Emerson Electric Co.

PFAS REACH Restriction Consultation Response

Justification to add:

(1) a new use sector: Industrial Automation Monitoring and Control (IAMC)

(2) a 12-Year Derogation for fluoropolymers in this sector

SEPTEMBER 21, 2023

CONTENTS

CONTENTS (continued)

The statements, responses, commentary, and estimations made in this derogation request beyond those cited to are Emerson Electric Co.'s ("Emerson") alone and are based on Emerson's good faith effort, research and knowledge Emerson is aware of at the time this derogation request is submitted to ECHA. Emerson intends to continue to research and acquire knowledge regarding PFAS and may at a future time have updated information and analysis regarding the subject matters in this derogation request. However, Emerson does not undertake to update any such statements, responses, commentary, and estimations submitted in this derogation request to reflect later developments.

Emerson has issued these statements, responses, commentary, and estimations in this derogation request to solely address this ECHA derogation request for industry comments. Emerson's statements, responses, commentary, and estimations in this derogation request should not be read, construed, or applied as to speaking to matters beyond what ECHA has requested under this derogation comment request. Emerson encourages industry to continue to find and/or develop PFAS alternatives.

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Emerson Electric, a global technology and engineering company with significant operations in Europe, including more than 16,500 staff and 51 manufacturing sites spread across 21 Member States, is fully committed to making industrial products that are safe for our end-users and the environment, consistent with Europe's Chemicals Strategy for Sustainability and Green Deal initiatives. Emerson is committed to comply with all applicable environmental laws and regulations in the European Union (EU).

Emerson has closely reviewed the REACH Annex XV Per-and Polyfluoroalkyl Substances (PFAS) restriction proposal and has identified missing uses that are critical to the EU and the world. This paper provides justification to add Industrial Automation Monitoring and Control (IAMC) as a new use sector to fill a critical gap in the missing uses of the restriction proposal. Subsequently, a request is made for a 12-year derogation of fluoropolymers, in accordance with Restriction Option 2 (RO2). These requests are submitted within the framework of the restriction proposal and are summarized in **Table 1.2**. **In this document fluoropolymers and fluoroelastomers are both referred to as fluoropolymers.**

TABLE 1.2 **New use sector and fluoropolymers derogation requests**

REQUESTS	DESCRIPTION
New Use Sector Request	Industrial Automation, Monitoring and Control, hereby known as IAMC
Derogation Request	**12-Years allowing the use of fluoropolymers in:** Industrial Automation, Monitoring & Control Equipment

The rationale and details justifying these requests are provided below and will conclusively demonstrate the criticality of this use sector and the use of fluoropolymers as an enabling material in critical-to-the-world applications.

Summary of the Rationale for Our Requests:

- IAMC equipment is foundational to the safe, efficient and sustainable production of any semi-automated or fully automated manufacturing process, including those used to produce most of the products that comprise the 14 use sectors identified in the REACH Annex XV restriction proposal.
- The exclusion of IAMC equipment as a use sector from the derogations established in the restriction proposal will result in severe economic distress in the EU, including impacts on employment within the EU and shortages within the EU and throughout the world of critical products such as semiconductors, process chemical feedstocks, and sterilization equipment, among many others.
- IAMC equipment was a €56B industry in Europe in 2022 and is expected to grow to €111B by 2030.
- IAMC equipment frequently operates in harsh environments where only fluoropolymers can deliver the performance needed for safe and efficient operations.
- No suitable alternatives exist today that can deliver the properties required to ensure the safe and sustainable operation in these harsh and challenging IAMC operating environments.

- In the event that suitable replacements become commercially available, implementation timelines are in excess of five years due to complex re-design and re-certification activities.
- Fluoropolymers are typically a cost premium over non-PFAS materials. They are used because the technical requirements of existing IAMC applications eliminate the possibility of utilizing existing alternatives.
- The fluoropolymers used in IAMC equipment are discrete solid plastic parts that meet the OECD's definition of a polymer of low concern[1].
- IAMC equipment providers are downstream users of fluoropolymers so emissions are mostly negligible until end-of-life, which is on the order of 15+ years.
- IAMC equipment using fluoropolymers are key enablers of decarbonization initiatives such as wind, solar, H2, and mobility, which are foundational to fulfilling European sustainability priorities.

2 INDUSTRY DESCRIPTION

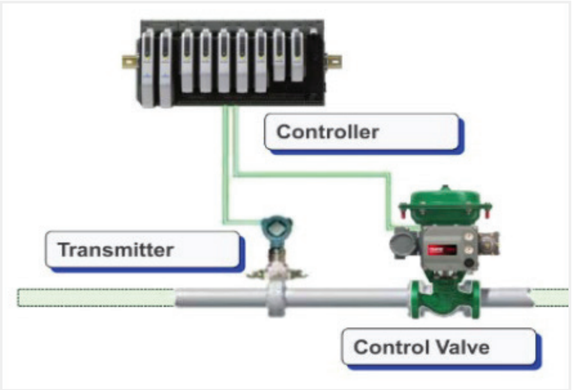
IAMC equipment are the control systems and associated instrumentation, including the devices and controls used to automate industrial processes. The scope of equipment consists of complex electromechanical products that measure a variety of parameters such as temperature, humidity, pressure, corrosion, and density as well as process control products such as valves, actuators, flow measurement devices and regulators, as outlined in **Table 2.1** below.

TABLE 2.1 **Scope of IAMC equipment**

1. Pressure, Flow, Level and Temperature Measurement	**8. Distributed Control Systems**
2. Corrosion, Erosion & Heat Trace Monitoring	**9. Hygienic & Sanitary Measurement**
3. Energy Monitoring & Management	**10. Vibration Sensors**
4. Density & Viscosity Measurement	**11. Electrical Power Distribution & Control**
5. Liquid, Flame & Gas Detection	**12. Valves**
6. Machinery Monitoring, Protection & Maintenance, Test & Measurement	**13. Regulators**
7. Marine Measurement & Analysis	**14. Actuators**

Figure 2.1 demonstrates the role of IAMC equipment in industrial processes. In this simple illustrative example, a flow meter is monitoring fluid flow and sending signals to an industrial control system, which in turn adjusts the valve stem height for optimum flow control. These products operate as a unit and failure could be catastrophic. Any errors could create an unstable and unsafe situation that may result in severe harm to people and/or the environment. IAMC equipment has boundless configuration flexibility to accommodate the broad processing needs of the many industries served.

FIGURE 2.1 **Example of an IAMC equipment configuration**



In 2022, IAMC equipment generated revenues of €195 billion globally and €56 billion in Europe[1]. However, IAMC equipment is used as a critical component in a wide range of downstream user sectors whose socio-economic footprint is several times larger. Through its use in those downstream sectors, IAMC equipment enables delivery of essential resources such as clean water, safe food and reliable energy, and essential goods such as pharmaceuticals, including vaccines, medical devices, electronic components, defense equipment and petroleum.

