HEAVY DUTY MOBILE EQUIPMENT

ENGINE COMPARTMENT SUPPRESSION SYSTEMS

By Mr. Steven E. Younis

***Mr. Steven E. Younis** is an Independent Professional Fire Protection Engineering Consultant to ACAF Systems, Primary Flow Signal - Fire Suppression Group, LLC.*

ACAF Systems have a new suppression system which is a new technologically advanced single-agent, dual-action compressed air foam (CAF) - CAF mist fire suppression system developed to address vehicle engine compartment fire suppression applications in heavy duty mobile equipment. Due to the nature of the configuration of the typical engine compartment, the suppression system utilizes a pre-engineered local application fire suppression system design.

Through the use of a single control device, the system delivers both CAF and CAF mist to the fire through separate nozzles that are positioned to deliver foam and foam-mist in one integrated stream, thus enhancing the fire suppression capabilities of each agent into one combined more efficient fire suppression agent. The combination of the two sprays with one agent strengthens the suppression capabilities of both components into the creation of a single more effective suppression system. This, in tandem with state of the art system components and fire detection, make for a highly advanced, very effective fire suppression system.

Both CAF and CAF mist have excellent fire suppression characteristics on their own merit, but specific applications, specifically engine compartments, where the conditions have a potential to consist of air turbulence, wind contribution, spray fires, cascading fires, and pool fires, an agent must have the integrity to deal with all of the aforementioned potential fire threats. The combination of the two sprays with one agent has proven to effectively suppress these types of fires continuously in testing. Testing has demonstrated that through combining the two sprays, even in turbulent conditions with a spray fire, that the action of the CAF-CAF mist will consistently extinguish and keep suppressed, even the most difficult fire.

The suppression system is designed as a compact self-contained, stored energy system. The system was developed and is designed to minimize equipment installation and storage space along with utilizing an environmentally friendly or "green" suppression foam. The foam used in the system is Re-healing RF-3 foam manufactured by the Solberg Company and is compatible for use with hydrocarbon-based fuel fires.

FIRE SUPPRESSION DYNAMICS

Water mist on its own is an efficient proven fire suppressant, as is CAF, for many types of fires, but individually for these types of vehicle engine compartment fires, they do not perform consistently. Each agent has strong characteristics allow each to suppress different types of fires, but individually, neither can suppress all types of fire scenarios that need to be dealt with for the varying types of engine compartment applications. The combined characteristics of the agents create a new mechanism by which to suppress these types of fire situations. The CAF when combined or infused into the CAF mist stream enables more efficient entrainment into the fire through the addition of weight to the particles. Thus, making the solution sufficiently heavy enough to entrain into a spray fire in wind or turbulent conditions. With the ability of the suppressants to now be entrained into the fire, each agent contributes its own individual fire suppression characteristics to the suppression process – both contributing to cooling and breaking the combustion cycle, as well as the stability of foam to not breakdown and mist to provide steam and oxygen depletion. The combination is highly effective.

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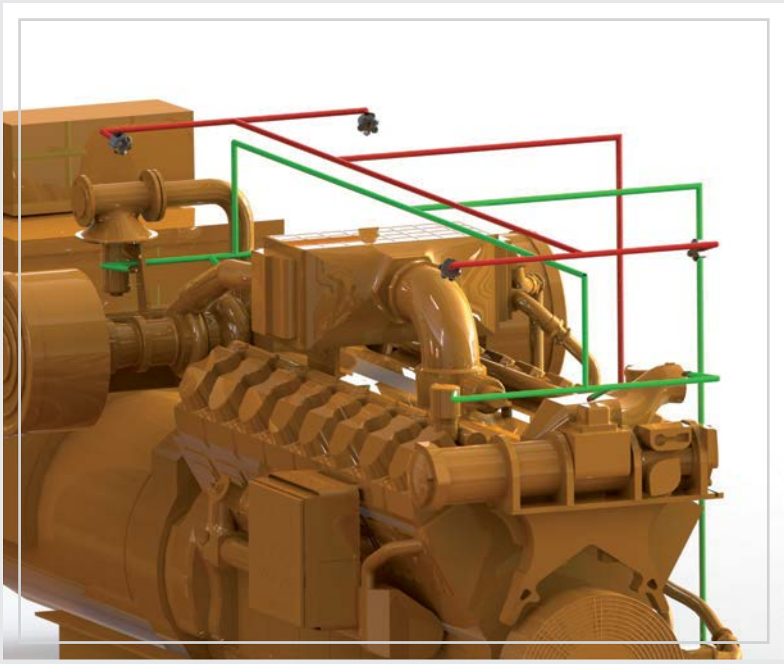

