国 际 民 用 航 空 组 织

工 作 文 件

A41-WP/96[1]
TE/22
28/7/22

大会 — 第 41 届会议

技术委员会

议程项目31：航空安全和空中导航政策标准化

淘汰飞机哈龙灭火剂

（由航空航天工业协会国际协调委员会（ICCAIA）、
航空公司飞行员协会国际联合会（IFALPA）提交）

执行摘要

业界正在积极寻求哈龙灭火剂的替代品用于商用飞机的货物防火，ICAO规定的哈龙灭火剂淘汰期限为2024年，这一目标似乎可以实现。然而，许多候选制剂以及已获批用于其他飞机防火用途的哈龙替代品都面临一项风险：它们可能必须服从于拟议的ECHA（欧洲化学品管理局）PFAS法规；从中期角度来看，该法规的适用范围将不限于欧洲。要想持续推进哈龙灭火剂的淘汰进程，十分重要的一点是在全球层面将飞机灭火视为PFAS法规的一个必要用途。

行动：提请大会：

a) 承认国际PFAS（全氟和多氟烷基物质）法规对飞机哈龙淘汰进度的重大影响。
b) 请求ICAO理事会敦促成员国考虑将飞机防火应用归类为永久必要用途，或给予永久免除/豁免，以确保采用现有最佳选项来维持安全的航空运输。
c) 请求ICAO理事会敦促各个成员国针对攸关航空安全的化学品进行分类方法和限制规定上的协调统一。

战略目标:	本工作文件关系到安全战略目标
财务影响:	无
参考资料:	A40 WP/93

[1].中文、英文、阿拉伯文、法文、俄文和西班牙文文本由ICCAIA提供。

1. 导言

1.1 ICAO 为货物灭火系统设定的哈龙 1301 最后淘汰期限是针对 2024 年 11 月 28 日之后申请型号合格证书的新飞机型号。ICCAIA 货舱哈龙淘汰顾问组（CCHRAG）已对本行业是否有能力满足这一期限要求进行了评估，并于 2021 年做出了更新[附录 1]。2021 年的新一期评估发现，有多种替代制剂正在开发之中，淘汰哈龙的工作可以按规定期限完成。

1.2 然而，评估也指出了可能导致淘汰延迟的监管和进度风险，特别是欧盟正在制定、近期即将实施的 PFAS（全氟和多氟烷基）物质监管行动。

1.3 正如 PFAS 列入《斯德哥尔摩公约》所产生的效果一样，欧盟当前的行动也计划上升到国际层面[2]，从而将监管效应扩大到全球规模。

1.4 本文件介绍了以下最新情况：寻找合适的哈龙替代品给航空业带来的挑战，尤其是为航空灭火用化学品取得必要豁免所面临的困难。

2. 讨论

2.1 如附录 1 所述，德国、荷兰、挪威、瑞典和丹麦正在编制文件来支持一项旨在修订 REACH 法规（化学品的注册、评估、授权和限制）的提案，以限制全氟和多氟烷基物质（PFAS）在欧盟市场上的生产、使用和处置。

2.2 如果该提案最终得到欧洲委员会采纳，它将对航空业能否顺利淘汰飞机防火哈龙制剂产生重大影响。

2.3 哈龙是氟化灭火剂，为替代哈龙而开展的研究活动主要集中在其他氟化烃灭火剂上。这是因为与其他替代品相比，氟化剂具有优异的化学稳定性，能够在非常低的浓度下灭火。

2.4 哈龙的潜在替代品包括：

- 三氟碘甲烷，CF3I。CF3I 在化学性质上非常接近哈龙 1301 (CF3Br)，多年来一直被视为一种潜在的替代品。
- 2-溴三氟丙烯 (CF3CBr=CH2) 或 2-BTP — 已经在手持式灭火器中作为哈龙 1211 的替代品使用
- HFC-227ea (CF3CHFCF3) 和 HFC-236fa (CF3CH2CF3) 均已作为哈龙 1301 的替代品用于厕所废物箱防火。

[2] 《斯德哥尔摩公约》是联合国环境规划署 (UNEP) 层面的一项全球性条约，旨在保护人类健康和环境免受持久性有机污染物 (POP) 的危害。它致力于消除或减少持久性有机污染物的排放，并建立了一个体系来处理被认定为危险性不可接受的新增化学品。

2.5 编制该提案的成员国已表示有意根据有无氯、溴或碘原子，将 PFAS 广义地定义为具有全氟化甲基 (-CF3) 或全氟化亚甲基 (-CF2) 的任何分子，该定义可能存在一些例外情况 [3]。鉴于这一拟议定义的广度，如果它得到欧洲委员会的接受，PFAS 的限制范围就可以扩大到已经使用或正在开发的哈龙替代品。如此广泛的 PFAS 定义足以涵盖上述所有候选替代品。

2.6 哈龙在商用飞机上有四项历史性的应用：

- 手持式灭火剂 — 商用飞机上最常用的非哈龙手持式灭火剂是2-BTP ($CF_3CBr=CH_2$)。
- 厕所废物箱灭火剂 — HFC-227 ea 和HFC-236fa已用于替代哈龙1211；
- 发动机和APU灭火剂
- 货舱灭火

