Just because you have checked it see if your fuel cap vent ports are clear, do not assume you are flying with positive pressure in your tanks!

By Dennis Kelly
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For the past several years I have been seeing signs of fuel flow problems with my 1946 Cessna 120. Periodically the engine would drop 50 or so RPMs shortly after liftoff. Each time, upon inspection, I would find some possible cause like particles of fuel selector valve lubricant swirling around inside the gascolator, but nothing conclusive. One day, shortly after liftoff, the engine went silent. While my heart was pounding, I nosed the plane over and started to pick a spot to land when, within seconds, the engine started running again. Excited, I started to climb and head to the nearest runway. The engine starved again and restarted within seconds after nosing over. Once again I climbed and the engine starved again. I nosed it over and the engine started. This time I kept the nose low and pulled the throttle back and landed on a nearest runway. I don't think I ever got more than two hundred feet above ground.

Upon inspection the only thing I could find was a very small amount of fuel valve lubricant in the gascolator. I replaced the fuel selector valve with a Weatherhead valve, removed and cleared all fuel lines from the valve to the carburetor.

A week later the problem occurred again. It was a warm day, in the ninety's, when several friends and I flew to a nearby airport to have lunch. After lunch, a friend and follow pilot, and I got into my airplane to fly back to my home field. The run-up checks went as usual. The takeoff roll was also normal, but thirty feet after liftoff the engine went silent. I promptly announced "we are going to land - there is plenty of runway left". Within seconds after nosing the plane over, the engine started running again. I pulled the throttle back and we landed without incident.

The takeoff attempt was made using the right tank which was half filled with auto gas which I had been using for years. We performed a prolonged full power ground run-up without any signs of starvation. Then, we taxied to the fuel pump and filled the left tank, which was low, with 100LL. We parked the plane and opened the cowling to let the engine cool down while we checked everything we could think of. About one hour later, after arranging for my friend to fly in another aircraft, I was able to fly my aircraft back to my home field without incident using the left tank.

The following morning, I started checking everything I could think of once again. Fuel cap vent holes, fuel contamination, fuel line blockage including the flex hose to the carburetor, gascolator screen and carburetor inlet screen, I found nothing. My new fuel selector valve has a delrin barrel which doesn't require a lubricant. I did not take the carburetor, a Stromberg, apart this time although I have had it apart several times recently. It has the delrin needle and weighted float. The needle lift exceeds the .048" prescribed in the manual.

Then, once again, I started fuel flow checks from each tank. While I was performing these checks, another friend, Howard, a pilot, builder of two aircraft and retired McDonnell Aircraft engineer, came up and asked what I was doing. After telling him about the incident, he stated, "That sounds like fuel tank ventilation to me" and went looking at the top of my wing. He then asked, "Where is your vent tube." I promptly stated that Cessna didn't use vent tubes. The tanks are vented through the two holes in each gas cap. He took the cap off and said, "This will generate a vacuum." At that point I directed him to look at the other Cessna 120 in the hanger, which he did.

When he returned, he stated, "I sure don't understand that. These caps will generate a vacuum in the tank."
After some additional discussion, I completed the fuel flow test, thirty plus gph from each tank, and we parted company.

Later that evening, I got to thinking about Howard's comments. I decided to find out for sure if a vacuum is being generated in the tank during flight. I called Howard and asked him how I could determine this for sure. He suggested I empty all fuel out of one of the tanks, disconnected the fuel line to that tank. Then, cap the fuel line going to the fuel selector valve. Next, connect a Rate-of-Climb Indicator to the fuel line going into the empty fuel tank. Go fly the plane. If there is a vacuum forming in the tank, the Indicator will indicate a climb. If positive pressure is forming in the tank the Indicator will indicate a dive.

After acquiring a ROC Indicator and hooking it up to my right tank as suggested, I headed for the runway. On takeoff, the ROC Indicator climbed past the 2000 ft/mi mark before the tail of the plane lifted off the ground and stayed there until I landed and slowed down. Howard was right. There is a vacuum forming in the fuel tank during takeoff and flight.

