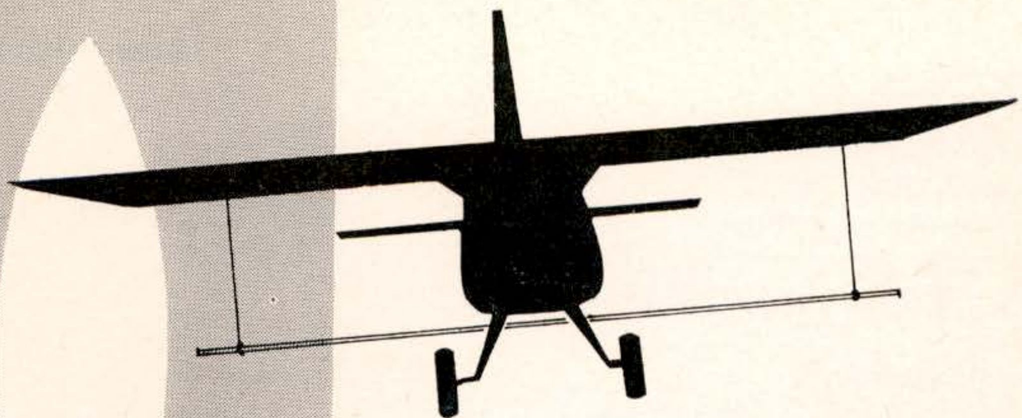
1960

Agricultural Aircraft Equipment

N. Shafer



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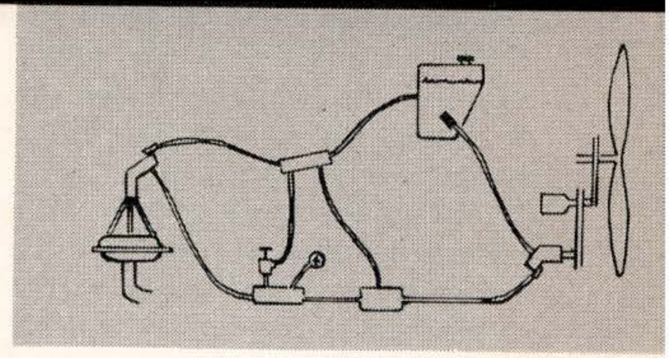

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Agricultural Aircraft Equipment

by Neal Shafer[1]

INTRODUCTION

The need for improved aircraft spray dispersal equipment has become more acute the past few years with the rapid increase in use of aircraft in agriculture. Problems such as uniformity of coverage and drift control were needed areas of study.

Changes in existing spray dispersal equipment have been made as a result of field performance trials at the Nebraska Agricultural Experiment Station. These changes include:

Relocation of spray booms and nozzles.

Installation of a multipurpose hydraulic system instead of the conventional fan-driven pump.

A hydraulically driven rotor feed mechanism for a more uniform delivery of seeds and granules.

Modifications in the design of the venturi distributor.

This bulletin gives a detailed account of the installation, operation, and performance of this dispersal equipment as tested on the Piper PA-18A airplane. Equipment is also applicable to other types of agricultural aircraft now being used. A list of various aircraft equipment and where it can be obtained is included.

POWER SOURCE FOR DISPERSAL EQUIPMENT

Wind-Driven Fans

Wood or metal wind-driven fans are the most common source of power for driving spray pumps, agitators, or feed mechanisms on agricultural aircraft.

Such fans are capable of delivering 1 or 2 on up to as much as 8 or 10 horsepower (hp), depending on size and number of blades. They must be equipped with brakes, otherwise fans will run continuously, causing excessive wear on the pump or other driven mechanism. For best performance, fans should be located directly in the propeller slipstream. However, this position may produce the greatest turbulence and drag. Turbulence may affect distribution of sprays, dusts, or other dry materials.

Drag from wind-driven fans is a constant factor in flight whether spraying or ferrying. This extra drag reduces the safety margin. A five-bladed steel fan, 18-20 inches in diameter, on a 1-inch Simplex pump reduced airspeed of a 105 hp Aeronca Champion airplane as much as 5 miles per hour (mph) when using the same power setting. Fans or fan blades may break loose causing damage to the aircraft, pilot, or both. In case of loss of a fan blade or damage to the fan, the brake permits stopping the pump before dangerous vibrations start.

[1] NEAL SHAFER is a former member of the Department of Agronomy faculty, University of Nebraska.

The location of the wind-driven fan and pump usually is some distance from the tank. This entails external plumbing, line strainers, control valves, and controls which add further to weight, drag, and turbulence. Disregarding drag and turbulence, wind driven fans have an average power efficiency of 35 percent.

Engine-Driven Pumps

Direct mounted, engine-driven, spray pump installation is limited to those engines having an accessory pad. Such installations permit internal plumbing. There must be a clutch mechanism provided to prevent excessive pump wear and to insure pilot and aircraft safety.

There may be difficulty in priming centrifugal pumps if they are located above the fluid level of the tank. A spray pump mounted on the aircraft engine may be several feet from the tank. This requires extra length of pipe and additional fittings, with an accompanying addition in weight. Line drag is also increased. The power efficiency of a direct mounted, engine-driven pump is near 100 percent.

Hydraulic Drive System

Simple hydraulic systems can be assembled from surplus aircraft accessories at relatively small cost. Hydraulic motors and pumps are available in various sizes to fit most power needs. Most major aircraft supply houses list such surplus units in their catalogues.

Installation of a hydraulic system is not limited to those aircraft having engines with an accessory pad. Satisfactory installations have been made using a V-belt drive to derive power from the aircraft engine. On aircraft equipped with an electrical system, power is obtained by installing dual pulleys on the generator and connecting the generator to the hydraulic pump with a short V-belt (Figure 1). Engines not equipped with a generator can be adapted to drive a hydraulic system by machining a pulley which fits over the propeller shaft behind the propeller.

