Aeromotive, Inc. Technical Bulletin #401

From: Aeromotive Technical Department

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Re: **HOT FUEL HANDLING: What is it, what causes it and how to solve it**

What is a "Hot Fuel Handling Problem" and how do I know when I'm having one?

Hot fuel handling problems are typically manifested first by cavitation, and if that is allowed to persist, are often followed by vapor lock and a complete loss of fuel pressure. Cavitation is a complex but important topic to understand, which we'll cover in some detail below, but identifying when cavitation is occurring and preventing it from starting, or becoming worse in the form of vapor lock, is crucial to both safe vehicle operation and fuel pump health and service life.

The symptoms or signs of cavitation include an abnormally loud fuel pump and fuel pressure fluctuations as seen on a fuel pressure gauge. During cavitation the growling and surging sounds produced by the pump and the bouncing fuel pressure gauge indicate the pump is seeing an intermittent flow of fuel entrained with bubbles of vapor. This mix of liquid and vapor can radically and abruptly load and unload the pump and motor resulting in fluctuating pressure.

When cavitation becomes vapor lock, we see a precipitous drop in pressure along with the pump becoming abnormally quiet. Once fully vapor locked the pressure will be virtually zero and the pump may not be heard at all. At the point of vapor lock the pump is typically running in a complete vapor bubble, and for all intent and purpose is running dry.

What is cavitation?

Cavitation is often misunderstood to be a condition where the pump sucks air from an uncovered pickup, or when it picks up air bubbles from an aerated fuel container. Though symptoms of aeration may be similar to that of cavitation, they are completely different conditions with unique causes, cavitation having the worst consequences by far.

Technically, cavitation is the phase change of liquid into vapor. Cavitation creates bubbles which form spontaneously within a liquid when exposed to a significant pressure drop in a localized part of the system. This typically occurs at the pump inlet or on the suction side, but high velocity / restricted area of flow after the pump can also cause cavitation.

It's important to note that as fuel temperature rises in the system the potential for cavitation bubbles to form increases as the fuel temperature moves closer to its natural boiling point. This can mean a system with some restrictions / pressure drop would not cavitate with lower fuel temperatures but may begin to cavitate at higher fuel temperatures.

As cavitation bubbles move on with flow into a part of the system at normal pressure they can collapse back into liquid, but in the process produce a high-speed jet of liquid through the center of the collapsing bubble. This release of energy may create micro-abrasions and pitting of the nearby solid surfaces. This can be a major problem where the repeated formation and collapse of cavitation bubbles over time produces significant structural damage to system components.

What causes cavitation (which leads to vapor-lock and/or hot fuel handling problems)?

- Fuel is difficult to keep liquid. All fuels are classified as volatile liquids, meaning they can easily change from liquid to vapor, along with being highly combustible. That said, fuel must remain liquid in the fuel delivery system, up to the point of injection or ingestion, or proper fuel pressure and fuel metering through injectors or carburetor boosters becomes impossible. That said, fuel must become vapor once in the engine for the purpose of combustion. Liquid fuel in the combustion chamber is not available for combustion until it vaporizes.

- Today's pump gas is a complex blend of hydrocarbons, formulated seasonally, to support EPA mandates for minimal cranking emissions (easy starting) depending on environmental temperatures. Winter blend gas is blended to vaporize in cold weather to support rapid, cold engine starting, and is commonly still at the pump on early, warm spring days, which can be particularly problematic for creating hot fuel handling problems.

- Today's skyrocketing Horsepower capabilities, combined with increased use of alcohol-based fuels including e85 and Methanol (which require 30-120% more flow volume compared to gasoline), require ever larger, higher flow fuel pumps; from Brushless Gear Pumps up to 10-GPM and mechanical pumps up to 33-GPM, fuel flow requirements are off the chart. With fuel tank capacities between 15-20 gallons, fuel recycle rates for a full tank are between 30-seconds and 3-minutes for pumps in this class, running at full speed / maximum flow capacity.

- Each significant step up in pump flow requires the appropriate, larger fuel lines, higher flow filters and regulators. Neglecting the installation of the necessary upgraded supporting components when swapping pumps is a common problem and a significant cause of flow restrictions, creating a much higher risk of cavitation.

- The typical flow path for a full-flow, recycling fuel system is through the chassis, alongside the exhaust, over the hot pavement and through the hot engine bay, then back to the tank. High recycle rates (large fuel pumps) will eventually increase fuel temps up to and beyond critical levels for cavitation to develop, even in a perfectly plumbed system. Critical tank temps vary with season and altitude but are typically between 130-150 deg. F.

How to reduce the odds of having hot fuel handling problems, cavitation and vapor lock.

- The area of lowest pressure in a typical fuel system lies between the fuel pump inlet and the fuel tank outlet. It's vital to fit the tank with the proper size fitting and to run the recommended line size for external pumps, including a prefilter if desired that is course enough and large enough to be invisible to the pump. Mount the pump inlet even with or below the fuel cell outlet, with the straightest line approach possible from the tank into the pump is also critical.

- From the pump outlet port to the engine/regulator combo, line should be sized as recommended for the pumps flow rate, again with a large, high flow filter that can handle the volume with nominal restrictions. Also avoid hard 90-deg connections, or abrupt changes in flow area / line sizes in the flow path that will create a high velocity pressure drop.

- Inadequately sized or improperly maintained (clogged) filters downstream of the fuel pump commonly create hidden restrictions and hidden, extreme back pressure between the filter and the pump. Though not necessarily a cavitation risk, high pump head pressures (more than 10 - 50 PSI over the fuel rail) can develop and will result in high current draw while killing the cooling flow through the electric motor, producing overheated fuel and potential vapor lock. Post filter restrictions are also commonly responsible for premature fuel pump failures.

- Route fuel lines carefully through the chassis and the engine bay, minimizing exposure to extreme heat, particularly exhaust system components, especially the headers. Insulating fuel line from heat transfer will help, but the best solution to control heat transfer is to insulate the heat source itself, that is wrap the exhaust system with high quality exhaust heat wrap where the fuel lines or fuel system components are in proximity.

- Reduce unnecessary fuel recycling by staging multiple pumps using engine load/boost activation for auxiliary pumps, incorporate Fuel Pump Speed Controllers for brush style pumps, or TVS (True Variable Speed) control options for all Aeromotive Brushless fuel pumps. The fewer times the fuel in the tank takes a trip through the chassis and engine bay per hour the cooler the fuel will be in the tank, reducing hot fuel handling problems.

- Keep the tank as full as possible in extremely hot weather, as the fuel level drops in the tank the remaining fuel will be recycled more and more frequently through the vehicle.

- Understand "returnless" fuel systems will prevent fuel tank temperature from rising but will expose fuel trapped in the lines and the fuel rails to extreme heat for extended periods, creating its own set of problems, not to mention the reduction in fuel delivery efficiency and potential for engine lean-out under high load.

With careful selection and correct installation of proper components, the conditions responsible for creating Hot Fuel Handling Problems can be effectively addressed and the likelihood of problems significantly reduced. **With Aeromotive Fuel Systems you can "Feed the Beast"!**