

# **White Paper**

## **The Eclipse 500 Fire Suppression System**

### **Using the PhostrEx™ Agent**

#### ***Pioneering the World's First Commercially-Viable Halon Replacement***

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# **The Eclipse 500 Fire Suppression System Using the PhostrEx™ Agent**

## **Preface**

Eclipse Aviation Corporation (“Eclipse”) will certify the Eclipse 500 with a new fire extinguishing agent called the PhostrEx™ fire suppression agent. The PhostrEx™ agent, and its application in the Eclipse 500, have already won approval from the Environmental Protection Agency (“EPA”) and have passed all Federal Aviation Administration (“FAA”) certification fire testing. This new agent addresses many of the drawbacks of Halon fire suppression systems used extensively by the aerospace industry since the 1950’s. This paper describes the history of fire suppressants, the chemistry and toxicology behind the PhostrEx™ agent, and the methods that were used by Eclipse engineers to develop and certify this revolutionary technology.

# 1 History of Early Fire Suppressants

Materials that extinguish fires have been crucial for a long time. In the early part of the last century, the inexpensive production of chlorine from seawater led to hand-pumped extinguishers filled with carbon tetrachloride ( $\text{CCl}_4$ ). In the 1920's, these were used for small aircraft fires in Europe, though the Army Air Corps adopted carbon-dioxide based extinguishers in 1931. Methyl bromide ( $\text{CH}_3\text{Br}$ ) was found to be more effective, but also more toxic than  $\text{CCl}_4$ . Its use was rejected in the U.S. because of its toxicity, but it became the standard material for aircraft fire suppression in England in 1938. It was used by Germany during the Second World War in both marine and aircraft fire suppression, though casualties from methyl bromide poisoning were reported. Chlorobromomethane ( $\text{CH}_2\text{ClBr}$ ) was developed as a less toxic but highly effective alternative to methyl bromide by the Germans, and was later adopted by the U.S. Air Force for protection of power plants, portable extinguishers, and airport ramp patrol vehicles.

In 1948, the U.S. Army conducted systematic research to find a less toxic but still highly effective alternative to methyl bromide. The Army Corps of Engineers coined the term Halon to describe **halogenated hydrocarbons**; in other words, materials that contain combinations of carbon, fluorine, chlorine, bromine, and iodine. The numbered suffix of a Halon with formula  $\text{C}_a\text{F}_b\text{Cl}_c\text{Br}_d\text{I}_e$  is Halon *abcde*, but trailing zeros are dropped and hydrogen is not numbered. For example, Halon 14 is  $\text{CF}_4$ , Halon 1301 is  $\text{CF}_3\text{Br}$ , Halon 1211 is  $\text{CF}_2\text{ClBr}$ , and Halon 1001 is  $\text{CH}_3\text{Br}$ . As a result of these studies, four agents were selected for further evaluation, Halons 1301, 1211, 1202, and 2402.<sup>1</sup>

Halon generally, and Halons 1301 and 1211 specifically, were terrifically successful in a wide range of applications until, in the mid-1970s, evidence began to emerge that these "inert" materials were causing subtle and dangerous changes to the global environment.<sup>2</sup> To explain briefly, Halons do not react with gases in the troposphere, nor do they dissolve in water and precipitate with rain. When released, they are lofted into the stratosphere (8 to 15 km, or 25,000 to 45,000 ft) by diffusion and convection over a period of about one year. Once they get to the stratosphere, they are trapped for an average of eleven years. The unfiltered sunlight that strikes Halons in the stratosphere breaks them apart, liberating free chlorine, bromine, and iodine atoms that catalyze depletion of ozone. Although ozone is constantly produced by the sun and destroyed by chemical reactions in the stratosphere, the presence of these halogen atoms shifts the balance and lowers the average amount of ozone in the stratosphere.

