How the 'Uniflow' Fuel System Setup Works

by Nigel Fraser Ker

Introduction

The 'uniflow' fuel setup for glow powered models is an ingenious way of ensuring that fuel pressure at the engine's carburetor does not vary with the amount of fuel in the tank (yes, it will still vary with muffler pressure but more about that later). If your engine works fine then I would leave your setup alone! However, if you suspect that your engine runs lean towards the end of the tank, you should consider uniflow as a possible solution. Although a very simple design, it's not immediately obvious how it works so I have written this explanation in the hope that it will be helpful.

What is it?

The uniflow fuel system is one where there are three connections to the fuel tank - one is a breather to the top of the tank (normally blocked off) and the other two are clunks - one coming from the muffler and one going to the engine (or header tank if fitted). This configuration means that the column of fuel in the tank is supported by atmospheric pressure and therefore its level does not affect pressure at the carburetor.

There are two ways of explaining how uniflow works. read on...

First Principles

Before I get down to a detailed description of the uniflow system itself, let's go through a few basic principles of fluid mechanics. We will need to talk about fuel pressure and a convenient way to refer to it here is in terms of 'inches of fuel'. For example, look at Figure 1 where we have a fuel tank which is 2 inches high and which is full of fuel. We can say that the pressure of the fuel at the bottom of the tank (Point A) is 2 inches because it will support a column of fuel two inches high. We can prove this by adding a tube to the bottom of the tank and seeing how far up the tube the fuel will be pushed. Of course, it will rise to be level with the liquid in the tank.

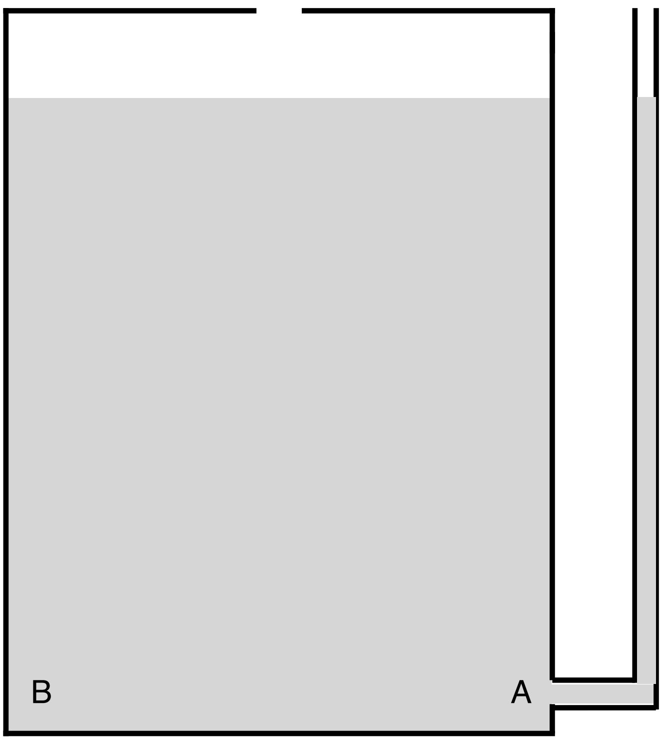


Figure 1

It is important to realize that the pressure at any level in a static liquid is exactly the same at any other point in the liquid at the same level. Thus, the pressure at Point A is the same as at Point B.

Another important point is that this pressure is defined in relation to the atmospheric pressure that is all around us. The actual pressure at Point A is defined by the rather unscientific equation:

2 inches of fuel + the barometric pressure that day = a heck of a lot!

Fortunately, we don't have to worry too much about this but atmospheric pressure does have an important part to play in this system. Most fuel tanks have a vent or breather of some sort at the top to allow air in as the fuel is used. Looking at Figure 1, if we were to block this breather, fuel would not be able to get out of the pipe at Point A because the atmospheric air pressure will push it back and prevent a vacuum being formed at the top of the tank. You may have heard the saying "nature abhors a vacuum"!

