ExxonMobil Petroleum & Chemical BV (EMPC) Comments on Annex XV restriction report on per- and polyfluoroalkyl substances (PFAS)

Aviation hydraulic fluid additive

21 September 2023

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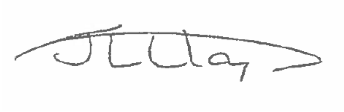

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Acronyms and Abbreviations

ECHA	European Chemical Agency
EEA	European Economic Area
EiF	Entry in Force
EPDM	Ethylene Propylene Diene M-class rubber
ESIG/ESVOC	European Solvents Industry Organization for substances of low volatility
EtCHxS	Potassium decafluoro(pentafluoroethyl)cyclohexanesulphonate
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PEBHF	Phosphate-ester based hydraulic fluids
PFAS	Per- and Polyfluoroalkyl Substance
PPE	Personal Protective Equipment
R&D	Research & Development
SEA	Socioeconomic Assessment
SpERCs	Specific Environment release categories

1. EXECUTIVE SUMMARY

This response is submitted on behalf of ExxonMobil Petroleum & Chemical BV ("EMPC"). For the purpose of this submission, EMPC is acting in its own name and in name and on behalf of the other affiliates potentially affected by the proposed REACH restriction (hereafter referred to as "ExxonMobil"). EMPC is a subsidiary of Exxon Mobil Corporation and part of the ExxonMobil group of companies ("ExxonMobil Group").

The anti-corrosion additive is an essential component of aviation hydraulic fluids, as it slows the rate of electrochemical erosion of the internal surfaces of hydraulic actuator systems, ensuring that they meet the very strict safety and performance requirements as defined in industry and regulatory standards. Hydraulic actuator systems are essential in aircraft as the power safety-critical sub-systems such as flats, slats, tail plane fins and landing gear.

The PFAS substance used as an anti-corrosion additive in aviation hydraulic fluid offers a unique combination of properties, including very good electrochemical corrosion resistance, high conductivity potential, good solubility to the hydraulic fluid, as well as a relatively low treat rate (i.e., concentration in the final product). Most importantly, however, it has excellent chemical and thermal durability and is stable across a broad range of harsh service conditions, such as broad temperature swings (from below freezing to as high as 50 °C), high pressures and corrosive chemicals.

ExxonMobil have evaluated more than 200 potential alternatives over several decades but have not yet been able to identify any that offers the same set of technical properties and performance as the current additive. All of the alternatives examined so far cannot meet the safety and performance requirements of Original Equipment Manufacturers (OEM), so they are not considered technically feasible.

As a result, work on identifying and developing a potential alternative must continue before any work on potential substitution begins. The substitution process in the aviation industry is governed by strict procedures, which require diligent documentation and approvals by several actors, including the OEMs, the aircraft manufacturers / operators and the regulatory / certification authorities in multiple jurisdictions globally. Substitution in these cases could take as long as 30 years in some cases, considering that failure in any step may push the process back to the previous one or all the way to the beginning.

For the hydraulic fluid additive, for which no potentially suitable alternative has yet been identified, it can take well over 20 years, considering the long testing needed for qualification and certification, and this would take it beyond the expiration of the currently proposed derogation in the restriction proposal.

In such a scenario, it would not be possible to use the currently certified hydraulic fluids in airplanes in the EEA, which could severely impact their flightworthiness. It will not be possible to use hydraulic fluids that cannot meet the specifications for corrosion resistance, as all equipment in an aircraft must be certified. In an extreme scenario, this could stop the maintenance and servicing of aircraft in the EEA and may even lead to grounding of the fleet, as they will not be able to use a safety-critical component, i.e., the hydraulic actuators.

Another aspect that needs to be considered is the fact that use of the current anti-corrosion additive enables the use of higher-pressure actuators in the newer, more energy-efficient aircraft models, such as the Boeing 787 or the Airbus 350. Furthermore, the hydraulic actuators will still be a critical component in all new aircraft, including low carbon models, such as electric or hydrogen-fuelled, which are expected to contribute to the EU's decarbonisation ambitions.

Therefore, the currently proposed derogation of 13.5 years for anti-corrosion additives for aviation hydraulic fluids cannot be considered adequate, as more time is required to develop, qualify, certify and implement a suitable alternative that can meet the strict safety and performance specifications of the aviation industry and competent authorities.

As a conclusion, and considering the high difficulty in identifying an alternative despite decades of research and the very high risk for the aviation industry, and impacts to EU society in general in the event that aviation hydraulics could no longer be used, ExxonMobil would request that the currently proposed derogation becomes time-unlimited, as per the text below:

> **Additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry.**

Nevertheless, work on alternatives is ongoing, in an effort to improve the environmental footprint of the products, along with the overall performance of the hydraulic fluids and the aircraft components. As such, and to capture the possibility that an alternative is identified in the future, the validity of the time-unlimited derogation can be re-evaluated at regular intervals, depending on the status and availability of alternative additives.

This report details the use in the aviation hydraulic fluid product, as well as technical feasibility criteria and the control of potential emissions. In addition, the overview of potential alternatives and potential for substitution are discussed, as are the aircraft safety considerations. The report concludes with a socio-economic analysis which covers both the scenario where use continues, and that where the derogation is time-limited, and finally the requested derogation is detailed.

2. BACKGROUND INFORMATION

Exxon Mobil Corporation manages an industry-leading portfolio of resources, and is one of the largest integrated fuels, lubricants and chemical companies in the world. The ExxonMobil Group evolved an operating model and global organization to better leverage the scale of its increasingly integrated company and global brands. There are three core businesses with operations around the world[1]:

- Upstream business - Focused on strengthening energy security by expanding low-cost-of-supply, high-return oil and natural gas operations.
- Product Solutions business - Integrating downstream and chemicals operations to develop lower emission fuels and innovative products needed by modern society.
- Low Carbon Solutions Business - Helping lower emissions by providing solutions to industrial and commercial customers in growing markets for carbon capture and storage, hydrogen and biofuels.

ExxonMobil´s history of operating in Europe is more than a century long and Europe has played an important role in some of the key milestones that marked their development into a manufacturer of the products that drive modern transportation, power cities, lubricate industry and provide petrochemical building blocks that lead to thousands of consumer goods.

The ExxonMobil Group's Corporate brands include:

- Esso: Customers around the world have come to respect and rely on Esso-branded fuels, services and lubricants for their personal and business needs;
- Exxon: Customers have also come to respect and rely on Exxon-branded fuels, services and lubricants for their personal and business needs;
- Mobil: Marketed around the world, Mobil is known for performance and innovation. Mobil is recognised for its advanced technology in fuels, lubricants and services; and
- ExxonMobil Chemical: There is a broad portfolio of petrochemical product brand and service solutions. These products play a key role in enabling the manufacture of affordable, sustainable and safe products that are helping meet the growing demands of an increasing global population.

