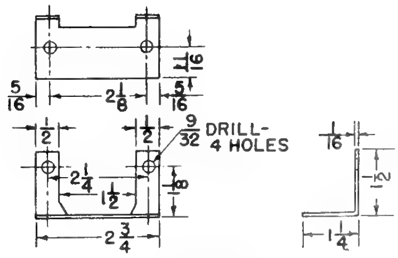






SPINNER CAP

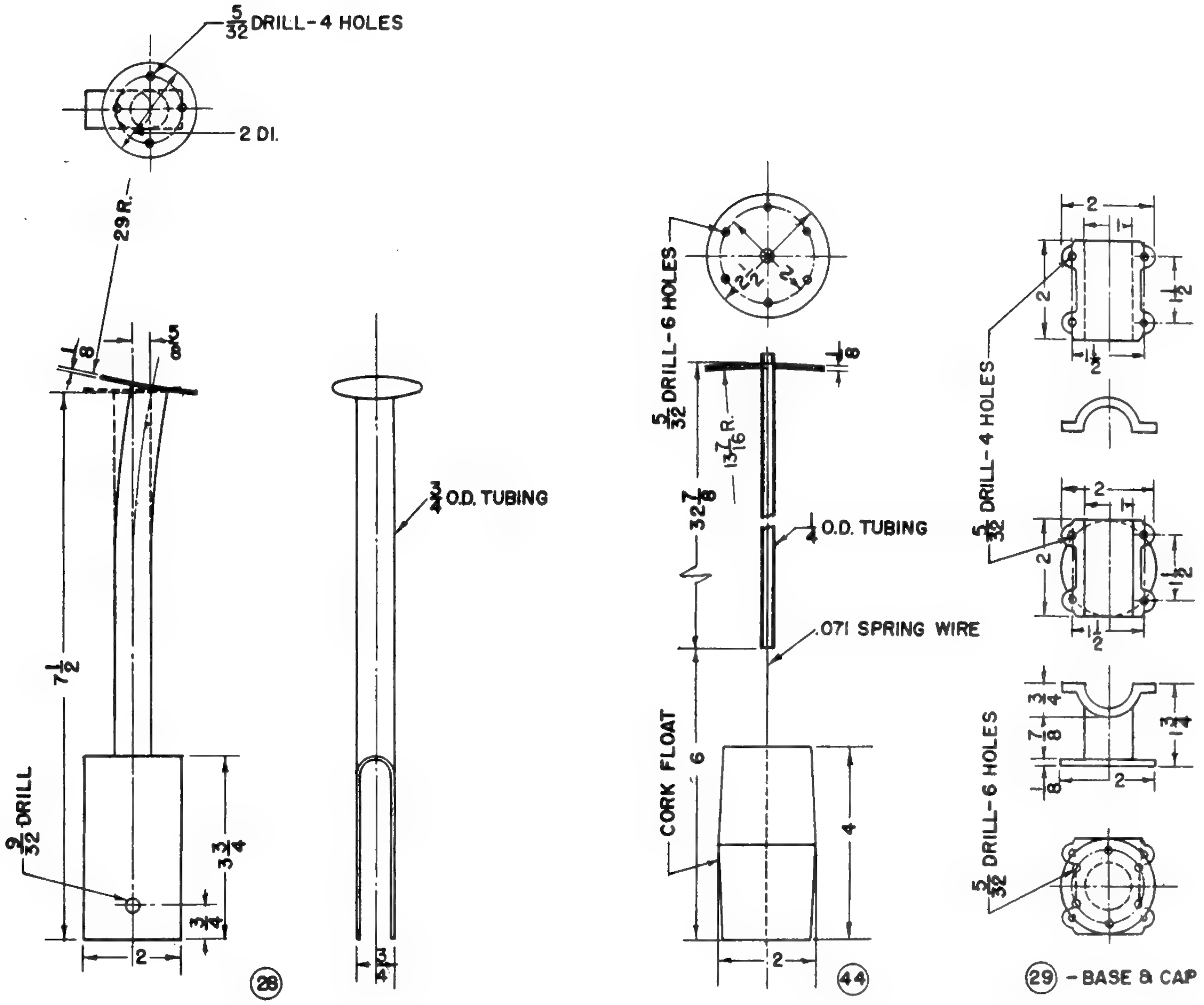




BRACE FOR 10

Plate 6c.

(10)



5/32 DRILL-4 HOLES
2 DI.
29 R.
3/4 O.D. TUBING
9/32 DRILL
5/32 DRILL-6 HOLES
O.D. TUBING
.071 SPRING WIRE
CORK FLOAT
5/32 DRILL-4 HOLES
5/32 DRILL-6 HOLES
(28)
(44)
(29) - BASE & CAP

Plate 6d.