根据新的PFAS法规，用作哈龙替代品的化学品在上述所有应用领域都可能面临潜在的限制。

2.7 应予指出的是，泡沫灭火剂中使用的 PFAS 还受到另一项限制，泡沫灭火剂也广泛用于航空领域，例如用于机场消防，该领域遵循自己的监管时间表。加诸同一化学族的这两项限制对高性能消防产品的可得性造成了巨大压力。

2.8 在制定拟议的限制条件期间，拟定提案的成员国以及负责为提案提供专家意见的欧洲化学品管理局 (ECHA) 将征求各方意见并对必要用途进行审议。“必要用途”这一术语的定义目前正在拟定，该定义如何适用于具体物质以及潜在的限时许可限量目前尚在酝酿之中，仍需密切跟踪和报告。

2.9 运输是社会运转的必要条件，对于实现人员、服务和货物的自由流动至关重要。航空运输必须符合安全和适航性法规。然而，航空运输业没有合适的替代品用于空中灭火，这必然要求各国在全球层面确立协调统一的必要用途分类。

2.10 类似的监管行动正在部分国家部署实施，如美国和中国 — 即一些大型灭火剂制造商的所在地，其他主要工业国也将迅速跟进。《斯德哥尔摩公约》有望加速这些国家的行动进展。

3. 结论

3.1 如本工作文件附录1所述，业界正在积极寻求哈龙灭火剂的替代品用于商用飞机的货物防火，ICAO 规定的哈龙灭火剂淘汰期限为2024年，这一目标似乎可以实现。

3.2 然而，许多候选制剂以及已获批用于其他飞机防火用途的哈龙替代品都面临着一项风险：它们可能必须服从于拟议的ECHA（欧洲化学品管理局）PFAS法规；从中期角度来看，该法规的适用范围将不限于欧洲。

---

[3] 该提案限制范围内的PFAS具有以下分子式：X-(-CF2-)n-X’，其中n等于或大于1和X，X’不是H（因此包括X-CF3），意指包含至少一个饱和且完全氟化的脂肪族碳原子的氟化物质，亦即具有至少一个全氟化甲基 (-CF3) 或至少一个全氟化亚甲基 (-CF2-), –) 的任何化学品，包括支链氟烷基以及包含醚键、含氟聚合物和侧链氟化聚合物的物质。

3.3 要想持续推进哈龙灭火剂的淘汰进程，十分重要的一点是在全球层面将飞机灭火视为PFAS法规的一个必要用途。

— — — — — — — — —

A41-WP/96
TE/22
Appendix
English only

APPENDIX

ICCAIA CCHRAG

Cargo Compartment Halon Replacement Advisory Group

2022 Technical Assessment Update

Prepared by
André Freiling, ASD
Sidney Teixeira, AIAB
Boris Meislitzer, AIAC
David Shaw, AIA
Tomonari Yamada, SJAC

1. Table of contents

2. Glossary

2.1 Abbreviations

CCHRAG	Cargo Compartment Halon Replacement Advisory Group
CoRAP	Community Rolling Action Plan
ECHA	European Chemical Agency
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
GHG	Green House Gas
GHS	Globally Harmonised System
ICAO	International Civil Aviation Organisation
ISO	International Standards Organization
LOAEL	Lowest Observed Adverse Effect Level
MPS	Minimum Performance Standard
MSDS	Material Safety Data Sheet
NFPA	National Fire Protection Association
NOAEL	No Observed Adverse Effect Level
ODS	Ozone Depleting Substance
OEM	Original Equipment Manufacturer
PED	Portable Electronic Device
PFAS	Per- and polyFluoroAlkyl Substances
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SNAP	Significant New Alternatives Policy
TRL	Technology Readiness Level

2.2 Definition of terms

Participant: Company selected by the CCHRAG to contribute to the assessment. Any company developing a Halon replacement agent can apply to contribute to the assessment

3. Executive Summary and Conclusion

The Cargo Compartment Halon Replacement Advisory Group (CCHRAG) is committed to continuously support the ICAO 2024 deadline for halon replacement in cargo compartment fire suppression for new type certification aircraft applications submitted after 28 November 2024.

In the 2018 – 2019 timeframe, the group had performed a technical assessment of potential technologies in order to determine if a conceptually validated halon-free fire suppression system would be available in time to meet that deadline. The result of the assessment was published for the 40th ICAO General Assembly as Information Paper, ref. A40-WP/93.

For the 41st Assembly, the CCHRAG has performed an update of the technical assessment including reflections on actual regulatory issues and schedule considerations.

As a result of the recent assessment, the CCHRAG concludes that

- there are solutions available in the industry which are beyond TRL4 and have robust plannings for subsequent TRLs in place
- there are risks to be anticipated correlated to world-wide regulatory aspects, especially the upcoming PFAS regulation[4]
- there are remaining development risks to be mitigated, but no showstoppers are identified to date
- weight increase for any Halon replacement system is imminent and will lead to increased fuel burn and correlated CO2 increase

4. SCOPE / MOTIVATION (Introduction)

The purpose of this report is to update ICAO on the activities of the CCHRAG. As stated in the Information Paper ref. A40-WP/93 issued for the 40th ICAO General Assembly, the CCHRAG is providing the potential consequences and risks with respect to the 2024 deadline in correlation to the actual Technology Readiness Level assessment. This document includes an evaluation of a set of key criteria which have been concluded by the CCHRAG to be the most critical indicators for technology readiness. This document also reflects the industry assessment in terms of development scheduling compared to the timeline which was proposed in 2016. This latter proposal led to the ICAO deadline for halon replacement in cargo compartment fire suppression for new type certification aircraft applications submitted after 28 November 2024.

