Falco Construction Note 61006-1

Fuel and Brake System Installation

This Falco Construction Note replaces Advanced Builder Memo "Chapter 43 Fuel and Brake System Installation"

Fuel System Design Notes

The fuel system on the Falco is deceptively simple. The complications arise primarily out of water-in-fuel considerations. Water enters the fuel system in two ways: from condensation in the tanks, or from a fuel truck. Water will settle to the lowest point, where it may stay. If water is in the lines, it will probably be pushed through the system while the engine is running. During cold weather, any water that is in the system can freeze and block the fuel lines. Remember that gasoline is a mixture of hydrocarbons and dissolved air. At high temperatures and/or high altitudes bubbles of vapor will form in the fuel as the higher fractions and dissolved air is released. The fuel system must be able to handle the vapor as well.

Most production Falcos had a single fuel drain on the firewall. Even though there was no way to drain water out of the low points of the system, we have not heard of this creating any problems. In the ideal fuel system, any water that is put into the tanks can be drained out of the system. This is not always easy to accomplish.

The Series IV Falcos had a low-point drain for the aft tank, located aft of frame No. 6 on the bottom of the fuselage. While shooting touch-and-goes in Oslo, Norway, one of these Falcos was landed with the gear up. The aft tank was empty, but there was a small amount of fuel in the low-point drain. The drain valve became hot from the friction with the runway, and a fire resulted. The pilots were unharmed, but the aircraft was destroyed by the fire. All belly drains should be flush, partly to keep the aerodynamic drag down and partly to avoid a repeat of this scenario.

The usual method of collecting water at the lowest point in the aircraft will be defeated by inverted flight if all water is not drained off before flight, since an upside-down gascolator with water in it will dump water into the fuel line. Pitts, Christen Eagles, and other competition aircraft use a paper type filter which will not allow water to pass. These aircraft are usually single tank aircraft. Water in the system backs up at the filter, and if the filter becomes saturated with water, the engine begins to stumble, but experience has shown that it does not quit precipitously.

The Falco fuel system makes maximum use of nylon tubing. The use of nylon tubing is discussed in some detail in Chapter 41 "Engine Installation." Nylon tubing makes the installation much easier. Running the line from the aft tank to the fuel selector valve in aluminum is extremely difficult, and it is a relatively simple matter in nylon tubing.

The fuel selector valve that we use has brass automotive compression fittings. The fittings are flareless fittings, so all you have to do is to put in the tubing and tighten the fitting. You must be very careful to push the tubing *all the way in* so that the ferrule is over the tubing. If you don't get the tubing all the way in, you will have a slow leak. It is a good idea to mark the tubing with a felt-tip pen so that you can see if the tube has moved while you tighten the fitting.

Front Tank to Selector Valve

The tubing to the fuel selector valve should run "uphill" enough so that any water will flow to the sump and not to the fuel selector valve. The Falco sits on the ground in a nose-high attitude. Ordinarily, it is considered best to have fuel lines either running downhill or uphill. The idea is that you do not want to create a high point for fuel vapors to collect, but this is not always possible. As shown on the drawings, this segment of the fuel system is not ideal, since the line doesn't go "uphil" as much as you would like. It's possible to make P/N 740-2 taller, but this would put it close to the sharp-pointed screw for the throttle quadrant cover. Remember that this tube must be below the arms of the throttle quadrant.

The sump drain installation is a devilishly clever method devised by Karl Hansen. A piece of aluminum is drilled and tapped with the 1/8" pipe threads of a Saf-Air CAV-110 drain valve. The pipe threads are just large enough so that the plate will bottom out on the hexagonal part of the drain valve. A fitting with 1/8" female pipe threads is screwed in place and down tight on the aluminum plate. The plate is then installed on a block of wood on the bottom of the airplane.

