THE PROPER CARE & FEEDING OF THE ROTAX MOTOR

PART 41

by Mike Stratman

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Ever experience a rough-running engine only to have the problem clear up with a quick squeeze of the primer bulb? What you're obviously demonstrating is a poor fuel delivery system. Badly designed or failed fuel systems are actually one of the leading causes of engine-outs and forced landings. Causes range from clogged filters and pinched lines to rotten primer bulbs and dried out pumps. Yet the cold facts are, the simplest of oversights can put an end to fun weekends and expensive ultraflights.

This month we're going to put an end to the madness. Starting from the fuel tank and ending at the carb, we'll design a fuel system that gets the job done with plenty of room to spare. Along the way we'll also lay to rest such myths as air bubbles in the fuel line and what that tiny "weep hole" on Mikuni fuel pumps is for.

Fuel Tanks and Fuel Pickups: Starting from the source, the design must include several important features. Without a proper tank vent you will experience a forced landing. I say it this way to get your attention. This situation is the proverbial time bomb! As fuel exits the tank, air must be allowed to enter. If not, the fuel flow will cease due to the vacuum being created. Of course this takes a little time, hence the reference to the time bomb. The number of people who fall into this trap is incredible! Something as simple as replacing your fuel cap with a new one that you forget to vent will get you every time. Multiple vents and/or forward facing "Pitot-type" vent lines are a necessity. If a vacuum created by fuel exiting will prevent fuel flow, then the reverse is true. A forward facing vent line that pressurizes the air cavity in the fuel tank will actually increase the system's flow characteristics.

Tank placement is an important part of any ultralight design. Of course, the less distance uphill the fuel must travel, the simpler job the pump will have to perform. A couple of things to consider that may not be so obvious: Multiple tanks must be at the same level during flight including climbout. If your pickups are teed together, the fuel will always seek to find a common level in both tanks by siphoning the higher tank into the lower tank. If you must have tanks on separate levels, you must have valves to manage the flow from each tank separately. This leaves room for operator error in fuel management.

Fuel Level Gauges and Methods: Fuel level gauges or sight readings are imperative. The visual method is obviously the least expensive and preferred method. White Polyethylene cans are ideal for seeing the fuel level. Sight gauges using a piece of clear Urethane or nylon hose and elbow fittings also work well. Make sure you're not tempted to pile cargo in front of your sighting method. More expensive electronic and capacitance type gauges are available when visual methods are not possible. Whichever type you run with, make sure you can check the level at a glance. If you are going to register your aircraft with FAA, the Fed will pay special attention to your fuel monitoring system. He will make absolutely certain that if you run out of fuel, you simply paid no attention to your fuel level. As many general aviation pilots can tell you, when you run out of fuel, forced landings can be real expensive. You can kiss good-bye to thousands of dollars in fines as well as your ticket for quite a while.

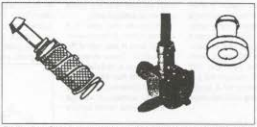

Figure #1 - Special attention must be paid to fuel tank pickups. Here are two of the most common. On the left is a brass screen that slips onto the pickup line. On the right is a tank access fitting with shut-off valve. This valve uses the grommet shown to seal the tank from one side only access.

Special attention should be paid to fuel pickups. There are several ways to go on pickups. Method one that is quite common is a valve or fitting in the bottom of the tank. A push-in rubber grommet is often used here because most of the time this is a blind or one-side-only access-type installation. Under the right circumstances, this works well, but can be prone to leakage and the grommet requires periodic replacement (we sell hundreds of grommets every year).

Another method is to enter from the top and use a fixed pickup line. The pickup line should not be removable or run through the fuel cap. This will allow for the possibility of the pickup hanging up on the sides of the tank when reinstalled – another time bomb.

If you prefer removable fuel tanks for easy refueling, quick disconnect couplings are ideal. A bulkhead fitting near the fuel cap works well. Remember, most of these fittings need a nut installed from inside the tank, so make sure you have enough access before you start drilling holes. Quick disconnects that shut off in both directions prevent fuel spillage and keeps the lines primed with fuel. Regardless of which system best fits your design, make sure the pickup cannot "suck up" to a flat surface and is at the lowest point in the tank during climbout. Tank valves with built-in filter screens are available, keeping the larger debris in the tank. Corrosion-proof brass screen filters are ideal for top exit pickups. In either case, periodic inspection and/or maintenance is necessary. A big dose of debris could prove to be a problem. [See *Figure 1.*]

F A I L - S A F E F U E L D E L I V E R Y

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Figure #2 - Gascolators are ideal for draining water from fuel systems. Built-in FAA-approved Curtis drain valve allows for easy water removal. The port on the top is ideal for fuel primer line pickup.