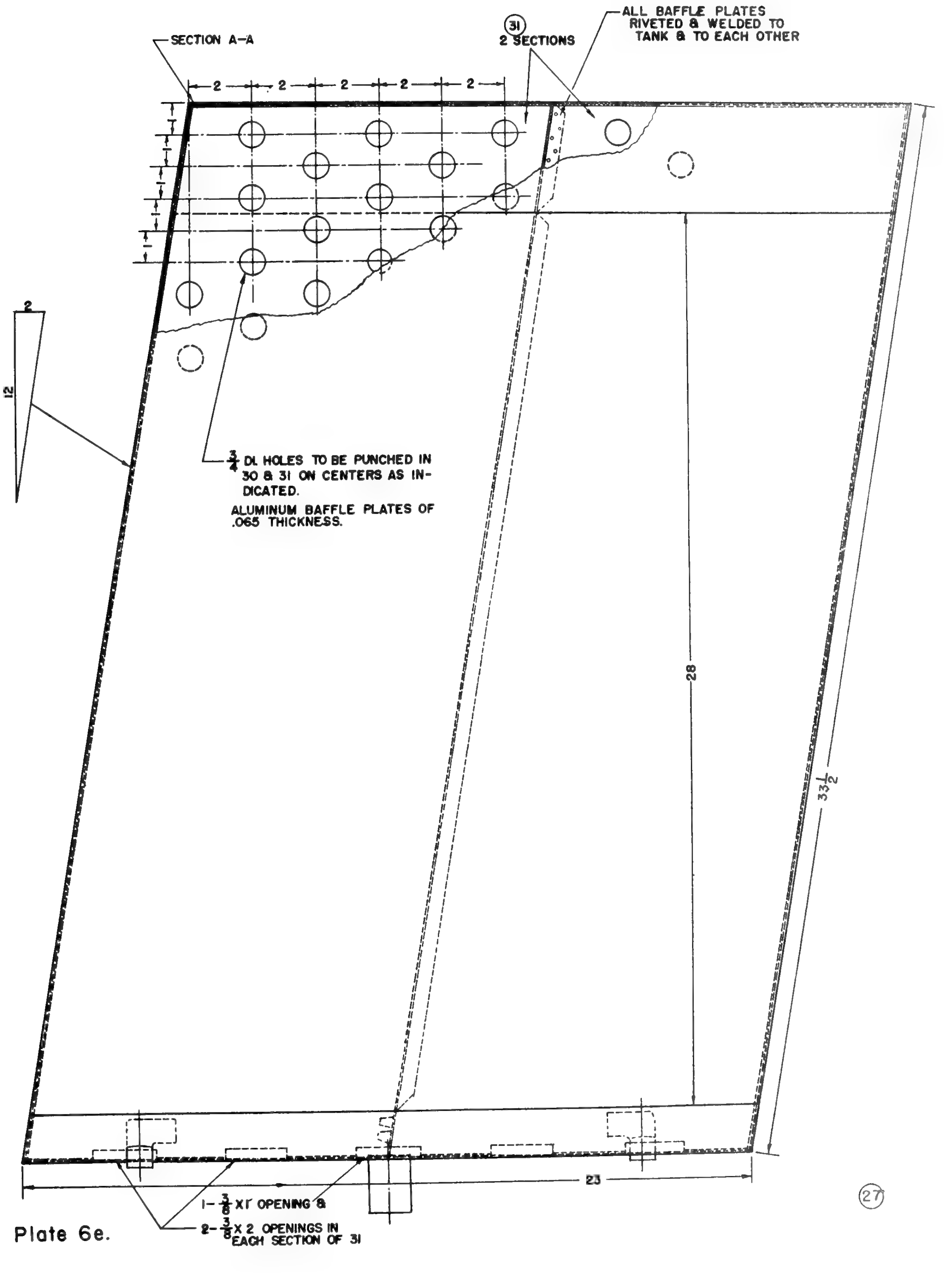
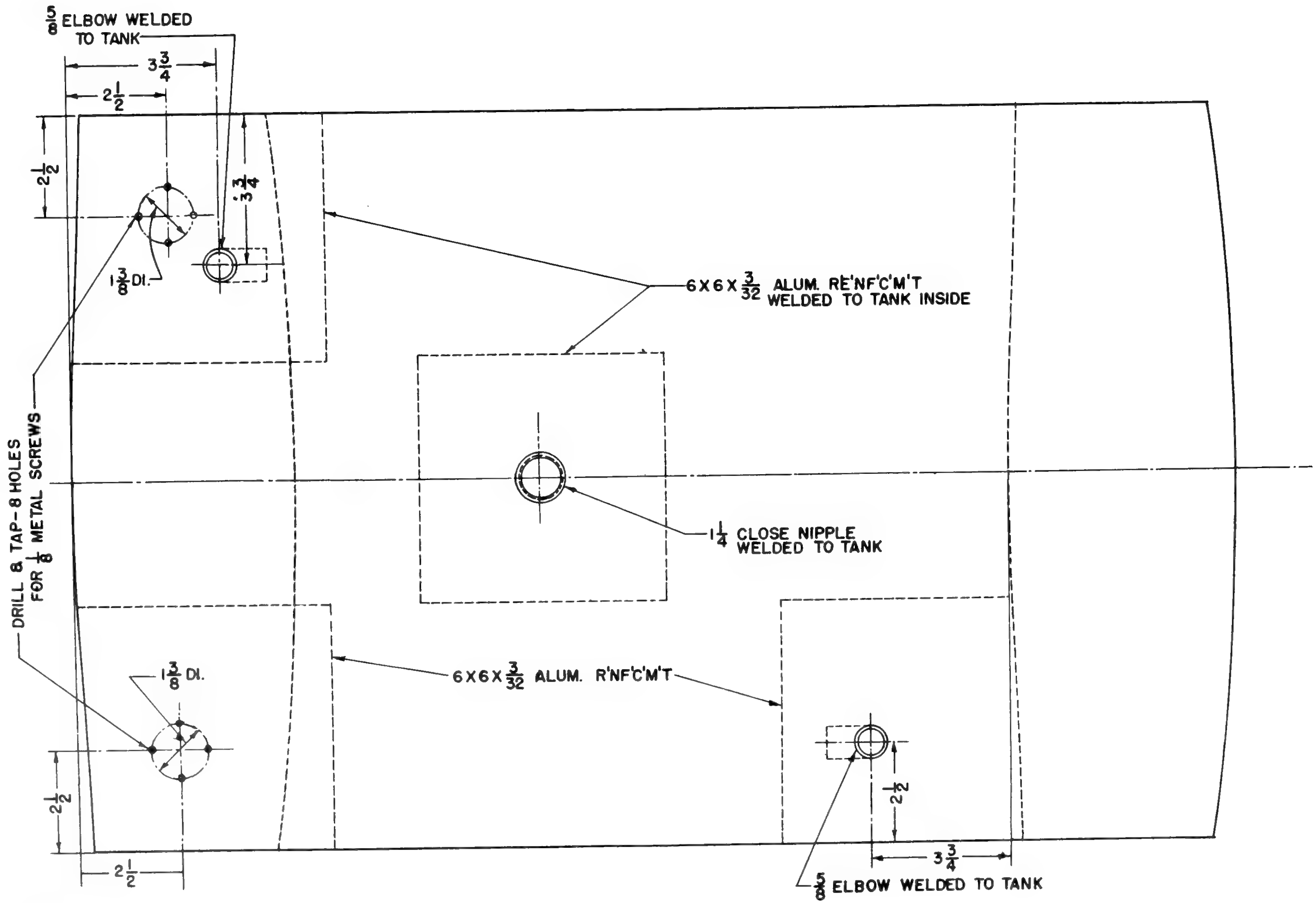

SECTION A-A
31
2 SECTIONS
ALL BAFFLE PLATES RIVETED & WELDED TO TANK & TO EACH OTHER
2
2
2
2
2
1
1
1
1
1
1
2
12
3/4 DI. HOLES TO BE PUNCHED IN 30 & 31 ON CENTERS AS INDICATED.
ALUMINUM BAFFLE PLATES OF .065 THICKNESS.
28
33 1/2
23
1- 3/8 X 1 OPENING 8
2- 3/8 X 2 OPENINGS IN EACH SECTION OF 31

Plate 6e.



5/8 ELBOW WELDED TO TANK
3 3/4
2 1/2
2 1/2
3 3/4
1 3/8 DI.
6 X 6 X 3/32 ALUM. RE'NF'C'M'T WELDED TO TANK INSIDE
DRILL & TAP-8 HOLES FOR 1/8 METAL SCREWS
1 1/4 CLOSE NIPPLE WELDED TO TANK
1 3/8 DI.
6 X 6 X 3/32 ALUM. R'NF'C'M'T
2 1/2
2 1/2
2 1/2
3 3/4
5/8 ELBOW WELDED TO TANK

Plate 6f.

