

Trucks and Trailers for Drone Operations



INCREASING THE EFFICIENCY
OF DRONE SPRAYING



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Spray Drones **Take Agriculture** **and Industry** **by Storm**



Not every drone operation is designed to be efficient. Some are unique, specialized operations that require a special set of skills by the operator and a special setup to get to the location.

Viewed as a futuristic possibility just a few years ago, spray drones have undergone a remarkable journey to become a legitimate and widespread application tool in agriculture and allied industries. The application of pesticides, fertilizers, and biologicals by drones has demonstrated that their uses include protecting the public by reducing mosquito populations, lessening the impact of invasive weeds on terrestrial and aquatic environments, and improving crop yields by using fungicides. When driving rural roads, it is common to see drones spraying corn, soybeans, and wheat. Historically, a large sprayer would have been used even if it meant mudding a field in less-than-ideal conditions for the sake of a timely application.

The current uses are just the tip of the iceberg compared to how spray drones will be utilized in the future. Whether spraying, collecting data, or merely taking photographs, drones have found wide use in multiple industries, including farming. The market for drones continues to set new sales records and show unprecedented growth. The following factors have encouraged agricultural use of drones:

- A drone spraying setup costs significantly less than a new, fully equipped self-propelled agricultural sprayer. A person can start a new business venture by investing somewhere between \$100,000 to \$200,000 to purchase two drones and a fully loaded truck and/or trailer with tanks, pumps, and generators. In comparison, a modern-day new ground sprayer can range between \$500,000 and \$1 million depending on the options purchased.



This efficient setup all fits on a truck with no trailer needed. This can be important for regions with winding roads or field entrances that are not designed for larger equipment. However, the driver might require a commercial driver's license (CDL), making it more difficult to find an employee.



While drones can operate when the soil is too wet for ground rigs, you still need to be able to access the site. Is there a gravel lane or pull-off to access the field, or will your truck/trailer cut ruts and get stuck getting to the spot? Plan your days so that you can stay on the side of a road or have nice pull-offs for the wetter times.

- Drones can operate when the ground is too wet to support ground equipment. A couple of inches of rain might keep a ground rig out of a field, but a drone sprays over a crop without worries about compacting soil or damaging a crop. As agricultural enterprises become more intense in management, more frequent and timely applications become ever more important. For example, a wheat farmer 20 years ago may have crossed the field just one or two times during the entire growing season, but now progressive wheat farmers commonly make four or more passes during a growing season.

- Farmers can utilize drones to make their own timely applications at the best growth stage for maximizing insect, weed, or disease control. By doing some or all their own applications, farmers can lower their production costs and avoid waiting for their local retailer to schedule the treatment, which could take some time if there is a long list of farmers. As already mentioned, high-intensity crop management has increased the demand for custom applicators to cover many acres in a narrow optimum time frame; some farmers who are last on the list will end up with less-than-ideal application timing. Spray drones offer the ability for more people to enter the spraying market to fill the gaps that other operators cannot.



Finding experienced operators is important when building out your truck/trailer setup. Pilots should discuss issues with the team and address problems before they arise. Experienced operators can tell you what is reasonable to expect and can be an invaluable source of information that may make the difference between success and failure.

- The increase in the carrying capacity of drones has opened the doors for more acres to be treated on each application pass. Advances in battery technology have helped drone manufacturers increase carrying capacity and charge batteries quickly enough to limit downtime. A few years ago, a drone with a 5-gallon tank capacity doubled the volume that its predecessors carried. That trend continues: Today drones are marketed with tanks holding 20 or more gallons. These larger tanks can now apply the higher volumes required by some product labels while still getting enough acres done to remain profitable. However, larger drone sizes and tank capacities mean a larger crew is needed to move the drones around.



Drones are an obvious attraction to many young people who want to get involved with agriculture. The physical controls and troubleshooting of technology are like those for other technologies that are commonplace in the environment of today's youth.

- Drones offer a potential enterprise for younger generations to be added to the farm. When operations are landlocked, it can be difficult to find production methods that add enough monetary value to a farm to support another person. By adding a spray drone enterprise, a farm can potentially save money by applying products themselves and earning income through custom hire work. The younger generation has a competitive advantage as the technology, controls, and troubleshooting for spray drones are like those for many other technologies they grew up learning how to use. This gives them experience that other generations may not have. Using a drone to commercially apply agricultural can generate the revenue to support those who want to remain on the family farm.

- The younger generation has less interest in applying products with conventional spray equipment. But young people grew up using joysticks and controllers (for example, using PlayStation), making drones very attractive to them. In a recent article, the military found that younger users with a background in dirt biking and all-terrain vehicles made the best pilots. As this younger generation enters the workforce, they would rather fly a drone than sit in a ground sprayer.

- Insurance agencies and lending firms are becoming more familiar with spray drone operations, allowing users to be more confident of insurance protection and financing to support spray drone enterprises. Along this same trend, overall general information about spray drones is becoming more readily available, and researchers are helping operators fine-tune application methods to limit potential issues.

- The Federal Aviation Administration (FAA) is adapting the pilot and drone licensing processes to be less cumbersome and confusing for users who are not familiar with FAA rules, regulations, and operating procedures. The FAA is making reasonable efforts to make operating spray drones easier.

- The cost of drones has dropped. At the beginning, a 2-to-6-gallon drone capable of spraying 5 acres per hour cost between \$40,000 and \$60,000. As the technology and production lines have improved, the cost has gone down. Today a 16-to-20-gallon unit spraying 40 to 50 acres an hour costs \$30,000 to \$40,000. In addition, the number of used drones on the market allows people to purchase them at a reduced cost and reduce their initial investment.

"It is my dream to farm and to work into my family farm, as it's what I love, and I want to do it long term. But there isn't really room for me at this time, thus why I got into drone spraying. 2025 was my first year, and there was for sure a lot that I learned." — Written by a 20-year-old farmer

Opportunities to Learn About Drones

When drones became part of a national discussion, they piqued people's curiosity, generating questions, conversations, and discussions. Each new adaptation increased the interest in how best to deploy drones. But behind that excitement was a significant misconception. Earlier pilots erroneously thought a spray drone was an easy way of making lots of money. These operators were drone wise, but unfortunately, many were not well versed in what it took to grow a crop and conduct an application to meet a farmer's standard.

They would tell their customers that their drone sprayed a 30-foot swath, applied 5 gallons per acre, and flew 25 miles per hour (mph). In fact, the early drones had pumps that could only deliver up to 2.15 gallons per minute, producing an application rate closer to 1.4 gallons per acre at the maximum speed. Drone operators received lots of complaints about the drone's poor performance, primarily because the pilots did not understand the application side. These operators had to field calls from less-than-happy customers who paid full price but got a less-than-complete job. To compound the problem, there was little relevant data to help applicators do a better job.

Many who had entered the drone market thinking it would be a lucrative business venture became disillusioned when their operations failed to produce the financial returns they had expected. Those who survived those initial challenging times and those starting their business within the past five years have a higher chance of succeeding in the industry. Why? A massive education campaign across the United States has occurred over the past five years in which research has focused on enhanced safety, efficacy, and efficiency; it has provided a deeper understanding of the equipment needed and of ways to use drones' capabilities to control pests.

Once universities and public entities geared up their research efforts on drones, they began to redefine what a drone could and could not do. These new research findings provided the drone industry with scientific facts to help operators better understand drone operations and enhance their ability to establish businesses. For spray drones, environmental conditions can dictate the success of an operation, and it can be difficult to develop rigid recommendations that apply across platforms and environments.

Spray drone research and education are important due to drones' widespread adoption across the industry. With manned airplanes and helicopters, researchers could more easily target their audience because relatively few individuals and companies performed such operations. Because spray drones are more widely utilized, and drone pilots may have limited aerial applicator experience, research and outreach have become much more critical. To further complicate matters, there is a greater variety of new platforms that could influence the recommendations provided.

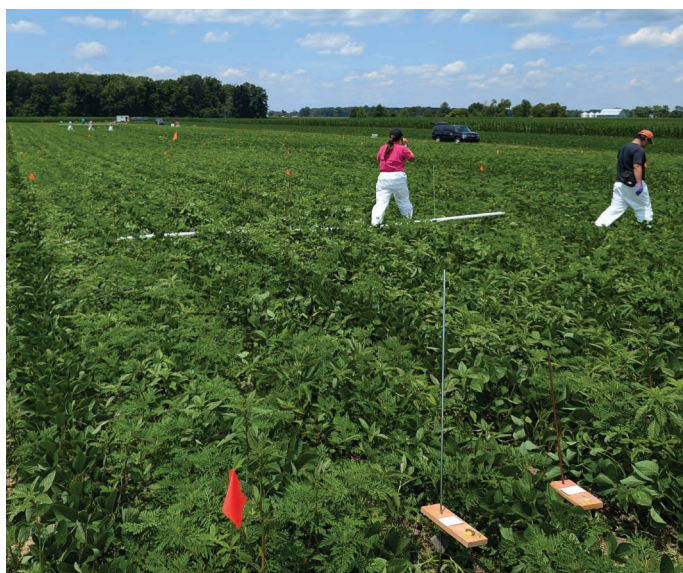
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Proper swath testing is essential to a successful spray drone business. No one wants to pay for a spray job that leaves streaks of unapplied and missed areas where pests continue to damage the crop. See next page for photos.

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Keeping Up with Drone Technology

“Currently we are spraying from a 10-gallon tank, but new drones can carry 20 gallons. We are going 30 feet per second, while the new models travel 45 feet per second. Staying up with the latest drone technology provides the impetus for continued education.” — A drone operator



Active university research on swath widths, droplet deposition, and canopy penetration is currently underway. Practices accepted today will undoubtedly change as the findings of the research are released to drone operators.

University extension staff, researchers, professionals, trade association personnel, and commercial companies have been at the forefront of introducing the latest science behind the practical use of drones, as well as explaining the regulations and teaching applicators how to sell their services to potential clients. It is common to hear discussions of topics such as FAA licensing requirements, differences among drone models, differences between effective and advertised spray widths, and the influence of travel speed and height above a crop canopy on spray delivery.

Complying with federal and state regulations has become a significant topic of conversation. Federal aviation regulations can be complex and complicated to understand, especially for those outside of the aviation community. Also, at times, documents and labeling are specific to traditional aviation. Because of this, early adopters were not well versed in licensing or reporting requirements. Obtaining the proper license and keeping records is important to the industry.



Significant effort in drone outreach programs has helped interested parties understand the requirements for adopting this technology and has helped new applicators refine their operations to make efficient and effective applications.

To further complicate matters, obtaining the needed licensing was an extended process that could take over two years, during which one would hear little from the FAA. These issues were exacerbated by confusion about which process to do first and what groundwork had to be completed before applying for certain exemptions and certifications. Earlier adopters were forced to invest a generous sum of money into a unit that they might not get approval to fly, or at least the timeline on when they would get to fly was unclear, and they would potentially miss out on an entire application season. Today it's still true that you will need to purchase a drone and have it registered prior to getting your part 137 certificate (required for larger drones that apply product); however, the two-year wait period has been reduced to as short as 45 days.



It takes a lot of work, time, and money to get licensed by the Federal Aviation Administration and become certified to apply pesticides by your state's department of agriculture.

Even now that changes to the original regulations have simplified pilot licensing and drone registration, the nuances of remaining in compliance still take time for a pilot to comprehend, and it can be difficult to keep up with the frequent changes. State agencies (e.g., state departments of agriculture) have further added to this complexity, now requiring operators to obtain the same level of licensing as required for a conventional aerial applicator. However, due to the drastic cost difference between conventional aerial equipment and drones, farmers are now taking to the sky, presenting a new unique challenge most state agencies are still trying to tackle. With these struggles to become certified and compliant, businesses have developed models to help current and potential applicators to understand drone capabilities and regulations. Several private and public companies now exist to help drone operators comply with federal regulations, submit required monthly reports, apply for waivers, and monitor distinct aspects of the operation. With continued education and the continued interest of university researchers, pilots flying spray drones today are better equipped to succeed. While there are many who could be credited for their efforts to educate drone pilots, Dr. Steve Li from Auburn University should be mentioned as one of the earlier pioneers who championed both research and education in using drones for pesticide applications. University weed scientists, entomologists, and plant pathologists quickly ramped up efforts to develop recommendations and outreach efforts.



Researchers have been vigorously comparing application technology using high-clearance ground rigs, airplanes, helicopters, and drones.

While there has been great effort to provide resources on effective application parameters and information on rules and regulations, there has been a general lack of guidance on how to develop efficient infrastructure to effectively utilize spray drones in the field. The intent of this publication is to provide examples of current trucks and trailers utilized to support drone operations. It includes an overview of generators, pumps, motors, hoses, and tanks.

Some of the ideas and practices being used by the drone industry are simple, but pilot experiences have shown they work well for making effective and profitable treatments with spray drones. (Note: Drone setups take a variety of configurations: just a truck, a truck and trailer, or a trailer that may be pulled by an ATV or other equipment. To simplify, we will often use *truck/trailer* when we mean the entire range of configurations.)



Educational programs in the classroom are great opportunities to share information on the latest drone research and inform farmers and commercial pilots about a technology that may be used on their farm now or in the future.



Local flight demonstrations are always a sought-after program. Seeing and hearing the drone take off in person gives people a true perspective on the technology.



Each commercial operator has a slightly different setup, including various features to make long days easier. Seeing several different setups at field days can give you ideas of what may work for your own operation.



Drone training occurs at all levels. Field talks and demonstrations introduce the hardware in ways classroom instruction cannot. Industry professionals are the best to teach about truck and trailer setups for spray drones. While universities can give an analytical analysis of effective applications, commercial operators with experience know how to be efficient and make money.

Trucks and Trailers: The Hub of an Efficient Drone Operation

Initially, equipping trailers and retrofitting trucks for drone use took a secondary role compared to drone technologies, updated regulations, and insurance questions. Perfecting the truck/trailer situation would also take a back seat because trucks and trailers can be the most expensive assets of the enterprise. Applicators wanted to make sure they could be successful before investing in such infrastructure. As the rules, regulations, and application parameters became better known, drone trucks/trailers took on a more pivotal role in the industry. The success of day-to-day operations can depend more on the truck/trailer setup than on the actual drones applying the products.

KNOW THIS

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The question “How many acres does your drone get done in a day?” is one of the most common questions left unanswered. As early adopters shifted their focus to that question, the importance of the truck and trailer rose. It became obvious to everyone that a drone sitting on the platform was losing money because it was not spraying acres. The answer came down to how quickly the drone sitting on the ground or platform could be filled and the battery replaced, and how quickly the operator could get the drone set up or packed up in order to make it to the next site. Pilots now had to modify and/or retrofit their existing trucks/trailers to make them more efficient, more comfortable, and safer.

There is no perfect setup that each operator should strive to have. Before we start looking more closely at the critical components on a trailer or truck, we need to understand that the work should dictate what is needed. One pilot might require a top deck to look over a tall cornfield, but another pilot treating a low-growing crop like strawberries or weeds in a pond might not need the extra expense of a platform.



Some operators need large and efficient spray drone infrastructure while others may be able to accomplish their goals with a pickup or UTV and a few jugs with their chemicals.

A large-scale efficient drone operator may want 1,000 gallons of clean water for mixing chemicals, cleaning equipment, and washing hands. This would require a trailer that could carry this weight and a heavy-duty truck to pull it. The weight might require the driver to have a commercial motor vehicle license (CDL). Conversely, an operator managing vegetation under a power line, on the roadside, or in a pond might not need to haul that much water. Instead, they could use a smaller water tank, haul it in the bed of a pickup truck they already own, and land on a small platform on the ground. These examples show that the type of work conducted should drive the selection of the truck and/or trailer and the other equipment. At the same time, you don't want your operation to be too specialized, limiting you to only treating certain kinds of properties. Many current operators wish they would have designed a more versatile rig able to handle both big and small fields.





Do you plan to use your truck and/or trailer only for your drone operation, or will you want to utilize it for other purposes? This may affect how you secure tanks, generators, and other necessary equipment.

Small, unique operations may desire a setup that can fit in the back of a UTV or a small trailer, in order to access areas that may not require large amounts of product or battery life but cannot be accessed by other equipment.



KNOW THIS

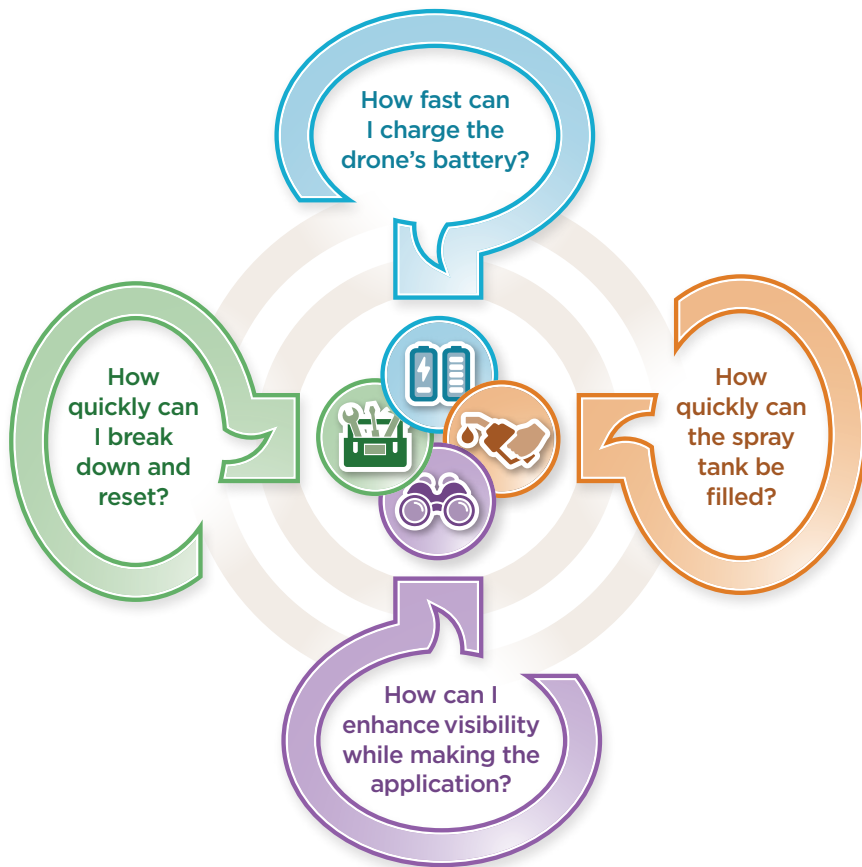
Many operators wish they would have designed a more versatile rig able to handle both big and small fields.



Common Needs of Drone Setups

Regardless of the drone model or its manufacturer, all spray drone operations share certain needs that impact how a trailer or truck is plumbed and what equipment is carried. The key question "How do I keep my drone spraying continually?" largely comes down to four questions:

1. How fast I can change the drone's battery and charge the battery?
2. How quickly can the spray tank be filled?
3. How can I enhance my visibility while making the application?
4. How quickly can I break down and reset?