Getting the Fuel to the Engine

Let us imagine that the engines in glow-powered models were always below the fuel tank. In this scenario we could rely on gravity to supply the fuel to the carburetor. However, this simple system causes two problems.

The first is of course is that the engine will not get any fuel if the model is an aircraft and it flies inverted. The clunk in the tank ensures that the line falls into the fuel (wherever this happens to be) but this will not help if the fuel has to run uphill to get to the carburetor. This is why we connect a pipe from the muffler on the engine to a breather at the top of the tank - this creates a little pressure in the tank which pushes the fuel up the fuel line to the engine. To give you an example, on a recent test on my 54-sized four-stroke engine, at full throttle the pressure produced by the muffler was sufficient to support a column of about 5 inches of fuel. In other words, the carburetor could be 5 inches above the level of the fuel in the tank and still work okay.

The second problem is that even if the muffler pressure is constant, the fuel pressure at the carburetor will vary because when the tank is full the pressure will be high and when the tank is nearly empty the fuel pressure will be low. This is a nuisance because if you set the engine's needle valve correctly for a full tank it will be slightly wrong when the tank is empty and visa versa. Any engine without a separate fuel pump or uniflow setup will suffer from this problem and you sometimes hear people complain that their engine runs lean as the tank empties.

The Uniflow Setup

Now imagine a situation (see Figure 2) where both the breather (at Point B) and the line to the engine (at Point A) are situated at the bottom of the tank. This diagram gives a simplified purely schematic version of the uniflow setup.

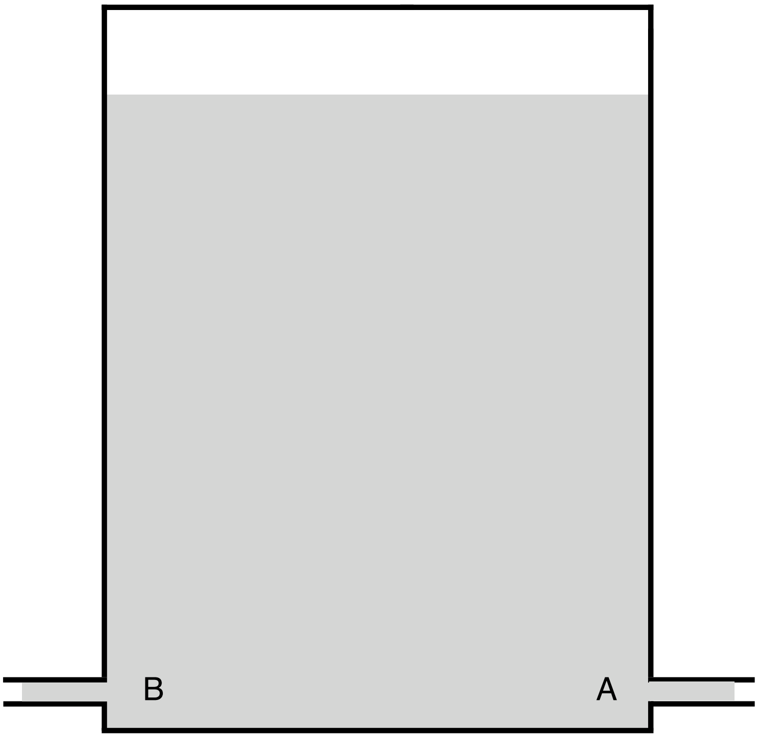
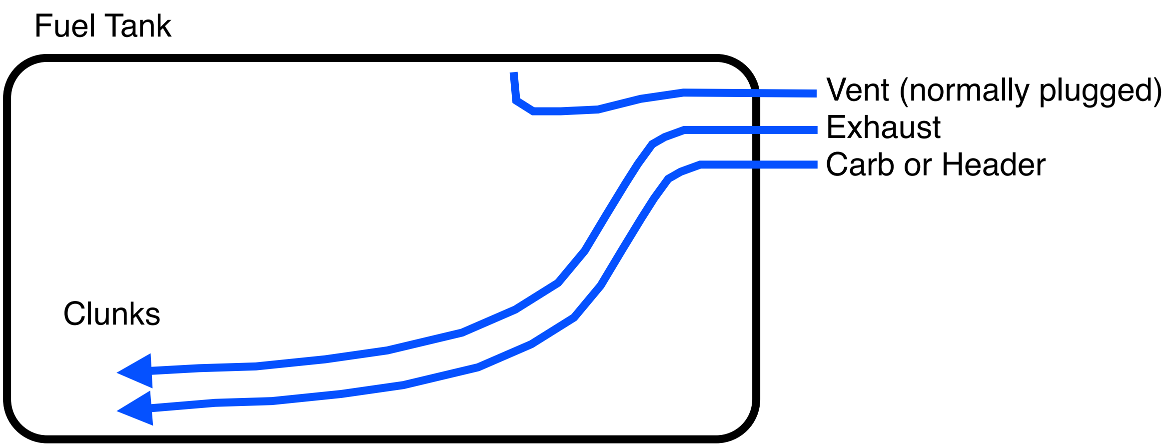