1 www.precedenceresearch.com, Report Code: 2179; Category: Semiconductor and Electronic; Published 2022

3 OVERVIEW OF RELEVANT PRODUCTS AND USES OF PFAS

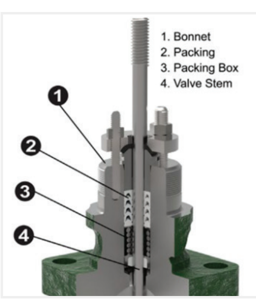
3.1 Overview

A range of different fluoropolymers (including fluoroelastomers) such as PTFE, PCTFE, EFTE, PFA, FEP, FKM and FFKM are used in critical components of IAMC equipment, such as liners, seals, valve packing, valve seats, wire and cable insulation, as well as electronic components.

Table 3.1 on the following page, shows which fluoropolymers are used in which applications (i.e., components) as part of which types of IAMC equipment. Each application is described in further detail below:

Liners: Liners are commonly used in IAMC equipment to protect surfaces from corrosion and wear and to provide a low friction surface. They are almost exclusively made out of fluoropolymers, which are applied as a thin coating or as a pre-fabricated sheet.

Seals: All IAMC equipment utilize seals for containment of gases or fluids and to reduce fugitive emissions. Types of seals are dynamic or static and include o-rings, bellows, grommets, bushings, and gaskets for important functions such as safety shutoff applications and penetration of transducers into the process fluid or gas. These seals and bushings are also used for isolation between housings, compartments, and from process fluids as required for electrical safety.



Valve Packing: Valve packing is used in rising stem and rotary valves for isolation and process control to prevent leaks between a dynamic stem or shaft and the valve body.

Valve Seats: A seat is a mechanical seal used in relief valves and pressure regulators to create a tight seal between the moving and stationary parts for control of fluid flow and pressure containment.

Wire and Cable: Wire and cable are used extensively to power and connect IAMC equipment. Fluoropolymers are commonly used to insulate wires and cables for protection against environmental threats and to prevent electrical leakage.

Electronics: All IAMC equipment use electronics to maximize functionality and increase industrial process efficiency. Fluoropolymers are used in electronics such as waveguides, capacitors, Printed Circuit Boards (PCBs), LCDs, etc., that are exposed to the harsh IAMC environment, especially when it is not possible to protect them in an enclosure.

The vast majority of IAMC equipment contains critical components, such as seals and electronics, that are made with fluoropolymers.

EMERSON

TABLE 3.1 **Applications of fluoropolymers in IAMC equipment**

		TYPES OF IAMC EQUIPMENT													
APPLICATIONS	**FLUOROPOLYMERS**	**1.** Pressure, Flow, Level and Temperature Measurement	**2.** Corrosion, Erosion & Heat Trace Monitoring	**3.** Energy Monitoring & Management	**4.** Density & Viscosity Measurement	**5.** Liquid, Flame & Gas Detection	**6.** Machinery Monitoring, Protection & Maintenance, Test & Measurement	**7.** Marine Measurement & Analysis	**8.** Distributed Control Systems	**9.** Hygienic & Sanitary Measurement	**10.** Vibration Sensors	**11.** Electrical Power Distribution & Control	**12.** Valves	**13.** Regulators	**14.** Actuators
Liners	PTFE, PFA, FEP, EFTE	☑	☑		☑										
Seals	FKM, FFKM, PTFE, PCTFE	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Valve Packing	PTFE												☑		
Valve Seats	PCTFE, PTFE, EFTE												☑	☑	☑
Wire and Cable	PTFE, PFA, FEP	☑	☑		☑	☑	☑	☑		☑	☑	☑			
Electronics	PTFE	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

3.2 Downstream Uses

IAMC equipment with fluoropolymer components is used in a wide range of downstream user sectors.

The comprehensive scope of sectors and products is difficult to determine, but key examples are provided in **Table 3.2**. **Other examples of downstream user sectors not mentioned in the table include mining, oil and gas, rail and other mass transportation, and construction operations. Specific case studies of where IAMC equipment is used in innovative applications, and how the fluoropolymer components of such equipment are critical to its operation, are outlined in Appendix A.**

TABLE 3.2 Examples of downstream uses

SECTOR	PRODUCT	FLUOROPOLYMER COMPONENTS
Water treatment and food processing	› Measurement equipment and valves in the production of chlorine. › Sensors for detecting chlorine in drinking water. › Solenoid valves for control of potable water and clean-in-place systems.	› PTFE and PFA liners; › PTFE membranes; › FKM and PTFE seals.
Semiconductor manufacturing	› Pressure regulators to control the pressure of media used in etching and chemical vapor deposition processes for semiconductor manufacturing.	› PTFE and PCTFE valve seats.
Pharmaceutical and food manufacturing, power generation	› Industrial relief valves for pressure vessels such as boilers, heat exchangers, chemical reactors, etc. › Sensors for measuring temperature, pressure, pH, and dissolved oxygen. › Distributed Control System (DCS) technology.	› PTFE, FKM & FFKM in valve seats at high temperatures (>150°C) and high pressures (>100 bar). › FKM seals and PTFE components in electronics of DCS.
Medical	› Solenoid valves to control the cryogenic fluids such as liquid nitrogen in devices used to remove tumors.	› PTFE seals.
Solar power	› IAMC control systems such as Programmable Logic Controllers (PLCs) are needed to control key parameters such as voltage, frequency, reactive power. They are also used to perform key activities such as troubleshooting and remote starts/stops.	› PLCs contain fluoropolymer containing electronic components.
Wind power	› Control systems similar to the solar panel solution. Additionally, IAMC equipment is used for condition-based monitoring via vibration sensors. › Valves used for buoyancy control of offshore wind turbine platforms and for cooling water flow for wind turbines.	› High-end electronics containing fluoropolymers.
Sustainable energy/ mobility: Hydrogen	› IAMC equipment plays a large role in hydrogen production (Distributed Control System technology) to control the desalination and electrolyzer units, gas blending and balance of plant equipment, storage and distribution/ refueling (valves and regulators).	› Control systems contain fluoropolymers in electronics; › Valves and regulators contain PTFE packing and PCTFE valve seats; › Refueling valves contain FKM seals.
Sustainable energy/ mobility: Batteries	› Control systems similar to solar, wind and hydrogen, and measurement solutions such as mass and density, pH, viscosity and level measurements of the anode, cathode and electrolyte batches.	› Control systems contain PFAS electronics; › Measurement solutions contain PFAS liners, seals, electronics, etc.
Chemicals	› Density meter to control the hydrochloric acid (HCl) concentration produced by the liquid dye hydrolysis process. The HCl is reused as an input for the manufacture of methyl chloride (CH3Cl) that is in turn used to manufacture the dye products.	› PFA surface coating of vibrating fork.
Processing of stones, minerals, clay etc.	› Radar Level measurement devices for solid materials.	› PTFE sealing the waveguide and antenna.