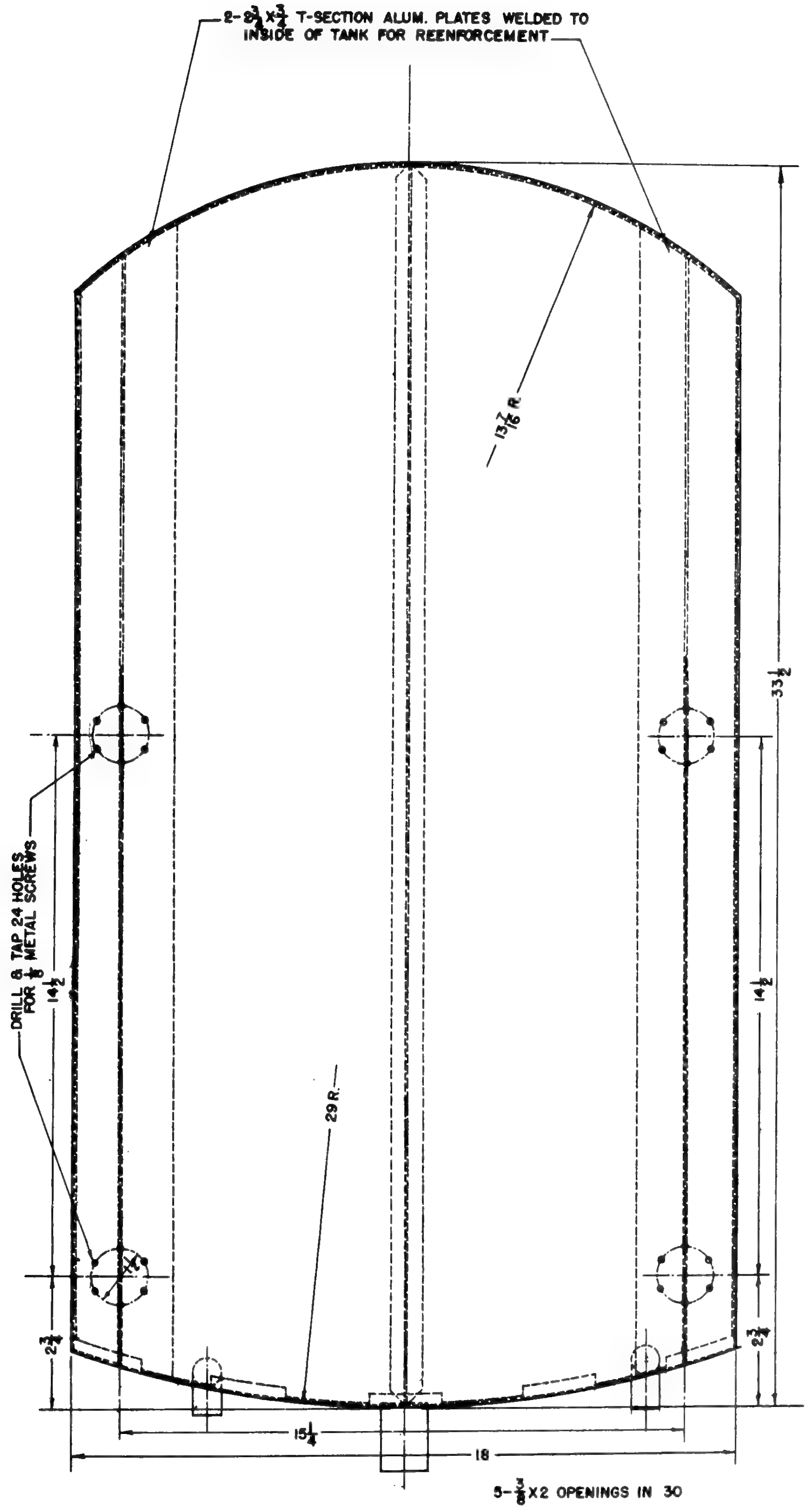

2-2¾X¾ T-SECTION ALUM. PLATES WELDED TO INSIDE OF TANK FOR REENFORCEMENT
13 7/16 R.
33½
DRILL & TAP 24 HOLES FOR ⅛ METAL SCREWS
14½
14½
29 R.
2¾
2¾
15¼
18
5-⅜X2 OPENINGS IN 30

Plate 6g.

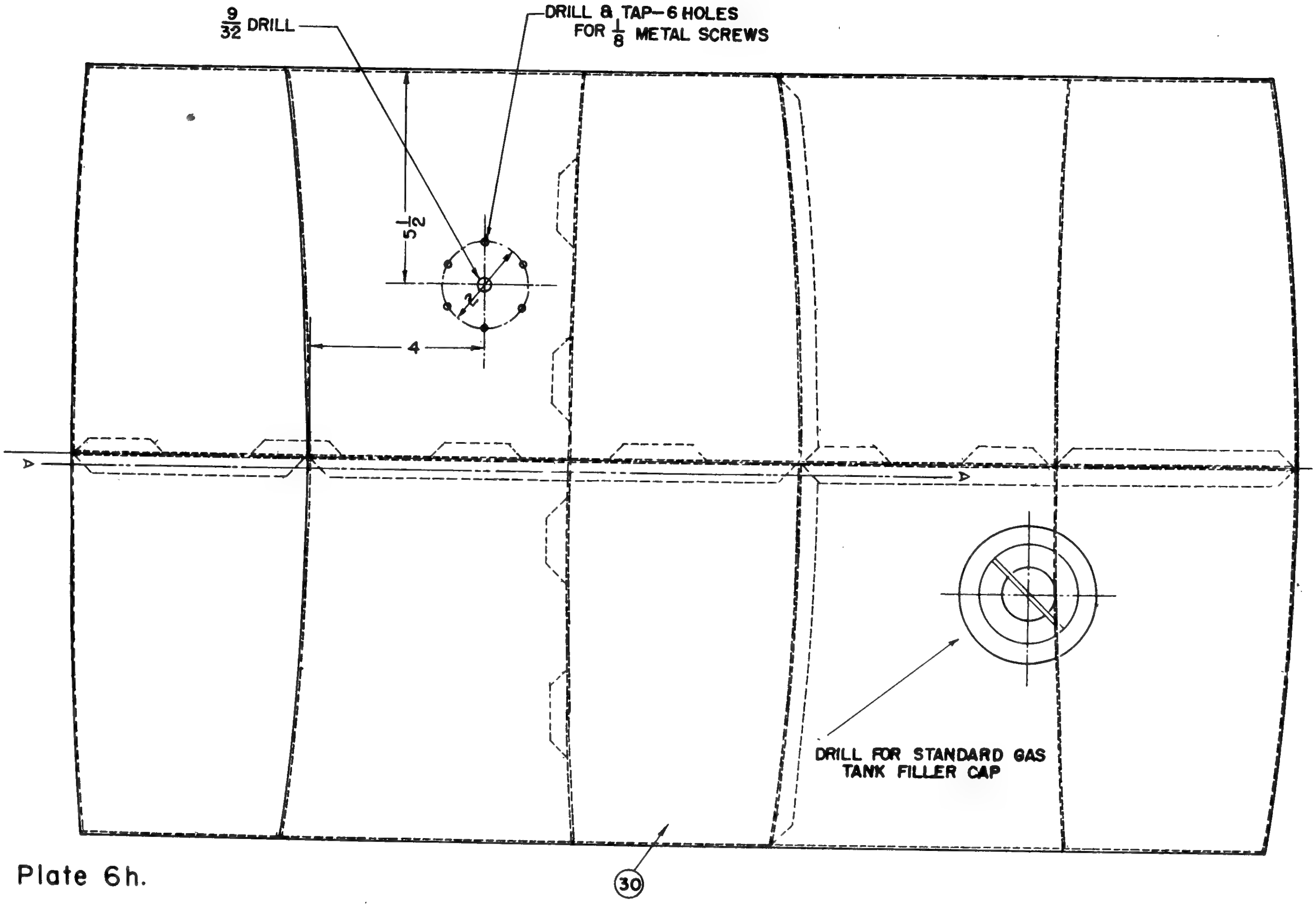
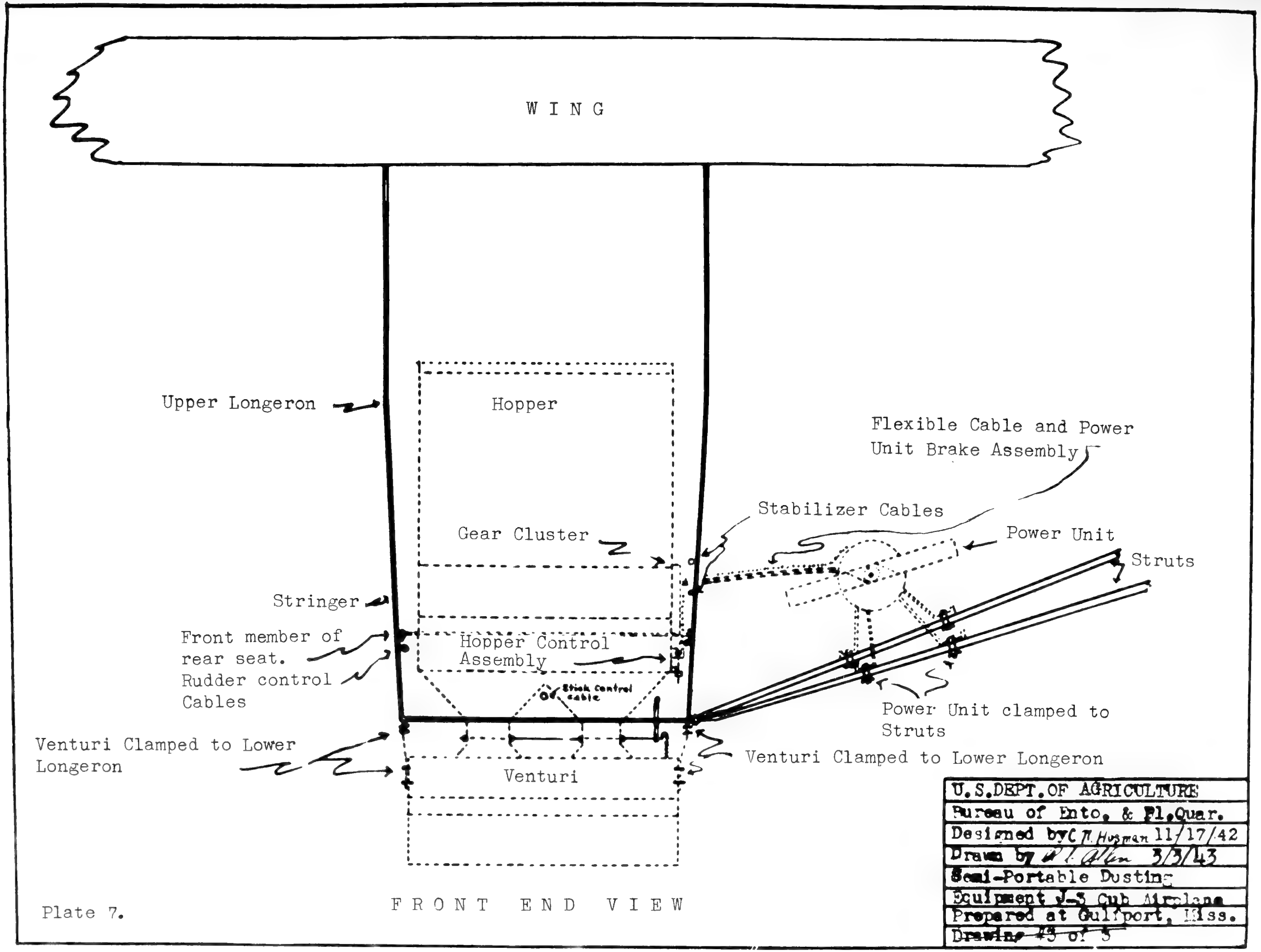