Figure 2

Remember our basic principle (above) that the pressure at Point A is the same as at Point B as long as it is at the same level. Therefore, if the pressure at the breather (which is connected to the muffler) is, for example, 5 inches of fuel, then the pressure in the pipe to the engine will be the same. The fuel in the tank cannot run into the engine under gravity alone because to do so, a vacuum would be created in the area at the top of the tank - atmospheric pressure prevents this happening. Instead, fuel is supplied to the engine only at the pressure supplied by the muffler - as the fuel is used, gases from the muffler gradually bubble in to fill the tank. The neat part about this is that it doesn't matter how much fuel there is in the tank, the delivered fuel pressure will always be the same as the pressure in the pipe from the muffler. Therefore, you can set your mixture setting safe in the knowledge that it will not vary depending on the amount of fuel in the tank. Note that neither the standard setup nor uniflow will prevent the pressure changing with the revs. However, although this is less noticeable (and therefore works best) on models where the revs stay relatively constant, e.g. on helicopters, it will always be better than having not having the uniflow setup at all.

The way that the uniflow tank setup is put together in practice is as follows…



Hold on, what's the vent for?

Yes, you do need a vent at the top of the tank to let the air out when you are refueling. However, this is normally blocked off with a plug.

A more practical explanation...
When people ask me about the uniflow setup, I sometimes find it is easier to describe it in practical terms so let me try to explain it this way...

Find an old coke bottle or something similar to represent the fuel tank. Fill a sink full of water and put the bottle into the sink and allow it to fill up with water. Then, keeping the bottle's opening submerged, turn it upside down and lift it out so that just the opening is under water. The bottle remains full of water. Why doesn't the water drain out? Well, this is because the atmosphere is pushing on everything all around us including the surface of the water in the sink and, although this is difficult to imagine, this is keeping the water in the bottle. In fact, the atmosphere (at sea level) pushes hard enough to keep the water in a bottle that is up to 32 feet high! If the bottle was taller than that, a vacuum would be formed at the top because the weight of air above us isn't sufficient to support any more. In fact, this is why water pumps in mines are situated underground rather than on the surface (unless it's a very shallow mine!). It is also the principle behind how mercury barometers work except that since mercury is so much heavier that water, atmospheric pressure will only support a column of mercury about a meter or so in length. This is lucky because otherwise barometers would be so tall you wouldn't be able to fit one in your hallway! Anyway, getting back to our upside-down bottle, if we want to get the air out, we have got to push it out with compressed air. Fortunately, we live at the bottom of a sea of air that is conveniently at the right pressure to do this. Therefore, if we bubble some air into the bottle with say a drinking straw, the same amount of water will come out. Try it, you'll see what I mean.

What I am trying to get at here is that it doesn't matter how much fuel you have in the tank, if air can't get in then the fuel inside isn't going to come out. Now, take a look at another couple more examples...