The surprising environmental impact of Halons and other halocarbons on the ozone layer led to the first international treaty to place consensual limits on a specific form of pollution. The Montreal Protocol on Substances that Deplete the Ozone Layer was signed in 1987 and called for a total ban on production of many halogenated compounds, including Halons, in 1994. Subsequent amendments and domestic implementation of the Protocol through the U.S. Clean Air Act have led to restrictions on the production and use of ozone depleting compounds. The 1994 moratorium is in place, and existing stockpiles are being conserved for critical uses including military and

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<sup>1</sup> Ford, C.L. *Halon 1301 Systems in Halogenated Fire Suppressants*, ed. R.G. Gann, ACS Symposium Series 16, (American Chemical Society: Washington) 1975, chapter 1.

<sup>2</sup> S. Rowland and M. Molina, *Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalyzed Destruction of Ozone*, Nature **249**, 810 (1974).

aviation applications until acceptable alternatives can be found. Eclipse has developed a viable alternative.

Since the ban on Halon 1301 was announced, government agencies, including components of the U.S. Departments of Defense, Commerce, and Transportation, have conducted vigorous research programs to find alternative fire suppressants. These programs have identified alternatives that have invariably been heavier, more costly, more toxic, or in other ways, less suitable than the Halons that would be replaced. The U.S. Air Force, U.S. Navy, and National Technical Information Service (NTIS) jointly spent over \$60 million dollars for research that resulted in alternatives that were either flammable or toxic under realistic deployment conditions.<sup>3</sup>

In the 18 years since the Montreal Protocol was signed, there have been many committees, studies, conferences, and papers produced whose theme involves replacement of Halons. However, to date, Halon 1301 is still the only fire suppression agent that has been certified for aircraft engine fire suppression.<sup>4</sup> Every commercial jet in today's fleet relies on an exemption from the Clean Air Act and the Montreal Protocol because it *must have a Halon 1301 fire suppression system in its engine compartments to be certified by the FAA*. Many military systems also continue to use Halon 1301 for suppression of engine and auxiliary power unit, cargo bay, and cabin fires, as well as for fuel tank explosion suppression.

## 2 Rethinking the Problem

The rich history and experience with Halon fire suppressants has led to a cultural attitude within the engineering community that nothing can beat the combined performance characteristics of these extinguishing materials. As a result, candidates with similar chemical and physical properties have been exhaustively studied. Hydrofluorocarbons such as  $C_2HF_5$ ,  $CF_3I$ , brominated alkenes, and many other materials that are variations on the Halon theme, have been considered, at great expense and with little success.

Eclipse has stepped outside of the conventional culture by completely reconsidering the problem of fire suppression from a chemical and physical point of view. Fire represents a class of chemical reactions that oxidize fuels and produce heat. Conventional fire suppressants, including  $CO_2$ , water, and Halons, for example, are stable chemical compounds. We posed two basic questions:

- Are reactive materials more suitable as agents to suppress fires?
- Can we exploit flow patterns in a fire to use agent more efficiently, rather than flooding the fire zone with extinguishing materials?

The secret behind the effectiveness of Halon 1301 is its chemistry. The primary difference between Halon 14 ( $CF_4$ ) and Halon 1301 ( $CF_3Br$ ) is the presence of a bromine atom in the latter. In a hot fire, the Halon 1301 molecule decomposes and releases the

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<sup>3</sup> W. Grosshandler, R.G. Gann, and W.M. Pitts, eds. "Evaluation of Alternative In-Flight Fire Suppressants for Full Scale Testing in Simulated Aircraft Engine Nacelles and Dry Bays," NIST SP 861, 1994. And R.G. Gann, ed., "Fire Suppression System Performance of Alternative Agents in Aircraft Engine and Dry Bay Laboratory Simulations," NIST SP 890 (2 volumes) 1995.

