

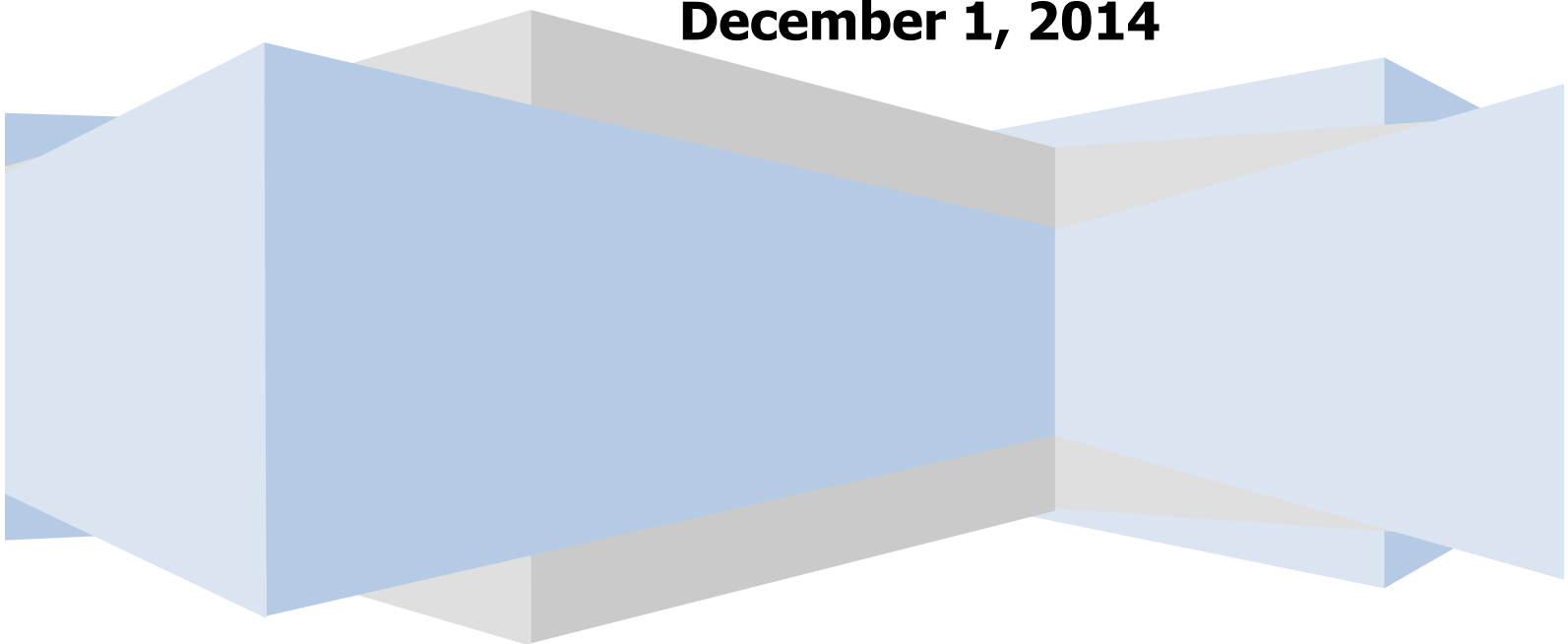
Halon Replacement Aviation Rulemaking Committee

FAA Halon ARC

Final Report

Findings & Recommendations

December 1, 2014



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Executive Summary

Halons are the principal fire-extinguishing agent used onboard aircraft because of their unique fire extinguishing properties. Due to their detrimental effect on the earth's ozone layer, their production (not use) was banned through the Montreal Protocol, an international treaty that has been ratified by every country in the world. Under the Protocol, halon ceased to be produced in developed countries in 1994, and in developing countries in 2010. As no new halon is being produced, the supply of previously produced halon is finite and will eventually run out. While residual supplies are being used or held for use in key areas including civil aviation, military, oil and gas, and other critical fire protection applications, their use in civil aviation represents the largest source of future demand for halons.

Until alternatives are certified and implemented, commercial aircraft will continue to need halon to meet current fire protection requirements. Specifically, halons are used in lavatory bottles, handheld extinguishers, engine nacelles and auxiliary power units (APUs), and cargo compartments. While the supply of stockpiled and recycled halon currently meets demand, over the 30-40 years needed to support the existing fleet the risk of supply chain disruptions and contamination of the reserves increases significantly. In addition, at some point in the future the scarcity induced price of halon will reach a level where the use of halon will no longer be economically viable. As that timeframe approaches and the cost increases due to reduced supply, the risk of sales of contaminated halon presents a growing concern.

In recognition of these issues, their potential impact on safety, and the resulting need for aviation to transition from halon to replacement agents, the International Civil Aviation Organization (ICAO) adopted amendments to the International Standards and Recommended Practices (SARPs) in two ICAO Annexes (Annex 6 – Operation of Aircraft, Annex 8- Airworthiness of Aircraft) addressing the transition to halon replacement agents in three of the four specific civil aviation applications noted above. The United States proposed and supported the adoption of these amendments. The key issue now is ensuring the smooth transition to safe and effective alternatives.

The Halon Replacement ARC was established to evaluate U.S. compliance with international standards for adoption of halon replacement agents in civil aviation. In that regard, the ARC considered safety, environmental, and availability issues that impact halon replacement, while acknowledging the complex technical and economic aspects of implementing functionally equivalent replacement agents in each of the four major aircraft application areas.

Policy Context

The SARPs approved by the ICAO Assembly and now included in two ICAO Annexes to the Chicago Convention mandate the replacement of:

- Halon 1301 in lavatory fire extinguishing systems used in aircraft produced after December 31, 2011 (this requirement is considered to have been met in the US);
- Halon 1211 in handheld fire extinguishers used in aircraft produced after December 31, 2016 (aircraft manufacturers have committed to implementing available alternatives for this use in new production aircraft over the next several years); and,
- Halon 1301 in engine nacelles and auxiliary power unit (APU) fire extinguishing systems used in aircraft for which application for type certification will be submitted after December 31, 2014.

In addition, the next ordinary session of the Assembly in 2016 is to consider a specific timeframe for the replacement of halons in cargo compartments.

Many members of the ARC have watched the pace of transition to alternatives for several years and are of the view that the actual shift to alternatives will continue to be slow in the remaining areas of concern in the absence of the discovery of a drop-in replacement, a policy signal that significantly raises the cost of halon, or a requirement that alternatives be implemented. While the increased scarcity of halons over time should lead to increased prices that would make alternatives more attractive, the time it will take for this process to lead to the adoption of alternatives is likely to be long, especially relative to the time needed to certify new alternatives. As a consequence, the ARC believes it will take a firm requirement to accelerate the adoption and implementation of alternatives in the near or medium term.

With respect to FAA rulemaking, the FAA indicated to all ARC members that the agency's existing regulations concerning aircraft fire suppression systems allow the use of halon "or equivalent" as an extinguishing agent. The ARC understands that the FAA has decided, based on available information, that regulatory action is not currently warranted. Some ARC members disagree with this decision, and believe that among the issues the FAA should consider are the level of supply of halon, and the continuing need to ensure that deployed halon meets certified standards for halon quality.

Even without U.S. regulation the requirements of the SARPs fall initially on airframe manufacturers. As the sale of airframes is a global business and U.S. airframe manufacturers want continued access to international markets, the ARC believes that it is very likely that national rules in other countries, such as those being implemented in the European Union, will serve as a forcing function for the transition to alternatives.

As these rules are finalized and the transition process moves forward, the ARC believes that there will be an increasing need for interaction between airframe manufacturers and the FAA, particularly as FAA moves to certify the specific alternatives selected for use. In addition, there will be an increased need for FAA to reach out to operators to ensure that they understand how this transition will affect their current and future operations, and regarding the near-term risks associated with reliance on halon. To help facilitate this interaction and to ensure that FAA is able to coordinate all halon-related activities under its purview (including the certification of

alternatives), the ARC recommends that the agency create a high-level halon focal point.

With respect to halon alternatives, substitute agents or systems that meet the relevant minimum performance standards (MPS) developed by the FAA have been identified for all four of the applications listed above, are commercially available for three of the applications, and are currently being used in one application, lavatory fire extinguishing systems. Therefore, all new installations of fire extinguishing systems for engines and cargo compartments on civil aviation aircraft continue to deploy recycled Halon 1301, and all new installations of handheld extinguishers continue to deploy recycled Halon 1211. It is anticipated that handheld extinguishers containing a halon alternative will begin being installed on new production aircraft in the next few years.

The currently identified substitutes for engine nacelles/APUs and cargo compartments would carry space and weight penalties compared to current halon systems, could require significant design changes to implement, and some have environmental concerns. As a result of these facts and the continued availability of halon, airframe manufacturers have not yet pursued qualification and installation certification for some of these potential substitutes. Instead, airframe manufacturers have focused on qualification testing for potential substitutes that either do not carry a space and weight penalty or do not have environmental concerns, so far without success. With statutory deadlines for halon replacement now imminent in the European Union and under consideration in other countries, airframe manufacturers may be forced to accept some of these tradeoffs in order to comply with national regulations. The fact that these requirements will only be imposed on new type certifications may enable airframe manufacturers to consider these changes and any related offsets in the context of the much larger changes that are likely to take place in the development of a new aircraft.

Based on its review of the status of development and implementation of halon alternatives for aviation applications, the ARC believes that the timelines for halon replacement contained in ICAO resolution A37-9 and codified in amendments to Annexes 6 and 8 of the Chicago Convention, with the possible exception of a short delay in the deployment of handheld extinguishers in new production aircraft, can be achieved by the aviation industry with existing technology.

Because the focus of the ICAO SARPs is on new production aircraft or new type certifications, the transition to alternatives will take place over a long period of time. Given the finite supply of halon, it is important that operators are aware of the halon supply situation. In short, while the global supply of halon is thought to be large, a good portion of the supply is held by owners or in countries that have long-term needs. While the residual amount is still estimated to be significant, ARC discussions with those in the business of supplying halons to aircraft manufacturers and operators note that there is a relatively small amount of halon in the supply chain at any one time, and there is limited ability to project future supplies. Because halons will continue to be required to service aircraft throughout their useful life, and because, in some cases, halons are being sourced from or near unstable areas of the world, the ARC is concerned

about the potential for future supply disruptions. As a consequence, the ARC is urging the FAA to reach out to the aviation community and individual airlines to discuss the situation and the possible benefits of holding additional stocks.

Another way to ensure continued supply and to provide environmental protection is to avoid unnecessary use. The ARC's estimate of Halon 1301 being used to service existing equipment (7-8% of that deployed) is much higher than for most other halon applications. Only a small percentage of these releases are used to extinguish fires. The vast majority are non-fire releases (false alarms), or releases that occur during testing or handling. Because there is significant uncertainty in this estimate, the ARC recommends that FAA further investigate this issue to determine if current emission rates and unnecessary discharges are unacceptably high and if there are steps that can be taken to reduce them.

As halon is no longer being produced, the need to transition to safe and effective alternatives is imperative. This transition should be done in a thoughtful and timely manner. The ARC believes that the recommendations included in this report will help the civil aviation community to achieve this goal, and in particular for the FAA as part of the broader civil aviation community to work cooperatively to play an important role in facilitating this transition.

1. **Halon Replacement Aviation Rulemaking Committee**

1.1. ARC Overview

Halogenated hydrocarbons (halons) are the principal fire-extinguishing agent used in civil aviation due to their unique ability to quench flame propagation reactions on the molecular level, and thus are optimized for applications where weight and space are at a premium. However, due to the significant ozone depletion potential (ODP) of halons, their production was banned under the Montreal Protocol on Substances that Deplete the Ozone Layer, a universally-ratified international treaty that phased out production in the United States and other developed countries in 1994 and worldwide by 2010. These provisions were adopted in the United States through the Clean Air Act, which provides broad statutory authority for the U.S. Environmental Protection Agency (EPA) to implement and enforce regulations to reduce the effects of ozone depleting substances.

At present, halon is used in four major aircraft application areas: Lavatory Bottles, Handheld Extinguishers, Engine Nacelles and Auxiliary Power Units (APUs), and Cargo Compartments. As halon is no longer in production, the aviation industry now relies on recycled halons. While this approach fulfills current demand for halon, at some point in the future halon will no longer be available or economically viable, and as that timeframe approaches the risk of contamination of halon reserves is a growing safety concern.

In recognition of the need for aviation to transition from halon to replacement agents, the International Civil Aviation Organization (ICAO) adopted amendments to the international Standards and Recommended Practices (SARPs) in two ICAO Annexes (Annex 6 – Operation of Aircraft, Annex 8- Airworthiness of Aircraft) addressing the adoption of Halon replacement agents in civil aviation applications. The United States proposed and supported the adoption of these amendments.