Gascolators: Something that is appearing on more and more ultralights is a water sump or gascolator. As oxygenated fuels become more common, water contamination of fuel is a real possibility. [See Part #37, "The Good, The Bad, and the Ugly of Oxygenated Fuels," Oct. 1993.] This device is mounted directly below the tank at a low point in the system. Because water is heavier than fuel, it will settle to the bottom of the gascolator. A built-in Curtis drain valve allows the water to be purged easily. A fine mesh screen also filters debris but does require periodic maintenance. The gascolator type illustrated here has a port to access your engine primer system, an item we will talk about a little later.

Primer Bulbs: Next in line from the fuel tank is the primer bulb. The squeeze bulb must be in the cockpit to provide access to the pilot while in flight. The reason to have the bulb next in line is to manually overcome blockage in any device before the carb. The pilot should be able to do this easily while in flight. Primer bulb should always be mounted horizontally. Primer bulbs are equipped with a check valve that has a floating ball that allows fuel flow in one direction only. Some bulbs use a heavy steel ball. When mounted in the vertical position, the fuel pump must work to lift the ball off the seat. This places an unnecessary burden on the fuel pump, reducing flow capabilities.

Only use a high grade heavy duty marine-type primer bulb. Avoid the less expensive Taiwan-made snowmobile surplus bulbs. You should be looking for quality rather than price on a primer bulb. We have been selling one particular brand for years without ever hearing a single complaint. As you can well imagine, "No news is good news" in the parts business.

Make a full inspection of the bulb as part of your regular preflight procedure. You should consider replacing primer bulbs at regular intervals on your scheduled maintenance program. Because primer bulbs are rubber, ultraviolet rays and the elements will cause degradation. Dried out and cracked bulbs can cause forced landings.

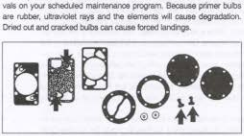

Figure #3 - Fuel pump repair kits can zero time any Mikuni fuel pump. Arrows show flapper valves that cause the fuel to flow in one direction only. This is as simple as it gets yet surprisingly effective.

Fuel Pumps: Regardless of your choice, the fuel pump should be next en route to the carb. Fuel pumps fall into two categories: impulse and electric. Impulse pumps are supplied as standard equipment on all Rotax 2-stroke motors. These pumps function, as their name implies, off a pulse created in the crankcase of the engine. As the piston travels up and down, the area below the piston is subjected to alternating pressure and vacuum, much the same as the combustion chamber itself. This pulse is used to flex a diaphragm inside the fuel pump. One-way flapper valves route the fuel through the pump in a one-way fashion. [*See Figure 3.*] A lot of people will run the dual round pump even on a single-carb engine by routing the lines back together after the pump. If you inspect the internals of the pump, you will find a common discharge cavity in the round pump. You will also find a much more sophisticated style valve than the flippers in the single or rectangular pump. The thought of hanging your hide on a dangling piece of gasket material is a little unsettling. But as simple as these pumps are, they do a surprising good job.

Because these pumps work off the crankcase impulse, there are several considerations. First, the line from the crankcase to the pump must be no longer than 12 inches and must be fairly rigid so as not to absorb the pulse. A one-piece or solid line is preferable. Hoses using several layers can separate internally, collapsing the passage and are impossible to detect from external inspection. You must also consider that because they function off the crankcase pulse, they are subjected to performance based on engine rpm – a constantly changing variable in the equation of fuel delivery.

Figure #4 - The "weep hole" is located as shown by the arrow. This hole allows for fuel from engine crankcase to be purged if it reaches the pump chamber.