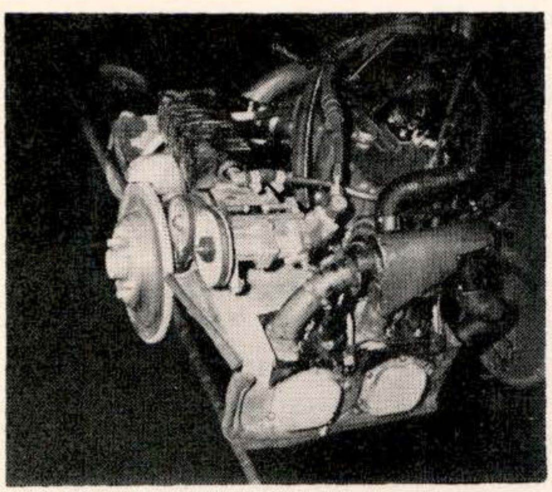

Figure 1. Hydraulic pump mounted on an aircraft engine and driven by a V-belt from a second pulley on the generator.

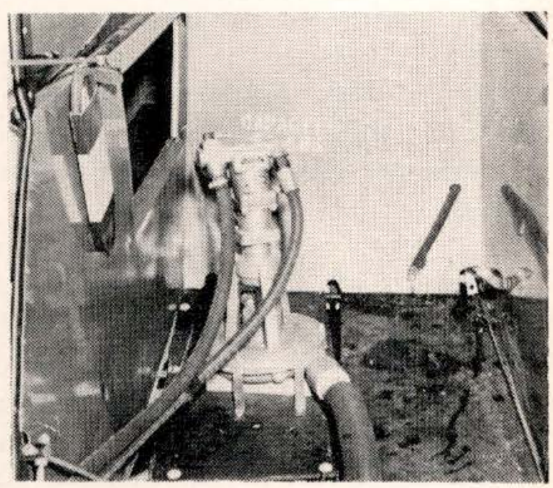

Figure 2. Hydraulically driven spray pump installation located in the baggage compartment of a Piper PA-18A airplane.

Such an adaptation has been built by J. E. Henry, Agricultural Engineering Department, Ohio State University, Columbus, Ohio, and installed on an 85 hp (modified) J-3 Cub airplane.

Hydraulic power (pressure) is carried through high pressure hose to the hydraulic motor which drives the spray pump. There is no problem with priming when centrifugal pumps are used because the pump may be located on the fuselage floor beside the spray tank. In actual practice, a pump installation on the floor of the baggage compartment of a Piper PA-18A airplane has been entirely satisfactory (Figure 2).

Such an installation reduces the external plumbing to a bare minimum—one pressure line going to the spray boom. A wide range of power settings is possible with a hydraulic system. By choosing only the horsepower required to do each job, maximum efficiency is assured. Regardless of how low or high the gallonage, the amount of spray material pumped is correct.

During take-off and ferrying the hydraulic system may be shut off, cutting horsepower requirements to near zero (0.39 hp). This reduces wear on the hydraulic system, the spray pump, and other dispersal equipment.

The essential parts of a simple hydraulic system for use in driving a spray pump are shown in Figure 3. Because of the high speeds attainable with a hydraulic system, centrifugal or turbine pumps should be used. Pump speeds may go as high as 4500 rpm and when the spray tank runs empty, brass gear pumps, rubber impeller pump or nylon roller pumps could be ruined before the hydraulic system could be stopped.

Hydraulic pumps and motors are available in a wide range of sizes and capacities. The capacity in cubic inches per revolution is a function of the pump angle—the angle built into the pump between the pump shaft and the cylinder block. The greater the pump angle, the greater the stroke and consequently the greater the capacity in cubic inches per revolution (Table 1). When no hydraulic fluid is by-passed, the speed of the hydraulic motor will be a direct function of the displacement of fluid by the hydraulic pump. Thus, to obtain maximum power the hydraulic pump should be of equal or greater size than the size of the hydraulic motor.

For best performance the hydraulic pump should be of .507 or .610 cubic inch capacity. Pump and motor sizes are usually listed according to their capacity but may be given in degrees. The range of speeds obtainable with a .610 cubic inch capacity pump is shown in Table 1.

Table 1. Hydraulic motor performance using a .610 cubic inch pump at 3000 rpm.

Motor size (Cu. in. per revolution)	Motor angle in degrees	Approximate motor speed obtained in rpm	Rpm ratio of motor to pump
.210	10	9000	3:1
.310	15	6000	2:1
.410	20	4500	3:2
.507	25	3600	6:5
.610	30	3000	1:1