4 TONNAGES OF PFAS USED

Emerson estimates that an industry total of 2,140 tonnes of fluoropolymers are used in IAMC equipment sold in Europe annually. This is based on an extrapolation of Emerson's product sales over the past year and Emerson's estimated share of the total European IAMC market. A breakdown of the estimated tonnage of fluoropolymer by application (i.e. type of component in IAMC equipment) is provided in **Table 4.1** below. Additional details of the average service life of these components, and on the potential for release to the environment during service life are also provided in **Table 6.2** and **Section 8**.

TABLE 4.1 Annual tonnage of fluoropolymer used in IAMC equipment in Europe (Emerson estimate)

APPLICATION	FLUOROPOLYMERS	ESTIMATED ANNUAL TONNAGE IN EU (METRIC TONNES)
Liners	PTFE, PFA, FEP, ETFE	260
Seals, Diaphragms	FKM, FFKM, PTFE, PCTFE	1,510
Valve Packing	PTFE	220
Valve Seats	PCTFE, PTFE, ETFE	140
Cable & Wiring Insulation	PTFE, PFA, FEP	<10
Electronics	PTFE	<10
Total		**2,140**

The IAMC market is forecast[2] to grow at a compound annual growth rate (CAGR) of 9% between 2023 and 2032. This means that the tonnage of fluoropolymers used in IAMC equipment is also expected to grow significantly. Emerson estimates that the tonnage of fluoropolymers used in IAMC equipment could reach approximately 10,000 tonnes per annum by 2038.

A detailed breakdown of the tonnage of fluoropolymers into different types of IAMC equipment or into different downstream user sectors is not available at this stage.

2 www.precedenceresearch.com, Report Code: 2179; Category: Semiconductor and Electronic; Published 2022

5 FUNCTION PROVIDED AND PERFORMANCE ENABLED BY PFAS IN IAMC SECTOR

5.1 Overview of Operating Profile

The IAMC sector requires high performance and reliability of components used to prevent failures that could result in harm to people and the environment, either directly or indirectly. The key technical properties important for IAMC are durability, high and low temperature resistance (-200°C/+260°C), chemical resistance and high mechanical strength in harsh environments. Petroleum and Mining is being referenced here because it is a use sector that was assessed in the REACH restriction proposal[3] and is analogous to IAMC in many regards.

The operating profile to which IAMC equipment is exposed is defined by the industries that leverage the technology (see **Section 3.2**). These applications often involve exposure to multiple extreme environmental conditions simultaneously. The IAMC environmental parameters (as indicated using the Ansys Granta Materials Database[4]) often include the following:

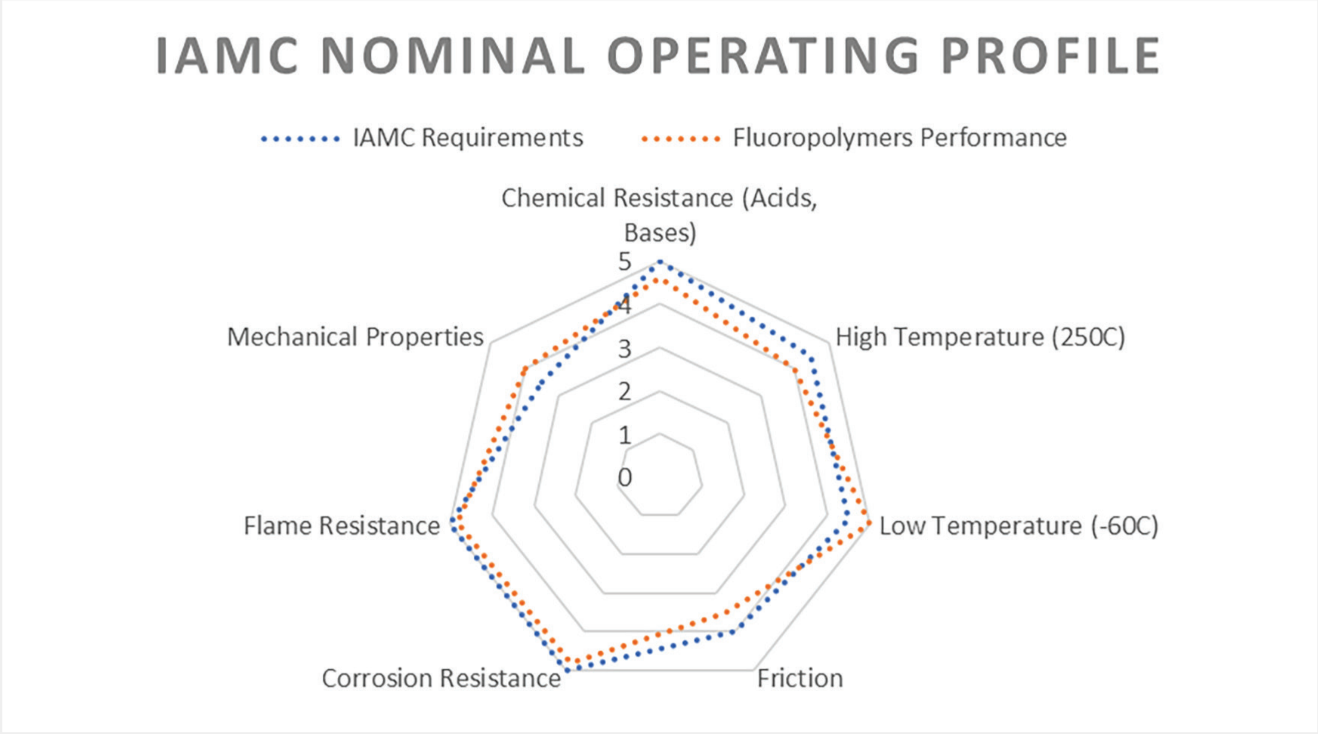
- Hazardous environments are prevalent and include fire, explosion, and toxic chemical threats. These environments often require equipment certifications, namely ATEX Directive 2014/34 in Europe.
- Broad chemical exposure is common due to the massive number of chemicals processed every day. These chemicals span the entire pH range and are processed at different temperatures and pressures. Example harsh chemicals include sulfuric acid, hydrofluoric acid and chlorine.
- Low temperatures near -60°C. Beyond this for cryogenic processing, IAMC equipment can be exposed to temperatures down to -200°C.
- High temperatures near 260°C.
- High pressures near 150 bar to accelerate and influence reaction rates and to increase volume-time efficiencies. Pressures up to 1,000 bar exist in some chemical processes.