Throughout the assessment, no proprietary information was submitted and the participant's identities remain anonymous. Moreover, the assessment does not recommend any specific technologies, but provides a review of the current technologies against the identified key criteria and their status against the technology readiness timeline.

5. Participants to the assessment

All organizations (participants) which were involved in the 2019 assessment were invited to update their status on the key criteria described in this report.
One participant has stopped the development of Halon replacement agents. One participant offered an additional Halon replacement technical solution compared to the previous assessment. As in the previous

[4] Most candidate agents, as well as already-approved substitutes for halon in other aircraft fire protection applications, are at risk of being subject to the proposed ECHA (European Chemical Agency) PFAS regulation which on a mid-term perspective will not stay limited to Europe. It will be very important to consider aircraft fire suppression as permanent essential use under PFAS regulations on a global scale, in order to maintain progress in replacing halons.

assessment, one participant submitted information on two solutions. In summary, seven participants delivered information on nine technical solutions. Questionnaires were distributed and follow-up online meetings were held with each of the participants to provide status on the assessment, answer questions, and/or collect additional information.

6. Technologies

The following technologies have been proposed, also in comparison with the 2019 assessment:

Technology	Number of technical solutions - 2019 assessment	Number of technical solutions - 2021 assessment
Chemical Agent	3	5
Inert gas (either bottled, generated by solid propellant or generated by onboard gas generators	4	3
Combined inert gas / water (or foam) mist	2	1

Table 1: Comparison of assessed technologies

For the 2021updated assessment, information on each technology was documented on a simplified spreadsheet listing 10 different criteria related to the categories: firefighting performance, physical properties, environmental, health & safety, production and schedule requirements. The participants indicated if their technology had met the criteria (was “compliant”) and/or provided notes with status or more details.

7. Assessment evolvement

For the 2019’s assessment, 8 key criteria were selected out of 37 criteria asked in the questionnaire to participants. For the 2021’s assessment, 10 criteria were chosen to reduce the complexity of the assessment and to cover all categories.

Cat.	#	Full initial assessment criteria coverage	2019 key criteria	2021 key criteria coverage
Fire fighting Performance	1	Cup burner fire extinction/suppression concentration established (ISO, NFPA)	X	X
	2	Other Industry Standards met (UL, ANSI, NFPA, etc.)		
	3	FAA MPS testing concentration determined	X	X
	4	Test method determined to demonstrate compliance with paragraph 25.851(b)(2)	X	*1)
Physical properties	5	Agent & System Weight is less than or equal to Halon system	X	X
	6	Agent & Systems Size is less than or equal to Halon system		
	7	Long & short range applicability		
	8	Clean agent (gaseous) - no clean up required	X	X
	9	Boiling Point		
	10	No damage to aircraft materials after agent discharge	X	*2)
	11	Freezing point is less than normal operating conditions		
	12	Freezing point is less than minimum operating/storage conditions		
	13	Decomposition temperature is greater than fire conditions (or HF formation and thermal decomposition products are under the dangerous toxic level for humans)		
	14	Not thermally conductive		
	15	Not electrically conductive		
	16	No aircraft hydromechanical interfaces required (e.g. bleed air, fuel tank inert gas, etc.)		
	17	Operational impacts have been identified & mitigated		*3)
	18	System (knockdown & metered) available whenever airplane is powered	X	*3)
Production	19	Currently used in other industries and/or applications		X
	20	Supply chain established		
	21	Agent readily available		
	22	Agent modification not needed for aircraft application		
	23	Risks for system adaptation is mitigated or low		X
Health and Safety	24	Not a Montreal Protocol listed ODS		X *4)
	25	Not a Kyoto Protocol listed GHG		
	26	Not GHS-listed Hazardous material		
	27	US EPA SNAP approved		
	28	US EPA TSCA Inventory listed		

Cat.	#	Full initial assessment criteria coverage	2019 key criteria	2021 key criteria coverage
	29	EU REACH Registered, Authorised, and/or Restricted		
	30	Not a PBT, POP, or endocrine disrupter		
	31	Present on other regulatory lists		
	32	US OSHA Regulated		
	33	Not a Carcinogenic, mutagenic, repro-tox substance (CMR)		
	34	Cardiac sensitization: LOAEL, NOAEL is less than or equal to Halon 1301		X
	35	Oral, inhalation, dermal toxicity is less than or equal to Halon 1301		
Schedule	36	Current TRL is greater than 3	X	X *5)
	37	Aviation Authority Certification experience		
	-	TRL6 Roadmap in place (expected TRL6 completion date with +/- 0.5 years accuracy would be appreciated)		X *5)

Table 2: Assessment criteria coverage

Notes to table 2:

*1) This criterion is regarded to be covered by the compliance statement to item #1, Minimum Performance Standard Tests. Therefore, this criterion is not part of the 2021 re-assessment.

*2) This criterion is regarded to be covered by the compliance statement to item #8, Clean agent (gaseous) - no clean up required. Therefore, this criterion is not part of the 2021 re-assessment.