With specific regard to chemicals and specialties, it has manufacturing capacity in every major region of the world, serving large and growing markets. More than 90 percent of the company's chemical capacity is integrated with refineries or natural gas processing plants[2]:

- The portfolio includes product and services (branched alcohols, branched higher olefins, butyl, EPDM rubber, linear alpha olefins, neo acids, plasticisers, polyethylene, polymer modifiers, polyolefin plastomers and elastomers, polypropylene, solvents & fluids, synthetic base stocks, tackifiers, transformer oils and thermoset systems);
- The industrial sectors supplied include: adhesives and sealants, agriculture, automotive, building and construction, compounding, consumer products, healthcare & medical, hygiene and personal care, industrial applications, energy, packaging, synthetic base stocks.

This document is being submitted by ExxonMobil in response to the public consultation on the universal PFAS restriction proposal, which was initiated by ECHA and runs until 25 September 2023.

The ExxonMobil Group does not manufacture per-and polyfluoroalkyl substances (PFAS). As part of their response, ExxonMobil wants to present relevant data on the uses and applications of certain PFAS and respond to ECHA's public consultation questions, which are applied in a number of

[1] https://corporate.exxonmobil.com/who-we-are/our-global-organization#Aglobalcompany

[2] https://www.exxonmobilchemical.com/en/

products in industry sectors and applications including, but not limited to, the uses identified in this report.

ExxonMobil will be submitting reports covering the following uses:

- Fluoropolymers are used in upstream, refining, and petrochemical manufacturing.
- Aviation hydraulic fluid additive
- Additives in lubricants
- Processing additive for polyethylene
- Clean agent in fire suppression systems.

Please note that the information able to be submitted at this juncture is incomplete. The scope and potential impact of the proposed restriction is unprecedented and open-ended. Many thousands of substances would be subject to the restriction, and few of these substances are identified in the proposal on an individual basis. Accordingly, more time would be needed to do a more comprehensive and complete assessment. Due to the absence of identification of the individual substances that are in scope of the proposed restriction, the current assessment has been limited to those substances that are known to be used by ExxonMobil and are within the proposed restriction's scope. ExxonMobil reserves our rights in this context.

The information provided will describe in detail the sectors and sub-uses involved and the potential impact of the current restriction proposal, demonstrating the necessity of the use of certain PFAS in these applications, the potential for substitution, and the importance of the use, and continued use, with specific regard to the European Economic Area (EEA).

3. OVERVIEW OF THE USE

3.1 Sectors and Sub-uses

Exxon Mobil Corporation is one of the largest integrated fuels, lubricants and chemicals companies globally. Its business encompasses all aspects of the oil and gas industry, including Upstream, Products Solutions (including downstream and chemicals), and Low Carbon Solutions. The value chain of ExxonMobil businesses extends to end users of products and services, which can be found across all industry sectors in the EU, including, but not limited to, automotive and aerospace, building and construction, chemical processing, including agrochemicals and pharmaceuticals, packaging, etc.

In commercial aircrafts, flats, slats, tail plane fins and landing gear, i.e., all kinds of safety-critical mechanical subsystems, are powered by hydraulic actuators. The mechanical power produced by these actuators stems from pressurised hydraulic fluids. A typical actuator cylinder consists of a cylinder housing, one or more pistons and piston rods, and seals. The hydraulic fluid enters the bore of the cylinder and pushes the piston and piston rod, which in turn moves the connected part. Actuators are usually linear, which is the typical type with a cylinder and piston/piston rod assembly, and rotary, in which the piston turns a pinion gear.

For reasons of passenger safety, hydraulic fluids used in the actuators need to be fire-resistant and also to perform across a range of operational temperatures, from below freezing to over 50 °C, due to high altitudes and a broad range of operational climates.

- The fire resistance properties are required to provide for aircraft and passenger safety.
- The low-temperature performance properties are required to ensure trouble-free operation of aircraft hydraulic systems under a broad range of atmospheric conditions.

Phosphate-ester based hydraulic fluids (PEBHFs) are widely employed to meet these technical requirements. However, their hygroscopic nature makes them susceptible to thermal degradation as flight operations are carried out[3].

Because of their chemical and electrical properties, PEBHFs can also lead to electrochemical erosion of precision hydraulic system components, disrupting aircraft control. Electrochemical erosion, or electro-corrosive wear, is an electrochemical phenomenon that is driven by an electrokinetic streaming current. In a phosphate ester fluid, electrical charges are swept downstream by the high-pressure fluid flow through high-precision hydraulic components. This creates an electrical potential that drives oxidation of iron metal to soluble iron ions, corroding hydraulic system components. This causes degradation of the ability to control the aircraft hydraulic systems and can lead to complete system failure of critical aircraft controls.

Figure 3-1 shows the progression of the electrocorrosive wear in an aircraft servovalve.

[3] Andreas Helwiga, Konrad Maiera, Gerhard Müllera, Torsten Bleyb, Jörg Steffenskyb, Horst Mannebach. An optoelectronic monitoring system for aviation hydraulic fluids. EUROSENSORS 2015

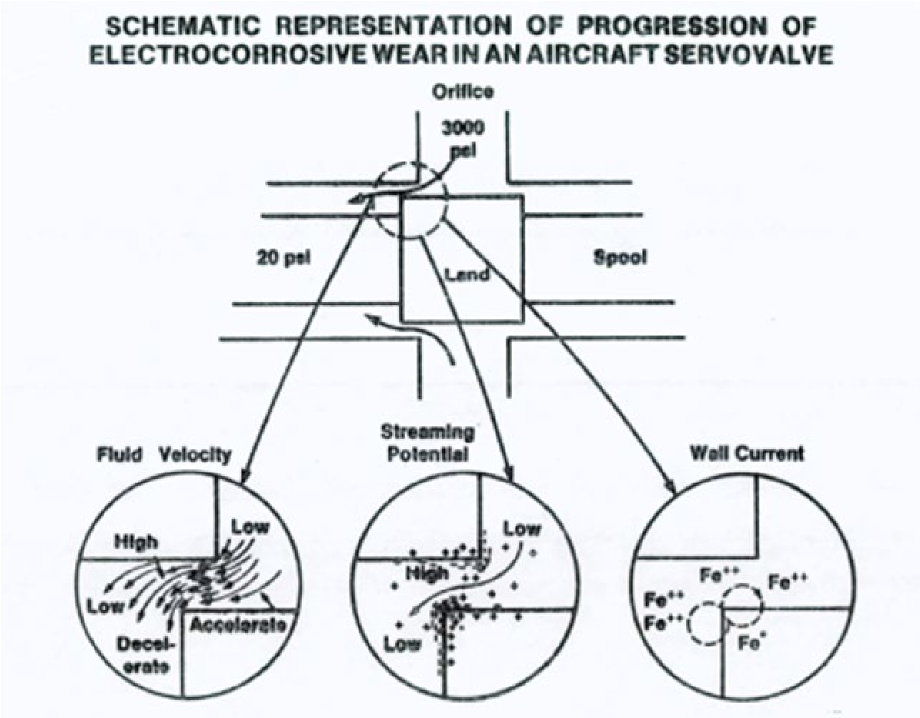

Figure 3-1: Progression of the electrocorrosive wear in aircraft servovalve[4]

To prevent electrochemical erosion, additives are added to the hydraulic fluid as corrosion inhibitors.