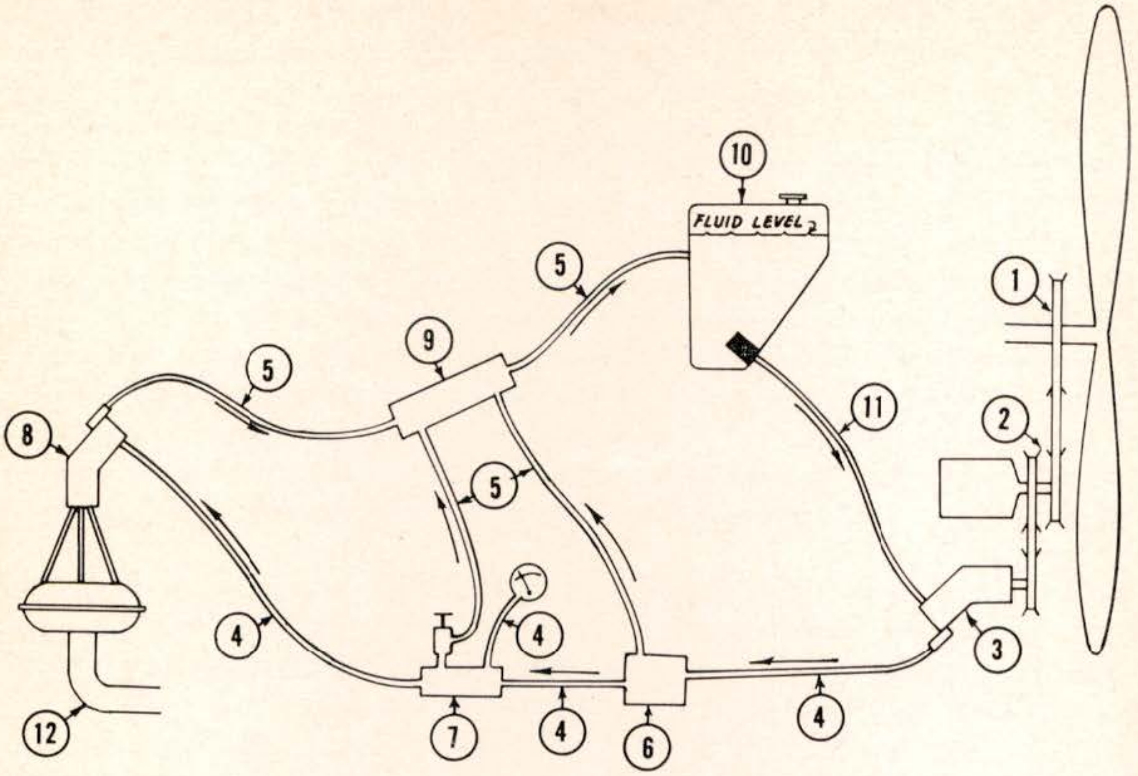

FIGURE 3. SIMPLE HYDRAULIC SYSTEM FOR LIGHT AIRCRAFT.

1. Seven and one-half inch diameter pulley on propeller shaft.

2. Double pulley on generator (on Lycoming engines with electric system). On engines without pulley driven generators or electrical system, run belt direct from propeller shaft pulley to 5 inch pulley on hydraulic pump.

3. Hydraulic pump.

4. High pressure hydraulic hose with ½ inch inside diameter.

5. Low pressure hydraulic hose with ⅝ inch inside diameter.

6. Hydraulic pressure release valve, (set for about 1500 psi) to protect hydraulic system in case of internal failure or jam.

7. Pressure manifold on which is mounted the hydraulic pressure gauge and the needle control valve which regulates the speed of or stops the spray pump.

8. Hydraulic motor splined directly to shaft of spray pump.

9. Low pressure manifold (collects the by-pass fluid and the return line from the hydraulic motor).

10. Hydraulic fluid reservoir (capacity 4 to 6 qts. plus expansion space) vented to atmosphere by a 1/16 inch hole drilled in the pipe plug, filler cap. The reservoir can be any shape to fit space available, but it is desirable that it be as deep as possible so that the intake line to the hydraulic pump does not pump air if the fluid splashes or becomes low. The reservoir is not under pressure and can be made of welded sheet aluminum.

