Support Your Local Engine
By Frank Granelli

LAST MONTH I wrote about four-stroke model engines and compared their many design, but few operational, differences from two-stroke engines. Throughout this series I have covered starting, maintaining, and getting the most from your engine as you run it, but in the real world, model engines require support equipment to operate. I took this for granted in previous installments, but this month I'll cover onboard and fueling equipment.

The most basic piece of engine-support equipment is the onboard fuel tank. Without someplace to store fuel in the aircraft, flight times tend to be short. Fuel tanks designed for RC models are usually blow-molded using fuel-resistant synthetic materials—not metal. Metal fuel tanks are usually designed for and used in CL aircraft, although many CL modelers also use "plastic" tanks.

L-R: Narrow tank used vertically, flat-bottom tank for use over retract nose gear, high-pressure tank for pressurized fuel systems, standard sport square shape, square tank with "bumper" to protect fuel lines, popular space-saving "slant" tank. Center bumper tank comes with fittings installed.

In RC's early days, the metal tanks could sometimes interfere with radio reception. They can also be dangerous if they come into contact with an electrical charge from the receiver battery.

Today's RC fuel tanks come in many sizes, styles, shapes, and construction materials. A photo shows just a few of the options. Most trainer models use some form of 8- to 16-ounce square tank.

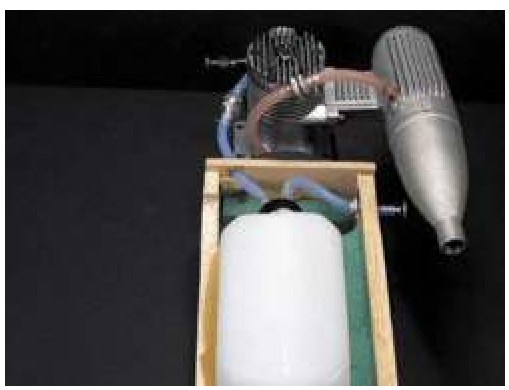
Tank's centerline is roughly 1/2 inch below fuel inlet. Usual way to get this height is *to place receiver battery under tank, which is tilted slightly downward at rear to ensure all fuel is available for pickup.*

The fuel tank's size depends on the engine's displacement. The .25 cu. in.-displacement engines use 4- to 6-ounce tanks, .40-size engines use 8- to 11-ounce tanks, and .60-size engines work best with 12- to 16-ounce tanks. Size does matter with fuel tanks. You will see why shortly, but first there is a concept you need to consider.

In all of my previous engine-theory writings, I treated the fuel as if it were just waiting there at the carburetor, ready to jump into the engine's fire to be burned for our modeling pleasure. That is not quite the way it is. Many forces are at work to help the reluctant fuel flow into an engine and meet its fate, the most obvious of which is gravity.

However, gravity is tricky for several reasons. To begin with, *an aircraft in flight is its own center of gravity.* I am not referring to the famed CG, but the fact that an aircraft creates its own "gravity" field whenever it changes direction. Without getting too technical, Newton's laws of force, momentum, and acceleration are at work.

For instance, in a sharply banked, tight turn, fuel would flow toward the aircraft's bottom, away from the turn's direction and the engine's fuel inlet, and not toward the side facing earth's gravity. At the top of a reverse outside Loop—an outside loop performed from level, inverted flight—fuel would flow toward the aircraft's top rather than toward the earth below its bottom. Again, this would be away from the engine's fuel inlet.



Although fully padded to protect against fuel foaming, tank is placed nearest fuel-inlet side. Note fuel filters on inlet and muffler pressure line back to tank with wire ties, to keep them all connected. Fuel dot is extended on right side for illustration purposes.

Keep pickup "clunk" 1/4 inch short of tank's rear to ensure unhindered flow. Overflow tube reaches into bubble but is not fully against top.

If you doubt this concept, hold a cup of water while riding in a light full-scale aircraft. It is fascinating to see the water stay firmly inside the cup as the aircraft loops and barrel rolls. (You better make that wine instead of water; you might want it to calm down after the maneuvers are over if you are not the pilot.)

