Fuel Management

This short article was written for the PPL/IR Europe magazine in November 2007.

All my contacts with other PPLs suggest that fuel management is poorly addressed in PPL training, and my own experience confirms this. However, there is a justifiable reason for this practice: the aeroplanes are generally old, few of them have any fuel flow indication, and fuel gauge accuracy usually verges on useless. As a result, PPL training practices err on the safe side and most flying is done with the mixture set to fully-rich and few pilots are taught about leaning. Much reliance is placed on using ground based logs of flight times to determine the remaining fuel on board (FOB); this generally works because conservative fuel consumption figures are used and most training flights are short. The downside of this system is that a large part of the aeroplane's real range is not available and a pilot wishing to embark on a long flight is venturing into unfamiliar territory, and quite spectacular fuel planning related incidents do happen.

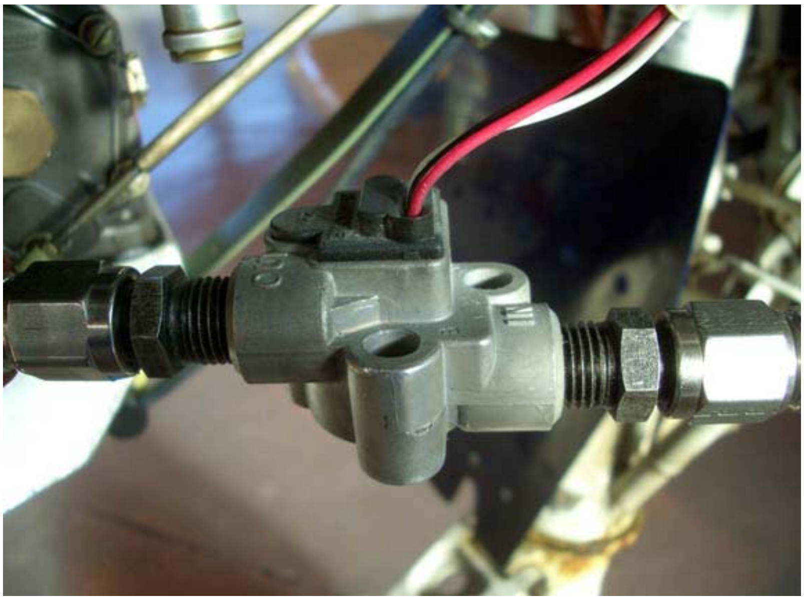
One way to find out the actual fuel consumption is to look into the Pilot's Operating Handbook (POH; also known in US aviation speak as the AFM). However, for the typical training aeroplane's engine which has been around the clock several times, this data will bear only a passing resemblance to reality and on occassions the prop actually fitted is not the one which the POH data refers to. In any case the POH assumes that there is a method for setting the engine to the specific operating point; for example peak EGT. In all my training I never saw an EGT gauge, and the only method offered was to lean until the RPM drops, then advance the mixture a little, and apply carb heat to ensure the RPM still drops when carb heat is applied. I wouldn't like to guess how accurate this method is but I think one would be lucky to get within 20% of the book fuel flow figure.

On such an aeroplane, there is only one way to determine the actual cruise fuel flow and that is to do two flights, with identical climb/descent profiles but with the cruise sections differing by say 1 hour. Starting each flight with an accurately filled tank, and filling to the same point afterwards, one can easily work out the difference between the two flights. The process should be repeated at several different altitudes. All one then needs is consistency in setting the engine operating point... Pilots who are renting have little choice but for the others there is fortunately a much better way.

The Electronic Fuel Flowmeter

Liquid flow measurement is a very old craft with many methods ranging from mechanical to ultrasonic/doppler, but the several products on the aviation market use a miniature turbine which contains a magnet and the passage of the magnet past a fixed coil generates a pulse which is amplified, shaped and sent to a panel mounted instrument which converts the pulse rate to a direct indication of fuel flow in litres or gallons per hour.

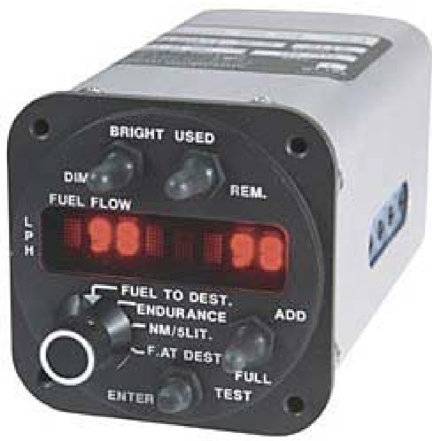
Most if not all products used in GA use a turbine sensor made by Flo-Scan, P/N 201B



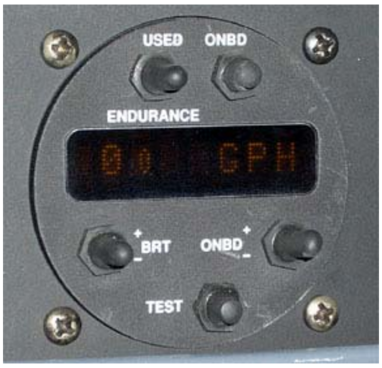
which was designed for the boat business and is resold with “aviation paperwork” and at the customary inflated price by the flow indicator manufacturers. The 201B generates around 30,000 pulses per USG/hour; the actual figure (called the “K-factor”) is supposed to be individually measured and marked on each unit. This K-factor is configured in the instrument, and the result should be an accurate fuel flow indicator system.

