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210 Exhaustion or Starvation

By Paul New

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I've been flying for a very long time and thus far have escaped the dreaded fuel exhaustion event. I write this article at the request of the NTSB and at great risk of jinxing my current record. I'm just a regular guy with private, single, multi and instrument ratings and about 3,000 hours flight time. I am not a professional pilot or flight instructor and would not want to pretend to be an authority on how one should operate their airplane. However, as a lifelong piston aircraft mechanic, I do have some thoughts on fuel management that I hope will be of some value.

The term "running out of gas" includes a couple of possibilities: fuel starvation and fuel exhaustion. At first thought the two seem the same, but they are quite different. It is true that both result in the engine's inability to produce thrust and keep the pilot calm. Fuel starvation is when the engine no longer has access to the fuel available in the aircraft. Examples include neglecting to change tanks, carburetor float sticking, or fuel gascolator bowl leaking. Fuel exhaustion is when all the fuel available in the aircraft has been consumed or lost prior to reaching the intended destination. Not having enough fuel in the plane is almost always an operator error. Running out of gas is at best embarrassing and at worst, deadly.

Fuel Quantity Sensing

The 1960 through 1969 have a single float type resistive fuel level sender in each wing. This simple system returned in 1978 and remained until the end of production in 1986. There are no field adjustable components to allow for calibration of the system. The system con-

sists of a float on an arm attached to a rheostat which is wired directly to the relative fuel quantity gauge, then to a circuit breaker. The gauge is just a simple millivolt meter calibrated in gallons or pounds. There's not much to go wrong in such a simple system unless it's forty plus years old.

One might imagine how improbable it is that a single float mounted near the center of such a long tank could present accurate levels. The issue is that the float often touches the bottom of the tank while some fuel remains, but even more troublesome is that it will touch the top of the tank before the tank is completely full. In operation, inaccuracy at the top and bottom positions are small but serve to reinforce the time-honored tradition of not trusting the fuel gauges.

The 1970 210K (first year of the round tubular landing gear) through the end of 1977 210M (last s/n 21062273) have the PennyCap fuel level system. This is a fairly sophisticated capacitive system more commonly found on larger aircraft. It incorporates an inboard and outboard capacitive sending unit in each wing. A signal conditioning unit is mounted in the cabin with adjustments for empty and full. The conditioning unit outputs a small voltage to the gauges which are simple millivolt meters, similar to the float type system.

The PennyCap system gets lots of bad press which is usually well deserved but not because of its original design. In truth, when working properly, this system is very accurate and stable. The issue is that now forty plus years since production, the conditioning unit just can't perform as intended. In its day the low-quality printed circuit board, tinned connector pins and sockets, open slider calibration rheostats, and capacitors did the job just fine. Unfortunately, these parts of the system don't age very well. Combined, they make maintaining this system in reliable operation nearly impossible.

Wet Wing Tank Structure

The 210 models of most concern for fueling issues are the 1967 and newer with the cantilever wings (no struts). In 1967, Cessna changed from a strutted wing design with bladder tanks to a cantilever wing structure design with an integral fuel tank, also known as a wet wing. The term "wet wing" implies the wing structure, and external skins make up part of the tank.

Inside each tank are five structural ribs that can create a dam effect to the fuel as it makes its way to the outlet ports. There are holes and passages at the bottom edges of the ribs designed to allow this fuel to pass through to the outlet ports. There are similar holes and passages designed into the tops of the ribs that, when fueling, allow air to escape to the filler port and vent at the outboard end of the tank. If these holes and passages are restricted, the usable fuel will be much less than shown in the POH.

During repairs of many 210 wing leading edge skins over the years, our shop has found several wings that had numerous sealant repair attempts. We tested and observed that with all the ribs blocked, the combination of trapped air in the top of the tank and the extra unusable fuel in the bottom of the tank, the maximum actual capacity could easily be up to five gallons short of the anticipated fuel capacity. That's approximately a 10% loss of total fuel capacity. In other terms, that ten gallons is VFR reserve or the majority of IFR reserve fuel requirements. Going missed on an instrument approach at the destination airport is a terrible time to find out that the tanks don't hold as much as planned.