3.2 PFAS used in the application

Potassium decafluoro(pentafluoroethyl) cyclohexanesulphonate (EtCHxS; CAS: 67584-42-3) has been added as a corrosion inhibitor in PEBHFs since the 1970s and continues to be used today. **Figure 3-2** shows the structure of the EtCHxS salt.

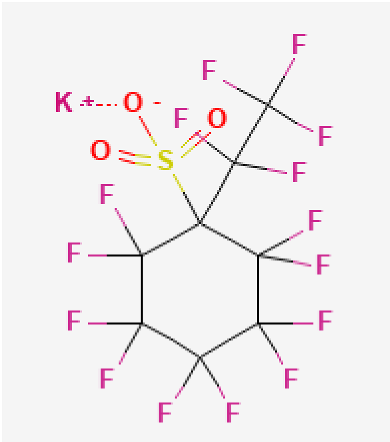

Figure 3-2: Chemical structure of EtCHxS (one isomer)[5]

EtCHxS is an amphiphilic saturated cyclic organo-fluorine compound belonging to the broader group of per and poly-fluoroalkyl substances (PFAS). These substances are generally characterised as having surfactant-like qualities, high thermal and chemical stability, and the potential to aggregate or assemble at water-air, and water-surface interfaces. Due to its ability to efficiently transfer and dissipate energy/heat, its high chemical and thermal stability, and its affinity to form a coating and act as a chemical “barrier” between fluids and surfaces, these molecules have additional smaller volume

[4] Burrous, M., "Recent Developments in Aviation Hydraulic Fluids," 25th Aerospace Fluid Power Conference, Oct. 31-Nov. 1, 1977, Jackson, Mississippi

[5] https://comptox.epa.gov/dashboard/chemical/details/DTXSID40880565

industrial and chemical applications, including as a corrosion inhibitor in PEBHFs to prevent electrochemical erosion.

Relatively low additive treat rates of perfluorinated materials are required to achieve effective corrosion inhibition and significantly extend the life and the safety and reliability of PEBHF systems. Without and prior to the inclusion of the additive as a corrosion inhibitor, airlines were subject to routine damage and maintenance cost, as well as increased risks to worker and passenger safety associated with aging or corroded systems. As aircraft hydraulic system designs have advanced, more thermal and mechanical stress has been placed on the fluid. This has increased the necessity for the use of EtCHxS as a corrosion inhibitor.

3.3 Performance requirements

3.3.1 Technical feasibility criteria

All components used in the aerospace sector need to meet very high performance and safety requirements, as the safety of the craft, its cargo and, most importantly, its passengers is of utmost importance for the manufacturer and the operators. Hydraulic fluids are required to operate under extreme conditions, such as very high or low temperatures, very high or low pressures, mechanical stress and corrosive chemical and environmental agents. PFAS substances are often used therein because of their versatility and their unique combination of performance and durability under a broad range of conditions.

Performance requirements include but are not limited to:

- **Electrochemical corrosion resistance**: The primary function of the corrosion inhibitor is to minimise electrochemical corrosion in the hydraulic cylinder throughout its very long service life. Electrochemical corrosion resistance is determined by measuring the wear on the servo-valves as part of a rig test.
- **Conductivity**: To prevent failure modes, corrosion inhibitors for PEBHFs must increase the electrical conductivity of the phosphate ester fluid by dissociating into ionic charge carriers. The use of fluorinated compounds decreases the association energy of the ions and permits this to happen.
- **Chemical and thermal stability / durability**: Critically, the erosion inhibitor must be stable under harsh service conditions. Aircraft components are exposed to temperature and pressure extremes with many rapid changes of temperature during a typical flight. All components must be resistant to such conditions and not break down or transition out of the liquid phase to ensure continued operation under all circumstances. Durability, not only to physical, but also to chemical stress is an essential property of a corrosion inhibitor used in hydraulic fluids.
- **Solubility to the hydraulic fluid**: Lubricant additives must always remain in the lubricant to provide their function. If they are not sufficiently soluble, they could migrate out of the hydraulic fluid or form a different phase with different properties which could damage the cylinder or some other part.
- **Chlorine content**: An elevated chlorine content could lead to faster damage of the hydraulic system components.
- **Treat rate**: While not exactly a technical criterion, it is important for the formulation of the additive package and the lubricant. Each hydraulic fluid contains an additive package with a carefully developed composition of components to ensure that it meets all specifications from OEMs. The additive package formulator needs to consider all the potential interactions among the different components and to ensure that there will not be unwanted reactions which could impair the lubricant's performance. A low treat rate allows for a small footprint of the corrosion inhibitor in the additive package.

- **Material compatibility**: The corrosion inhibitor additive must be compatible with the materials used in the hydraulic cylinder. In combination with a low treat rate, it can ensure that it will not affect the cylinder or the piston in any way.

3.3.2 Quality standards and qualification procedure

The aerospace industry and its suppliers of equipment must ensure that all components and formulations provided conform with the specifications of numerous safety and quality standards. These standards cover a wide range of areas, including product safety, configuration management, raw material testing, post-delivery support, etc. There are a number of international organisations developing and publishing such standards, including SAE, but aerospace companies, such as Boeing and Airbus also publish standards that need to be met by all their suppliers.

The exact composition of the hydraulic fluid, including the PFAS is approved in several performance and regulatory specifications (Airbus NSA 307110N, Boeing BMS 3-11P, SAE 1241D, and others). Without the PFAS the hydraulic fluid would not meet stability/fluid life requirements. Hydraulic fluids must be compliant with the relevant industry specification, and this information needs to be communicated on the product label and the Certificate of Analysis, otherwise it cannot be sold.

In Europe, the aviation industry must comply with the airworthiness requirements specified under EU Regulation No 216/2008, and there are similar airworthiness requirements in all countries where aeronautical products are sold[6]. The whole process of manufacturing and selling aviation hydraulic fluids requires the cooperation of multiple stakeholders, namely the suppliers of parts or equipment, the OEMs, the airline operators, and the airworthiness authority in each relevant country or region.