*3) These criteria were initially set up to cover operational phases of the aircraft at which for example not enough bleed air would be available to support on-board gas generating systems. However, an assessment participant could hardly estimate such an impact because only the OEM would know about the characteristics of the individual aircraft product. Therefore, these criteria are not part of the 2021 re-assessment.

*4) During the 2019 assessment it has turned out that the breakdown within the health and safety category is too detailed. In the 2021 assessment, the criterion has been generalized to globally request health and safety issues. The wording has been changed to: "Not present on regulatory lists (e.g. Montreal protocol listed ODS, Kyoto Protocol listed GHG, GHS listed Hazardous material, ECHA/EPA regulatory lists, SNAP/REACH regulated, etc.)"

*5) For the 2021 assessment, the criterion has been changed to: "Current TRL is equal or greater than 4" in order to achieve information about the technical progress. In addition, the following criterion has been added: "TRL6 Roadmap in place (expected TRL6 completion date with +/- 0.5 years accuracy would be appreciated)" This criterion serves as an indicator if the industry is confident that the 2024 date can be reached.

8. FIREFIGHTING PERFORMANCE

8.1 Overview

The technical assessment of the firefighting performance properties of the extinguishing agent was covered by the following items:

- cup burner fire extinction/suppression concentration established (Ref. ISO 14520, Part 1: Annex B and NFPA 2001 Appendix B)

- FAA Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems (Ref. DOT/FAA/TC-TN12/11 - May 2012) (MPS) testing concentration determined

8.2 Cup burner fire extinction/suppression concentration established

The majority of participants (7 out 9 solutions) stated compliance either by conducting cup burner testing or referring to existing standards. Two of the participants have not established a concentration for a full system due to the non-gaseous state of their agent or due to other reasons.

The cup burner concentration should be conducted prior to FAA MPS testing. Depending on the exact nature of the agent, evaluation in a cup burner may not be possible, and some other action might need to be performed prior to FAA MPS.

The CCHRAG concludes that participants' interest has been demonstrated by conducting tests on several solutions.

8.3 FAA MPS testing concentration determined

In the previous assessment the CCHRAG stated that it is essential that more agents successfully complete MPS testing no later than 2020 to reduce the risk of not meeting the 2024 deadline. In 2019, one more agent successfully passed the MPS testing. In total, 2 agents (3 solutions) currently have successfully passed MPS testing including the recently defined multiple fuel fire test which will be implemented in the upcoming update of the MPS. One participant stated that the agent under his development will be subject to full MPS testing in Q3 2022 with successful rehearsal testing in 2021.

The MPS test results for the aforementioned 2 agents are publicly available on the FAA website[5] [6].

The participant who stated successful MPS testing with a combined water mist/inerting system also stated that a pure inerting system would also successfully pass the test.

Since successful MPS testing is necessary to meet FAA and EASA certification requirements, the CCHRAG concludes that the majority of the solutions assessed are still contingent on passing critical testing demonstrations.

It has to be noted that the MPS is currently undergoing a revision and that one test case - the so-called multiple fuel fire test - will be different to the already performed and passed test. This test will have to be repeated for the candidate agents with the risk of failure.

---

[5] Minimum Performance Standard Aircraft Cargo Compartment Halon Replacement Fire Suppression System Testing, by Karsten Kirbach and Dhaval Dadia, FAA International Aircraft Systems Fire Protection Forum, May 08-09 2018; below link dated Aug 26 2021
https://www.fire.tc.faa.gov/ppt/systems/May18Meeting/Dadia-0518-MPSTestingClass-CCargoCompartment.pptx

[6] MPS for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems, Dhaval Dadia, Aircraft Fire Safety Conference, October 31, 2019; below link dated Aug 26 2021
https://www.fire.tc.faa.gov/2019Conference/files/Cargo_Halon_Replacement_I/DadiaFAAAlternateAgent/Dadia%20-%201019%20-%20Blend-D.pptx

8.4 Fire Fighting Performance Conclusive Statement

CCHRAG concludes that two solutions successfully passed MPS testing.
MPS is under revision and an altered test is to be re-performed with the risk of failure. Remaining Integration and Certification risks are still to be mitigated.

Note: Even though passing the MPS testing is a key criterion and a pre-requisite to qualify the performance of a fire suppressant, it does not address the challenge of designing and integrating that agent and system into the aircraft prior to certification plan submittal. While demonstration of an agent and its support system's firefighting performance may be achievable, ensuring that performance on an aircraft under extreme conditions may pose significant challenges to the system design and aircraft integration requirements. Continued technology development and refinement is needed to guarantee successful certification.

9. PHYSICAL PROPERTIES OF EXTINGUISHING AGENT

9.1 Overview

Two criteria regarding physical properties of extinguishing agent were evaluated:

- "Agent and system weight is less than or equal to halon system"
- "Clean agent (gaseous) - no clean up required"

9.2 Agent and system weight is less than or equal to halon system

In order to minimize the CO2 emission caused by increased fuel burn due to increased system weight, this criterion has been rated of high importance by the CCHRAG. Also, this criterion is important because it will aid in system integration providing a quicker, less costly transition to clean fire suppression agents for the growing fleet (drop-in replacement).

All participants who have performed more detailed studies of integration and system layout have indicated non-compliance with weight criteria.

