Cavitation (aka Vapor Lock) Mysteries Revealed by

Summer is upon us and the classic pilot complaints and reports
flow have started. Last summer I wrote three long posts in Beec
cavitation. Together those posts formed a primer on Cavitation
offer a nice background to help understand what's actually goir
pump and fuel lines.

Cavitation is often referred to as Vapor Lock when discussing e
but I don't like the term because "Lock" is misleading; it implies
locked and that no fuel is flowing. In fact, the system is working
capacity, it's not locked.

First, let me expound a little on why the fuel flow falls off with a
the "pump business" for 25 years so it's in my wheelhouse.

I think George Braly's Socratic teaching method is great. Give a
the student figure it out, in figuring it out the student gains a d
understanding. For those of you who would just like to have it e
me take a swing at it.

Pumps need atmospheric pressure in order to work. Pumps tha
like the engine driven pumps on our beloved Continentals that
up out of the low wing tanks in a Bonanza are even more deper
atmospheric pressure.

Picture when you are drinking through a straw. Most people thi
"sucking" the beverage up into their mouth. In fact what is happ
are lowering the pressure in the straw and atmospheric pressur
tasty beverage up the straw. If you can picture somehow trying
straw in a vacuum, you can easily see that it wouldn't work. No
pressure, between the surface of the liquid and the inside of th

no fluid movement.

At sea level, standard atmospheric pressure is 14.7 PSI, express
all us pilots know, 29.92 inches of mercury. If you want to keep
column of water like in your straw it would be about 33 feet.

As you climb, obviously you have less atmospheric pressure. By
15,000' you are down to about 1/2 the sea level pressure. So w
the pump now putting out less flow at the same pressure? In a

Cavitation is a word that is used regularly but I find that it's poo
explain cavitation I like to use the swimming pool example. Ima
standing in the shallow end of a swimming pool and you take y
move it as fast as you can just under the surface. You'll see a w
bubbles appear behind your hand and they will immediately dis
you stop moving your hand. Your hand did not break the surfac
did not come from the atmosphere. Where did the bubbles go?
and break the surface like air bubble, what are they? It's cavitat

What you have done is put more energy into the water than it h
You've created little vacuum, or more accurately steam bubbles
as soon as the energy that created them stops.

Now here's the next interesting observation. If you put on your
down to 33' feet, you can't create those bubble that you easily
inches below the surface. You are not strong enough to make t
33', no one is. (I picked 33' because it one additional atmosphe
a swimming pool in a Himalayan village at 15,000' you would fi
to create cavitation bubbles with your hand because it would be
atmosphere of pressure. We know from this thought experimen
make a fluid cavitate at higher pressure, and it's easier to make
pressure.

The next variable in the cavitation equation is the vapor pressu
Water has a very low vapor pressure as compared to most liqui
because of the polar nature of the water molecules. Water is att
resists cavitation. This is the same property that accounts for s
capillary action. Gasoline does not have these properties and h
pressure meaning that it's easier to create cavitation bubbles.
pressure increases when it get hotter making it even easier to c
gasoline vapor pressure can vary quite a lot depending on the b
"spec".

We went over the importance of atmospheric pressure and how
getting the liquid to the pump and how it's even more importa
pulling a suction lift. Then I gave a little dissertation on cavitati
affected by pressure and the property of the liquid called "vapo

As the plane climbs there is less and less atmospheric pressure
the fuel up to the pump. The pump is still creating low pressur
but since there is less atmospheric pressure available the fuel c
pump as easily. At some point pressure drops below the fuel's
cavitation bubbles begin to form inside the pump and in the pi
side. It's like moving you hand through the water in that imagi
Himalayan swimming pool. The same amount of energy that wo
cavitation bubbles at sea level will easily form them at altitude.

The formation of the bubbles is exacerbated by the fact that fu
high vapor pressure and will form cavitation bubbles easily. It's
if the fuel is hot which raises the vapor pressure further .

The bubbles are formed in the pump and go into the pump fro
but they immediately collapse on the discharge side because of
pressure. What's happening is that the bubbles are occupying a

normally be occupied by fuel. The volume of the bubbles displa
results in a lower flow rate. Pretty simple actually.

The electric fuel pump is in a better position with regards to ca
sits lower in the plane and has a flooded suction. When you tur
pump it restores some or all of the lost atmospheric pressure a
pressure in the mechanical fuel pump and suction lines high en
cavitation bubbles.

Now there is more going on here. For example, I don't understa
fuel pump doesn't always restore full fuel flow. According to so
pump has to be built so that it performs at the top of its spec o
the problem. I'd think the electric pump would easily restore th
the cavitation. I also don't fully understand some of the fluctuat
pressures that some pilots are reporting. It may be that the cav
getting big enough to cause the pump to momentarily lose prir

As I have been thinking about it there are a couple more things
might be helpful if explained a little further. In the earlier sectio
fact that it's actually the atmospheric pressure that pushes the
As you go up in altitude you have less atmospheric pressure so
together and at some point, the low pressure in the suction line
form bubbles, that is what we call cavitation. It would be accura
fuel is boiling, but I don't like to use that term when explaining
implies heat. We live in a sea level atmospheric world and we ge
fluid will boil at any temperature, the boiling point is establishe
properties and pressure.