It has been said that patience is a virtue. I'm not one of those that exercises my patience very often unless fueling a 210. Even a 210 with properly installed sealant can take a while for all the air in the top of the tank to be displaced with fuel. To mitigate this problem, many 210 owners top up the first tank, then the second, then return to the first and finally the second to be sure the tanks are truly full.

Calibration Time

There is also an AD relating to some models that requires calibration of the fuel system, specifically the empty position. In addition to knowing the gauges properly read empty when the tanks are empty, it's a great idea to find out just how much fuel the tanks actually hold. Checking one's fuel tank capacity and fuel level display is a great idea whether the AD applies to your airplane or not.

For close to real life results, the fuel from the tanks can be drained from the fuel line in the wheel well at the gascolator. The thought being that this would leave the proper unusable fuel in the tank just above the tank's drain valve. Once all is drained, the fuel selector should be turned to any position other than "BOTH" to prevent a leaky selector from allowing fuel to migrate from one tank to another. Each tank should be filled and noted how many gallons were added. The

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fuel pump gauges at the fuel farm or the fuel truck are required to be checked for calibration at regular intervals, so they are a reasonable data source for the total fuel added. After approximately five minutes, more fuel can be added to each tank and noted how much extra was added. Hopefully, there won't be a surprise at the amount of fuel the tank holds.

Pilot/Mechanic Thoughts

Most of the Cessna fleet are antiques. It may be difficult to think of them in that light, but that's the way it is. These are wonderful handmade machines with many unknown variations created during the build process as well as during the decades of operation and maintenance. It's unreasonable to expect the fuel gauges to be accurate or reliable. Every operator should have methods in place to know, with confidence, how much fuel is on board the aircraft from startup to cruise to shut down. Considerations include the following:

- Every operator should start with a confident knowledge of the true capacity of his or her fuel tanks. This is foundational with everything else relying on an accurate baseline. A calibration check is highly recommended.

- Patience is necessary when fueling to ensure a full tank is actually full by allowing enough time for all the air to escape.

- The "dipstick" method works well for checking intermediate fuel levels. The dipstick should be calibrated to the specific airplane. The results may vary greatly depending on the level position of the airplane.

- Some planes have a “tab” built into the filler neck for a visual at some intermediate fuel level. These are accurate but only if the plane is sitting at some specific pitch (they almost never are).

- Any available in-flight reminder system should be used. Most modern navigation systems have programmable reminders with “pop up” warnings when it’s time to change tanks. I strongly recommend against relying on one’s own memory or that of a passenger. Switching every thirty minutes is a good starting point.

- Flight plans should be completed with confirmed fuel burn values for all phases of flight and taxi. Accident data shows we’re not always the best at this.

- Leaning is critical. A 210 at full rich cruise might consume 24 gph. At a normal rich of peak cruise, about 18 gph could be expected. A lean of peak cruise might be 15 gph. Forgetting to lean at the appropriate time could reduce the range by 25% to 40%. That’s a drastic difference even on a shorter flight.

- Pay attention to enroute changes in flight plan. Weather may dictate a climb or descent from the planned cruise altitude. The gallons per hour may stay the same, but the miles per gallon could change significantly.

Mitigating the Statistics

According to the NTSB, there are about fifty accidents per year in the United States related to fuel management. It is the sixth leading cause of general aviation accidents in the US, with 56% of those being fuel exhaustion and 35% being fuel starvation. Some sort of pilot error is sited as a factor in 95% of all of those. Almost half of the fuel mismanagement events are at the hands of commercial or air transport category pilots. Interestingly, only 2% of these events occur with a student pilot. (Reference: NTSB Safety Alert 067 “Flying on Empty”).

Being aware of possible problems, making procedural changes, understanding the plane’s fuel system, and adding reminders are all very helpful. Every operator must use all the mitigations available and remain vigilant to successfully avoid fuel starvation and fuel exhaustion.

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