Halon Extinguisher Replacement Program for Aviation Weapon Systems

INTRODUCTION

This nomination is for the Halon Extinguisher Replacement Program for Aviation Weapon Systems Integrated Product Team (IPT). It covers the last two fiscal years of the Program Executive Office (PEO) Aviation research and development program to replace the current aviation hand-held fire extinguisher (HHFE) (NSN: 6830-00-555-8837) charged with 2.75 pounds of the Ozone Depleting Substance (ODS) Halon 1301. The team is made up of representatives from many organizations, but the IPT itself is represented by the following core team members:

Chairman and Project Leader:	Alivio Mangieri: Product Management Office for Aviation Ground Support Equipment
Leadership Representative:	Frederick Reed: Program Executive Office for Aviation
Technical Representative:	Timothy Helton: Aviation and Missile Command
Test Representative:	Kevin Dowell: Army Test and Evaluation Command
Senior Scientist (Consultant):	Dr. Joseph Mather: Aviation and Missile Command

BACKGROUND

1. **Program Description**. The Halon HHFE is currently mounted in rotary wing weapon systems (H-60s, H-47s and OH-58s) and is a vital part of their mission. It uses a Class I ODS, however, which was banned from production by the Montreal Protocol in 1994. This initiative was in compliance with the Army Acquisition Executive (AAE) policy for Project Managers (PMs) to eliminate their dependency on ODS. PEO Aviation tasked the Product Manager for Aviation Ground Support Equipment (AGSE) with qualifying a non-ODS fire suppression agent and an associated fire extinguisher hardware configuration.

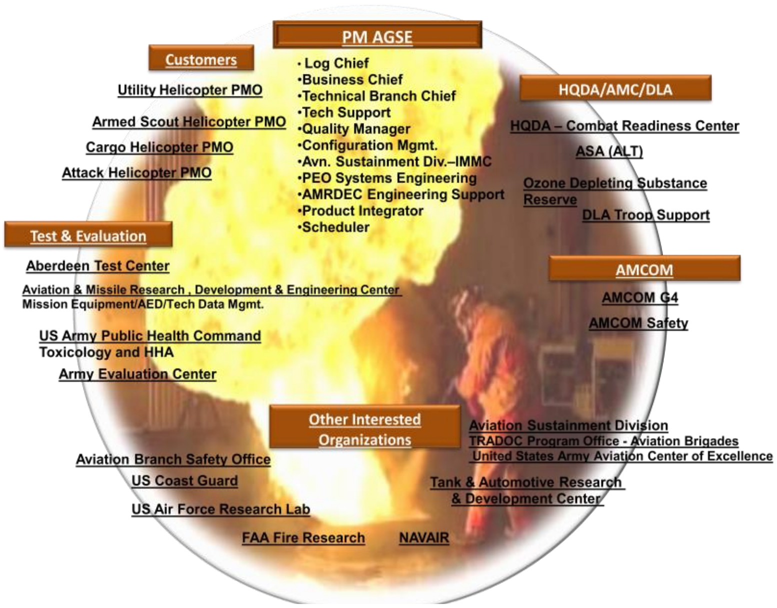


Figure 1 Non-ODS HHFE IPT Members

For this difficult task, PEO Aviation, the U.S. Army Aviation and Missile Command (AMCOM) and PM AGSE called upon the subject matter experts (SMEs) within AMCOM and the U.S. Army Test and Evaluation Command (ATEC) to spearhead a team of many stakeholders. Under the leadership of PM AGSE, this IPT included representatives of all the affected aviation PMs, along with other organizations depicted in Figure 1.

In addition, input from commercial experts in related industries was integrated into the development effort.

The HHFE is an item required for mission readiness. All Army rotary wing aircraft must have a required quantity installed during the pre-flight checklist to be mission capable. But more than that, it must be an effective fire suppression tool and perform without failure when it's needed.

The real significance of the hand-held extinguisher to Army aviation cannot be easily quantified, since not all fire events where HHFEs were used have been documented. While its importance is uncertain, recent research by AMCOM using the Combat Readiness Center (CRC) Risk Management Information System (RMIS) supports the findings of discussions with Army aviators, identifying this item's fire fighting capability as vital to air operations. Also, supported by a survey conducted with over a hundred Army aviators representing every aviation unit worldwide, the need for handheld fire suppression was first and foremost from the inception of this program. Performance first!