4 QUESTIONS TO ANSWER TO KEEP YOUR DRONE SPRAYING!

Focusing on these four things will help you be maximally efficient and realize the potential of your drone setup.



Loading and unloading a drone is key to increasing efficiency.



These questions tie directly to equipping a trailer/truck to allow the operational use of a drone to apply pesticides effectively in whichever way the operator deems efficient. If those four things cannot be optimized, then a premium must be charged to make up for those lost minutes. And that premium may be difficult to justify, especially in commercial operations.

Common needs for drone operations that impact trucks and trailers include:

- An area on or around the trailer/truck where operators can work safely with good visibility of the drone
- A spot where the drone can land and take off without lengthy setup and teardown periods
- A location for keeping paperwork organized
- A bank of batteries, which need to be recharged throughout the day
- A generator with sufficient capacity to charge batteries, placed in a location where the batteries will not overheat
- Fresh water tanks and pesticide mixing vats
- Transfer pumps and plumbing that can fill the drone swiftly
- Mixing tanks with agitation to keep products suspended when the spray mixture is waiting to be applied
- A place where drones can be secured when transported from one jobsite to another



A PLACE FOR EVERYTHING & EVERYTHING IN ITS PLACE

Certain traits are needed in all rigs. Factor them in when designing your drone truck/trailer.

These are not minor points when considering how to equip a trailer or truck. Time must be invested in both preparation and planning focused primarily on one's goals. For instance, a farmer using a drone to spray fields around the farm might not require a 1,000-gallon tank due to having water nearby. On the other hand, using a drone to spray commercially may require 2,000 gallons of water to keep the drone working continuously all day. If the truck/trailer is not equipped to handle the desired workload, you will either send it to get more water, causing a pause in operations, or have to purchase a tender truck to bring water and supplies, adding more expense to support the operation. Each time a commercial operation stops to refill the water tanks, it is losing money because the drone is not in the air.

The consensus among midwestern commercial operators working large tracts of farm ground is that a drone should land and take off again within 45 to 90 seconds after landing. As the drone lands, it quickly needs to have its battery replaced and the spray tank refilled. Keeping drones in the air is comparable to a pit crew on a racing team installing four new tires, filling the fuel tank, and washing the windshield to get the driver back on the course without losing much time.

While the drone is spraying a field, the technicians prepare for the next landing. They need to put fuel in the generators, place the spent battery on a charger, add pesticides to a batch tank and get it agitated, and get the charged battery ready to insert when the drone next lands.

KNOW THIS

Each time a commercial operation stops to refill the water tanks, it is losing money because the drone is not in the air.



Commercially manufactured drone trailers are available, or one can be constructed by the operator.

A Trailer and Truck for Today and Tomorrow

A drone truck/trailer should allow the pilot and the person tending the drone to work together as a team to minimize downtime and maximize flight time. It is easy to say we want to fill a drone with product and insert a fully charged battery within 60 seconds of landing; however, this is only possible if the truck/trailer is equipped to keep the drone flying.

KNOW THIS

A trailer should allow the pilot & the person tending the drone to work together as a team to minimize downtime and maximize flight time.



Those utilizing trailers and trucks to service their drones have designed and modified them to be self-contained units carrying everything they need for the day's work, including generators, extra batteries, water tanks, chemical mixing tanks, battery chargers, and drone repair parts. Carrying a full complement of equipment, parts, and supplies is part of achieving the 60-second turnaround from touchdown to liftoff. How does the choice of truck and/or trailer help with efficiency? Sometimes, minute details can make a huge difference. For instance, how much time does it take to secure and unsecure drones and equipment when you need to move just a few miles down the road? It is easy to lose 30 minutes in that move if your setup is not designed to pack away quickly. The easier it is to store drones, chargers, and all other equipment, the less time is wasted readying the truck/trailer for the move. It can be difficult to size your truck/trailer setup to be most economical. Sitting down and doing the math can be the difference that leads to a successful enterprise. When comparing different truck/trailer setups, think about the total cost per square foot of space. For example, if your pickup truck costs \$60,000, an 8.5-by-20-foot flatbed trailer \$30,000, and a drone \$40,000, plus \$10,000 for tanks, generators, and plumbing, then your

total cost is around \$700 per square foot (32 square feet in truck bed, 170 square feet on trailer). A deckover trailer might double your square footage for the trailer without doubling the cost.

Think long and hard about what you need, whether you are setting up your own trailer and truck, buying a ready-made one, or paying a company to custom-build one based on your specifications. You want to size your equipment to fit your operation with the flexibility to expand or reduce the size of your operation in the future. Oversizing your infrastructure undermines one of the benefits of drones: the relatively low cost of adopting this technology. An operator who overspends on fixed start-up costs will find it difficult to compete with tight economic margins. If the operator is undersized, then they will not be able to realize the gains of the economics of scale. Operators need to develop realistic goals as to what they expect to achieve by speaking to those who have proved to be successful and then purchasing equipment to meet their goals.

KNOW THIS

You want to size your equipment to fit your operation with the flexibility to expand or reduce the size of your operation in the future.



Also, keep versatility in mind. If you can unbolt the drone-specific fixtures and use the truck/trailer for other enterprises during other times of the year, then half of the costs can be allocated elsewhere, and you could more reasonably increase the size of your truck/trailer or realize a lower start-up cost for your spray drone enterprise. The ability to remove drone-related fixtures also makes your truck/trailer more marketable if you find that you need to switch from a trailer to a truck, or vice versa. Likewise, consider the cost of changes to your setup: For example, you may be able to start out with a smaller, cheaper generator, because it is relatively easy to swap a generator for a bigger one later. In contrast, it takes more capital and effort to buy a different drone or a different truck/trailer.



Some operations can use something as simple as this to keep their drones flying.

Changing one component can cause a chain reaction leading to other changes in the spraying setup. Consider a time in farming when a 3-row corn head, a couple of 250-bushel wagons, and a single-axle grain truck kept the grain moving from field to bin. Imagine that a farmer decided that a 16-row corn head would speed up his harvest. That single purchase required the farmer to possibly purchase a new tractor, a 1,500-bushel grain cart, two semis to haul the grain to the local elevator, or a larger dryer to deal with the volume of grain being handled. The simple move from a 3-row corn head to a 16-row corn head changed the whole complexion of the operation.



As with farming or any other business, your spray drone equipment needs to fit your operation. If it's too small, you won't be able to expand or accommodate greater demand, but if it's too large, it can be difficult to cover fixed costs that aren't providing monetary value.

KNOW THIS

Changing one component can cause a chain reaction leading to other changes in the spraying setup.



When using drones, the equivalent would be adding a second drone. To support it, changes could include purchasing a second generator, upgrading to high-volume transfer pumps, or revamping how hoses are routed. Needing more water might make a truck obsolete due to space limitations, or an enclosed trailer may no longer be an option due to the weight it would be asked to carry. The current landing platform may not be large enough to land larger drones or even multiple drones. You should consider whether it is realistic to expect your operation to expand, and at what rate of expansion might occur.



Using a gas-powered pump can provide greater flow without requiring additional electrical demand from a generator. However, you need to consider the noise, and the time it can run between refills, to decide what is right for your operation. Convenient valve locations can improve cleanout time and limit trip hazards that might arise from moving between valves that are spaced farther apart.





Generators make or break an operation. Do you know what your electrical requirements are? Reading manuals to find the specifications of your battery chargers and pumps will help you decide how big a generator, or how many generators, you need. Some operators prefer one large, powerful generator, while others prefer multiple smaller generators. Contacting a professional electrician might be a good idea.

For operators in the fragmented portion of America, a truck setup makes more sense than a trailer when one thinks about the day-to-day activity. For those areas an average day will consist of treating a 10-to-20-acre property, then packing up and driving possibly 10 to 30 minutes to the next 20-acre property. These applicators will treat four to eight properties daily on a good day. Drone operators may need to charge a different fee when flying small acreage than when applying to large fields that are more efficient to cover. When you want to expand this kind of truck setup, the ramp-up differs from that for a trailer: There is little space to add more to the truck, so you would likely have to add a second truck.

However, you cannot compromise on some aspects of the truck/trailer, such as having sufficient space for the operator to work safely and, if using a trailer, ensuring you have a truck of sufficient size and quality to pull it dependably. Farmers who are looking to save money by spraying their own fields may want to take a low-cost approach using homemade setups, while contractors who need profitable margins should take a more liberal approach to ensure they can deliver the number of acres needed when called upon. Unhappy customers are not repeat customers.

Is your platform large enough for your drone to land consistently without falling off the trailer or truck? You also need enough room to access the tank to fill it. The automated return-to-home function can help, but some human interaction may be necessary to be efficient with landing. Most drones automatically land with the same orientation they had when they took off. If the fill cap is easily accessed before you take off, it will likely be easy to access once the drone lands again.





Electrical power is a very important consideration for a drone operation. Fuel economy, fuel capacity, fuel source, noise level, plug-ins, and cost are all aspects that need to be thought about when considering how to invest.



The rails alongside the steps here provide the person going up and down something to securely hold on to.

It is important to consider the legal requirements of a drone truck/trailer setup. One key consideration is how much weight a trailer is designed to carry. The extra weight of a diesel generator along with larger water tanks might exceed the trailer's gross vehicle weight rating (GVWR). A larger trailer might require a new truck with the pulling capacity to move and control the heavier trailer. In some cases, this could cause your GVWR to exceed 26,000 pounds, which might require the driver to hold a valid commercial driver's license (CDL). The 26,000-pound threshold applies to the GVWR of the truck, the trailer, the combination of the truck and trailer, or the total loaded weight of truck and/or trailer.

A state can determine whether farmers require CDLs to operate equipment over the 26,000-pound threshold on their own fields. For instance, Indiana farmers working on their own ground are exempt from CDLs. However, a farmer using the same truck and trailer for commercial purposes requires a CDL when exceeding 26,000 pounds; they lose the exemption when they become a commercial operator working for other farmers or industries.

Also, some drone setups have elevated platforms for the drone to land on, and the operator often spends much of their time on the flight deck. The OSHA rules for the platform are often overlooked: There are rules about ladders used to access the work area and rules about operating safely in elevated work areas. For example, ladders must meet certain load specifications, and 42-inch-high guardrails must be installed on elevated work areas that are more than 4 feet high, or some other fall protection must be provided. (If your work platform on your trailer is already elevated, will the guardrails make you unable to drive under power lines or other overhead obstacles? Or will you need guardrails that can be collapsed when you are driving between operating locations?).

Furthermore, generators can be very loud and may fall under certain ear-protection standards. If your business falls under OSHA oversight, it may be important to look for low-noise generators to avoid ear-protection requirements. Farmers and self-employed individuals may be exempt from OSHA rules, but no one wants to end a 12-hour day by falling off an 8-foot-high platform, and generator noise can be troublesome if you are around it all day.

Do you have a plan for what you need the current drone to do and how the truck/trailer will help you to meet your targeted goals, not only now but in the future as well? Spending more today on the truck/trailer and equipment means saving money in the long run if and only if you can achieve the expected return on investment and be profitable in the short term. A setup that works today will likely be retrofitted with new equipment or replaced by another truck/trailer in just a few years as the business expands or as drones change. As drones are sold with larger tanks, you will need capacity to haul more water to keep the drone spraying. While larger drones provide many advantages, they will more than likely also change the dynamics of the water tanks, pumps, and generators.

Take-Home Messages

- Size your generator(s) to suit your power needs throughout your rig. The generator needs to supply enough power to your battery charger(s) to minimize recharge time, run all electric pumps to fill your drone and mix chemicals, and run any auxiliary fans to keep batteries or the operator cool while working. Also, make sure you have sufficient plug-ins for any operator amenities such as a place to charge a phone, power a hotspot, plug in a radio, or other things that may be important to you or your workers over a 12-hour workday. Most drone battery chargers specify how much power they require to optimize battery charging time.

- Size your pumps to refill your drone fast enough to have it land and take off again in less than 60 seconds. If you plan to fill your drone with 10 gallons of chemical mix, then your pump must be rated above 10 gallons per minute (gpm); remember that you also need time to swap out the battery and perform any other tasks. You also need to increase pump capacity if you plan to agitate with the same pump because some of the gpm rating will go toward agitation.

- Have a plan for your water source before building your trailer as this can influence the number of tanks and their size. Also, have a plan for your rinsate before building your trailer as this can impact how many tanks you have or the way you plumb your tanks.

- Be clear on future labor needs when planning your truck or trailer build. Self-employed individuals are often highly motivated and accustomed to long work hours, but when they try to expand their business, it is difficult to find quality labor for seasonal efforts. Think about the quality of labor needed to drive a truck that is pulling a trailer, to have the expertise to operate and troubleshoot a drone, and to obtain the certifications required to apply chemicals. If you can find this person, can you pay them enough while still maintaining your profit margin?

- Do not overlook the safety of your operators during the design process. Elevated platforms are sometimes necessary to maintain visibility of the drone while operating, and they make nice landing and takeoff locations. If you plan to spend your time on the top deck, make sure you have plenty of room to move around without falling off or have proper safety precautions to keep from falling off.

- Plan your truck/trailer to minimize setup and teardown time. Try to plan your rig so that when you are setting up, you either don't have to move your drone to its takeoff location or have to move it only a few feet. Use straps and tie-downs that are quick to tighten and loosen.

Keep battery charging stations near the operator and drone takeoff/landing zone, and minimize the distance from the fill station to the drone.



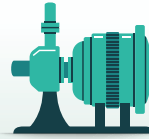
01 GENERATOR

Make sure you size your generator(s) to suit your power needs throughout your rig.



02 PUMPS

Size your pumps to refill your drone fast enough to have it land and take off in less than 60 seconds.



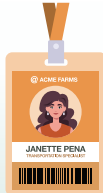
03 WATER

Have a plan for your water source before building your trailer.



04 LABOR

Be clear on future labor needs when planning your truck or trailer build.



05 SAFETY

Don't overlook the safety of your operators during design.



06 SETUP

Plan the rig to minimize setup & teardown time.



TAKE-HOME MESSAGES

Make sure you factor these elements into your design when building your rig.



This trailer has an automatic refill system for drones. The male-female couplers allow the product mix to automatically fill the drone. It is expected that within a few years robotic arms will be used to automatically lift the battery, place it in a charger, and put a fully charged battery into the drone. Innovations on the trailer will continue to drive drone operators to be more efficient.

Supporting the Drone with Proper Equipment

The efficiency of a spray drone depends on how effective a trailer or truck is in accomplishing the four basic tasks of storing, launching, landing, and refilling the drone. With average flights taking 7 minutes from launch to landing, the truck/trailer and all its components must meet all operational demands, including charging batteries and filling the tank. It is the sum of all the equipment working together that keeps the drone in the air.

KNOW THIS

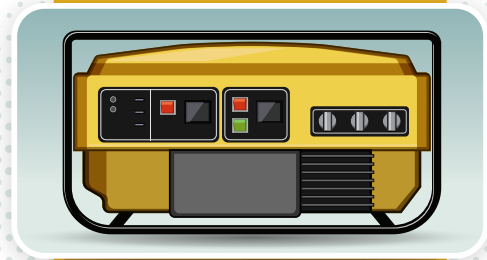
The efficiency of a spray drone depends on how effective a trailer or truck is in accomplishing the four basic tasks of storing, launching, landing, and refilling the drone.



A properly sized generator is the cornerstone of an efficient drone operation.

Generators: Providing the Power to Operate

GENERATORS



Generators are the power plant of the spray drone operation, and without a functioning power plant, the operation will fail. The first consideration is, How much power do you need? As society experiments with the transition to electric vehicles, the first question we often ask is, Can our electric infrastructure handle everyone moving to electric power sources? The same questions should be asked about your generator for your spray drone operation. Many of us have generators to power a few necessary items for our house when the power goes out, and it is logical to attempt to use the same generator for the spray drone business. However, often the generator we purchase to power a refrigerator and television is undersized for a drone business.

Whether the goal is to fill the drone's tank and replace the battery in 60 seconds or 2 minutes, the power-producing generator must keep batteries charged, pumps pushing liquid forward, hoses transporting liquid, agitators mixing products in batch tanks, internet routers connected, and air conditioners running. Starting early in the predawn hours, a generator needs to run all day and sometimes deep into the night.

The generator is often the most difficult piece of equipment to size for the operation. Without prior experience, it is challenging to determine how much power you require. If the generator does not supply enough power, the turnaround time to charge one or multiple batteries

becomes too long to maintain continuous operations. When drone pilots are asked what they would change if they could do it over again, many would purchase a more powerful generator. We commonly hear from drone operators that the first generator they selected either failed to keep up with the power demands or had to be replaced often when it did not hold up to the rigors of constant field use. An underperforming generator increased the odds of various problems:

- Batteries took too long to recharge.
- Pesticide products would not completely suspend in the tank.
- Pumps were unable to move product quickly enough from the batch tank to the drone.
- There was not enough power to add more drones to the fleet.

The simple fact is that not all generators are created equal. While some small combustion engine generators can cost \$15,000 or more, the majority are priced from \$4,000 to \$10,000. More powerful generators cost \$12,000 to \$20,000 when more kilowatts are needed. But when considering what generator to purchase, price alone is *not* the main selection criterion.

KNOW THIS

Without prior experience, it is challenging to determine how much power you require.



KNOW THIS

When drone pilots are asked what they would change if they could do it over again, many would purchase a more powerful generator.



STEPS FOR PURCHASING A GENERATOR

1. Does it deliver the kilowatts needed?

2. What fuel do you expect to use?

3. Are there additional features you want?

4. Can you work around the decibel ratings?

5. Do you have a brand preference?

Those that pass this five-point evaluation can then be compared side by side according to price.

Differences in price can depend on the fuel used to power the generator (i.e., gasoline, diesel, tri-fuel), the technology used to reduce noise levels, additional features such as push-button start and stop, and brand preferences. Also consider the heat the generator produces. It is tempting to save money by going with a lower-cost unit. This can be a very costly mistake unless you know the *real* power the generator produces.

The selection process becomes much easier once you know how much power a generator produces (see next section). You can then compare the different brands and models with similar power ratings along with additional features to help decide which generator best meets the needs of your drone operation and which offers the best price.

There are three basic types of small combustion engine generators used by drone operators: those that produce electricity using (1) gasoline, (2) diesel, and (3) propane. Small drone operations have a fourth option: using an already charged battery as their power source. All generators work well as long as their kilowatt output matches or exceeds the needs of the operating equipment. The generator also needs to have enough outlets in the correct voltage styles (110 and 220 volt) to accommodate items other than drone chargers. Larger and more expensive generators may be able to supply three-phase power, which may be necessary if you choose a high-flow electric pump.



A gas-driven generator generally costs less on the front end, and the lighter weight allows for greater portability.



A diesel-powered generator costs significantly more than gas-driven units but is more durable and dependable under field conditions. Their heavier weight makes them less portable.

Getting the Kilowatts You Need

For generators, one should know a minimum of two numbers regarding kilowatts—peak/starting kilowatts and constant kilowatts. The peak/starting kilowatts is the total kilowatts the unit can produce but can only be handled for a short duration. The other number is the constant running power, that is, how much power the generator can deliver over an extended period. The peak wattage is usually given in large numbers on the side of the generator and in the product listing, but you may have to look up the constant output in the specifications.