Meeting the specification requirements is only one part of the complex qualification procedure that a formulation intended for use in the aerospace industry. The very high requirements in these applications mean that all formulations must undergo long and rigorous testing. The same applies in case a change needs to be introduced to the formulation. It must be demonstrated that the hydraulic fluid still performs according to the stringent performance and safety specifications. The main steps of this process are summarised in **Figure 3-3**.

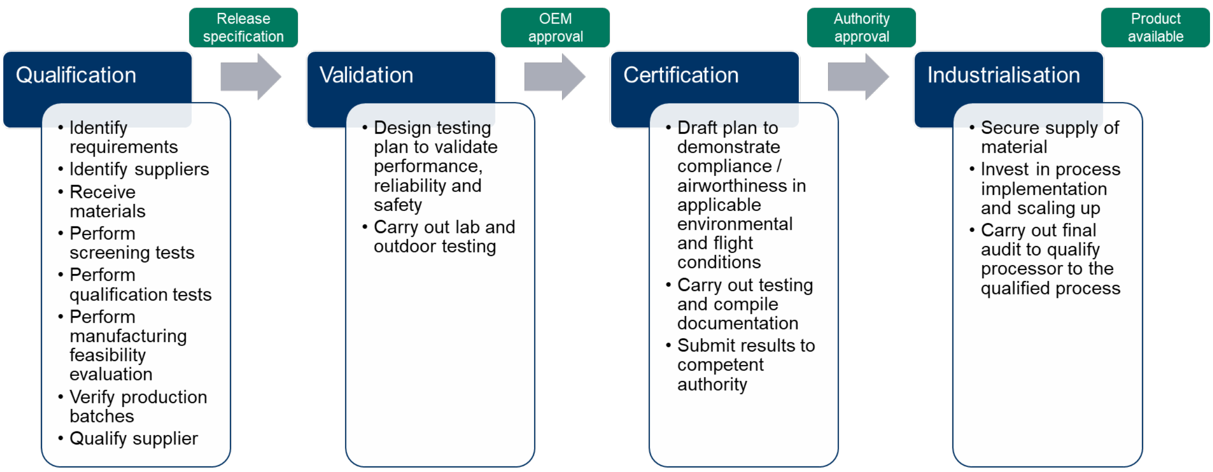

Figure 3-3: Qualification, certification and industrialisation process for the aviation industry

It should be noted that the process described above commences only once a potentially suitable alternative has been identified. There is a very long phase before qualification begins, which is dedicated to identifying or developing potential alternatives to take forward. This R&D phase involves

[6] ECHA, EASA (2014). An elaboration of key aspects of the authorisation process in the context of the aviation industry. Available online at: https://www.easa.europa.eu/en/downloads/17236/en, accessed on 25 August 2023

extensive desk and laboratory research to ensure that the selected potential alternative meets a minimum of properties and performance specifications. In the case of the anti-corrosion additive, it would also include defining the composition of the hydraulic fluid and carrying out tests on the full mixture to ensure it meets the preliminary specifications set by the lubricant and manufacturer and their customers.

The entire process described above is iterative. Every step in the process above, from development to industrialisation, may fail and push the process back to a previous step or all the way to the beginning.

For some of the more complicated and demanding components, the complete substitution process, from development all the way to industrialisation can take more than 30 years and involves the lubricant manufacturer, the OEM and the aircraft manufacturers. All steps of the process, including the approvals at all phases, are documented and filed. In relatively simpler changes, though, as can be considered the case of the corrosion inhibitor, some of the phases can be shortened.

3.4 Control of potential emissions

3.4.1 Production

ExxonMobil does not manufacture EtCHxS or other PFAS, so they do not control the emissions at that phase. Any discussion on emissions at the production stage should be presented by the manufacturer/s of the substance.

3.4.2 Hydraulic Fluid Blending

The PFAS corrosion inhibitor additive is transported as a solid in secondary containment and any handling of the containers and the material takes place indoors, by personnel wearing appropriate PPE and following established health and safety protocols for chemical handling, in line with the conditions of safe use prescribed in the material safety data sheet (MSDS).

Blending of the additive in the hydraulic fluid takes place in a closed system, with limited potential for release to air and no direct release pathway to water or soil (solvent-based process). The finished product is packaged and distributed in sealed containers (with secondary containment), to be transported to the downstream users.

In addition, at the time of writing, it should be noted that ExxonMobil's blending operations take place in non-EEA locations.

Due to the stringent permitting, monitoring, and emissions controls at finished lubricant blending facilities in the US (as documented by the OECD and the Industry Solvents Association (ESIG/ESVOC)), fugitive releases of a low-volatility, low-solubility, low-treat rate additive to either workers or the environment are expected to be negligible[7].

Specific Environmental release categories (SpERCs) developed by the European Solvents Industry Organization (ESIG/ESVOC) for substances of low volatility[8] (< 100 Pa) and low solubility[9] (< 1 mg/L) estimate release factors of 0.1% to air and 0.0001% to water. These values are in line with estimates from the manufacturing monitoring assessments, further supporting de minimis emissions and exposure of EtCHxS during the formulation and distribution life stages.

[7] https://www.esig.org/wp-content/uploads/2020/05/8_ind_ESIG-SPERC-factsheet-update-4.6a.v2-lubricants.pdf AND https://one.oecd.org/document/env/jm/mono(2004)21/en/pdf

[8] Ionizable chemical compounds and highly fluorinated PFAS are expected to exhibit negligible vapor pressures at standard temperature and pressure (expert judgement / read across). Existing models are limited in their ability to predict properties for PFAS substances accurately.

[9] VEGA Prediction using Water solubility model (IRFMN) (version 1.0.0) WS = 0.28 mg/L

3.4.3 Service life

Based on communication with OEMs, it is understood that hydraulic system volumes for commercial aircraft vary from less than 100 L up to approximately 1200 L. Volumes for the most common commercial aircraft types are in the order of 100 to 300 L. This corresponds to an average additive volume of less than 200 ml (~ 0.2kg, considering a density of approximately 1 kg/l) per hydraulic fluid system. These systems are sealed and operated as closed systems, given the sensitivity of the systems to water, particulate, and other potential contaminants.

PEBHFs are used only in closed aviation hydraulic systems. They have low vapor pressures and are handled only by trained maintenance personnel. To maintain system performance, they are kept isolated from contact with water. Nevertheless, there is still potential for a small amount of leakage during the service life of the hydraulic fluid. It should be noted, however, that maintenance, service, and testing of aircraft systems is a highly controlled, documented, and meticulous process. As such, any fugitive loss from routine maintenance and service activities is expected to be negligible.