11. Low pressure, fire resistant, intake line to pump with a ¾ inch inside diameter.

12. Intake line to the spray pump from the spray tank.

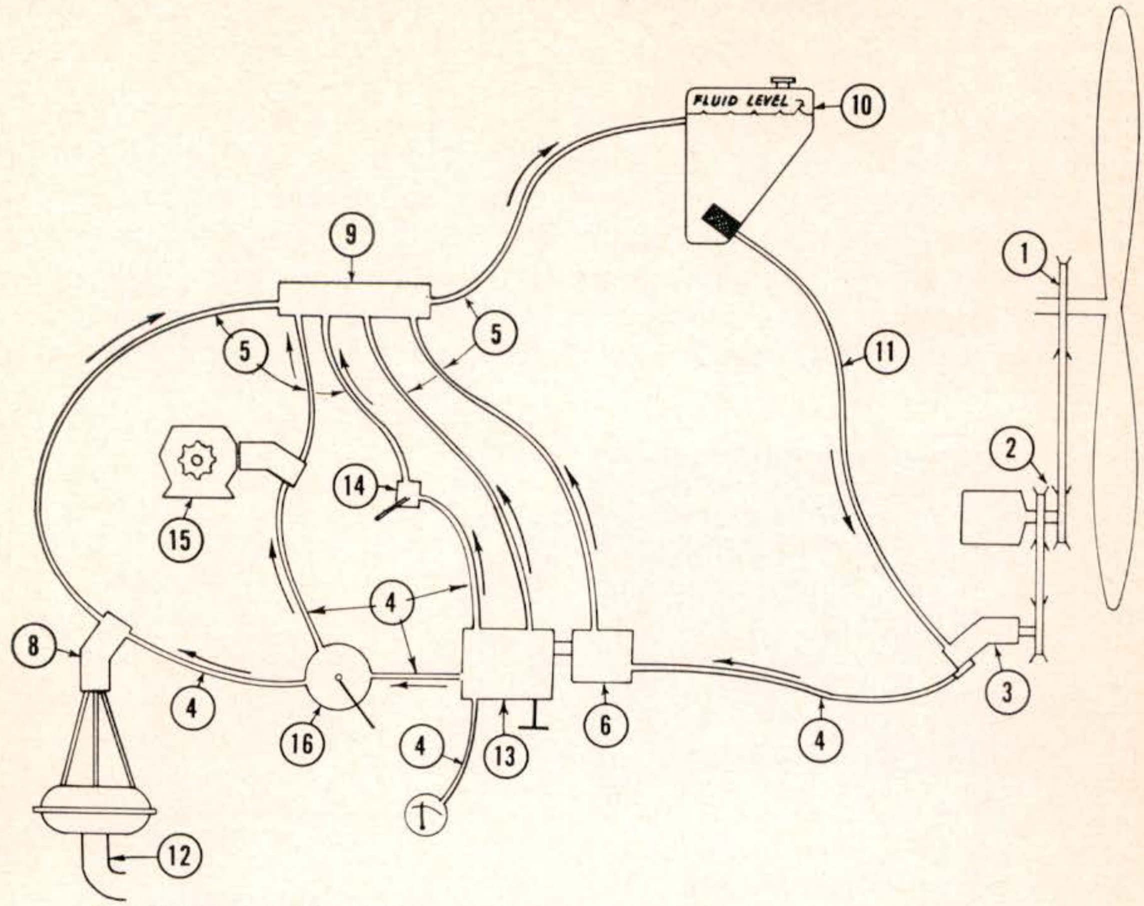

FIGURE 4. MULTIPURPOSE HYDRAULIC SYSTEM FOR LIGHT AIRCRAFT

Figure 4. Additional Equipment Used With the Multipurpose System.

13. **Pesco pressure compensating flow control valve which regulates the speed of the spray pump or rotor (replaces needle control valve).**
14. **Hydraulic unloading valve to start and stop the fluted feed rotor. It is left in the "on" position while using spray system.**
15. **Boston Gear Reductor, 20 to 1 ratio with hydraulic motor.**
16. **Two-way selector valve to direct flow to either the spray pump motor or to the rotor drive. One system is shut off when the other is in use.**

By installing an additional hydraulic motor, hydraulic lines, and a two-way selector valve the same hydraulic pump may be used to drive the hopper agitator or a rotor feed mechanism. Such a multipurpose hydraulic system is shown in Figure. 4.

The infinite range of power settings makes a hydraulic system ideally suited for driving mechanical feed mechanisms such as a fluted feed metering device for dry materials. The fluted feed mechanism was developed by J. E. Henry, Agricultural Engineering Department at Ohio State University.

Use of a fluted feed rotor with vanes arranged like reel type lawn mower blades will provide a more even feeding mechanism. With the straight vane as shown in Figure 5, a slight pulsing in the hydraulic system can be noted at slow rotor speeds. With such a device output is controlled by varying the speed of revolution of the fluted rotor (Figure 6). The fluted rotor is driven by a hydraulic motor through a gear reduction box. Since the hydraulic motor is a positive displacement pump, rotor speeds will be nearly constant for a given load and power setting. With this type device an aircraft engine tachometer can be used for a direct indication of speed; with a standard 2 to 1 ratio tachometer and a 20 to 1 ratio gear box the tachometer reading is ten times the rotor speed. Starting and stopping are nearly instantaneous. Even when operating at speeds of 3,000 rpm or over, a hydraulic motor will stop in less than one complete revolution when the control is thrown to the "off" position.

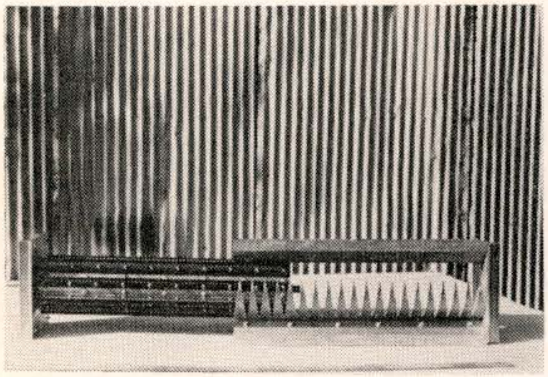

Figure 5. Bottom view of the fluted feed mechanism showing cast aluminum housing, abrasion resistant rubber vanes, and restraining fingers to reduce pulsations in output.

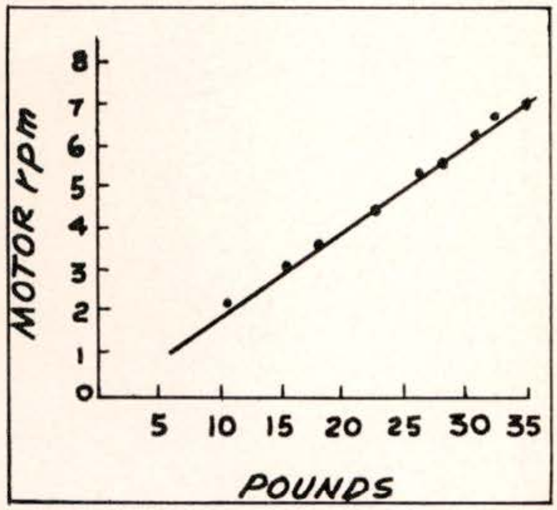

Figure 6. Output from hydraulic driven fluted feed mechanism using 5 percent dieldrin granules (30-60) mesh).

When used to operate a spray pump, however, the hydraulic motor is left in the "on" position during the actual spraying and turns at the end of each run. It is not advisable to start and stop the spray pump at the beginning and end of each swath because the sudden starts and stops may eventually cause pump impeller shaft fatigue. Thus, the hydraulic system operates continuously while a field is being sprayed. The spray is turned "on" and "off" with a quick acting gate valve in the pressure line. A large capacity globe valve is used to by-pass the spray solution when the gate valve is closed, if agitation is desired. If no agitation is wanted the by-pass valve can be closed if a centrifugal spray pump is used since no excessive pressure will be built up.

When the hydraulic system is used the proper operating speed of the fluted feed mechanism is obtained by a gear reductor box. Normal operating speeds of the feed mechanism rotor will range from 10 rpm up to 100 rpm. At such slow speeds there is little chance of metal fatigue due to the nearly instantaneous stops. Therefore, the hydraulic system is turned "on" and "off" for each swathing using a small, unloading control valve installed just beneath the throttle. Anyone who has operated a duster gate will appreciate this.

