HOT STARTS

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"Hot Starts" -- Remember that phrase? It used to be quite common and to most mechanics and pilots it was, or perhaps still is, synonymous with the gas turbine engine. In recent years, it has spilled over into some of the reciprocating power plants that power the general aviation fleet. However, the meaning is quite different when applied to modern reciprocating engines and implies difficulty in starting the power plant when it is hot or heat soaked from recent use.

This condition is primarily associated with fuel injection engines and usually occurs only during hot summer weather. This situation is further aggravated by the fact that the pilot-owner of today does not know nearly as much about his airplane and engine as his predecessor once did. There are many valid reasons why he is not as knowledgeable, but the fact remains; and this new breed of pilot-owner and the machines he flies are steadily increasing in number with each new day. So let's get acquainted with "hot starts" as applied to fuel injection engines.

Maybe you already own an aircraft powered with a fuel injected engine and if so, you are aware of the simplicity of its starting procedures. As a matter of fact, there isn't much difference in starting procedures between fuel injection and carburetor engines and both are quite simple under all normal conditions - although there are times during hot summer temperatures and under certain conditions when a fuel injected engine may not start as easy as its carburetor-fed cousins. While this is no major difficulty, it can be annoying.

There is a sound reason for this little annoyance and once you understand what provokes it and how your airplane is equipped to handle it, you'll know exactly how to avoid it.

The engine in a modern airplane is closely cowled to reduce airframe drag and subsequently increase the overall efficiency. Consequently, there is very little space inside the cowling and it is void of any unnecessary openings. Figure 1 is typical of such an installation.

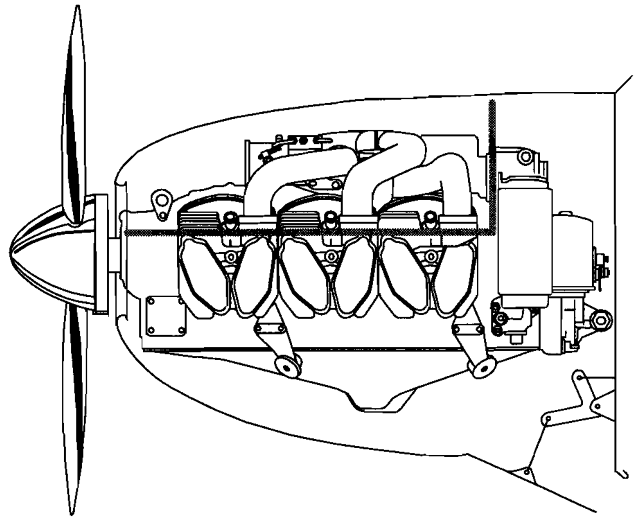

Figure 1. Typical example of a tightly cowled engine in a well designed airframe.

Cooling of the engine depends on air being forced into the cowling by the propeller during operation and the "ram" effect during flight. Figure 2 illustrates airflow during in-flight conditions on a typical installation. Of course when the airplane is on the ground and the engine is at rest, no cooling is necessary. But! - things do get a bit warm inside the cowling immediately after shut-down. This temperature rise results from the fact that the air trapped inside the cowling is heated by residual engine heat.

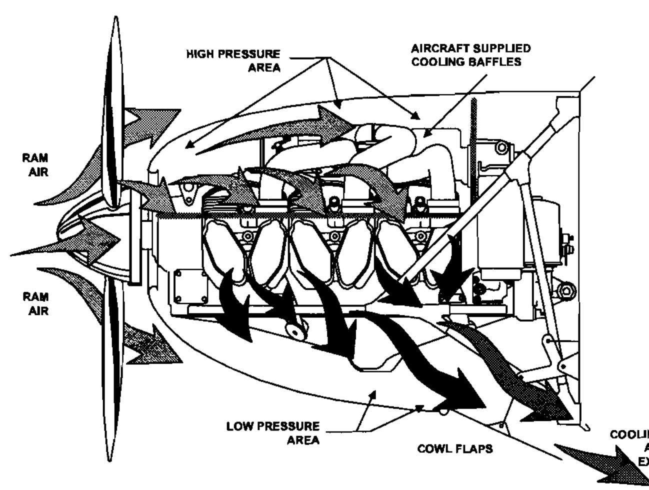

Figure 2. Notice how air entering the cowling opening in the front is forced around the cylinders by means of baffles and moves into the lower cowling where it passes overboard through the cowl flap openings. Cooling air also enters the accessory section via strategically located vents.

