A METHOD FOR EXTINGUISHING ENGINE NACELLE FIRES BY USE OF INTUMESCENT COATINGS

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ABSTRACT

The objective of this program is to explore **a novel** approach to engine nacelle/APU and other machinery space fire protection using strategic placement of intumescent materials within the ventilated aircraft engine nacelle. Intumescent materials are typically coatings that respond to impingement of a fire by swelling and possibly forming a protective char, to physically and thermally protect the coated structure. The approach includes a survey of intumescent coaling manufacturers for the viability of the coatings, expected expansion rate. potential application in the nacelle. fraction of the nacelle **flow** reduced by the coating. durability **of** the coating during normal flight operations. and adhesiveness and vibration-resistance of the expanded char following activation of the paint by a fire. **An** estimate will be made of the reduction in suppressant needed as a result of using this technology. This technology provides **a** lightweight, low cost approach to reducing airflow in the engine nacelle/APU.

BACKGROUND

INTUMESCENT MATERIALS

Intumescent materials are typically coatings that respond to impingement of a fire by swelling and possibly forming a protective char, to physically and thermally protect the coated structure. The intumescent coating can be applied as a very narrow and thin strip, in a form of one or more closed rings on the exterior of the machinery, which are located to swell against the enclosure at locations where clearance is minimal. Using intumescent materials in an engine nacelle, if a fire occurs (such as due to a leak of tlammable fluids onto hot exterior machinery components). the resulting flame would impinge onto a portion of such intumescent material, which would swell upon heating, normally several orders of magnitude beyond its original thickness. This swelling would block off the downstream airflow path in the vicinity of the fire, depriving it of a steady flow of oxygen and facilitating self-extinguishment. If the blockage is only partial. and the flame follows the re-directed airflow around the sealed-off area, the local intumescent-covered portion in that region would also swell, sealing off a perimeter of the machinery space and depriving oxygen flow until the fire self-extinguishes. In this manner, a series of “fire-walls” can bc formed using a minimal quantity of intumescent. If an extinguishing system is also used, it can improve its effectiveness or permit smaller systems hy weakening the fire and reducing the airflow dilution of the extinguishant. Previous analysis performed by the USAF suggested feasible application for machinery spaces (the concept having recently been submitted by the USAF for government patent protection, but not yet physically demonstrated).

AIRCRAFT ENGINE NACELLES

Aircraft engine nacelles, as with other machinery spaces, comprise an enclosure that houses a hot piece of operating machinery (an aircraft engine in this case). Such spaces also have fluid lines that are routed within the enclosure on the exterior of the machinery, to provide fuel, oil or hydraulic/brake fluid for the machinery (all of which are flammable). These enclosures/nacelles are typically ventilated with forced airflow (by a fan or by the free stream outside the aircraft), to prevent the accumulation of any flammable vapors. and possibly also provide some machinery cooling. In a typical fire scenario. one of the fluid lines leaks and sprays or streams the flammable fluid onto the hot machinery, which results in a fire. The ventilation airflow continues to support the fire, and directs the orientation of the resultant flame torch downstream. An automatic extinguishing system may be discharged from upstream to apply extinguishant to the fire, but due to rapid dilution by the ventilation airflow and short residence time near the fire (and robustness of a bluff-body stabilized flame), many of these fires will not be extinguished with extinguishant quantities permissible for many of these applications (and weight-sensitive aircraft in particular). In addition, after initial extinguishment, the fire may re-ignite due to the fluid continuing to flow onto the hot surface with replenished airflow after the extinguishant has been drawn downstream. Due *to* this situation, current machinery applications have serious problems with fire events, and extinguishing techniques only have limited success, or require extinguishing quantities and hardware that are impractical. Other diverse techniques proposed to date to avoid the limitations of traditional extinguishing systems have not been adequate for many of these applications, or have additional unacceptable disadvantages.

Figure I is a cross-sectional view of the region between the exterior of a piece of hot machinery and the enclosure (or nacelle) that surrounds the machinery. The machinery exterior (1) is hot enough to ignite fluids in this region, or near a source of electrical energy such as a wire bundle or connection. The outer enclosure or nacelle (2) is some distance from the heated machinery. In this example, a region chosen in proximity to a structural rib (3) is illustrated. The clearance between the rib and machinery is commonly no more than 1-3 inches. Other components may also be present or used as substitutes to the ribs that also result in local small clearances. They may be general enclosure contours, conduits, or other components. In addition, some such components may be present on the machinery surface itself, which may reduce the clearance with the enclosure. An intumescent coating (4) will be applied in the form of a narrow strip onto the machinery surface, or the components attached on it, in the region of reduced clearance. This region is just downstream of a location where a fluid line *(5)* is mounted. Intumescent materials expand greatly in size when impacted by a flame or extreme heat, forming a carbonaceous