Header Tank

The header tank design that we use is a type that has been developed by acrobatic pilots over the years. The particular design that we have was developed by Henry Haigh for use in the Pitts. The Pitts has a single tank which is wider than it is tall. As a result, about 6 or 7 gallons of fuel must be carried by acrobatic pilots to be assured of a continuous flow of fuel in all attitudes. The header tank was developed to allow competition pilots to take on board only the fuel needed for a short competition routine plus a small reserve. The tank that we use is a version of the Pitts header tank, but made for the Falco.

In normal flight, the header tank receives fuel from the aft tank via a 3/4" hose. The reason for the large hose is to allow the tank to refill itself quickly during periods of normal flight. A 3/8" vent return line allows the displaced air to return to the aft tank.

The header tank has a flop tube, which is a standard Pitts flop tube. During inverted tank, the flop tube follows the fuel to the lowest point. The 3/4" supply line now becomes the vent line to the aft tank. The 3/8" vent return line is now at the bottom of the tank. A gravity-operated check valve is installed in the vent return line to keep fuel from flowing back to the main tank, emptying the header tank. The check valve is nothing more than a steel ball in the vent return boss on the top of the header tank. During inverted flight, the ball seats in the 90° fitting in the boss, sealing the tank from draining.

To help you understand the operation of the header tank, it would be a good idea of do a series of drawings of the aft fuel tank and the header tank. Show the aft tank half fuel of fuel, and draw in the fuel at various flight attitudes. Be sure to show straight up, straight down, inverted and erect flight. Note that fuel will seek its own level, so be sure to show the fuel in the overboard vent line and in the vent return line. Also try to imagine the fuel rushing through the tubes as the flight attitude is changed.

Note that the vent fitting for the aft tank is located at the top front. For this reason, the overboard breather line should run aft and down behind the tank. In inverted flight, fuel in the aft tank will flow into the overboard vent line. On return to normal erect flight, some fuel may be lost overboard. This will be minimized with the routing of the line to the aft of the tank.

Warning

It is essential that the vent return line from the header tank be routed to the top of the aft fuel tank and connected there with a tee fitting. One Falco builder, John Harns, failed to connect the vent return line to the vent fitting of the aft tank. Instead, he looped the vent line from the header tank over the aft tank (without any connection) and then out of the bottom of the airplane. Thus, he reasoned, he now had two vent lines! The result was predictable—after aerobatics, the fuel from the header tank and aft fuel tank was syphoned out of the airplane. Once the header tank vent line is filled with fuel, it will syphon all of the fuel out of the aft fuel tank and the header tank. This is the same as putting an open drain in the bottom of the header tank. *Don't even think about doing this; it is extremely dangerous.* With the vent return connected as shown in the enclosed sketches, it cannot syphon. This system has been used for years on the Pitts and many other acrobatic aircraft. Don't change it!

Overboard Vent Lines

The vent lines for the tanks are an important part of the fuel system. As you draw fuel out of the tanks, air must flow into the tanks to replace the lost volume. Without vents, the tanks will collapse—the engine-driven fuel pump has enough power to suck the sides and bottom of the tanks in.

The vents for the tanks should be located on the bottom of the fuselage or wing. There will be times when fuel will run out of the tanks, so you will want the vents in a position where the fuel will drain safely out. The fuel and vapors coming out of the vents is a combustible mixture. Clearly, you want to make sure that the vents are located in a position where they will not ignite.

The main thing to worry about in this regard is the exhaust pipes. Under ordinary circumstances, the vents will not be bothered by being downstream of the exhaust, but if the engine backfires, the consequences could be serious. We think that the best thing to do is to install the vents out in the wing. This way they are away from the exhaust.

It is best to have the vents in a high pressure area. The normal procedure is to put the vent on the bottom of the wing, extending below the wing by a couple of inches. The bottom of the tube is cut off at 45° and placed so that the air stream forces air up into the tube. On the aft side of the tube, a .063"Ø hole is drilled in the tube. This is the type of vent that is installed on the Beechcraft Bonanza. In the event that the vent is covered with ice, the small hole acts as the vent. Since it is on the aft face of the tube, it does not accumulate ice. Because the hole is very small, it does not affect the positive pressure generated by the air stream. This type of vent is one of proven technology. We know that it will go against the grain of many Falco builders to hang a tube out into the air. It will cause some drag, but this type of vent is used on a lot of fast aircraft, including the SF.260.