This condition can occur in nearly all modern airplanes, twins and single engine alike, and especially so on those airplanes having no upper cowl openings. On a hot summer day it will take approximately two or three hours for this trapped heat to dissipate appreciably. And here's where "hot starts" get started.

What actually happens? Within ten to fifteen minutes after shutdown in hot weather, the heated air inside the cowling heats the fuel in all of the lines and fuel metering components located inside the cowling and forward of the firewall.

Under these conditions the liquid fuel begins to expand and vaporize. if the fuel selector valve is left on (and normally it should be) the pressure from the expanding fuel begins pushing the liquid fuel remaining in the lines back to the fuel tank from which it came. Figure 3 illustrates this condition.

Very quickly most of the fuel in the lines and components inside the cowling will have turned into vapor. If the fuel selector valve was turned *off* after engine shutdown, the expanding vapors then force the liquid fuel and vapors through the fuel metering equipment and into the engine's induction manifold, eventually to escape into the atmosphere.

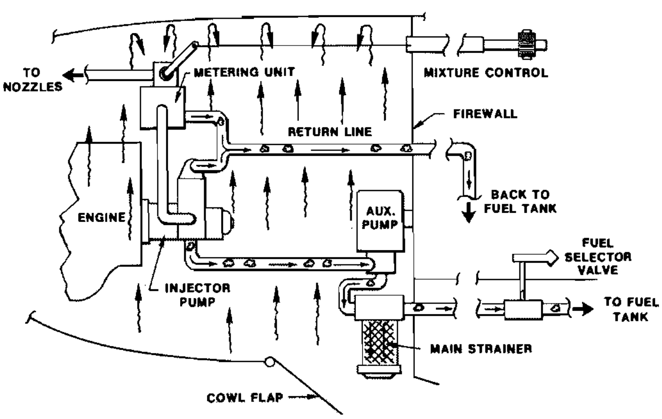

Figure 3. A simplified, though typical diagram of the fuel supply system and its components forward of the firewall. Notice how the heated air rises to the top of the cowling. All fuel lines are shown in X-ray fashion to show what happens inside. Notice the puffs of vapor separating the liquid fuel and that expansion has begun to force the fuel back to the full tank

Since we prefer to keep the fuel for turning the propeller rather than permeating the atmosphere, it's better to leave the fuel selector on - this way the vaporizing fuel pushes its way back to the tank from which it came.

All airplanes equipped with fuel injection have at least two fuel pumps, one engine-driven injector pump and one electric "auxiliary" or "booster" pump. The injector pump can deliver fuel only when the engine is running or being cranked. The electric auxiliary fuel pump can be operated anytime, whether the engine is running or not.

As its name implies, the auxpump serves a variety of purposes, including the complete elimination of "hot start" situations.

The engine-driven injector pump differs considerably from the pump used for carbureted engines. On carburetor type engines the fuel pump usually serves one basic purpose: supplying fuel to the carburetor from the storage tanks in the airplane. On an injection system the engine-driven pump provides several functions. In addition to supplying fuel, the injector pump also contains some of the metering equipment and therefore provides some of the initial metering.

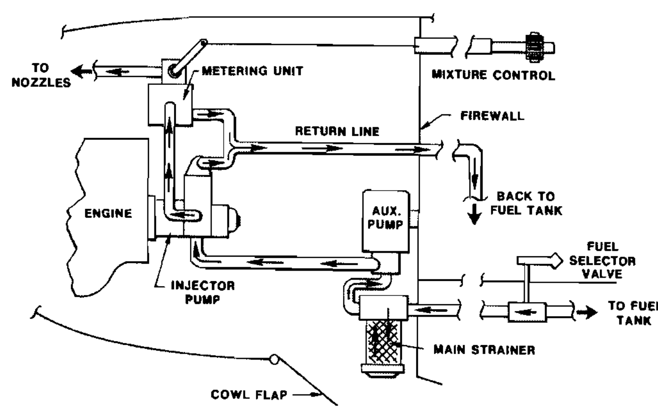

Figure 4. This illustration shows normal fuel flow when the engine is running. Note the return of excess fuel from the injector pump and metering unit. This excess fuel returns to the tank from which it came.