SPRAY DISPERSAL EQUIPMENT

Booms

To reduce the amount of spray picked up in the wing tip vortices it is suggested that spray booms be placed as far below the wing as practical (Figure 7). Increasing the distance between the wing and the end of the boom from 2 to 4 feet produces a noticeable reduction in wing tip swirl of spray. Moving the boom forward until in line with the leading edge of the wing also helps reduce the "wing effect" on the released spray.

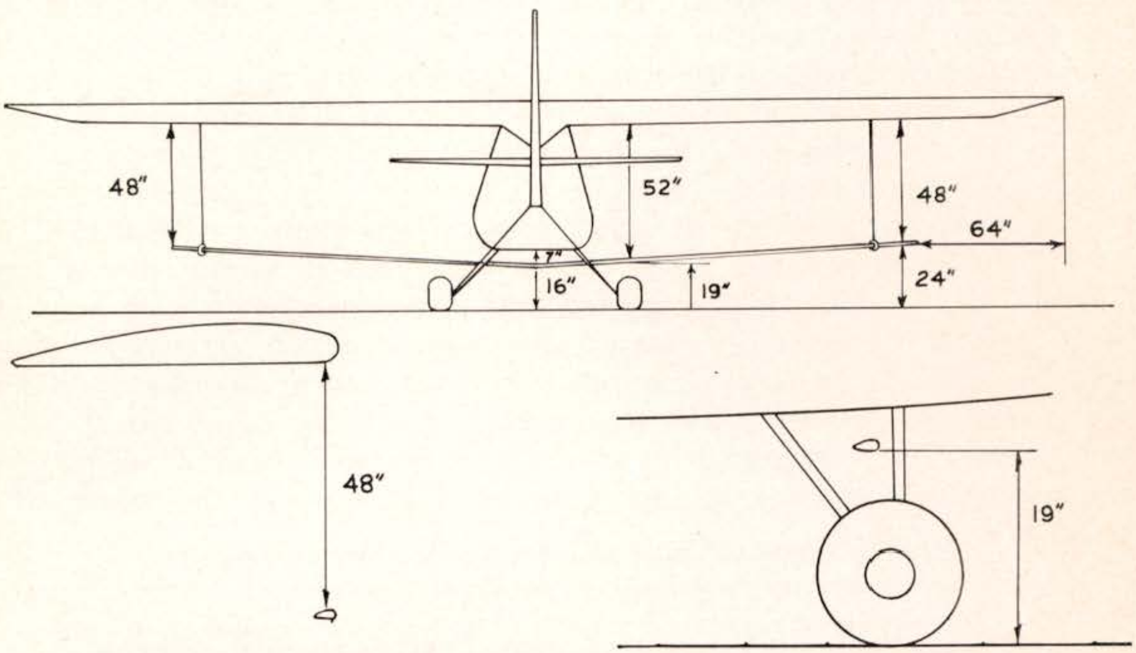

FIGURE 7. SUGGESTED BOOM LOCATION ON HIGH WING MONOPLANES

Streamlined booms are suggested to reduce drag. J-3 wing struts have been quite satisfactory. They are of steel construction and are stronger and easier to weld than aluminum streamlined booms. Removable plugs in the ends of the boom permit easy flushing between chemicals. Streamlined booms are especially important where high volumes per acre will be used. Drag on round booms becomes restrictive with boom sizes of one inch diameter or greater.

Nozzle Locations

Along with boom position, nozzle location along the boom has an important effect on spray distribution. Nozzle outlets should be on the upper surface to minimize nozzle plugging when using wettable powders or gummy materials. Round booms may be rotated so nozzles are facing forward, to the rear, or downward. For a given nozzle size, facing the nozzle to the rear will give the coarsest spray while facing it forward into the airstream will produce the finest spray.

Spacing nozzles at regular intervals along a boom does not give uniform spray application when the spray is released. The propeller slipstream imparts a clockwise rolling force to the air as it flows from the propeller along the fuselage and past the tail. This force displaces spray from 3 or 4 feet right of center to a point actually left of center and extra nozzles must be used to assure even spray application.

From just beyond the propeller influence there is an increasing outward displacement of spray all the way to the wing tip. Since the spray released from the nozzles will be affected by this outward force, the nozzles must be arranged to offset this effect. If nozzles are located on a boom which extends to the wing tips a great deal of the spray from the center 3 or 4 feet of boom will be carried upward and around in the wing tip vortices. Spray has been observed to rise as much as 10-15 feet above the wing when caught in the whirling vortex of air set in motion at each wing tip. Spray carried up to such heights can drift considerable distances. To minimize this effect it is suggested that no nozzles be placed closer than **5 feet** from the wing tip.

An increasing number of spray applications require volumes of 5 gallons or more per acre. Such volumes are hard to attain when using only 12 to 15 nozzles. It is suggested that those operators who anticipate some jobs at 5 gallons per acre or more use the nozzle arrangement requiring at least 42 nozzles. If most of the work will be in volumes lower than 5 gallons per acre, then the arrangement using 24 nozzles will be satisfactory. Both arrangements give a spray pattern which is triangular shaped in cross sections; i.e., spray deposit is heaviest in the center and

Table 2. Suggested nozzle locations for high-wing monoplanes.