3 See Annex E.2.15 and B.9.16
4 https://www.ansys.com/en-gb/products/materials/materials-data-for-simulation

These challenging environments demand the use of high performance and high reliability materials like fluoropolymers, which are vital as an engineering material class, not because of one particular characteristic, but because of the multiple properties any one of them simultaneously possesses. This is demonstrated in **Figure 5.1** where IAMC requirements and fluoropolymers performance are overlayed. The overlap in performance across this specific array of properties is what sets fluoropolymers apart from other materials and makes them a requirement for many IAMC applications. Fluoropolymers' most commonly leveraged properties include:

- Broad chemical resistance to virtually all chemicals.
- Low temperature performance down to -200°C.
- High temperature performance up to 260°C.
- Corrosion resistance
- Intrinsic flame resistance with a high heat of combustion and limiting O2 Index
- Good electrical properties, excellent dielectric properties
- Low friction / Non-adhesive resistance
- Purity / inert

FIGURE 5.1 **IAMC's operating profile requirements overlap with fluoropolymers performance, which is why their use is so common in industrial applications**



EMERSON

5.2 Technical Functions Provided

As noted in **Section 3**, fluoropolymers are widely used within the different components of IAMC equipment. With reference to the specific operating profile outlined in **Section 5.1**, it should be considered what specific technical function(s) fluoropolymers provide in these components that provide the required level of performance under these strict conditions.

An overview of key uses across the IAMC sector is shown in **Table 5.1** below, providing details of i) the application, ii) the specific PFAS/fluoropolymers used, iii) the type of IAMC equipment used, and iv) the specific functional properties provided within each use.

TABLE 5.1 List of common fluoropolymers and their functional properties leveraged for each application

APPLICATIONS	FLUOROPOLYMERS	IAMC EQUIPMENT	FUNCTIONAL PROPERTIES
Liners	PTFE PFA FEP ETFE	› Pressure, Flow, Level and Temperature Measurement; › Corrosion, Erosion & Heat Trace Monitoring; › Density & Viscosity Measurement	› Chemical Resistance › Intrinsic Flame Resistance › Low Friction / Adhesive Resistance › High & Low Temperature Resistance › Purity / Inert › Corrosion Resistance › Mechanical Strength
Seals (O-Rings, Gaskets, Waveguides, etc)	FKM FFKM PTFE PCTFE	› All IAMC Equipment	› Chemical Resistance › High & Low Temperature Resistance › Low Friction / Adhesive Resistance › Intrinsic Flame Resistance › Rapid Gas Decompression Resistance › Excellent Dielectric Properties, low dielectric constant for microwave transparency
Valve Packing	PTFE	› Control & Isolation Valves	› Chemical Resistance › High Temperature Resistance › Mechanical Properties › Fugitive Emissions Standards
Valve Seats	PCTFE PTFE EFTE	› Valves, Regulators & Actuators	› Chemical Resistance › Mechanical Properties (compressive modulus) › Purity › Low Temperature Resistance
Cable & Wiring Insulation	PTFE PFA FEP	› All IAMC Equipment	› High Insulation Resistance › Excellent Dielectric Properties › Temperature Resistance › Flexibility › Chemical Resistance
Electronics (Waveguides, Capacitors, PCB, LCD, etc.)	PTFE	› All IAMC Equipment	› Excellent Dielectric Properties, low dielectric constant for microwave transparency › Low Dissipation Factors › Low Flammability

5.3 Performance in Specific Applications

5.3.1 OVERVIEW

IAMC equipment must be designed with substantial robustness to operate reliably in industrial processes. This equipment is built with high safety margin and high-performance materials often defined by industry standard bodies such as ATEX or IECEx. For example, a bad flow meter measurement could shut or open a valve incorrectly or make a change in a sulfuric acid production process and cause a catastrophic safety issue. Errors, which could arise from a component material breaking down due to chemical attack, thermal degradation, or a locked system due to unacceptable surface friction, are very rare because of the use of high-performance materials.

As previously stated, fluoropolymers provide an unmatched multitude of high-performance properties simultaneously to deliver the required functionality to the components used in IAMC equipment. These applications leverage fluoropolymers' performance in many ways with chemical resistance being a common thread. PTFE is the highest performing fluoropolymer. This is due to strong polar carbon-fluorine bonds providing a layer of unreactive and highly hydrophobic fluorine atoms around the carbon-carbon backbone. This construction results in a high molecular weight, high crystallinity, and high-density material with higher performance attributes than other materials.

This section considers the level of performance provided through the use of fluoropolymers in each different component type used in the IAMC sector (as discussed in **Section 3**). Specific case studies detailing the type of IAMC equipment used in particular high-value applications in society, and the specific function provided by fluoropolymers are presented in **Appendix A.**

5.3.2 LINERS

Fluoropolymers' ability to resist virtually all chemicals coupled with the other high-performance properties makes them appropriate for liner applications (see also **Table 6.3** for a comparison of this performance with alternatives).

Fluoropolymers can provide a consistent performance across almost the entire list of chemicals in Emerson's liner selection guide. Having a material that can be used in almost all liner applications simplifies the selection process, reduces costs, and avoids an incompatible liner being placed with any process media.

5.3.3 SEALS

Fluoropolymers such as PTFE are a unique press fit material which flows to fill gaps and imperfections creating a seal against explosive gases. PTFE also has an unmatched temperature range and can flow into imperfections which enables IAMC products temperature rating and flame protection performance. Fluoropolymers are used when operating conditions exceed the performance requirements of other sealing materials like rubber and soft plastics. Below are three examples of sealing operating conditions that require the use of fluoropolymers, namely PTFE, PCTFE, FKM and FFKM.

1. **Temperature Resistance:**
   Fluoropolymers' ability to retain its most important performance properties over a temperature range that is among the broadest of any polymer is an important factor in sealing applications. This is due to the strength of its carbon-fluorine bond, which exceeds carbon-hydrogen bond strength in hydrocarbon-based polymers by over 20%. This gives PTFE a very high and low operating temperature, up to 260°C and down to -200°C, respectively. PCTFE is used in cryogenic and high temperature sealing applications. FKM and FFKM are used in high temperature sealing applications.

2. **Chemical Resistance:**
   Chemical compatibility of seals is critical in low carbon fuel sources such as biodiesel, bio/digestor gas containing hydrogen sulfide, and hydrogen applications. Chemical compatibility is also critical in oil & gas, chemical production, and plastic production. Often these materials are specified by the downstream user as they know their application(s) best.

3. **High concentration oxygen applications:**
   Another example is the use of PTFE seals in high concentration oxygen applications. PTFE has high ignition and oxygen index[5] values, which makes it ideal for these applications to prevent combustion. This is due to fluorine's presence in the chemical structure and its inherent flammability resistance. PTFE and PCTFE achieve a Limited Oxygen Index (LOI) of 95%. LOI is the minimum concentration of oxygen, expressed as volume percent, needed for a material to continue to burn on its own once it ignites at atmospheric pressure. Materials with high oxygen index are preferred for oxygen service; the higher the oxygen index, the lower the propensity of a material to ignite and burn. Conversely, the lower the oxygen index, the higher propensity of a material to ignite and burn. PTFE's inherent flame resistant properties are essential in applications such as semiconductor manufacturing, chemical processing, maritime diving, firefighting, and aerospace (see also **Table 6.4** for a comparison of this performance with alternatives).