All engine-driven fuel pumps must have the capacity to provide more fuel than the engine can use, even at full throttle. The automotive (diaphragm) type pump simply recirculates this excess delivery within its chambers. Since the injector pump operates at higher pressures and delivery, it is provided with a return line system. The injector pump also supplies more fuel to the metering equipment than is needed. This excess fuel returns through the return system to the tank from which it came (see Figure 4).

All injector pumps are fitted with a bypass valve which allows the auxiliary pump to bypass the vane portion of the pump and yet utilize the metering section of the injector pump when the injector pump is inoperative. During normal operation the injector pump draws fuel from the tanks, meters it to some degree, and then delivers this partially metered fuel, under pressure, to the metering unit or control.

The metering unit contains the fuel metering valve, which is mechanically linked to the air throttle. On some engines the metering unit also contains the mixture control, while other installations have the mixture control built into the injector pump. In either case, fuel passes through the mixture control valve prior to reaching the fuel control metering valve.

Whenever the pilot moves the throttle, the fuel metering control will move in direct or related proportion. The metering unit is also provided with a return line for returning excess fuel which isn't delivered to the cylinders for combustion. The return line from the metering control connects to the return line on the injector pump, and from here the return system goes back to the storage tanks or (in some installations) to a small hopper tank located somewhere along the main fuel line. This return system plays a very important role in preventing "hot start" difficulties.

The Auxiliary Pump

When you turn on the auxiliary pump, it draws fuel from the storage tank and delivers this fuel under pressure to the engine driven injector pump. If the engine is at rest, fuel from the auxiliary pump will pass through the injector pump bypass valve and into the metering section of the injector pump. The partially metered fuel leaves the injector pump and flows on to the metering control.

If the mixture control is open, the fuel arriving from the injector pump will continue on to the distributor valve and nozzles. However, if the mixture control is placed in cut-off or full lean position, the fuel leaving the injector pump will arrive at the mixture control in the metering unit and then enter the return line system. Once in the return line system, the fuel returns to the tank from which it came.

To "Fix" a Hot Engine

Ready? Let's start a typical fuel-injected engine that's been shutdown for approximately twenty minutes when the ambient temperature on the ramp is 90°F.

Procedures for a routine, warm engine start on this fuel injection engine would consist of:

1. Mixture control - full rich,
2. Throttle – "cracked" or slightly open,
3. Magneto switches - on (if separate from starter switch).
4. Starter - engage.

Usually a small amount of liquid fuel will remain in the injection lines leading to the nozzles. As the engine begins cranking, this retained fuel is injected into the intake valve ports (Figure 5) and drawn into the cylinders. Upon ignition, the fuel ignites and the engine bursts into life; then, just as suddenly as it started, it dies. A false start and the prima facie indication that a "hot start" situation exists.

Since the fuel lines inside the cowling are full of vapor rather than liquid fuel, the engine driven pump will not pump or "remove" the vaporized fuel in sufficient quantity to support combustion. Therefore, the engine's refusal to continue running after the initial start up is simply due to fuel starvation.

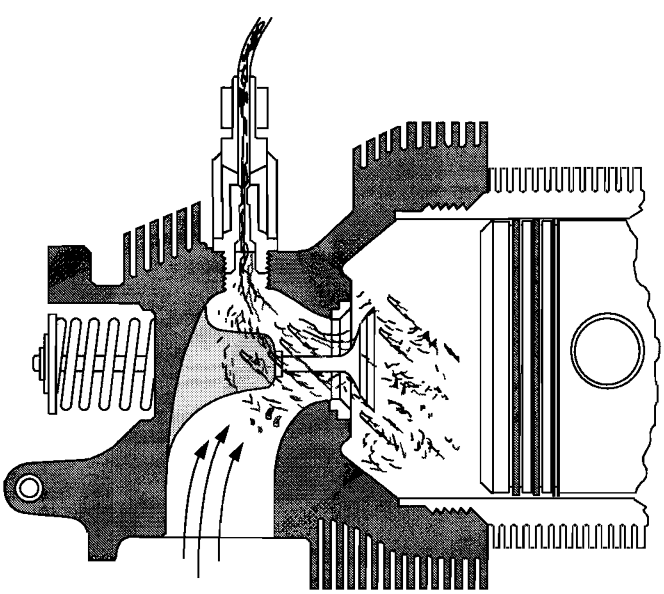

Figure 5. Fuel enters the intake valve port by way of the injector nozzle located in the cylinder head, and then passes into the cylinder through the open intake valve in the usual manner.