The devices powered by a generator, such as pumps, likewise have two different power draws, initial start-up (surge) and constant. As a device powers up for the first time, the wattage needed will typically exceed the constant wattage needed to maintain operation. This is known as a *surge*. The generator must be capable of handling the surge from the devices as they power on to ensure the unit does not bog down and stall.

Not only should the generator be capable of handling the surge, but it also must be able to deliver enough constant power to maintain whatever devices are utilizing it throughout the day. In layperson's terms, the total constant running power of all devices hooked up to the generator must not exceed the actual constant running power of the generator.

The wattage is often influenced by the fuel that runs the generator. Consider the following power specifications for a generator that can run on three types of fuel but produces different amounts of power on each:

	Gas (watts)	Propane (watts)	Natural gas (watts)
Peak wattage	13,000	12,000	10,000
Constant wattage	10,500	9,500	8,500

Because 13,000 will appear prominently on the generator, people might have the mistaken impression that this generator supplies a constant power of 13,000 watts, but it might be as little as 8,500 watts if natural gas is used as the fuel. The latter represents 65% less power than the advertised number. This is why you need to review product manuals before deciding that a generator will work for your specific operation.

The ratings in manuals and on generators are most often expressed in watts. But the equivalent in kilowatts is probably a better number to look at. Take the wattage and divide it by 1,000 to get kilowatts. If a generator lists the peak wattage as 9,500, that is 9.5 kilowatts (9,500 divided by 1,000). This keeps you from being impressed by the larger numbers!



While it is not common, a generator may list two numbers to describe the power produced. This Coleman generator highlights two different numbers related to wattage—6,250 and 5,000. The first is the peak output, while the second is the constant running power. Make the best purchase when comparing generators by using the constant running power.



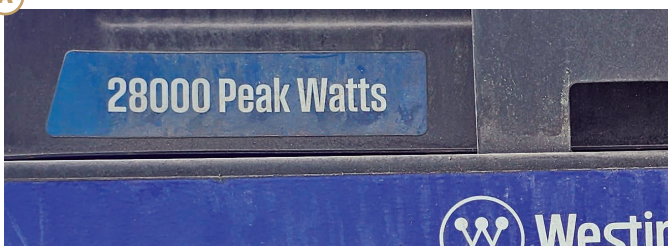
Every generator will have its own specifications for the constant power it can deliver over the course of a day. This Kubota 14,000-watt (14-kilowatt) diesel generator actually delivers 12 kilowatts of constant power.

Newer models of drone chargers can require up to 13 kilowatts of power to fast-charge a battery. Knowing what you need and what constant power the generator can produce eliminates many models from consideration.

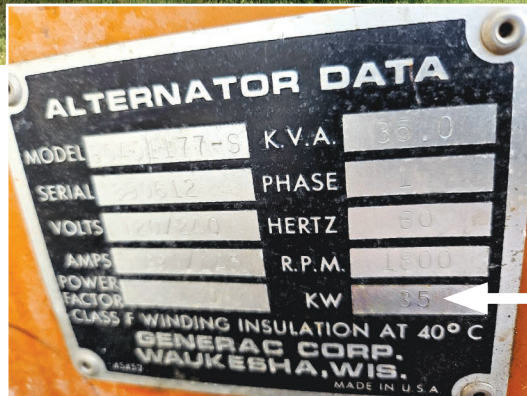
Knowing the specifications of a generator becomes critical when running more than one battery charger along with one or more pumps. One charger can draw an average of 5,000 watts (5 kilowatts), while fast charging with the same charger requires around 9 kilowatts. Five kilowatts would be the absolute minimum that a generator would have to produce to run a single charger. However, this yields a slow, 20-minute charging time instead of 10 minutes with a generator that provides enough power for fast charging.

A reasonable assumption is that each charger powered by a generator needs 10 kilowatts of constant power, meaning a generator that supplies 28 kilowatts (28,000 watts) of constant power would run two chargers.

It is recommended to get a generator that can produce 20% more power than what your calculations show you need for the drone and truck/trailer components. This gives you an extra fudge factor to account for ratings that do not go by the book and allows you to add other equipment as needed.



(A) This Westinghouse generator lists 28,000 watts (28 kilowatts) of peak power. Its constant running power is listed as 20 kilowatts in the product's brochure. (B) This generator lists 13,000 watts (13 kilowatts) of peak power. Its constant running power is rated at 10.5 kilowatts if it runs on gasoline.



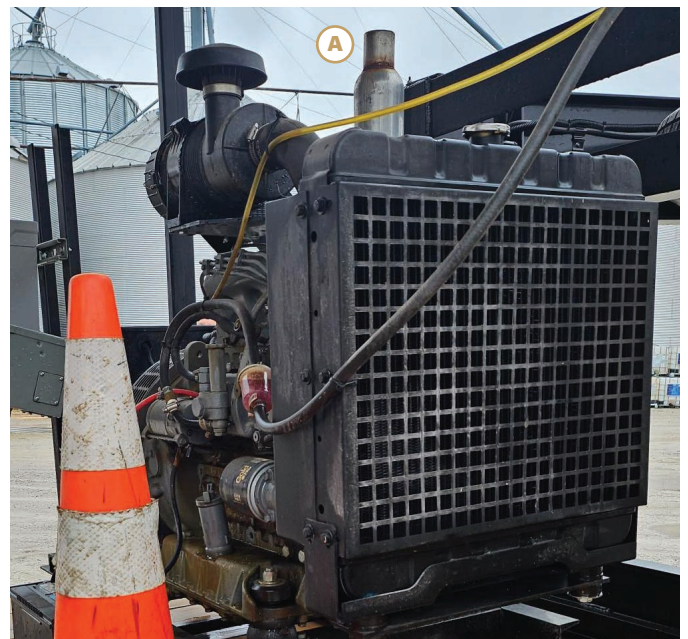
The diesel generator on the back of this trailer is powerful, supplying 35 kilowatts.

Consider the Noise Level

An often-overlooked criterion of generator performance is the noise level while operating. This is important for three reasons: (1) Loud generators make it difficult to communicate among the crew. (2) Employees could suffer permanent hearing loss. (3) Loud noise over extended periods can cause a reduction in situation awareness. Normal conversation is rated between 50 and 65 decibels (dB). Noise levels above 85 decibels can damage a person's hearing. Remember that the decibel scale is logarithmic, meaning a small change in the number corresponds to a major change in the noise level. One generator manufacturer lists the decibel rating at 67, which is comparable to talking loudly. Two other manufacturers list the decibel level of their generators at 78 (comparable to the noise made by a garbage disposal or blender) and 85 (comparable to a diesel truck or loud vacuum cleaner).

Most often, these "official" decibel numbers are not measured next to the generator but at some distance away. Many of the decibel measurements are taken 23 feet away from the generator. In contrast, drone operators often work within 5 to 15 feet of a running generator. This means the noise level is much louder than specified by the manufacturers of the generators. To safeguard against hearing loss, employees should wear hearing protection when working around generators or place the generator in a place that dampens the noise to acceptable levels without hearing protection.

Remember that the decibel level is not the only consideration but also the duration of exposure. For example, it may be acceptable to be exposed to 100 decibels for 15 minutes, while for only 85 decibels, an exposure of eight hours is acceptable. A successful drone operation will be exposed to the generator for much of the day, except during travel times, so be conservative with decibel levels when choosing the generator.



Many of the manufacturers of generators have adapted mufflers to make them quieter. (A) A vertical exhaust sends hot air and fumes directly upward, where the hot exhaust could damage a wood platform and equipment located above it. (B) A side-facing muffler is better for diffusing noise and heat away from people and equipment.

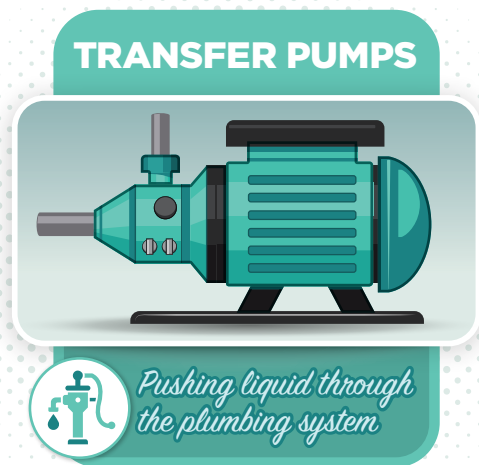
Meters to measure decibel levels can be purchased online fairly cheaply if you are questioning the rating that you find in the manual. There are also phone apps that can provide at least approximate noise levels; the National Institute for Occupational Safety and Health (NIOSH) has released a sound meter app for iPhones (<https://www.cdc.gov/niosh/noise/about/app.html>).

PROTECTING ONE'S HEARING

The United States Occupational Safety and Health Administration (OSHA) regulations require companies to implement hearing protection programs for employees. Be sure to familiarize yourself with regulations about hearing thresholds at <http://www.osha.gov/noise>.

To combat issues with communications, most drone operations work with personal communication devices (radios with earpieces) or develop hand/arm signals to assist in communication in noise-ridden environments. Last, when you are working in loud environments for extended periods of time, situational awareness can decrease throughout the workday. This presents unique dangers in that operators could fail to hear an inbound drone or vehicle approaching the worksite. Extra safety measures should be in place to ensure safe operations.

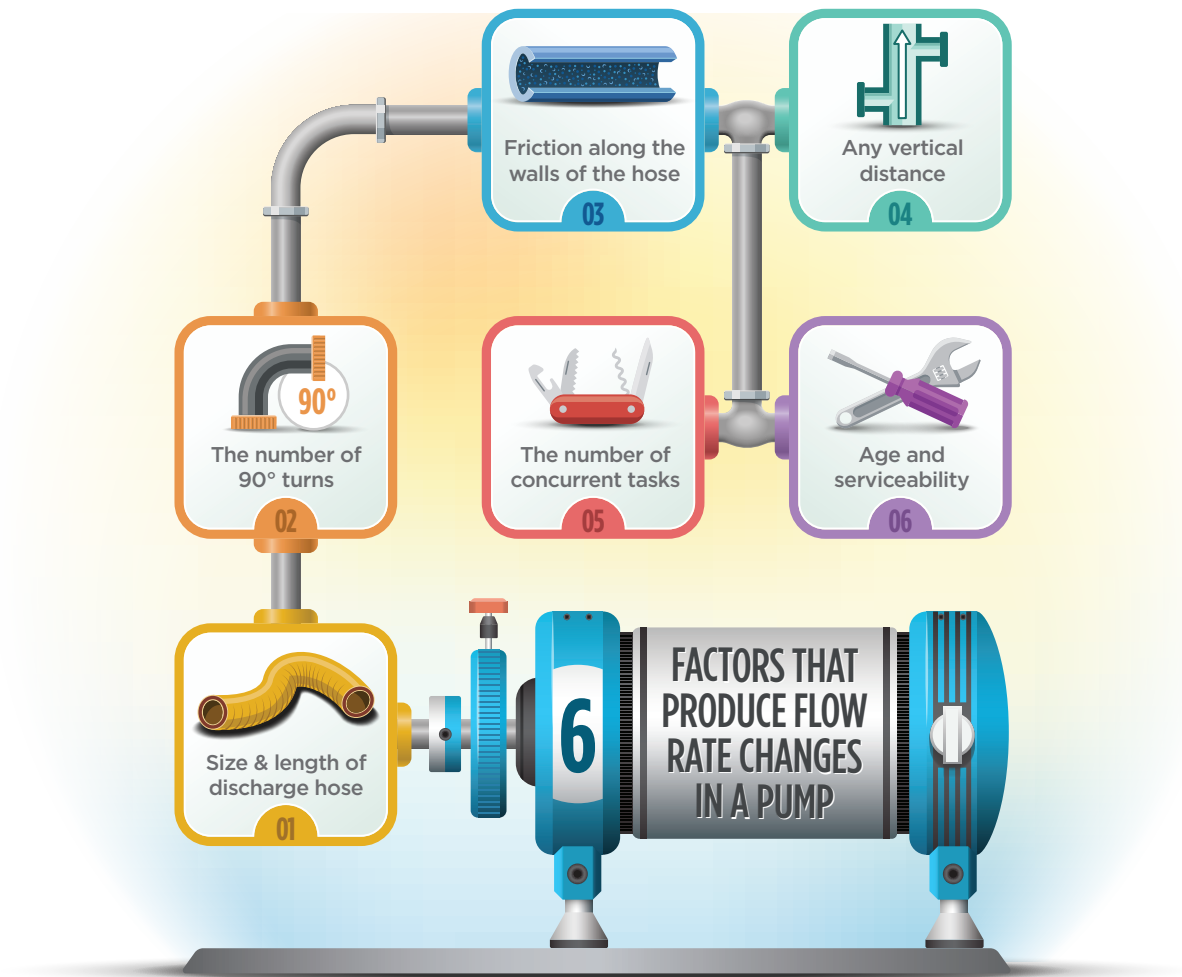
Transfer Pumps: Pushing Liquid Through the Plumbing System



Pumps rank a close second to generators in their importance. You can have the best plumbing and the best generator, but the pump is at the heart of the plumbing system that drives the operation. Pump specifications are based on gallons delivered per minute (gpm). This flow rate is determined by the design of the pump and the revolutions per minute that the pump can spin to achieve the desired rate (such as 20 gallons per minute). It is typically expressed on a tag affixed to the pump. The gallons per minute the manufacturer lists on the pump or in the accompanying datasheet is like the Environmental Protection Agency's gas mileage listed for every car in the showroom. Whether for a car or a pump, the ratings are normally higher than you may achieve in real life, because the flow rates are measured under ideal testing circumstances.

Other factors that can produce minor changes in how many gallons per minute a pump can deliver include:

- The size and length of the discharge hose
- The number of 90° turns
- Age and serviceability
- The number of concurrent tasks (i.e., agitating, mixing, and filling simultaneously)
- Friction along the walls of the hose
- Any vertical distance (that is, pumping up a vertical height)



This pump moves 4 gallons per minute and is dedicated to moving fresh water to the batch tank.



This model of a Red Lion pump can deliver 76 gallons per minute and could take care of the needs of most drone trailers.

The pressure generated by a transfer pump is part of its internal design and is not something a drone operator typically regulates like is done on a boom sprayer. Most choose not to have gauges along the length of the hose to measure pressure. In this case, this is why one should match hose sizes to the inlet and outlet sides of the pump to ensure its performance based on the manufacturer's design for the unit.

In other situations, an operator might place a pressure regulator on the equipment. But usually knowing the pressure is not as important as it is when calibrating spray equipment like boom and gun sprayers.



The more the pump is asked to do, the more the flow of the fluid to its final destination is reduced.

Two Make One: Pumps and Engines Form a Unit

All pumps require an attached engine or motor, whether it be gas or electric, as the most common way to push the fluid forward. A pump and the attached engine/motor are often assembled by different companies. For example, one combination might be a Honda gas engine coupled to a John Blue pump or a Briggs and Stratton engine running a Banjo pump. This means the engine selected must deliver the power to run the pump at the stated gallons per minute listed by the pump's manufacturer.



Here a gas Honda engine and Banjo pump form a single unit.

Pumps and engines can be initially purchased as a set. Not only are they properly matched to each other, but buying them together has a lower cost than buying each separately.

It is typical for the pump to wear out long before the engine. When this happens, the pump can in most cases be rebuilt with a kit from the manufacturer. Rebuild kits and a little time in the offseason can save you a lot of money and keep a pump just as strong as a new one. Consider rebuilding pumps every third year as part of a preventative maintenance program. In extreme circumstances, if damage has occurred to the pump, a replacement can be sourced with similar specifications, keeping your flow rate the same.

Engines are rated by wattage, which is often converted to horsepower. The following table converts among watt, kilowatt, and horsepower ratings.

Watts	Kilowatts	Horsepower
3,000	3.0	4.0
4,000	4.0	5.5
5,000	5.0	7.0
6,000	6.0	8.0

1 kilowatt = 1.34 horsepower; 1 horsepower = 0.7457 kilowatts



This Honda 3000 gas-powered engine, which produces 3,000 watts (3 kilowatts), is considered a 4-horsepower engine. A popular option is to spend an extra \$200 to get an electric start, which makes starting the engine easier than pulling a "rope."



The manual indicates this Briggs and Stratton gas engine has a gross horsepower rating of 8.25 and a net horsepower rating of 6.5.



This Vanguard engine has a gross horsepower rating of 13, as marked on the front of the engine.

Small engines have similar problems to generators and pumps when it comes to assigning horsepower ratings. There are two versions of horsepower, known as *gross* and *net*. Gross horsepower is the maximum power the engine can produce on a test stand, without any attachments like mufflers, pumps, and other loads placed on it. The more critical of the two ratings is the net power, which provides the horsepower after accounting for accessories. There are manufacturers that do not list the net horsepower in their specification sheets or manuals.

Three Styles of Pumps. Transfer pumps are normally driven by a gas or diesel engine or an electric motor. They can be identical except for what is on the driver side of the pump. In other words, the same pump could be coupled to a gas engine or an electric motor. There are three main types of transfer pumps:

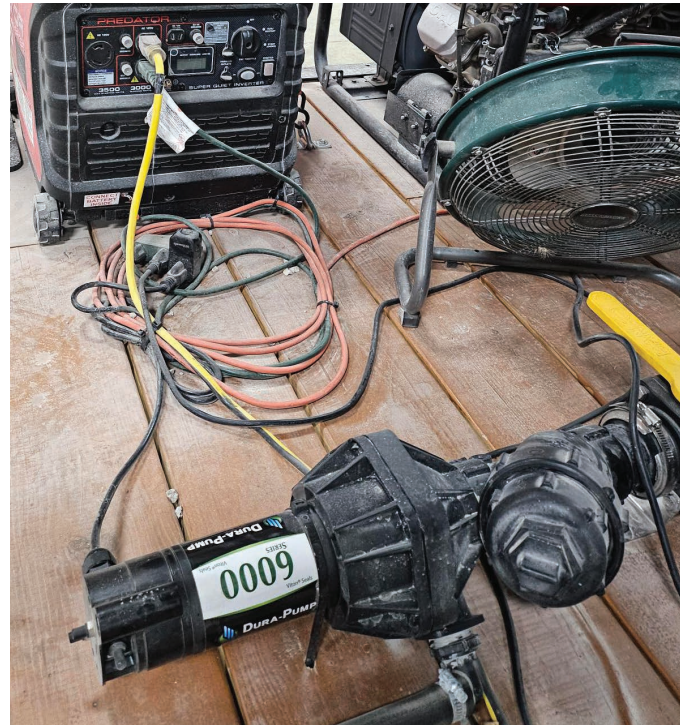
- **Battery-driven transfer pumps.** The battery basically provides the fuel that drives the electric motor. Batteries allow for greater portability; however, the two main challenges with batteries that limit their use are a low flow rate and the need to recharge the battery numerous times during the day or to charge it constantly with a generator or alternator driven by a motor. Electric pumps driven by batteries may be used for lower-volume transfers. Because of these limitations, this is the least utilized style of transfer pump.