Estimates from routine operation and fluid replacement supports the use of a conservative operational leakage rate (of hydraulic fluid) of approximately 14.4 mL / day from a 100 – 300L hydraulic fluid system (i.e., 0.0014% - 0.0048% / day)[10]. Averaged over a year this corresponds to approximately 5.3L per system. Typical commercial aircraft contain 2 or 3 hydraulic systems. So, for a fleet of approximately 6,700 aircraft in the European Union commercial fleet (as of 2016)[11] this corresponds to 70,000 – 110,000 kg/yr of fugitive release of hydraulic fluid. 'At an expected nominal treat rate of EtCHxS, approximately less than 100 kg per year of EtCHxS for the entire commercial fleet may have the potential to leak. Note that this calculation is hypothetical and actual emissions are expected to be far less.

3.4.4 End of life

ExxonMobil does not manage the waste hydraulic fluids, as this is the responsibility of the end users.

Waste oil, including hydraulic fluids, collection and management in the EU are regulated by the waste framework directive (WFD) 2008/98/EC[12]. According to Article 21 of the WFD, waste oils are to be collected separately and treated giving priority to "regeneration or alternatively to other recycling operations delivering an equivalent or a better overall environmental outcome than regeneration".

According to information received from OEM and aircraft manufacturers, waste fluids are collected in double hulled hazardous waste containers which are then transferred to approved intermediate surface storage on site, before finally being transferred to hazardous waste incineration facilities as high caloric waste for thermal treatment with energy recovery. Since the transport and handling of the spent fluids occurs after secondary containment, fugitive release to air, water, or directly to soil are expected to be negligible. Additionally, as a condition of operation, many national and regional authorities require documentation of licensed and environmentally compliant waste handling, disposal, and treatment to the authorities on a yearly basis.

[10] Source: direct communication with OEM customers

[11] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20191206-1

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705

4. OVERVIEW OF POTENTIAL ALTERNATIVES

4.1 Introductory Note

The assessment of potential alternatives is based on the recommendations found in 'ECHA's Guidance on Analysis of Alternatives under REACH Authorisations', published in 2021[13].

Basically, the workflow to identify alternatives encompasses to first describe the functionality of the PFAS substance in the particular use, followed by the analysis of the performance that an alternative must achieve. The latter requires in-depth experience of the characteristics of such alternatives to determine the extent to which such hypothetical candidates fall short in substituting away for the use of the PFAS substance.

This effort requires technical expertise within ExxonMobil to review the status of readiness for the suitability/unsuitability of potential alternative substances. Particular attention is paid to the research efforts in the past years. A literature search on further alternatives based on publicly available information is also being carried out. The analysis so far has been carried out in a scientifically sound manner and encompasses the following key assessed dimensions:

- Description of the functionality in the particular use and the technical feasibility criteria;
- Efforts made to identify alternative, including own R&D efforts, if any, and other publicly available information;
- Identification and shortlisted alternatives;
- Assessment of shortlisted alternatives, which includes: availability, safety considerations as technical and economic feasibility of the assessed alternative.

4.2 Availability of alternatives

Non-fluorinated erosion inhibitors have been tested over several decades, and all showed poor performance even in older designs, which had lower performance specifications. Extensive R&D testing with alternate non-fluorinated erosion inhibitors has not identified any potential replacement chemistries with adequate stability to be feasible in aircraft service.

ExxonMobil has assessed more than 200 alternatives to PFAS corrosion inhibitors in over three decades of research.

The materials that have been tested are all ionic pairs, meaning that they contain a positive element and a negative element. For the current erosion inhibitor, potassium is the positive element, and the fluorinated sulfonate (a PFAS) is the negative element.

A wide range of ionic pairs have been tested, many of them at different treat rates. This information is confidential and will be submitted as confidential information.

These potential alternatives have been evaluated by ExxonMobil at various levels. Evaluations included:

- Literature research to assess the known properties of the alternative salts.
- Testing to determine properties and performance according to the criteria described in Section 3.3.1
- Rig testing, in which the reformulated lubricant is tested in a simulated environment of the actuator's operation.

[13] How to apply for authorisation_v1_corrected (europa.eu)

4.3 Technical feasibility of alternatives

ExxonMobil has assessed more than 200 alternatives to PFAS corrosion inhibitors in over three decades of research.

Figure 4-1 presents a summary of the results of PFAS alternative tested in PEBHFs, identifying the major reasons for failure of the various alternatives.

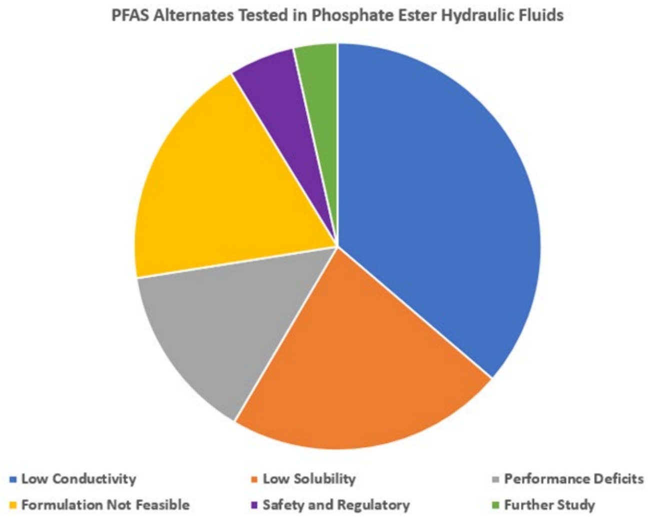

Figure 4-1: Results of PFAS alternative tested in PEBHFs

The vast majority of the assessed alternatives would fail to meet conductivity requirements, it being too low, or would not be sufficiently soluble in the hydraulic oil.

Other major deficiencies reported for the assessed potential alternatives included:

- Poor stability at high temperatures or in presence of oxidative agents, which would reduce the expected service life of the hydraulic oil and increase the risk of equipment failure, raising safety concerns.
- Incompatibility with other components, as they would react forming undesirable substances, such as acids, resulting in a too high TAN (total acid number).
- High treat rate, which makes formulation of the additive package and the whole hydraulic fluid formulation very difficult to achieve, as the concentrations of all other constituents will need to be adjusted as well.
- High chlorine content, which can damage the cylinder and other components.
- Deposition concerns, due to poor stability of the additive in the hydraulic fluid.

4.4 Safety considerations related to alternatives

4.4.1 Chemical hazard profile of potential alternatives

The potential alternatives to the fluorinated corrosion inhibitor include a diverse set of organic, inorganic, and organometallic chemistries. Some of the alternatives are fluorinated and likely to have similar concerns around environmental persistence as the target substances and PFAS chemistries in general. However, the focus of the industry is primarily on non-fluorinated alternatives.