5.3.4 VALVE PACKING

Several factors must be considered when choosing a valve packing material, namely fugitive emission standards, chemical resistance, temperatures, and pressures. Using parameters provided in the International Organization for Standardization (ISO) 15848-1, fugitive emission estimates were made for two valve packing solutions, PTFE and graphite, and normalized using a two-liter bottle volume to show the significant performance comparison perspectives. Correspondingly, a two-liter bottle would take 518 days to fill with helium due to leaks in valve packing using PTFE and 5.1 days with graphite. This demonstrates that PTFE provides two orders of magnitude better emissions control over the next best alternative.

5.3.5 VALVE SEATS

Valve seats are commonly made out of PTFE and PCTFE to accommodate performance requirements such as chemical resistance, inertness, temperature resistance, and mechanical properties such as compressive modulus and creep resistance.

Fluoropolymers are especially important in applications where the high purity of sensitive flowing media has to be maintained throughout the process like in etching solutions in semiconductor manufacturing. Fluoropolymers yield intrinsic inertness and purity due to the layer of unreactive fluorine atoms attached to the carbon-carbon backbone. PFA, FEP and ETFE are also used as valve seats in high purity applications.

5.3.6 WIRE AND CABLE

Wires and cables are exposed to the harsh IAMC equipment operating profile and require the same level of reliability. The use of fluoropolymers in IAMC equipment is driven by outstanding electrical properties, such as low dielectric constant, and flame resistance. Other properties such as chemical resistance and crack resistance are also important. Additionally, fluoropolymer insulation is durable and has the highest longevity of materials used in IAMC applications.

For example, fluoropolymers are used to insulate conductors in high reliability applications such as IAMC equipment, aerospace and petroleum and mining. They are chosen for these applications because of their low dielectric loss tangent, high dielectric strength, high chemical and temperature resistance, and low

5 E. Alfredo Campo, 3 - Thermal Properties of Polymeric Materials, Editor(s): E. Alfredo Campo, In Plastics, Design Library, Selection of Polymeric Materials, William Andrew Publishing, 2008, pp. 103-140. ISBN , 9780815515517. https://doi.org/10.1016/B978-081551551-7.50005-X

surface friction, important for passing wires through tight conduits. Dielectric loss tangent is a measure of signal attenuation as it passes through a material (lower is better). Dielectric strength is a measure of the maximum voltage the material can withstand without breaking down - higher is better (see also **Figure 6-2** for a comparison of this performance with alternatives).

Additional detail on use conditions of fluoropolymer cable and wiring insulation in IAMC equipment include:

- Low Temperature: -55°C
- High Temperature: 200°C
- Indoor/Outdoor proportionality: 70% Indoor/30% Outdoor
- Humidity: Ambient
- Dust: No issues

5.3.7 ELECTRONICS

Electronics can be exposed to the harsh IAMC environment, and in some cases, it is not possible to protect them in an enclosure. In these instances, fluoropolymers are necessary given their high performance, namely their electrical, thermal and intrinsic flame resistance properties. Electronic components include PCB structures, waveguides, capacitors, piezoelectric devices and liquid crystal displays.

For example, fluoropolymers are necessary in applications where low dielectric constant electrical properties are required, such as a waveguide used in a tank level monitoring transmitter for a toxic chemical. Waveguides are hollow tubes that transport microwave signals from antennas to electronics. Polymer waveguides are often used when harsh chemicals, such as chlorine or sulfuric acid, are involved and where corrosion-induced surface damage can occur resulting in attenuation of the microwave signal. Polymer selection for waveguides is predicated on dielectric constant properties, which define the material's ability to store energy, and other typical environmental parameters such as chemical and thermal resistance. Low dielectric constant polymers are needed for waveguides to prevent signal attenuation through absorption into the material. Fluoropolymers are a good match for this application because of their low dielectric constant, which for PTFE is intrinsic due to the non-polar and ordered chemical structure, and high chemical and thermal resistance (see also **Figure 6.3** for a comparison of this performance with alternatives).

6 ASSESSMENT OF ALTERNATIVES

6.1 General

6.1.1 IDENTIFICATION OF ALTERNATIVES

Multiple classes of materials have been considered as potential alternatives for fluoropolymers in IAMC equipment:

- Metals and metal alloys (e.g. stainless steel (SS), titanium, Hastelloy, nickel, copper, and brass).
- Non-fluorinated polymers (e.g. Polyetheretherkeytone (PEEK) and Polyeitherimide (PEI)).
- Non-fluorinated elastomers (e,g, Ethylene Propylene Diene Monomer (EPDM), Hydrogenated Nitrile Butadiene (H-NBR), and Silicone).

Emerson's assessment of alternatives to date[6] has been limited to desk-based paper studies, using existing data for evaluation of fit-for-service requirements. There is a formal process for evaluating potential alternatives involving the following steps:

1. **Information Gathering** - what is the component, what is the component made of, current PFAS material, what was the driving requirement(s) for selection of a PFAS?
2. **Assess Candidate Materials Using Published Property Data** - look up published values using material intelligence databases, publications, etc.
3. **Down-Select Process** - assess the full range of requirements including, but not limited to, the following:
    - Performance Requirements
    - Manufacturing Implications
    - Supply Chain Risks
    - Costs
    - Health & Environmental Implications
4. **Conduct Side-by-Side Comparison Testing**
5. **Implementation**

6.1.2 AVAILABILITY

It is considered that types of potential alternatives (as indicated above) for fluoropolymers in IAMC equipment are broadly similar to those considered in the petroleum and mining sector in the ECHA restriction proposal.

It is noted that in the ECHA restriction proposal, it is indicated that[7] the alternatives considered have been identified because they are products that are currently marketed and sold in Europe, and consultation with industry and national authorities suggest they are in use in significant volumes. However, it is also noted that very limited specific quantitative data on the relative levels of production, sales or use of alternatives are available.

6 September 2023
7 See Section E.2.15.2.2

6.1.3 TECHNICAL FEASIBILITY

The following evaluation of the technical feasibility of alternatives uses a combination of Emerson's in-house data, publication data and thorough discussions with Emerson material experts and experts consulted from the broader materials industry.

Metals and Metal Alloys

Most evaluated metals cannot match fluoropolymers' corrosion resistance to e.g. chlorine, and metals are heavier and have a less favorable carbon footprint in their manufacturing process.

Corrosion resistant metals such as SS, titanium, Hastelloy, nickel, copper, and brass were explored as alternatives to fluoropolymer liners and considered unacceptable because of significant incompatibility with some chemicals and lack of purity in certain applications. PTFE is commonly used to coat metals such as 316L SS to protect the surface from corrosion in harsh chemicals. A study by Waseem Akram[8] compared corrosion rates for 316L and PTFE-coated 316L SS in two acidic mediums, hydrochloric acid (HCl) and nitric acid (HNO_3). Results are provided in the table below and show a significant corrosion performance increase (fewer Millimeters (MMs) Per Year) by adding the protective layer of PTFE.