9/32 DRILL
DRILL & TAP–6 HOLES FOR 1/8 METAL SCREWS
5 1/2
4
2
A
A
DRILL FOR STANDARD GAS TANK FILLER CAP
30

Plate 6h.



WING
Upper Longeron
Hopper
Gear Cluster
Stringer
Front member of rear seat.
Rudder control Cables
Hopper Control Assembly
Stick control cable
Venturi Clamped to Lower Longeron
Venturi
Flexible Cable and Power Unit Brake Assembly
Stabilizer Cables
Power Unit
Struts
Power Unit clamped to Struts
Venturi Clamped to Lower Longeron
FRONT END VIEW
U.S.DEPT.OF AGRICULTURE
Bureau of Ento. & Pl.Quar.
Designed by C. T. Husman 11/17/42
Drawn by 3/3/43
Semi-Portable Dusting
Equipment J-3 Cub Airplane
Prepared at Gulfport, Miss.

Plate 7.

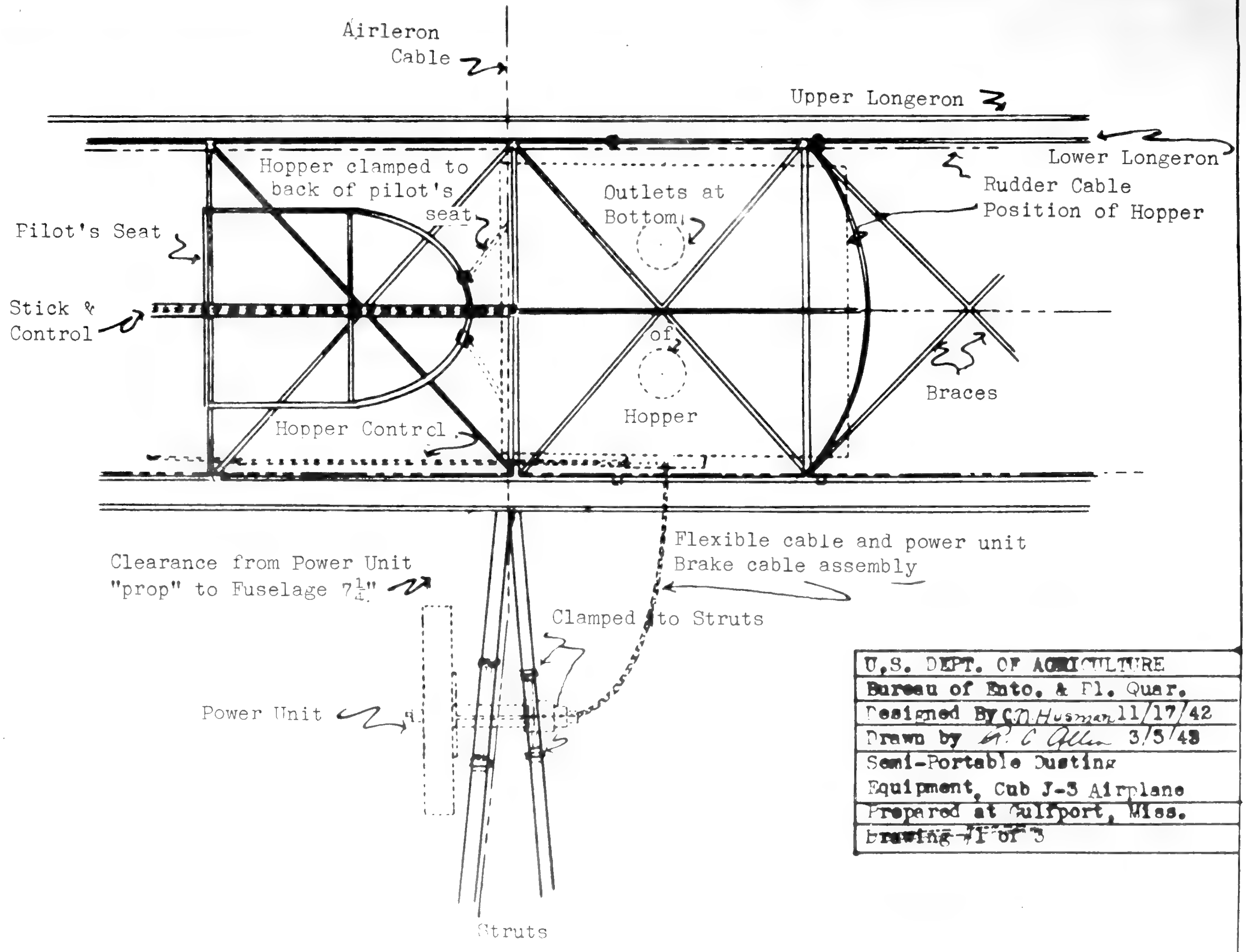


Plate [illegible]