High volumes (42 nozzles) Distances from aircraft center		Medium and low volumes (24 nozzles) Distances from aircraft center	
Left boom	Right boom	Left boom	Right boom
0'-6"	0'-6"	0'-6"	0'-6"
2'-0"	1'-3"	2'-0"	1'-3"
2'-9"	2'-0"	3'-0"	3'-0"
3'-0"	3'-0"	4'-0"	4'-0"
4'-0"	3'-6"	4'-6"	5'-0"
4'-3"	4'-0"	5'-6"	5'-6"
4'-6"	5'-0"	6'-6"	6'-6"
5'-0"	5'-3"	7'-0"	7'-0"
5'-6"	5'-6"	8'-0"	8'-0"
6'-0"	6'-0"	8'-6"	9'-0"
6'-3"	6'-6"	9'-6"	11'-0"
6'-6"	6'-9"	11'-6"	12'-0"
6'-9"	7'-0"	12 nozzles	12 nozzles
7'-0"	7'-3"		
7'-6"	8'-0"		
8'-0"	8'-6"		
8'-3"	9'-0"		
8'-6"	11'-0"		
9'-6"	11'-6"		
11'-0"	12'-0"		
11'-6"			
12'-0"	20 nozzles		
22 nozzles			

tapers to both edges. Figure 8 shows the theoretical deposit from such nozzle arrangements. Uniform deposit is based on a 40 foot swath; the difference in expected deposit is shown where a 60 or an 80 foot spacing might have been used accidentally. If the swath spacing is less than 40 feet then there will be streaks where excess amounts of spray have been deposited. Table 2 shows the suggested nozzle locations for either 42 or 24 nozzles. For anyone planning to make new booms and install these noz-

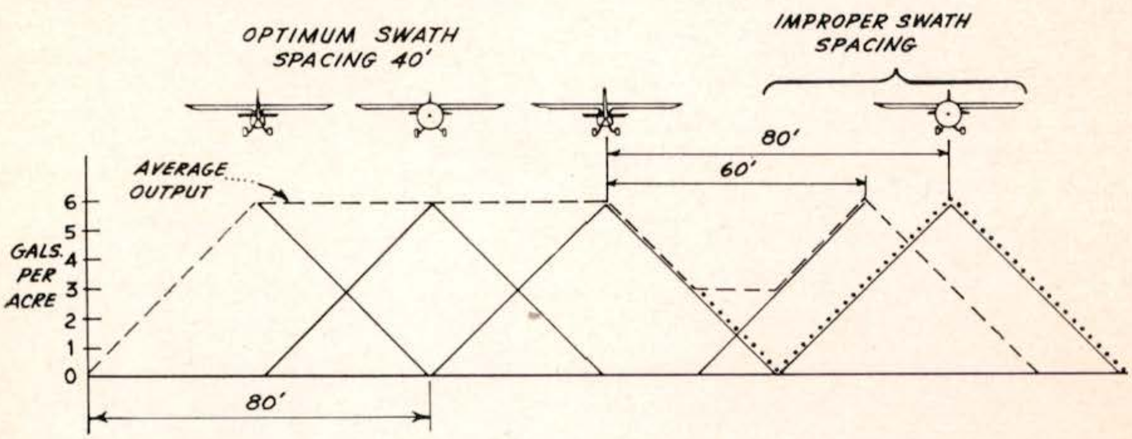

FIGURE 8. TRIANGULAR SHAPED PATTERN OBTAINED WITH SUGGESTED NOZZLE LOCATION

zle locations, it is suggested that the 42 outlets be installed. All the outlet positions required in the 24 nozzle arrangement will be included if the arrangement for 42 nozzle outlets is installed. The unused outlets can simply be capped or plugged when not in use.

The best spray distribution is attained with a boom height of about 5 to 6 feet above the crop. Spraying at a lower altitude, with the aircraft wheels touching the tops of the crop, actually gives poorer swath distribution than when wheels are 4 to 5 feet above the crop.

DRY MATERIAL DISPERSAL EQUIPMENT

Vaned Rotor Feed Mechanism

Line drawings giving dimensions and the cast aluminum housing of the vaned rotor feed mechanism were obtained from Mr. J. E. Henry of Ohio State University. The rotor, vanes, abrasion resistant rubber, and hopper modifications were all obtained or constructed locally. Improvements which were made over the original plans drawn up at Ohio State University include the use of steel end washers on the ends of the rotors to eliminate rapid wear resulting from aluminum against aluminum.

A suitable gear reduction box was obtained which permitted direct mounting of a hydraulic motor on the gear box (Figure 9).

The original plan called for several different sized V-belt pulleys in order to obtain the necessary speed reduction. No coasting of the rotor has been observed; the rubber vanes fit very closely, giving almost instantaneous stops. The rotor attaches to a mounting plate on the bottom of the hopper. This mounting plate is flush with the bottom of the fuselage and allows full hopper capacity. In fact, the conversion from a standard Piper hopper to a mounting plate 5 x 20 inches in size **increased** the hopper capacity about 10 gallons.

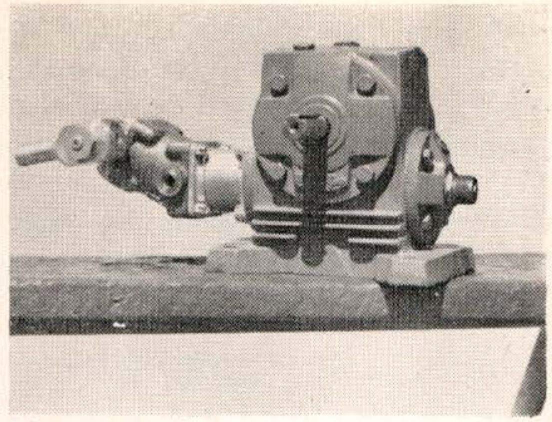

Figure 9. Hydraulic motor on Boston gear reductor for driving vaned rotor feed mechanism.

Venturi Distributor

Several changes were made in the venturi from the dimensions given in the Proceedings of the 1956 Nebraska Aerial Applicators Short Course. These changes were necessary since the rotor feed system delivers material from a 5 x 20 inch throat. Six different passageways are formed by the various walls inside the venturi. Thus, the internal walls were spaced so the material from the 20 inch throat would be divided in six equal parts.