TABLE 6.1 **PTFE is commonly used as a protective coating to prevent corrosion of SS in IAMC applications**

ACIDS	CORROSION RATE: MM PER YEAR	
	Bare 316L SS	316L w/PTFE Coating
HCL	0.8	0.02
HNO_3	17.4	0.1

Source: Akram, W., Farhan Rafique, A., Maqsood, N., Khan, A., Badshah, S., & Khan, R. U. (2020). Characterization of PTFE film on 316L stainless steel deposited through spin coating and its anticorrosion performance in multi acidic mediums. Materials, 13(2), 388. https://www.researchgate.net/publication/338614979_Characterization_of_PTFE_Film_on_316L_Stainless_Steel_Deposited_through_Spin_Coating_and_Its_Anticorrosion_Performance_in_Multi_Acidic_Mediums.

Additionally, other challenges were identified that prevented these materials from emerging as viable alternatives including higher density (increased weight), increased maintenance cycles, and higher life-cycle CO_2 emissions associated with the production process.

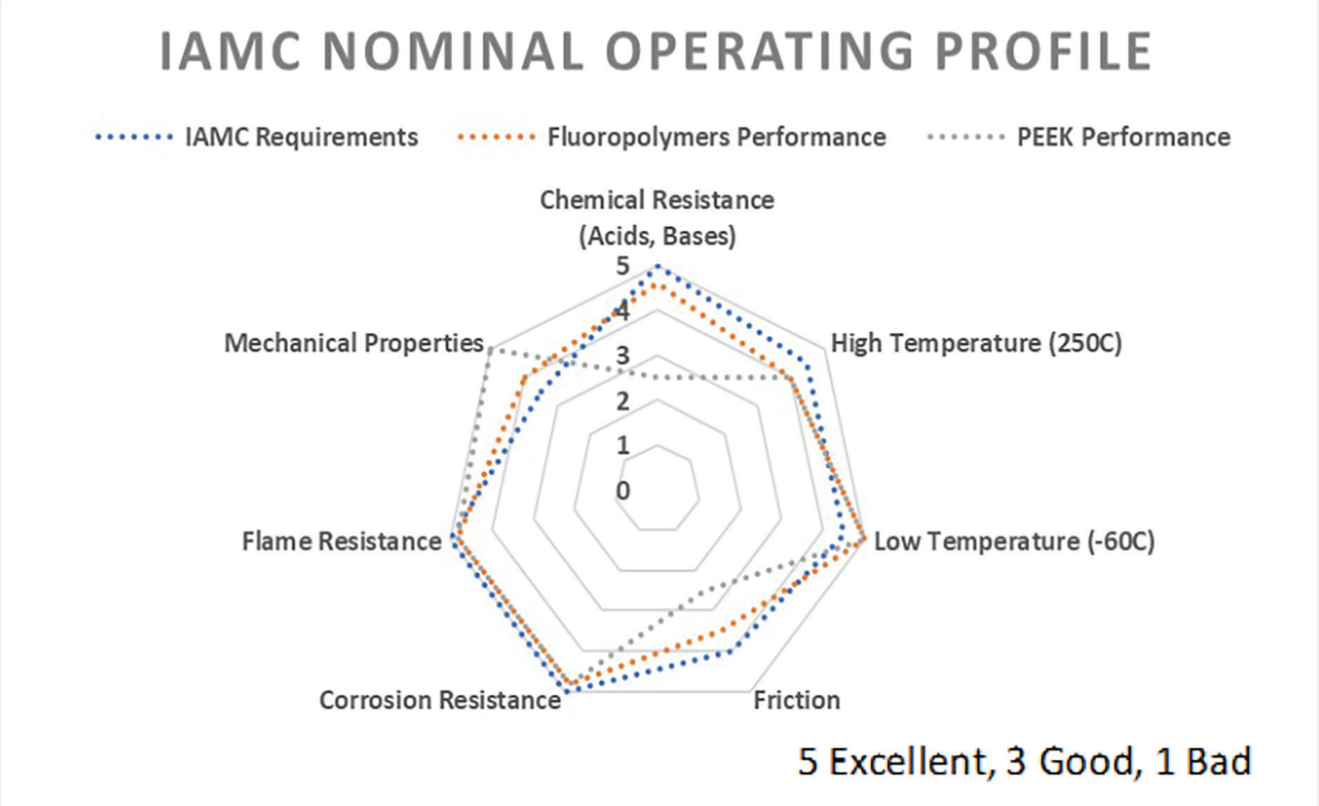
Non-fluorinated Polymers

Other polymers can demonstrate superior performance in one single property. For example, Polyetheretherkeytone (PEEK) has slightly higher temperature performance than fluoropolymers. However, fluoropolymers are the best choice when both high temperature and chemical resistance are needed simultaneously. This is also demonstrated in **Figure 6.1** where PEEK is overlayed for comparison purposes.

Engineering plastics such as PEEK (**Figure 6.1**) and Polyphenylene Sulfide (PPS) were considered as alternatives for liners, tubing, waveguides and seals but were deemed unsuitable due to their inability to fulfill all the criteria required for IAMC equipment. PEEK and PPS can fulfil the high temperature performance requirements. However, their chemical resistance is inferior to fluoropolymers, especially for chemicals such as hydrogen sulfide (sour) gas and strong acids. Also, PEEK's compressive modulus is too high making it unfit for seats in valves and regulators and its moisture uptake prevents its use in certain waveguide applications. Another polymer considered was acetal, which has excellent lubricity properties. However, its chemical resistance and temperature limitations prevent it from being an appropriate candidate. Another alternative is Polyimides such as Vespel™. They are generally much higher in compressive strength and therefore do not make good lower pressure seal parts. Also, they are incompatible with some medias such as water and steam.

8 Akram, W., Farhan Rafique, A., Maqsood, N., Khan, A., Badshah, S., & Khan, R. U. (2020). Characterization of PTFE film on 316L stainless steel deposited through spin coating and its anticorrosion performance in multi acidic mediums. Materials, 13(2), 388. https://www.researchgate.net/publication/338614979_Characterization_of_PTFE_Film_on_316L_Stainless_Steel_Deposited_through_Spin_Coating_and_Its_Anticorrosion_Performance_in_Multi_Acidic_Mediums.