Pulse Pump Weep Holes: There has been some discussion over the existence of a weep hole in fuel pumps. If you look very carefully, you should find a tiny hole (.017" or about 1/64" diameter) either in the indent on the rectangular pump or on the impulse boss on the round dual pump. [*See Figure 4.*] Rotax has issued a service bulletin claiming that all aircraft pumps must have this hole. This hole is there in case the operator installs the pump in such a way to allow fuel from the crankcase pulse line to fill the pump. This hole will allow the pump to purge the fuel rather than become inhibited with a blockage. The pump must be mounted so that this hole is at a low point. This will allow any buildup to be purged quickly. Theoretically, the fuel should never reach the pump if the pulse line is installed correctly. The line should run uphill at some point before reaching the pump, kind of like a toilet trap. I have heard unsubstantiated reports of drain tic changes in pump performance with the hole covered or not. The weep hole obviously compromises the pulse cavity of the pump with a "leak," although very small, leading me to think there may be some truth to this rumor. It would certainly make for some interesting test if someone wanted to take the time.

Regardless, in order to keep current with the bulletin from Rotax, we are carrying only the weep hole flavor. You should check with your favorite parts source when purchasing a new pump to see if they have the weep hole type. They can be hard to find and therefore could cost more. If you like, you can drill your own hole if you have the equipment to drill that small of a hole. Rebuild kits are available for most brands containing all diaphragms and gaskets, allowing you to zero time most any pump. This should be done annually to avoid dried out and/or cracked diaphragms or gaskets.

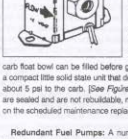

Figure #5 - Facet makes an excellent solid state fuel pump that uses 12 volts DC power to produce a constant 5.8 psi.

Electric Fuel Pumps: A lot of operators like the ideal of an electric 12-volt DC fuel pump. Starting is easier because the carb float bowl can be filled before grinding the starter. Facet makes a compact little solid state unit that does an excellent job of delivering about 5 psi to the carb. [*See Figure 5.*] Unfortunately, these pumps are sealed and are not rebuildable, making it a rather expensive item on the scheduled maintenance replacement list.

Redundant Fuel Pumps: A number of pilots have chosen the time-honored system of redundant fuel pumps. There is nothing to say you can't run both impulse and electric pumps on the same system. The proper way is to run the pumps in parallel rather than in series. Tee the fuel line out before the pumps, and back together immediately after the pumps. Because all pumps (and squeeze bulbs) have check valves for one-way action, a return to tank flow is not possible. [*See Figure 6 for circuit diagram.*] The electric motor should be fitted with a panel switch to allow the operator to prime the carb and to shut the pump down when not necessary. If the pressure of this dual system is too great, the carb overflow vents will signal this immediately. *What you are looking for is a fuel pressure from 3 psi to 5 psi at the carburetor.* Rotax has issued Service Information #S19 UL91-E dealing with the fuel delivery system, most of which is included in this article. There is also a test to determine proper fuel flow using the fuel consumption graphs versus a measured bleed-off pressure. This is a great idea if you are equipped with low-pressure gauges. Messing with the float level is never the answer. Periodic re-

placement of the needle float valve #261-705 may be necessary. The VITON tip can become worn or damaged. Close inspection under a magnifying glass is the proper inspection procedure. If the system continues to deliver too much pressure, a pressure regulator is the proper solution.

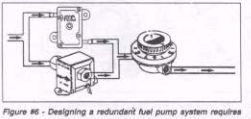

Figure #6 - Designing a redundant fuel pump system requires some special plumbing and equipment. Shown here is a parallel system that uses both electronic and pulse pumps with pressure regulator.

Figure #7 - Purolator makes an ideal fuel pressure regulator. The external dial allows you to dial a pressure from 1 psi to 5 psi.

Fuel Pressure Regulators: The Purolator Co. makes an adjustable fuel pressure regulator (CPS #8511) that can be adjusted from 1 psi to 5 psi. A simple turn of a dial gives you the pressure you want. With a dual system as already outlined, this pressure regulator is not only advisable but may be required. Install regulators in reach of the pilot immediately after the fuel pumps are returned to the same line.

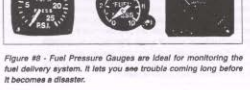

Figure #8 - Fuel Pressure Gauges are ideal for monitoring the fuel delivery system. It lets you see trouble coming long before it becomes a disaster.

Fuel Pressure Gauges: A growing trend is starting toward the use of fuel pressure gauges. While this is standard equipment on most general aviation aircraft, its use on light homebuilts is becoming more common. If a delivery problem is experienced, it will often show as a fading fuel pressure. There are two different types to choose from. Electric units run in the $250+ range due to the rather expensive and sensitive transducer needed to sample these low pressures. Recently we have been able to find some mechanical-type gauges that can be "hard plumbed" into the fuel lines. These units do not need 12 VDC to function and cost less than $100.