<sup>4</sup> FAA Advisory Circular AC20-100 9/21/1977.

bromine atom into the combustion zone. Bromine, unlike fluorine, catalyzes a recombination of reactive chemical species in the flame, shutting off the heat release and extinguishing the fire. Bromine atoms in the stratosphere play a similar catalytic role in converting ozone to molecular oxygen. The catalytic action of bromine is the reason that Halon 1301 outperforms Halon 14 and many other suppressants on the basis of the mass of material that is required to extinguish a typical fire.

Although Halon 1301 releases bromine into the flame, it does so reluctantly. The bond between carbon and bromine in CF<sub>3</sub>Br is quite strong, so the rate of bromine release is very slow at typical flame temperatures. It is reasonable to expect chemicals that liberate bromine more easily than CF<sub>3</sub>Br in a fire zone might be more effective at suppressing the fire. We have found that this expectation is correct and that a broad class of materials with weakly bound or *labile* bromine are much more potent than Halon 1301.

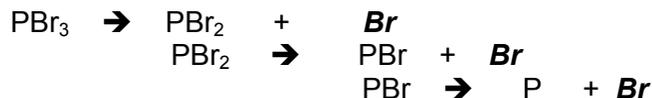
For example, we have found that a 500-kilowatt kerosene fire in a 20-knot wind can be extinguished with about two teaspoons of a labile bromine agent.

Preliminary experiments on robust fuel fires, computational quantum chemical models, laboratory kinetics measurements, and complete toxicological evaluations bore out the promise of this new class of suppression agent.

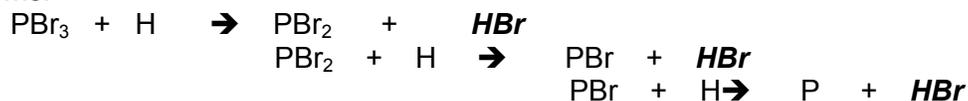
### 3 The Power of the PhostrEx™ Agent

The labile bromine compound studied extensively by Eclipse is phosphorous tribromide, or PBr<sub>3</sub>. This material is 87% by weight bromine and reacts rapidly with moisture in the atmosphere to produce simple, water soluble acids HBr and H<sub>3</sub>PO<sub>3</sub>. As a result of this reaction, which occurs in 0.087 second at 50% relative humidity, the agent cannot be transported to the stratosphere and therefore has *ZERO* ozone depletion potential and contributes nothing to global warming. Its byproducts are rapidly deposited by rainfall and neutralized to simple salts on the ground.

In a fire, this material decomposes about one thousand times more rapidly than Halon 1301, and it undergoes three sequential losses of bromine atoms:



Furthermore, the agent can react with reactive species in the flame such as hydrogen (H) atoms:



HBr is part of the catalytic flame inhibition cycle and can be generated also by the reaction of agent with water in the air and on surfaces:



The essential point is that efficient delivery of bromine as atoms or hydrogen bromide gas into the combustion zone quenches a fire using tiny quantities of suppressant.

Figure 1 depicts the chemical reaction and catalytic conversion which takes place when this agent is applied to a fire.