If you use a 12-volt battery to power a pump, you may need a device to convert 120-volt power from the generator to 12 volts to charge the battery.



A gas-driven pump.



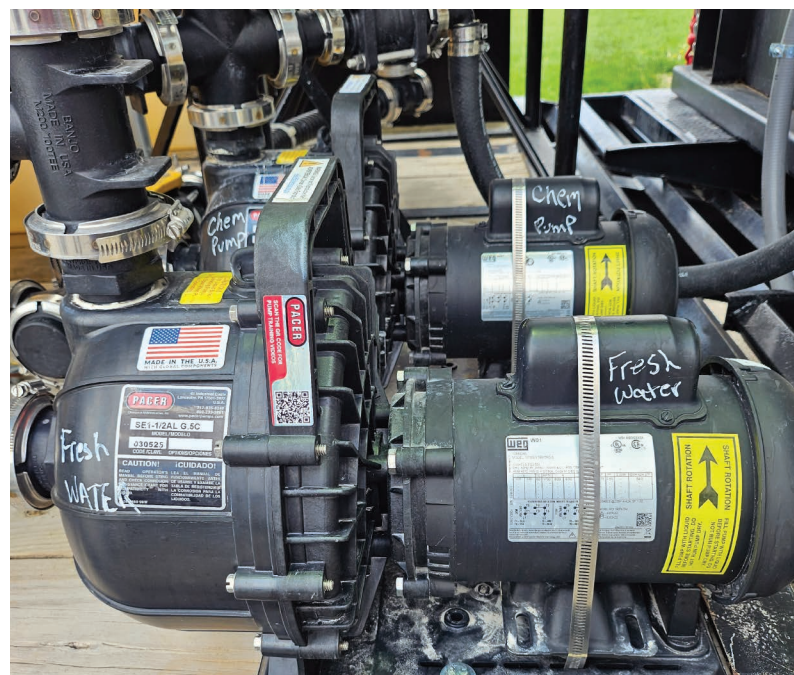
An electricity-driven pump.

- *Gas-driven transfer pumps.* Gas-powered engines bring additional power to the trailer/truck to drive pumps. If the pump is powered by a gas engine, then the generator's power can be fully utilized for charging the drone's batteries. Gas-driven pumps are handy because they can be relatively cheap to operate and are widely available if a repair needs to happen or a total replacement is needed. The relatively high flow rates that gas-driven pumps can supply typically suit almost any drone operation, but these pumps can be oversized for certain parts of an operation and can be noisy while running (remember the OSHA noise ratings). This method has minimal drawbacks currently other than the added expense and need to carry around fuel (which is already necessary for a drone operation).

- *Higher-flow electric-driven transfer pumps.* These pumps plug into a generator for a direct source of power. Match up the electric motor to the size of the pump to handle the desired flow. It takes a 2-to-5-horsepower electric motor to run a 2-inch pump.

These pumps are generally much quieter to operate and can provide sufficient flow for drone operations. However, their motors can be more expensive and sometimes require three-phase electrical power, which not all generators are equipped to provide. Parts may be more challenging to find, or you may not be able to quickly replace the motor and pump. To use these transfer pumps, (A) you must purchase and maintain a secondary generator dedicated to this, or (B) you will need a primary generator capable of handling this as well as charging your batteries.

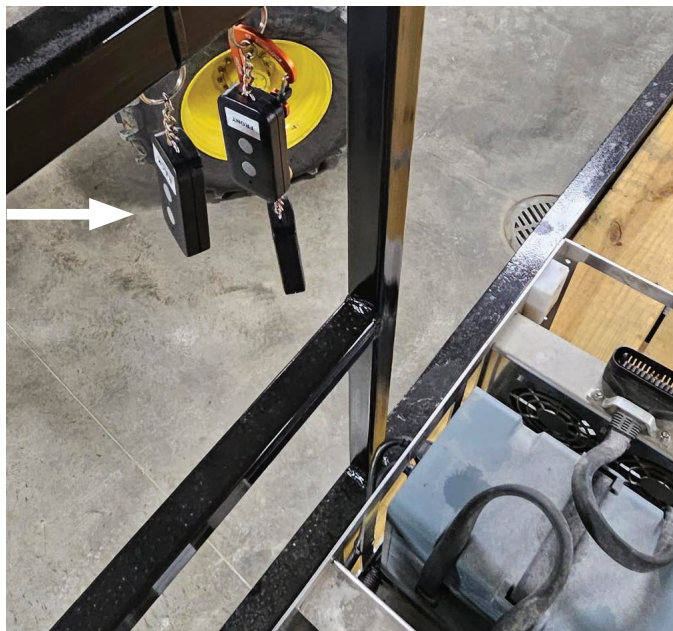
Prioritizing a single-phase motor is generally desirable for drone operators. Not only are these cheaper, but single-phase motors run on standard outlets like those associated with generators. A three-phase pump is used primarily in industry requiring a lot of power, or for filling ground rigs with 1,000 gallons of water.



Setting up a number of pumps that are dedicated to specific liquids ensures cross-contamination will not take place.

More Flow Is Not Always Better

Using a transfer pump that pushes out too much flow has its own set of issues when filling a small tank. A pump moving 150 gallons of water a minute into a 20-gallon drone tank creates excess foam and splashing, quickly overflowing the tank. But that same pump would be perfect for quickly filling a 300-gallon batch tank.



Some electric motors come with a remote control to turn the motor on and off. This allows someone working on an elevated platform a way of operating the motor without having to go back to the lower deck.

More Pumps, More Options

Some operators use a single pump to move fluid to all parts of the drone operation. At a minimum, the pump should deliver 20 gallons per minute if the goal is to fill a 20-gallon tank in a minute. An additional consideration when working with one pump is your cleanout procedures, as these need to be strict and followed thoroughly to ensure no cross-contamination occurs.

Remember that flow rate is impacted by 90° turns, smaller hoses, and multitasking. A 50-gallon-per-minute pump sending 20 gallons to the batch tank leaves 30 gallons to fill the drone within a minute.

Others take the approach of using two or more pumps instead of one. For instance, a separate transfer pump is used to move fresh water over to the batch tank. Additional pumps are dedicated to filling the drone from the batch tank or to running inductors within tanks. For some operations, the extra expense for additional pumps is worth it for the efficiency and safety they bring to the operation.



Multiple pumps are often used to help facilitate working more efficiently. Here a 4-gallon-per-minute pump is dedicated to mixing the chemicals in the tank.

Another perk to multiple pumps is reducing the likelihood of cross-contamination. If a single pump is pushing fresh water into the batch tank, then is used to fill the drone, the system would then have product residue throughout its plumbing. A second reason for multiple pumps is that the flow may be acceptable for one application but not another. For example, filling a 300-gallon batch tank could use a high-volume pump, while a 20-gallon drone tank could use a smaller pump. With multiple pumps, you can size the pump to the needs of specific parts of the spray operation. Spending time thinking about the best pump(s) to purchase is worthwhile.

Another consideration when mounting your pump on a truck/trailer is the vibration and roughness of driving down the road and the effects this has on the pump and motor. County roads and even some highways are very rough with numerous potholes, chipped pavement, or pavement ridges that can cause the truck/trailer to vibrate or bounce roughly, potentially fracturing components of the pump and motor. Although these pumps and motors are generally made for challenging conditions, spray drone setups often travel some very difficult back roads that may be gravel, dirt, or not a road at all and may prematurely cause issues that don't normally occur as quickly with other uses.

When you are bolting down the motor and pump, it may be a good idea to place a thin piece of rubber or other dampening material between the motor/pump and the trailer/truck deck. This can help reduce the impact of a rough road and can also reduce noise while the pump and motor are working during the spray drone operation.

Keeping spare parts on hand for the pumps and motors may be as critical as spare parts for the drone. Electric pumps may be cheap enough to carry a spare unit or at least some extra wire, fuses, or connectors. It is common for electric pumps to have small lead wires and/or connectors “burn up” or blow a fuse protecting the electric motor. Less-than-ideal conditions will also cause electric motors and pumps to be jostled around, pulling on wires and/or connections. With pull-start gas-powered engines, it is common for the pull cord to break, or the internal spring to go bad. It is always a good idea to have a spare pull cord on hand (they are typically interchangeable) or to convert the engine to an electric start. Although less common than pull cords going bad, the connection between the engine and pump can shear a keyway or damage a Lovejoy connection that allows the engine to drive the pump. If you are using a gas-powered engine, it may also be handy to have a can of ether for those times it doesn’t want to wake up. Look at the components that make up your motors/engines and pumps and always keep a spare of the critical failure components on hand.

Tanks: Holding the Mixture



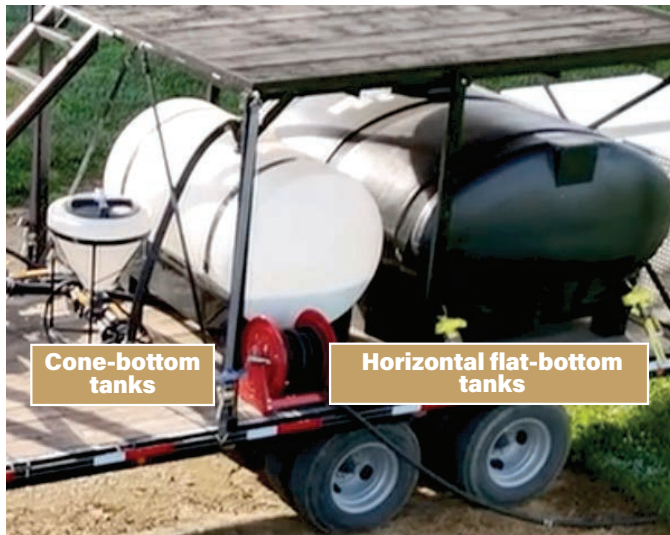
Storage tanks are most used to store products and water on trucks and trailers. Tanks have different designs (such as flat-bottom vs. cone-bottom, vertical vs. horizontal), are constructed of different materials (poly, fiberglass, and steel), and can be different colors (green, white, black). Poly tanks are preferred as they have a proven track record of working, are lightweight, and are readily accessible locally.



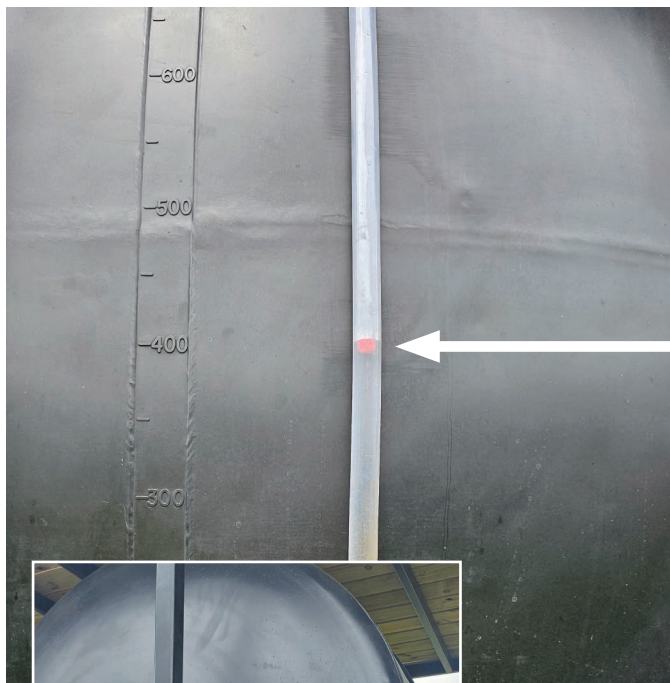
The main issue with poly tanks is that sunlight penetrating through the tank can cause the buildup of algae. If you can see the level in the tank, that means sunlight can penetrate it. Whether the tank is clear, yellow, blue, or green, the operator must periodically clean it to remove the algal growth. A black tank is preferred by some as it blocks sunlight, which reduces the growth of algae. But the black tank defeats the main reason lighter-colored tanks are selected: being able to see visually how much product is left in the tank. To help with this, a black tank can be fitted at the bottom and top with an elbow and a clear sight gauge in between the two (see photos above). The fluid level is then displayed in the clear tube, where you can match it to the gallon markings on the poly tank. Another option is to place floating indicators in the sight gauge hose that can be easily seen alongside the gallon marks.

If you choose to use a lighter-colored tank on your trailer, try to limit the amount of sunlight that reaches the tank to limit the amount of algae growth. You may be able to enclose a portion of the truck/trailer to block the sunlight on several sides or arrange other items so that they shade the tank. It is also worthwhile to consider some form of a baffle if you are selecting a tank large enough that the sloshing of water may influence the driver’s ability to control the truck. For tanks used for mixing pesticides, it is best to use a cone-bottom tank instead of a horizontal or vertical flat-bottom tank. The cone allows the product to be completely emptied out, and clean water added to remove any remaining pesticide residues.

While poly tanks have found a strong foothold in agriculture, there are legitimate concerns that the porous material on the internal surface can trap pesticide residues. The worry is largely that herbicides will be pulled out of the plastic into the tank and sprayed on a crop sensitive to those chemicals.



A cone-bottom tank for mixing products along with two horizontal tanks to hold water. Most batch tanks are cone shaped because they can be completely emptied and do a better job with agitation. The black tank would control and prevent the growth of algae.



This black tank has an indicator hose with a light-weight red bead that allows a quick assessment of how much fluid is left in the tank.



This tank contains a pesticide. The flat bottom would make it difficult to remove any remaining residue without a great deal of effort. These are often used to store clean water, or they are dedicated to a specific product.

With poly tanks being the primary tank type used on drone trailers, why is the cross-contamination concern largely unseen? Nearly all the products being applied by agricultural drones are fungicides and insecticides, which do not cause visual symptoms even when sprayed on nontarget crops.

As herbicides are incorporated into the drone business, cross-contamination problems will have to be addressed. With less water in the tank and the use of more concentrated solutions, drone operators may have to take additional precautions to prevent cross-contamination. Some operators will run neutralizing agents through the system and drone, which is a simple procedure to remove unwanted residues in between applications.

Others use stainless-steel tanks, because stainless steel's smooth surface lacks the pores found in poly tanks. Cone-shaped stainless steel tanks come in 60, 100, 120, 150, and 230 gallons, which gives plenty of size options for drone operators. But these tanks will add additional weight and cost.

The next question to discuss is, How do I agitate my mix? Most pesticide products suspend rather than dissolve in water, and when the water in the tank is not being moved, the suspended product can settle to the bottom. To either prevent settling or resuspend product that has settled on the bottom, agitation of the mixture is required.



A common practice is to agitate the tank's contents by recirculating the fluid inside the tank, pulling it out at the bottom and running it through a hose and back into the top of the tank. While that might be adequate in some circumstances, most of the agitation occurs at the top of tank, which often will not mix the material at the bottom of the tank; it can also produce a lot of foam.

A more effective method is to have the agitation take place below the surface of the fluid. An eductor nozzle placed near the middle of a cone-shaped tank with the valves pointing downward toward the bottom provides maximum mixing of suspended materials. This provides an excellent internal current to keep the solution suspended.



A hose running to the top of the tank to allow for recirculation of the fluid.

MISUNDERSTOOD TERMS

There are two words that sound the same but have different meanings.

An **inductor** is a cone-bottom tank used for mixing chemicals and for holding the material that will be transferred into the drone.

An **eductor** is a nozzle within a tank that employs a high-velocity stream of liquid to mix the products in the inductor tanks.



The inside of a tank with two eductors to provide current to suspend or resuspend pesticides.

Hoses: Serving as the Arteries



You never appreciate a hose until it ruptures, spilling pesticides on the truck/trailer, coating equipment, contaminating the environment, and endangering workers. This results in work stopping until the spill is remediated, the equipment cleaned, and necessary reporting calls made to government regulatory agencies when applicable. While it is just a hose, it is critical for moving fluid to where it is needed in an efficient and safe manner, like generators and pumps.



A pump showing its inlet to allow fluid to enter and an outlet to move the fluid forward to its desired destination. In this example, suction hoses are used to pull in and push out the liquid.

Manufacturers build pumps with an inlet and outlet sized to deliver the optimal flow rate. Operators should attach a hose that matches the diameter of the pump's inlet and outlet to take advantage of the design.

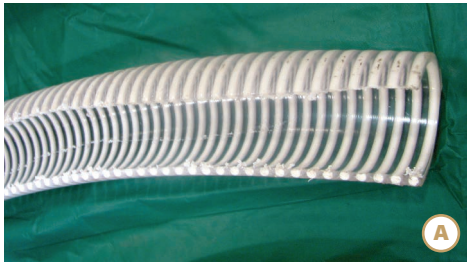
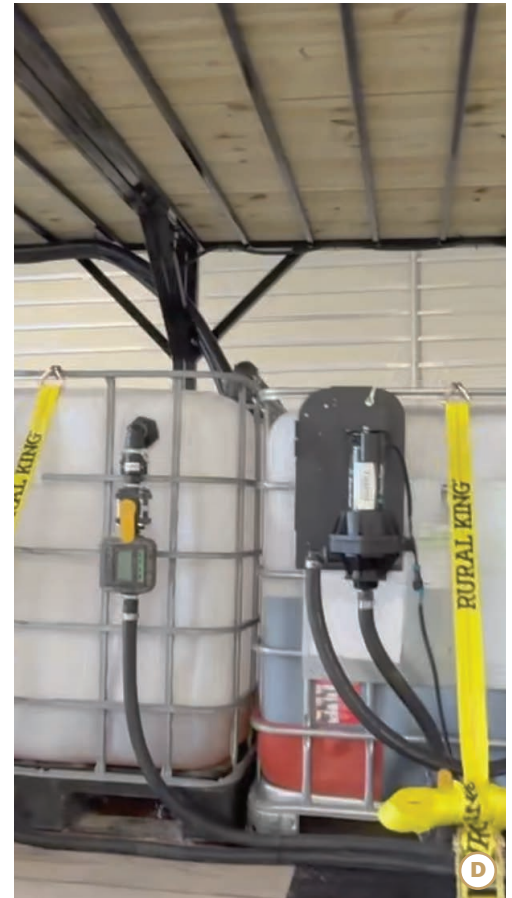
In general, smaller pumps that are rated to push 15–18 gallons per minute use a 1-inch-diameter hose. A high-capacity transfer pump used on drone trailers can transfer 150 or more gallons per minute, requiring a 2-inch-diameter hose to allow product to flow freely.

It is common for hoses to be made of rubber. Rubber hoses that are under 1¼ inches in diameter are lightweight yet sturdy enough that they can be used on both the inlet (suction) and discharge sides. Larger rubber hoses add weight because fiber and steel braids are added to keep them from collapsing. Even with the reinforcement, larger rubber hoses should generally be used only for discharge, not suction.



A popular substitution to avoid the weight of a 2-inch rubber hose is a ribbed suction hose made of PVC. These typically are used on both the inlet (suction) and discharge sides of a pump. Rubber and ribbed suction hoses should be inspected frequently and replaced every 1–3 years depending on use. Replacing hoses in the offseason can prevent major accidents during the busy season.