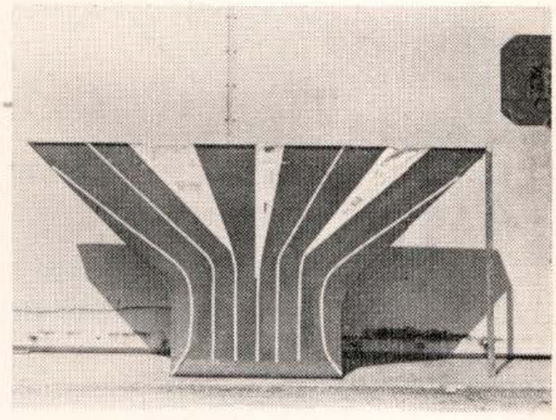

Figure 10. Bottom view of the venturi showing the location of interior walls by white lines and blanked-off areas by solid white.

This was accomplished by removing the blank streamlined center section. The original venturi was 2.5 inches wide at the front or intake end. It was necessary to put in an additional wall on each side in order to narrow the throat width to the 20 inch dimensions of the vaned rotor. The present location of the internal walls is shown in Figure 10. The changes can be noted more clearly by comparing the

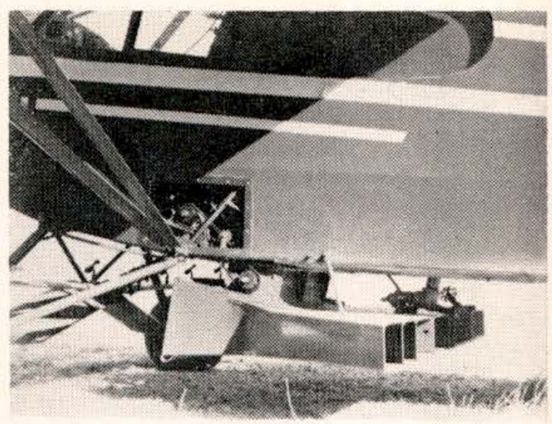

Figure 11. Venturi distributor or spreader attached to airplane showing its relative position and location.

[1] Air quantity is an important factor where high poundage or bulk is dispensed since choking or total stoppage of flow occurs when material output exceeds removal by air stream. This has been noted on one installation where vertical depth of throat was decreased about 50 percent to obtain more ground clearance with a "low-bellied" airplane.

distinct white lines which mark the present wall locations with the lines of rivet heads which indicate the location of the original internal walls.

Removal of the central streamlined section and redesigning the side walls apparently resulted in a greater air velocity and quantity through the venturi.[1] Swath width was greater with seeds and granules than with the previous venturi design. The amount of drag remained substantially unchanged. Total intake area and the location and dimension of the outlet areas also remained unchanged. Figure 11 shows the attached spreader on the airplane. The chain driving mechanism shows the connection from the speed reducer (Figure 9) to the vaned feed rotor (Figure 5). By disconnecting two brackets the spreader can be slid forward and off.

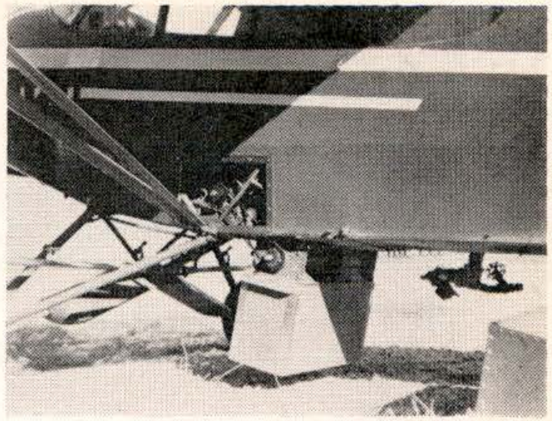

Figure 12. Collecting box attached to rotor in place of the spreader. This feature enables output data to be obtained without an actual flight test.

The collecting box, shown in Figure 12, can then be slid into position. This feature enables all output data to be obtained without loss of material or necessity of waiting for ideal weather conditions to run flight tests. With the engine running at 2000 rpm the rotor is turned on for a definite interval of 10, 20, or 30 seconds, depending on the amount of output desired. After collecting the material the box is slid forward and off and the contents are weighed. If necessary, the changes in calibration setting are made to obtain the desired output of the rotor.

Calibration Data

Table 3 presents information regarding output requirements of an aircraft, dry material distributor in pounds per minute for various swath

Table 3. Output requirement for dry material by aircraft spreader in pounds per minute as determined by swath width, air speed, and application rate.

Swath width in ft.	Acres per minute at 80 mph.	Desired application rate in pounds per acre									
		5	10	15	20	25	30	40	50	60	100
20	3.2	16*	32	48	64	80	96	128	160	192	320
25	4.0	20	40	60	80	100	120	160	200	240	400
30	4.8	24	48	72	96	120	144	192	240	288	480
35	5.6	28	56	84	112	140	168	224	280	336	560
40	6.4	32	64	96	128	160	192	256	320	384	640
45	7.2	36	72	108	144	180	216	288	360	432	720
50	8.0	40	80	120	160	200	240	320	400	480	800
55	8.8	44	88	132	176	220	264	352	440	528	880
60	9.6	48	96	144	192	240	288	384	480	576	960
65	10.4	52	104	156	208	260	312	416	520	624	1040
70	11.2	56	112	168	224	280	336	448	560	672	1120

* The total amount of output required is determined by multiplying the acres covered per minute by the desired application rate in pounds per acre. Therefore, $3.2 \times 5 = 16$. To obtain output requirement for a different air speed, e.g. 70 mph, with a 20 foot swath and a desired application rate of 5 pounds per acre, multiply acres covered per minute, 2.8, by desired application rate, 5, to determine that 14 pounds of output is required per minute.

widths and application rates in pounds per acre. Table 4 presents actual calibration data obtained using the hydraulically driven vaned rotor feed mechanism.