Another method is that used on the Mooney aircraft. Their fuel vents are small NACA flush inlets located on the bottom of the wing. The inlets do not go anywhere, and the vent is located in the closed off "inlet". Apparently, ice does not collect inside this "inlet".

Some Falco builders have placed the vents on the aft face of the aft wing spar. Two vent lines are glued into the wood, and the tubes "daylight" on the aft face of the spar. Both vents may located on the same side of the aircraft, or one vent may be located in each wing. While we have no proof that this is an area of positive pressure, we suspect that it is. So far, we have not had any problems with this type of vent. A screen may be installed to keep bugs out, since bugs can—and do—clog fuel vents.

One builder installed the screen with silicone rubber RTV compound. Unfortunately, a small amount of this compound got in the vent for the front tank and clogged it. As a result, the front tank was partially collapsed before the problem was found.

You should check to make sure that each tank is vented and that the vents are open. To do this, stuff a rag around a hose and put it in the tank filler neck. With an assistant blowing in the hose, you should be able to feel air coming out of the vents. You can use an air hose, but it should be used with extreme care, since an air compressor can generate a lot of pressure and could burst the tank.

Firewall Forward

The electric fuel pump is installed on the far right side of the firewall and the gascolator is installed just to the right of the cabin heat valve assembly. As with the previous arrangement, the rudder pedal support brackets are used for the support fittings.

The gascolator has a 100-mesh screen and a sediment collection bowl. Pulling up on the knob on the top opens the drain valve at the bottom.

The fuel line from the firewall bulkhead fitting to the gascolator is a short piece of aluminum tubing. The AN833-6D bulkhead fitting must be turned so that it faces up and slightly outboard. The fitting is installed in the gascolator is turned so that it faces down and slightly aft.

The electric fuel pump is a Weldon C8100E pump, available from Weldon Tool Company. See the F.8L Falco Kit Price List. You can expect the price of the pump to change each November 30—the time at which their union contract changes. This pump is a high pressure pump for injected engines only. A similar pump is made by Dukes and has been used on Mooneys and Pipers. Mooney found that the pump had a tendency to throw blades and self-destruct. As a result, they went to a Weldon pump. For this reason, we recommend only the Weldon pump. Both the Weldon and Dukes pumps are designed so that fuel will flow through them even when the pump is off; therefore, no bypass plumbing is required.

The Weldon pump has inlet and outlet ports with female .5625-18 UNF-3B threads per MS33649-6. A standard AN815-6D flared-tube union is used with an O-ring for a static seal.

The engine-driven fuel pump's inlet port is specified as .5625-18 UNF-2B, and a note on the Lycoming installation drawings says "Do not install flared tube fitting end in fuel pump ports". Apparently, the problem is that the pump does not have sufficient internal clearance for the flared-tube end, so if a fitting like an AN815-6D is used, the flared tube end must be machined off. The need for a special type of fitting arises because the fuel pump in an automotive pump. The required fittings are made by Weatherhead, Parker and Flo-Dan, and are also sold by Lycoming using a Lycoming part number.

It appears that the simplest installation is as shown iin the drawings, using a 45° fitting in the inlet to the engine driven fuel pump. When you order your engine, specify a 45° fitting. Failing that, you can get a Weatherhead P/N P/N C5365x6, which is a 45° fitting and includes an O-ring. (In case you want to change the design, Weatherhead P/N P/N C5315x6 is a straight fitting, P/N C5515x6 is a 90° fitting of the same type.)

Weatherhead fittings are widely distributed. They are used in many industrial and automotive applications. You will find that your local FBO will be able to purchase the fitting used on a Piper, Cessna or Beech through the normal channels. If you want to purchase the Weatherhead fitting yourself, then you should write or call Weatherhead for the name of a distributor near you. The address is: Weatherhead Company, Sub. of Dana Corp., 302 East 131st Street, Cleveland, Ohio 44108. Telephone: (216) 449-6500. Don't say you are building an airplane. You will probably be treated like a leper.