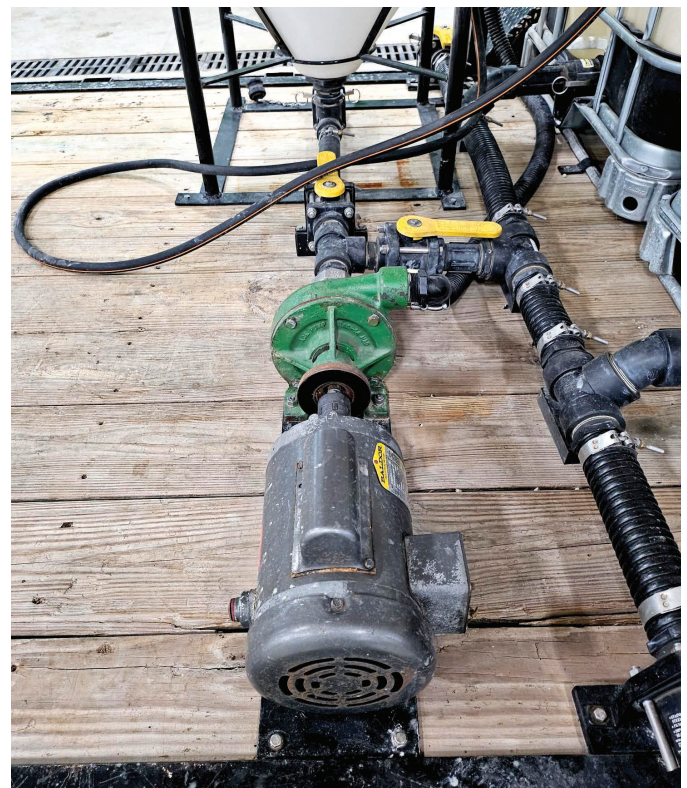


(A) A clear PVC-based suction hose showing the ribs that prevent the hose from collapsing. (B, C, D) Suction hoses in use on drone trailers.

Reduce 90° Turns Whenever Possible

When plumbing hoses, try to limit the number of 90° plastic fittings, which can restrict the flow. It is always better to use more hose and let that form the bend so that the flow will not be restricted as much as with a 90° plastic elbow.

In addition to reducing 90° elbows in plumbing, consider the valve and connector size in relation to the hose. For example, if you go to your parts store and ask for a 1-inch ball valve, what is the internal diameter of the valve? If it is a standard port, the diameter of the port may be $\frac{3}{4}$ inch, so if you are sizing all your tubing to 1 inch, you will be restricted to the $\frac{3}{4}$ -inch port size. However, if you ask for a 1-inch full port valve, the internal port size will be 1 inch and will be sized properly for the 1-inch tubing.



Prepare for Cleaning Out the System

Make sure to plumb your rig for easy cleaning of the hoses, pumps, and tanks. Try to reduce the amount of plumbing that the pesticide has to travel through to be agitated and to fill the drone. Make judicious use of valves from your clean water supply to give you options to clean necessary components of your operation. This may include a separate hose that is plumbed directly to the clean water tank that can be used to wash off the drone or other components of the truck or trailer without cleaning out the hose and plumbing that you use to fill the drone.



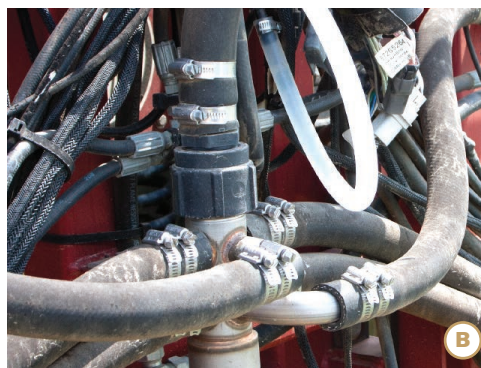
Types of Hose Clamps

Clamps squeeze the hose onto a fitting to keep it from being blown off under pressure. As expected, there are many styles of clamps that can be used to tighten and secure a hose. Standard clamps (aka worm-gear or radiator clamps) and T-bolt clamps are two of the more popular styles used by drone operators. Standard clamps are among the least expensive and most versatile all-purpose clamps in the marketplace. These clamps are especially effective when permanently placed on hoses. The main problem is that removing and refastening standard clamps weakens the metal of the band, which leads to the gears and teeth no longer fitting snugly into the grooves.



The two components of a standard clamp.

While some prefer to use a single worm-gear clamp, others believe that two clamps provide additional protection. Because the clamp's screw is straight, the clamp cannot curve around the hose where the screw is found, creating two "corners" where the clamp doesn't completely tighten at each end of the screw. This can also lead to the clamp being stripped when it is tightened too much. Using two clamps with the screws facing in opposite directions allows the "round-on-round" section of one clamp to always be beside the screw of the other. While they are more expensive, T-bolt and spring clamps



(A) A limitation of standard clamps is that at some point they can be stripped if the screw is tightened too much. (B) These pressure hoses have two standard clamps with the two screws aligned with each other. (C) A better method is to have the screws opposite each other, which allows the weaker area around the screw to be offset by a tight "round-on-round" section of the neighboring clamp.

are beginning to see more use, primarily because they are much stronger than the standard clamp. A T-bolt clamp pulls directly against the other side of the clamp, allowing more tension to be placed on it. The hose is completely encircled, allowing for a tighter grip all around the hose. Whatever style of clamp is used, make sure that



(A) A close-up view of a spring clamp. (B) A pair of T-bolt clamps used to keep the hose attached to the fitting.



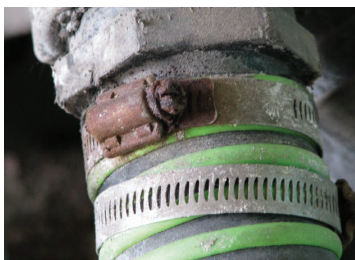
everything on it is stainless steel, including the bolt, screw, and nut. Because some pesticide products are corrosive, clamps with parts made of mild steel can become corroded and fail.

When assembling hoses or completing maintenance, it is common to put your hoses and connectors together and leave the hose clamp loose until the very end to make sure you don't need to pull it back apart. Make sure you go around to all the hose clamps before resuming operations and make one final fit check of the hose clamps, so you don't get a blown hose on first start-up. It is also good to check clamps periodically, as they can work loose.

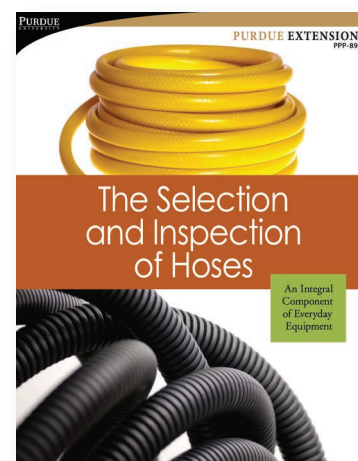
Hose Reels:



Clamps made entirely from stainless steel are always preferred because they last longer than their counterparts made of mild steel. Stainless steel protects against corrosion, and clamps made of it can be taken on and off with minimal metal fatigue. Just be sure the entire clamp—the band, screw, and housing—is made of stainless steel.



Examples of corroded standard clamps and T-bolt clamps from weather and chemicals.

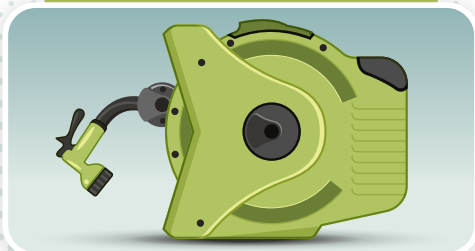


More information on hoses and clamps can be found in Purdue Pesticide Programs publication PPP-89 at <https://ag.purdue.edu/departments/extension/ppp/resources/ppp-publications/>.

Reducing Clutter on the Deck

Hose reels are far more important than people realize in terms of convenience and safety. In a drone operation,

HOSE REELS



*Reducing clutter
on the deck*

leaving hoses left unrolled on the ground or platform can lead to trips and falls. According to insurance statistics, trips and falls are one of the leading causes of claims being paid for injuries sustained. Given that many people work on elevated platforms when operating drones, a fall from these heights could lead to permanent and/or life-threatening injuries.

Hose reels provide additional benefits that extend the life of hoses:

- Improving accessibility
- Reducing rubber hose degradation from sun damage
- Minimizing abrasion to the outside of the hose
- Helping avert kinks
- Helping prevent hose collapse

The main types of retraction reels include the following:

Manual hand-crank reel. This is the least expensive retraction hose reel. The operator must manually turn a handle to retract the hose back onto the reel.

Automatic spring-loaded reel. With these, the operator slightly tugs on the hose to disengage the brake, allowing the hose to neatly retract onto the reel.

Motorized retraction. These reels can use a battery or a generator for their source of power. Some come equipped with a push-button start, a foot pedal, or a remote-control device. While motorized retraction reels are more expensive, they simplify the process of handling a hose. So, when might you choose a manual versus automatic hose reel? The important thing to understand is where and



This hose is neat and tidy, but you wouldn't want to trip over it on the upper deck of a truck or trailer. If you don't use hose reels, make sure you don't have to constantly walk over the hose to conduct the operation.

how your drone will take off and land. If you plan to take off and land from an elevated surface that needs to be clutter-free area, an automatic reel could be needed. The reels used should be purchased with some forethought so they do not interfere with routine activities. The operator is likely not willing to hand crank the hose for each fill-up, and you can't have hose clutter that you might trip over.

If you plan to land and take off from the ground, leaving the hose out on the ground may not be a big issue as you may have plenty of room to walk and navigate around the hose. This operation is simple, requiring the operator to reel the hose only when packing up to leave the takeoff site.

Depending on the rigidity of the hose, winding the hose too tightly can cause slight kinking of the hose, which will slightly restrict the product flow. Obviously, the larger the diameter of the hose reel, the less likely the hose will kink. It is also important to consider the reel adapters used to connect tubing. Sometimes the connector to the hose reel or the supply to the reel is reduced, so your maximum flow rate could actually be restricted by the orifices of the reel itself. Another minor consideration with hose reels is the O-rings used to seal around the rotating parts. If the hose reel is advertised for use with oil and chemicals, the O-rings are likely already resistant to many of the pesticides being used. Hose reels not designated for chemical usage may have O-rings that are not resistant to common pesticides and chemicals, creating a potential for leaks. Replacing such O-rings with chemical-resistant O-rings is typically easy to do and can prevent a potential leak during light or moderate use. It is also important to get a hose reel that is properly sized for your operation. It may seem like you should get



The hose reel has to be matched to the size of the hoses being used to fill the drone.

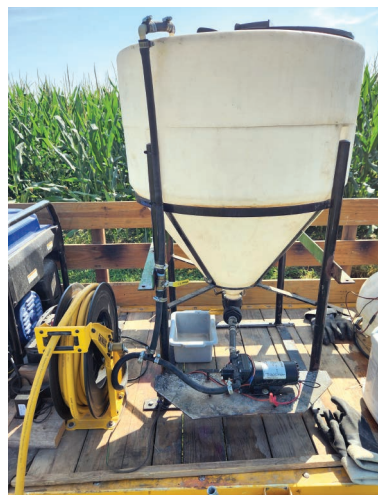


Hose reels for hoses delivering clean water.



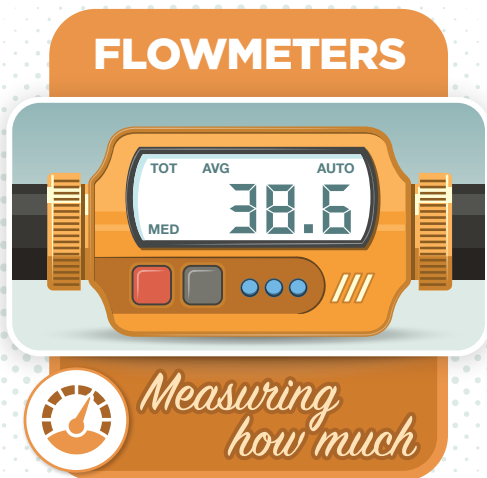
the biggest hose so you don't run out of length, but there could be extra gallons of pesticide left inside the hose that must be cleaned out when you pack up. This creates more rinsate, takes time to clean, and creates more exposure opportunity. Think about getting a hose reel that fits your trailer perfectly and then have an additional hose extension on hand that can be connected in a special-use case when

the distance needed is longer than anticipated. Hose reels in the marketplace can range in price based on capabilities and brand. Whatever unit is purchased, make sure the reel can accommodate the hose dimensions and length desired.



Make sure your hose reel's diameter is large enough that the hose does not kink when rolled up. Kinking may reduce flow rate and may not be an easy problem to identify when trying to diagnose the cause of a slow refill.

Measuring How Much



Flowmeters: It is a common practice to use a flowmeter when measuring products into batch tanks. Meters, like pumps, are rated for gallons per minute. In terms of flow rates, the meter and pump should match one another. Pushing a small amount of mix through a flowmeter rated for higher capacities will not yield an accurate reading. Remember that the drone operator may be working out in the sun, which can make some screens hard to see. Make sure the flowmeter has a screen that can be easily read in all levels of light. It is also important to understand what levels of liquid you might be using and whether a flowmeter is necessary. Flowmeters can be expensive, so it's not helpful to purchase them unless you really need them. Some pesticide mixtures require a high volume of water and low volume of chemicals. In that case, if your water tank or mix tank has a calibrated sight gauge, simply using that gauge to add water and a graduated measuring cup to measure the pesticide may be sufficient. If you plan to use bulk tanks for the pesticides, then a flowmeter will likely be necessary, but if most of the products you use will be in 2.5-gallon jugs or smaller, then it is unlikely a flowmeter will be necessary for mixing or applying. Remember that if you use a bulk tank, you will likely need a battery to run a pesticide transfer pump, and that battery will need to be charged. Do not forget that dry flowable formulations may require a scale for weighing the product. Previous publications have noted the inaccuracy of using a volumetric measuring device for products mixed by weight.



Flowmeters in operation on drone trailers.



Metering chemical with a flowmeter when going from a larger chemical tank into the mixing tank.



The best option for measuring dry products is to weigh them. This provides the most accurate measurement.

NOZZLES



*Dispensing
the product*

Nozzles: Dispensing the Product

There are two basic product-dispensing nozzles used by drone operators: a gasoline-type and a valve-type dispenser. For smaller drones, either type works. The gasoline-type dispenser nozzle is clean and easy to handle. The main issue is that it takes extra time to fill larger drones due to its restricted orifice, which limits how fast a fluid flows, and often causes lots of foam and air to be put in the tank. Many drones come equipped with push-through gas caps (also known as capless gas fillers) that accept gasoline-style nozzles without having to be unscrewed, like those found on many newer trucks and cars. If not, they can also be purchased aftermarket. The other advantage to the gas-pump-style handle is that you can continue pumping while you change the battery because the nozzle's automatic shutoff feature will keep the mixture from overflowing. While most common caps accept the standard $\frac{3}{4}$ -inch nozzle found on most gasoline-type nozzles, some aftermarket lids can accept the 1-inch fill nozzle that is more commonly found on diesel pumps. However, increasing nozzle size does not automatically ensure increased fill speeds as the tubing and connections that supply the nozzle must have the capacity to handle the increased flow. Another advantage to using the gasoline-type handle with the pass-through lid is that the connection is sealed, limiting splash contamination of the person filling the drone.

Valve nozzles have the advantage of dispensing products slightly quicker than a gasoline-type nozzle. This is important



The drone's tank has been modified with a cap that does not need to be removed when filling the drone, making the process easier, cleaner, and quicker. This is a simple change that many drone pilots have adopted to save time when filling.



A modified gasoline-type nozzle is used to quickly fill a drone.



A gasoline-type nozzle that is used to fill a drone. The drone in this operation has a modified gas cap that the nozzle will fit into.

for swarm and large-scale operations, which are more concerned about volume. Smaller applicators with smaller properties can afford more downtime; however, large applicators cannot. In this instance, applicators prefer the valve-style nozzle.

Most drones have a screen filter at the inlet of the product tank to catch any debris or contamination and keep



Commercial drone operations using a gasoline-type nozzle to dispense products.



Valve nozzles to fill drones are becoming popular with operators.

it from entering the drone. If using a lid and nozzle that do not seal well, it may be a good idea to remove the filter on the drone and add a filter just prior to the nozzle. This will catch any debris while limiting exposure to pesticides that might splash back from the filter in the drone. Removing the filter from the drone inlet and placing one on the back side of the nozzle will help maximize your



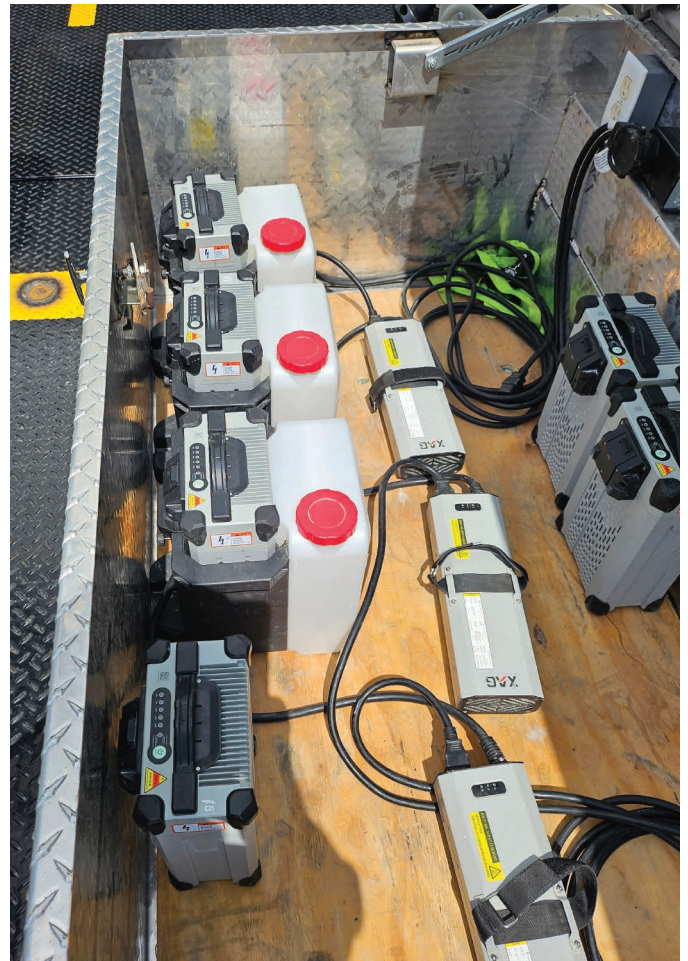
flow rate as the pump will be “pushing” the liquid through the filter. In contrast, the screen on the drone inlet has to accommodate the flow without being pressurized. If your operation has an extra person who is available during fill-ups to operate the valve, then this is likely the best option. If you won’t have an extra person to help during the filling period, a gasoline-type nozzle that can be left alone will likely be the best option.