That evening I called Howard to tell him he was correct about the vacuum and asked him how to measure it. He suggested I use an Airspeed Indicator to accomplish the task. To measure a vacuum, connect the fuel line from the empty tank into the Static Port on the back of the Indicator. There are published formulas and tables to convert the airspeed reading to column inches of water and a conversion factor to convert inches of water into pressure.

The next morning I borrowed an Airspeed Indicator and obtained copies of the published formulas, tables and conversion factors needed for the next test.

The next test flight, with the Airspeed Indicator Static Port attached to the empty tank, I obtained readings of 90 mph during liftoff and climb and 100 mph on downwind to land. Later test, with the Pitot Port on the indicator attached to the Static System in the plane, the readings climbed to 105 mph (-.195 psi) on climb and 115 mph (-.235 psi) on down wind.

That evening I decided to experiment with a forward facing vent on the fuel cap. In the plumbing supply section of my basement I found a ½" copper 90 degree elbow. In the adhesive section I found some JB Weld. With these, I modified the cap to include a forward facing vent tube which covered both vent holes in the cap. The next morning, using a Rate-Of-Climb Indicator, I verified that a positive pressure was being formed in the tank during takeoff and flight. Using the Airspeed Indicator, this time connecting the Pitot Port on the indicator for pressure, to the fuel line, I tested the modified cap and obtained readings of 80 to 105 mph during takeoff and level flight.

I then put auto gas back in the right tank along with my modified forward facing vent cap and made another test flight using that tank. The plane performed beautifully. The engine ran noticeably stronger than usual with no indication of starvation. Putting positive pressure into the tank had a direct impact on the problem. I was so impressed with the modified cap that I began calling it my 95 cent supercharger.

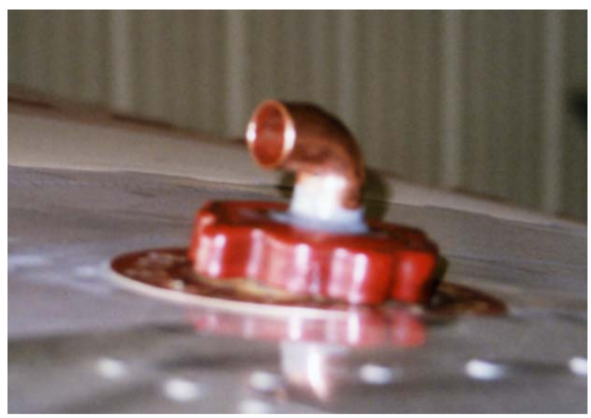

Photo 4

I eventually performed the same test on my left fuel tank and got the same results.

During the period in which I was testing the fuel tanks for vacuum, I transferred both 100LL and portions of last batch of auto fuel purchased from one tank to the other. The fuel starvation problem always followed the auto fuel. Testing indicated the auto fuel contained some alcohol, but I am not sure this actually caused the problem. Clearly, something in that batch of fuel contributed to the starvation.

To determine if the vacuum could reduce the fuel flow enough to starve the engine during takeoff, I borrowed a special adapter plate which covered and sealed the left tank filler tube. The plate has a fitting to attach the Airspeed Indicator and a manual valve which can be used to regulate the vacuum in the tank. Using this tool, I was able to determine that the above vacuum, 100 to 110 mph readings, reduces the fuel flow to around twenty three gallons per hour, three times what the engine requires at full throttle. So the vacuum does not reduce fuel flow from the fuel tank to the carburetor enough to starve the engine. Something more is happening. But, this vacuum does reduce the fuel pressure at the inlet to the carburetor.

Photo 5

The following week I installed a ¼" forward facing vent tube in a set of new unvented cap and placed them on my fuel tanks. A flight test indicated 95 mph (+ .160 psi) on climb and 105 mph (+.195 psi) on downwind of positive pressure. This means the tank pressure is going from -.195 psi with the Cessna cap to + .160 psi with the forward vented cap during climb when the engine had been experiencing starvation, a +.355 psi difference. The engine runs stronger at full throttle and the number two cylinder head temperature, my hottest cylinder, is staying noticeably cooler during climb out with these caps. Both factors indicate that the engine had been running lean during full throttle operation.

