Supplement for Fixed Wing and Rotary Aircraft

Extension
University of Missouri

College of Agriculture,
Food & Natural Resources

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Aircraft Field Calibration checks

The most common way to verify aircraft spray calibrations is done utilizing an onboard GPS system. Almost all ag aircraft now have a GPS system and can determine acres covered or acres per load. A known quantity of fluid is placed in the hopper and applied. Determining the application rate is performed by simply dividing the volume of liquid applied over the number of acres covered. Several popular aircraft have a 500-gallon capacity. When applications are made to a 100-acre field the application rate is 5 gallons/acre. This type of comparison is utilized by aerial applicators on almost every load or field to verify application rate(s) and system accuracy.

Many label guidelines have specific rate and/or droplet spectrum requirements. This may require that applicators go to the suppliers' tables or USDA (www.ars.usda.gov) models to pick the appropriate nozzle type and size. These models are also available as an application called "Aerial Spray". These are available for computer, iPad, and phone use.

Basic Formulas for Aircraft Spray Calibration

Calibration is a process to determine how much liquid solution must be delivered from the nozzles to deposit the required amount of product active ingredient (AI) per acre. The amount of material applied by an aircraft can be adjusted only by a change in ground speed or a change in flow rate. Swath width should never be used as a method of changing the application rate without physically changing the nozzle configuration. The basic steps of aircraft calibration are:

Case 1

1. Determine the acres your aircraft system treats per minute at the speed and estimated swath width you plan to fly. The effective swath width should match that determined by pattern testing.

   Equation 1

   Acres per minute = .00202 x swath width (ft) x speed (mph)
   Example using: 60 ft swath and 120 MPH.
   Acres per minute = (.00202)(60 ft)(120 mph) = 14.4 acres/minute

2. Determine the gallons you must spray per minute to apply the recommended gallonage rate.

   Equation 2

   GPM = (Acres/min()(GPA))
   Example using: 10 gallons per acre.
   GPM=(14.4)(10)=144 GPM

3. Once the flow rate has been determined, select the nozzle orifice size and number of nozzles needed to deliver the correct number of gallons per minute within the allowable operating pressure range of your system. It is generally recommended that spray pressures remain greater than 30 psi and less than 60 psi.

Case 2

Determine the number of nozzles to use. Assume you are using a nozzle with a flow rate of 3 GPM at 35 psi.

Equation 3

$$\text{Number of nozzles} = \frac{\text{Total flow}}{\text{GPM per nozzle}} = \frac{\text{144 GPM}}{\text{3 GPM/nozzle}}$$

= 48 nozzles needed

A total of 48 nozzles would need to be operational to obtain the desired application rate. The positioning of each nozzle should be selected, and the system pattern tested to verify distribution pattern uniformity and nozzle pattern changes required.

Case 3

Determine what nozzle tip size to use. For this calculation, the total number of nozzle outlet positions on the boom or the total number of positions one plans to use must be selected before calculations begin. Assume that 66 nozzles are needed.

Equation 4

$$\text{GPM per nozzle} = \frac{\text{Total flow}}{\text{Number of Nozzles}} =$$

$$\frac{\text{144 GPM}}{\text{66 nozzles}} = \text{2.18 GPM/nozzle}$$

Based on this calculation, one would select a nozzle that has a flow rate close to 2.18 GPM in the desired pressure range of 30-50 psi.

Calculating flow rates from individual nozzles once they are mounted on a boom system is difficult, especially when equipping an aircraft for high application rates. Individual nozzle flow rates vary depending on location, turbulence in the boom, and the number of boom restrictions. After placing nozzles on the boom, make a trial run to ensure the proper application rate is being applied and that the spray results in a uniform deposition. A high number of larger nozzles (larger orifices) result in high fluid velocities inside the boom and a large pressure drop from the center of the boom to the end of the boom where the last nozzle is located. This pressure differential may result in narrower effective swath widths. Full three-inch liquid systems (no restrictions smaller than three inches from the pump outlet on) are recommended for field applications greater than 9 GPA.

Weather monitoring

Meteorological conditions at the time of application(s) should always be monitored continuously throughout an application. There are many sources of weather available: television, phone, local weather stations, subscription programs at base stations, direct feeds to GPS systems, and others. These are not always close enough to the actual application site to be completely relied upon for accuracy. Applicators typically utilize several other aids such as wind on trees or water, flight characteristics of the aircraft, and a smoke plume or dollop generated by spraying a small amount of oil into the exhaust manifold.

Smoke provides a very accurate determination of wind direction visible from the cockpit during applications. Smoke is also a good indicator of potential inversion conditions. Smoke will typically rise and/or disperse laterally under unstable conditions indicating the lack of a low-level inversion. Smoke that suspends in the air for prolonged periods, and disperses horizontally without rising, is an indication of inversion conditions. Low level mixing or wind will eventually disperse low level inversions that develop. Many labels advise applicators to avoid or be extremely cautious under low wind speed situations.

Applicators also utilize smoke to estimate wind speed. One certainly can't tell the difference in .5 or 1 MPH increments, but a professional applicator may get a good estimate. Comparing smoke evaluations and known weather measurements by a professional daily gives them the ability to be quite accurate.

Supplement for Spray Drones

Introduction

The current state of the drone application industry is one of rapid expansion and change. There are constant changes to hardware and software and operators trying new things. The demand and adoption rates are outpacing the research and regulation. The number of spray drones in operation in the US is unknown, but best estimates at time of printing are 4000-6000. That is up from a few hundred in 2021. Operators at this stage are heavily reliant on home grown and crowd sourced research along with data from manufacturers and distributors. FAA and state regulators are reacting to the heavy demand with unclear direction and certainty of the scale and longevity of this technology. The information provided here is based on 4+ years of using the technology and working with operators across the US. The following content has been kept as generalized as possible due to the constant evolution of the technology.