When fluid is moving through a pipe it creates turbulence. We a
are pilots, that turbulence creates drag. For the purposes of un
you can just think of it as drag, and the drag is further lowering
suction pipe and at the inlet to the pump.

Just like on an airplane any obstructions create further drag. In
obstructions are things like elbows, valves, strainers, or fittings
through. All these things are lowering the pressure in the suctic
the fuel closer to its vapor pressure with the resultant bubbles

As a pump expert, when I look at the suction pipe arrangement
total mess. What you want is a short straight pipe with no obstr
have is a long pipe with a bunch of obstructions; the coarse fue
actually in the tank, the selector valve, the gascolator and the s
fuel pump, and a whole assortment of elbows and fittings throv
measure. All these things are working against us and adding to
problem.

Some obstructions are worse than others. Obstructions that are
are much worse than obstructions that are far from the pump.
elbow right at the inlet of the pump would be a disaster.

Why? you ask. Whenever the fluid passes an obstruction a low p
created just downstream. Think Bernoulli. If the fluid is close to
the cavitation bubbles will form at the low-pressure spot just p
If this low pressure spot is far from the pump, depending on al
surrounding pressure and vapor pressure, the bubbles are likel
before reaching the pump. If the low pressure area is right in fr
bubbles are likely to remain intact and enter the pump resulting
for the reasons we've already discussed.

Obviously, our Bonanzas are certified aircraft and you just can't
suction piping around for kicks. Most of the problems inherent
are baked in the cake. However, there is some variability in the
between the firewall and the pump.

Here are a couple of areas to examine:

Make sure the hose that leads from the firewall to the pump is
If it's a Teflon hose it's probably Ok and you can easily inspect i
lurking under a fire sleeve it may be slightly crushed or degrad
important part of the fuel suction setup since it's close to the p
be tip-top.

Try to keep the fuel hose away from anything hot. Heat lowers
of the fuel and takes it that much closer to cavitation. Even if I l
I'd consider putting a fire sleeve over it to help insulate it. Also,
sure the cooling air duct for the pump is in place and in good s
the duct is to help cool the pump, which fights off cavitation te

Try to eliminate all the fittings between the firewall penetration
Try to have just one hose from the firewall penetration to the p
fittings. Have the hose make long radius bends. If there is a 45
elbow actually attached to the pump find a way to get rid o
gas to flow into the pump with as long a straight run as you ca
know what's possible here, however, my Bonanza is NA so I'm r
32 GPH to the engine at 15,000'. My pump is probably cavitatin
altitude, but I can still get 12 -13 GPH to the engine so I'm not
a result, I haven't really looked at the suction piping. But the TN
pay special attention.

All of the problems with cavitation are on the suction side of th
pump itself. Once the fluid is through the pump and the pump
cavitation is no longer a factor. Newtonian liquids are incompre
push on them as hard as you want, you just can't pull them.

The mechanical fuel pump used in our Continental aircraft engi
and it falls in the family of pumps called Positive Displacement

displacement pumps all share a common trait, they create a cav
cavity.

This gives all positive displacement pumps two common qualiti
rate is set by the RPM. The volume of the cavities is built into th
that it will pump a certain amount per revolution. So, in order t
rate, you must change the RPM. Second, there is no theoretical
pressure they can generate. Since liquids are incompressible, th
generated when you crush the cavity is only limited by the stren
materials, and horsepower available. That's why there is always
relief mechanism on a Positive Displacement pump. And, that w
return line.

For any everyday example of a Positive Displacement pump (PD
washer. When you let go of the trigger, the pump is still pumpi
going through the pressure relief valve and is piped back to the
were no pressure relief valve the pump would continue to build
something gave; the engine might stall because it just couldn't
power, or something might break or slip like a shaft or a belt. T
try to go to infinity and it would only stop when if finds the wea
machine.

Our pumps are always pumping the same amount of fuel at a g
no cavitation). I don't know what it is, but let's just say it's 40 G
if you are flying along at 2500 RPM burning 13 GPH, that mean
going back to the tank. Push the throttle or mixture in so now y
GPH, now 15 GPH is going back to the tank via the return line. T
pressure is set by the pressure relief valve, not the pump. The p
lots more pressure as long as the fuel is getting to the pump.

And there we are, back to cavitation. The problem is that the fu
the pump, it's boiling and creating bubbles. The bubbles in the

occupying space that would be occupied by fuel if it weren't cav
flow drops off.

This leads me to my last point. I consider myself to be somewh
but I'm not a Continental fuel injection expert. I have a good wo
how the system works, but I find myself occasionally puzzled.

The most recent example of my puzzlement is in a recent post
has also talked to TAT and I understand that there is a larger o
installed to help with this, somewhere in the engine." I can't thi
orifice would need to be installed anywhere in the system. If the
suction side of the pump, then it's in the perfect position to cre
bubbles in exactly the wrong place. If anyone can explain what
be interested in hearing about it

There you have it, my musings as a "pump expert" regarding ca
pilots have always referred to as "Vapor Lock". I hope this narra
improve your understanding of our fuel system and the causes

Jack Letts