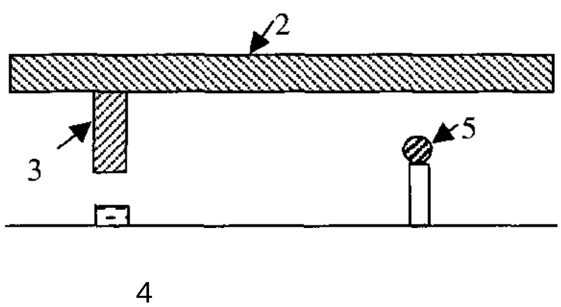

Figure 1. Cross section view of region between nacelle and hot machinery.

structure, possibly with an outer char layer, to form an effective thermal barrier against extreme fire conditions, and are widely used in many applications. Intumescent materials can expand twelve times or more beyond their initial size when impacted by a flame, and are typically applied as a viscous liquid, which hardens.

The fluid line may have a leak, which would result in sprayed or leaking fluid that can ignite on or near the hot surface (Figure 2). The flame ***(6)*** would thus orient itself downstream in the direction of ventilation airflow (7). Such a flame would impinge upon the strip of intumescent material placed downstream. Upon impingement, the intumescent material (8) would expand, on

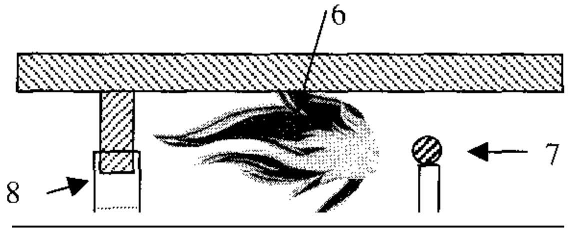

Figure 2. Fluid leak and subsequent fire.

the order of 10 or more times its original thickness, thereby forming around the rib or component above it and blocking off the flow of air locally. Such a local fire block would weaken the fire due to oxygen starvation (by preventing airflow in that direction) and possibly extinguish it.

An overall layout of the intumescent material is illustrated for an entire engine nacelle (or associated machinery space) (Figure 3). The narrow strips of intumescent material (4)are placed on the outer engine surface (1) across from several of the annular ribs that encircle the interior side of the nacelle (2). **An** individual strip ring would expand at the location just downstream of the location of the fire origin. It is important that each of these independent "rings" of intumescent material be actual enclosed curves, whose ends meet at some point on the engine surface. Therefore, if the air flows around a local region that has expanded (and redirecting the flame orientation as well), then the adjacent portions would also swell accordingly until the entire circle ***of*** intumescent swells. effectively closing off downstream airflow, stopping the flow ***of*** air and starving the fire in that region of the nacelle. Although each of these rings must be closed. it is not necessary that they form a two-dimensional plane, and can meander along the engine surface as long as they are in close enough proximity to the nacelle to effectively seal it. **As** stated, the intumescent material can be placed on components attached to the engine surface, rather than directly to the engine surface itself, if it proves advantageous from a sealing standpoint. The rings only need to be placed downstream of fluid line locations where fires may originate.

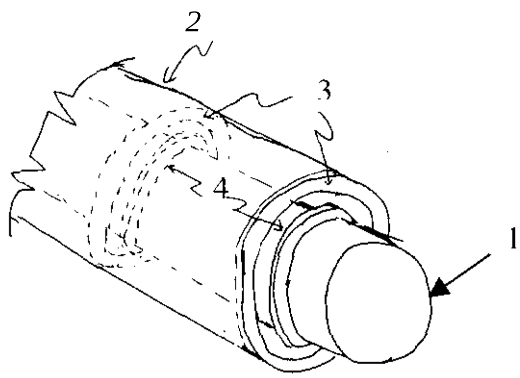

Figure 3. Overall layout of intumescent material

Many aircraft currently use firewalls at some location adjacent to engine nacelles to prevent fire propagation away from the engine. Unfortunately, these locations are usually limited to areas like the engine pylon (if the engine is mounted away from the aircraft body or wing), because it is desired to avoid constriction of the ventilation airflow directly around the engine under normal operating conditions. Such firewalls can also be heavy, are only necessary when an actual fire occurs, and are needed near the site of the fire. The intumescent material design described here could provide such protection in a lightweight form at the location of the fire, without normally impeding the flow of air.