Description of Spray Drones and how they function

Spray drones, as they are commonly called, come in many shapes and sizes and are very similar in technology to common camera drones. The majority are battery powered multi rotors with a spray system and tank. They incorporate GPS guidance and software to operate autonomously. Most spray drones have sensor systems that include radars and cameras to improve safety and autonomous operation. They are capable of a variety of tasks and types of operations but are most used in row crop fungicide and insecticide application. Many also spread dry material like seed and fertilizer.

Spraying Systems

There are two main types of spray systems on drones, pressure atomized and rotary atomized.

Pressure atomized systems use spray tips (T-Jet style) to force liquid through small orifices to be atomized into droplets. The same as common spray systems used outside of drones on other traditional sprayers. Different tips can be used to change the pressure and droplet size.

Rotary atomized systems are becoming the dominant system in spray drones. Instead of pressure and orifices, rotary atomized systems use a spinning disc and centrifugal force to atomize the liquid into droplets. The type of disc and speed of the disc will determine the droplet size.

All drone systems use electrically driven pumps, and some type of flow meter to electronically control the flow rate.

Swath and Drift

Spray drones do not rely on booms to determine the swath width. There are some drones that have booms, but even their swath is not determined by their booms. The most used drone today, the Agras T40, has only two rotary atomizers located beneath the rear propellers. It does not use a boom.

Instead of booms, the “Swath” of all drones is primarily determined by the speed and height of application. Other factors include droplet size, product type and density, and wind direction and speed. Because of all these factors, the swath of any particular drone is not static, and is subjective. Generally, the faster and higher a drone flies, the wider swath it will create due to propeller vortex. A uniform swath relies on overlap from the next swath. The spray system will deposit the highest concentration of droplets beneath the drone and taper off further from the drone.

Drift can be reduced by using larger droplet sizes and drift reducing adjuvants. Droplet sizes used with spray drones tend to range from 50 – 500 microns, with most applications in row crop being done on the upper end of that scale. Slowing down and flying lower can also reduce drift, however this competes with efficiency, because it will also reduce swath and of course speed meaning the operator will cover fewer acres per hour. Large scale application operators fly at speeds between 15-30 miles per hour at a height of 10-15 feet above the crop. Following label guidelines for max wind speed during application is generally sufficient for operators, however wind direction is important to pay attention to and to leave a large buffer zone or change application parameters when wind is above 10 mph.

Flight Control

Spray drones are generally controlled remotely from a ground station device. This device can come in multiple forms such as a dedicated RC, laptop, tablet, or smartphone. The ground station can be used to manually control the drone or to plan an autonomous route which the drone will fly without manual input. There are also hybrid operation methods that use a combination of manual input and autonomous flight.

Autonomous operation is the most common.

Generally, the operator will use software to plan a field boundary, obstacle areas/no-fly zones, and non-spraying areas. The system will then create a route for the drone to operate within that boundary. The operator will edit the route to be appropriate for the operation by inputting flight height, speed, direction, start point, application rate, route spacing, etc.… The drone will operate along the route, following the operator's preprogramed directions.

Field Operations

Operating a drone in the field requires several pieces of equipment, typically a trailer or truck setup with chemical handling equipment, a generator, charger, and multiple drone batteries. An air conditioning unit in the trailer helps protect battery life, electronics, and battery charging. For large trailers with an operations and observation deck on the top, a safety rail should be installed around the roof perimeter. The access ladder should be secured to the roof to prevent falls.

Spray drones have small tanks and limited flight times. A drone will typically empty the tank and return to the landing zone every 4-10 minutes. The operator will then land the drone, fill the tank, and replace the battery. The operator will use the ground station to return the drone back to the field and resume the application from where it left off. While the drone is flying the operator will connect the depleted battery to the charger and use the generator to rapidly charge batteries and cycle them throughout the day.

Per current FAA regulations the operator is required to keep line of sight with the drone, only operate one drone at a time, and have a person on site designated as a visual observer.

Chemical Handling

Current tank sizes of drones are between 2.5 and 17.5 gallons. Because of this small size, it is generally preferred to mix chemical in a separate tank and pump it into the drone tank. Application rates with a drone are typically much lower than that of traditional ground application, therefore chemical is mixed at a higher concentration in comparison. Drones are considered aerial application; therefore, the operator must follow aerial application guidance on chemical labels.

Because drones lack agitators, it is imperative to perform a jar test. Common tank mixes such as Miravis Neo and Warrior II can react in the tank and transform into equipment-clogging gel. Some product labels prohibit their use in aerial equipment. Careful attention must be given to label application rates to ensure compliance and efficacy.

Regulations

FAA regulations for spray drones are continuing to change. Here is a current list of the requirements from the FAA:

1. FAA 137
2. FAA 44807
   a. For drones over 55 lbs.
3. FAA 107
4. Drone registration with the FAA
   a. a.N number for drones over 55 lbs.
   b. b.Must utilize the Remote ID number for the drone to register
5. Pilot must have an FAA Third Class Medical Certificate
6. Liability insurance is required
7. Proper state applicator licensing
   a. Commercial Applicators:
      Category 13 Commercial Aerial Applicator & Category 1A Plant Agriculture
   b. Private Applicators:
      Category 23 Private Aerial Applicator & Category 20 General Agriculture (Private Pesticide Applicator)

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