Many of the organic alternatives are surfactant-like chemistries and may have surface active properties which can pose risks to human health or the environment. Furthermore, while some of these chemistries have existing registrations and well documented uses under REACH, others may be used at low quantities (< 1tpa) and thus exempt from registration requirements, but with relatively well-known properties, while there may be others that are novel chemistries or formulations which have not been studied extensively, yet, and as such may be data-poor substances.

Irrespective of chemical structure, alternative chemistries with incomplete physio-chemical and hazard profiles may ultimately result in a regretted substitution. Any future alternative chemistries which are evaluated by the industry and determined to meet performance and technical specifications would be simultaneously evaluated for ecological and human health properties (hazard) as well as for their potential to be released into the environment (exposure) such that the relative potential risk of these materials relative to that of the current corrosion inhibitor substance are well characterised.

4.4.2 Safety risks for aviation hydraulic systems

The hydraulic system is critical to the aircraft's safety as it controls the aircraft. Hydraulic actuators in aircraft are used in adjusting flight control surfaces (e.g., wing and tail flaps, rudder, spoilers), extending and retracting landing gear, positioning engine inlet guide vanes and thrust reversers, and opening and closing cargo doors.

If the hydraulic system were to fail, the aircraft functionality will be severely compromised and it could result in accidents, e.g., if the pilot could not use it to steer it or adjust altitude, or if the landing gear would not deploy or retract properly. For that reason, hydraulic fluids must meet very stringent safety and performance (reliability) standards, as discussed in Section 3.3.2.

If a lubricant manufacturer or aircraft manufacturer were to use an alternative that did not meet the technical specifications / feasibility criteria (as discussed in Section 4.3), there would be a higher risk of failure for critical aircraft functions. In practice, technical specifications were (and are constantly being) developed to ensure that, like any aircraft component and material used therein, all aircraft lubricants and hydraulic fluids meet rigorous performance criteria to minimise the risk of failure for critical aircraft functions Therefore, use of any additive that does not satisfy all the safety and performance specifications, and, as a result would be less safe than the use of EtCHxS, for the aircraft, its cargo and, most importantly, its passengers, would not be allowed to be used in operational aircraft.

4.5 Economic feasibility of alternatives

The corrosion inhibitor additive is used at very low concentrations in the hydraulic liquid, so it is expected that any alternative used will not have a significant impact on the overall cost. It should be noted, however, that additional costs will include research for acceptable alternatives, performance testing, validation and certification.

4.6 Actions and time required for potential substitution.

As discussed in Section 3.3.2, even a relatively minor change in a safety-critical component, such as the substitution of the PFAS corrosion inhibitor in hydraulic actuator fluids, can take several years to complete, due to the long, rigorous testing that needs to be carried out for qualification and validation with the customer, to ensure that it meets all safety and performance specifications.

The qualification process of a reformulated hydraulic fluid, depending on the complexity of the change and the formulation, can take as long as 10 years, **provided that a suitable alternative has been identified**. In practice, the whole procedure can take significantly longer, as it has proven very difficult to find and develop alternatives that can meet the performance specifications and pass qualification testing.

1. **Identification of need to change**. This is the first step in the process, in which the chemical of concern is identified and the options for substitution are first assessed.
2. **Identify possible alternative substitution (Duration varies)**. At the moment, this is the most uncertain step, as the duration depends on the function of the additive, the criticality of the

application it is used for, and the harshness of the conditions expected to be present during its operation. Tasks in this phase include:

a) Research to identify or develop a new corrosion inhibitor.

b) Definition of the formulation composition

c) Carry out laboratory testing to ensure it meets criteria.

d) Repeat steps a) to c) as many times as necessary.

3. **Qualification**: Conduct performance/rig testing (~2 years)

   This testing qualification phase includes:

   a) Batch testing on lab blends at various concentrations of the alternative to ensure full test specifications are met.

   b) Large scale rig testing; airplane wing and landing gear simulator testing in high/low temperatures and pressures.

4. **Validation**: OEM and regulatory approvals and flight testing (~8 years, but can be as long as 15 years in some more complex cases)

5. **Implementation**, which includes securing supply of the alternative, investing in any equipment and construction required, running test production lots and scaling up for full commercial production.

It can take ten years or longer for this process, **provided that a suitable alternative has been successfully identified**. Considering the extensive work to identify alternative corrosion inhibitors for use in aviation hydraulic fluids, and failure to do so, in over three decades, a timeline of 13.5 years, as that proposed in the derogation in the restriction proposal cannot be considered feasible.

Work on identifying a potentially feasible alternative can take several years, pushing the overall timeline to 15 to 20 or more years. In practice, the possibility that an alternative will be developed and adopted even in that very long timeline is very small and it could mean that, with a time-limited derogation, there will be a significant risk that aviation hydraulic fluids will not be able to meet safety and performance / reliability specifications.

4.7 Conclusion

Despite being a mature technology with a considerable history of industry research and experience, passenger aircraft remain completely reliant on PFAS-containing phosphate ester hydraulic fluids for control of electrochemical erosion. To date, no alternative chemistries or technological breakthroughs are under development nor could be reasonably anticipated within the constraints of the current proposed derogation period of 13.5 years after EiF.

The industry has continued to seek and test alternative chemistries over the past decades. To date, all potential candidate chemistries have failed to provide adequate protection against electrochemical erosion in aviation hydraulic systems (with the notable exception of two molecules which are also PFAS).

Further, given the severe consequences associated with potential failure of hydraulic systems, multi-year in-flight evaluation and rigorous regulatory and performance testing is required for any alternative chemistry (once identified) for use in commercial aircraft, to confirm that no unexpected effects or unintended consequences will surface in the wide range of aircraft types in current operation. As such, there can be no guarantee of success within any prescribed timeline.

An alternate approach to replacing EtCHxS-treated PEBHFs would be to completely redesign current aircraft hydraulic systems operation and maintenance practices, which is unlikely to have a cost, timeline, or likelihood of success which can be supported by the airline industry at present.

In summary, the currently proposed derogation of 13.5 years after EiF for anti-corrosion additives for aviation hydraulic fluids is not appropriate, as much more time is required to develop, qualify, certify and implement a suitable alternative that can meet the strict safety and performance specifications of the aviation industry and competent authorities.

5. SOCIO-ECONOMIC ANALYSIS

5.1 Introductory Note

This socioeconomic impact assessment compares two scenarios, the 'continued use scenario' and 'limited-derogation scenario':

The 'continued use scenario' considers a scenario whereby ExxonMobil's requested time-unlimited derogations for uses are granted (i.e., the company can 'continue using' PFAS where required), which means that the use of additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry, can continue.

The 'non-derogation scenario' considers a scenario whereby the restriction is implemented in its current form, and i.e., a time-limited derogation will be applicable to the use of additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry.