3. **ESOH Risk Analysis**. IPT meetings were used to provide task status, review documentation and discuss risk management during all phases of the program. Team members representing PEO Aviation, PM AGSE, ATC, and AMCOM briefed management on the project status, findings and recommendations by using schedules, Gant Charts and project risk analysis. PM AGSE provided the programmatic and development leadership, including providing funding for all materials, analysis, agent development and testing.

The initial project phase included baseline testing of the existing Halon 1301 HHFE, fire hazard case studies and agent options analysis. This stage was followed by design conceptual stages, developmental extinguisher testing, prototype development, production of representative developmental agent and extinguisher samples, qualification, and technical documentation of the developmental agent and extinguisher designs. Though starting in 2008, the Hydrofluorocarbon (HFC)-227ea/Special Sodium Bicarbonate (SBC$_S$) development was completed, qualified, documented, and made ready for procurement in the 2012-2014 time-frame. Health Hazard assessments and Toxicology Evaluations were conducted, Airworthiness Approval was granted, and the completed Non-ODS HHFE (HFC-227ea/SBC$_S$) was transitioned to the Defense Logistics Agency (DLA) for procurement and fielding during this time period as well.

Early on in the program, the team addressed Health Hazards and Toxicology in accordance with AR 40-10. The project funded the US Army Public Health Command (PHC) to assess the HFC-227ea/SBC$_S$ agent. As outlined in Army Acquisition Executive (AAE) ODS policy, the team requested that the Environmental Support Office (ESO) obtain approval from the Environment Protection Agency (EPA) for the new agent through the Significant New Alternatives Policy (SNAP) program.

The team also ensured that human factors were taken into consideration. Tests were run using 95th percentile male and 5th percentile female aviation crewmembers, outfitted in the most current outer-garments (Fire Resistant Environmental Ensemble - FREE) and personal protective equipment (including armor, vests, helmet, and heavy flight gloves). These crewmembers were able to remove the Non-ODS HHFE from an OH-58 aircraft bracket - deemed the most difficult to access - and discharge the HHFE while wearing heavy flight gloves. This is illustrated in Figure 2.

Exposure risks for aviation personnel were supported by concentration tests conducted in an enclosure that represented the smallest crew volume of any Army aviation system in the fleet.

4. **Technical Merit**. The final design focused on two blended fire suppression agents, both using HFC-227ea with a suspended amount of SBC_S. One formulation was based on nano-sized particles, and the other based on jet milled pharmaceutical-grade Sodium Bicarbonate. In addition, for optimal performance, new nozzle designs were developed and tested.

The IPT baselined the current Halon 1301 extinguisher's size, shape, use and performance, to provide the warfighter with a replacement that has the same fire-fighting capability, while not increasing size or operational difficulty, and with only minimal increase to the weight. The overarching goal was to provide a drop-in replacement for the extinguisher that's currently mounted on rotary-wing aircraft. However, the team also established requirements to meet other critical mission criteria that included strict environmental parameters for aviation weapon systems. The physical commonality of the Halon1301 and the Non-ODS HHFE are illustrated in Figure 3.