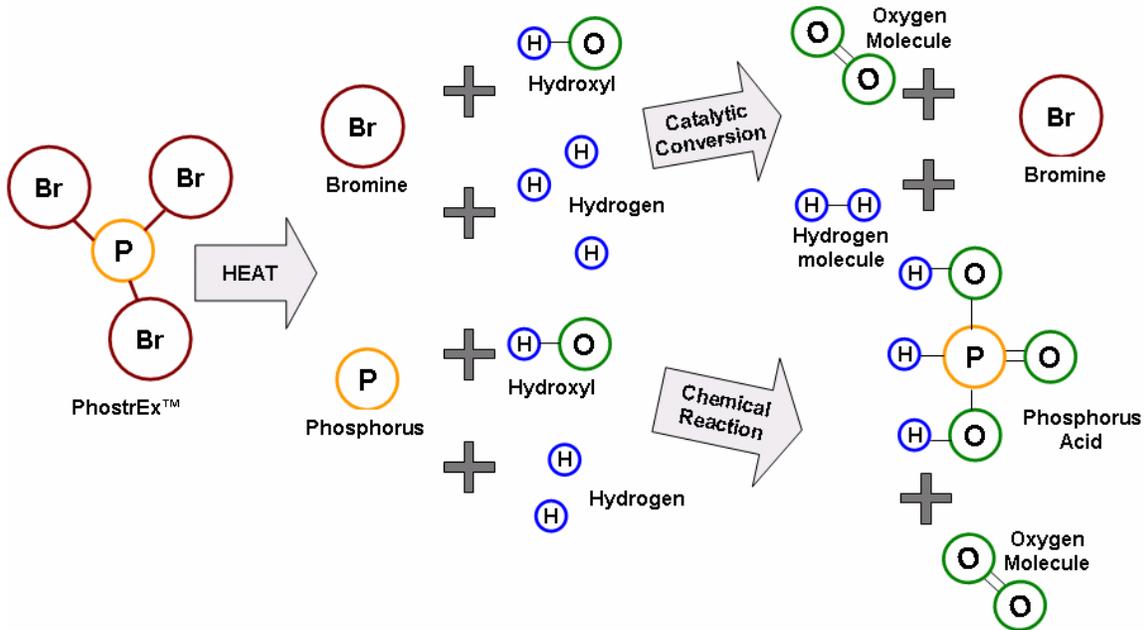


Figure 1. PhostrEx™ agent flame poisoning chemistry

## 4 Understanding the Whole Fire Suppression Challenge

The second aspect of fire suppression that we have reconsidered is physical. Current fire suppression approaches flood the engine compartment with agent. Current certification of commercial jet engines by the FAA requires demonstration of Halon 1301 concentrations of not less than 6% for not less than 0.5 second as measured with normal airflow and no fire. This empirical requirement is based on extensive fire testing in the 1950s; however, engine and nacelle designs have changed significantly in the last half century.

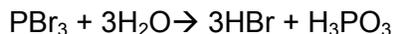
We have discovered that only certain zones within a partially enclosed space have the combined features of a fuel source, air flow, ignition, and flow pattern to support a sustained fire. These flame-holding regions vary in location for different installations and may also change over the flight envelope of a single aircraft. Agent delivered to non-flame holding regions has no influence on fire suppression and is therefore wasted. By combining modern tools of computational fluid dynamics, in-flight testing, and setting fires in a high fidelity simulation of the Eclipse 500 nacelle, we have identified these flame-holding regions and targeted the distribution of the labile bromine agent and its decomposition products (primarily HBr) to them.

As an added benefit, we have found that ambient flows within the nacelle can be used to transport agent to flame-holding regions more effectively and with less engineering complexity (and no plumbing weight) than is commonly used for total-flooding Halon systems.

## 5 Toxicology

As an intrinsically-reactive agent, it was essential to understand potential toxicity issues with the PhostrEx™ agent. This was accomplished in two discrete steps. First, measurements of the interaction between the agent and biological systems needed to be performed. An independent toxicology study was performed by the U.S. Air Force Armstrong Laboratory on acute and subchronic toxicity for PBr<sub>3</sub>. The report is authored by Robin Wolfe, Marcia Fledman, David Ellis, Harry Leahy, Carlyle Flemming, Darol Dodd, and Jeff Eggers and is entitled *Acute and Subchronic Toxicity Evaluations of the Halon Replacement Candidate Phosphorous Tribromide*. This report is available through the National Technical Information Service. (NTIS order number AD=A329386/7INZ).