But in straight, level flight, the earth's gravity *does* pull the fuel toward itself and therefore toward the engine. And most important, the earth's gravity is fully at work on the ground where we *set* high- and low-speed mixtures. These mixture settings stay constant despite the changes in fuel-flow directions once in flight. Somehow we must include the effects of a constantly changing "gravity" on fuel flow.

We compensate for the variable "gravity" with tank position. If the fuel tank is positioned so that its horizontal midline is located 3/8 to 1/2 inch *below* the engine's fuel inlet, usually the needle valve, the engine will need to draw fuel against the force of the earth's gravity while on the ground. In effect, the fuel will have to flow "uphill" to get into the engine.

Once in flight, many common maneuvers can only serve to "richen" the mixture. In level, inverted flight or rolls, the earth's gravity tends to pull the fuel "downhill" into the engine, resulting in a slightly richer mixture. When the aircraft's motion pulls fuel away from the inlet, as in the tight turns and outside loops mentioned previously, the "mixture leaning" effect is reduced since the engine has already been set to pull fuel "uphill."

A photo shows the best tank position in relation to the engine's needle valve. Tank distance from the engine is also critical. For .25-.65 engines without fuel pumps—most trainer engines—the fuel tank should be a maximum of 4-5 inches behind the engine. The closer, the better. Remember that the engine must draw the fuel over this distance as well as fight gravity.

Why can't we just put a 16-ounce tank behind a .25 cu. in. engine and fly for an hour? Because of something called "head pressure," which is the second force pushing fuel into the engine.

The weight of the fuel itself is acting to push it through the small opening, into the engine. The larger the tank size, the heavier the fuel is and the greater the force pushing it out of the tank. In the .25-engine scenario, the needle valves would have to be set extremely "lean" to compensate for the full tank's high head pressure.

But as the tank empties during flight, the head pressure drops. Approximately halfway into the flight, the pressure gets so low that the mixture settings, made with a full tank, are too lean. The engine dies in the next vertical climb or high-gravity ("high-G") maneuver. The initial mixtures could be set extra rich to compensate, but then the first half of the flight would be underpowered, if the aircraft could even take off, and not much fun at all.

But isn't muffler pressure— the third force acting on fuel flow—supposed to compensate for varying head pressure? It is and it does. But remember that the engine is pumping pressure into that large, full tank *while you are setting the mixtures on the ground.*

In flight, the muffler pressure remains constant—well, relatively constant based on the engine's speeds. As the head pressure drops, the flow forces still decline since the engine does not apply more pressure just because the fuel level is getting lower.

Muffler pressure is far more effective in helping to keep flow rates constant during steep climbs and high-G maneuvers, which momentarily reduce fuel flow, than in compensating for long-term flow reductions. Still, muffler pressure does help somewhat to reduce head pressure's detrimental effects. This is why there is a range of tank sizes rather than one best size for each engine displacement.

In addition, today's engine designers include muffler pressure's effects when they design the carburetor. Since muffler pressure increases fuel pressure, designers can increase the size of the carburetor's air inlet for additional power, and believe me, they do.

Therefore, much of the muffler pressure is already being "used" to feed additional fuel into a carburetor that would otherwise be drawing too much air and not enough fuel. There is not much left over to compensate for tank size and maneuvers.

The "dummy fuselage" photos are almost self-explanatory, but some parts are worth mentioning. Notice that the tank's fuel-outlet line is roughly the same height as the engine's fuel inlet. Try to run the fuel line directly to the inlet, without going far downhill, and then way back up. If there is too much "uphill," the engine could quit lean as fuel levels reach the last few ounces and head pressure vanishes. If your engine always quits before the tank is empty, check for this roller-coaster condition.

Also note that the fuel tank is not centered behind the engine. The tank's fuel outlet is positioned slightly more toward the side with the needle valve. This reduces the uphill/downhill effect no matter which direction the aircraft banks or rolls. Fuel flow remains almost constant. If possible, mount the tank inside a thin foam layer to reduce possible "bubbling" from the engine's vibration, as shown.

If the engine is tightly cowled, or the fuel line to the engine cannot easily be disconnected for refueling, you will need a third line to the fuel tank. This "fill line" must be blocked off after filling to prevent muffler-pressure loss during operation. The photo shows a "fuel dot" used for this purpose, which is simple and popular. Little can go wrong unless you somehow lose the dot while refueling.