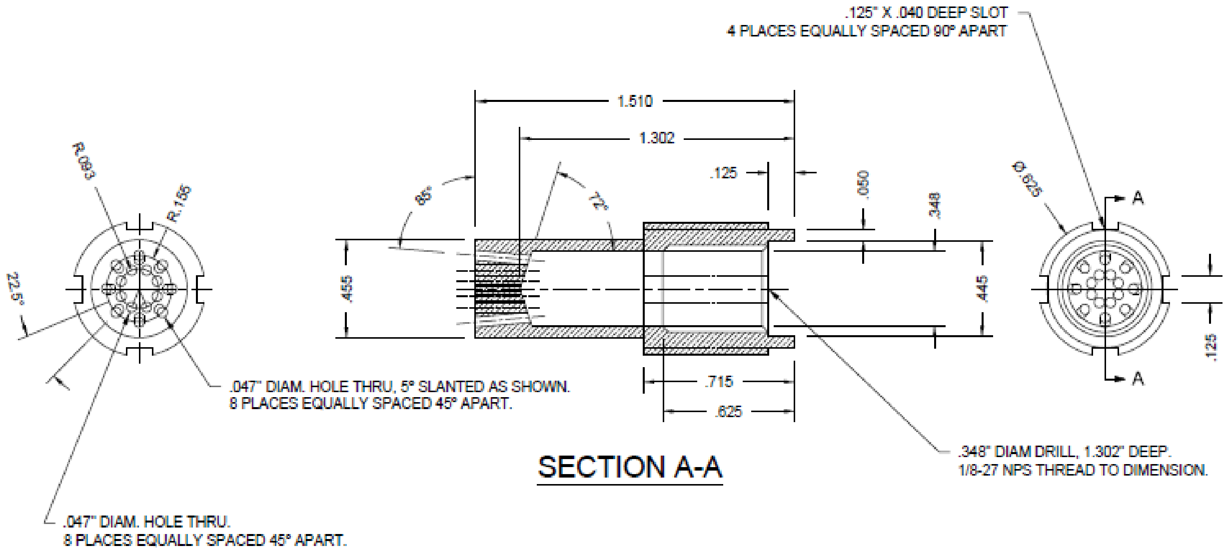
Although the early hardware and agent configurations developed were more effective than commercially available configurations using the same agents, they did not have the same fire fighting performance of the Halon 1301 HHFE. At that juncture the team performed exploratory testing with a standard Sodium Bicarbonate powder, which then led to the use of SBC_S that was produced at a very small particle size: less than 2 microns in diameter. At this size, no special coating was required to prevent the powder from caking while achieving enhanced powder suspension in the HFC-227ea. The small particle sizes also eliminated PHC toxicology concerns with undesirable particle coatings. The "suspendability" of the SBC_s in the HFC-227ea allowed the agent mixture to discharge at a consistent composition ratio, which allowed for optimal fire fighting capability. It also enhanced the fire fighting capability of the powder.

Using 5% by weight of the SBC_S with the HFC-227ea, the team was able to exceed the capabilities of other available non-Halon clean agents of the same quantity. Discharge trials showed that the blend also presented no visual obscuration for crewmembers during flight operations. When agent development was finalized, two types HFC-227ea/SBC_S blends, using the same HHFE hardware configuration, could meet the JP8 fuel pan fire capabilities of the Halon 1301 configuration that was being replaced. This was critical to developing a "drop-in" replacement, with the hardware configuration remaining the same size and with only a minimal increase in weight.

Development of accelerated aging testing protocols and specialized test hardware to ensure the quality of the agent (specially the SBC_S constituent) would not be degraded when subjected to temperature cycling was sought by the team. With no previous test of this type known to the Army, the team developed the needed accelerated aging test criteria, worked with industry experts to develop high pressure glassware, developed safety and fixturing hardware in-house and performed successful testing that provided a good measure of the agent's characteristics once subjected to extended time under extreme field conditions. Test results from this effort were favorable. The special hardware developed for this test and thermal cycling equipment used is shown in figure 4.

While researching and testing discharge nozzle technologies, it was learned that the best extinguishing performance for all agents tested was with nozzles fabricated/developed by the core team. The optimal nozzle design for the Non-ODS HHFE is illustrated in Figure 5.

Figure 5. Details for the final nozzle design. The drawing below was one of dozens included in the TDP provided to DLA Troop Support.



Many commercial nozzles were tested, along with nozzles provided by an agent manufacturer (DuPont). Several new nozzles were also developed and tested during the development phase. Commercial nozzles were not as effective as the developmental nozzle in fire suppression tests.

The team also sought a way to measure critically important quality parameters of SBC_S and worked with specialized commercial labs to develop tests to measure moisture content down to 500ppm of water and a sodium bicarbonate particle surface area measurement method based on an adaptation of proton nuclear magnetic resonance. These methods were both developed and documented so they could be used in the quality control of the Special Sodium Bicarbonate powder (these methods were included in the detail specification for the agent).

The team needed a method to measure and document the cross-sectional area and throw range of the replacement configurations discharge, to ensure repeatable performance once it was manufactured on a larger scale. The team developed a test utilizing planar laser technology that could visually show the cross sectional area of the spray pattern.

This test was also useful when comparing agent throw range of developed configurations, compared to the Halon configuration. PHC toxicology evaluation of health risks and live animal testing when subjected to nano-sized particles of SBC served as the basis for EPA's concurrence for use of the smaller sized SBC_S from the SNAP perspective.