The CCHRAG concludes that a weight increase cannot be avoided for any of the halon replacement solutions presented, at least for those which passed the MPS testing.

A couple of participants who are not experienced in delivering aircraft systems stated compliance to this requirement. However, the CCHRAG anticipates a weight increase associated with non-halon cargo fire suppression systems after detailed integration and system layout studies.

As an outlook, one participant stated that a replacement agent which will undergo MPS testing in 2022, might come close to Halon 1301 system weight. No detailed information was provided at this point in time.

The following schematic depicts the increased system complexity and weight of the already published system architecture proposals.

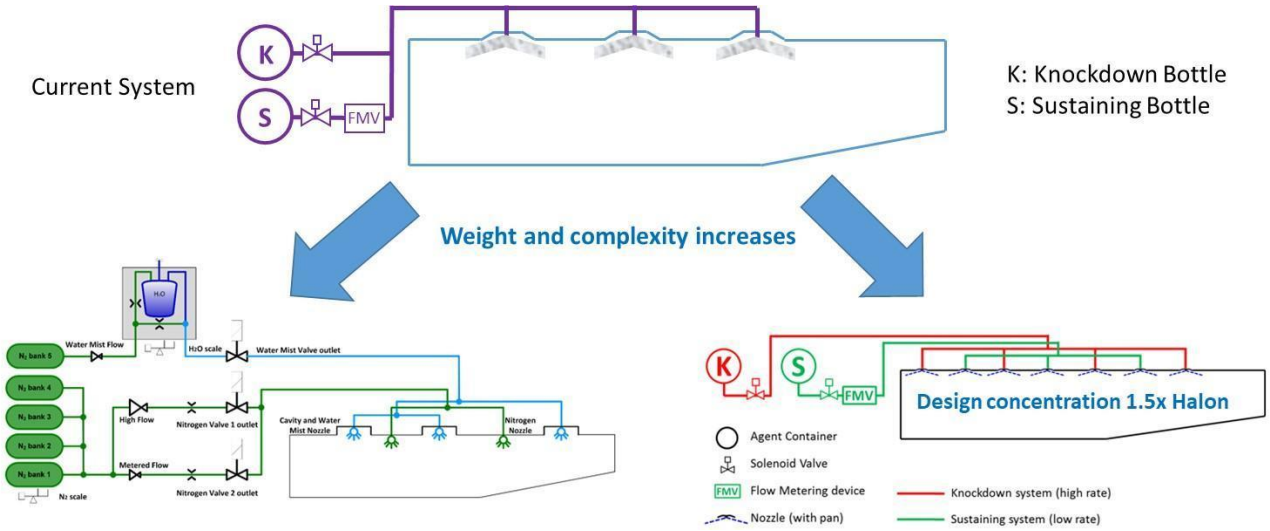

Figure 1: Halon Replacement System Architectures

9.3 Clean agent (gaseous) - no clean up required

It is important that the aircraft stays clean after a fire extinguishing discharge to minimize damage to the aircraft and cargo contained in the compartment. This is especially relevant in case of a spurious discharge when no actual fire occurred. Participants report that all gaseous agents are compliant.

One Participant that proposed a non-gaseous agent identified a non-compliance and the need for further investigation.

Based on survey results, CCHRAG concludes that the majority of the proposed agents are gaseous, and the need for additional maintenance efforts within the compartment after an inadvertent agent discharge can be kept to a minimum.

However, the participants have not provided details of the maintenance procedure at this stage of the assessment. Although gaseous, a substance might be chemically interacting with the cargo compartment materials or the transported goods. Material compatibility analyses are ongoing and not finalized.

9.4 Physical Properties Conclusive Statement

CCHRAG concludes that weight increase is imminent.
Material compatibility risks to be mitigated

10. PRODUCTION / Industrialisation

10.1 Overview

The CCHRAG assessed the production properties with the following two items:

- “currently used in other industries and/or applications”
- “risks for aircraft system adaptation/integration are mitigated or low”

10.2 Currently used in other industries and/or applications

All participants indicated that their solutions are currently used in other industries, except for one participant who has developed the aerospace application specifically. One solution is also used in the cabin for PED fire suppression by some commercial aircraft operators.

10.3 Risks for aircraft system adaptation/integration are mitigated or low

Six participants for total seven solutions, including two solutions which passed the FAA MPS test, indicated low risks. However, for the solutions which have not passed the FAA MPS test yet, the risk should be defined again. In addition, among those seven solutions, one is more suitable to smaller aircraft than larger aircraft for longer flight time.

One participant who owns two solutions cannot assess the risk without the involvement of direct suppliers to aircraft OEMs because they are the chemical manufacturer.

10.4 Production / Industrialization Conclusive Statement

CCHRAG concludes that all solutions are at pre-industrial / prototype status. Integration risks are to be mitigated.

11. Regulations / ENVIRONMENTAL, HEALTH & SAFETY

11.1 Overview:

Two criteria regarding Regulations and Environmental, Health & Safety were evaluated:

- "Less toxic than Halon 1301"
- "Not Present on regulatory lists & Cardiac sensitization"

11.2 Less toxic than Halon 1301

For the 2 solutions that have already passed MPS testing it was reported that

- 1 solution has been evaluated in the European CoRAP. Regarding hazard, the available information shows that the substance causes adverse effects on reproduction, potentially leading to impairment of sexual function, fertility and on development.[7] However, the need for follow-up regulatory action has been identified. This solution is also more toxic than Halon in terms of LOAEL and NOAEL.
- The second solution is considered non-toxic; however, the solution is technically complex and heavy compared to Halon 1301

For the remaining 7 solutions not MPS tested yet it was reported that

- 5 solutions have less or equal cardiac sensitization or toxicity levels compared to Halon 1301,
- 1 solution requires confirmation of impact and
- 1 solution is reported to have greater impact than Halon 1301.