Other popular methods exist, such as the Great Planes Fuel Filler Valve, that block the fuel flow into the engine while filling the tank, to prevent accidental engine flooding. However, sometimes such systems require longer fuel-line runs to the engine. It is often a good idea in such cases to use a third line anyway.

The filler valve connects to the tank, as would a fuel dot, allowing the engine's fuel line to be made as short and direct as possible. Block off the unused port with a short piece of fuel line capped with a small 4-40 bolt. There are so many onboard refueling systems available that you should check your local hobby shop to find the ones that seem best to you.

Hooking the lines up inside the tank is also fairly simple. The cutaway photo shows how to position a three-line system inside the tank. If the tank has a bubble section, position the muffler pressure/overflow brass tubing inside the bubble for maximum tank capacity. Most fuel tanks include enough brass tubing to fabricate any three-line system.

Try to reach into the bubble with as straight a brass tubing "run" as possible. This helps prevent the fuel "pickup" line from wrapping itself around the vent tubing and getting stuck in a full forward position, which could cause the engine to quit during the next vertical maneuver.

Some modelers prefer to use rigid plastic tubing on the pickup line to prevent this, but sometimes that also prevents the engine from receiving fuel during long vertical dives or spins. That is a modeler's choice, however.

To further reduce the chance of pickup-line fouling, the fuel-inlet tubing (the fill line) should be a straight line into the tank, as shown. Most fuel pumps have no trouble filling the tank against any extra pressure this may cause. Squeeze the filling line while installing the fuel-dot cap or quickly close whatever fueling system you are using to prevent spilling fuel once the pump line is removed.

Bending the brass tubing is fairly easy, but you must be careful to avoid kinking it if you bend it by hand. Several great tubing benders, shown, prevent kinks while providing just the angles needed. There are many others, so get the one you prefer.

If you accidentally bend the tubing, carefully apply pressure on the sides of the spot using pliers. This makes the tubing round enough to allow operation if you do not have a spare brass tube (available in most hobby shops).

Some flexible tubing—called fuel line—is also required to connect the tank's brass tubing to the engine, muffler, and fill port. At one time there were many types of fuel line available, but only two are commonly used today.

Pure silicone fuel line is used inside the tank. This semiclear tubing is extremely flexible and allows the pickup line to conform to the aircraft's maneuvers without kinking or leaving the fuel itself. It is also fuelproof and is unaffected by model fuel. It lasts almost forever without stiffening or degrading.

On the other hand, pure silicone fuel line is prone to cracking or rubbing wear. It also tends to slip off the brass tubing if it's improperly secured. It is great inside the tank but does not last long outside of it. Therefore, a form of "reinforced" silicone fuel line has become popular.

As is pure silicone, reinforced silicone is totally fuelproof. Unlike pure silicone, it is resistant to cracking and vibration wear and tends to stay connected. Fuel lines, which were once problematic, are now nearly trouble-free for years. Just make sure there is no firm contact between the fuel line and the fuselage structure, to prevent wear caused by vibration.

What about the fuel line's size, or diameter? This is not as critical as it once was since engine-fuel draw has greatly improved. Consider it, but don't lose too much sleep over it. Small-diameter fuel line is good for up to .25 cu. in. engines. Larger engines, up to .65 cu. in., require medium-diameter fuel line. Engines larger than .65 cu. in. work well with large-diameter line.

The best way to know for sure what size to use is to compare the engine's inlet diameter (inside measurement) at the high-speed needle valve to the inside fuel-line diameter. Try to match these diameters as closely as possible.

A slightly larger-diameter fuel line is preferable to a smaller size if a perfect match is impossible. Just make sure that the fuel line has a firm grip on the engine's fuel inlet and will not slip off.

In emergencies, I have used medium-diameter fuel line on 1.40 cu. in. engines without noticeable differences, so fuel-line diameter may not be extremely important.

The last part of tank installation is the fuel filter, but this is not open to debate. Reality trumps anyone's opinion; use a good filter or have problems. It is that simple. Competition fliers have proven this many times throughout many years. I relearn this lesson every 200 or so flights on my competition aircraft.