The Halon Replacement ARC was established to evaluate U.S. compliance with international standards for adoption of halon replacement agents in civil aviation. Toward that end, this ARC will address safety, environmental, and availability issues that impact the transition from halon to alternative agents, while accommodating the complex technical and economic aspects of implementing replacement agents.

1.2. ARC Charter

The Halon Replacement ARC Charter was signed on July 2, 2013 by FAA Administrator Michael Huerta. The ARC was jointly sponsored by the Deputy Associate Administrator of Aviation Safety, John Hickey, and the Deputy Assistant Administrator of Aviation Policy, International Affairs, and the Environment, Carl Burleson. The ARC was initially provided 12 months to investigate, prioritize, and provide recommendations to the Co-Sponsors on the objectives

outlined below. Due to the U.S. Government shutdown in the fall of 2013, the ARC did not hold their first meeting until November 2013. Due to this delay, it was determined that the ARC would need additional time to complete their objectives, and the Charter end date was extended from July 2014 until February 2015.

1.3. ARC Objectives

As outlined in the Charter, upon completion of its review, the ARC is expected to develop this report detailing its findings and recommendations on actions that should be taken to manage the safe and orderly transition out of halon as the primary fire suppression agent in civil aviation. While the report will be given to the FAA for consideration, the recommendations will be directed towards all stakeholders that may have a role in this transition. The report details potential collaborative industry-government initiatives on mutually beneficial solutions for halon replacement, taking into account the safety, environment, and economic issues affecting the need to regulate this replacement. The ARC recommendations are focused on 5 main objectives:

1. Recommendations for an industry-government framework and a top-level plan for halon replacement activities,
2. Recommendation on the organizational structure, scope, and specific work program of this industry-government framework and plan,
3. Proposals for halon replacement timelines based on existing international standards,
4. Proposals for assuring the safety of halon reserves through non-regulatory or regulatory mechanisms,
5. Specific implementation plans, in which halon is used, for each of the four major aircraft application areas: Lavatory Bottles, Handheld Extinguishers, Engine Nacelles/APUs, and Cargo Compartments.

1.4. ARC Tasks

Section 4 of the ARC Charter outlined the tasks that the committee was to undertake. The ARC focused their attention on the 10 criteria listed in section 4(b) of the charter. These criteria were subsequently investigated, prioritized, and summarized. Specifically, the ARC reviewed each criterion, gained consensus on the direction that should be taken in their evaluation, and determined whether additional investigation was needed or if the ARC evaluation could be summarized based on the previous discussions.

Task 1: International Standards (through ICAO Annexes 6 and 8).

The ARC developed a summary that focused specifically on the Standards and Recommended Practices (SARPs) in ICAO Annex 6 (Operation of Aircraft) and ICAO Annex 8 (Airworthiness of

Aircraft), which were incorporated following the 37th ICAO Assembly Resolution in 2011. SARPs currently exist in these Annexes for lavatory bottles, handheld extinguishers, and engine nacelles/APUs, but not yet for cargo compartments. The ARC reviewed the ICAO SARP development process, the associated ICAO Assembly Resolutions, and a description of the differences filed by the United States as coordinated through the Interagency Group on International Aviation (IGIA) process. It also reviewed the international response to those SARPs. This issue and related matters are further discussed in Section 2.

Task 2: Status of alternative agents for each individual capacity in which halon is currently used in civil aircraft.

The ARC developed a summary of the status of alternative agents in each of the four main uses of halons (lavatory bottles, handheld extinguishers, engine nacelles/APUs, and cargo compartments) in areas such as cost, availability, environmental effects, and other factors. This is further discussed in Section 3.2.

Task 3: Status of existing halon reserves.

The ARC reviewed available data sources on the estimated amount of halon available to civil aviation. Data sources included:

- U.S. Import/Export data on Halon 1211 and 1301,
- Models as developed by the Halon Technical Options Committee (HTOC),
- Amount of halon used/needed by the civil aviation estimated using HTOC, EPA, and industry reports, responses to the ICAO State Letter on halon reserves, responses to a survey developed by the ARC and distributed to aircraft service companies, data on U.S. sales of halon from the Halon Recycling Corporation, and anecdotal information provided by aviation industry experts.

The results of this task are discussed in Section 3.1.

Task 4: Recycling of existing halon reserves.

The ARC reviewed the process for recycling halon including: a general overview of the process, the related industry consensus standards to which recycled halon is certified, and the potential vulnerabilities in the process that could lead to contamination of halon used in civil aviation. The review included the RGW Cherry Report, "A Study on the Quality Control Process of Fire Extinguishing and Suppression Agents". Review of this task was necessary to demonstrate how the United States is able to comply with ICAO Assembly Resolutions that call for States to ensure that the halon used in civil aviation is safe for use.

Task 5: Feasible timelines for widespread implementation of alternatives in each capacity in which halon is used.

This task is closely aligned with Task 2 above, and describes available agents that are being implemented into aircraft systems (lavatory systems) now, and those that may require more

research to develop (handheld extinguishers, engine nacelles/APUs, cargo compartments). The results of the evaluation of this task were summarized together with Task 2, and are further discussed in Section 3.2.

Task 6: Airworthiness approval issues related to alternative agents.

Alternative agents and systems will need to be certified. The ARC developed a summary of the certification and approval processes required for issuance and continued validity of an airworthiness certificate. This summary provided a general overview of the aircraft life cycle (design, production, operation, and maintenance), and also provided background on the acceptable means of compliance that certificate holders use to show compliance with airworthiness requirements. This information was then used by the ARC to make recommendations on what guidance material may be necessary for certificate holders to show compliance with halon alternative fire extinguishing agents or systems. The results of this task are discussed in Sections 2.4 and 4.3.2.

Task 7: Environmental issues related to alternative agents.

The ARC summarized the status of environmental issues related to known alternative agents based on the data that was collected as described in Task 2 above. The ARC summarized the processes and procedures that are required to gain any required environmental approvals for new alternatives (e.g. EPA Significant New Alternatives Program approval). The results of the evaluation of this task were summarized along with Task 2 and Task 5, and are discussed in Section 3.2.2.

Task 8- Economic Issues related to halon replacement.

The ARC summarized the economic principles and known factual information regarding the economics of halon replacement in general, and in the specific areas of concern to the aviation community. As regards economic impacts of the shift to alternatives, it was recognized that as alternatives begin to be put into use, the producers of alternatives or alternative systems will gain economies of scale, which will push down the relative price of alternatives further. Over time, and depending on the timing of the conversion to alternatives, the scarcity-induced price of halon may increase to such an extent that users do not find its continued use viable. Finally, there may come a time in which the vast majority of users have converted, and the value of halons is reduced to nearly zero. The ARC recognized that this could serve as an incentive to vent remaining halon, an outcome that would have negative environmental consequences. Given this potential outcome and the uncertainty on the size of the stockpile, the ARC continues to support the rapid movement to alternatives (taking into account cost and environmental impact) and careful efforts to reduce unneeded emissions and extend the life of halon stocks.

As regards the economic impact of the shift to alternatives in the specific areas of civil aviation covered in the ICAO action, the ARC noted potential impacts related to the cost of the alternative, the cost of the new system, and the cost of any weight imposed impact on fuel

utilization. Those impacts will be variable, depending on the size and weight of the alternative selected for the specific use, and the other changes that might be made at the same time in the development of the new production aircraft on which the alternatives will be introduced. That said, the sections of the report on individual aviation applications attempts to provide a broad assessment of the impacts of using what are currently considered to be the most likely alternatives.

Task 9- Production issues related to halon replacement.

The ARC discussed and summarized issues related to the production of alternatives that affect the ability of the civil aviation industry to evaluate potential replacement agents or systems. In that regard, it was noted that the interest of product developers and manufacturers in halon alternatives would be influenced by the size of the market, the cost of development and production, and the likely profit that could be earned from sales. Some concern was expressed that the relatively small quantity of alternative substance needed for aviation might limit the number of producers willing to invest in commercialization, and that if the market were of sufficient size, more manufacturers would be interested in commercializing alternatives.

Task 10- International issues with halon replacement.

The ARC investigated applicable foreign requirements that may affect U.S. manufacturers and air carriers. Specifically, the ARC is aware of the existing EC rule, the ongoing rulemaking by the European Aviation Safety Agency (EASA), and other action taken by Hong Kong and Singapore. These are outlined and discussed further in Section 2.5.

1.5. Membership

(M) – Member

(A) - Alternate

(O) - Observer

Name	Organization
(M) Tom Cortina, Industry Co-Chair, Executive Director	Halon Alternatives Research Corporation (HARC)
(M) Curtis Holsclaw, FAA Co-Chair, Deputy Director, FAA Office of Environment and Energy	Federal Aviation Administration (FAA)
(M) Sarah MacLeod, Executive Director	Aeronautical Repair Station Association (ARSA)
(M) George Novak, Assistant Vice President, Civil Aviation (A) Leslie Riegle, Director of Environmental Policy	Aerospace Industries Association (AIA)

(M) Bob Ireland, Managing Director, Engineering & Maintenance (A) Paul King, U.S. Airways (M) Bruce Popp, Federal Express (A4A/IATA combined member)	Airlines for America (A4A)
(M) Robin Bennett, Halon Replacement Strategy and Technology Engineer (A) Robert Wright, Lead Engineer, Propulsion Technology Development	Boeing
(M) Steve Seidel, Senior Advisor	Center for Climate and Energy Solutions (C2ES)
(M) John Demeter, President, Wesco	Fire Suppression Systems Association (FSSA)
(M) Joe Sambiasi, Manager, Airworthiness & Maintenance (A) Walter Desrosier, Vice President, Engineering & Maintenance	General Aviation Manufacturers Association (GAMA)
(M) Dave Hoffman, Business Development Manager, Firetrace International	Halon Alternatives Research Corporation (HARC)
(M) Bill Polits, Vice President, H3R (A) Patricia Burns, A-Gas Remtec	Halon Recycling Corporation (HRC)
(M) Dan Verdonik, Director, Environmental Programs	Hughes Associates
(M) Ian Campbell, Director of Advanced Technologies	Meggitt Safety Systems
(M) André Freiling, Head of Fire Protection Pressurized Fuselage, Airbus (A) Bruce Mahone, Director Washington Operations, Aerospace	Society of Aerospace Engineers (SAE)
(M) Tadd Herron, Product Line Manager, Sensors & Integrated Systems (A) John Trinajstich, Manager, Business Development, Sensors & Integrated Systems	UTC Aerospace Systems
(M) Chinh Vuong (Aircraft Certification Service) (M) Richard Hill (FAA Technical Center) (M) Robert Warren (Flight Standards Service) (M) Caitlin Locke (Flight Standards Service, Co-Sponsor Support)	Federal Aviation Administration (FAA)

(M) Benjamin Jacobs (Office of the General Counsel) (M) Katie Haley (Office of Rulemaking)	
(M) Paul Horwitz, Deputy Director, Stratospheric Protection Division (A) Bella Maranion, Sector Analyst	Environmental Protection Agency (EPA)
(M) Kenneth Dormer, Defense Acquisition and Logistics Consultant (O) Tim Helton (Engineer, U.S. Army AMCOM) (O) Marco Tedeschi (NAVAIRSYSCOM, Aircraft Fire Protection)	Department of Defense
(M) Federico San Martini, Foreign Affairs Officer (A) Sandy Perez, Foreign Affairs Officer	State Department
(O) Alain Coutu, Airworthiness Officer, ICAO Air Navigation Bureau	International Civil Aviation Organization (ICAO)
(O) Julian Hall (O) Thomas Mickler	European Aviation Safety Agency (EASA)

1.6. Meetings/Telecoms

The Halon ARC was not able to begin its work for almost four months after the ARC charter was approved. It met for in-person meetings 7 times, beginning in November 2013 and ending in October 2014. Formal meetings resulted in specific action items for ARC members or small working groups to complete and bring back to the full group. When necessary, these individuals or working groups also held teleconferences to discuss these related tasks. Materials presented at ARC meetings were distributed in advance by the ARC Co-Chairs so that the ARC would be prepared to engage on related issues. ARC meetings were hosted by members with offices located in the Washington D.C. metro area.

2. **Background**

2.1. The Montreal Protocol and the Phase Out of Halons

The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) was adopted in 1987, and it has since been ratified by 197 parties around the world, making it the first universally ratified treaty in UN history. Today, the Montreal Protocol calls for the phase out of production and consumption of nearly 100 chemicals, including halons. In accordance with Protocol adjustments, production of halons in the United States and other developed countries ceased in 1994 and halon production ceased in developing countries in 2010. Although new production has been phased out globally since 2010, the Protocol allows the Parties to use and trade in previously used halons. To date, global supplies of previously used halons have been sufficient to supply residual important uses, including the use of halons in aviation.