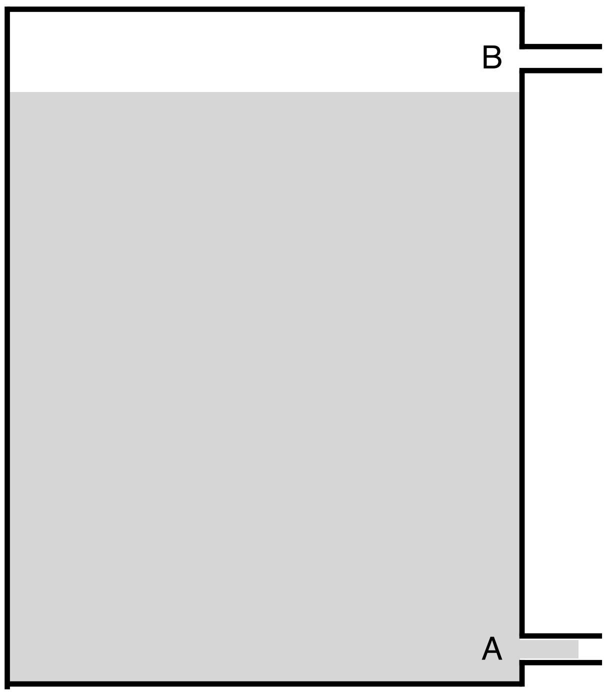


Figure 3

Look at the fuel tank in Figure 3. Assuming that the outlets are not connected to anything and are open to the air, fuel will drain out of the pipe at Point A quite quickly and this will gradually decline to a trickle as it runs out. Going back to a full tank again, if we blow into Point B, fuel will spurt out of Point A even faster than before and as the tank empties, although the flow will gradually slow down, it will not get as slow as it did when you weren't blowing. What is happening here is that there are two forces at work. First of all there is the pressure of the weight of fuel which gradually decreases as the fuel runs out. Secondly, there is the air pressure at Point B. In the first situation it was open to the atmosphere so it was exactly balanced by the air pressure at Point A so it made no difference.

However, in the second example, you blew into Point B creating a pressure difference between the two outlets and this pushed the fuel out faster. Had we blocked Point B, no fuel would have come out at all because it will be held back by air pressure just like the upside-down bottle in the sink.

Now let's look again at the simplified uniflow setup.

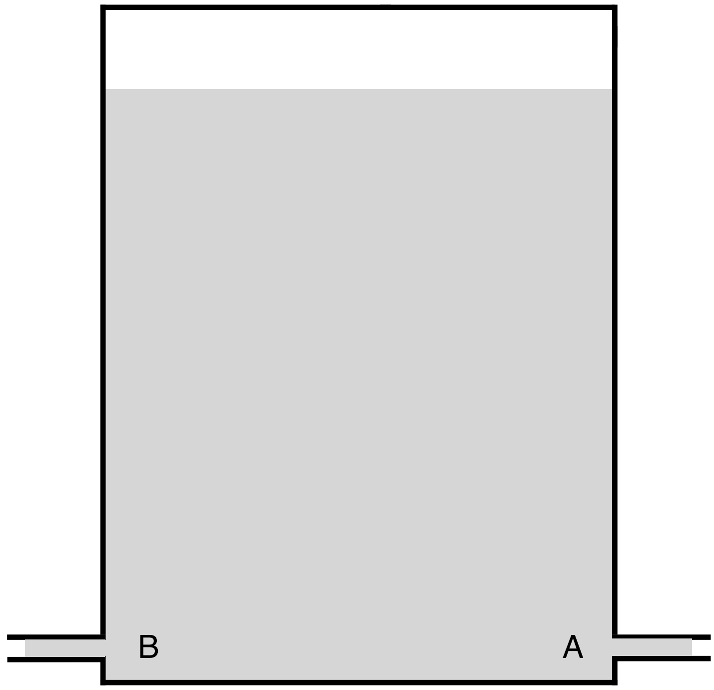


Figure 4

Here, no fuel can get out of Points A or B (provided they are at exactly the same height) because the atmosphere is pushing the fuel back. If we now add a little pressure to Point B then the same pressure will 'appear' at Point A. The level of the fuel in the tank will make no difference. The fuel tank could be be ten feet high and the pressure would still be that applied to Point B.