The drawing show two hose assemblies which are normally supplied with the engine. These hose assemblies are sometimes missing from the engines, and details are provided so you can make your own.

Production aircraft are now required to use fire sleeves over all hoses in the engine compartment. This adds to the expense and weight of the installation, and to the bulk of the hoses since it increases their outside diameter. The purpose of fire sleeves is to give you about 4 minutes of additional time in the event of an engine fire. Most homebuilt aircraft do not have such hoses installed, and many older production aircraft do not as well. Certainly, there can be no argument that using the fire sleeves will increase the safety of the aircraft in the event of an engine fire. You can be your own judge and install the fire sleeves as you wish.

Silver Fuelgard Transducer

The transducer for the Silver Fuelgard is supposed to be installed between the electric fuel pump and the engine-driven fuel pump. On Continental engines, it is installed between the injector body and the spider. The Continental system has a fuel return line, so this is the only place that the sender will read accurate information. On the Lycoming engines, the FAA is worried that the pressure drop across the transducer might affect the performance of the engine.

Karl Hansen installed his transducer on the firewall between the electric and engine-driven fuel pumps; however, vibrations generated from the electric fuel pump cause his fuel totalizer to indicate high. This and the difficulty of locating the transducer on the firewall makes the installation between the injector body and the spider seem more attractive. We are not aware of any problems with Continental engine installations, and we have come to the opinion that the transducer should be installed between the injector body and the spider. If you agree with this assessment of the situation, then you should install the transducer as shown in the drawings.

Brake System Installation

The brake system on the Falco is fairly typical of light aircraft. To simplify the installation, we will be using Nylo-Seal nylon tubing. The installation of this system using aluminum tubing is a true nightmare. Tony Bingelis installed the lines in aluminum, and it took him something like 18 hours just to run the tubes. This involved a lot of fitting, bending, checking the bends, etc. In the end, Tony got disgusted and ripped all of the aluminum tubing out of the airplane and installed nylon tubing.

The only unusual thing about our installation is that the parking brake valve is not set up for this type of tubing. We use a Cleveland parking brake valve. As received, the valve has two flared tubing fittings installed. These fittings are an integral part of the valve design, as they are counterbored for springs. In order to use the nylon tubing, we have substituted flareless Swagelok fittings. These have to be counterbored for the springs. To complicate matters, the inside diameter of the Swagelok fittings is larger than that of the flared tube fittings, so we have to install new springs. We also install an extension arm and a knob.

The master cylinders for the Falco are Cleveland 10-46 cylinders. These do not come with the clevis, P/N 143-10, which must be ordered separately. These have the ports perpendicular to the 3/16" hole at the lower end. This is essential to place to ports facing up-and-aft. If the ports face outboard as originally intended, the fittings will hit the fuselage side walls.

The reservoir we supply in our kits is a Volkswagen brake reservoir. This plastic reservoir is extremely light, and it simple to install with a strap clamp. There is some risk that the FAA inspectors might object. Normally, they do not like to see any plastic in front of the firewall. On all of Falcos built so far, inspectors have not objected to the nylon line for the brake reservoir. We do not see that it creates any substantial risk to the pilot of the plane. The only way that we can see is that in the event of sustained inverted flight after an in-flight engine fire, you might not have brakes.

The routing of the tubing past the rudder support bracket (P/N 761) is something of a problem. The best solution is to pass these tubes through the bracket. This is shown in Detail A of Drawing No. 154.