ANALYZE THE HAZARDS

In order to utilize the suppression system, the hazards associated with vehicle engine compartments must be documented, analyzed and understood before moving forward with design and installation. To this end, hazard analysis is used as the first step in a process used to assess the risks associated with the equipment being protected. The result of the hazard analysis is the identification of different type of hazards associated with the equipment at risk. From the analysis, the proper fire suppression and design configuration can be established. One cannot move forward with the design of the fire suppression for the engine compartment applications until the hazards and associated risks are thoroughly understood. Additionally, a designer cannot design the system without a thorough understanding of the fire suppression systems available to perform the task.

The designer of the suppression system must have a thorough understanding of the systems. Once the foreseeable hazards and risks have been determined and assessed, the designer must consider the potential ignition and re-ignition sources potentially associated with those hazards. Upon establishing these potential sources, the designer must take into account and evaluate all other tangible conditions associated with the fire suppression equipment such as effect on and by operational conditions, air turbulence (wind/air movement conditions), leakage rate from the compartment, space for suppression system installation, available surfaces for system installation and attachment, tank size and storage space availability, nozzle placement, nozzle and system protection from damage, variability in temperature conditions, material compatibility, etc. From this, the designer can establish the system requirements, design, configuration, and installation requirements that will best protect the specific engine compartment of concern.

One must begin with the identification of the fuels and ignition sources that are part of the normal operational conditions and functions of the engine and compartment in order to assess the risk levels accurately. Once these hazards are documented, the possibility of fire potential, likelihood of fire, and the consequences caused by the potential fire events must be evaluated and prioritized. A designer must document every foreseeable hazard in order to develop the most flexible comprehensive design for the vehicle' engine compartment. The designer must consider all potential ignition and fuel sources as part of the analysis inclusive of any superheated surfaces that may potentially exist. This will be the primary factor in determining the final system design and configuration.

Briefly, what will a designers need to consider:

- Potential fuel sources may consist of such flammable liquids as diesel fuel, gasoline, oils, hydraulic fluid, brake fluid, lubricants, coolants, transmission fluid, among others.
- Potential fire types - spray fire and type (high or low pressure); pool fires (belly or lower collection pan; or on upper horizontal surface of the engine block); or cascade (down the side of engine or compartment from a low pressure running leak or collateral issue as a result of a spray leak).
- Potential ignition hazards - electrical equipment (e.g. alternators, generators, starters, etc.); engine block; exhaust manifolds; exhaust system components & mufflers; heat exchangers; turbochargers; valves; brakes; bearings; external non-engine electrical generators or motors; fluid pumps (brake, fuel, hydraulic); travel clutches, etc.

When doing a hazard analysis in the vehicle engine compartment environment, one must consider all of the above, but also be able to consider additional factors as each case is unique and presents its own individual hazard characteristics. Be aware that no single fire scenario is applicable to an engine compartment situation and all possible scenarios must be considered when performing the hazard analysis in order to provide the optimal level of fire suppression capability.

UNDERSTANDING THE OPERATIONAL CHARACTERISTICS & SYSTEM DESIGN

In order to properly design and utilize a fire suppression system, a firm understanding of the characteristics, capabilities, and design parameters of all of the components of the fire suppression system. This will make the process of analysis and design much clearer and more effective.

Compressed Air Foam

The suppression system is for special hazards, is pre-engineered and automatically delivers foam through a network of piping. The expanded material is applied to the hazard area much the same as foam water systems are. CAF, however, has many distinct properties that need to be considered in the design and installation of a system.