Take-Home Messages

- The generator is the life support of the operation. It is essential not to undersize this component of the operation. It must be able to support all electrical devices on the truck or trailer, which may include a battery charger (for your remote control and drone), pumps, a phone charger, fans, an air conditioner, and/or lights.
- Undersized pumps are as bad as an undersized generator. Not generating enough fluid power to agitate the

pesticide or fill the drone in an acceptable amount of time loses you time and money. Remember, as you add pesticides and adjuvants, the advertised flow rate of the pump will likely be reduced.

- Tanks, hoses, and connections need to be plumbed for efficiency. Don’t make too many restrictions (90° turns, small ports, nozzle selection) that will reduce the pump’s ability to deliver the desired flow rate.
- Make sure your system can be cleaned efficiently. If you plan to apply for a diverse set of farmers who want different products applied, you don’t want to spend a lot of time cleaning your system.
- Reduce clutter as much as possible. Safety may be cliché, but working on elevated platforms can be extremely dangerous if you are tripping over hoses.



The use of valve-type nozzles can save time over the course of a day if it fits your operation. But make sure a time-saving idea doesn’t cost you time by preventing you from doing other essential tasks while filling the drone.

Different Styles of Trucks and Trailers for Spray Drones

We previously stated that the truck/trailer is directly connected to how efficient a drone operation can become. Some define efficiency based on a drone landing and taking off in 60 seconds, while others use a different interpretation of efficiency. The 60-second “fill and fly” that a commercial sprayer aims for may not be the goal of a state highway department controlling brush along an interstate or a farmer applying fungicides to their own cornfield.

It is the truck/trailer that creates efficiencies and inefficiencies with drone applications. As an example, imagine you start off wanting to do 250 acres a day the first year, while experimenting with the ins and outs of a recently purchased drone. As you approach the halfway point in the season, you realize that you can handle more work and are more efficient than when you started. At that point the goal changes from 250 acres daily to 400-plus acres daily. When this occurs, you realize quickly that your initial setup will not meet your new demands.

There is no standard for how to set up or design your trailer or truck. Many people will set up their initial rig but then need to modify it as their business develops, whether to expand the business or to serve a wider range of clients or something else. Some mix pesticide products on the trailer, while others bring a hot load of premixed product and use transfer pumps to fill onboard storage tanks. Plumbing, electrical, and charging stations should be set up to minimize trip hazards and promote an efficient workflow.

Over the past decade, our understanding of what is needed for drone operations has changed dramatically, causing truck/trailer designs to change accordingly. Some would rather use a truck than a trailer, while other companies have a fleet of both trailers and trucks to treat small and irregular fields as well as much larger midwestern agricultural fields. There are so many things to think about, including whether to use a truck or a trailer, what size generator to purchase, and what kinds of areas your customers will want you to treat: agricultural fields, aquatic ponds, rights-of-way, or forestland.

When approaching the design of your truck/trailer setup, be realistic about your goal in utilizing the drone. For most people, the goal could be lumped into one of two categories: saving money or making money. For farmers, the goal may be to save money by applying products themselves, avoiding the expense of hiring a third-party applicator or purchasing a large high-clearance sprayer. This goal should be reflected in the approach to the truck/trailer: How do you make your setup as frugal as possible while being efficient and effective? For example, a farmer would likely want to use tanks and generators they already own (or that they can use for other purposes throughout the year). And you might have the truck/trailer structure (such as a rack or platform) fabricated from scrap iron by a local machine shop to save money. If your goal is to save money, but you end up spending as much for a spray drone, truck, and trailer as you would for a high-clearance sprayer, then you might be defeating your purpose.

In contrast, if your goal is to make money as a contractor spraying for landowners, farmers, or other industrial purposes, you will likely need a truck/trailer setup that is specific to the drone operation. This unit will be more focused on maximizing efficiency and achieving a professional look to represent the business. With this approach, the business may not be able to afford the small inconveniences resulting from a makeshift trailer with dual-purpose items, such as a less-than-ideal tank size that leaves you 10 acres short of the water needed to finish a job. Commercial operators may need to pay greater start-up costs to ensure they can actually deliver the service they are offering. Inconsistent generator performance, tanks that are too large or too small, and trucks/trailers that are not the ideal size for the operator can all make a business less lucrative.

There is no one-size-fits-all proper way to equip a trailer or truck. Here we describe different options, which we term *limited-use trailers*, *enclosed trailers*, *truck bed inserts*, and *deckover trailers*.



Limited-Use Trailers

Limited-use trailers fit well for smaller jobs where a single drone is used to complete the work. Typically, in fragmented environments you are dealing with tighter areas and less room to move equipment. In these situations, smaller limited-use trailer and truck systems are advantageous. It can make more sense to send out two smaller trailers rather than one larger trailer to do a group of 20-acre fields. Additionally, limited-use trailers are a great entry point as they are rather affordable compared to other options.

Limited-use trailers are typically ideal for do-it-yourself farmers or industrial applications that might not use the drone extensively but only in special cases where a traditional control method is impractical (such as a right-of-way brush control crew that may only periodically use a spray drone). For example, if you have a 500-acre farm and you plan to spray two-thirds of the farm with the spray drone, you will spray only 300–350 acres in a year. If you have a 100-gallon tank you can hot-load from the farm and a trailer big enough to fit the tank and a generator, then you can spray 50 acres in the morning (assuming 2 gallons per acre) and then refill and spray 50 acres in the afternoon. That makes about 3 to 3½ days of spray drone work per spraying pass, so spending \$50,000 on a perfect trailer setup probably doesn't make a whole lot of sense for these operations.

Estimated Cost of Trailer Setup

\$2,000–\$15,000

Benefits of Limited-Use Trailers

- They are very affordable.
- They are less costly to transport.
- They can more easily get in and out of tight spaces.
- They are efficient for small farms and fields (including specialty crops and test plots), ponds and pastures, test plots, and specialty crops.
- They can be used for other tasks when you are not flying the drone.
- They can easily be pulled by a smaller truck or even an ATV.

Drawbacks of Limited-Use Trailers

- They are inefficient to use on a commercial scale when treating many acres.
- They can't be used as a landing zone, requiring the drone to land on the ground. This can throw up dust and debris, which can be mitigated by using landing pads or wetting down the area prior to operations.
- You may need a weed eater or brush cutter to make a landing zone.

LIMITED-USE TRAILERS: **EXAMPLE 1**



A limited-use trailer outfitted with an electric generator, a cone inductor tank for mixing, a storage box, a water tank, and a hose reel.

- Line of sight may be a challenge without an elevated work platform.
- You may have more difficulty keeping curious people out of the landing zone.
- They can carry only a limited supply of water and chemicals, so access must be close to the site of application.
- They may have limited utility for highway travel speeds based on the tires.
- They may have limited ability to carry heavy weights.
- Setting up and packing up may be cumbersome and inefficient.
- Supplies and equipment are exposed during inclement weather.



This lightweight trailer is being pulled around a farm by an all-terrain vehicle. It has an excellent storage box in the front of the trailer. The estimated cost for the trailer and equipment was about \$4,500.



A pesticide can be added directly to the spray tank or to the 60-gallon inductor tank when larger batches are required. A 12-volt electric pump is used to move the water.



The trailer's rub rail is used to hold the nozzle in place.



A small spray drone fits well on the front end of the trailer, where it is secured when transported.

LIMITED-USE TRAILERS: **EXAMPLE 2**



A general view of a limited-use trailer. The outside wooden frame keeps materials and equipment from falling off the trailer.



Close-up view of the equipment and supplies on the trailer. It consists of an induction mixing tank, electric generator, batteries and charger, chemical, and clean water tank.



A car battery is used to power an electric pump that pushes water from the clean water tank into the 60-gallon induction mixing tank and then out to the nozzle that is used to fill the drone. This is a "use what you have" approach: It utilizes a 12-volt pump the farm already had. Charging the battery requires an inverter that reduces the 120 volts from the generator. Although not an ideal setup for larger acreage, it is cheap and effective for a small to medium-size farm. Applying 2 gallons per acre, this setup could spray approximately 30 acres with one tank of water. The pump has a capacity of 6 gallons per minute, so it will take minutes instead of seconds to fill the drone. In some cases, the pump can be plugged into the generator, unless the generator is already at maximum capacity from charging the batteries.



Filling the drone from an auxiliary tank with a premixed pesticide, which is placed on an all-terrain vehicle.



A ladder in the ATV bed serves to raise the pilot high enough to observe the drone as it is making an application. Climbing up and down the ladder multiple times with a controller in your hand is potentially dangerous.

LIMITED-USE TRAILERS: **EXAMPLE 3**



This small, concentrated, and compact trailer has everything needed for spraying larger acreage. This trailer has running lights, signals, and brakes, which allow the operator to go on highways. The diesel generator provides more than enough power to charge batteries for multiple drones.

This is an excellent example of using a larger trailer with double 7,000-pound axles that can carry more weight. This trailer could be close to reaching its gross vehicle weight limit with the combined weights of the two 265-gallon clean water totes, the generator, and the inductor mixing tanks. The larger inductor allows for larger loads of chemical mixtures to be made at one time, which keeps the drone spraying for longer periods of time.

The smaller inductor is where the chemical products are placed before being transferred to the larger tank. Clean water is added to the larger tank, not only creating the diluted mixture but providing a swirling action to mix the products. A higher-output electric pump that can move product through a 2-inch line is plugged into the diesel generator.



Enclosed Trailers

Enclosed trailers are popular as a first entry into the drone business. They allow supplies and equipment to be safely stored out of the weather and can be locked to reduce the threat of theft. When spray drones first began to catch on, enclosed trailers were seemingly the ideal setup for the operation. Enclosed trailers are widely available to purchase, both new and used, and are reasonably priced. At the end of the day, there is no extra effort to unload anything from the trailer, and it can be used as a storage location so equipment doesn't take up shop space when not in use. The enclosed trailer shades tanks from harmful sunlight and helps keep batteries cooler. However, extra time and effort are required to set up the drone at the application site, and most trailers seem to be packed tight, making it cumbersome to maneuver in the trailer. These trailers often don't have an elevated platform to keep sight of the drone and sometimes require effort to make a suitable landing and takeoff location.

Estimated Cost of Enclosed Trailers

\$3,000–\$50,000, plus cost of truck

Benefits of Enclosed Trailers

- A wide selection of enclosed trailers is available locally.
- They are a relatively low-cost option.
- Contents are protected against inclement weather.
- Storage, sorting, and shelving are straightforward.
- Locked doors provide security for equipment, especially when staying overnight or on the road.
- Trucks already in inventory can be used to pull them.

Drawbacks of Enclosed Trailers

- Axles limit the amount of weight carried.
- A limited number of gallons of water can be carried (space and weight).
- Entering fields and farms can be difficult in some locations due to low ground clearance.
- They are not designed to go off-road where the trailer is subject to flexing.
- There is no place for the drone to land except on the ground.
- Heat can be an issue if generators are located in an enclosed trailer.
- Line of sight is difficult to manage over tall crops.
- There is limited space for storing larger drones within the enclosed area.
- Mixing pesticides and storing fuel in the enclosed area can lead to applicator exposure to fumes. Chemical spills can increase this exposure even if you do your best to prevent them.
- Setup and teardown take longer than with other trailer options.

ENCLOSED TRAILERS: EXAMPLE 1



An enclosed trailer provides storage and shelving to allow repair parts, drones, and equipment to be locked up when not in use or protected against bad weather.





Due to the trailer's space and weight limitations, the two tanks of clean water and the electric generator are carried on the truck bed. The yellow tank holds clean water to wash hands and clean the drone after the application is completed.

ENCLOSED TRAILERS: **EXAMPLE 2**



Utilizing the full extent of a drone trailer. With this setup, supplies and a limited amount of water can be carried. It is an ideal setup for smaller jobs. The Honda gas engine is used to power the trailer. Notice the number of electrical outlets in this trailer, which increases its usefulness.



This trailer allows the drones and other critical components to be locked up. Not storing or mixing chemicals in an enclosed trailer lessens applicator exposure. This excellent applicator is wearing the personal protective equipment required both for pesticide use and for roadside work.



ENCLOSED TRAILERS: **EXAMPLE 3**



The water supply for the drone is carried within this trailer. A smaller induction tank and a larger mixing tank provide the ability to keep the drones flying without having to repeatedly stop to mix more product. It is typical for enclosed trailers to carry no more than 500 gallons of water. Larger water tanks are seldom used within the enclosed area as the extra weight puts more stress on axles. This is why one needs to know the trailer's gross vehicle weight rating. Exceeding this weight rating can jeopardize the integrity of the trailer.



If the ladder is used to get on top of the trailer to achieve line of sight, then the trailer should have a reinforced roof that can handle the weight of a person.



It is important to have a dedicated hose for clean water to rinse off the drone before storing it in the enclosed trailer.



Three coolers, two chargers, and six batteries require a generator that can produce 25 kilowatts of power.



A box trailer that has had its roof modified so the operator can work there and observe the drones making an application.

ENCLOSED TRAILERS: **EXAMPLE 4**



An enclosed trailer built by the drone operator. The trailer has a powerful 125-kilowatt Cummins Onan diesel generator (1) and an enclosed lift (2).



A view from inside the lift looking across the deck toward the drone.



An inside view of the trailer showing a 2,100-gallon yellow clean water tank.

The lift mechanism. The lift is used to bring the batteries and drones to the upper platform.



The lift showing the batteries and chargers. Once the day's operations are complete, the drones are brought back into the lift, which brings them down into the trailer.

Truck Bed Inserts

When working across fragmented rural areas, truck bed inserts are the most convenient option for any drone operation. Spraying environments in these areas are normally rather tight with small access points, making it hard to maneuver a truck-and-trailer combination. Additionally, a lot of spray companies already in business have a truck sitting around that is not heavily utilized, creating an even more affordable entry point. Many operations are now starting to utilize a truck for ease of access and if needed will either bring a water tender trailer to the application area or have one delivered. This allows the operator to set up the truck in a location with good access to complete the mission.

One of the greatest benefits of truck bed inserts is the increased ground clearance compared to most trailers and the ability to make turns and get to areas that are limited in space. Many farms have long access lanes or fields that are along roads where it may be dangerous to park. Drone trucks can pull into much tighter areas than trailers, including small field entrances or long lanes that don't have a great place for a trailer to turn around. This is especially relevant when significant rain makes farm lanes and roadsides soft. A truck bed insert on a four-wheel-drive truck can likely get around without getting stuck or making the big mess that a trailer might.

The big negative of a truck comes when one considers scaling up this operation. Most of the time, adding a second drone will not really benefit as these setups are working smaller fields and tighter environments. Because of this, scaling up in the fragmented portions of the country may require acquiring additional trucks and inserts, along with pilots to operate them, rather than going out and purchasing an additional drone.

Estimated Cost of Insert Setup

\$2,000–\$20,000, plus cost of truck

Benefits of Truck Bed Inserts

- They work well for a one-person operation.
- The operator can get in and out of sites easier than when pulling a trailer, especially for tight places like narrow farm lanes.
- Companies can retrofit trucks that are already titled, registered, and tagged.
- They can access difficult places and turn around in fields.
- They have extra clearance for off-road work.
- Carrying weight over axles allows heavier loads to be transported.
- Landing on and taking off from platforms removes the concern over flying debris posed by landing on the ground.
- The platform allows the pilot to see over the crop.

Drawbacks of Truck Bed Inserts

- The limited amount of water that can be carried on a truck requires a water tender or extra time spent refilling water tanks.
- There is limited space for supplies and equipment.
- There may be issues with driving under low power lines or overhanging trees.
- Equipment can be exposed to the environment. Some operators utilize storage boxes on the truck for protection.
- On smaller landing platforms, there is limited room to work around a drone.
- Drone securement in transport can be limited.
- The raised platform brings safety concerns for employees.
- If you must stay overnight, all equipment is exposed unless you use storage boxes for drones and batteries.



TRUCK BED INSERTS: **EXAMPLE 1**



This drone operation works out of the bed of the truck, which carries the electric generator, water tank, and other supplies.

This is a two-person operation with a pilot on the platform and another person on the ground. The drone lands on the ground, where it is serviced. Many truck insert platforms are used to allow for better observation. They are normally too small for a 6-by-6-foot drone to land with enough space between the rotors and the workers. But some inserts do have enough room for the drone to land on top where the pilot is, which allows a single person to conduct the operation from the top of the insert once the generator is running.

The platform shown here is built with expanded metal. A spill when filling the drone on the platform will result in liquids falling into the truck and onto the equipment. Some products used are corrosive, which can cause additional damage. A deck made of polycarbonate or diamond-composite plate metal might be a better option but would increase the weight and cost of the insert.



TRUCK BED INSERTS: **EXAMPLE 2**

A flatbed truck is a weight-carrying truck, that is, is designed to hold more weight, meaning it can carry additional gallons of water. As a rule of thumb, a single axle with dual tires can carry 20,000 pounds; two axles can carry 34,000 pounds; and a single axle is rated to carry 800 pounds for each width of tread. The extra length of the bed shown here provides more space for equipment and supplies. The hose on the platform (1) is used to fill the drone on the ground. Landing on the ground might be easier given the limited space on the platform. Another hose reel is near the water tank (2). The top tank on the platform is pulling the chemical mixture from the black tank holding the mixture to the drone. An electric pump is used to move fresh water (3). A Honda motor powers the pump transferring product from the chemical tanks.



The base of the drone fits into a wooden frame. Straps that fit around the arms help to keep it from moving during transportation.



TRUCK BED INSERTS: **EXAMPLE 3**



This truck insert has safety structures where the pilot stands: a gatelike protective panel separating the pilot from the drone landing site, to keep them away from the spinning rotors, as well as a railing along the edge to keep them from falling off. The truck has a nice set of storage boxes along the side for supplies and spare parts. The generator is set up to charge the batteries for a single drone. Batteries are charged on the platform, eliminating the need to climb the ladder frequently. There is a hose reel on the top side for filling the drone.



Placing the gas generator within the truck allows for additional room to land the drone on the platform.

TRUCK BED INSERTS: **EXAMPLE 4**

An excellent example of a truck insert that the pilot uses to fly a single drone. The trailer carries extra water to allow the pilot to keep the drone in the air for much of the day. Although the water wagon limits the benefits of the truck bed insert, the wagon can be dropped at a central location near the fields. The truck then moves around the fields, easily entering tight spaces, and returns to the water wagon to refill occasionally.



TRUCK BED INSERTS: **EXAMPLE 5**



Hydraulic wings allow for a wider platform to land and work around a drone. The truck can go into most fields. The operator can keep the left wing closed when parking alongside the road. The unit can be detached allowing for the truck to be used for other purposes. The drone can remain strapped to the upper deck when traveling from field to field.



Deckover Trailers

Deckover trailers have become quite popular for commercial operators working the larger acreage of midwestern farms. The longer platform provides more flexibility for pilots to operate more than one drone. The deckover trailer is the best setup for keeping the operator safe, carrying large volumes of product and water, and providing good viewing areas for keeping a line of sight with the drone. Although these trailers are the best for space, loading, and operator line of sight, they are generally the most expensive of the four common setups. These trailers are built for covering many acres and working long hours in a day. These trailers are generally very expensive and very specific to spray drone use but are highly efficient, and an operator can get a good return on the investment if the environment is suited to this setup. However, in a lot of areas this system could be overkill, and your return on investment might be lower.