Over the last two decades, the Protocol's Halons Technical Options Committee (HTOC) has tracked the very successful efforts that the Parties and their respective users have made in shifting to halon alternatives. One area of concern, however, has been the continued reliance on halons by the aviation community. Accordingly, the Parties to the Protocol requested the HTOC to work with ICAO to investigate and encourage the expeditious development and implementation of alternatives to halons for aviation uses.

Toward that end, the HTOC worked for several years with the ICAO secretariat and ICAO stakeholders through the Halons Working Group. After several years of discussion, that group agreed that proposed timelines for halon replacement should be incorporated into ICAO Standards and Recommended Practices (SARPs), and ultimately be adopted by States in their national frameworks.

2.2. International Civil Aviation Organization (ICAO) Efforts

2.2.1. ICAO Overview

The International Civil Aviation Organization (ICAO) was formed in 1944 with the signing of the Convention on International Civil Aviation (the "Chicago Convention"). The mission of ICAO is to promote the safe and orderly development of all aspects of international civil aeronautics, and provides a forum for issues affecting civil aviation to be discussed. It is headquartered in Montreal, Canada, with seven regional offices throughout the world. At present, the Organization is comprised of 191 Contracting States.

There are 19 Annexes to the Chicago Convention that provide for international Standards and Recommended Practices (SARPs) on most major aviation issues. The Annexes are not binding, but rather are intended to promote interoperability between the national regulations of States related to civil aviation. SARPs are a fundamental part of the ICAO work program. SARPs are intended to provide standardization and regularity across 19 varied areas of civil aviation. A

Standard is defined as “any specification to whose uniform application is recognized as necessary for the safety or regularity of international air navigation.” A Recommended Practice is defined as “any specification whose uniform application is recognized as desirable for the safety, regularity, or efficiency of international air navigation.”

According to the Convention, one of the primary obligations of States is adherence to the SARPs, as stated in Article 37; “Each Contracting State undertakes to collaborate in securing the highest practicable degree of uniformity in regulations, standards, procedures, and organization...such uniformity will facilitate and improve air navigation.” However, in cases where States may be unable or unwilling to comply with certain SARPs, Article 38 allows for States to file differences to SARPs; “Any State which finds it impracticable to comply in all respects to any such international standard or procedure...shall give immediate notification to ICAO of the differences between its own practice and the established international standard.”

Any ICAO stakeholder can recommend the development of a SARP, however the basis for the development of many SARPs typically arises from the direction given by an Assembly Resolution. Assembly Resolutions are in essence the documented consensus of the Assembly that directs the Council to undertake certain action.

2.2.2. Assembly Resolutions Regarding Halon Replacement

In collaboration with States and industry, ICAO first introduced proposed actions for the international aviation community regarding halon replacement in 2007. This was done with the strong support of the United States, which presented several formal working papers endorsing collaboration and cooperation throughout the aviation community to affect the transition beyond halon reliance.

This resulted in a series of Assembly Resolutions from the past three ICAO Assemblies directing specific action to the Council based on the progress of developing and identifying halon replacements and implementing such replacements into aircraft fire suppression systems.

2.2.3. ICAO 36th Assembly

The 36th Assembly was held in 2007, and the United States presented a proposal that lead to the adoption of Assembly Resolution A36-7 that:

- agreed that the international aviation community should develop and implement halon replacements;
- urged States to advise their industry to move forward at a faster rate in implementing halon alternatives;
- requested that the Council consider a mandate to be effective in 2011 for the replacement of halon in lavatories for new production aircraft and lavatories, handheld extinguishers, engine nacelles/APUs for aircraft for which a new application for type

certification has been submitted;

- requested that the Council consider a mandate to be effective in 2014 for the replacement of halon in handheld extinguishers for new production aircraft;
- encouraged ICAO to continue collaboration with the International Aircraft Systems Fire Protection Working Group and the United Nations Environment Programme's (UNEP) Ozone Secretariat through its Technology and Economic Assessment Panel's Halons Technical Options Committee on the topic of halon replacement for civil aviation;
- and directed the Council to report to the 37th Assembly on progress made with halon replacements in civil aviation.

2.2.4. ICAO 37th Assembly

The 37th Assembly was held in September 2010 and adopted Resolution A37-9, based on the progress reported by the Council as directed by A36-7, that further;

- urged States to intensify development of acceptable halon alternatives for fire extinguishing systems in cargo compartments and engine nacelles/APUs, and to continue work towards improving halon alternatives for handheld fire extinguishers;
- directed the Council to establish a mandate for the replacement of halon in lavatory fire extinguishing systems used in aircraft produced after a specified date in the 2011 timeframe, in handheld fire extinguishers used in aircraft produced after a specified date in the 2016 timeframe, and in engine nacelles/APUs fire extinguishing systems used in aircraft for which application for type certification will be submitted after a specified date in the 2014 timeframe;
- directed the Council to conduct regular reviews of the status of potential halon alternatives;
- urged States to advise their industry to verify the quality of halon in their possession or provided by suppliers through effective testing or certification to an international or State recognized quality standard;
- urged States to inform ICAO regularly of their halon reserves and for the Council to report on the status of halon reserves at the 38th Assembly, and
- directed that the Council shall report to the next ordinary session of the Assembly on progress made developing halon alternatives for cargo compartments and engine nacelles/APUs fire extinguishing systems as well as the status of halon alternatives for handheld fire extinguishers.

On the basis of this decision, Annex 6 and 8 Chicago Convention was amended to include the

related dates and requirements for halon replacements for lavatory, handheld extinguishers, and engine nacelles/APUs.

2.2.5. ICAO 38th Assembly

The 38th Assembly was held in September of 2013, and adopted a Resolution based on the progress made since the 37th Assembly that:

- urged States and their aviation industries to intensify development and implementation of acceptable halon alternatives for fire extinguishing and suppression systems in cargo compartments and engine nacelles/APUs, and to continue work towards improving halon alternatives for handheld fire extinguishers;
- urged States to determine and monitor their halon reserve and quality of halon;
- encouraged ICAO to continue collaboration with the International Aircraft Systems Fire Protection Working Group and the United Nations Environment Programme's Ozone Secretariat through its Technology and Economic Assessment Panel's Halons Technical Options Committee on the topic of halon alternatives for civil aviation;
- encouraged States to collaborate with the Industry Consortium for engine nacelles/APUs and the Cargo Compartment Halon Replacement Working Group established by the International Coordinating Council of Aerospace Industries Associations;
- urged States to inform ICAO regularly of their halon reserves and directs the Secretary General to report the results to the Council, and
- directed the Council propose to the 39th Assembly a timeframe for the replacement of halon in cargo compartment fire suppression systems.

2.2.6. ICAO 39th Assembly

The 39th Assembly of ICAO is expected to meet in September 2016. The ICCAIA Cargo Compartment Halon Replacement Working Group is expected to propose a timeline for the replacement of halon in cargo compartments of new designs by December 2015 that will be considered for adoption at the 39th Assembly. Assuming that the 39th Assembly agrees on a timeline for such action, the interim review process within ICAO and by Member States would take, at a minimum, three years to implement due to the nature of the affected Annexes. Therefore, the earliest possible date that could be proposed would be 2020 for replacement SARPs for cargo compartments to become effective in the applicable ICAO Annex.

2.3. ICAO Standards and Recommended Practices

Each of the Annexes to the Chicago Convention focuses on and provides standards for a specific area of civil aviation. Annex 6 ("Operation of Aircraft") provides criteria for safe operating practices, written in the form of operational standards. Annex 8 ("Airworthiness of Aircraft") provides a broad range of specifications that any member State may use to determine whether an aircraft in its jurisdiction is airworthy. Under Article 33, once a State of Registry approves a particular aircraft by issuing a certificate of airworthiness (C of A), other member States of ICAO must recognize that C of A as valid. As a condition of this reciprocal recognition, however, each State of Registry should only issue a C of A to aircraft that meet or exceed certain minimum standards, established by ICAO. ICAO developed Annex 8 to be the technical standards underpinning the Article 33 framework. Note, however, that Annex 8 does not replace or supersede national airworthiness regulations, which member States develop to whatever extent they deem necessary. In the event that a member State's national regulations must deviate from the ICAO annexes, the State must file a difference with the organization to notify other members.

Another significant component of ICAO's technical framework is Article 41 ("Recognition of existing standards"), which temporarily postpones the implementation of any new technical requirements adopted by ICAO. More specifically, Article 41 provides that such technical standards shall not apply to newly submitted aircraft and aircraft-equipment prototypes, or "type designs," for a period of three years after adoption by ICAO. In the context of halon-reduction efforts, this limitation applies or would apply to all existing and proposed Annex 8 SARPs pertaining to the aircraft type design of lavatory extinguishers, engine nacelles/APUs, and cargo compartment fire suppression systems.

2.3.1. SARPs related to the Montreal Protocol

As of 2014, Annexes 6 and 8 of the Chicago Convention contain numerous SARPs imposing current and future limitations on the use in aviation fire suppression systems of halon (and other substances listed in Annex A, Group II of the Montreal Protocol on Substances that Deplete the Ozone Layer). As noted in section 2.2.3, with respect to lavatory systems, ICAO requires the use of a substance not listed in Annex A, Group II of the Montreal Protocol in the lavatory systems of currently produced aircraft after December 31, 2011 and in new aircraft type designs submitted by December 31, 2014. With respect to handheld fire extinguishers, ICAO requires the use of a substance not listed in Annex A, Group II of the Montreal Protocol in the handheld extinguishers of currently produced and new aircraft type designs after December 31, 2016. With respect to engine nacelles/APUs, ICAO requires the use of a substance not listed in Annex A, Group II of the Montreal Protocol in the engine nacelles/APUs of new type designs submitted after December 31, 2014. It should be stressed that none of these requirements calls for the retrofit of any halon systems in the current fleet.

2.3.2. USG Differences to the ICAO SARPs

As a Contracting State to the Chicago Convention, the United States is required to either comply with or file differences to the Standards contained in the ICAO Annexes, and to publish any differences in the U.S. Aeronautical Information Publication (AIP). Differences are filed in three categories: those that exceed the ICAO standard, those that meet the standard by different means, and those that do not meet the standard. Differences filed by member States are not considered permanent; rather States are meant to continuously review the status of their differences and inform ICAO if and when a difference is no longer necessary.

Following the final amendment of Annexes 6 and 8, the United States filed a difference to these new SARPs. The United States' difference indicates that there is no pending or existing regulatory or statutory action restricting the use in fire extinguishing of substances banned by the Montreal Protocol. It is important to note, however, that the United States strongly supported the actions taken by ICAO at both the 36th and 37th Assemblies, including amending the annexes to include SARPs that would reduce the use of halon.

Before filing a difference, the United States Government coordinates internally via the Interagency Group on International Aviation (IGIA). This group is chaired by the Department of Transportation, and is managed internally by the IGIA Secretariat within the Federal Aviation Administration. The IGIA provides direction on all international aviation policy matters affecting two or more agencies of the United States Government. Incoming correspondence on aviation policy matters (e.g., letters of inquiry received by the IGIA or another body of the United States Government) are distributed to stakeholders via IGIA processes, which involve assigning an action office and a due date for response. The proposed response is then circulated to all IGIA members for a five-day comment period, after which time IGIA sends a final response to the Department of State for transmission back to the requesting organization (e.g., the ICAO Secretariat).

The United States Government has filed the following differences to ICAO's halon-related SARPs:

Annex 6 (parts I, II, and III)

Annex Reference	Standard or Recommended Practice	State Legislation, Regulation, or Document Reference	Level of Implementation of SARPs	Text of the Difference to be notified to ICAO	Comments including reason for the difference
2.4.2.3	Standard	14CFR23.851 14CFR23.1197 14CFR25.853 AC20-42D	C	b) not be of a type listed in Annex A, Group II of the <i>Montreal</i>	The United States only requires that the type of extinguishing

				<p><i>Protocol on Substances That Deplete the Ozone Layer</i>, 8th Edition, 2009.</p>	<p>agent used for hand fire extinguishers “be appropriate to the kinds of fire likely to occur where that agent is to be used” and for use in a lavatory disposal receptacle “be capable of extinguishing flames emanating from any burning of fluids or other combustible materials in the area protected”.</p>
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Annex 8

Annex Reference	Standard or Recommended Practice	State Legislation, Regulation, or Document Reference	Level of Implementation of SARPs	Text of the Difference to be notified to ICAO	Comments including reason for the difference
1.2.5	Standard	Code of Federal Regulations Title 14 (14 CFR) parts 25.854, 29.851, 23.1197, 25.1197, 29.1197,	C	b) not be of a type listed in Annex A, Group II of the <i>Montreal Protocol on Substances That Deplete the Ozone Layer</i> ,	The U.S. Federal Aviation Administration is still evaluating potential replacements for halon use in commercial

		121.265, 121.308		8th Edition, 2009.	aircraft. While viable replacements have been identified, the U.S. FAA has not yet mandated a replacement agent.
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2.4. Summary of USG Airworthiness Approval Processes and Procedures

To determine where it may be appropriate to make recommendations for the development of guidance material or regulatory changes to coincide with the SARPs already put in place by ICAO, the ARC discussed with FAA their regulatory authority and developed a summary of the U.S. certification and approval processes required for issuance and continued validity of an airworthiness certificate.