T O P V I E W

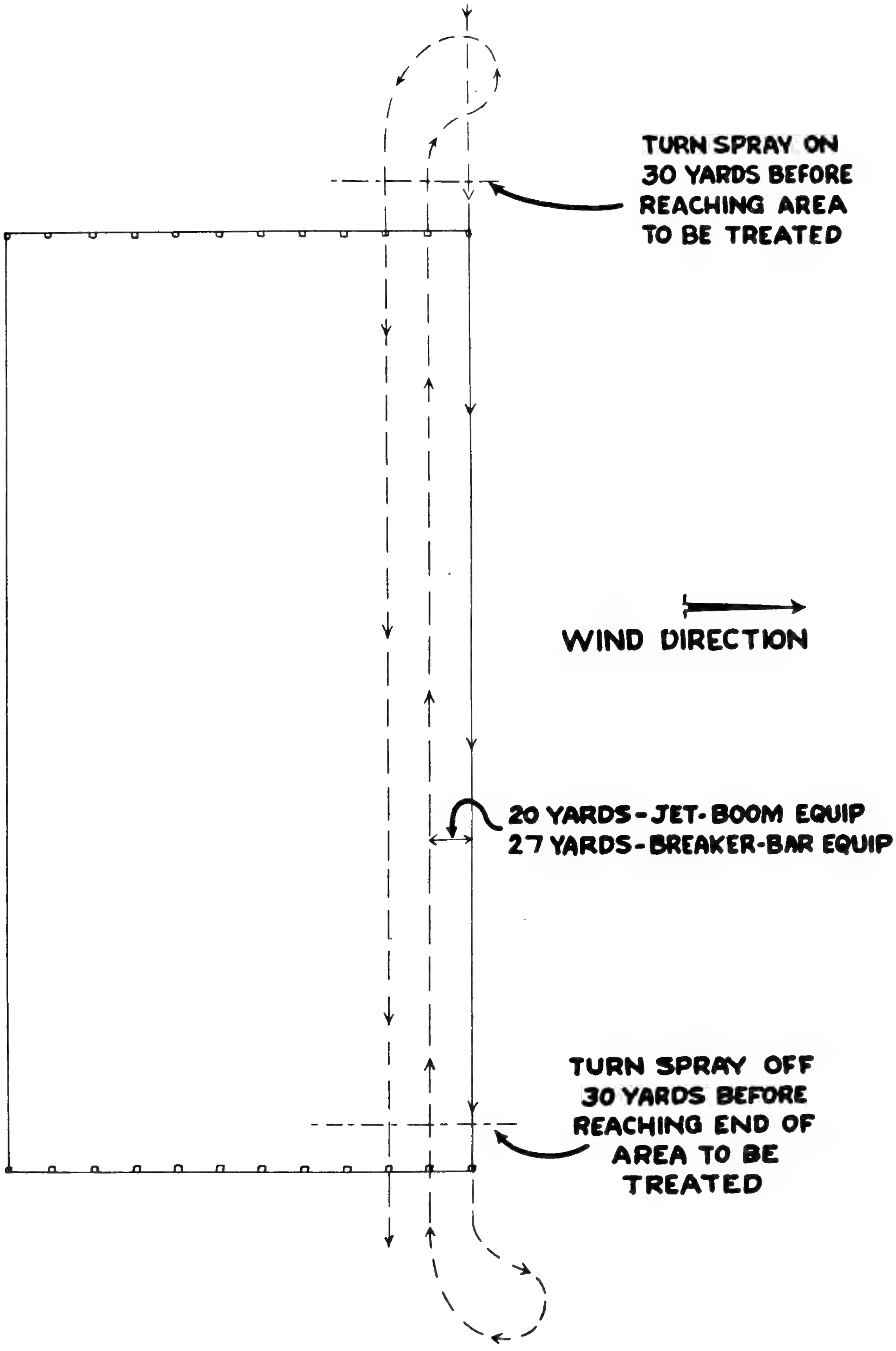
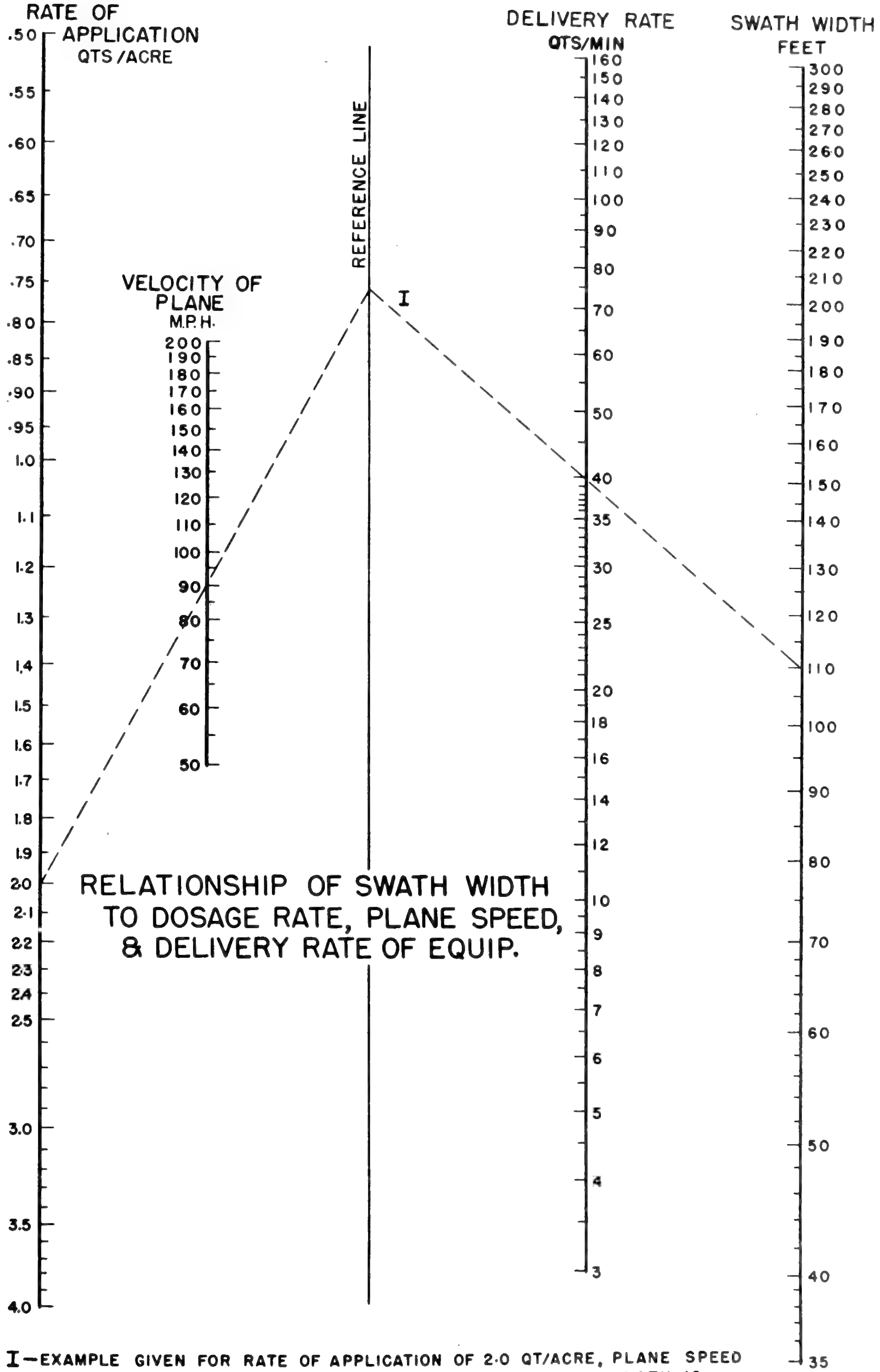


Plate 9. Flight pattern for treating an area with DDT Solutions using slow-moving aircraft



I—EXAMPLE GIVEN FOR RATE OF APPLICATION OF 2.0 QT/ACRE, PLANE SPEED OF 90 M.P.H., AND A DELIVERY RATE OF 40 QTS/MIN. SWATH WIDTH IS DETERMINED AS 110 FEET.

PREPARED BY BUREAU OF ENTOMOLOGY & PLANT QUARANTINE, ORLANDO, FLA. & THE AAF COMMITTEE ON AERIAL DISPERSAL OF INSECTICIDES, AFCTR, ORLANDO, FLA.