What about carburetor 'suck'

A lot of people talk about carburetor suck and say that this is what feeds the engine. Well, all I will say is that in a closed system like the fuel system on most glow-powered models, the 'suck' from the carburetor and the blow from the muffler amount to the same thing. The 'suck' that people refer to is really a lowering of pressure in the carburetor in relation to atmospheric pressure and gives almost precisely the same effect as a little more muffler pressure. As stated at the beginning, the uniflow system only eliminates the effects of the changing level of fuel in the tank.

If the pressure at the carburetor varies with revs, what's the big deal?

Well, the 'big deal' is that when you are setting the needle valve on your engine, you are doing so with a specific amount of fuel in the tank and as soon as that level changes, the pressure at the carburetor will change and therefore the mixture will change slightly. How many times have you heard people say something like "I always let the engine run a little rich just in case..." What the modeling community have learnt over the years is that engines tend to run a little lean as the tank gets empty and that by setting the needle a little rich when they are 'fine tuning' the engine just before take-off (i.e. with a full tank of fuel) that they are making allowances for the leaner mixture as the tank empties.

I don't need the uniflow system - I have a header tank

I have spoken to some people (particularly aircraft modelers) who believe that by mounting the header tank higher than the main tank, this will create more fuel pressure into the carburetor. However, this is not so because since it is a sealed fuel system, the weight of the fuel in the pipe leading up to the header tank tends to reduce the pressure in the header tank and thus the pressure at the carburetor.