The FAA fulfills its statutory mandate to ensure minimum standards in the interest of aviation safety are developed, implemented and overseen through its design, production, operation and maintenance regulations. The approved design standards dictate the production, operation and maintenance parameters. Once the design is approved, the product, article, part or material must be produced, operated, maintained or altered to that standard. The standards are limited to those requirements necessary for continual safe operation of aircraft under the jurisdiction of the United States.

2.4.1. Overview of FAA Statutes and Regulation for Aviation Safety

United States Code (U.S.C.): Title 49 (Transportation, Subtitle VII – Aviation Programs) provides the FAA its statutory authority to establish safety standards for the design, production, operation and maintenance of civil aviation articles. The following excerpts describe some of the specific functions that the FAA carries out that are related to the airworthiness approval issues being discussed in the Halon ARC.

- Promote safe flight of civil aircraft in air commerce by prescribing minimum standards required in the interest of safety for appliances and for the design, material, construction, quality of work, and performance of aircraft, aircraft engines, and propellers [49 U.S.C. 44701(a)]
- Issue type certificates, production certificates, airworthiness certificates [49 U.S.C. 44702(a)]

Title 14 of the Code of Federal Regulations (14 CFR) contains the standards that the FAA has

developed to implement its statutory mandates. The regulations applicable to halons include:

- Part 1 – Definitions and Abbreviations
- Part 21 – Certification procedures for products and parts
- Parts 23 (Small Airplanes), 25 (Transport Airplanes), 27 (Small Rotorcraft), 29 (Transport Rotorcraft), 33 (Engines) – Airworthiness standards for various product types
- Part 26 – Continued airworthiness and safety improvements for transport category airplanes
- Part 39 – Airworthiness directives
- Part 43 – Maintenance, Preventive Maintenance, Rebuilding, and Operations
- Part 91 – General Operating and Flight Rules

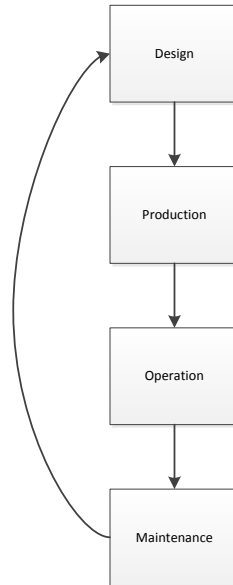
These regulations define the requirements that an applicant must establish to obtain the specific type of approval sought. In addition to the regulations, the FAA issues guidance material describing an acceptable means that could be used to satisfy the defined requirements as set forth in the specific regulation. After the applicant has presented the requisite showing, the FAA makes findings of compliance that the applicant has satisfied the safety requirements in an acceptable manner.

2.4.2. Aircraft Life Cycle

The FAA's statutory authority can be divided into three main functions, which allow the FAA to manage its oversight of the aircraft lifecycle process.

- Standards and Policy – development and implementation of certification standards - Through the rulemaking process, the agency proposes the minimum standards for obtaining approval of the design and production of civil aviation products, appliances, parts, materials and process. The standards are developed from input by the aviation industry, other government and regulatory agencies, and FAA research and expertise.
- Certification – after an applicant makes the proper showing and the agency finds compliance, an appropriate certificate or approval is issued. Thereafter, appropriate certificates of airworthiness can be issued for the product, appliance, part, material or process.
- Continued Operational Safety (COS) – after the certificate or approval is issued, the agency undertakes fundamental surveillance and oversight.

Each of these functions is visible throughout the 4 main phases of the aircraft life cycle:



2.4.3. Design

The procedures for issuance of the various design approvals are found in 14 CFR part 21. The applicant must submit the drawings, specifications, information on materials, dimensions, processes and tests results, and analysis necessary to establish that the design of the article meets the applicable safety (certification) standard.

The FAA issues a type certificate (TC) to approve the design of completed products, which in the United States includes aircraft, aircraft engines and propellers. Major changes to the design of completed products are approved through issuance of an amended type certificate (ATC) or supplemental type certificate (STC). These documents are issued by FAA after an applicant establishes that the design meets the appropriate airworthiness requirements as described in the applicable 14 CFR standard.

The design standards include requirements for providing operators and maintainers of the products, articles and materials information essential for safe operation. These documents include flight manuals and flight manual supplements that outline steps and limitations necessary for safe operation. Similarly, maintenance and alteration documents, such as aircraft or engine maintenance manuals, airworthiness limitations and service bulletins provide the methods, techniques and practices for returning a product, article or material to its original or to a properly altered condition.

2.4.4. Production

Although products may be manufactured for a short duration under the provisions of the TC, a production certificate (PC) is issued when a TC or STC holder makes a showing that its quality system will manufacture duplicate items under the FAA-approved type design.

The production approval holder is responsible for maintaining a quality system that ensures airworthy products, articles, parts and materials are released. The quality system requirements also include provisions for issuance of airworthiness approvals, obtaining feedback from users, and quality assurance elements for continuous improvement.

2.4.5. Operation

Airworthiness approvals are issued for products, articles, parts and materials to establish eligibility for operation or use under the jurisdiction of the FAA.

Airworthiness certificates are issued by the FAA for individual aircraft under 14 CFR part 21, subpart H. Airworthiness certificates are required for an aircraft to operate within the United States, as described in 14 CFR part 91. The airworthiness certificate is issued to individual aircraft manufactured under the approved design and production authorization after the aircraft is shown to conform to its type design and is in a condition for safe operation.

Other types of airworthiness approvals are issued to aircraft engines, propellers, articles, parts and materials after being they are shown to be designed and produced under a TSOA, LODA or PMA.

2.4.6. Maintenance

An aircraft's airworthiness certificate is effective as long as the maintenance, preventive maintenance, and alterations are performed in accordance with 14 CFR parts 43. The requirements for such activities are directed by the various types of aircraft operations. General operating rules are contained in part 91; additional operations and maintenance requirements are found in parts 121, 125, 129 and 135.

Part 43 defines the requirements for maintenance, preventive maintenance, rebuilding and alteration of any aircraft with a U.S. airworthiness certificate as well as for articles eligible for installation on those aircraft. The safety regulations control the following:

- Persons allowed to perform the maintenance, preventive maintenance, rebuilding or alteration;
- Documents and standards that must be followed to ensure the work performed returns the product or article to at least its original or properly altered condition;
- Records that must be created after the work has been accomplished; and,
- Persons authorized to approve the work on the product or article for return to service.

2.5. International Considerations

The international considerations related to the halon replacement SARPs are applicable to

States that will be issuing a type certificate for the aircraft (through implementation of the Annex 8 SARPs), or will be issuing an individual certificate of airworthiness to the aircraft (through implementation of Annex 6 SARPs).

The European Parliament and Council of the European Union passed Regulation (EC) No 744/2010 intended to decommission equipment containing halon in Europe except for specific critical use applications that allow for halon use until specified cutoff dates and end dates. With regard to halon use in aviation, the cutoff date represents the date halon replacements are required to be used in new aircraft designs and the end date represents the date that halon replacements must be installed on all new production and existing aircraft. The EC and ICAO required dates for halon replacement are compared in section 2.5.1 below. EU Regulation 744/2010 allows for, "derogations from end dates and cut off dates ... for specific cases where it is demonstrated that no alternative is available."

EASA, as the EU agency responsible for the regulation of civil aviation in Europe, was directed to implement the EU regulation. EASA initiated a two-phased approach to rulemaking. The first phase removed the reference to halon as the accepted fire-extinguishing agent in the applicable EASA Certification Standards (CS). The ARC is aware that EASA has now undertaken their second rulemaking phase, which is anticipated to prohibit the use of halon-dependent systems in specific applications by specified timelines in both newly type certificated and newly manufactured aircraft.

In the case of the SARPs that were incorporated into Annex 8 related to halon replacement, applicable to design requirements for lavatory extinguishers and engine nacelles/APUs, the responsibility to implement these SARPs (or to file a difference with ICAO as to why it could not be implemented) is with the State. However, should the State not adhere to the ICAO SARP, and should the aircraft be exported to a State that does adhere to the ICAO SARP in their national design standards, the importing State would determine whether it would accept the aircraft or if the design must be modified to conform to national design standards.

In the case of the SARPs that were incorporated into Annex 6 related to halon replacement, applicable to airworthiness requirements for issuance of an individual certificate of airworthiness for handheld extinguishers and lavatory extinguishers, the responsibility to implement these SARPs (or to file a difference) falls with the State. The issuance of an airworthiness certificate signifies that the aircraft conforms to the national design standards and is in condition for safe operation.

The effect of these SARPs on the U.S. aviation industry will be primarily focused on aircraft manufacturers. To export their aircraft to foreign markets they will be subject to the requirements of the importing State. Remaining competitive in the international market place is of paramount importance and consequently it is expected that ICAO standards would be followed as much as possible. In fact, the ARC was of the view that the movement to alternatives was likely to be spurred less by the availability of halon, and more by the ICAO mandates and the related EU rules on halon use in aviation. In essence, it was recognized that

airframe manufacturers would implement alternatives in response to the more stringent of either EU or ICAO rules in order to enable sales to both major markets.

Some member States have already issued guidance material for the issuance of certificates of airworthiness for aircraft to be entered on their national registry. At least one other country requires import aircraft to be outfitted with lavatory systems that do not contain halon, which aligns with the ICAO dates as set forth for lavatory systems in Annexes 6 and 8.

2.5.1. Current status of International Requirements

The figure below outlines a listing of international requirements for both new design and new production aircraft that were publically available during the deliberation of the ARC. This listing includes cutoff dates and end dates for halon use in civil aviation as directed by the European Commission, specified dates in the ICAO SARPs, and regulatory action from both the Hong Kong Civil Aviation Directorate (HK CAD), and the CAA of Singapore (CAAS).

	Requirement	Lavatory	Handheld	Propulsion /APU	Cargo
New Design	EC Cutoff Date	2011	2014	2014	2018
	ICAO New Design	2014	NA	2014	NA
Current Production	EC End Date (includes retrofit)	2020	2025	2040	2040
	ICAO New Production	2011	2016	NA	NA
	HK CAD	2011	2016	NA	NA
	CAAS	2011	2016	NA	NA

Notes:

EC: European Commission Regulation 744/2010 dates published August 2010 effective December 31 of stated year; information on Montreal Protocol, EC Regulation & alternative

agents in "Book 2" incorporated into EASA CS-25 Amendment 12, July 2012.

ICAO: International Civil Aviation Organization halon replacement "resolution" (A37-9) adopted at ICAO General Assembly Meeting on October 6, 2010. Amendments to Annexes 6 & 8 adopted in June 2011. Effective December 31st of stated year.

HK CAS: Hong Kong Civil Aviation Department Airworthiness Notice No.60A P.1 (March 30, 2012) effective December 31 of stated year.

CAAS: Civil Aviation Authority of Singapore Advisory Circular AC SAR-1(0)(December 15, 2011) guidance to Chapter 3.10 of the Singapore Airworthiness Requirements (SAR). Effective December 31st of stated year.

3. Assessment of ARC Tasks

As described above, the ARC was directed to evaluate 10 specific tasks in the pursuit of ARC objectives. The ARC then reviewed these evaluations, and summarized the major conclusions that comprise the key issues regarding the transition to halon replacements in civil aviation. These key issues are the foundation for recommendations that have been developed by the ARC, and require the main focus of all stakeholders involved in halon replacement activities.

3.1. Status of Halon Reserves

The FAA charged the ARC with investigating the status of worldwide halon reserves. Specifically, the ARC was asked to submit “proposals for assuring the safety of halon reserves through non-regulatory or regulatory mechanisms.”

For purposes of this report, the ARC is interpreting the phrase “assuring the safety” to mean ensuring the long-term availability of recycled halons that meet the specifications of the commercial aviation industry.