Plate 10

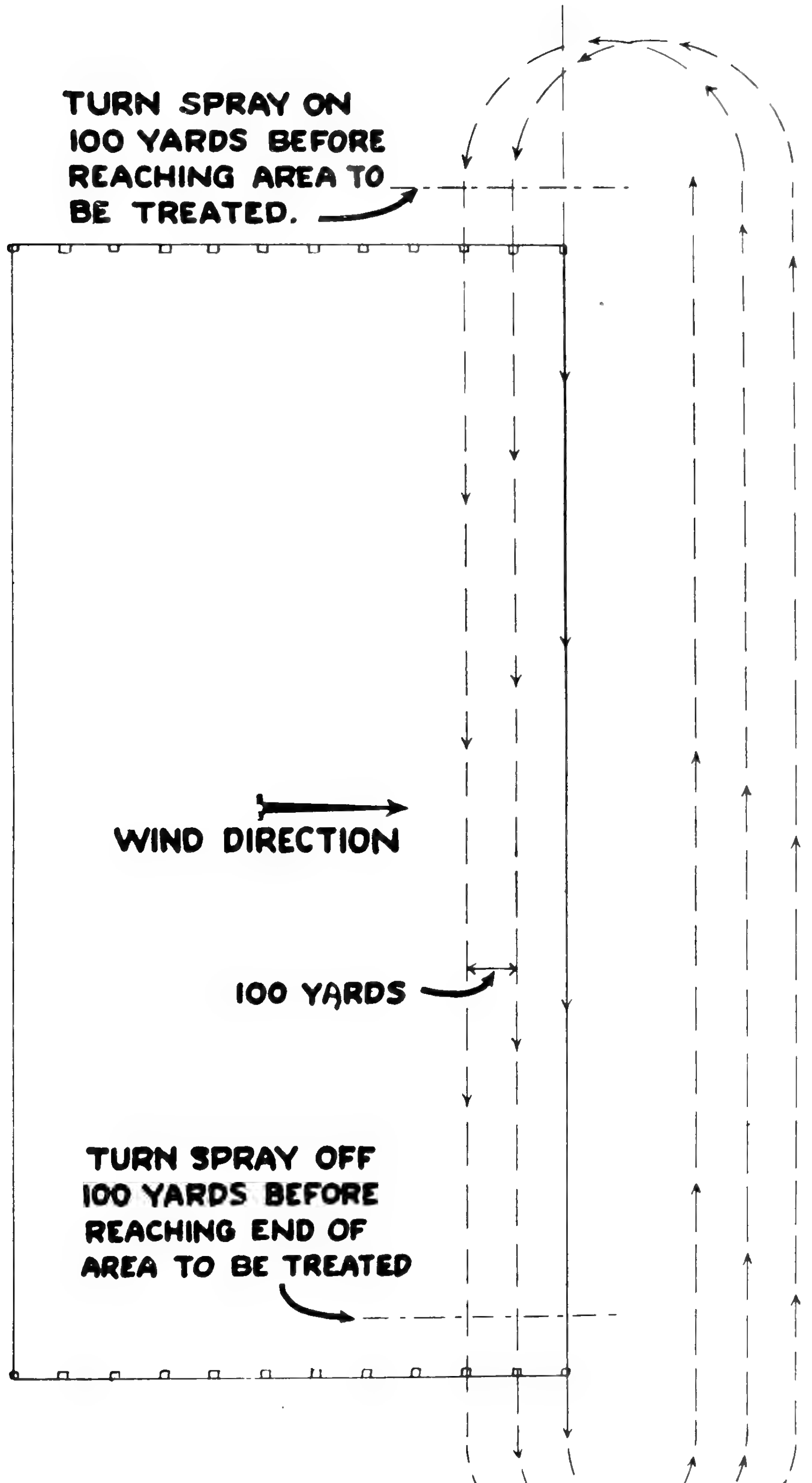


Plate 11. Flight pattern for treating a small area with DDT Solutions using large airplanes

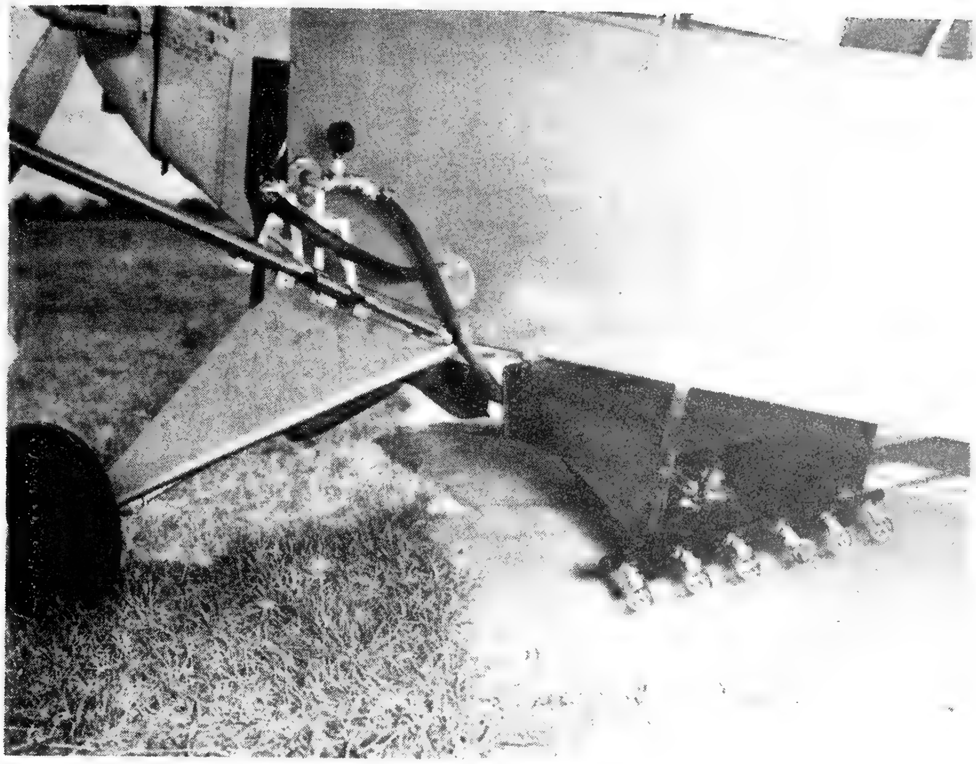


Figure 1.--Spray equipment mounted on L-4 series airplane. (Photo by AAFCTR, Orlando, Fla.)

Figure 2.--Spray supply tank installed in PT-17 (Stearman) airplane.

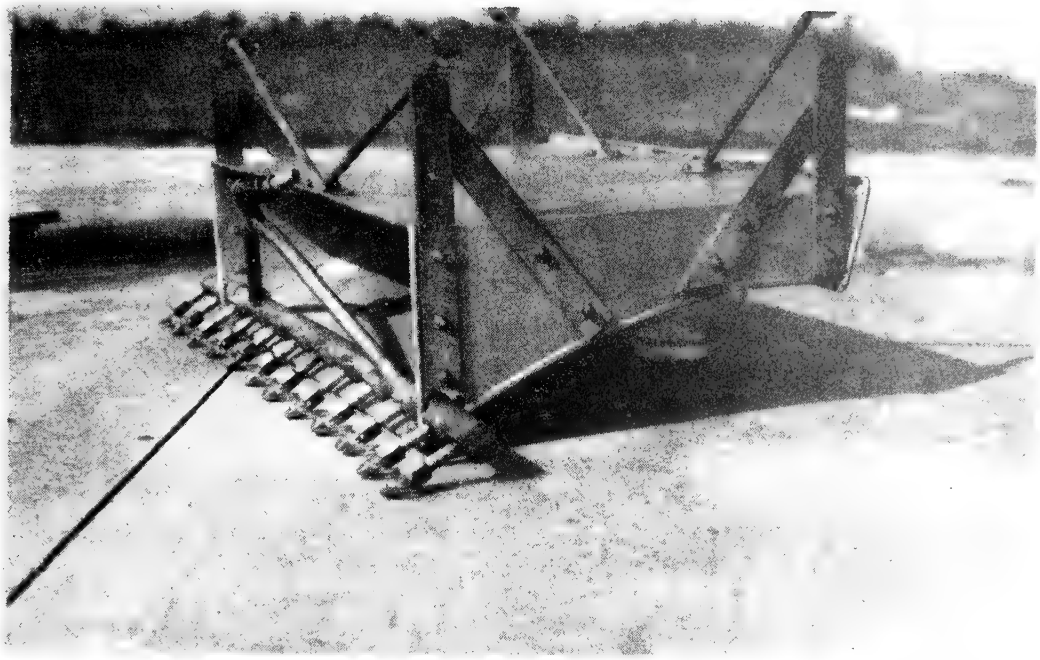


Figure 3.—Venturi and spray nozzles for PT-17 (Stearman) airplane.

Figure 4.—Breaker-bar spray equipment mounted on L-4 series airplane. (Photo by AAFCTR, Orlando, Fla.)