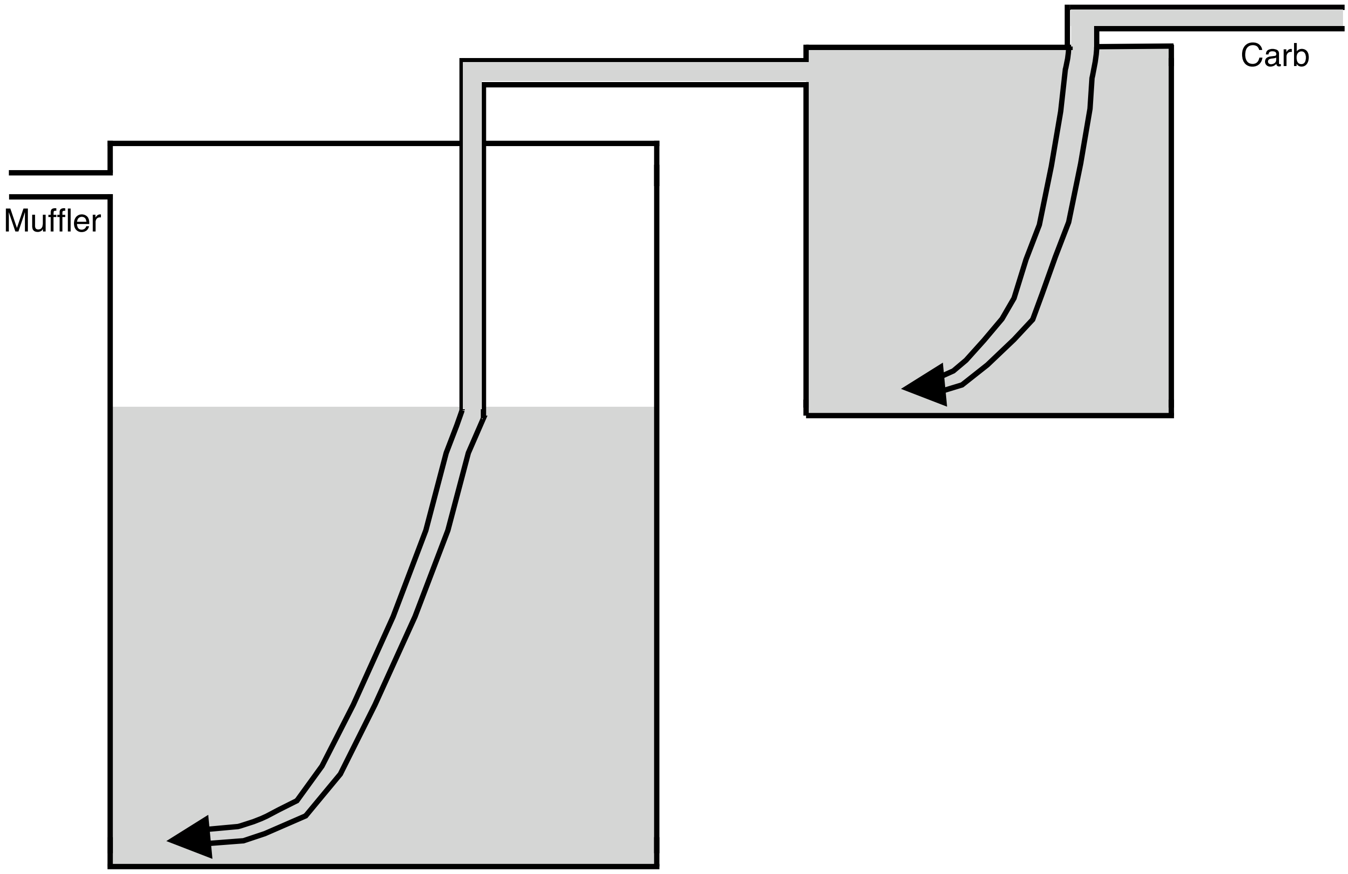


Figure 5

It works rather like a siphon in reverse. See Figure 5 (note that this is a standard setup but the following is also true for a uniflow). When you used a siphon to get fuel out of your dad's car, you dipped a plastic tube down into his tank and sucked until the pipe was full of fuel (trying not to get a mouthful of gas!). You then blocked the end of the pipe with your finger and lowered it into your can so that the end was lower than the level in his tank. The fuel magically flows from his car into your can! Unfortunately, the same thing happens with a header tank that is higher than your main tank so you have to use the muffler pressure to overcome the weight of fuel in the pipe. The idea that a header tank gives you more fuel pressure is a myth.

Note: If you run a header tank (that is higher than the main tank) and you run the main tank dry at the end of the run, at the point where the fuel in the main tank runs out, the mixture will actually richen because the siphon effect will stop.

So what good is a header tank?
Header tanks, which are often used on model helicopters, are a great way to ensure that you have bubble free fuel right to the end of your main tank. If you don't have a header tank, as the main tank gets empty, there is a danger of getting bubbles in the fuel line as your model bounces around, churning up the fuel. With a header tank, your source of supply is always nearly completely full of fuel and therefore you get a nice clean supply to the carburetor. Any bubbles that do come through from the main tank simply bubble harmlessly to the top of the header. Some people advocate the use of a straight piece of pipe going into the centre of the tank as the pickup instead of a clunk. The idea is that there are no bubbles in the middle of the fuel so it must be a clean supply. This sounds okay but you do lose the benefit of the extra fuel sitting at the bottom of the tank so I do not recommend it.

If you have a header tank and you really want to go all out to eliminate variation in fuel pressure, you could add a second uniflow setup to that one too! However, it's good practice never to run the model's fuel so low that the header starts to empty so really, a uniflow setup in the header should be unnecessary.