In addition to this toxicology data, it was critical to evaluate toxicological risk, which includes plausible scenarios for exposure to the material. The risk assessment, which was prepared by the DoD Tri-Service toxicology program, was initially generated for a generic nacelle and hangar storage. Although the PhostrEx™ agent is a strong irritant in pure form, its physical and chemical properties virtually preclude its entry into the human body. The vapor pressure of the agent is 2.25 Torr (2.96mbar) at 20°C. As it slowly diffuses from a puddle or spill, the agent vapor reacts rapidly with moisture in the air and at wet surfaces to produce phosphorous acid (H<sub>3</sub>PO<sub>3</sub>) and hydrogen bromide gas (HBr) according to the following reaction:



H<sub>3</sub>PO<sub>3</sub> is a solid in its pure form (m.p. 73°C) and is extremely soluble in water (300 g/100 cm<sup>3</sup>); these physical characteristics preclude its easy transport away from the fire extinguishing canister (FEC) which is located in the pylon of the Eclipse 500. It is also worth noting that the Oral LD50<sup>5</sup> for this material is 1895 mg/kg body weight, so even ingestion of all of the H<sub>3</sub>PO<sub>3</sub> that is produced by discharge of an FEC would be uneventful.

Each gram of the PhostrEx™ agent that is completely hydrolyzed produces 0.897 gram of HBr gas, so the maximum amount of HBr that could be generated by discharge of a FEC is 24.21 grams or 6.71 liters at one atmosphere pressure and zero degrees Celsius. Transport of this gas occurs by two mechanisms; diffusion and advection.

The exposure limits of HBr gas are well established. According to the National Institute for Occupation Safety and Health (NIOSH), the threshold limit value is 10mg/m<sup>3</sup> as an eight-hour time-weighted average. The American Conference of Governmental Industrial Hygienists (ACGIH) has also set a limit of 10mg/m<sup>3</sup>. The NIOSH Immediately Dangerous to Life and Health (IDLH) threshold is ten times higher, or 100 mg/m<sup>3</sup>. Our analysis has shown that the possible hazard to humans in and around the aircraft following an accidental discharge of the FEC is less than this threshold. The byproducts of the agent (HBr specifically) also have an odor detection threshold of 6.7 mg/m<sup>3</sup>, which

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<sup>5</sup> LD stands for "Lethal Dose." LD50 is the amount of a material, given all at once, which causes the death of 50% (one half) of a group of test animals. The LD50 is one way to measure the short-term poisoning potential (acute toxicity) of a material.

is below the harmful level described above. In other words, humans are able to detect concentrations of the gas which are lower than those which may be harmful.

The PhostrEx™ agent cartridge is hermetically-sealed and cannot be refilled, so maintenance personnel are not required to handle the agent. Accidental discharge of the unit produces localized concentrations of water-soluble acids that are easily and safely cleaned with water, so that the risk profile for this material is qualitatively different than that for Halon, which is easily inhaled if valves or seals leak during maintenance.

## **6 Bringing this New Technology to the Eclipse 500**

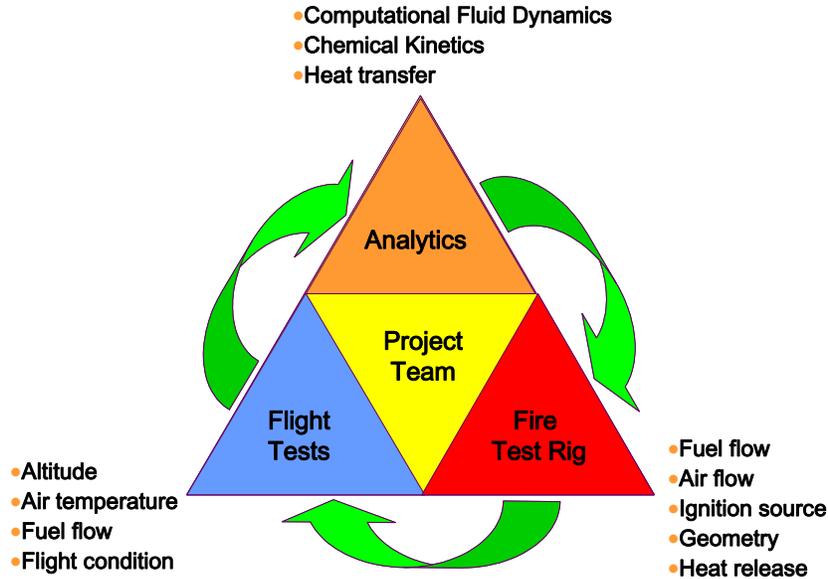
Eclipse worked with a freelance scientist to develop and certify a patented material, the PhostrEx™ agent, as a fire suppressant on the Eclipse 500. We met with the EPA in Washington, D.C. to discuss our plans to develop and certify this agent for the Eclipse 500. The EPA, having fought the aviation industry for years over Halon's exemption to the Clean Air Act, was enthused about Eclipse coming forward to change things for the better and has been very supportive.