Estimated Cost of Trailer

\$20,000 to \$150,000, plus cost of truck

Benefits of Deckover Trailers

- They provide ample room to carry the day's supplies.
- You can fly multiple drones from the platform.
- They offer an excellent line of sight and contact with the drone.
- These trailers can carry heavier weights, including more water and diesel generators.
- Working on the platform keeps the operation and pilots away from cars.

- Landing on the platform when parked alongside the road keeps dirt and debris from flying upward and nicking the drone's blades or hitting people on the ground.

- You can have an enclosed portion to provide a secure spot to store your drone.

Drawbacks of Deckover Trailers

- They can be difficult to maneuver in small farm lanes or field entrances.
- They often require parking alongside roadways, which can lead to traffic accidents.
- They require workers to understand how to safely work alongside moving traffic.
- They need to be fitted with lights, cones, and other warning signs to inform the motoring public.
- They may require handrails or extra safety provisions to be OSHA compliant.
- The trailer length may limit the ability to cross creek beds or swales when accessing fields, due to ground clearance issues.
- They may have issues driving under low power lines or overhanging trees.
- They draw more attention from the motoring public, who at times will park alongside the road to view the drone flying.
- They may require a commercial motor vehicle driver's license (CDL).
- Typically they are the most expensive option.

Instead of permanently bolting down the generator, chains are used to secure it to the trailer. The generator can then be removed with a forklift to allow for winter storage or for repurposing it and the trailer for other uses when not making applications.



DECKOVER TRAILERS: **EXAMPLE 1**



On this gooseneck deckover trailer, the operator uses the deck to sit and view the drone, while mostly landing the drone behind the trailer. However, if there was no landing zone on the ground, the deck would be a backup place for the drone to land if needed, and the operator could stand on the tongue if needed. Landing on the ground requires the pilot to descend to the ground to fill the drone and replace its 30-pound battery (unless working with a second person). Batteries are charged by the generator near the front of the trailer. This placement keeps the generator as far from the work area as possible to reduce the noise.

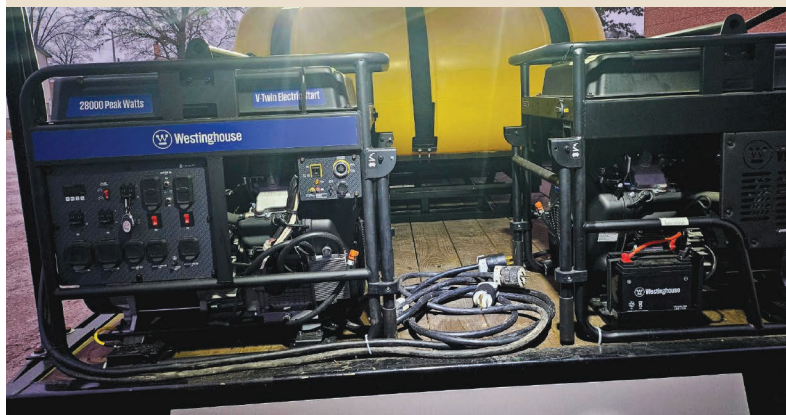


The trailer was designed to make it efficient. A solid composite deck keeps spills from damaging equipment below it. There are handrails alongside the steps leading to the top of the platform. The cooling system is under a cover. There are drone storage boxes in the back. An excellent toolbox in the front of the gooseneck provides a spot to store tools, spare parts, and chemicals.

All photos on this page show the same trailer, but the operator modified the equipment to better suit his needs.

DECKOVER TRAILERS: **EXAMPLE 2**

A heavy-duty two-axle trailer designed to carry the additional weight of extra water tanks. The tanks can store enough water to keep the drone flying for extended periods of time. The pilot, working within the framed area in the center, has the option to land the drone on either side of the platform.



These two generators on the trailer can produce 56 kilowatts of power.



Each side has its own hose reel to fill the drones. Hose reels can reduce clutter and make cleanup and teardown fast, necessary for a drone business.



A trapdoor at the top of the stairs opens onto the platform.

DECKOVER TRAILERS: **EXAMPLE 3**



This is a pilot's upgrade from an enclosed trailer to a deckover trailer (see page 58). A place for storing tools and supplies was built on the front of the trailer. A large diesel generator powers the trailer and charges the batteries.

DECKOVER TRAILERS: **EXAMPLE 4**



Chargers and coolers are located within the center framework. The diesel generator is placed on the back of the trailer and the fuel tanks in front to spread the weight out.



The pesticide mixture is premixed elsewhere and brought to the site, where it is offloaded into the white totes. A filter can be seen (arrow) and valves that control the flow and agitation of the mixture.

DECKOVER TRAILERS: **EXAMPLE 5**



An area for the pilot to work, here located at the end closest to the truck, provides protection against stepping off the edge of the platform. This trailer carries a total of 1,000 gallons of water. On top are two toolboxes where chargers, coolers, and batteries can be kept when not in use.



A heavy diesel generator powers the trailer.



An additional gasoline engine is used to power the pumps.



Securing the drone is critical even when moving a short distance. The only problem with this type of securement is that two people will be required to lift it onto the trailer after the job is completed and down again at the next jobsite. A well-designed storage location for the drone is an important part of a quick setup and teardown, which can be important when spraying smaller fields that require moving the trailer often.



DECKOVER TRAILERS: **EXAMPLE 6**



A wide-angle view of a very efficient drone trailer. The pilot works within the area protected by railings to avoid falling off and to protect them from the drone just in case a drone malfunctions.



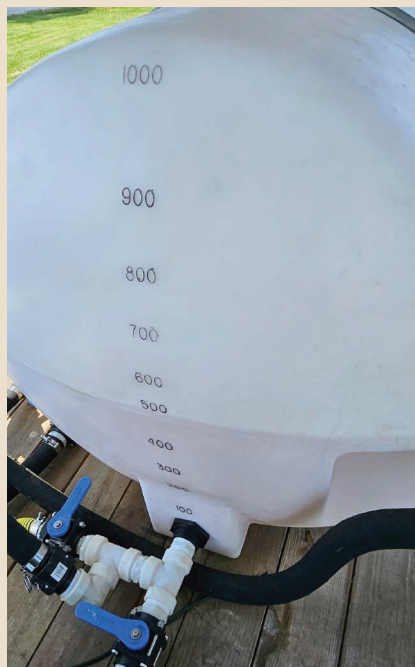
Three gasoline DJI generators are used to power this drone operation.



Coolers and the battery chargers are located at the top and side edge of the platform.

CONTINUED ON NEXT PAGE

DECKOVER TRAILERS: **EXAMPLE 6** CONTINUED



A 1,000-gallon tank could spray 500 acres at 2 gallons per acre.



Red tape on the edge of the trailer deck marks the location of the steps for stepping down onto the ground.



Top view of the trailer's platform. There is enough space on the platform for two drones to land. This also shows that the filling nozzle and charging stations protrude onto the upper deck so the whole operation can be conducted from there without constantly going from the top deck to the lower deck.



A close-up view of the fans within the cooler used to cool batteries. However, the batteries are not protected from sunlight while charging.



The work area showing the placement of the controllers and the umbrella. Notice that the umbrella does not have flaps coming down, allowing the drone pilot to clearly see the platform and the drone as it flies over the fields.



A pilot seated at the workstation. The taller pole allows for the relay to keep a better connection with the drone in fields with less visibility.



A storage box provides space for additional supplies, controllers, and paperwork.

DECKOVER TRAILERS: **EXAMPLE 7**



This trailer has a platform designed to handle two drones. The middle is an enclosed area called the command center, which separates the platform into two parts. The pilot walks up one flight of steps and slides the door open to enter the command center.



*The command center is equipped with an air conditioner and a mini-fridge. The windows are made of indestructible polycarbonate to keep a drone or a shattered blade from penetrating the center. No pilot or crew member can have consumed any alcohol within 8 hours of the operation, according to federal regulations, and they may not have a blood alcohol content of 0.04 percent or greater, so the mini-fridge is **ONLY** for food and nonalcoholic beverages.*



A diesel generator provides power to the entire trailer.



The cart is equipped with battery chargers. When charging, they are under a table, which provides shade to keep the batteries cooler.



An elevated flap at the end provides a visual cue signaling the end of the platform.



The cart rolls out to the drone with the charged battery. This allows the depleted battery to go directly into the charger, speeding up the operation by 20 seconds. More important, the technician doesn't have to bend, reducing fatigue. A key advantage to this operation is there is no reason to go out to the end of the platform since swapping the battery and refilling the drone is done in the center. The dark gap between the wooden sections (white arrow) allows spills on the platform to drain to the sides to the trailer.

DECKOVER TRAILERS: **EXAMPLE 8**



A series of small white totes are part of an auto-mixer. Each tote can contain a specific pesticide that can be metered into the water line running to the application drone.

Safety Concerns with Drones

A major selling point for drones is the enhanced safety they can provide during an application. However, incorporating a drone into a spray business adds a new set of safety concerns that most experienced applicators have not previously faced. These specific safety concerns must be addressed so that employees remain safe when working around drones. Long hours, elevated decks that are often homemade, large and top-heavy equipment, chemicals, and spinning rotors are all hazards that require special attention in spray drone operations. The best way to mitigate these hazards is to plan ahead or make adjustments to current trucks and trailers when building your truck/trailer setup to limit fatigue and make operating areas safe and efficient.

KNOW THIS

Incorporating a drone into the spray business adds a new set of safety concerns that most experienced applicators have not previously faced.



SAFETY CONCERNS WHILE WORKING WITH YOUR DRONE RIG

Drone use creates many opportunities for mayhem.
Know all of the risks to stay safe.

Fatigue: Reduce Heat Exposure and Bending Motions

Mental stress and physical fatigue resulting from spending long hours in the sun and heat, carrying heavy batteries, and doing a lot of bending can lead to on-the-job injuries. It goes without saying that working long hours in 100° weather requires employees to drink plenty of fluids. Remaining hydrated and eating appropriately will lessen the likelihood of employees suffering from heatstroke. Additionally, an umbrella can significantly reduce an employee's exposure to the sun. However, most standard umbrellas are not designed to handle the strong gusts generated when a drone approaches and lands on a platform. During landing, wind speeds can potentially exceed 20 mph, which may damage conventional umbrellas. As a result, these umbrellas may require replacement each season, or multiple times a season. To avoid this, it's a good idea to choose umbrellas that are made to hold up in windy conditions. Consider purchasing an umbrella that has been wind tested and whose manufacturer publishes those numbers as part of the product's description.



Heat exposure is as much of a risk as anything when it comes to operator safety. A simple umbrella can help make or break a day. Umbrellas should be large enough to cast shade and durable enough to withstand air movement caused by the drone. It is best to use umbrellas that do not allow sunlight to pass through the mesh as some shade cloths do.



An open canopy, providing shade for the entire operator's station and batteries.

Bending and carrying also add up over the course of a day. Think about the wear and tear on the body from the following activities:

- Carrying batteries up steps
- Setting them down (first bend, 30 pounds)
- Taking the spent batteries out of the drone and putting them down (second bend, 30 pounds)
- Bending again to get the nozzle to fill the tank (third bend)
- Bending to lay the nozzle back down on the ground or deck (fourth bend)
- Bending back down to pick up good batteries and replace them on the drone (fifth bend, 30 pounds)
- Bending back down to grab the hose and spent batteries to remove them from the area (sixth bend)

Remember that these steps are often repeated each time the battery is replaced and the tank filled. Let's say the operation is doing 200 acres a day and getting 5 acres per tank load. That means it will take $40 \text{ fills} \times 6 \text{ bends} = 240 \text{ bends}$ over the workday. Of those, 160 (four bends per load) will involve lifting a battery: $160 \text{ bends} \times 30 \text{ pounds} = 4,800 \text{ pounds}$ lifted during the workday, or almost 2.5 tons. Anything that can be done to reduce the number of times an operator bends can help alleviate fatigue.



Access to the fill nozzle on the top deck with limited clutter offer a safe and fast way to fill up the drone.

Try to elevate your charging station to about waist high or slightly lower so the operator does not have to bend down when getting a battery or returning it to the charging station. If the station is too high, lifting the battery to chest high can be a struggle by the end of the day as well. The same consideration applies the fill nozzle placement. Install a hook or handle that allows you to hang the fill nozzle at about waist high. Even if the nozzle is stored elsewhere when traveling, leaving the nozzle more accessible during the operation can significantly reduce fatigue compared to picking it up off the ground or floor each time you fill up. Additionally, by the end of the day, you would likely be “dropping” it instead of setting it down softly, which can increase the likelihood of it breaking. A busted nozzle or leak can lead to chemical exposure or wasted product. Last, as the nozzle hits the ground, dirt and debris will most likely get introduced into the nozzle and then into your spray system, causing more fatigue on your drone.



The nozzle used to fill the sprayer has a sleeve that it can be placed into. This will help to prevent a lot of bending during the day.



A battery box is elevated to allow this person to get their feet underneath. That allows the operator to lift the batteries straight up using the form that is used by weightlifters. This will help reduce fatigue and back pain. The actual height of the battery box will depend on the height of the individuals handling the drone batteries.



One small mistake while trying to land can end in disaster. Always follow through with the controller until the drone has completely landed.

Losing Control of the Drone: Be Careful When Setting the Controller Down

Landing a drone should always be viewed as a dangerous operation no matter how many times you have conducted this maneuver. It is never a good idea to place the controller down in an unsecured location.

When the drone is approaching the landing site, it creates wind velocities that can push an untethered controller off of its resting position. Falling onto a platform can switch the controller out of autopilot and into manual mode. The concern is the controller falling where its sticks are having input, causing the drone to go in whichever direction the input tells it. This can put employees at risk and result in crashes.



Proper mounting for a controller not in positive hand control. There is a convenient hook for the controller while the pilot fills up the drone or swaps batteries.

Drones are good but not always as good as they need to be. It can be tempting to begin getting the battery and fill nozzle ready before the aircraft has fully landed. It can be especially tempting when the aircraft has successfully landed without issue for a number of consecutive fill-ups. One commercial operator was flying an imagery drone, and the aircraft had finished the mission and was returning home. Since it had landed many times with no issues in the past, the author decided to “scout” the soybeans while it landed on its own. But the GPS signal degraded, and the drone landed about 30 feet to the south in a large tree. Spray drones can have similar troubles, such as unexpectedly missing the landing zone and falling off the trailer, causing significant damage.

Another example from one of the authors is that a friend had been operating an agricultural drone on his farm all day. On the last flight of the day, the operator set his controller down in the landing area. As the drone came in for the landing, the controller flipped onto the sticks and gave input to the drone, causing the drone to fly away and crash into the ground.

Spinning Blades and Jagged Edges: Are You Protected?

When a drone lands on or takes off from narrow platforms, this brings you near spinning blades that can cause injuries. It's true that injuries like those shown in the photograph happen infrequently, but they unfortunately occur. While it takes only seconds for someone to be severely injured, these can be life-changing events for that person. In the worst-case scenario, this could lead to years of headaches involving insurance companies, attorneys, and courts.

Due to the risks, it is important to have as much separation between you and a drone as possible. Separation from the drone is not the only requirement: Consider a drone crashing into a trailer, causing the rotors to split and shatter. In this instance separation alone would not protect the operator. More thought should be given to protecting the operator, and others involved, in a worst-case situation.



Many spray drones have the capacity to carry full-grown humans. With that capacity comes a great amount of force from the rotors to keep it in the air. Encountering a spinning rotor can be life changing if not life threatening.

These accidents are most likely to happen when someone approaches the aircraft to change batteries or fill the drone before the rotors have fully stopped. With some drones, after the aircraft lands, it takes an extra few seconds before the rotors stop spinning. If you are working in pairs, it may be a good idea to have a phrase or word the pilot says to signify the rotors have stopped spinning and it is safe to approach the aircraft.

Refills: The Drone Must Remain Off

Older drone models and even a few newer ones do not have an internal backup battery. When the spent battery is replaced with a fully charged one, the drone has to reboot its internal systems. Completing this process requires 30 to 90 seconds. Once it is complete, the drone is now energized and ready to be engaged by the pilot. A potentially dangerous procedure is to try to save time by first removing the spent battery and replacing it with a charged battery. While the drone is rebooting, the person then fills the spray tank. Then, by the time the drone is refilled, the drone itself has nearly completed its reboot procedures. However, this means the person is technically working within an energized environment throughout the refill procedure. If the rotors were to power on, the person would be in the danger zone, which has the potential to lead to serious injuries.

Conversely, many of the newer models have an internal battery that keeps the drone from going through the reboot process. Typically, that stored power is not enough to activate the drone's rotors but ensures the drone is continuously on.

It is best to balance efficiency and safety, but each situation may be unique. Carefully think of the most likely safety breaches of your operations, and do your best to address or avoid those hazardous situations. Fill-ups and battery changes can also create issues with the battery/drone connector if you are not careful. With many spray drones, the battery plug is protected when a battery is fully installed; however, when the battery is pulled out, the plug can be exposed to splashes from the pesticide being transferred into the drone, or to seeds or dust from spreading seed or fertilizer. These can cause the pins to rust or corrode, or can block the connector pins from fully connecting to the battery. Try to limit any potential contamination of the connector by limiting the amount of time the battery is out of the drone and limiting any splashing or dust when filling up the drone.



Make sure the power is shut down when inspecting blades.



Inserting a fully charged battery, like this one, can cause the drone to power up.

Pesticides: Follow the Label and Wear PPE

Many using spray drones seem to think they are exempt from having to wear the personal protection equipment (PPE) required by pesticide labels. Drone operators handling these products and drones need to follow the same PPE requirements as those using ground rigs. Not wearing the required PPE while mixing pesticides or filling the drone negates the safety gained by removing the crew from the application zone.

KNOW THIS

Drone operators handling products and drones need to follow the same PPE requirements as those using ground rigs.



Regular cleaning and rinsing of the drone can keep chemical residues at a minimum, making transport and setup safer for the handlers. PPE only helps if worn appropriately. Wearing long sleeves is great; rolling up those sleeves, as this operator has done, creates risky exposure. Utilize PPE, and utilize it appropriately.

Due to the style of application, the drones themselves are often contaminated with pesticide residue. Placing a drone that has not had its external surface rinsed inside an enclosed trailer or lifting it onto a trailer between jobs can create even more contact points with pesticide residues found on its surface. Because of this, it is important to wear basic PPE (gloves, long-sleeved shirt, long pants, eye protection, and closed-toe shoes) to reduce exposure to pesticide residues anytime you come in contact with a unit that has been utilized for application.