Figure 5.—L-4 series airplane equipped with breaker-bar spray equipment. (Photo by AAFCTR, Orlando, Fla.)

Figure 6.—PT-17 (Stearman) airplane equipped with breaker-bar spray equipment. (Photo by AAFCTR, Orlando, Fla.)

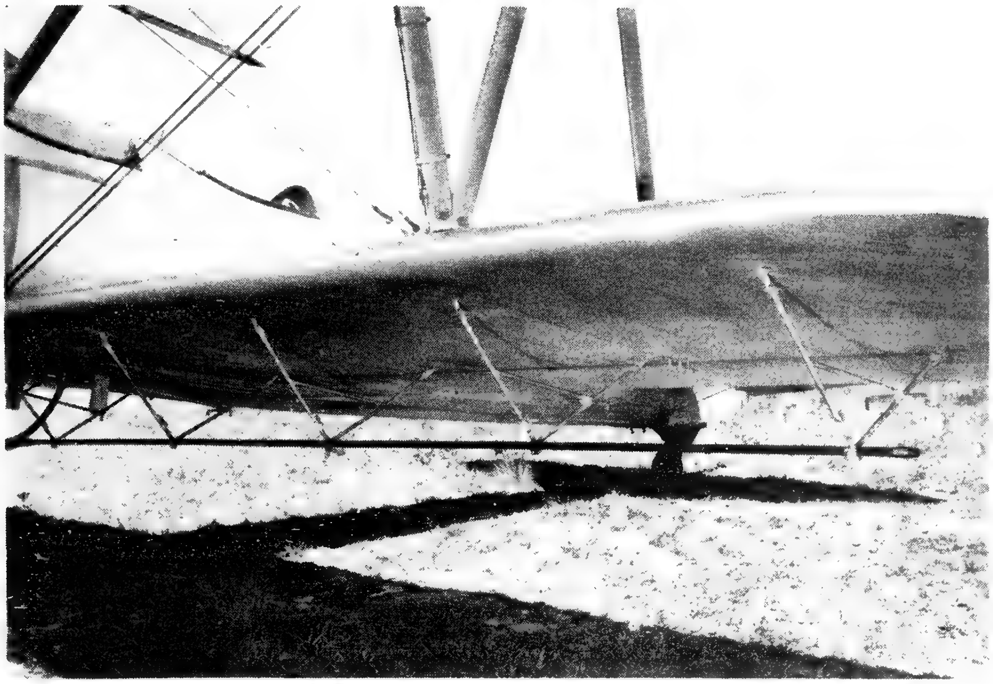


Figure 7.—Breaker-bar spray equipment mounted on wing of PT-17 (Stearman) airplane. (Photo by AAFCTR, Orlando, Fla.)

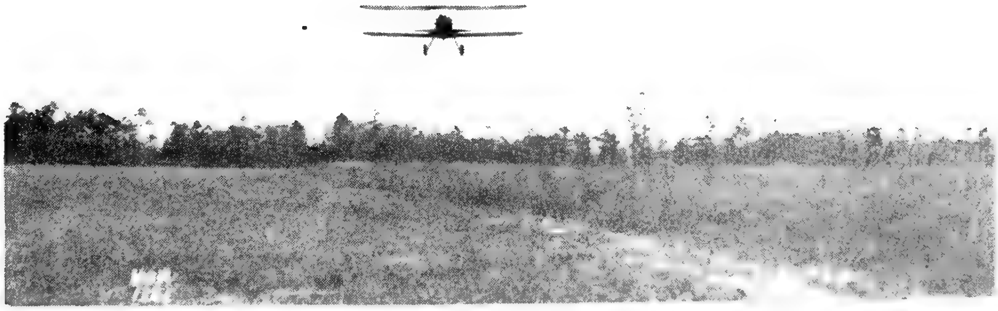


Figure 8.—Application of DDT sprays from PT-17 (Stearman) airplane equipped with breaker-bar spray equipment.

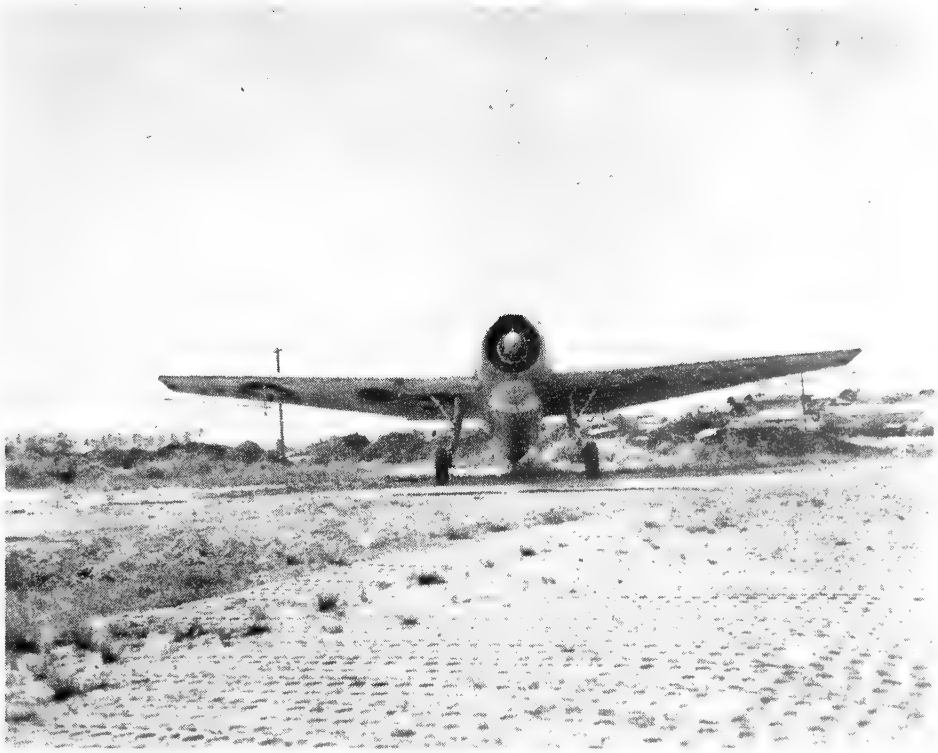


Figure 9.---Navy TBM airplane equipped with breaker-bar spray equipment. (Photo by U. S. Navy)

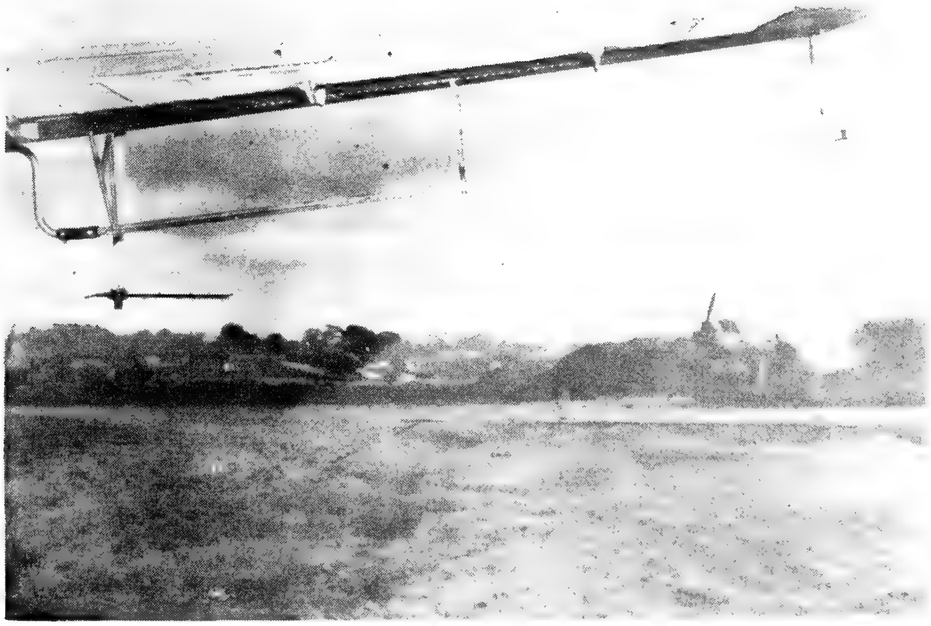


Figure 10.---Breaker bar spray boom mounted under wing of Navy TBM airplane. (Photo by U. S. Navy)