FIGURE 6.1 **Fluoropolymers' chemical resistance and friction properties compared to PEEK**



Source: Ansys Granta Materials Database

Non-fluorinated Elastomers

Traditional elastomers such as Ethylene Propylene Diene Monomer (EPDM), Hydrogenated Nitrile Butadiene (H-NBR), and Silicone were considered as alternatives for seals, but were deemed unsuitable due to their inferior chemical resistance, temperature limitations, and mechanical properties. Most elastomers cannot perform at operating conditions that exceed 150°C. Silicone has higher temperature resistance but is inferior in mechanical performance and is also not recommended in high friction and high wear applications. Using materials that are not adequate for the operating condition is not recommended and would, at a minimum and best case, require an unrealistic number of maintenance cycles. Furthermore, safety of workers and the environment could be compromised due to increased probability of failure and possible releases of hazardous materials.

6.1.4 ECONOMIC FEASIBILITY

Cost is not the deciding factor for use of fluoropolymers in IAMC applications. Fluoropolymers are typically more expensive than non-fluorinated materials. They are used because the technical requirements of existing IAMC applications eliminate the possibility of utilizing existing alternatives. The primary consideration for IAMC applications is performance to ensure that safe and efficient operations are maintained.

Even if technically feasible alternatives were available today, the time needed for careful and comprehensive engineering work that accompanies a material change in a highly regulated segment such as IAMC can be, based on Emerson's experience, in excess of five years with substitution costs ranging in the hundreds of thousands of Euros for a single IAMC product. Even though substitution costs could be substantial, the on-going costs of increased production facility downtime due to more frequent maintenance cycles and shorter life of components caused by decreased performance of any alternative would likely be much higher. **Table**

6.2 provides an overview of the current performance of fluoropolymers in the different types of IAMC applications in terms of longevity, replacement time and downtime for maintenance, and assesses the implications of using alternatives and the associated costs.

Another significant consideration is the intensive engineering effort that accompanies a material change in IAMC's highly regulated segments. Activities to be conducted include finding and evaluating alternatives, modifying designs, re-qualification testing and re-certification (ATEX, Pressure Equipment Directive 2014/68/EU), supply chain cadence change, and customer relations. Some of the standards that are directly applicable are:

- IEC 60079-0 (Explosive atmospheres: General equipment requirements)
- IEC 60079-11 (Explosive atmospheres – Part 11: Equipment protection by intrinsic safety)
- IEC 60079-1 (Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures)
- UL 1203 (Explosion Proof and Dust ignition proof electrical equipment for use in hazardous locations)
- ANSI/ISA 12.27.01 (Requirements for Process Sealing Between Electrical Systems and Flammable or Combustible Process Fluids

TABLE 6.2 **Overview of implications for replacing fluoropolymers in IAMC equipment with alternatives and the associated costs**

	LINERS	SEALS	VALVE PACKING	VALVE SEATS	CABLE & WIRE INSULATION	ELECTRONICS
Performance characteristics associated with fluoropolymer containing components	**Pressure, Flow, Level, Temp, Corrosion, Erosion, Heat Trace, Density, Viscosity**	**All IAMC Equipment**	**Control & Isolation Valves**	**Valves, Regulators, Actuators Semiconductor Application**	**All IAMC Equipment**	**All IAMC Equipment**
Overall longevity	15 years, no moving parts in an electromagnetic flow meter	15 years	15 years	10 Years, Regulator is disposed of with the Chemical Vapor Deposition (CVD) equipment	20 Years	15+ years
Frequency of replacement	The liner is almost never replaced. Lifetimes are tied to the instrument it is protecting and sometimes the system that the instrument is monitoring.	The seals are almost never replaced. Lifetimes are tied to the life of the device.	The seals are almost never replaced. Lifetimes are tied to the life of the device.	In high purity applications such as semiconductor manufacturing, the failure mechanism usually involves the metal diaphragm cracking. In the case of any failure, a new regulator would be installed, not a new components such as a PCTFE seat. Lifetimes are tied to the semiconductor manufacturing equipment, which can be shorter than the actual regulator's life.	20 Years	No replacement
Overall level of downtime for maintenance	Almost never	Almost never	Almost never	Almost never	No downtime	No downtime

	LINERS	SEALS	VALVE PACKING	VALVE SEATS	CABLE & WIRE INSULATION	ELECTRONICS
Performance characteristics associated with fluoropolymer containing components	**Pressure, Flow, Level, Temp, Corrosion, Erosion, Heat Trace, Density, Viscosity**	**All IAMC Equipment**	**Control & Isolation Valves**	**Valves, Regulators, Actuators Semiconductor Application**	**All IAMC Equipment**	**All IAMC Equipment**
The risks associated with lower level of performance (Low, Medium, High)	Magnetic sensors require liners to prevent corrosive attack from aggressive chemicals or slurries. These sensors will not operate accurately if they are corroded.	Seals are essential to the operation of most valves. Seal failure most likely will result in a leak and subsequent valve malfunction, which could result in a dangerous release of a hazardous fluid.	Packing is essential to the operation of most valves. Packing failure most likely will result in a leak and subsequent valve malfunction, which could result in a dangerous release of a hazardous fluid.	Valve seat performance degradation will result in seat leakage that will lead to degraded process control and reduced plant performance and efficiency.	Depending on the durability of a replacement material.	Replacing a material (PTFE) which has been the standard for Microwave industrial applications for 50 years comes with high risk. Many of the customers' processes contain explosive or poisonous fluids which need to be sealed off.
The costs associated with lower level of performance	Cost of maintenance requires the process, chemical or otherwise, to be stopped to allow for replacement of the liner. The cost to shut down a process varies but it can be significant (millions of Euros).	The seals would not be replaced, but the entire valve would be replaced more frequently to offset the performance deficiency. The main cost concern would be shut down costs which could be very significant.	Cost to shut down a process to replace the packing or the entire valve and/ or cost of increased fugitive GHG emissions associated with leaking packing.	The feasibility of the manufacturing process would be at risk, so the whole application could be lost with substantial economic losses associated.	Depends on replacement material.	

6.1.5 HUMAN HEALTH AND ENVIRONMENTAL RISKS

Safety is the deciding factor for use of fluoropolymers in IAMC applications. These materials are selected due to their high performance. A good example is PTFE liners' chemical resistance, specifically its ability to prevent toxic substances from leaking. The use of inferior performing alternatives could lead to a breach of containment and a subsequent release of toxic media, which could harm humans, the environment and critical equipment. Another example is PCTFE's limited oxygen index compared to alternatives. PCTFE is commonly used for oxygen enriched applications such as life support for space travel and Navy diving, as well as aerospace fueling applications like rocket propellant and oxidizers.

All potential alternatives (metals, non-fluorinated polymers, and non-fluorinated elastomers) are high performance materials that will likely be persistent similar to fluoropolymers, resulting in substitution of one persistent material with an inferior performing one, leading to increased maintenance cycles and generation of higher amounts of waste.

6.2 Specific Applications

6.2.1 LINERS

A potential alternative to liners is to make the metal being protected out of a material that can withstand the operating environment, eliminating the need for a protective layer. Exotic metals such as Titanium or Hastelloy C76 might withstand some of the corrosive environments in which IAMC equipment operate but their viability is in question due to the additional weight and increased CO_2 emissions associated with their manufacturing processes. Another potential alternative is to apply a hard coating to the surface to be protected. Tri-chrome conversion coatings or tungsten carbide or others may be suitable in some applications.