The most common contamination likely occurs if the drone pilot who operates the controller also changes the battery or fills up the drone. If they don't wear gloves while filling up the drone or changing batteries, then the controller likely has pesticide residues on it as well. So even if they wash their hands after filling up, if they touch the controller, they are contaminated again. It is common for the operator to take a drink or eat a snack while the drone is in the air, but if chemical residues are on the controller, they are likely getting on the snack or drink. If the pilot is doing the filling and battery swap, it may be best to use some oversized, chemical-resistant gloves that can be easily slid on before reaching for the battery or fill nozzle and then easily slid off when switching back to the controller.

Eye protection seems to take a back seat with applicators; however, safety glasses are a critical component in protecting one's eyes. Landing on the ground generates a lot of debris as the drone's downforce will forcibly throw dirt, debris, and small rocks into the air. Drones leak, and as much as we try to avoid contact with chemistry, a leaky nozzle as a drone leaves a workspace can create drift that can easily impact the eyes. When working on the ground, safety glasses are a must-have at all times, whether operating or loading the aircraft.



Pesticide residues will likely cover the drone after every operation, requiring proper PPE while handling the drone and its components. The unit has clearly been utilized for work, but the handler has no PPE on whatsoever.



Pesticide labels vary on what is required when handling the product. Often more PPE is needed when mixing the product(s) than when dispensing the products into the drone.



Farm lanes that are mostly gravel and dirt create a lot of dust and debris that can fly into the operator's eyes when the drone is landing or taking off. Proper eyewear is essential. To help avoid dirt and debris, sites like this can be wet down before beginning operations. This will not stop all dirt and debris issues but does help.



Keeping an eye on the drone while it is landing and taking off can be difficult if turbulence from the drone cause dust and dirt to get in the eyes of the operator. Utilizing a landing pad in certain environments can help reduce the risk of flying debris and damage to the aircraft.

Fumes and Spills: Be Careful Where You Mix

Products with volatile components release fumes, especially when temperatures increase, and spills and splashes do happen, despite our best efforts to avoid them. Fumes and spills are particularly concerning in an enclosed trailer: It is important to mix outside of any enclosed area so that fresh air will dilute the fumes and limit your exposure.

If you must mix in an enclosed trailer, try to have two doors on opposite ends of the trailer (side door and rear door) open with a fan moving air in through one door and out the other to increase the frequency of air exchanges in the trailer and limit fume exposure.



Chemical batch setup inside trailer. Be cautious when utilizing this method to avoid additional exposure risks. Mixing chemicals inside enclosed trailers can cause fumes to irritate the handler. Ensure proper ventilation if your tanks and chemical jugs will be opened inside.



Chemical spills can soak into wood decks, and these decks can also become slippery when wet. Adding a coating to keep chemicals from soaking into the wood and adding nonslip surfaces are best practices when building your truck/trailer setup.

Secondary considerations for the mixing environment relate to the decking material of a trailer. Wood decks are perfect for absorption of pesticides, creating a secondary exposure risk that can continue for an extended duration. This is worst in an enclosed trailer, where fumes can accumulate, but also a problem for other trailers: If that untreated wood is exposed to moisture, the water has the potential to move absorbed product out of the wood again. Should this occur when you are parked in the wrong area, you could have a really bad day. To assist with this, operators suggest sealing the wood with a light-colored garage floor coating or a nonskid material used on boats to help reduce absorption of chemicals.

Building a platform out of diamond plate decking is also another option, but that material really heats up in full sun. To reduce this, operators have applied a light-colored grip paint to the deck to cool the platform. This also provides anti-slip properties and protects the platform. But diamond plating can also be heavy and harder to replace over time.



Falls: Put Handrails Along Steps

Slips, trips, and falls are prevalent in every work condition, even on a drone trailer. As shown earlier in this publication, most truck/trailer setups have some upper platform or raised area that the operator and handler must access. When handrails are not present alongside a ladder or steps, that presents an added risk to the individual and could cause some interesting balancing acts. This is especially true if a person is carrying batteries and controllers up to and down from the upper platform. Additionally, it might be beneficial to put grip strips on steps to prevent slipping as steps get wet. OSHA requirements relating to steps can be found at <http://osha.gov/sites/default/files/publications/osha3124.pdf>. It is also very important to install guardrails around the operator station when working on an elevated deck. A small misstep along the side of a trailer can cause a broken limb or much worse if the operator falls from the top deck of a trailer or truck. These accidents increase in incidence as operator fatigue increases throughout the day.



A handrail on the right side provides support when going up and down the steps. Another handrail on the left side would be a great addition.



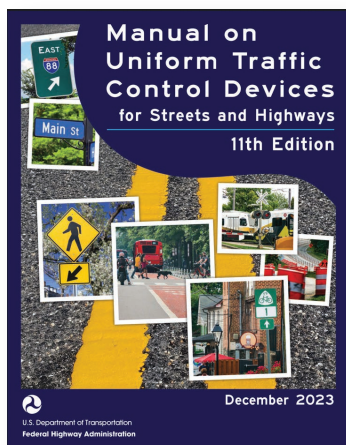
A ladder without handrails leading to the observation platform is an injury waiting to happen. On the positive side, these wood steps with expanded metal will help with foot grip when going up and down the steps.



Typical entry into a farm field in a central state. Although this field entrance is wide for easy access, if a crop were growing in the field, a long truck and trailer might not be able to fit entirely off the road, requiring the drone operation to be conducted with at least a portion of the setup on the edge of the road.

Roadside Parking: Be Selective When Parking

Many farm fields have narrow and sharp lanes leading off the highway that make it nearly impossible to pull a larger trailer into the field. This requires the trailer to be parked alongside the road and the drone launched from there. Parking along a road places the public and crew in a precarious and often dangerous position. This is especially true in the early morning and late evening hours when work is being conducted in low-light conditions. Working alongside a roadway puts drone workers at risk, because they are not trained like highway department employees. It might benefit all drone operators to review the United States Department of Transportation document *Manual on Uniform Traffic Control Devices for Streets and Highways*, found at https://mutcd.fhwa.dot.gov/kno_11th_Edition.htm. Drone operators should focus on chapter 6 of the manual, "Temporary Traffic Control." It provides practical tips for working safely along roadways.



Night operation on a roadside. This is one of the most dangerous operations drone applicators can conduct currently. Lights on the drone make it easy to see in the dark, but don't forget about the lights for your truck/trailer, especially when parked on the road.



A two-drone swarm operation parked on a road due to limited access. Parking along a road can be a hazard to the operator as well as to passing vehicles. Parking two trucks and trailers in a row can make it difficult for cars to see around both rigs to pass. If you must park on the road, make sure vehicles can safely get around you, and be careful not to accidentally walk into traffic.

Consider the following safety tips for working along a road:

- Pull the truck/trailer off as far as possible to allow vehicles approaching from the rear room to maneuver.
- Wear high-visibility clothing to attract the attention of the driving public.
- Do not park a trailer or truck in a no-passing zone. Drivers needing to move around you might be forced to cross the double line markings on the road, which could create dangerous situations with oncoming vehicles.
- Drone employees should always exit the truck onto the roadside shoulder, not the road.
- Place two or three cones behind the rig and two in front to warn those approaching that you are parked there. In addition to cones, some drone operations use flashing lights or strobe lights attached to the top decks to provide additional warnings to drivers approaching the parked equipment. For working at dusk and dawn, blinking red lights seem to work better in catching the attention of motorists.



Lighting is affixed to this trailer to help drone operators conduct nighttime operations. Guardrails on the top deck help keep the operator from falling off and may be an OSHA requirement for your operation.

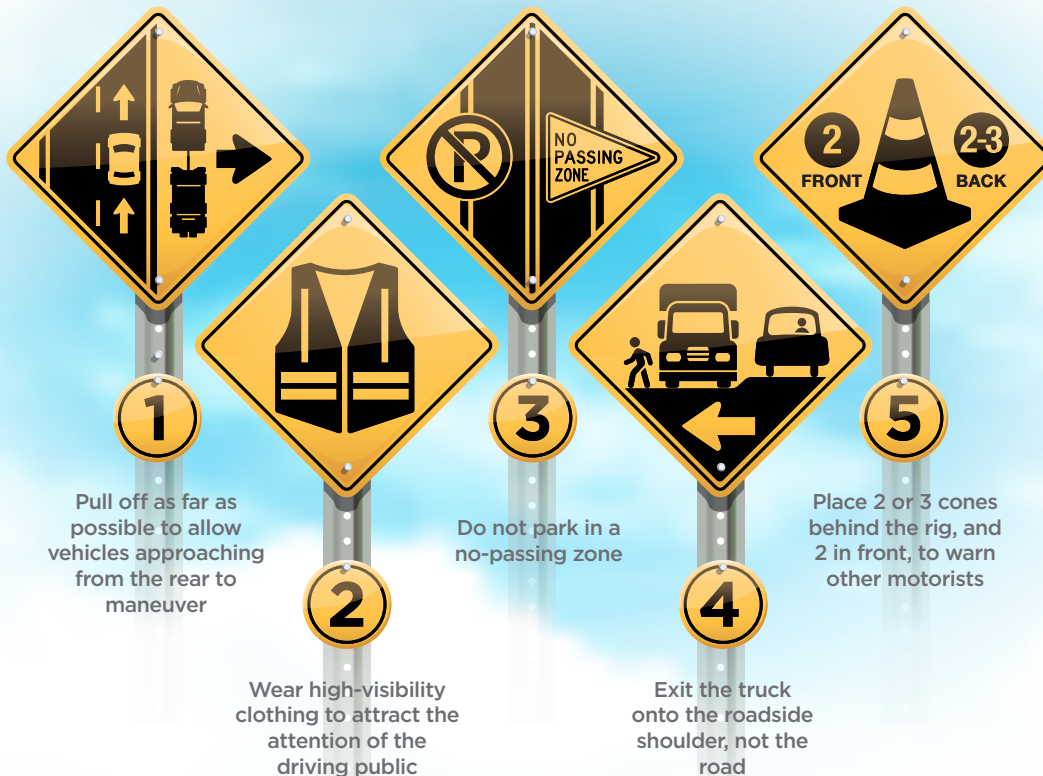


Wearing high-visibility orange is important when operating on or near roads. At least this person has on a high-visibility shirt and glasses on this photo, but they aren't wearing PPE. Both PPE and visibility are part of any good operation.

Even if you wear proper PPE, don't forget that drivers may not be paying attention; avoid putting yourself in a bad position along the roadside.



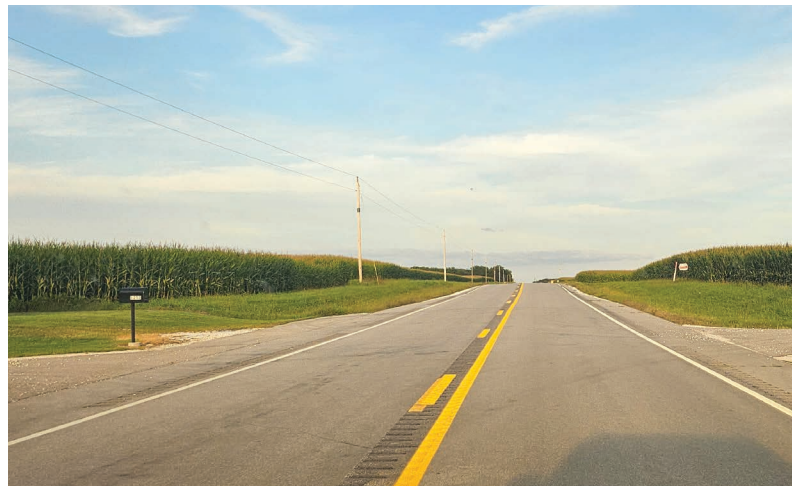
The wide deck allows for plenty of workspace for refilling the drone and swapping batteries. Red lighting helps to reduce the effect of light blinding someone during night operations.



5 SAFETY TIPS FOR WORKING ALONG THE ROAD

Although working with a drone poses its own safety challenges, do not overlook the hazards present at the roadside.

These dangerous situations can be limited when planning the spray order for the day. Know which fields will require you to park on the road, and try to complete those fields during the daylight. If you must start or end your day in the dark, do so on fields where you can pull off the road completely. Also, think about the rain forecast: If ground conditions become soft, you may have to park on the road more often. If there is a good chance of significant rain in the forecast, try to knock out the fields on more dangerous roads before it rains. Then, when it is wet, do the fields where you can pull off further into farm lanes or park along less dangerous roads. This is not always possible, especially if you don't want to skip over customers who have been on the list for a while, but planning and thinking ahead can sometimes work out and make a safer operator environment.



Avoid parking in a no-passing zone as this can put you and the driving public at increased risk when they have to cross the line to miss your trailer and truck.



Paying attention to where you park is an important part of being a responsible driver. (A) Can you see that if you had parked on the other side, you would have forced people to pass in a no-passing zone? Who would have been at fault if this created a head-on accident? (B) Using cones is necessary on any road if you want to protect the driving public and reduce your exposure to lawsuits. Today these gravel roads seem as dangerous as the interstate as the traffic moves at highway speeds even these roads were not built for that. (C) This road is being repaved: The drop-off between lanes could cause a driver to lose control of their vehicle as they approach the drone trailer.





Power Lines: Locate Them Before Flying

Power lines are ubiquitous across rural landscapes to the point that we almost forget they are there. When working near power lines, extra care must be taken as the drones are sent out on a spray mission.

Try to mitigate the hazards posed by power lines as much as possible. If possible, park on the opposite side of the road from the power line to create space when launching and landing. In addition, drones should maintain a minimum of 15 feet of separation from all distribution lines, which are typically 35 kilovolts and below. For high-voltage transmission lines (60 to 765 kilovolts), a separation of 25–35 feet should be utilized depending on the situation and the voltage of the line.



Extreme care must be taken when working around power lines and wind farms.

Blowouts: Size Your Tires for the Trailer Weight

An often overlooked and underappreciated component of trailers is the tires that carry your investments. A trailer tire is designated by the letters ST (special trailer). This designation indicates the tire is designed to be used on cargo, utility, and boat trailers. These tires feature reinforced sidewalls to handle the weight and stress. The two primary factors determining how much load a trailer can handle are the gross axle weight rating (GAWR) and the capabilities of the tires.



Consider the amount of money you plan to make in one day of flying. That's how much you would lose if you have a tire blow out and can't work that day. Make sure your equipment is in good working order before the season begins.



Especially when purchasing used vehicles or trailers, you should inspect the tires for age, wear, or weather cracking. At least once a year, you should jack up the trailer or truck and check for wheel bearing issues. This also allows you to spin the tire around to inspect all areas of the tire.

Driving: Know the Law and Follow the Rules

As larger equipment and supplies like water tanks are put on a trailer or truck, the weight obviously increases. This raises serious questions about the trailer and/or truck: Are they built to support the additional weight based on the gross vehicle weight rating (GVWR)? Trucks and trailers are designed to carry a maximum amount of weight, given as the GVWR. The established GVWR includes the weight of the trailer and truck and can be found on the driver's door or on the tongue of the trailer.

Things to consider:

- Are the weights of the generators and water tanks evenly distributed?
- Is the equipment properly secured on the lower and upper platforms?
- Are the tires sized to carry the expected loads?
- Are the axles rated to carry the expected loads?

Another question to ask is whether the driver requires a commercial motor driver's license (CDL). A DOT officer could put the driver and truck/trailer out of service for not having a CDL when it is required. Drone operators operating commercially should try to stay under the 26,000-pound GVWR threshold. Finding an operator with a CDL is difficult enough, but paying them what that driver's license commands is generally not practical for those operating a spray drone business.

Conclusion

The spray drone industry is rapidly evolving and becoming an integral part of our agricultural society. What was a novelty just a few years ago is almost commonplace in some regions, almost as if we are in the times when the first mass adoption of tractors on farms occurred. Like those early tractors almost a hundred years ago, many unknowns accompany this new technology, and experience, research, and trial and error are required to operate a successful spray drone operation. Hopefully this publication encompasses some early experiences and research to help you as an operator learn about an integral part of the operation: the truck and/or trailer. Although new drones are constantly being released on the market, and rules for flying spray drones are changing, the information in this publication will likely stay relevant since the methods used to get the operation out to the field will likely fit many spray drone platforms.

The key aspects of the spray drone operation that must be considered are getting the operation out to the field, packing enough water and product for your operation, reducing time spent refilling the tank and swapping batteries, making it back home safely, and taking account of the cost to maximize each of these components. Remember to be realistic about your original investment, and understand if you are wanting your drone operation to save money or make money. From there you can begin building a truck and/or trailer setup that will suit your goals.

Drone technology is in its infancy, only scratching the surface of what will be possible as advances by the military are commercialized by industry. When observing drone technology, one could directly compare it to global positioning systems (GPS) in that both are technological advancements that come directly from the military. When GPS was first commercialized, it was nearly unattainable for the average person financially and had limited uses in the pre-GPS infrastructure of society. Today everyone has a GPS system capable of tracking their every movement, built into their everyday phone. Similarly, the drones of today will fail in comparison to the drones of tomorrow. As the drones advance, the drone pilots and companies of today must be ready to change and advance as well.

Views and opinions differ on what constitutes an efficient trailer or truck, and how to equip it to maximize the time the drone spends in the air. Numerous factors will and should drive the decision on what type of equipment you need. These factors include the landscape itself (fragmented acreage vs. continuous), budget, desired total acreage, target pest, volume needed based on labeling, and size of operation and expansion potential, to name a few. Overall, you should put more time into planning as this can save you headaches and gain you profits in the future.

Ask Before You Do

You have thought everything out, examining all facets of what you think the drone trailer needs. You've penciled out the costs. A bank loan gets you ready to find a trailer, a truck, and the necessary equipment.

This is the perfect time to hold off making those purchases. Your best investment is to ask others in the drone business a very simple question:

"If you could do it over again, what would you do differently?"

Their ideas and suggestions may influence the type of truck/trailer you purchase, and the equipment you will put on it. In the long run, their advice will save you time and money if you avoid repeating what others wish they had not done to begin with.



The end goal and desire of any setup is to keep the drone in operation. To do this, the system at a minimum must be able to charge batteries, hold chemicals, hold clean water, and push that material to the unit.

In the beginning, operators started with as little as a flatbed trailer with a few tanks. Do not be overwhelmed when looking at all the photos and think you have to go and invest heavily in a heavy-duty truck and trailer, as sometimes the best option for your environment may not be that. Do understand that whatever you utilize will need to meet those minimum requirements and will most likely be responsible for holding and keeping safe equipment ranging from \$20,000 to \$100,000 in value. With that in mind, it's a good idea to think about the safety of this equipment, especially as people begin to understand the value of these units.

Drone technology and the truck and trailer setups trailers used to support drones have come a long way and will continue to evolve over the next decade. As these technologies evolve, we will see new use cases that will also continue to push the technology, creating the unique time we are in today, in which we are seeing traditional trade/practices impacted by technology at a level never anticipated. Fly smart, fly legal, and fly safe.







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Further Reading



The Evolution of Spray Drones: Their Capabilities and Challenges for Pesticide Applications (PPP-154)



Using Spray Drones in Indiana: Certification Requirements (PPP-156)

▶ Visit <https://ag.purdue.edu/departments/extension/ppp/resources/ppp-publications>



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