Eclipse chose Mass Systems of Baldwin Park, California, to produce and qualify the Fire Extinguishing Canister (FEC) on behalf of Eclipse. Mass Systems developed the FEC to Eclipse's engineering specifications and subsequently produced development and certification articles for test. Mass Systems was also responsible for qualification testing on the FEC for certification credit.

Our strategy throughout the Eclipse 500 development program has been to treat the FAA as a partner from beginning to end, so that their concerns are addressed, and their expertise is used to guide our development and certification efforts. This model was used for the fire suppression program as well.

Eclipse engineers designed and built a Fire Test Rig (FTR) that contained the world's first exact replica engine installation for the express purpose of certifying a brand new fire extinguishing system by test (as opposed to using the standard indirect method that utilizes a halonizer). This rig represented the most important part of our project triad (depicted in Figure 2).

In an attempt to understand what happens in an engine compartment fire, Eclipse engineers designed and built a rig that would provide an exact simulation of the Pratt & Whitney Canada PW610F engine inside the Eclipse 500 nacelle. Working with Pratt & Whitney Canada engineers, we reproduced the external shape of the engine and every external part of the PW610 in exact detail using Pratt's computer models. Using Eclipse's computer models of the engine build-up components, such as bleed tubes, engine inlet, wiring harnesses, and nacelle components, we were able to establish a "fire zone" between the outside mold line of the engine and the inside mold line of the nacelle. Although components within this zone did not have to provide functionality, they did have to be aerodynamically correct.



**Figure 2. Project Organization**

Having established an exact replica of the PW610F engine installation, the next task was to establish methods for starting fires at various locations, simulating air and fuel flows, and acquiring data. The FTR included the following systems to manage testing and acquire the necessary data to develop and certify the PhostrEx™ agent.

- Fire suppressant system
- Water cleansing system
- Waste fluid system
- Ignition system
- Electrical system
- Fuel system
- Backup Halon suppressant system
- Pneumatic system
- Data acquisition system
- Test warning system

The basic testing methodology incorporated the use of fuel atomizing nozzles impinging on a glow plug for ignition and encouragement of the fire. This system was replicated at various locations around the fire zone based on an analysis of ignition sources, fuel sources, flame holding capability, and available airflow (oxygen). Engineers quickly discovered that the conditions that would support a fire are very few, and the available oxygen is the primary factor influencing the amount of heat release and the robustness of the fire. The Eclipse 500 flight envelope was used to determine airflow requirements for the test. Eclipse engineers used the flight envelope as a starting point and then added conservative margins to ensure that the FTR testing ALWAYS represented the worst case condition in flight. This was also done as a way to enable rig testing to occur before flight test assets were available. The tested flight envelope on the FTR is significantly larger than the Eclipse 500 flight envelope but we were always able to extinguish a fire regardless of heat release, location, flight condition, or FEC temperature.