3.1.1. Worldwide Halon Reserves

Halon production ceased in developed countries in 1994 and in developing countries in 2010. No one knows for sure how much of the halon produced before that time is left in the world, or how much of that halon will be available in the future for use in civil aviation.

3.1.1.1. Estimates Based on Modeling Data

The Halon Technical Options Committee (HTOC), a group of fire protection experts that advise the parties to the Montreal Protocol on issues related to the phaseout of halons and the transition to halon alternatives, has developed a model that provides estimates of the quantity of halons that exist in the world. The HTOC model projections are based on historically reported halon production and destruction, as well as estimates of likely emissions from discharges, recycling, and leakage from storage over a period of many decades. These estimates are often referred to as bottom up estimates. The current HTOC model estimates are that there are about 95 million pounds (43,000 metric tons) of Halon 1301 and about 73 million pounds (33,000 MT) of Halon 1211 in the world today. This includes halons installed in aircraft, halons installed in other fire suppression systems or extinguishers, and halons stockpiled by governments or private companies for future use. The model breaks down the likely location of these halons into the following geographic regions:

Halon 1301		Halon 1211	
North America	= 14,000 MT	North America	= 11,000 MT
Europe	= 8,000 MT	Europe	= 13,000 MT
Japan	= 17,000 MT	Japan	= <1,000 MT
Rest	= 4,000 MT	Rest	= 9,000 MT

Estimates of worldwide halon reserves have also been derived from atmospheric measurements of halons (Newland et al., 2013). Such estimates are often referred to as top down estimates. For halons, the bottom up and top down estimates compare well. For Halon 1301, the HTOC model predicts global reserves of 106 million pounds (48,000 MT) in 2010 and the Newland et al; top down estimate predicts reserves of 95 million pounds (43,000 MT). For Halon 1211, the HTOC estimates global reserves to be 92 million pounds (42,000 MT) in 2010 and Newland et al. estimate 81 million pounds (37,000 MT). Using an average of the two estimates for 2010 and projecting to 2014 yields an estimate of 88 million pounds (40,000 MT) of Halon 1301 and 66 million pounds (30,000 MT) of Halon 1211.

3.1.1.2. Limitations of Modeling Data

Over the years, the parties to the Montreal Protocol have requested UNEP to ask the ICAO Secretariat to send halon reserves data reported to it to the Ozone Secretariat. Few countries have provided detailed information. As a consequence the modeled data is based on a very limited amount of direct, quantified, national input. Further, the HTOC model does not provide any direct information on the quantities of halon that could become available for use in civil aviation now or in the future.

There is likely to be a significant difference between the amount of halon that is predicted to exist, and the amount that could become available to aviation. There are a number of different reasons for this. First, some of the halon thought to exist may be inaccessible due to physical constraints and/or national restrictions on exports. In addition, a portion of the existing halon is owned by users that have equipment that still relies on halons and have continuing long-term needs. Examples of these situations include the approximately 6-7 MT of Halon 1211 in China, the 17,000 MT of Halon 1301 that is currently installed or stockpiled and reserved for future use in ground-based fire protection systems in Japan, about 2,300 MT of Halon 1301 and 700 MT of Halon 1211 stockpiled by the U.S. military for use in existing critical weapons systems, and about 1,000 MT of Halon 1301 installed in oil facilities on the North Slope of Alaska and other places around the world.

Given these and other factors, there is considerable disagreement among ARC members on the percentage of the total halon supply that is likely to become available for use in civil aviation in the future. Some members believe, based on their experience, that a significant percentage of the halon installed or stored around the world, particularly in developing countries, may be either contaminated, inaccessible, or slowly being emitted from leakage. Other members believe that a much smaller percentage of the world's halons are contaminated, inaccessible, or being emitted, and that some of the long-term users mentioned above will make their halon stocks available for purchase in the future, especially if the price of halon rises.

As a consequence of the divergent expert opinions, there is a huge difference in the future outlook for filling and servicing the halon systems of a growing fleet of aircraft for the next 40-50 years. This difference in opinion among ARC members serves to highlight the lack of concrete information available on worldwide halon reserves and the uncertainty of future supply. The lack of concrete information about halon reserves is the basis for a specific ARC recommendation that FAA acquire and disseminate on a regular basis information about halon supplies and the availability of halon for civil aviation.

3.1.2. Aviation Halon Supply Chain

The United States aviation industry's halon needs and a significant percentage of the world's aviation halon needs are supplied by a small number of US-based halon recyclers. These suppliers search the global community in an effort to identify "used" halon, and their halon is acquired from both domestic and international sources. Halon sourced from outside of the U.S. must first be granted EPA import approval, which is obtained by providing EPA with documentation that will allow the Agency to independently verify that the halon is truly recycled (i.e. recovered from an existing fire suppression system). Halon sourced within the U.S. generally comes from local fire equipment distributors that install and service fire suppression systems and extinguishers. When a halon system or extinguisher is ready for decommissioning, these fire equipment distributors normally perform the task. The halon removed is usually sold to one of the domestic halon recyclers.

Halon recyclers are responsible for transporting the decommissioned halon systems to their factories; sampling and testing the halon for any impurities; consolidating the halon into larger storage cylinders; recycling the halon through equipment designed to remove impurities and return the halon to commercial aviation standards; re-sampling the finished product to determine if it meets the above specifications; and, finally, shipping the recycled halon to the commercial aviation customer. The process of testing and certifying halon quality is of great importance to halon users, and all halon users are urged to make certain that the substance they are purchasing meets the specification required for their use. In the commercial aviation context, the customer for certified halon is an airframe manufacturer, a suppression system manufacturer, or an aviation service company.

As noted above, used halons become available in most cases when a fire suppression system or extinguisher is decommissioned because the hazard it is protecting, such as a computer room, telecommunications facility, ship, or aircraft, is no longer active. Therefore the supply of recycled halons is mostly based on the rate at which halon systems and extinguishers are decommissioned from service, rather than the price recyclers are willing to pay for used halons. Up to now the price of halon has not risen to the point where most users can recover the cost of switching to a non-halon system simply through the sale of the halon. Even if halon values were to rise significantly, it is unknown to what degree most users would choose to replace an existing halon system with a new fire protection system. Halons provide excellent fire protection and historically most users have chosen to maintain their existing halon systems as long as they are protecting an active hazard. As such, the overall supply of used halons has been mostly independent of the price recyclers are willing to pay. It is possible that future increases in the price of halon, along with other incentives to remove halon systems from service such as those provided by the Leadership in Energy and Environmental Design (LEED) program, could change the relationship between the price and availability of halons.

The other factor that can impact both the price and availability of used halons is national regulations. Regulations that ban the use of halons, such as those instituted in 2001 by the European Union have historically produced a short-term increase in the supply of used halons accompanied by a sharp decrease in the value. This transformation of used halons from an asset to a liability can have the impact of increasing unnecessary emissions, and thus reducing

the long-term supply of used halons. Regulations that provide a barrier to the movement of used halons such as bans on export and the designation of halons as hazardous waste could result in regional imbalances in the supply of halon and possibly an increase in unnecessary emissions. This is the basis for the ARC's recommendation that FAA work with EPA and the State Department to encourage policies to remove international barriers to the movement of used halons.

3.1.3. Aviation Demand for Halons

The estimates provided below are based on information obtained from the following sources: HTOC, EPA, and industry reports; responses to the ICAO State Letter on halon reserves; responses to a survey developed by the ARC and distributed to aircraft service companies; data on U.S. sales of halon from the Halon Recycling Corporation; and anecdotal information provided by aviation industry experts. This section focuses mostly on Halon 1301, which, because of the much larger installed base of Halon 1301 compared to Halon 1211, serves as an effective case study to illustrate the risks of continuing with a status-quo approach.

3.1.3.1. Aircraft Production

At the current time it is estimated that approximately 3-4 million pounds of Halon 1301 are currently installed in commercial aircraft worldwide. Based on industry projections of fleet growth and fleet replacement,¹ and the ARC's earliest estimates of halon alternatives implementation in engine nacelles/APUs and cargo compartments of new-design aircraft,² the amount of Halon 1301 installed inside aircraft is likely to increase to 7 million pounds by 2030. To support this growth, approximately 200,000 pounds per year of Halon 1301 is required to supply new deliveries of aircraft. This demand is expected to rise to 375,000 pounds per year by 2030.

¹ * Boeing Long-term Market, Current Market Outlook, 2013 numbers (<http://www.boeing.com/boeing/commercial/cmo/>). Boeing CMO does not include most of the business jet and turboprop classes of aircraft (light, very light, mid-sized business, etc.)

** Bombardier Global Forecast, 2012 numbers
http://businessaircraft.bombardier.com/content/dam/bombardier/en/ownership/whitepapers/4500_Bombardier_MarketForecast%202013_V24-LR.pdf

*** Flight International's 2011 business aircraft census <http://www.flightglobal.com/features/nbaa/census/>

² ARC's earliest estimate of the implementation of halon alternatives in engine nacelles/APUs and cargo compartments:

First application for new type certificate without Halon 1301 engine/APU: 2016

First delivery of a new design aircraft without Halon 1301 engine/APU: 2022

Earliest Possible ICAO Deadline for cargo/baggage: 2020

First application for new type certificate without Halon 1301 cargo/baggage: 2022

First delivery of a new design aircraft without Halon 1301 cargo/baggage: 2028

All existing designs stay with Halon 1301 throughout their production lives

3.1.3.2. Aircraft Maintenance

Based on information provided by equipment manufacturers, operators, and aircraft service companies, the ARC has come up with a rough estimate of the amount of Halon 1301 used by US-based companies to service aircraft fire protection systems of 120,000 pounds per year. Based on this estimate, the ARC estimates that about 250,000 pounds of Halon 1301 are used per year to service the worldwide fleet of aircraft. This number is likely to increase as the size of the world fleet increases.

The ARC's estimate of 250,000 pounds of Halon 1301 being used each year to service aircraft is much higher than previous estimates. If correct, it would represent an emission rate in the range of 7-8% per year, which is much higher than for most other halon applications. Only a small percentage of these total releases are used to extinguish fires. The vast majority are accidental releases or occur during testing or handling. Because there is significant uncertainty in this estimate, the ARC recommends that FAA further investigate this issue to determine if current emission rates and unnecessary discharges are unacceptably high and if there are steps that can be taken to reduce them.

In August of this year the FAA released the latest revision of TSO-C1e for cargo compartment fire detection instruments. The new detectors have a much improved false alarm rejection capability and this will reduce unnecessary halon discharges in the cargo holds. The ARC commends FAA for the recent update of TSO-C1e.

Currently there is a state of confusion over the re-qualification requirements for the high-pressure vessels used for engine nacelles/APUs and cargo fire extinguishers. The requirement in question is specified in FAA Order 8900.1, Volume 3, Chapter 57, Section 1, 3-4548 High-Pressure Cylinder Maintenance. Paragraph B.3 states that, "Maintenance providers may not install cylinders in a U.S. registered aircraft certificated in any category if the cylinders are not approved, qualified, and/or re-qualified under 49 CFR." However, 3-4546 paragraph A.4 allows high-pressure cylinders to remain installed in the aircraft past the time when their 49 CFR required requalification is due.

System supplier safety engineers recommend periodic weight checks of the extinguishers to ensure a slow leakage is not present. After the 49 CFR requalification period, typically 5 years, is past, this weight check and 3-4548 paragraph B.3 would require an otherwise acceptable extinguisher to be re-qualified simply because it was removed from the aircraft. This is the basis for the ARC's recommendation that 3-4546 paragraph A.4 be reviewed with a goal of allowing fire extinguishers that pass the weight check and a general visual inspection to be re-installed on the aircraft and avoid a 1% to 2% halon loss inherent with hydrostatic testing.

3.1.3.3. Total Demand

Based on the above estimates for aircraft manufacturer and aircraft maintenance, the ARC estimates that total annual worldwide aviation demand for halon is roughly 450,000 pounds per year, and will grow over the next several decades.

The Halon Recycling Corporation (HRC) has collected data for the past 5 years on the amount of halon sold each year in the United States by the major halon recyclers. HRC recently collected additional data from these companies on the amounts of halon sold in the U.S. for aviation uses (aircraft manufacturers, aircraft equipment manufacturers, aircraft service companies). Although there is no way to directly correlate this data with the estimates for

aviation halon demand presented in section 3.1.3, it does provide a data reference point for those estimates.