From a geographical scope, emphasis has been placed predominantly upon describing the nature of impacts inside the EEA. This is based on clear information from ECHA's original SEA restrictions guidance, which highlights that "*In setting the geographical coverage and undertaking the assessment of impacts, it should be kept in mind that the final comitology decision… on whether or not to grant an authorisation will most likely focus mainly on impacts inside the EU. As a consequence, it is recommended that the emphasis be placed on describing and possibly quantifying what happens inside the EU*"[14]

Whilst the key focus of the SEA is considered to be EEA society as a whole, information is also provided regarding higher level direct impacts to ExxonMobil and its customers. This is in order to provide clarity regarding wider downstream and societal impacts. For example, in certain instances, direct impacts to ExxonMobil can also be associated with indirect impacts that will impact EEA society more widely. Such instances include direct job losses to ExxonMobil within the EEA associated with the limited derogation scenario having an indirect effect on unemployment more widely within the EEA.

It is also noted that whilst efforts have been made to quantify impacts where possible, some of the impacts are described qualitatively.

Importantly, the restriction proposal highlights that "*as specific information on costs of a ban of PFASs for the different actors associated with the addressed uses was scarce and mainly qualitative, the derogations and their duration were mainly based on the availability and applicability of alternatives to PFASs*". ExxonMobil wishes to add that whilst the scope of applicable derogations to ExxonMobil within the restriction proposal is limited, significant information has been provided in the above analysis of alternatives which conclusively highlights the significant lack of technical and economic feasibility for substitution of PFAS over a series of time frames (associated with each of the uses in question). In this regard, the current SEA is provided to further support ExxonMobil's requests for derogations as summarised in Section 6 of this report.

5.2 Continued use scenario (aligned with preferred derogations)

5.2.1 Introduction and scenario definition

The PFAS restriction proposal includes a specific derogation for the use of anti-corrosion additives in aerospace hydraulic fluids. More specifically, the proposed derogation 5(o) is about:

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[14] ECHA (2008): Guidance on Socio-Economic Analysis – Restrictions Available at: https://www.echa.europa.eu/documents/10162/2324906/sea_restrictions_en.pdf/2d7c8e06-b5dd-40fc-b646-3467b5082a9d.

additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry until 13.5 years after EiF.

As discussed in Chapter 4, there are currently no technically and economically feasible alternatives available.

In addition, the efforts so far, with over 200 substances evaluated and no suitable alternative found, indicate that developing a suitable alternative should not be expected in the near future. It can take several years before a technically feasible alternative is developed. After that, the lengthy qualification and validation process (often requiring 10 years or even longer) will need to follow, leading to an overall timeline for substituting EtCHxS in aviation hydraulic fluids that far exceeds the 13.5 transitional period of the proposed derogation.

It would thus be more realistic, for this particular proposed derogation, to offer a time-unlimited derogation, until the time that a suitable and safe alternative can be developed. In that scenario, the use of EtCHxS in aerospace hydraulic fluids will continue, providing safe functioning of safety-critical parts with minimal releases to the environment.

The proposed time un-limited derogation would thus be as below:

Additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry.

5.2.2 Market and business trend considerations

PEBHFs make up a very small fraction of the total lubricants market. Lubricants for all of aerospace represent an extremely minor fraction of the market, and most aerospace lubricants are jet oils or other fluids. A rough estimate indicates that PEBHFs are less than 10% of the aerospace lubricant market[15]. To date, similar use data is not readily available for the EU market. As such, it is assumed for the purpose of this assessment, that the relative proportions (%) of lubricant end-use market share may be reasonably extrapolated to the EU markets.

Hydraulic system volumes for the most common commercial aircraft types are in the order of 100 to 300 L. This corresponds to an average maximum additive volume of 100 ml per hydraulic fluid system. As discussed in Section 3.4.3, a typical annual leakage rate, thus requiring replenishment is 5.3 L of hydraulic fluid per system, which corresponds to less than 5 ml EtCHxS per year. As each aircraft may have 2 or 3 such systems and the current fleet in the EU is approximately 6,700 aircraft, the total quantities needed just for replenishment are less than 100 kg.

The overall demand for new aircraft is expected to increase in the mid- and long-term, also considering the potential emergence of alternative-fuel aircraft, which have the potential of covering up to 89% of the intra-EU air travel market by 2040[16], and which also form part of the Destination 2050 initiative[17]. These new technology aircraft still need to operate hydraulic systems, so demand for anti-erosion / corrosion fluids will continue.

5.2.3 Risks associated with continued use.

As discussed in Section 3.4 on control of emissions along the EtCHxS supply chain, it can be anticipated that there are minimal PFAS emissions during the formulation, service life and waste stages. The hydraulic fluids are used in closed systems, where prevention of leaks is essential to

[15] Grand view research website – U.S. Lubricants Market Size, Share & Trends Analysis Report By Application (Industrial, Automotive, Marine, Aerospace), And Segment Forecasts, 2020 – 2027. Available online at: https://www.grandviewresearch.com/industry-analysis/us-lubricants-market, accessed on 25 August 2023

[16] Deloitte website - Europe's Aviation Landscape in 2040. Available online at: https://www2.deloitte.com/nl/nl/pages/consumer/articles/europe-aviation-landscape-in-2040.html, accessed on 25 August 2023

[17] Destination 2050 website – A route to net zero European aviation. Available online at: https://www.destination2050.eu/, accessed on 25 August 2023

maintain their functionality. As a result, the direct risk to human health and the environment from exposure to EtCHxS is expected to be negligible.

On the other hand, hydraulic fluids are essential safety components for aircraft, and the corrosion inhibitor additive is critical at ensuring that these fluids meet the safety and performance requirements as per industry and regulatory standards. Therefore, aviation hydraulic fluids contribute to safe aircraft over their very long service lives.

5.3 Limited derogation scenario (aligned with current PFAS restriction proposal)

5.3.1 Introduction and scenario definition

If the proposed derogation does not change, it would mean that EEA-based / operating aircraft will not be able to use EtCHxS containing hydraulic fluids to replenish the fluids in their actuators after the transitional period of 13.5 years after EiF expires. Following the standard timelines of regulatory processes, the PFAS restriction will come into force sometime in 2025, the proposed derogation will cease applying around 2038-2039. Hydraulic fluid formulators will not be allowed to manufacture and place their products in the EEA until they substitute the EtCHxS with a non-PFAS alternative.

Aircraft mechanics may have to replace the whole hydraulic fluids, as replenishing with a different formulation could result in reactions among the different components and impairment in the overall functionality of the fluid and the hydraulic system.

It is expected that alternative hydraulic fluids will be used, but this presupposes that the alternative corrosion inhibitor would have comparable performance to EtCHxS. As discussed earlier, this seems to be highly unlikely, and it is possible that they will have lower electro-corrosion resistance.

