Understanding "HEAT SOAK"

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It has been discovered that many engine compartment fires are being blamed on an vehicle engine phenomenon known as "**heat soak**". There appears to be a misunderstanding in the fire science field regarding the circumstances surrounding this condition. The term, "heat soak" refers to a raise in the engine coolant system temperature and pressure after the engine is turned off. This article is designed to clear up some of the misunderstandings and offer some insight as to how the condition actually occurs.

The "heat soak" phenomenon begins with the actual combustion process. The engine is the component where the combustion process occurs. For ease of purpose, we will only discuss the gasoline powered engine. However, this condition occurs in all internal combustion engines.

The engine is the center of the propulsion system. The engine is composed of numerous components such as the pistons, crankshaft, engine block containing the cylinders, intake and exhaust manifolds, intake and exhaust valves, etc. The crankshaft is an odd shaped rod, located inside the engine block, which attaches to the pistons via connecting rods. The number of engine cylinders determines the number of pistons used.

When the engine starts, the crankshaft rotates and pulls each piston, one at a time, towards the base of the cylinder. The order of the which these pistons rotate is controlled by the crankshaft. When a piston reaches the base of the cylinder, the pressure inside decreases, creating a vacuum. At this time, the intake valves open, inundating the cylinder with a mixture of fuel and air.

As the crankshaft continues to rotate, the pistons are forced back up to the top of the cylinder, increasing the pressure and compressing the mixture. At the point where the piston reaches the uppermost portion of the cylinder, the spark plug fires, igniting this compressed mixture, and detonating it. The rapid expansion of the gases from the detonation forces the piston down, which turns the crankshaft, supplying further power to continue the process.

The detonation of the mixture releases energy, mostly in the form of heat. Temperatures of the mixture detonation can reach temperatures over 2500°F [1], which increase the temperatures of the cylinder, head, and engine block. The exhaust gases are then released out the exhaust valves, into the exhaust manifold, and out the exhaust system. The power generated from this process is then delivered from the crankshaft to the transmission, and subsequently to the vehicle wheels, creating forward momentum of the vehicle.

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[1] Source: **Auto Mechanics Fundamentals**, Stockell,Goodheart-Wilcox,1995, pg. 191

The exhaust system is composed of several components, including the exhaust manifold, catalytic converter on newer vehicles, exhaust muffler, exhaust resonator, and exhaust pipe.

After the combustion process occurs, the exhaust valves open, and the gases from the detonation of the mixture are forced out into the exhaust manifold. From this location, the gases travel down the piping into the catalytic converter, resonator, muffler, and finally exhaust pipes. The catalytic converter is an important part of the exhaust system, due to the extremely high operating temperatures it can reach. The normal operating temperatures are between 900°F to 1500°F, with peak temperatures of approximately 1800°F. [2]

The reason why the engine operates at such a high temperature is due to the thermal efficiency of the engine. A typical gasoline engine is approximately 25% thermal efficient. This is due to approximately 75% of the energy released from the detonation of the combustible mixture, being transferred through the engine by incomplete combustion, radiation of heat through the engine block, and the heat reducing properties of the engine's coolant and lubrication systems.

Finally, the most important system involved in the "heat soak" phenomenon, is the coolant system. This system is composed of several components, including the engine block, water pump, fan, thermostat, radiator, coolant, and coolant hoses. The water pump is usually connected to the other end of the crankshaft. The engine coolant used is composed of a combination of ethylene glycol, propylene glycol, and water. The type of coolant used, ethylene or propylene glycol, depends upon the specific coolant manufacturer. A typical coolant should be a mixture of 50% coolant with 50% water, otherwise overheating problems can occur.

The coolant system is designed to cool the engine from the temperatures created from the combustion process occurring inside the engine cylinders. The coolant flows from the radiator, through the upper radiator hose, through the thermostat, to the water pump, and into the engine block. The coolant then circulates around through pre-designed passages inside the block, and then flows back through the lower radiator hose into the radiator. The fluid inside the radiator is then cooled through the radiation of heat, and by the cooling properties of air flowing over the radiator while the vehicle is in motion, or when the fan is operating.

The phenomenon known as "heat soak" occurs when the engine is turned off. At this time, the combustion process is terminated. This terminates the momentum of the crankshaft, which in turn stops the turning of the water pump. As the coolant is no longer being circulated, the engine block and cylinder temperature increase for a period of approximately 3 to 10 minutes, depending on the engine design and additional components.

[2] Source: **Chilton's Auto Repair Manual**, Chilton Book Co., 1986, pg. U183

During this time, the engine block radiates heat to the air surrounding the engine, which slowly cools the engine. However, the cooling process occurs slowly, and as a result, the temperature of the engine block transfers the heat to the coolant. The coolant temperature then increases, which in turn increases the pressure inside the coolant system. This is why the vehicle's coolant temperature gauge increases over a period of time after the engine has been turned off.

Ethylene or Propylene Glycol has a flash point of approximately 210°F, [3] and an ignition temperature of approximately 500°F to 700°F. [4] If there is a break, rupture, or leak in any of the connections of the coolant, the coolant will be forced out at a high pressure, spraying an atomized mixture of fluid inside the engine compartment. If the coolant contacts the exhaust manifold, which is typically operating at a temperature of 900°F to 1100°F [5], the coolant will reach temperatures greater than its ignition temperature and probably result in a fire.

The common misconception held is that the "heat soak" phenomenon will increase the temperature of the exhaust manifold and exhaust system. As the combustion process is occurring, the exhaust manifold reaches its maximum design temperature. The exhaust manifold is usually located at the side of the engine ”head" and is exposed to the open air. This allows the manifold to radiate heat while the engine is operating. While the exhaust manifold is attached to the engine “head” by bolts, the surface area in contact with the head is significantly smaller than the surface area exposed to the surrounding air. This results in more heat being released through radiation than is being added from the small surface area due to conduction.

When the engine is turned off, the combustion process terminates. This in turn, halts the continuation of heat being added from the combustion process. As a result, the temperature of the exhaust manifold decreases almost immediately. A fire can originate at the exhaust system, but only over the short period of time where the temperatures are still high enough for any combustible or flammable liquid to reach its ignition temperature. This firm has conducted numerous tests on several different vehicles with different engine configurations. These tests involved using thermocouples attached to the exhaust manifold in different locations, and recording the temperatures attained. The results of these tests further substantiated this conclusion.

The "heat soak" phenomenon does occur and can be the potential cause of an engine fire. However, the circumstances surrounding the fire and the type of combustibles ignited, should be consistent with the type and location of the damage found, and be corroborated by statements from witnesses.

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[3] Source: NFPA 325M, **Fire Hazard Properties of Flammable Liquids,Gases,and Volatile Solids**, National Fire Protection Association, 1991 Edition.
[4] Source: **Kirk’s Fire Investigation**, Third Edition, pg. 174
[5] Source: **Kirk’s Fire Investigation**, Third Edition, pg. 174