The K-factor is configured using some method documented in the Installation Manual and it may not be legal for the pilot to do this himself.

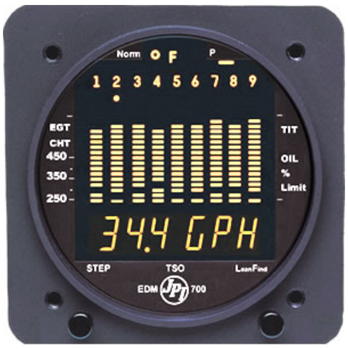
Several panel mounted indicator instruments are available. The leading maker of dedicated flow indicators is Shadin, whose Microflo product is probably the most popular retrofit; the following illustration is the Microflo-L



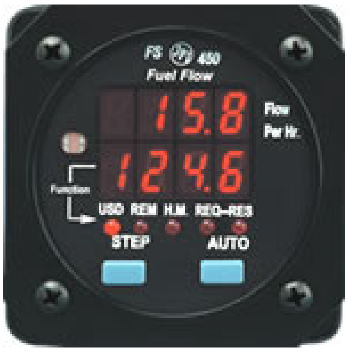
and over the years has appeared in several versions like this TB20/TBM700 one



The well known manufacturer of EGT/CHT indicators, JPI, offers a fuel flow option on their popular EDM-700 instrument



plus the dedicated EDM-450



Finally there are many other instruments which combine fuel flow with all kinds of other functions e.g. air data.

These instruments will all indicate the current fuel flow rate. However, the real advantage of accurate flow measurement is obtained when the instrument is linked to a GPS, and the GPS (if programmed with the route being flown) then displays a constantly updated FOB based on the current ground speed (GS) and the remaining distance to run. Any modern IFR GPS has this feature.

Installation

Ideally, setting the instrument to the K-factor of the transducer yields an accurate installation. In practice, one needs to make adjustments to the K-factor to achieve good accuracy.

A major potential problem with the turbine flow transducer is that it must be mounted in the correct place in the fuel pipework. Obviously, the flow rate must be identical anywhere along a particular pipe, but there can be considerable turbulence around bends in the pipe and the transducer is severely affected by such turbulence.

This turbulence initially manifests itself in the form of a K-factor which is some 10% to 30% away from the figure marked on the transducer. On many installations this problem has been “covered up” by setting an appropriate K-factor to compensate, but this is not the answer since the turbulence increases greatly with the flow rate, and varies anyway, and the overall accuracy thus varies according to one’s mix of short and long flights – on a short flight one spends relatively more time with a high flow rate.

I fly a 2002 TB20GT which had the transducer incorrectly placed at the factory. It was claimed this was done at the insistence of the DGAC (the French “CAA”) which required it to be located on the cockpit side of the firewall, in breach of the Shadin STC which was quite specific as to the location. The result was that every aircraft made had a flowmeter reading around 25% off, with another unpredictable 10% error according to flight duration, with a further huge error when the electric fuel pump was running, and with no help from the factory many of the pilots just gave up on it. Unfortunately, on a G-reg aircraft, the error could not be legally corrected and it was only after a few years when I transferred to the N register that I was able to move the transducer in accordance with the Shadin STC; Shadin granted the permission to use their STC without charge.

Another aircraft dependent factor is that some engines have a bypass which returns fuel directly to the fuel tanks; installing the transducer in the wrong place is going to yield interesting results!

Accuracy

The accuracy quoted for the whole system is normally around 1% to 2% which is much better than any fuel gauge. Despite efforts, I have found it difficult to get better than this, due to a combination of small errors. For example, a standard tactic to avoid departure delays is to fill up immediately after landing but this enables some fuel to be lost through expansion out of the overflow vents; avgas expands about 0.1%/degC so in a hot location one can lose 1-2% in this way and may prefer to under-fill very slightly. The turbine flowmeter measures volume flow and does not correct for density variations due to temperature, and it’s quite possible for the fuel temperature to fall from +30C on the ground to -20C in the air; this amounts to an amazing 5% “shrinkage”. Filling the tanks accurately can be difficult unless the aeroplane is exactly level. Occassionally, one detects discrepancies which can be explained only by an optimistic airport pump…

Usage

One could debate the extent to which one should use this data but I would hope that – as with GPS – serious pilots are no longer interested in traditionalist views and wish to embrace the best technology for the job provided any caveats are understood.

Obviously, it is necessary to preset the initial FOB value into the flowmeter when filling the tank to a known point. If this is done incorrectly, the FOB value will be wrong from then onwards – the instrument merely measures fuel flow and has no way of knowing how much fuel is actually in the tanks!

For any long flight, it is wise to generate a plog with the planned FOB figure at each waypoint – Flitestar can do this easily if you configure the aircraft data properly - and during the flight the figure for each waypoint is compared with the computed FOB from the flowmeter. If the FOB figure falls below the budget, this should correlate with stronger than expected headwind, but it could equally have been caused by a climb to a higher than planned altitude (for example, to get above weather). In these situations, the GPS-calculated FOB at destination can be invaluable in deciding whether one should still proceed to the destination, or divert to somewhere nearer.

However, it is vital that the accuracy of the system is regularly checked, and this should be done at each and every fill-up. The amount pumped into the tanks should be within around 1% of what the flowmeter says it should be, and this should hold for all types of flights; both long and short.