5.3.2 Summary of consequences of limited derogations

After the expiration of the transitional period for the hydraulic fluid derogation, the hydraulic systems will need to operate using fluids that do not contain the highly performing EtCHxS corrosion inhibitor. Any alternatives used would most likely have worse performance and could result in faster onset of corrosion damage in the hydraulic systems.

Modern hydraulic fluids have decades and millions of flight miles of use, and their performance is well known and documented. Any alternative ones would by necessity be much less studied and may have unknown lifetimes and performance against corrosion, which will introduce high uncertainty as far as their (and the hydraulic system's) service life is concerned.

To avoid catastrophic failures, with the potential associated loss of life, airline operators, taking safety as their priority, may decide to increase the frequency of checks or fluid and component replacement. It is also possible that they may decide to ground planes for such repair and maintenance activities at a higher frequency, instead of flying them with a higher risk of component failure.

This could result in disruption to air travel in general in the EEA, with fewer planes being available for service and, thus, reduced flight capacity.

5.3.3 Societal costs associated with limited derogations

5.3.3.1 Impacts for ExxonMobil

The impacts for the hydraulic fluid formulators, such as ExxonMobil, are expected to be comparatively low, considering the relatively low quantities of hydraulic fluids they sell to aerospace customers, compared to their other operations. Nevertheless, the time-limited derogation could still affect their operations in terms of overall output and revenue.

5.3.3.2 Impacts to downstream stakeholders

The main impacts in such a scenario will not be for the formulators, but, rather, for their OEM customers, aircraft manufacturers and operators and the general public.

A ban in the use of EtCHxS as a corrosion inhibitor in aviation hydraulic fluids after 2038/39 (i.e., 13.5 years after an assumed Entry into Force date of 2025) could have a significant impact in the operations of EEA-based aircraft. Due to the expected increased uncertainty of the lifetime of hydraulic systems, aircraft operators will need to update their maintenance protocols to ensure that the risk of failure due to electro-corrosive wear is controlled. This would mean longer downtime for aircraft and lower flight capacity, with associated costs. It should be noted that, after the drop in air travel during the Covid-19 pandemic, the number of passengers has since increased significantly, and it is expected that this trend will continue in the future. In February 2023, air traffic was 55.5% higher than the same month in 2022, but still below the pre-pandemic levels (2019)[18]. There has been strong growth in passenger kilometres travelled across the world, and the air traffic is on a trend to reach pre-pandemic levels in the next few years.

5.3.3.3 Wider impacts in the EEA

Hydraulic systems are not significantly associated with efficiency, but the more fuel-efficient new aircraft (Boeing 787 and Airbus 350) use 5000 psi systems instead of 3000 psi systems. These wide-body aircraft have lower fuel consumption compared to similar models, such as Boeing's 777 or Airbus's A-340 series[19].

Therefore, it can be said that fuel efficiency is a secondary effect of having a hydraulic oil that can withstand the high-pressure environment.

[18] IATA (2023). Air passenger market analysis – February 2023. Available online at: https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-market-analysis2/, accessed on 25 August 2023

[19] See: https://alliknowaviation.com/2019/12/14/fuel-consumption-aircraft/, accessed on 25 August 2023

6. SUMMARY

The anti-corrosion additive is an essential component of aviation hydraulic fluids, as it slows the rate of electrochemical erosion of the internal surfaces of hydraulic actuator systems, ensuring that they meet the very strict safety and performance requirements as defined in industry and regulatory standards. This is valid for all anti-corrosion additives in aviation hydraulic fluids.

The PFAS substance used as an anti-corrosion additive offers a unique combination of properties, including very good electrochemical corrosion resistance, high conductivity potential, good solubility to the hydraulic fluid, as well as a relatively low treat rate. Most importantly, however, it has excellent chemical and thermal durability and is stable across a broad range of harsh service conditions, such as broad temperature swings (from below freezing to as high as 50 °C), high pressures and corrosive chemicals.

ExxonMobil have evaluated more than 200 potential alternatives over several decades and have not yet been able to identify any that may be able to offer the same set of properties and performance that the current additive does. All of the alternatives examined so far cannot meet the safety and performance requirements of OEMs, so they cannot be considered technically feasible.

As a result, work on identifying and developing a potential alternative must continue before any work on substitution begins. The substitution process in the aviation industry is governed by strict procedures, which require diligent documentation and approvals by several actors, including the OEMs, the aircraft manufacturers / operators and the regulatory / certification authorities. Substitution in these cases can take as long as 30 years in some cases, considering that failure in any step may push the process back to the previous one or all the way to the beginning.

For the hydraulic fluid additive, for which no suitable alternative has yet been identified, it can take 15 – 20 years or even longer, considering the long testing needed for qualification and certification, which could take it beyond the expiration of the currently proposed derogation in the restriction proposal. In fact, it is very uncertain that an alternative will even be identified, much less implemented, in that timeframe, so a time-limited derogation, without at least the possibility of extension of its application, could result in aviation hydraulic fluids not meeting the very strict industry specifications.

In such a scenario, it would not be possible to use the currently certified hydraulic fluids in airplanes in the EEA, which could severely impact their flightworthiness, if a suitable alternative is not identified and implemented in the timeline available. It will not be possible to use hydraulic fluids that cannot meet the specifications for corrosion resistance, as all equipment in an aircraft must be certified. In an extreme no-derogation scenario, this could stop servicing of aircraft in the EEA and may even lead to grounding of the fleet, as they will not be able to use a safety-critical component, i.e., the hydraulic actuators.

Another very important aspect is the fact that use of the current anti-corrosion additive enables the use of higher-pressure actuators in the newer, more energy-efficient aircraft models, such as the Boeing 787 or the Airbus 350. Furthermore, the hydraulic actuators will continue to be critical components in all new aircraft, including alternative energy models, such as electric or hydrogen-fuelled, which are expected to contribute to the EU’s decarbonisation ambitions.

As a conclusion, and considering the high difficulty in identifying an alternative despite decades of research and the very high risk for the aviation industry and the impacts to EU society in general in the event that aviation hydraulics could no longer be used, ExxonMobil would request that the currently proposed derogation becomes time-unlimited, as per the text below:

> **Additives to hydraulic fluids for anti-erosion/anti-corrosion in hydraulic systems (incl. control valves) in aircraft and aerospace industry~~.~~**

Nevertheless, work on alternatives is ongoing, in an effort to improve the environmental footprint of the products, along with the overall performance of the hydraulic fluids and the aircraft components. As such, and to capture the possibility that an alternative is identified in the future, the validity of the time-unlimited derogation can be re-evaluated at regular intervals, depending on the status and availability of alternative additives.