5. **Internal Documentation**. The Non-ODS HHFE was tested and qualified per a detailed test plan (DTP). It was written so that the replacement would meet all aviation mission requirements. It included environmental tests such as high altitude, temperature shock, rough usage and more in accordance with MIL-STD requirements and Aviation Engineering Directorate (AED) oversight.

The DTP addressed not only performance criteria but also corrosion and compatibility concerns with the new agent. Included were tests to measure the corrosive effects of discharged agents on aviation unique materials. Some testing was also completed by industry, on whether the agent blend was compatible with materials used in the extinguisher itself, over an expected lifetime of the HHFE. There were also tests to ensure the final configuration would fit in the bracket that holds the existing HHFE, and would remain strapped in if subjected to a variety of forces, including projectile impacts. In addition, the DTP addressed unique human factor requirements.

The final configuration was documented in the technical data package (TDP) that comprised of 42 drawings. The TDP was approved and released to the Army database configuration management. The final test report, along with all other documentation, was shared with all IPT members and ultimately submitted to DLA for procurement.

In preparation for fielding, the team has reviewed hundreds of aviation weapon system technical manuals to identify those that will require updates to include the Non-ODS HHFE.

The Non-ODS HHFE obtained a safety confirmation from ATEC and an Airworthiness Release for fielding from AED. Core IPT members along with other SMEs played a vital role in the review and coordination of the two new MIL-DTL specifications developed and finalized in December 2012.

6. **External Coordination**. The team balanced all tasks, testing, schedules, materials, test resources, and personnel to best use funding, meet management requests, and keep the program on track. The team used Army test facilities, laboratories, airfields, specialized equipment and other resources to the fullest extent possible, including those made available by PHC, ATEC, the U.S. Army Redstone Test Center (RTC), the Army National Guard, and Air Warrior and Army Soldier Systems Centers. The team also fit-test the new HHFE on all aviation weapon systems.

In order to assist the user community, the team developed an audio/visual tool that outlines the proper use and maintenance of the Non-ODS HHFE. RTC provided personnel and an UH-60 Blackhawk backdrop when filming segments of tool. It will be launched on the Consolidated Aviation Portal and Storage (CAPS) website, and possibly other Common Access Card websites, when DLA has sufficient quantities of the extinguisher in stock to support fielding.

Presentations documenting the early development phase of the program were given by team members at the International Fire Protection System Working Group (IFPSWG) led by the Federal Aviation Administration (FAA) Fire Research Branch. Technical papers documenting the program’s successes were also written and submitted by core team members for the 2013 FAA Triennial Fire Research Conference and the 2014 National Fire Suppression Association (NFPA) Suppression/Detection Research Symposium. These are gatherings of the world’s leading fire suppression research experts. Over 100 pages of documentation were cleared by AMCOM Public Affairs for release and were shared with an international audience. The NFPA Fire Technology Journal editors also requested a manuscript of the work performed for publication consideration in a special issue of the NFPA Journal in early 2015.

The team will continue to follow DLA’s progress with awarding the Non-ODS HHFE procurement contract and provide assistance as required.

Test equipment and configurations developed during this program were recently adopted by the US Tank-automotive and Armament Command (TACOM) and the Tank and Automotive Research, Development and Engineering Center (TARDEC) and will be used at the Aberdeen Test Center in the very near future to support a program evaluating the aging of water-Potassium acetate hand-held extinguishers used exclusively on the Abrams Main Battle Tank (See Figure 6).

Naval Aviation Systems Command (NAVAIR) personnel in the IPT have expressed interest in using the Non-ODS HHFE, once additional Navy testing is conducted. In addition, recent Naval fire-tests with the H-53 Super Sea Stallion helicopter using the HFC-227ea/SBC$_S$ HHFE confirms that this new agent/hardware configuration is effective and is being considered for other special DoD system applications.

The FAA Fire Research Branch has recently asked for points of contact with the manufacturers of the small particle SBC$_S$ used in the Non-ODS HHFE development testing, and has requested team members to assist with FAA testing. They have also invited team members to attend meetings with FAA contractors, train contractors performing fire suppression testing for them, and provide assistance in discussions related to fire suppression.