During development testing, we set nearly 200 fires with various combinations of fuel flow, airflow, FEC temperature, and fire location. Through this development testing, we determined the significance of local flame holders, such as the engine fuel control, bleed

valve actuator, and engine starter-generator, and the fact that our nacelle airflows were predictable and reproducible. This also led to some fires migrating from the ignition area to another part of the nacelle where stoichiometric conditions and flame holders existed. Again, despite all of these “interesting” discoveries about how fires behave, we were always able to quickly extinguish them with just two teaspoons of the PhostrEx™ agent.

## **7 The Analytical Approach**

Eclipse has spent considerable time and resources building tools and methodologies to both correlate our Fire Test Rig (FTR) results to flight test data, and to enable us to apply these technologies to other Eclipse products, other aircraft, and even other industry applications. Our engineers used computational fluid dynamics (CFD) to understand the qualitative and quantitative features of airflow in the nacelle and its variability over the Eclipse 500 flight profile with respect to airspeed, altitude, slip stream, and crosswinds. Using these factors, we developed hierarchical models with ever-increasing complexity and resolution to understand ventilation rates, flame holders, agent mixing and the impact of the fire and heat from the fire to the resulting flow fields. In other words, the airflow through the nacelle, which is the most significant factor in the fire heat release and location, is significantly different before and after the fire is present.

Understanding airflow is absolutely critical in designing an efficient fire suppression system. One of the first experiments that Eclipse engineers performed to correlate CFD models to the FTR was a “tuft” test. Small pieces of yarn are taped to the surface to provide an indication of airflow direction. Aircraft manufactures routinely use this simple type of testing to quickly determine airflow separation on a wing or other surface. Eclipse engineers took this approach and applied it to the fire zone in the FTR. By plotting the orientation of each piece of yarn, engineers were able to determine flow direction throughout the nacelle. This information was then compared to the CFD plots and was found to have excellent correlation. Armed with correlated CFD models, Eclipse engineers can now predict the effect of any sort of change that may occur within the engine nacelle, or use the knowledge to apply airflow calculations to other engine installations.

Eclipse has pioneered a new approach to fire suppression system design that includes quantitative characterization of the fire and its extinguishment by reactive agents. The synthesis of computational fluid dynamics, high-fidelity fire simulation, and the use of ambient flows to distribute agent to critical locations within the fire zone are the subject of several pending patents. The company has developed and validated through certification a systematic and comprehensive method that will facilitate more efficient and rapid extension of the technology to aircraft other than the Eclipse 500, as well as to fire suppression challenges outside of the aerospace industry.

## **8 From Development to Certification**

The EPA’s approval to use the PhostrEx™ agent was very important in setting the FAA’s mind at ease with respect to environmental and toxicology issues. In this same spirit of constructive engagement with regulatory authorities, we held technical interchange meetings with the Fort Worth ACO and representatives from the FAATC to update them on our development work, solicit their recommendations, demonstrate the effectiveness of the agent in a real fire test, and clear the way for formal certification testing. The FAA

was supportive in our goals and direction and offered useful technical guidance based on their own research. The next step in the process was to develop the actual certification test plans and submit them to the ACO for review and approval.

The actual certification process is very straightforward. The regulatory requirements are clearly documented, requiring a certification approach, test design, and data gathering method to prove that the system works. Although there are other requirements throughout CFR Part 23, the major regulatory requirements for a fire extinguishing system are:

- § 23.1195 Fire extinguishing systems – covers basic applicability and definition
- § 23.1197 Fire extinguishing agents – covers agent requirements for extinguishing capabilities, thermal stability, and toxicity
- § 23.1199 Extinguishing agent containers – covers prescriptive design requirements
- § 23.1201 Fire extinguishing systems materials – covers compatibility of the agent with system materials and fire proofness.