Many types of intumescent materials are currently in use, including those already MIL-qualified and in use on aircraft such as cargo bay liners. **A** few examples are PittChar XP by PPG, No-Fire A-18 by No-Fire Technologies, Inc., and 3-6077 silicone ablative by Dow Corning. If one considers a strip 0.5 inches in width, 0.2 inches thick (to seal up a clearance **gap** of 2 inches or more) spread over an engine core of 30 inches diameter (which would represent an F-22 type engine), then a total volume of 0.005447 ft^3/ring would result. Accounting for the densities of the products just mentioned, a weight range of 0.393–0.460 lbs/ring would exist. Even if four rings were used at various regions of the nacelle, then a total weight of only 1.572–1.84 lbs. would be added. This weight is minimal in comparison to the size of extinguisher systems that are currently used, which can range from 10–20 lbs. total weight/engine.

The intumescent coating may only be needed in a limited region of the compartment, where the origin of fires is most likely. The intumescent material could also be mounted on the enclosure's interior side if it is deemed beneficial. If the gap is relatively large between the machinery and the enclosure, then a strip of coating may be placed on both the enclosure and machinery surfaces, which upon expansion could meet in the middle.

It is currently desired to find replacement extinguishing chemicals to the halons currently in use (which have stopped production due to ozone depletion), and such replacement chemicals have shown reduced performance relative to halons. As a result, the Department of Defense is seeking additional design techniques that can assist in the performance of these replacement chemicals, so they can be acceptably used in existing halon bottles, and by means of methods that restrict the flow of air in particular. This concept is ideal for this purpose, i.e., by weakening the flame due to oxygen starvation and inhibiting extinguishing chemical dilution by restricting airflow, thereby increasing its local concentration and residence time near the fire. This technique may be sufficient in many cases to permit the omission of an extinguishing system altogether.

OBJECTIVE

The objective of this program is to explore a novel approach to engine nacelle/APU and other machinery space fire protection using strategic placement of intumescent materials within the ventilated aircraft engine nacelle [1].

POTENTIAL APPLICATIONS

This technique may also be suitable for those applications where an extinguishing system may not be justified, e.g., unmanned aerial vehicles. It also has many potential commercial applications, including stationary turbines, marine engines and machinery spaces, buses and transportation equipment, fixed generator and compressor units and power equipment trailers, petrochemical facilities, and any other applications where liquid fueled, oiled, or hydraulically controlled equipment is operated and possibly stored within an enclosure. Other military applications include other aircraft dry bays (wing leading/trailing edge, equipment bays, landing gear bays, and auxiliary power unit compartments), armored vehicle engine compartments, and battlefield equipment/electronics trailers.

APPROACH

The following resources will be investigated for their discussions of optimization of fire suppressant delivery systems: National Institute of Standards and Technology, Federal Aviation Administration, Civil Aviation Administration, American Society of Mechanical Engineers, Japanese Society of Mechanical Engineers, Journal of the Combustion Institute (Combustion and Flame), Journal of Fire and Flammability, Society of Automotive Engineers, US Patent and Trade Office, Air Force Research Laboratory Technical Library, Air Force Institute of Technology, Advisory Group for Aerospace Research and Development (AGARD), and existing Next-Generation Fire Suppression Technology Programs (NGP) programs.

Manufacturers of intumescent coatings will be surveyed for the following information:

- Viability of the coatings, including the durability of the coating during normal flight operations and adhesiveness and vibration-resistance of the expanded char following activation of the paint by a fire.
- Effectiveness of the coatings, including the expected expansion rate and the fraction of the nacelle flow reduced by the coating.
- Application of the coatings in the nacelle.

Data from NGP Element 1.A. (Development Of Model Fires For Fire Suppression Research) will be utilized for the physical and function limitations of these systems. This information will include system configuration and fire models for aircraft engine nacelles/APU and other machinery spaces. An estimate will be made of the reduction in suppressant needed as a result of using this technology. Recommendations for a potential test program (proof-of-concept) will be developed as a result of this effort.

SUMMARY

Technology pursued by this effort will significantly advance the capabilities to suppress fires rapidly and effectively in manned (land combat vehicles) and unmanned (aircraft engine nacelles/APU) spaces. The utilization of intumescent coatings on engine nacelle/APU and other machinery spaces will allow utilization of current alternatives (although less efficient than halon) and not impact mission readiness because of the reduction in airflow.

ACKNOWLEDGMENTS

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REFERENCE

1. Bennett. M.V.. "A Method For Extinguishing Engine Nacelle Fires by Use of Intumescent Coatings," proposal submission in response to fiscal year 2000 Next-Generation Fire Suppression Technology Program (NGP) Proposal Solicitation, March 1999. Copy on file with the author.