Specifications for the Non-ODS HHFE hardware and the HFC-227ea/SBC$_S$ agent are published for public use. 42 drawings of the new HHFE were published in the Army database which makes up the TDP. This data was provided to industry by DLA Troop Support when the solicitation was published on FedBiz and the Defense Internet Bid Board System (DIBBS) in August 2014. The contract for the first production of the Non-ODS HHFE is anticipated to be awarded by the end of calendar year 2014, and fielding of the Non-ODS HHFE to the aviation community is expected to occur approximately one year after contract award.

Halon replacement discussions have been ongoing with the stakeholders for almost 20 years. Aviation users were asked to provide useful insight into their desired characteristics when developing/selecting a Halon HHFE replacement. Once the decision was made to qualify a replacement, discussions were held with the stakeholders under the auspices of the new IPT and a Non-ODS HHFE charter. Stakeholders (including all IPT members) were provided copies of reports and information as the program moved forward. Interaction included providing off-site personnel with a capability to view test videos and slides via teleconferences when travel was not practical. Decisions relating to down-selections, further development efforts and the path forward were made during these meetings, and that helped move the program toward the best solution available at the time.

Discussions with DLA Troop Support were also held to make sure they had input to plans, specification development, and programmatics. Team members met and briefed DLA personnel at their facility early in the program, when qualification test extinguishers were being manufactured. Some entities were also provided funding to maintain their involvement. The Aviation Branch Safety Office (ABSO) reviewed the initial Audio-Visual Tool Story Board, and later versions of the audio/video product, for critique and input. A scene from the Audio-Visual tool showing an RTC test pilot discussing the proper inspection of the Non-ODS HHFE is shown in Figure 7.

The Army's Environmental Support Office was asked to provide Headquarters Department of the Army assistance in regards to policy and guidance, and to coordinate the EPA review of the new agent from a SNAP perspective. The Aviation and Missile Research, Development and Engineering Center AMRDEC were asked to coordinate during the initial development through finalization of the DTP and to review test results and analysis. PHC was funded to perform toxicological analysis of the new agent and perform Health Hazard Assessments per AR 40-10.

AMRDEC and Research, Development and Engineering Command (RDECOM) Standardization Offices, DLA Aviation, DLA Troop Support, NAVAIR and the Air Force Research Laboratory reviewed, commented and provided suggestions on hardware and agent specifications while the Non-ODS HHFE was in development. ATEC and ATC provided test expertise, test facilities, contract actions for services/hardware/test materials, and fabrication of test equipment, parts and fixtures. DLA Troop Support participated during the entire program so they could have input for the eventual procurement, which is ongoing today. DLA Aviation provided insight to issues with past technical documentation so that the new specifications could be easily interpreted by industry. AMCOM provided PEO Aviation and PM AGSE with subject matter expertise, technical drawing assistance, specification lead, scheduling assistance, research of new materials, equipment and laboratory services, unique test development, DTP development lead and most all facets of the program.

SUMMARY

The Non-ODS HHFE IPT developed a technically and economically feasible replacement for the existing flight-critical, ozone-depleting extinguisher. The fielding of the Non-ODS HHFE (NSN: 4210-01-620-2962), and eventual replacement of the Halon HHFE, will significantly reduce the Army's annual use of Halon 1301 and eliminate an entire sector of the Army's dependency on a Class I ODS. The implementation of this Non-ODS HHFE will ultimately eliminate 30,000 pounds of Halon from Army aviation systems.

But it doesn't stop here. A Value Added Engineering program to decrease weight by using a lighter cylinder will be introduced once the initial configuration is fielded. Additional exploratory research using technologies similar to those developed for this program is in discussion, as well as research into newer technologies not available during the performance of this program, as funding becomes available. Testing of the HFC-227ea/SBC_S agent for engine nacelle and auxiliary power unit fire suppression, where Halon 1301 is still used, is also under consideration. In addition, testing to improve the suspension properties of powders in clean agents, utilizing technologies such as high watt density ultrasonics, would be worthy candidates for future work.

The Halon Extinguisher Replacement Program for Aviation Weapon Systems IPT is committed to following through on this program through fielding, by providing continued support to DLA Troop Support, on identifying and procuring sufficient quantities of the new extinguisher, and providing technical support. PEO Aviation and the core team stands ready to assist DLA, contractors, and suppliers by providing technical information, updating drawings, assisting with test oversight and any other possible issues to make the transition successful. Procurement support to DLA will also consist of First Article Testing (FAT) data review and approval, such as the results from pan fire testing shown in Figure 8, for the upcoming procurement contract.