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White Paper

Fuel Recirculation Issues And How They May Affect On-Site Power Generation Designs

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Purpose:

This white paper is written to provide the engineering community with possible solutions to the issue of fuel recirculation and its potential effect on on-site power generation installations. These guidelines are general in nature. For specific applications, you may contact the author to review details of a safe and reliable fuel system design.

Background:

A large majority of on-site power generator installations are based on diesel-fueled engines, which operate on No.2 diesel fuel/oil. In the typical design, diesel fuel is stored in a large fuel storage tank. This main tank is generally installed outdoors (above ground or under-ground). Due to limitations on the engine's fuel pump, namely its limited capacity for suction (or lift), a "day tank" is often required, and used, as the immediate fuel-source. The day tank's close proximity to the engine allows the engine-driven fuel pump to draw fuel reliably. A day tank may be specified as a free-standing (stand-alone) design, or as a skid-base design (also known as a sub-base tank). In either case, the engine's fuel supply piping is connected to the day tank, as is the engine's fuel return piping connection.

Definition of the Problem:

Diesel engines generally draw more fuel than is needed for the combustion process (as an example, a typical 2 megawatt generator draws approximately 300 gal/hr, but only consumes approximately 120 gal/hr at full load). The excess fuel drawn is designed to cool and lubricate the engine's fuel system. After circulating through the engine, this excess fuel is returned to the fuel storage tank (i.e.: day tank). This "return" fuel, if untreated, will carry the heat rejected by the fuel system and can, over an extended run period, elevate the temperature of the fuel stored in the day tank.

Most engine manufacturers specify a maximum inlet fuel temperature to allow the engine to produce its full output rating. As inlet fuel temperatures exceed 100°F, fuel density and lubricity decrease, and some engines can de-rate as much as 1% for every 10°F in fuel temperature rise. At approximately 165°F, some engines are automatically shut down by their protection systems.

Impact of National Codes and Standards:

Emergency power supply systems (EPSS) are generally specified and classified per NFPA-110, Chapter 4, to operate for a certain minimum amount of time following a loss of the normal power supply. As part of the overall EPSS design, a reliable fuel supply system should ensure that the engine will be able to operate for this minimum required time. Note that "operate" should be interpreted to mean that the EPSS will be able to carry the design loads, as stated in NFPA-110 5.6.2.

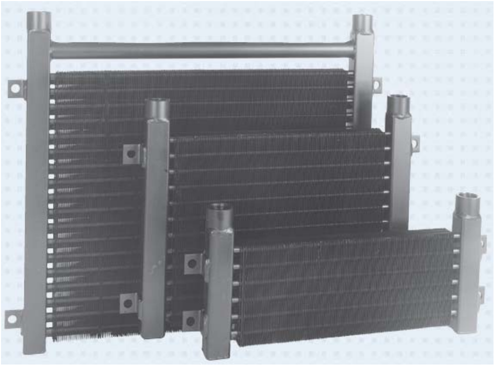
Design Solutions:

There are several methods available to treat, or cool, return fuel sufficiently to prevent it from heating the fresh fuel supply, therefore preventing an undesired de-rating or shutdown of the engine. Following are potential solutions to maintain an acceptable fuel temperature range in a day tank:

<u>Solution #1</u>:

Most generator-set manufacturers furnish their larger packages with a radiator-mounted fuel cooler. This fuel cooler should be designed to cool the engine's return fuel before it is routed back to the day tank. If the performance of the radiator-mounted fuel cooler is such that it will remove sufficient heat from the fuel to prevent it from reaching a critical high level, then this solution may be acceptable to the EPSS designer. However, it is not clear that the engine manufacturer's selection of the fuel cooler necessarily takes into account application-specific conditions such as the specified EPSS run time, local ambient temperature, or the size of the day tank receiving the returned fuel (i.e.: any residual heat in the return fuel would be dissipated less efficiently in a smaller day tank than it would in a larger day tank).

It is also important to understand that EPSS installations which utilize remote cooling packages (remote radiators) will lack the traditional "radiator-mounted fuel cooler", and therefore should have detailed specifications addressing how any return fuel should be treated before returning to the day tank. Bottom line: the EPSS designer should review the heat removal capabilities of the engine-mounted fuel cooler (if it exists), and confirm its suitability as it relates to the application at hand.



Typical fuel/oil coolers furnished for direct-mount on engine-cooling radiators.
Image courtesy of Thermal Transfer Products.

Solution #2:

In some instances, it may be feasible to direct the engine's return fuel back to the bulk storage tank, whether directly (if the engine-mounted pump is capable of overcoming pipe restrictions), or indirectly by way of a return fuel tank. A return fuel tank may be designed for the sole purpose of receiving return fuel from the engine. Such tank would be equipped with a pump, and once a certain level of fuel accumulates, the pump is activated to direct the hot fuel to the bulk storage tank. Here, the heated fuel can dissipate within a much larger volume of fuel. A drawback to this solution is that, without the benefit of the return fuel, the fuel supply day tank may need to be designed with a larger capacity to allow the required minimum run time. Also, a larger fill pump will be required (sized to exceed the maximum fuel drawn by the engine, rather than the maximum fuel consumption rate).

Solution #3:

A stand-alone fuel cooler may be specified to provide the specific cooling performance for the application at hand. A typical unit consists of a fan/motor assembly configured for either vertical or horizontal air discharge. Installed between the engine's fuel return connection, and the day tank, it would cool the return fuel before it re-enters the day tank. Working in conjunction with a fuel temperature sensor, the cooler's fan/motor is activated on demand. It is important to note that although many day tank manufacturers offer an optional fuel cooler to be pre-installed on the day tank, such fuel coolers are generally not selected for use with a specific engine and may result in removal of only a fraction of the required heat load from the fuel.

Images courtesy of Thermal Transfer Products.

<u>Solution #4</u>:

An automatic day tank-to-main tank fuel recirculation function may be specified for the day tank. As the fuel inside the day tank reaches a critical high temperature, a return pump/motor is activated to return the heated fuel to the bulk storage tank. Once activated, the return function remains active until the tank is drawn down to 50% level, at which point, the day tank's fill pump turns on to draw fresh (presumably cooler) fuel from the bulk storage tank. If the bulk storage tank has been specified with sufficient size to dissipate the return fuel's heat under an extended run scenario, then the day tank would be able to maintain an acceptable fuel temperature range for the engine. This solution requires that the day tank be specified with a temperature sensor, a return pump/motor connected to a suction tube of sufficient depth to reach the 50% level in the day tank, and control logic to perform this function.

Conclusion:

The effects of heated fuel recirculation may not be apparent during brief power outages, or at installations with very light loads on the EPSS. Depending on the performance of an installed fuel cooler and other factors such as the day tank size, the generator size and its applied load levels, it may take several hours for re-circulating fuel to elevate the fresh fuel temperature to a point that is detrimental to the EPSS. However, given the many past instances of natural disasters that have called upon the EPSS to run for many days, and the real and severe problems that could result from a generator that is incapable of maintaining the building's loads during an extended outage, a design engineer should exercise caution in this area when designing a critical on-site power generation system.

About the Author:

Mr. Hurtado offers design support to architectural and MEP engineering firms involved in the development of critical infrastructure projects with on-site power generation requirements. His expertise is focused in the areas of fuel systems, engine cooling, engine exhaust systems and electrical switchgear systems.

Additional resources and contact information available at www.hurtado.cc.