Beyond the obvious requirement to ensure efficacy of the agent, which we certified by test, there are some other significant tests Eclipse engineers performed both in a development and certification environment. Probably the most significant of these is material compatibility. Being a corrosive chemical, we wanted to ensure that the PhostrEx™ agent is compatible with not only the fire extinguishing materials in the fire extinguishing systems as required by regulation (incidentally, these have been tested and approved by the FAA), but ALL materials within the nacelle that may come in contact with the agent. In addition to the certification tests, Eclipse is performing compatibility testing on ALL materials within the engine installation, including stainless steels, aluminums, wiring harness materials, and nacelle composite materials. All of our testing thus far has confirmed that the PhostrEx™ agent has no interactions with these materials. Although this may not be surprising in the sense that all nacelle materials are implicitly designed to withstand acid aerosols from polluted urban airflows, Eclipse has taken a conservative approach and examined all of the nacelle materials with the actual agent under realistic exposure conditions.

## **9 Summary**

Halon fire suppressants, with a rich empirical history, have evolved into the accepted standard for aircraft fire protection. Their Achilles' heel, discovered in the 1970s, involves their environmental impact. Ozone-depleting compounds were banned by international treaty in 1987. Production of Halon 1301 stopped in 1994, and existing stockpiles are being rapidly depleted by the military. The aviation industry has relied on exemptions from national and international law to continue operating with Halon 1301 in aircraft. Eclipse's fresh look at the fundamental physics and chemistry of fire suppression reveals that alternatives with superior fire fighting effectiveness, better airworthiness, lower mass, reduced life-cycle cost, and no environmental impact are now available.

Eclipse has filed U.S. and international patent applications for the Eclipse 500 fire suppression system. The PhostrEx™ fire suppression system is superior to Halon systems in all respects.

- **Lightweight and more effective** – The PhostrEx™ agent is much more potent than Halon. Two teaspoons of the PhostrEx™ agent are equivalent to 2 ½ cups of Halon. The total Eclipse 500 fire suppression system weight is approximately 90 percent less than a traditional Halon system.
- **Low maintenance costs** – The PhostrEx™ system is much less complex than Halon systems and is designed to be maintenance free for 10 years. After 10 years, you simply remove and replace the canister. In contrast, most Halon systems require recurring maintenance every five years. Overall lifecycle costs for the PhostrEx™ system are projected to be approximately one-tenth of a Halon system, contributing to the low direct operating costs of the Eclipse 500.
- **Proven in extensive testing** – Eclipse initiated a multi-million dollar development effort to prove the efficacy of PhostrEx™ fire suppression system by testing it in nearly 200 actual fires identical to those that might occur in aircraft engines. A Fire Test Rig (FTR) was designed and built to provide a platform to simulate engine-born fires. Eclipse will be the only aircraft manufacturer to have an FAA-certified fire suppression system proven through actual fire testing.
- **Environmentally friendly** – The PhostrEx™ fire suppressant agent has no ozone-depletion potential and contributes nothing to global warming. When the PhostrEx™ agent is released from its hermetically-sealed canister, it works to chemically shut down a fire in less than one-tenth of a second, and then, combining with moisture in the air, quickly becomes inert. Because of this rapid reaction with moist air and surfaces, the agent cannot be transported to the stratosphere where ozone depletion could occur. In a fire, the PhostrEx™ agent decomposes 1,000 times more rapidly than Halon and undergoes three sequential losses of bromine atoms, which are the power behind this agent. These atoms catalyze suppression of the fire.

**Eclipse revolutionizes aviation again with the development and certification of a new fire suppression system using the PhostrEx™ agent, the world's first commercially-viable Halon replacement.**

For more information about the PhostrEx™ fire suppression system, visit [www.phostrex.com](http://www.phostrex.com), or call 1-866-898-1097.



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2503 CLARK CARR LOOP SE  
ALBUQUERQUE, NM 87106  
505-245-7555  
[WWW.ECLIPSEAVIATION.COM](http://WWW.ECLIPSEAVIATION.COM)