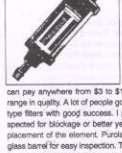

Figure #9 - Purolator makes an excellent filter with a replaceable screen. This type of filter must be safety-wired to prevent the thumb screw from vibrating down the threaded shank. See text for more on this situation.

Fuel Filters: Last in line before the carburetor is the fuel filter. You can pay anywhere from $3 to $15 for a fuel filter and get the same range in quality. A lot of people go for the less expensive snowmobile-type filters with good success. I prefer a unit that can be visually inspected for blockage or better yet disassembled for inspection or replacement of the element. Purolator makes a high quality unit with a glass barrel for easy inspection. The internal element can be removed for easy cleaning or replacement. A while back, a customer told us about a forced landing caused by this filter. The filter element is held in place on a threaded shaft by a thumbscrew. In this case, the thumbscrew vibrated back on the threaded shaft to a point where all four of the fuel inlet holes were blocked and down he went!

We have since published warnings in *Ultralight Flying!* magazine and send the unit out with a service bulletin to safety-wire the thumbscrew, a simple fix that in no way impairs the filter's performance. Check to see if you are running this type of filter and safety-wire it. *[See Figure 9.]*

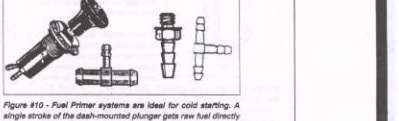

Figure #10 - Fuel Primer systems are ideal for cold starting. A single stroke of the dash-mounted plunger gets raw fuel directly into the intake area. A variety of fittings are available for easy access to the fuel line near the tank – dual carbs tees, and carb access fittings.

Fuel Primer System: Functioning as a parallel system, a fuel primer is standard equipment on most ultralights. Using a panel-mounted plunger (CPS #8613), fuel is delivered behind the carb slide to be drawn directly into the engine with the first rotation on starting. This setup can make cold starting a much easier job. It is also a great way to flood an engine. Dumping a lot of raw fuel into the lower end can foul plugs quickly if your ignition is not set to fire (switch off). Most new carbs are equipped with built-in ports, ready to accept the 1/8-inch inside diameter Urethane line (CPS #7015). There is some discussion as to the use of a fuel primer to diagnose a rich or lean situation instead of the choke or enrichener. [See Part #10, "Tuning the Bing Carburetor," July 1988.] You must remember that an enrichener valve is a metered extra rich fuel/air mix, while a primer plunger is raw fuel dumped into the intake area. Yes, they both will enrich the mixture, but the effect is nowhere near the same. Kind of like killing flies with a baseball bat. Sure it works, but there are more subtle and exacting methods.

Urethane Fuel Line: The proper choice of fuel line material is essential to safety as well as longevity. A clear blue Urethane line is the most common choice. The clear feature allows for easy inspection of fuel flow. The one-piece design cannot collapse without being seen on inspection, unlike a multiple ply hose. The Urethane is sometimes referred to as "lifetime fuel line" because it is totally unaffected by the fuel (it will discolor slightly). Almost without exception, most other materials will either react negatively with prolonged contact with fuel or degrade from the elements. Hose measuring 3/8-inch outside (1/4-inch inside) diameter seems to handle the fuel flow requirements of the bigger dual-carb engines just fine, and has become an industry standard.

Air bubbles in the fuel line are in themselves not dangerous, but do indicate a fitting or pickup line is sucking air. Trace the bubbles back to the source and check the joint for sealing. Tighten clamps or redo the joint until the bubbles cease. The bubbles will be vented harmlessly by the carb float system. Securing all connections with a proper clamp is essential. Just using the interference fit of a hose barb is asking for trouble. Squeeze bulb pressure can pull this arrangement apart. Using tie wraps to secure fuel line in place away from exhaust, etc. is okay only if you trim the excess immediately after installation. Long ends can be "tightened" for you, pinching the line off by some well-meaning individual.

Hopefully this rundown will give you some guidelines into avoiding the most common pitfalls associated with fuel delivery systems. A lot of time you are using off-the-shelf parts common to motorcycles, ATVs, and snowmobiles at a fraction of the cost of general aviation parts. There is nothing that says simplicity cannot function dependably when installed properly and maintained on a regular basis.

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