Do the two lines in the tank get tangled?
In my experience the answer to this question is no. I have yet to experience a problem with the lines in the tank getting tangled or hear of any problems of this kind from anyone else. I believe this is for two reasons. First, the lines are made of silicon tubing which tends to resist tangling. Second, the forces on the two clunks are the same so they will always tend to be thrown to the same part of the tank. All tanks are different so my advice would be to test your tank manually before fitting it into the helicopter. Shake it around and check that the lines are free to move and settle neatly at the lowest point in the tank.

What about when you fly inverted?
During inverted flight, the clunks fall down to the 'top' of the tank and the system works the same way as in normal flight.

What about fuel pumps and regulators?
Any system that is going to deliver a constant flow of fuel to the carburetor without any variations due to fuel level, yaw rate, orientation, etc. has got to be a good idea. However, if you're going to use a pump, be careful to filter the fuel that goes into them as they are quite sensitive to dirt. Otherwise, if they're good enough for the top boys, they're good enough for me. See here for a glimpse of Curtis Youngblood's setup. (Note: At the 3D Masters 2004, I noticed Kazuya Yamaguchi was running an Iron Bay fuel regulator.)

Are there any downsides at all?
There are two downsides to the system...

First, in theory, it is possible that if the engine is suddenly cut from full throttle to idle, that the carburetor could run rich for a fraction of a second. The theory goes like this... At full throttle the tank is being pressurized to its greatest extent. If the engine is suddenly cut to idle, the pressure at the muffler is also cut and the pressure in the tank will want to 'get out' - i.e. equalize with the surrounding atmosphere. There are two ways it can do this - either via the carburetor or the muffler. On a conventional setup, the pressure can get out more easily through the muffler than the carburetor because the line is full of gas. In the uniflow setup, the line is full of fuel which is more viscous than the air and is therefore more difficult to push out. The result is that for the fraction of a second while that tiny bit of fuel is pushed back up the muffler line, the mixture will be slightly richer than it would normally be. However, in practice the volume of air that wants to get out of the tank is so miniscule that the pressure will be very quickly equalized. I have yet to find anyone notice let alone complain about this effect. If it was a problem, I would recommend that a slower servo be placed on the throttle control unless a similar effect could be achieved electronically.

The second problem is that since the top of the fuel tank is sealed, when the aircraft is in the pits, i.e. not flying, it is quite possible for the vapor pressure of the fuel to start to push the fuel into the muffler. This can be a nuisance if the muffler is below the level of the tank because once the flow of fuel starts, it will carry on under siphon action. I get over this simply by placing a fuel clamp on the line which I engage when I'm not flying.

An Example - Fitting a uniflow system to a Thunder Tiger Raptor 30 Helicopter*
If you take a look at the fuel tank in a Raptor, you get a built-in vent (which by its design can only be used for that purpose) and a bung which has only one pipe going through it - rather inconvenient if you want two pipes with clunks. This is how I got around the problem. I used a lathe to turn up an aluminum bung with an outside diameter of 5/16" to go through the rubber grommet. Then I used a milling attachment to drill accurately two holes 73 thousandths of an inch either side of the centre of the new bung to accept some small annealed copper tube. I then glued them in from the back with two-part, high strength epoxy. This is the result...

Note that because of the extra length of the brass tubes, you would be wise to use extra-flexible silicon tubing to ensure that the clunks fall correctly to the bottom of the tank (in whichever orientation the tank is placed). Note also that in the right-hand picture, the grommet is temporarily off the aluminum bung, ready for insertion into the tank. There is very little room to play with when you come to install it.

History
Someone has asked me if I know who invented the Uniflow system. I have even been asked if it was me - sadly not! The (as yet unconfirmed) answer seems to be that it was invented by a French cleric by the name of Edme Marriott who lived in Dijon in the 17th Century. If anyone knows the details of the work in which he published this idea I'd be glad to hear about it.

Finally...
Well, that's it. I hope this explanation has been of help. If you have any suggestions or corrections to the above, please let me know at helilessons@gmail.com.

For additional reading see Model Helicopter Technique;
Vol. 2 No. 3 Page 12
Vol. 2 No. 4 Page 32
Vol. 3 No. 3 Page 37

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