[7] Substance Evaluation Conclusion document EC No 627-872-0

5 solutions are reported as being either already EPA SNAP approved or that the substance used is considered approved based on usage in other industries, which is an evolution from the 4 candidates reported in 2019.

It is foreseen that the definition of safe handling procedures and the specification of material characteristics in Material Safety Data Sheets (MSDS) will need to be developed for any Halon 1301 alternative.

11.3 Not Present on regulatory lists

Germany, Netherlands, Norway, Sweden, and Denmark have issued a questionnaire[8] as the next step for preparing a REACH Annex XV Restriction Dossier on per- and polyfluoroalkyl substances (PFAS) to restrict the manufacturing, use, and placement of PFAS on the EU market. One of the solutions which has passed MPS testing and is to date the most promising alternative falls into this substance category.

Risk of PFAS Chemical Restriction

If the amendment of REACH Annex XV to restrict the manufacturing, use, and placement of per- and polyfluoroalkyl substances (PFAS) on the EU market is ultimately adopted by the European Commission, it could have a very important bearing on the ability to replace halons in aircraft fire protection. Because the restriction proposal is only now in development, and the outcome is not certain, it is difficult to anticipate the impact on the industry's international Halon replacement efforts.

What fire suppression chemicals will be counted as PFAS?

The member states preparing the proposal have indicated an intent to define PFAS broadly as any molecule with a fully fluorinated methyl group ($-CF_3$) or a fully fluorinated methylene group ($-CF_2$) with some possible exclusions based on presence of chlorine, bromine or iodine atoms[9]. Given the breadth of this proposed definition, and if accepted by the European Commission, a PFAS restriction could extend to halon replacements that are already in use or are in development. One chemical that has been studied as a halon replacement agent is iodotrifluoromethane, CF_3I. CF_3I is chemically very close to Halon 1301, CF_3Br, and has been considered a potential replacement for many years. Depending on the final definition, CF_3I may face potential restriction as a PFAS. Another chemical that is already in use as a Halon 1211 replacement in handheld fire extinguishers is 2-bromotrifluoropropene ($CF_3CBr=CH_2$), or 2-BTP. 2-BTP contains a CF_3 group attached to another carbon atom, so it could also be considered a PFAS if a broad definition of PFAS is included in any final PFAS restriction. Lastly, HFC-227ea (CF_3CHFCF_3) and HFC-236fa ($CF_3CH_2CF_3$) have both been used as replacements for Halon 1301 in lavatory waste compartment fire protection. Both of these agents are likely to be included in a broad definition of PFAS.

It should be noted that there is another restriction for PFAS used in firefighting foams that are also widely used in Aviation, e.g. for airport firefighting which follows its own regulatory timeline. These two restrictions on a single chemical family is creating a great pressure on availability of performant firefighting products.

Will fire protection be considered an essential use?

---

8 https://www.reach-clp-biozid-helpdesk.de/SharedDocs/Downloads/DE/REACH/Verfahren/Beschr%C3%A4nkung/Consultation-PFAS.pdf?__blob=publicationFile&v=3 link dated August 26 2021

9 PFAS in the scope of this restriction intention have the following structural formula: X-(-CF2-)n-X' with n equal to or larger than 1 and X, X' not being H (thus including X-CF3), meaning fluorinated substances that contain at least one aliphatic carbon atom that is both, saturated and fully fluorinated, i.e. any chemical with at least one perfluorinated methyl group (-CF3) or at least one perfluorinated methylene group (-CF2-), –), including branched fluoroalkyl groups and substances containing ether linkages, fluoropolymers and side chain fluorinated polymers.

During the development of the proposed restriction, the member states developing the proposal and the European Chemicals Agency (ECHA), which is tasked with providing its expert opinions on the proposal, will invite comments and will consider essential uses. The definition of the term "essential use" is currently under development and its application to specific substances as well as potential time-limited allowances are still underway and require close follow-up and advocacy. Transport is deemed essential for society and is vital for fulfilling the free movement of individuals, services and goods. Air transport has to fulfil safety and airworthiness regulations. The fact that suitable alternatives to fluorinated hydrocarbon agents for airborne fire suppression are not available should lead to an essential use classification on a global scale which is harmonized between the nations. Similar regulatory actions are underway in some countries where some of the major agent manufacturers are located such as the USA where currently a PFAS action plan is rolled out. China has started rolling out its New Pollutant Action. Other important industrial countries will follow soon. The Stockholm Convention could speed up these developments.

How could REACH restriction of PFAS affect aircraft halon replacement?