Table 4. Calibrations of hydraulically driven, positive feed metering mechanism for the Piper PA-18A airplane using pesticide granules (30-60 mesh) with an 80 mph airspeed and a 45 foot swath width.*

Hydraulic regulator setting	Rotor rpm	Time in seconds to cover one acre	Output of granules in lbs/acre
1.00	1.0	11	5.7
1.50	2.1	11	10.8
2.00	3.1	11	16.3
2.50	3.9	11	20.5
3.00	4.6	11	24.3
3.00	4.8	11	25.2
3.13	5.0	11	26.4
3.25	5.2	11	27.6
3.25	5.2	11	27.3
3.25	5.6	11	29.7
4.00	6.3	11	32.3
4.50	7.2	11	36.6
4.63	7.2	11	36.9
4.63	7.4	11	37.3
4.75	7.6	11	38.8
5.00	8.0	11	39.2
8.00	11.5	11	48.7
9.00	12.5	11	49.7

* Calibration rates of seeds and granules for other aircraft, airspeeds, and swath widths can be determined using similar methods to that given above.

APPENDIX

Descriptive information on parts list as numbered on diagrams.

1. If a V-belt pulley is not installed on the airplane engine, one can be machined of aluminum alloy and mounted on the propeller shaft. See parts available list.

3. Vickers angle drive hydraulic pumps and motors. There are a number of models. All of them are satisfactory if they are rated as 1000 psi and 3750 rpm as normal. When ordering, specify a .600 or .610 cubic inch pump for right or left hand rotation. (This one is the driving pump for the system.)

4. This hose must be high pressure hydraulic hose. Aeroquip or Weatherhead type 303 (Mil. Spec. HSSII) Size 303-8 has a 13/32 inch inside diameter for high pressure line from hydraulic pump to hydraulic motor. Burst strength is 8000 psi. Size 303-4 has a 3/16 inch inside diameter for connecting to pressure gauge. Connecting fittings are AN-792-8D for the 303-8 and AN-792-4 for the 303-4.

5. Low pressure aromatic resistant hose. Aeroquip or Weatherhead—type 306 (Mil. Spec.-H-5593). Size 306-10, 5/8 inch inside diameter, use on return lines to reservoir. Connecting fittings AN773-10-D. (Mil. Spec.-F-5509). Connecting nipples for 5/8 inch tube to 1/2 inch pipe are AN-816-10D.

6. Large volume pressure release valve. V-9B-2 Kenyon with 1/2 inch tube and with AN 3/4-16 thread.

7. Use solid aluminum bar with about a 2 inch diameter; drill holes and tap with pipe thread to take the tube to hose nipples described under number 4 and 5.

8. Same units described under number 3.

9. Same as described under number 7.

10. Make reservoir of sheet aluminum or thin steel to fit available space in airplane.

11. Intake line to hydraulic pump. Use Goodyear AO-19 flame retardent hose with a 3/4 inch inside diameter.

12. Intake line to the spray pump from the spray tank. Aerial operator's choice.

Extra equipment for spray and dust application

13. Pesco hydraulic flow control valve (Model 05-1081-923).

14. On-off unloader valve and a V-4AB-manual check valve.

15. Boston reductor, 20 to 1 ratio type T-118. These speed reducers are offered in 3 mount types. Choose the one that fits best in your rig. The mounts are as described below. With input shaft facing front of airplane, the output shaft of type A projects out to the right, type B projects out on both sides, and type C projects out to the left.

16. Selector valve number V-13-1.

Where parts are available

Palley Supply Company, 2263 Vernon Avenue, Los Angeles 58, California. Hydraulic pumps and motors. Hydraulic hose and fittings. For items listed under numbers 6, 14, 16. (They can send free catalogue on hydraulics.)

Boston Gear Works—Chicago Branch; 5445 W. North Avenue, Chicago 39, Ill. Speed reducing gear boxes. Sprochets and chains. (Free catalog number R-56).

Any aircraft supply house. Hydraulic hose and fittings.

Burden Sales Company, 800 "O" Street, Lincoln, Nebraska. Hydraulic fittings. High pressure hydraulic gauges for 0-1500 and 0-200 psi.

J. E. Henry ,Ohio State University, Agricultural Engineering Department, Columbus, Ohio. Information on rotor assembly. Information on aluminum pulley on propeller shaft.

Borg Warner Corp.; Pesco Products Division, 24700 North Miles Road, Bedford, Ohio. Hydraulic flow control valve.

Any farm or auto supply store. Rubber V-belts and pulleys.

Columbia Exporters, Inc., 730 S.E. 11th Avenue, Portland 14, Oregon. Simplex pump and hydraulic motor.

National Mfg. Company, 1218 North 22nd Street, Lincoln, Nebraska, Aluminum bar.

Gordon & Morgan Machine Co., 3725 Touzalin Ave., Lincoln, Nebraska. Heliarc welding.

Notes On Hydraulic Pumps

All the pumps and motors in common use are WW II (surplus, new, or used).

When ordering hydraulic pumps and motors specify universal fitting and **with** the AN776 elbow 90°. This is necessary because during the war the AC fittings were changed to the AN type therefore some of the pumps and motors are threaded for AC and some for AN fittings.

Design and Construction Hints

The engine driven hydraulic pump should be installed so that the belt has as much "wrap" as possible on the pulley to enable sufficient power to be derived from the system without belt slip. Belt dressings are not needed but do no harm if used.

Storage Reservoir For Hydraulic Fluid

To avoid foaming in the system, with a resulting air lock which causes a loss of pressure, the return line should be carried below the level of the fluid. See Figure 5 or 6.