"Words" Won't Help

Such false starts will usually be followed by difficulty in re-starting. The unknowing pilot will continue cranking the engine while resorting to some favorite procedure, self-designed, to accommodate the situation. If this doesn't bring forth immediate results, more cranking and different procedures are tried, sometimes accompanied with "words" expressed in a manner designed to encourage the engine to be more cooperative. At last (usually) the engine starts - but only because the excessive cranking has pumped away the vapor, permitting liquid fuel to fill the lines and returning things to normal.

There has to be a better way - and here it is, in three easy steps:

1. Mixture control -- full lean or cut-off.
2. Throttle -- full open.
3. Electric auxiliary fuel pump - on high.

Relax for approximately twenty seconds and while you are waiting, here is how the solution is working for you.

The electric fuel pump is taking liquid fuel from the tank selected and pumping it through the heat-soaked lines under the cowling. In its cut-off position, the mixture control prevents this fuel from reaching the cylinders. This is exactly what is needed at this moment: Now the fuel takes the alternate path and returns to the tank or header from which it came.

Fuel Flow Purges Lines

During this process, the continual flow of fuel will purge the lines forward of the firewall of all vapors. Also this continued flow will reduce the wall temperature of the lines through which it passes. After approximately twenty seconds the fuel lines will have cooled sufficiently to retain the fuel in a liquid state after the pump is turned off. Figure 6 illustrates the purging process.

After twenty seconds, turn off the electric pump and make a normal start as follows:

1. Mixture control full rich.
2. Throttle cracked or partially open.
3. Starter engage.

No priming will be necessary because a small amount of fuel will make its way past the closed mixture control and into the nozzles during the purging operations. If this "three step" purging operation is conducted exactly as outlined, the engine will respond to a normal warm start procedure every time, and with no difficulty.

Just remember:

1. The *mixture control must be full lean* - to prevent flooding and to force the circulating fuel to flow back through the return system.
2. The *throttle must be full open* - because some single engine fuel injected aircraft incorporate switches in their throttle linkage to prevent the auxiliary pump from operating in the high position when the throttle is retarded.
3. The *auxiliary pump must operate in the high position for approximately twenty seconds* - to provide sufficient time to adequately cool the fuel lines and components inside the cowling.

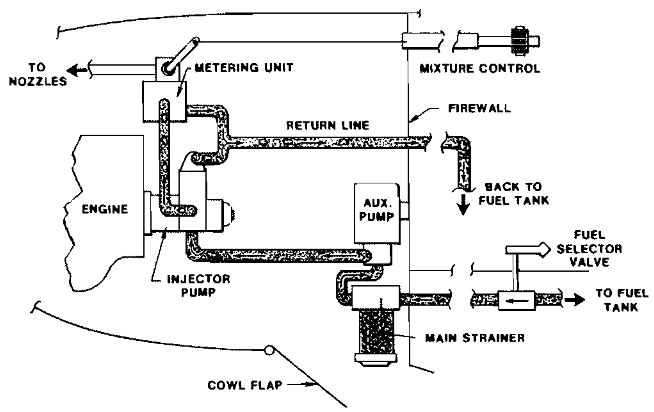

Figure 6. The electric pump is operating and you can begin to see the results. The supply line from the electric pump to the injector pump is almost free of vapors. Notice the vapors being returned through the return line system and that fuel is passing the mixture control to the nozzles.

Three to Remember

Finally, let's summarize the three important facts that you should remember about "hot start" difficulties:

1. The cause of this possible difficulty is simply heat soaking of the fuel lines inside the engine cowling or nacelle after engine shutdown in hot weather.
2. The actual condition is temporary fuel starvation due to vaporization of fuel in the lines inside the engine cowling.
3. The solution for preventing the difficulty is the auxiliary fuel pump which simply purges the vapors and hot fuel from the lines prior to starting.

It's just that simple.