The HRC data shows that average amount of Halon 1301 sold in the United States in 2011 and 2012 was 676,098 pounds. The average amount of Halon 1301 sold into aviation uses in the United States during that same period was 365,376 pounds, or 54% of total U.S. sales. Although the halon amounts reflected in the above data were sold to U.S.-based aviation companies, it is likely that some of this halon was used to service aircraft suppression systems from non-U.S. carriers or subsequently sold to non-U.S. aircraft manufacturers. Taking into account this fact, if there are about 350,000 pounds of Halon 1301 being sold into aviation in the US, it does not seem unreasonable that annual worldwide demand for Halon 1301 for aviation would be at least 450,000 pounds.

3.1.3.4. Balance Between Supply and Demand

Because of the significant uncertainty surrounding estimates of the accessible stockpile and future halon supplies, the ARC recommends that the FAA work with aircraft manufacturers and operators to accelerate the deployment of halon alternatives as a way of limiting the future growth of the halon-dependent fleet and thus reduce aviation's future needs for recycled halons.

The ARC estimates that U.S.-based aircraft operators, service companies, and fire equipment manufacturers have on hand at any one time about a 3-4 month supply of halon to maintain and service the existing fleet of aircraft. The ARC is not aware of any additional halon reserves or stockpiles being held exclusively for this purpose.

As noted above, a significant percentage of the global aviation industry's halon needs are supplied by a very small number of U.S.-based recyclers. These companies have informed the ARC that as a general rule, their industry has been operating on a "hand-to-mouth" basis since its inception 20 years ago, and that situation remains so today. They have limited supplies of halon on hand at any one time and can project potential future supplies about 12 months out at most.

Several factors suggest that the ability to continue to ensure a steady supply of halon may become more tenuous in the future. These include the fact that suppliers often obtain halon from foreign sources whose stability cannot be ensured; companies that service aircraft have on hand only a 3-4 month supply; the companies directly involved in the acquisition of halon are unable to project available supplies beyond a 12-month period; and there are no identifiable halon stocks that are being held for the aviation industry. Given these factors, the ARC concludes there is a potential for short-term supply disruption. This is the main basis for the ARC's recommendation that aircraft manufacturers, operators, and aircraft service companies make contingency plans in case of a supply disruption by increasing on hand reserves either individually, or collectively by creating an industry stockpile.

3.2. Status of Alternative Agents or Systems

At present, halons are used for fire suppression on civil aircraft in four extinguishing applications:

- Lavatory trash receptacle extinguishing systems (range 1-4 pounds of Halon 1301 per aircraft);
- Handheld extinguishers (range 7-50 pounds of Halon 1211 per aircraft);
- Engine nacelles/APU protection systems (range 16-187 pounds of Halon 1301 per aircraft); and
- Cargo compartment extinguishing systems (range 23-457 pounds of Halon 1301 per aircraft).

Substitutes for halons in civil aviation fire extinguishing systems are evaluated and approved according to the relevant Minimum Performance Standards (MPS) and testing scenarios developed by the FAA International Aircraft Systems Fire Protection Working Group (IASFPWG), along with certification requirements from airworthiness authorities. Key to the approval of substitutes is their ability to demonstrate fire-extinguishing performance equivalent to halon in specific applications.

Substitute agents or systems that meet the relevant MPS have been identified for all four of the applications listed above, are commercially available for three of the applications, and are currently being used in one application, lavatory trash receptacles. As a result, all new installations of fire extinguishing systems for engine nacelles/APUs and cargo compartments on civil aviation aircraft continue to deploy recycled Halon 1301, and all new installations of handheld extinguishers continue to deploy recycled Halon 1211.

The identified substitutes for the other three applications would carry space and weight penalties compared to current halon systems, could require significant design changes and installation certification to implement, and some have environmental concerns. These issues are discussed in more detail in sections 3.2.1 and 3.2.2 below. As a result of these facts and the continued availability of halon, airframe manufacturers have not yet pursued qualification and installation certification for these potential substitutes, including those that are commercially available. Airframe manufacturers have undertaken development and qualification testing for potential alternatives that do not carry a space and/or weight penalty and do not have environmental concerns, so far without success. With statutory deadlines for halon replacement now imminent in the European Union and under consideration in other countries, airframe manufacturers may be forced to accept some of these shortcomings in order to comply with these regulations. The fact that some of these requirements will only be imposed on new type certifications may enable airframe manufacturers to consider these changes and any related offsets in the context of the much larger changes that are likely to take place in the development of a new aircraft.

3.2.1. Installation and Operational Considerations

Halon alternatives that require additional space and increased weight raise installation and operational considerations. These can include bracket and mounting hardware changes,

increased bracket support, additional sidewall structural support, increased bottle volume and wall thickness, distribution system changes including larger and longer tubing, relocation of halon cylinders and equipment, and relocation or reconfiguration of other equipment. For new production aircraft, some of these changes must be approved by the local Aircraft Certification Office (ACO) to ensure compliance with regulations and an acceptable “means of compliance” must be demonstrated to ensure that the new agent’s effectiveness has been demonstrated, and that the proposed certification testing is adequate to account for changes relative to the manner in which halon systems are tested. In addition, the increased weight can have significant cost impact for operators from increased fuel consumption. As the weight increases, so increases the cost to the operator in terms of additional fuel burn. For example, for every 10 pound increase in a halon replacement on a typical commercial aircraft is estimated to increase fuel consumption by an average of 0.04 gallons per hour, with a potential average cost impact of about \$500 per aircraft per year (assuming jet fuel costs \$4 per gallon, average of 1300 flights per year averaging 2 hours per flight).

3.2.2. Environmental Issues

Hydrofluorocarbons (HFCs) are currently being used in lavatory extinguishing systems and are potential candidates for use in handheld extinguishers and engine nacelle/APU protection systems. HFCs are used extensively in other fire protection applications and their use has been instrumental in achieving the transition out of halon.

While HFCs are not ozone-depleting substances, they have been identified as greenhouse gases with high global warming potentials (GWPs). Based on this concern, the production of HFCs will be gradually phased down in the European Union between 2015 and 2030 as part of a newly approved regulation³. In addition, proposals to phase down the production of HFCs worldwide under the Montreal Protocol have been under consideration since 2009.

Although the current EU regulations and the proposed Montreal Protocol amendments would not preclude HFCs from being implemented for aviation use, there are likely to be constraints on future availability with cost impacts. Moreover, because of prior European restrictions and growing concern with climate change, the possibility that regulatory restrictions could be imposed more broadly including on HFCs in fire protection applications cannot be ruled out. Thus, some members of the ARC believe it more prudent to focus on development of non-HFC alternatives.

The main component of one of the other handheld alternatives discussed in section 3.3.3 below is a hydrochlorofluorocarbon (HCFC). HCFCs are ozone-depleting substances scheduled for production phaseout in 2020 in developed countries and 2030 in developing countries under the

³ Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

Montreal Protocol. In addition, the use of HCFCs for fire extinguishing applications is not permitted in the European Union under Commission regulation (EC) No. 2037/2000. As such, HCFCs are not likely to be viable candidates for implementation as halon replacements in aircraft applications.

In addition to the cost impacts discussed in section 3.3.1 above, the increased fuel consumption resulting from the increased weight of a potential halon replacement also has environmental impacts in the form of increased CO₂ emissions incurred during normal operations. For example, for every 10 pound increase in a halon replacement in a typical aircraft is estimated to increase fuel consumption by an average of 0.04 gallons per hour, with a potential CO₂ impact of over 1 ton per year (assuming an average of 1300 flights per year averaging 2 hours per flight).

3.2.3. Status of Alternative Development and Timelines for Implementation

The status of the development of alternatives and timelines for widespread implementation of alternatives are discussed below.

3.2.4. Lavatory Trash Receptacles

Halon 1301 has historically been used in lavatory extinguishing (lavex) systems, which are designed to extinguish trash receptacle fires in the lavatories of pressurized cabins. Trash receptacles are required to be installed with a lavatory system that automatically discharges into the container in the event of a Class A fire (i.e., involving paper materials). All lavatory systems using halon alternatives must meet the Minimum Performance Standard (DOT/FAA/AR-96/122) that includes the ability to extinguish a Class A fire and in the case of discharge, not create an environment that exceeds the chemical agent's no observable adverse effect level (NOAEL). In addition to MPS testing, installation certification and demonstration are also required by local airworthiness authorities.

A finalized MPS for lavatory systems was completed in February 1997. Through research and testing suitable alternative suppression agents and systems were developed for this application that meet the criteria for space and weight (near "drop-in" replacements requiring minimal design changes), the toxicity and installation certification requirements, and that cost the same or less than the halon extinguisher being replaced. Currently, new production aircraft are installed with non-halon lavatory systems that contain either HFC-227ea or HFC-236fa. In addition, some airlines are replacing existing Halon 1301 lavatory systems with these alternative systems during scheduled maintenance operations after ensuring that installation certification has been approved.

The use of HFCs in lavatory systems in aircraft is extremely small and availability is not likely to be significantly impacted by the current HFC phase down regulations/proposals, other than a potential increase in the cost of the agents. If alternatives to HFCs were required in the future due to regulatory changes or availability issues, it is likely based on the nature of the lavatory hazard that a suitable alternative could be developed in a reasonable timeframe.

3.2.4.1. Timelines for Implementation

ICAO resolution A37-9 and amendments to Annexes 6 and 8 of the Chicago Convention required the use of halon replacements in lavatories for new production aircraft by December 31, 2011 and for new designs by December 31, 2014. European Union ozone-depleting substance regulations required the use of halon replacements for new designs by December 31, 2011. Aircraft manufacturers have largely met this requirement.

Unlike the ICAO resolution, which does not require retrofit, European Union regulations include a requirement for retrofit of lavatory extinguishers containing halon in existing aircraft by 2020. As noted above, alternative lavatory extinguishers are drop-in replacements and operators can meet this requirement by changing out the halon extinguishers during normal maintenance if the appropriate certification requirements have been documented, which some airlines in Europe are already doing.

3.2.5. Handheld Extinguishers

All handheld extinguishers intended to replace Halon 1211 extinguishers must meet the Minimum Performance Standard (DOT/FAA/AR-01/37) to ensure their performance and safety. These standards require that any handheld extinguisher for final use be listed by UL or an equivalent listing organization. To be listed, the extinguisher must be able to disperse in a manner that allows for a hidden fire to be suppressed and does not cause any unacceptable visual obscuration, passenger discomfort, and toxic effects where people are present.

The MPS was published in August 2002. As of 2003, three halon alternatives, HFC-227ea, HFC-236fa and HCFC Blend B, have successfully completed all of the required handheld UL and MPS tests and are commercially available. These alternatives have increased space and weight characteristics that present installation and operational considerations as discussed in section 3.2.1 above, and environmental concerns as discussed in section 3.2.2 above. Based on these issues, airframe manufacturers have chosen not to pursue qualification and installation certification for these alternatives.

Development continues on another possible replacement agent known as 3,3,3-trifluoro-2-bromo-prop-1-ene or 2-BTP. This agent is not currently listed as a greenhouse gas or an ozone-depleting substance. It has the potential to be a near "drop-in" replacement with minimal space and weight impact for some aircraft. 2-BTP has passed the MPS and an additional full-scale test required by the FAA, along with achieving a UL 5B rating. It is EU REACH registered, however, the U.S. EPA review of the applications under the Toxic Substances Control Act and the Significant New Alternatives Policy is not yet completed. Nonetheless, the industry is already working on supply chain coordination and aircraft manufacturer implementation.

The FAA recently sponsored work on handheld extinguishers that involved optimizing FK-5-1-12 with a fine mist technology nozzle/extinguisher. It was optimized against an aircraft UL/5B Halon 1211 extinguisher that contains 2.5 pounds of agent. The FK-5-1-12 extinguisher was unable to extinguish the fire necessary to achieve the required UL/5B rating with 4 pounds of

agent. FAA is not pursuing additional optimization work at this time.

3.2.5.1. Timelines for Implementation

ICAO resolution A37-9 and amendments to Annexes 6 of the Chicago Convention require the use of halon replacements for new designs and new production aircraft by December 31, 2016. EU regulations require the use of halon replacements for new designs by December 31, 2014. It is possible that aircraft manufacturers could be delayed in meeting the ICAO requirement for new production aircraft due to the regulatory review time associated with 2-BTP. Should 2-BTP fail to gain final approval from EPA or meet FAA certification requirements, ICCAIA has committed to ICAO that aircraft manufacturers will implement the approved alternative agents. The ARC is not aware of any technical impediments to implementing any of the approved alternative agents for this application.

Unlike the ICAO resolution, EU regulations include a requirement for retrofit of handheld extinguishers containing halon in existing aircraft by 2025. Alternative extinguishers would have different brackets and supports than halon extinguishers and on some installations will require relocation to accommodate increased size and weight, which has implications for retrofit of existing aircraft.