Halons are fluorinated fire suppression agents and much of the research effort to replace halons has focused on other fluorinated hydrocarbon agents. This is because fluorinated agents have excellent chemical stability and are able to extinguish or suppress fires at very low concentration, relative to other alternatives. There are four historic applications of halons in commercial airplanes:

- Handheld extinguishers - The most common non-halon handheld fire extinguisher agent that is in use on commercial airplanes is 2-BTP ($CF_3CBr=CH_2$). This chemical could face potential restriction if a broad definition of PFAS is adopted.
- Lavatory waste compartment extinguishers - As already noted above, HFC-227ea and HFC-236fa have been used to replace Halon 1211 and both chemicals could face potential restriction if a broad definition of PFAS is adopted.
- Engine and APU fire extinguishers – Most of the agents being considered to replace Halon 1301 in engine and APU fire extinguishing could face potential restriction if a broad definition of PFAS is adopted.
- Cargo Compartment fire suppression - Most of the agents being considered to replace Halon 1301 in cargo fire suppression could face potential restriction if a broad definition of PFAS is adopted.

When will we know more about the risk to the 2024 deadline?

ECHA will perform a 6-month public consultation to be initiated at the beginning of 2023. When ECHA responds to these comments in 2023, it will be clearer how the prospects for replacing halon in aircraft cargo compartments are affected.

11.4 Regulations / Environmental, Health and Safety Conclusive Statement

CCHRAG concludes that health & safety risks for some high potential replacement agents are more severe than for Halon.

The risk of potential replacement agents being regulated has to be actively counteracted.

12. SCHEDULE

12.1 Overview:

Two criteria regarding Schedule were evaluated:

- "Current TRL is equal or greater than 4"
- "TRL 6 Roadmap in place"

Progress of development solutions is monitored in accordance with the Technical Readiness Level (TRL) method and rated from TRL 1 to TRL 9, where TRL 4 corresponds to a technology validated in the laboratory and TRL 6 corresponds to a technology demonstrated in a relevant environment:

Figure 2: TRL Definition

A generic timeline was drafted in 2016 during initial activities of CCHRAG to support the proposal of deadline for halon replacement in aircraft cargo compartments. This timeline also includes concrete criteria for TRL achievement in the context of the CCHRAG assessment.

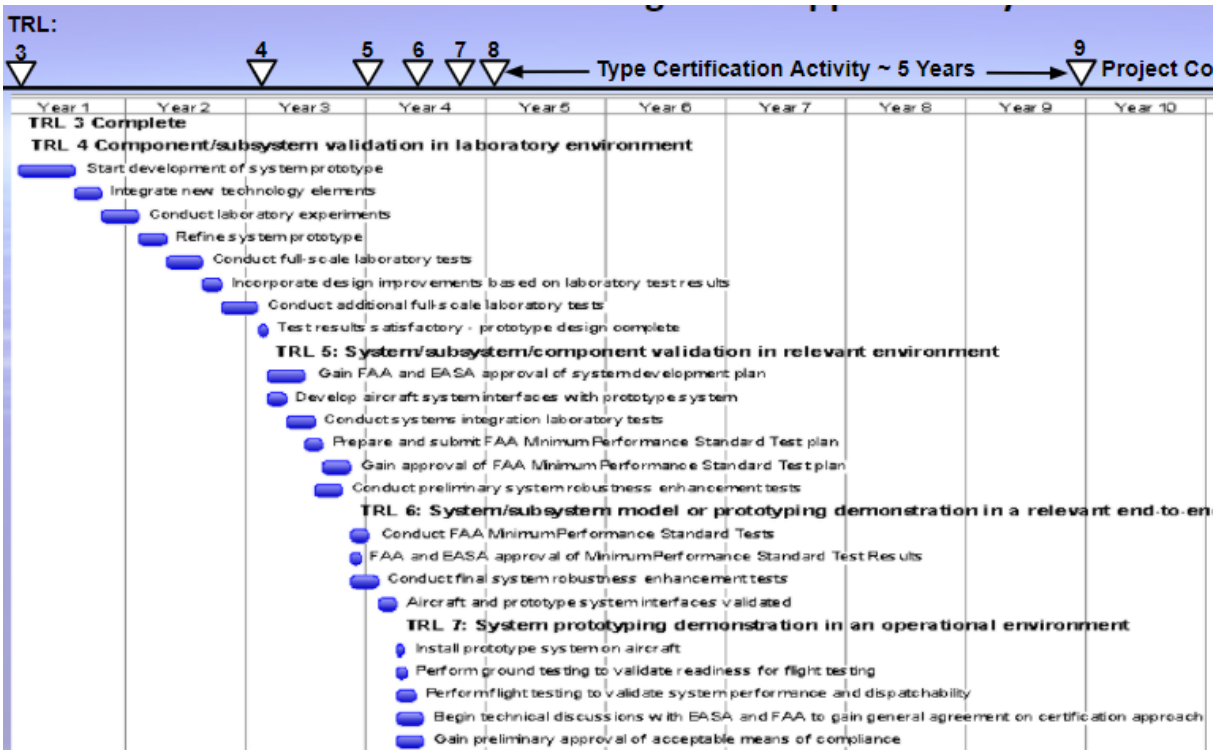

Figure 3: Initial Halon replacement schedule proposed by CCHRAG in 2016 (39th Assy)

This timeline indicates a halon-free system would be available for a new application for type certification by the 2024 timeframe, assuming TRL4 would be achieved in 2021. However, the proposed timeline might have been too optimistic in a sense that the achievement of 4 subsequent TRLs (5-8) within appr. one year seems more than challenging.