Despite triple-filtering the fuel during refueling, from a 100-mesh screen down to a 250-mesh screen, I must clean the onboard fuel filters in my competition aircraft every 200 flights or they start to clog. Alcohol-insoluble material builds up inside the filters and must be removed using paint thinner. If the filters didn't catch this material, it would eventually clog small carburetor sections or fuel-pump parts. Nothing but grief comes of this.

It is also a good idea to install a second filter in the muffler pressure line, between the muffler and the fuel tank. This limits the amount of junk the engine blows back into the fuel tank.

The only caveat about using filters is to make sure their sections are tight to prevent air leaks. Clean the filters every 200-300 flights for non-pumped engines or every 200 flights for pump-equipped engines.

The onboard fuel tank is perfectly sized, constructed, plumbed, and positioned; now we can go flying—except the fuel tank is still empty. We can't do more than test-glide the airplane without fuel, so how do we get it into the aircraft's tank?

For several years, my early refueling system was a 2-ounce turkey baster with a fuel tube attached. It was slow, but it worked! Such systems are still available, but in larger sizes, as shown. These squeeze bulbs are convenient backups if the primary refueling system fails at the field. You may want to include one in your field box just in case.

Du-Bro tool bends standard 1/8-inch-diameter tubing and includes four 3-inch tube sections. Blue Harry Higley tool works on 1/16- and 1/8-inch sizes. K&S system works on all sizes from 1/16 to 3/16 inch. All prevent kinks caused by hand bending.

Whitish silicone fuel line is best used inside tanks. Pink Prather Products, blue Aero

Trend reinforced silicone lines are more durable but stiffer. Great Planes refueling system mounts between tank and engine, and Tettra fuel dot uses a third line.

It is advisable to "bell" brass tubing ends that connect to fuel lines. Use 1/32-inch nail set to slightly expand tubing ends. Then use commercially available fuel-line clamp or thin wire wrap to secure fuel line to tubing.

Good, old fuel bulb is slow but always works. It is a great backup for any mechanical refueling system. Attached refueling nozzle contains its own 120-mesh filter.

But more sophisticated refueling methods are the most popular by far. As shown, there are four popular types. There are various kinds of hand pumps, some of which fit on the plastic fuel jug and use a hand-crank pump. Rotate the handle one direction and the fuel flows into the aircraft. Rotate the other way and out it comes after the flying day is done.

Some, such as the Du-Bro system shown, also hold the glow-plug igniter and spare parts. Others, such as Dave Brown Products' Pump-N-Go system, may include the fuel container as well.

There are refueling systems that attach directly to the fuel container and resemble the hand systems but use electric pumps. They usually also contain batteries for power. Field-box fuel pumps may also contain their own batteries, but most use the 12-volt field-box battery. Some systems, such as the yellow Sullivan fuel pump in the picture, have their own on-off/directional switches, and others use the fuel-pump switch on the field box's power panel (more about that next month), as the Mark X electric fuel pump does.

Du-Bro hand-refueling system (top right) mounts on fuel bottle holding glow igniter, spare plugs, glow wrench. Yellow Sullivan fuel pump mounts in field box with its own on-off/direction switch. Sonic-Tronics Mark X 12-volt pump uses power-panel switching. Black Thunder Tiger pump contains own 6-volt batteries. Photo courtesy Hobby Hut, Pompton Plains NJ.

Dave Brown Products' Pour "N" Pump hand system contains only one moving part—the rotating handle—and own fuel container already plumbed.

The fuel line used to plumb the refueling system is usually the same reinforced silicone line used onboard the aircraft. Many electric-fuel-pump manufacturers recommend that the large fuel line be used to reduce wear on the pump. Sometimes that requires using a short length of medium fuel line over the filling nozzle and then applying the large line over the assembly.

The refueling system has fuel filters; be sure to clean them more often than you clean the onboard filters. Refueling filters may be used for more than one aircraft, so they require more frequent service.

Now that the aircraft is fueled and ready to go, we need to turn it over and light the glow plug to get it started. We also need to hold it in place safely during run-up and settings.

Next month, which will be the last installment of the engine segment, I will cover field boxes, batteries, starters, glow-plug igniters, and chicken sticks. ***MA***