3.2.6. Engine and APU Compartments

Halon 1301 is typically used in engine nacelles and APUs to protect against Class B (flammable liquid) fires. The requirements of fire suppression systems for engine nacelle/APUs are particularly demanding since these compartments contain fuels and other volatile fluids in close proximity to high temperature surfaces. The surrounding environment also typically has complex airflows at low temperature and pressure, making some non-halon agents ineffective.

A critical acceptance standard for alternatives is the FAA's Minimum Performance Standard (MPS) testing program, also identified as MPSe or MPSHRe for application to the engine nacelle/APU, which establishes a minimum extinguishing concentration for Halon 1301 replacements. A fourth version of the MPS for engine nacelle/APU fire protection is available in draft form and should be published in the future. Four potential replacement agents, HFC-125, FIC-13I1, FK-5-1-12, and Powdered Aerosol F were tested based on a draft version of the MPS and Halon 1301 equivalent concentrations were determined. An engine nacelle/APU system using FK-5-1-12 was developed but it failed an FAA required live fire test using a cold soaked fire protection agent to simulate low temperature use. Also, an engine nacelle/APU system based on the use of Powdered Aerosol F failed an FAA required full-scale test that was a supplemental requirement to the MPS. Further work continues on both of these systems.

HFC-125 has been used successfully as an alternative to halon for engine nacelle/APU fire protection on U.S. military aircraft developed since the early 1990s. In addition, HFC-125 is currently being developed for use on a military derivative of a large commercial aircraft (Boeing 767; military derivative KC-46). HFC-125 has increased space and weight requirements that present installation and operational considerations as discussed in section 3.2.1 above, and

environmental concerns as discussed in section 3.2.2 above. Based on these issues, airframe manufacturers have chosen not to pursue qualification and installation certification for HFC-125 in engine nacelles/APUs.

PhostrEx, (active ingredient phosphorus tribromide, PBr_3) was certified by the FAA for engine nacelle/APU fire protection on the very light jet Eclipse EA500 in 2006. The certification of the Eclipse engine fire-extinguishing system was based on intensive fire-extinguishing tests for this particular application in lieu of establishing a minimum concentration requirement through MPS testing. PBr_3 is not considered to be a viable alternative to halon for engine nacelle/APU fire protection in most commercial aircraft due to high levels of toxicity and corrosiveness, and the lack of an established concentration performance requirement, or the means to create such a standard.

3.2.6.1. Timelines for Implementation

ICAO resolution A37-9 and amendments to Annexes 6 and 8 of the Chicago Convention require the use of halon replacements for new designs by December 31, 2014. Aircraft manufacturers have expressed concerns about their ability to meet that ICAO SARP by the required date due to setbacks in the development of FK-5-1-12 and Powdered Aerosol F systems.

EU regulations also require the use of halon replacements for new designs by December 31, 2014. Aircraft manufacturers have not discussed with the ARC whether they can meet this requirement or if they plan to ask the European Commission for derogation.

Unlike the ICAO resolution, EC regulations include a requirement for retrofit of engine nacelle/APU systems containing halon in existing aircraft by 2040. Unless a drop-in replacement for halon with similar physical properties and flow characteristics is developed, retrofit of a halon engine nacelle/APU fire protection system would likely entail complete removal of the existing system and installation of a new system that would have different hardware and different space/weight characteristics. This is likely to be difficult and costly.

Aircraft manufacturers, who up until now have been working separately to find an alternative to Halon 1301 for engine nacelles/APUs, have recently pooled their resources to form the Engine/APU Halon Alternatives Research Industry Consortium (IC). The goal of the IC is to develop a single agent/approach that can be implemented industry wide. Based on the experience with FK-5-1-12 and Powdered Aerosol F, which have been under investigation for several years, the industry is not optimistic that any currently known agent will be certification ready to meet a December 31, 2014 deadline.

3.2.7. Cargo Compartments

Cargo compartments that are protected by halon are typically located below the passenger compartment or occupy the lower deck on freighter aircraft. In the case of a fire, a quick discharge of halon is deployed into the protected space to suppress the fire, which is followed by a discharge that is released slowly to maintain a concentration of halon to prevent re-flame.

The slow discharge is maintained until the plane has landed to protect against any reduction in the concentration of halon caused by ventilation or leakage. Cargo compartment fire suppression agents and systems must be able to meet the requirements of four FAA fire tests required in the Cargo Compartment Minimum Performance Standard (DOT/FAA/AR-00/28, last updated as DOT/FAA/TC-TN12/11). The system must be able to suppress a Class A deep-seated fire for at least 30 minutes and a Class A fire inside a cargo container for at least 30 minutes. The system must be able to extinguish a Class B fire (Jet-A fuel) within 2 minutes, and prevent the explosion of a hydrocarbon mixture, such as that found in aerosol cans. In addition, the system must have sufficient agent/suppression capability to be able to provide continued safe flight and landing from the time a fire warning occurs, which could be in excess of 350 minutes, depending on the aircraft type and route planned. In an updated version of the MPS, published in 2003, the aerosol explosion protocol was modified to allow the inclusion of a non-gaseous system such as water spray. The most recent version was published in 2012, and included corrections made to the aerosol can simulator specifications, acceptance criteria section, and new criteria for the aerosol can explosion test. In addition, some sections were added to the test requirements to clarify some testing procedures.

Due to the growing concern regarding the hazards associated with the transport of lithium batteries in aircraft cargo holds, the regulatory agencies and the aircraft fire protection industry have recognized a potential need to modify the FAA MPS test protocol to address this fire danger. Additional test requirements implemented to address the hazards associated with lithium batteries would likely increase the challenge of finding a suitable replacement for halon alternatives in aircraft cargo compartment fire suppression systems.

To date, there have been no cases of Halon 1301 replacement with an alternative agent in cargo compartments of civil aircraft. MPS testing of halocarbon agents has shown that they are not technically or economically feasible due to the space and weight requirements of maintaining the high concentrations of these agents that would be necessary to meet the MPS. In addition, MPS testing of 2-BTP and FK-5-1-12 at below inerting concentrations resulted in overpressurization during the aerosol can test.

A combination of water mist and nitrogen has been tested and shown to meet the requirements of the current MPS. Commercial development of a water mist/nitrogen cargo fire suppression system is underway and one system manufacturer has projected achieving aircraft integration readiness for such a system by 2018. These systems are likely to have a large weight penalty compared to existing halon systems and present significant installation and operational challenges that are discussed in more detail below. As such, it is not clear that aircraft manufacturers would pursue qualification and installation certification for this alternative.

A non-halon cargo fire suppression system, such as a hybrid water mist and nitrogen system represents significant installation and operational challenges. For example, the water storage system would require safety features to prevent the water from freezing. Additionally, due to the large quantity of water required, significant structural changes would be necessary for

mounting heavy storage tanks. Many other design changes within the cargo compartments would also be necessary to prevent water damage to aircraft systems and structure associated with false cargo fire warnings and subsequent activation of the cargo fire suppression system.

Another example of the challenges associated with a system that uses nitrogen inerting for cargo fire suppression is the storage or generation of the nitrogen gas. Using compressed nitrogen gas stored in pressure vessels is not considered feasible due to the substantially large volume that storage of the gas would require. This fact has resulted in an onboard nitrogen generation system (NGS) being considered the most feasible concept for an onboard source of nitrogen for cargo fire suppression. However, there are significant challenges associated with the use of NGS for a cargo fire application. First, the reliability of available NGSs cannot support the cargo fire suppression application. Today, NGSs are not dispatch-critical systems and are not required for aircraft dispatch in the occurrence of a system failure. Considerable effort has been spent working with NGS suppliers to develop a highly reliable system that could be considered dispatch-critical in order to support the cargo fire application, but such a system is several years away from being developed. Furthermore, while NGSs are used on most aircraft today for center wing tank inerting, not all aircraft include an NGS as part of their basic design. This would result in additional cost, weight and reliability impact to those aircraft manufacturers in order to develop a new NGS design for each respective aircraft model.

3.2.7.1. Timelines for Implementation

ICAO will consider a date for requiring the use of halon replacements on new designs at the next Assembly in 2016. The International Coordinating Council of Aerospace Industries Associations (ICCAIA) has formed the Cargo Compartment Halon Replacement Working Group (CCHRWG) to provide a recommended date to ICAO. Since the earliest date that ICAO could propose SARPs for the use of halon replacements for cargo compartments would be the end of 2020, the CCHRWG will consider if it is possible for aircraft manufacturers to meet that timeframe.

EC regulations include a requirement for the use of halon replacements in newly designed aircraft by December 31, 2018. Aircraft manufacturers have not discussed with the ARC whether they expect to be able to meet this requirement or if they plan to ask the European Commission for derogation.

EU regulations also include a requirement for retrofit of cargo systems containing halon on existing aircraft by 2040. Unless a drop-in replacement for halon with similar physical properties and flow characteristics is developed, retrofit of a halon cargo compartment system would likely entail complete removal of the existing system and installation of a new system that would have different hardware and different space/weight characteristics. This is likely to be difficult and costly.

4. Halon ARC Recommendations

The following section reviews the process used by the ARC to develop recommendations, and the specific recommendations made by the Halon ARC to support the orderly transition from primary reliance on halons to reliance on alternative agents or systems.

4.1. Overview of Halon ARC Recommendations

The FAA and other ARC members understand the significance and urgency of managing the remaining halon and safely transitioning to alternative technologies. However, with respect to FAA rulemaking, the FAA clearly indicated to all ARC members that the agency's existing regulations concerning aircraft fire suppression systems allow the use of halon "or equivalent" as an extinguishing agent. The ARC understands that the FAA has determined, based on current information, that regulatory action is not warranted.

Some ARC members disagree with this determination and express continuing concern about the potential impact on aviation safety. These members also have concerns that actions by FAA that fall short of regulation will not result in a change in the status quo. No consensus among ARC members was reached on this issue. In spite of disagreement on the issue of regulations, the ARC was able to generate numerous recommendations for non-regulatory action.

The Halon ARC used three main groupings as a focus for their recommendations:

1. Framework for ensuring further action to find and implement alternatives to the use of halons in civil aviation.
2. Proposals for halon replacement timelines based on existing international standards and international engagement.
3. Recommendations for ensuring the safety and availability of halon reserves.

4.2. ARC Recommendations on a Framework for Ensuring Further Action to Find and Implement Alternatives to the Use of Halons in Civil Aviation

While the ARC is heartened by the fact that a large number of collaborative activities are being undertaken to find and implement alternatives to the use of halons in civil aviation, many members note that a number of activities have been ongoing for many years without result. Because of the ICAO and EU mandates, the ARC agrees that near-term results are essential. Given the existence of many groups and the desire to ensure that actions are not redundant, the ARC does not recommend the creation of another catalytic organizing body. Instead, the ARC understands that the task of finding and implementing alternatives does not rest with any one entity, and that it will take the coordinated cooperation of many.

4.2.1. FAA Halon Focal Point

In order to facilitate that coordination, the ARC believes that the identification of a dedicated halon replacement aviation focal point within FAA is essential. It is the view of the ARC that this focal point can be a person, office, or team. This focal point should be able to participate in and contribute to technical halon-related meetings, and should report directly to a senior level position within the FAA to ensure continued visibility over the issue. The focal point should be able to coordinate and communicate with relevant offices within the FAA (such as the Office of Aviation Safety, the Office of Policy, Environment, and International Affairs, and the Office of the General Counsel) and the U.S. Government (such as the Environmental Protection Agency, the Department of Defense, and the Department of State), as well as liaise directly with ICAO, other international regulatory agencies, and the aviation industry.

It is the view of the ARC that this person, team or office should be charged with:

- Explaining and promoting compliance with the ICAO halon mandates.
- Ensuring that the technical, legal and policy aspects associated with the FAA evaluation of halon alternatives are effectively coordinated and promoted.
- Ensuring that FAA participation in the various related forums and activities carries forward the messages agreed by FAA (and as recommended by the ARC) to be important.
- Developing and/or supporting the development and dissemination of reports and other outreach materials and communications that provide updated information on the status of the alternatives, the inventory and demand for halons, the potential benefits of building stockpiles to guard against potential supply disruptions, and efforts on testing and certifying aircraft using alternatives.
- Organizing regular opportunities for stakeholder dialogue through existing meetings or other forums to review the information above, obtain input, identify emerging issues, review progress, and consider adjustments in the overall approach.
- Participating in and reporting on the following:
 - Engine/APU Halon Alternatives Industry Research Consortium (IC)
 - ICCAIA Cargo Compartment Halon Replacement Working Group (CCHRWG)
 - ICAO International Halon Replacement Coordinating Meetings
 - International Aircraft Systems Fire Protection Working Group (IASFPWG)
- Working with industry via these groups to provide practical certification compliance guidance/policy as halon replacement alternatives are identified, ahead of certification plan development.
- Liaising with the Department of State and the Environmental Protection Agency on matters relating to the Montreal Protocol, and seeking authorization to participate as a consulting expert on the Halon Technical Options Committee.