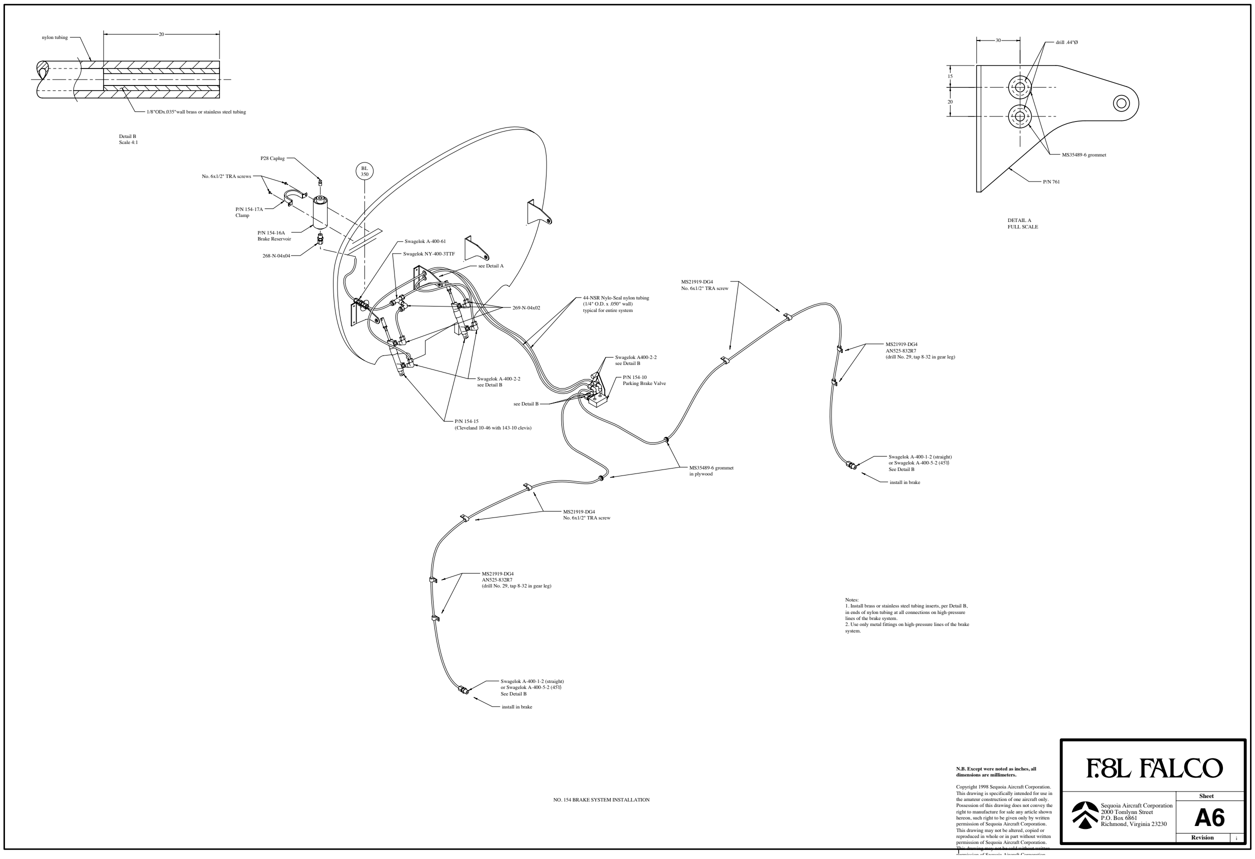

Figure 1. Drawing No. 154, Brake System Installation

The tube from the reservoir passes through the firewall with a normal bulkhead fitting. This line must be routed to both of the cylinders, so you must split the tube in two directions. There are several ways to do this. The method shown uses a Swagelok tee, with the female pipe thread on the branch. By installing a 90° fitting in the branch, these two fittings can be tied to the left rudder torque tube, and the tubes to the left brake cylinder can be lashed to the torque tube rather neatly. Dave Aronson did not have a Swagelok fitting, and he did the installation with the 264-N-04 union tee shown as an option. While this workes, it is not as neat an installation as the two fittings.

At the landing gear leg and arm, Dave Aronson routed the tubing down the inboard face of the gear. On the original production aircraft, this was done of the outboard face. The only difference that we can see is that the tubing takes a sharper bend (when the landing gear is up) if you route it on the inboard face.