In previous CCHRAG documentation, it is stated that "If a candidate system has not been demonstrated to be application ready (actively being worked in TRL 7) by the 41st Session of the ICAO Assembly, the reasons for not adhering to the timeline will be identified and ICCAIA will indicate the consequences on the 2024 deadline".

The pandemics has slowed down the development, but the industry is still actively working on Halon replacements.

12.2 TRL assessment

Participants have presented their self-assessment to indicate the solution TRL status. However, some of the participants might be more familiar with the TRL process than others, especially if they have experience in collaboration with aircraft OEMs. Within the nine presented candidate solutions, two solutions have already passed the FAA's Minimum Performance Standard (MPS) tests and become main promising candidates. One additional solution is planned to be MPS tested in the second half of 2022.

The two solutions that already passed the FAA's MPS tests stated to be at least compliant with TRL 4, which is in line with the CCHRAG view. Additional four out of the remaining seven solutions, were stated by the participants to have reached TRL 4 but would need further substantiation.

Within the nine presented candidate solutions, the two solutions that already passed the FAA's MPS tests stated to have a TRL6 roadmap in place, although no date for achievement had been disclosed. Additional three solutions, out of remaining seven solutions not yet tested to MPS, were also stated to have a TRL 6 roadmap in place.

Although TRL7 will not be fully achieved at the time of the 41st ICAO General Assembly, elements of this TRL have been already conducted, e.g. a flight test on the 2019 Boeing ECO Demonstrator.

The detailed TRL breakdown and criteria interpretation differ within the industry. This is why for one OEM, a certain TRL might be achieved and be still pending for another. However, the CCHRAG agrees that a robust TRL6 roadmap is in place for at least one agent which has passed the MPS test. Furthermore, CCHRAG agrees on the achievement of the initially defined main TRL criteria although a detailed assessment of additional, OEM-specific criteria might be outstanding.

TRL	Criterion	Achieved	Roadmap in place
6	Conduct FAA Minimum Performance Standard test	2/9 solutions	2/9 solutions
6	FAA and EASA approval of MPS test results	FAA test report to be issued	
6	Conduct final System robustness tests	ongoing	ongoing
6	Aircraft and prototype system interfaces validated	1/9 solutions	1/9 solutions
7	Install prototype system on aircraft	1/9 solutions	2/9 solutions
7	Perform ground testing to validate readiness for flight test	2/9 solutions	1/9 solutions
7	Begin technical discussions with EASA and FAA to gain general agreement on certification approach	1/9 solutions	
7	Gain preliminary approval of acceptable means of compliance	No	No

Table 3: CCHRAG TRL assessment

As a conclusion of Table 3 it can be stated that some but not all elements of TRL6 and TRL7 criteria as initially defined by the CCHRAG are fulfilled, so it is confirmed that TRL7 is actively being worked on at the time of the 41st Assembly.

12.3 Schedule Conclusive statement

CCHRAG concludes that at least one solution has a robust TRL6 roadmap in place.

13. Summary

Criterion	2019 Conclusion	2021 Conclusion	2022 status	Remarks
Cup burner fire extinction/suppression concentration established (ISO, NFPA)	Achievable	Achievable	Achieved	
FAA MPS testing concentration determined	Achievable on condition	Achievable	Achievable	2 agents have passed MPS testing, 2 show potential. Continued technology development is needed to guarantee successful certification.
Agent & System Weight is less than or equal to Halon system	Not Achievable	Not Achievable	Not Achievable	A weight increase is imminent for any of the halon replacement solutions presented. A consequence is an increased CO2 emission caused by higher fuel burn.
Clean agent (gaseous) - no clean up	Achievable	Achievable	Achievable	All relevant candidate agents MPS are gaseous - Material compatibility assessments ongoing.
Currently used in other industries and/or applications	Achievable	Achievable	Achievable	One solution is dedicated to the aircraft industry.
Risks for aircraft system adaptation/integration are mitigated or low	Achievable on condition	Achievable on condition	Risk to be anticipated	All solutions are pre-industrial / prototype. Integration risks to be mitigated.
Not Present on regulatory lists	Full compliance will take time and resources.	Achievable on condition	Risk to be mitigated	**High risk that candidate replacements will be regulated as PFAS.**
Toxicity is less than or equal to Halon 1301		Achievable on condition	Risk to be anticipated	Toxicity may be greater than Halon 1301.
Current TRL is equal or greater than 4	Achievable	Achievable	Achieved	
TRL6 Roadmap in place	-	Achievable on condition	Achieved	One solution has a robust TRL6 roadmap in place. Two additional solutions have TRL6 roadmaps in place.

Table 4: Summary table of technical assessment

Progress has been made for Halon replacement candidate agents. For some criteria, the status compared to previous assessments has changed from amber to green.

The risk for aircraft integration and toxicity have to be anticipated and mitigated. Higher toxicity might lead to additional measures to protect ground handling and maintenance staff. In this context, the previously assessed conditions turn into more tangible risks. The status of these criteria remains amber.

The system will be heavier and more integration space has to be allocated; and the status of this criteria remains red. The regulatory risk was non-existent at the time of the previous assessment cycles and the fact that promising candidate Halon Replacement agents might be regulated requires mitigation actions; therefore, the status compared to previous assessments has changed from amber to red.

— END —