- The ARC also recognizes the important roles played by the Bureau of Oceans, Environment and Science of the Department of State and the Stratospheric Protection Division of the Environmental Protection Agency in facilitating the imports of previously used halon, in keeping the Protocol parties involved, and in providing input to U.S. halon-related positions at ICAO meetings. Accordingly, the ARC recommends that representatives of those offices work to ensure that those offices are included in their agencies ICEA review process for ICAO issues dealing with halons. FAA should also engage with those offices on a periodic basis to monitor and discuss domestic and international progress related to halon replacement and to consider if further action is needed.
- To keep the interested public (including but not limited to groups represented on the ARC) apprised of ongoing activities, the ARC recommends that FAA issue a regular newsletter or report highlighting domestic and international action and progress in developing and implementing halon alternatives, and noting planned participation in related activities for the future.
- With regard to participation of the FAA focal point in monitoring the various global efforts, the ARC recommends that FAA should also seek an update from the Department of State or the Environmental Protection Agency on any halon related matters being discussed at Montreal Protocol meetings.

4.3. Recommendations for Halon Replacement Timelines Based on Existing International Standards and International Engagement

The ARC has reviewed the status of development and implementation of halon alternatives for aviation applications, and the conclusions are outlined in section 3.2 above.

Based on this review, the ARC believes that the timelines for halon replacement contained in ICAO resolution A37-9 and codified in amendments to Annexes 6 and 8 of the Chicago Convention, with the possible exception of a short delay in the deployment of handheld extinguishers in new production aircraft, can be achieved by the aviation industry with existing technology.

The ARC has also reviewed the status and future outlook of halon reserves available to aviation, and the conclusions are outlined in section 3.1 above. One of these conclusions is that unless steps are taken now to accelerate the implementation of halon alternatives, there is a risk that the aviation industry's current course of halon resource management will become unsustainable.

The ARC recommends the following actions in lieu of a rulemaking to accelerate the development and implementation of halon alternatives for aviation applications:

- Develop and broadly distribute guidance that raises awareness of the ICAO Annexes requiring halon replacement, highlights the United States' support for the adoption of the ICAO halon replacement timelines, and outlines the benefits to the aviation industry of compliance with ICAO Annexes.

- Increase engagement at the technical and management levels with the Engine/APU IC and the ICCAIA CCHRWG. As part of its engagement, FAA should work with the IC to accelerate its schedule for down-selecting an engine nacelle/APU alternative and encourage the CCHRWG to expand its efforts to support the development of an alternative for cargo compartments.
- Ensure that ample funding is available and that priority is given to halon alternatives research and testing at the FAA Tech Center.
- Support adoption at the 39th ICAO Assembly of a resolution for a reasonable timeframe for halon replacement in cargo compartments of newly designed aircraft, taking into consideration the ICAO Multidisciplinary Lithium Battery meetings and the ICCAIA CCHRWG recommendations.

4.3.1. Recommendations for International Engagement

Aviation is a global industry and accelerating the implementation of halon alternatives in aviation requires a global strategy. The ARC recommends that FAA take the following actions to increase its international engagement on these issues:

- Engage in ICAO activities and develop a working paper for the 39th ICAO Assembly in September 2016 that highlights the outcomes of this ARC, and provides a summary of the actions taken by FAA and industry in response to the recommendations of the ARC. The paper should also address how the United States is complying with the 38th Assembly Resolution and in cases where the United States has found difficulties in complying should discuss those issues and propose means by which States can manage an orderly transition from halon dependent aircraft systems.
- Submit revisions to the differences that were filed by the United States in response to the addition of new standards into ICAO Annexes 6 and 8. The revised differences should be reflective of the work undertaken by the ARC.
- Continue to engage with EASA on matters related to the effective implementation of the ICAO mandates. Engage with other States that manufacture transport category aircraft (i.e. Canada, Brazil, Japan, China, Russia, etc.) to determine what action they are taking to comply with the ICAO 38th Assembly Resolution and to seek a harmonized approach.

4.3.2. Recommendations for FAA Certification Guidance

Currently the process for obtaining FAA involvement in the acceptance of an alternate agent results in substantive discussions starting too late in the airplane certification cycle for success. This is largely driven by the fact that Certification Offices need a defined application – for example, a formal Application for Type Certificate – to begin reviewing a proposed agent, and cannot engage in hypothetical discussions outside of a certification effort. Recent history shows that the time required to define the certification requirements and test methods for an alternate agent does not fit within the typical time constraints of an aircraft certification program.

Certification of a new fire extinguishing or suppression agent is a very complex and time-consuming process, which goes well beyond the basics of establishing the performance of the agent against a fire threat. The manufacturer must also satisfy the FAA that the agent can be

delivered to the protected compartment under all threat circumstances and with sufficient distribution efficiency and speed to protect the airplane from the fire. This involves addressing items such as, but not limited to, deterioration over time, potential flight conditions, and allowable Minimum Equipment List dispatch with subsequent failures.

Lack of certainty about the methods for addressing all of these items presents a significant challenge to fielding a new agent, as there is little or no ability to accurately predict the steps involved in reaching a certified airplane, whereas the process for a halon-based system is well established and very clear. Even a system which is very similar to halon – another gaseous agent with a very low boiling point – can lead, under the current conditions, to large numbers of new and expanded testing and analysis requirements, resulting in unexpected delays and expenses during the late stages of a program.

The ARC recommends that the FAA Transport Airplane Directorate work with industry to develop guidance related to the following:

- Items that would need to be newly addressed for a replacement agent.
- The acceptable means of addressing those items.
- Those items which should be assumed to remain constant between a halon system and a replacement system.

This guidance would limit the uncertainty in planning and increase the confidence of a manufacturer or operator that introducing a replacement would not lead to unacceptable delays and expenses in bringing the replacement-equipped airplane to market. Coupled with earlier FAA involvement in the technology development phase of the replacement agent, i.e. before a specific aircraft has been identified, this guidance would promote replacement development and accelerate certification programs.

Due to the complexity of the certification process, and the enormous impact that certification details can have on a development program, gaining engagement in the development of agent certification criteria prior to a full application for type certificate would greatly improve the process of bringing a new agent into the field.

4.4. Recommendations for Ensuring the Safety and Availability of Halon Reserves

The recommendations of the FAA Halon ARC for ensuring the safety and availability of halon reserves fall under 3 main headings:

- Investigate the creation of an aviation halon stockpile.
- Conserve halon by reducing unnecessary emissions.
- Support measures to ensure the quality and availability of halon reserves.

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4.4.1. Investigate the Creation and Size of an Aviation Halon Stockpile

The ARC recognizes that the size of the available supply of halons is currently uncertain, and that a significant quantity of the halon being made available to the aviation industry comes from sources outside of the United States. Given the industry's current reliance on halons and the limited amount of halon in the supply chain, a disruption in supply could have significant impacts. Accordingly, the ARC recommends that FAA reach out to the airframe manufacturers and airlines to discuss the issue of halon supply, the potential for supply chain disruption, and the potential virtues of maintaining additional supplies of halon to obviate against potential short-term supply disruptions. In that regard, the ARC believes that private industry should, either independently or collaboratively, investigate the creation of a commercial aviation halon stockpile to mitigate the potential for a supply disruption. Applicable DOT, ASTM and ISO standards for quality, transportation and storage should be followed.

Moreover, the ARC believes that further work needs to be done to gather information on the size of available halon stocks. It is apparent that if even some primary assumptions about the available supply of halon turns out to be inaccurate, there could be significant impacts on estimates for how long existing and new aircraft could continue to be serviced. Therefore, it will be important for the FAA to avail themselves of industry resources such as those of the Halon Recycling Corporation and other aviation fire protection experts to gather, assemble and present information from the best U.S. and international sources on a yearly or biennial basis regarding the status of halon available to the aviation industry.

4.4.2. Conserve Halon by Reducing Unnecessary Emissions

By unnecessary emissions, the ARC is referring to halon emissions that occur when there is an absence of any safety-threatening fire event, and are categorized thus: 1) emissions during certification testing of aircraft fire suppression systems, 2) emissions due to improper maintenance procedures, and 3) emissions due to detection and alarm-related faults. In order to conserve the supply of halon available to the aviation industry the ARC recommends the following:

- For ground-based fire suppression systems, there has long been in existence the ability to use alternative methods to test suppression systems that do not require the release of halons. Where available, these methods are required by EPA regulations. The ARC recommends that for applications currently without alternative testing mechanisms, the FAA study the potential to conduct certification testing on aircraft systems by non-emissive means.
- Based on estimates of the amounts of halon being used to service the worldwide fleet of aircraft, the ARC has determined that halon emission rates from civil aviation could be as high as 7-8%, which is much higher than for most other halon applications. Because there is significant uncertainty in this estimate, the ARC recommends that FAA further investigate this issue to determine if current emission rates and unnecessary discharges are unacceptably high and if there are steps that can be taken to reduce them.
- An analysis using data from available Service Difficulty Report (SDR) concludes that for

the 10-year period between 2003 and 2013, out of 971 emission events, all but 7 occurred as a precaution. There were a significant percentage of false detections that resulted in halon discharges. The FAA should examine the certification and maintenance standards for engine nacelle/APU systems to determine whether there is an effective means to reduce the alarm and detection fault-related discharges. The ARC understands that the FAA considers the recent update of TSO-C1e for the cargo detection system to have been addressed going forward.

- Currently there is a state of confusion over the re-qualification requirements for the high-pressure vessels used for engine nacelle/APU, and cargo fire extinguishing systems. In order to reduce halon emissions from the unnecessary hydrostatic testing of halon cylinders, it is recommended that 3-4546 paragraph A.4 of FAA Order 8900.1, Volume 3, Chapter 57, Section 1, 3-4548 High-Pressure Cylinder Maintenance, be reviewed with a goal of allowing fire extinguishers that pass the weight check and a general visual inspection to be re-installed on the aircraft without undergoing hydrostatic testing.

4.4.3. Support Measures to Ensure the Quality and Availability of Halon Reserves

Quality: As a response to the issue of contaminated halons having been fraudulently sold into the aviation market (see FAA Airworthiness Directive, Docket No. FAA-2009-1225) the FAA, CAA, and Transport Canada requested a study be carried out to review the procedures used in North America and Europe for the quality control of extinguishing agents in fire extinguishers and fire suppression systems. The resulting report, A Study on the Quality Control Process of Fire Extinguishing and Suppression Agents, contains recommendations for optimized processes for consideration by the Airworthiness Authorities and industry. The ARC recommends that FAA solicit input from a wide range of stakeholders and confer with other States on their response to the recommendations contained in the report.

Availability: Regulatory barriers to the movement of recycled halons around the world, such as bans on export or the designation of recycled halons as hazardous waste, could result in regional imbalances in the supply of halon and possibly an increase in unnecessary emissions. As such, regulatory barriers to the movement of recycled halons have the potential to reduce the availability of halons for aviation in countries where it is needed. Therefore, the ARC has the following recommendations:

- Encourage efforts by EPA and the State Department under the Montreal Protocol to obtain improved information on halon supply and encourage appropriate transfers of recycled halons as a way of fostering a non-disruptive halon supply chain.
- Work with Contracting States under the Chicago Convention to encourage policies to remove international barriers to movement of recycled halons as a way of fostering a non-disruptive supply chain.

5. **References**

5.1. Document References

5.1.1. Annexes to the Convention on International Civil Aviation

- Annex 6, "Operation of Aircraft", Parts I, II, III
- Annex 8, "Airworthiness of Aircraft"

5.1.2. Title 14 Code of Federal Regulations

- Part 21: Certification Procedures for Products and Parts
- Part 23: Airworthiness Standards: Normal, Utility, Acrobatic
- Part 25: Airworthiness Standards: Transport Category Aircraft
- Part 27: Airworthiness Standards: Normal Category Rotorcraft
- Part 29: Airworthiness Standards: Transport Category Rotorcraft
- Part 43: Maintenance, Preventive Maintenance, Rebuilding, and Alteration
- Part 91: General Operating and Flight Rules
- Part 121: Operating Requirements: Domestic, Flag, and Supplemental Operations

5.1.3. "A Study on the Quality Control Process of Fire Extinguishing and Suppression Agents" - RGW Cherry Report

5.1.4. Halon Technical Options Committee (HTOC) 2010 Assessment Report

5.1.5. Review of the Transition Away From Halons in US Civil Aviation Applications – 2004 EPA Report