To understand the effectiveness of the fire suppression system one must first understand how CAF is created and discharged, as it is an important aspect of the design. Special nozzles are a key component of the process and distribution of the CAF over the hazard area. The foam concentrate/water flows through the piping as a water concentrate mixture to the mixing chamber. At the mixing chamber a compressed gas, either nitrogen or air, is infused into the water-concentrate solution. When exiting the mixing chamber the solution is now fully expanded to foam and takes on the flow characteristics of a gas, moving much more smoothly through the piping. It exits the mixing chamber in the fully expanded state, thus increasing the application rate and decreasing the time to fire suppression. The average expansion ratio of the Solberg RF-3 is on the order of 12-15 to 1.

CrossFire CAF - CAF Mist System

In order to enhance the CAF system's fire suppression capabilities in such applications as engine compartments, ACAF Systems has introduced an added CAF mist fire suppression component to the design in the development of the system.

Nitrogen gas drives the solution from the pressure tank to the CAF generator where it is mixed with nitrogen gas under high pressure to produce CAF, as previously described. The now created CAF is then directed to either CAF nozzles or CAF mist nozzles to create a combined foam spray over the hazard area.

The number of CAF generators is determined based upon the number of nozzles the system is required to supply. The size tank required will be determined by the number of nozzles or the amount of risk as determined by the hazard analysis. In applications where there are high quantities of fuel (diesel or hydraulic fluid) greater quantities of solution will need to be provided for longer release duration of the system. Each application and its hazards present their own unique set of design parameters and issues. The design must thoroughly understand the application and hazards, and document and determine options before finalizing the design solutions. A through hazard analysis and design analysis is key to finalizing an actual system design. ACAF Systems works with designers in selecting tank size and reviewing during the design process.

Suppression units and CAF generators are capable of supporting four CAF mist nozzles and six CAF mist nozzles. Additional CAF generators may be required to protect larger hazards areas. Through extensive design, analysis, testing, and evaluation, a balanced piping and nozzle design installation pattern has been established. Nozzles placement is the key to suppression of the fire. Typically for an engine compartment application, both the CAF and CAF mist nozzles are located in the corners surrounding the engine block. The nozzles have specific placement requirements relative to each other, with regard to placement within the compartment, and relative to the equipment being protected, in this case, the engine block.

The nozzles are placed with piping installed in a H-pattern with CAF & CAF mist nozzles placed at each the end of each branch location. The dimensions and spacing are designed

to fit each specific engine compartment configuration. The piping will be designed to be a balanced configuration to ensure that the foam and mist are equally distributed throughout the compartment for even fire suppression capability.
Nozzles are configured in a standard paired arrangement, where the CAF nozzle is situated in the plane with the mist nozzle, but behind the mist nozzle with an offset orientation designed to allow for optimal entrainment into the CAF mist stream.
The nozzle locations will be determined based on the configuration and compartment conditions (e.g. air movement vs. no air movement) of the equipment being protected.
Storage tank placement will be determined by the configuration of the piece of equipment on which the system is being installed, depending on the availability and location of adequate space.
The system may be equipped with different types of detection systems depending upon the application's configuration and conditions. The detection systems utilize either linear heat detection or IR flame detectors. For flexibility and redundancy, the system may be both electrically and pneumatic powered-activated in conjunction with a pilot line. The system is activated when there is a loss of pilot pressure. This may happen by automatic release by an electric solenoid valve or pneumatic linear heat detector. Manual release of the system is by an emergency manual release valve.
In order to assist design professionals through these processes, ACAF Systems has developed a step-by-step approach for hazard analysis and design of the system as a guide to methodically analyze, design, and configure individual design for their individual engine compartment applications. ACAF Systems will always work with the designer and owner through the entire process from concept to installation.

SYSTEM TESTING

In order to validate the performance of the suppression system, ACAF Systems commissioned independent testing to be performed at Southwest Research Institute, San Antonio, TX. Testing was performed in accordance with the parameters of the Factory Mutual Protocol titled *A Fire Test Protocol for Evaluating Fire Extinguishing Systems for Off-Road Vehicles and HDME.* The test protocol provided for a rigorous testing program that is designed to ensure that CAF systems, such as the system, perform as required, to comply with stringent safety and suppression requirements. ACAF System's suppression system passed all testing with excellent performance results. Thus, validating its ability to be used in vehicle engine compartment applications. For test results and further system information, contact ACAF Systems. ■