Photo 6

At this time my thought was that the fuel pressure at the inlet to the carburetor may be getting very low. Possibly to the point of vapor lock or the auto fuel simply will not enter the carburetor past the needle and seat at a rate sufficient to prevent starvation during takeoff. The Continental Engine Type Certificate specifies a minimum of 19 inches of column pressure, about .487 psi with 100LL at a specific gravity of .71, and a maximum of 4 psi. Although the column height from the carburetor to the fuel tank is greater than 19 inches, the vacuum generated by the Cessna caps is reducing the pressure at the carburetor.

The following spring, I decided to test this theory by attempting to measure the fuel pressure at the inlet to the carburetor. I took the brass plug, which covers the carburetor inlet finger screen off a spare carburetor. I then drilled a ¼ in. hole through the center of the plug and installed a short metal tube into the hole. Using this modified plug, I then was able to connect an Airspeed Indicator directly to the fuel inlet portion of the carburetor just below the needle and seat.

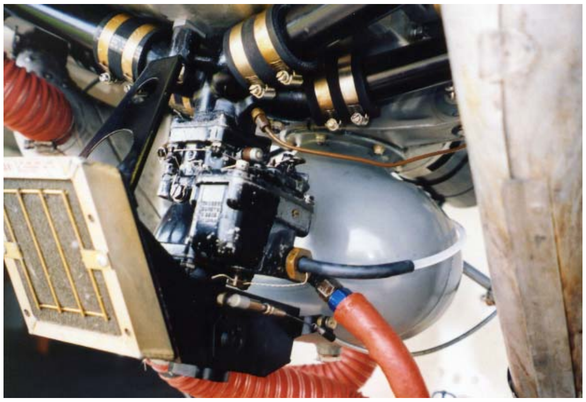

Photo 7

Photo 8

Next, I placed a Cessna type cap with the two holes in it on the right fuel tank and kept the forward facing vent tube cap on the left tank. Both tanks were about 5/8 full with 100LL. When I turned the fuel selector valve to the right tank, the Airspeed Indicator immediately rose to 186 mph (.61 psi). The left tank indicated 187 mph. Because I used a clear plastic tube from the carburetor to the Airspeed Indicator, I was able to determine that the fuel did not come out of the carburetor more than a few inches. Column pressure up the plastic tube would not be a factor in the readings.

The next step was to fly the plane. Once the plane begins moving, the fuel in the tank starts slouching around moving the Airspeed Indicator needle up and down a lot. The following readings are my best estimate taking the average of the needle swings.

The first takeoff was with the right tank and the Cessna cap. When I pushed the throttle in, the indicator dropped from 187 mph to 165 mph. As the engine started drawing fuel from the carburetor opening the needle at the seat the pressure drops. Then the plane started moving down the runway. At tail-up, the indicator had dropped to 120 mph (.256 psi about ½ the minimum pressure specified for the carburetor). At lift off, the indicator climbed up to 140 mph (.348 psi). During climb out it rose to 145 mph (.373 psi). On down wind, the indicator climbed to 180 mph (.575 psi). During the entire takeoff and climb the fuel pressure was well below the minimum pressure specified for the carburetor. Even so, there was no sign of fuel starvation with the 100LL used.

I landed and switched to the left tank with the forward vent tub cap and prepared to take off again. At idle the indicator showed 186 mph. As the throttle was pushed in, the indicator dropped to 165 mph. At tail up the indicator was still reading around 165 mph (.483 psi). At lift off it indicated 180 mph (.575 psi). Climb out, 210 mph (.783 psi), and down wind 240 mph (1.023 psi).

Based on these findings, I have decided to keep the vent tube caps on the plane even though they are not without their set of potential problems.

Formulas:

The formula for converting airspeed to psi is as follows:

From: Report No. 429
Aircraft Speed Instruments
by K. Hilding Beij

Formual (3a)

[(mph)squared] X .00049207 = column in of water

[(knots) squared] X .00065258 = column in of water

From: Machinery's Handbook
Miscellaneous Conversion Factors

[inches of water] X .03609 = psi.

By multiplying these factors together you get:

[(mph)squared] X .00049207 X .03609 = psi.
or
[(mph)squared] X .000017758 = psi.

[(knots)squared] X.00065258 X.03609 = psi.
or
[(knots)squared] X .000023551 = psi.

It works for both vacuum and pressure.
Only the sign (-,+) changes.