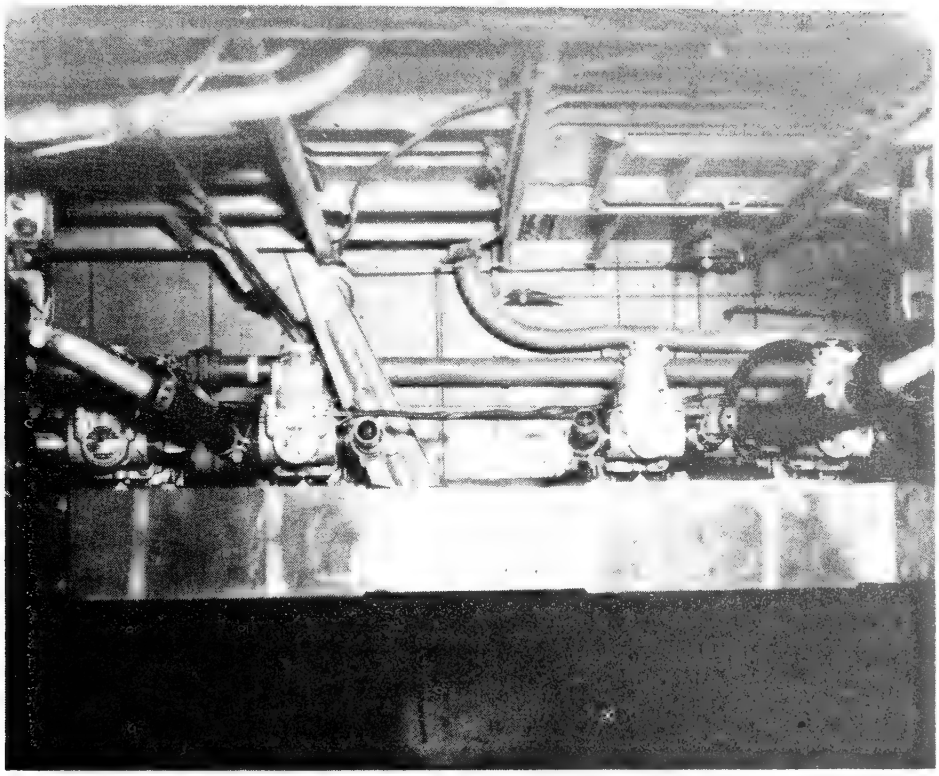


Figure 11.—Electric fuel pumps on the breaker-bar spray equipment for Navy TBM airplane.

Figure 12.—J3-65 Piper Cub equipped with a device for dispersal of exhaust-generated insecticidal smoke-sprays.

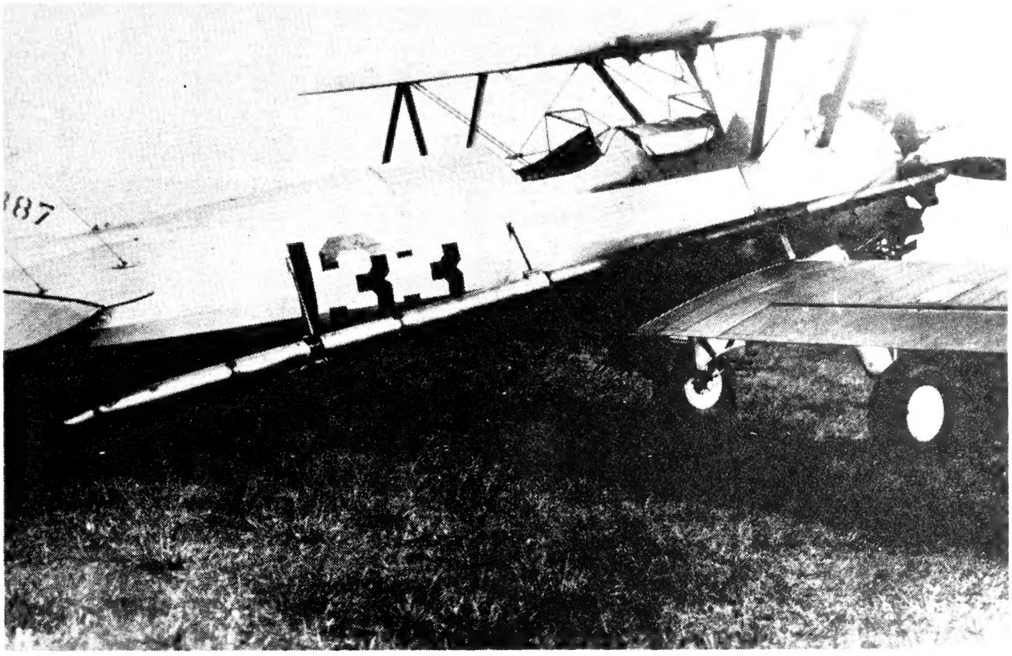


Figure 13.—Army PT-17 (Stearman) airplane equipped with a device for the dispersal of insecticidal smokes.

Figure 14.—Army PT-17 (Stearman) airplane applying insecticidal smoke.

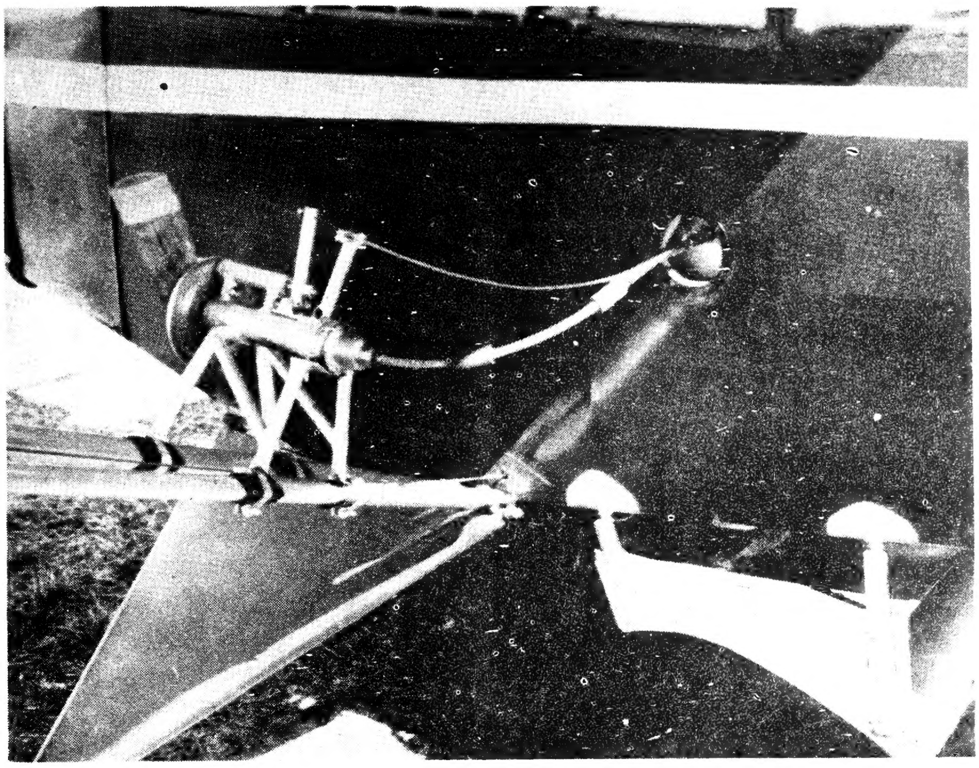


Figure 15.—J3-65 Piper Cub equipped with portable dusting unit.