Table 6.3 includes data from Emerson's liner selection guide to show performance of fluoropolymers and potential alternative materials against five common industrial chemicals. For temperature resistance, the value represents confirmed performance, not the limitation of the material. Although several material properties were considered in the down-selection of these candidate liner materials, chemical and temperature resistance are dominant.

TABLE 6.3 **Resistance of liner materials to five common industrial chemicals**

COMMON INDUSTRIAL CHEMICALS	ANNUAL TONNAGE (MILLIONS)	RESISTANCE OF LINER MATERIALS UP TO WHICH TEMPERATURE					
		PTFE	ETFE	PFA	Polyurethane	Neoprene	Natural rubber
Sulfuric Acid	20	120°C	120°C	120°C	Not resistant	Not resistant	Not resistant
Ammonia	19	120°C	120°C	120°C	20°C	80°C	Not resistant
Sodium Hydroxide	11	120°C	120°C	120°C	20°C	80°C	20°C
Benzene	8	120°C	80°C	120°C	Not resistant	Not resistant	Not resistant
Sodium Carbonate	3	120°C	120°C	120°C	Not resistant	80°C	80°C

Source: https://www.emerson.com/documents/automation/technical-data-sheet-magnetic-flow-meter-material-selection-guide-en-74360.pdf

6.2.2 SEALS

Metal-to-metal seals are gaining traction in static sealing applications, especially where high temperature and high-pressure performance is required such as in nuclear and aerospace. Challenges include low tolerance for surface imperfections, higher sealing forces (more bolts and more torque), and limitation of applications (static).

Most rubber materials and soft plastics cannot operate above 150°C or below -40°C, while PTFE has a very high and low operating temperature, up to 260°C and down to -200°C, respectively[9]. PCTFE is used in cryogenic and high temperature sealing applications. FKM and FFKM are used in high temperature sealing applications.

Table 6.4 below shows the dominant Limited Oxygen Index (LOI) performance of PTFE.

TABLE 6.4 **PTFE is commonly used in high concentration oxygen applications**

POLYMERS	LOI (%)
Acetal Homopolymer	15
Polyethylene / Polypropylene	17
Polyethylene Terephthalate	20
Polycarbonate	27
Nylon 6/6	29
Liquid Crystal Polymers	36
Polyvinyl Chloride	47
Polyimide	53
Viton FKM	57
PCTFE	95
PTFE	95

Source: Thermal Properties of Polymeric Materials, Editor(s): E. Alfredo Campo, In Plastics Design Library, Selection of Polymeric Materials, William Andrew Publishing, 2008, pp. 103-140. ISBN 9780815515517. https://doi.org/10.1016/B978-081551551-7.50005-X

6.2.3 VALVE PACKING

An alternative to valve packing is a valve bellows seal, which is a welded or mechanically formed metal barrier around the valve stem that can compress and stretch like an accordion. Because bellow seals are constructed of relatively thin metal and subjected to mechanical stress and chemicals, they routinely crack and fail. Often, a bellows seal has a PTFE packing above it to contain the process fluid in case of a bellows failure in operation.

Graphite is a potential alternative material to replace PTFE in valve packing. Using parameters provided in the International Organization for Standardization (ISO) 15848-1, the following shows the amount of time a two-liter bottle would fill with helium due to valve packing leaks using PTFE and using graphite:

- PTFE: 1.42 Years (518.3 days)
- Graphite: 0.014 Years (5.1 days)

This demonstrates that PTFE provides two orders of magnitude better emissions control over graphite. Removal of PTFE will result in increased emissions of potentially harmful gases that could be detrimental to people and the environment, further contributing to the climate change crisis. For reference regarding scale of use, over 1,000 valves can be used in a single chemical processing facility.

9 See e.g. Matweb, Ansys Granta Material Database

6.2.4 VALVE SEATS

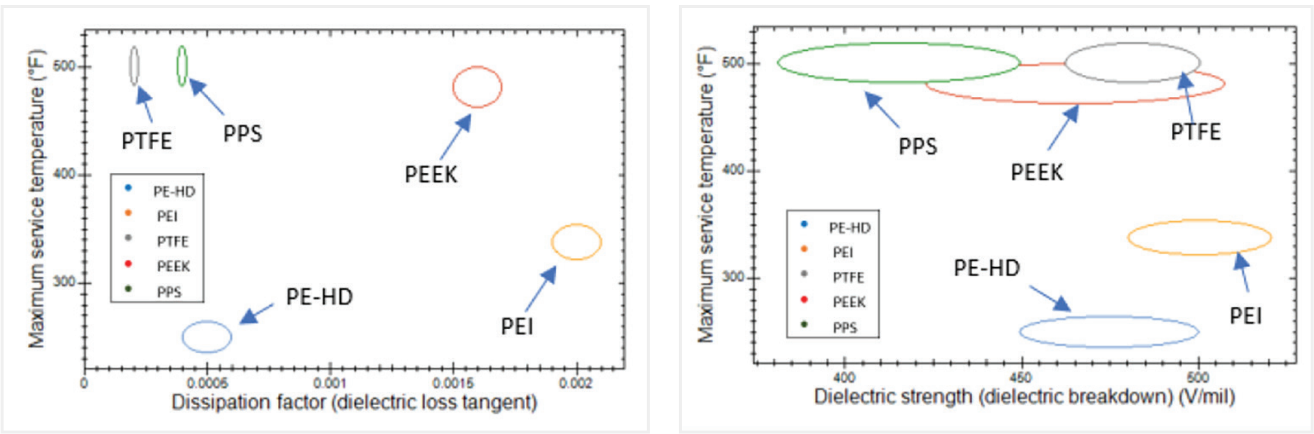
Metal-to-metal seated valves are gaining traction in sealing applications, especially where high temperature and high pressure performance is required such as in nuclear and aerospace. Challenges include low tolerance for surface imperfections, higher sealing forces (more bolts and more torque), and limitation of applications (mostly static or very low cycles). Often hard coatings such as tungsten carbide are applied to the metallic seal surface to mitigate imperfections and to reduce friction.

6.2.5 WIRE AND CABLE

Cables and wire that are used in IAMC equipment invariably require a non-conductive insulation material to prevent shorting and electrical shock. Alternative designs may eliminate the need for the cables and wire to be exposed to the operating environment. If alternative insulation is needed, Mica is worth consideration. It may serve as a suitable alternative in some applications, especially those where flexibility is not needed as mica is very brittle.

The **Figure 6.2** below shows that alternatives cannot match PTFE's performance in terms of a low dielectric loss tangent in combination with a high service temperature, as well as high dielectric strength in combination with a high service temperature.

FIGURE 6.2 **Dielectric loss tangent and dialectic strength of fluoropolymers and alternatives**

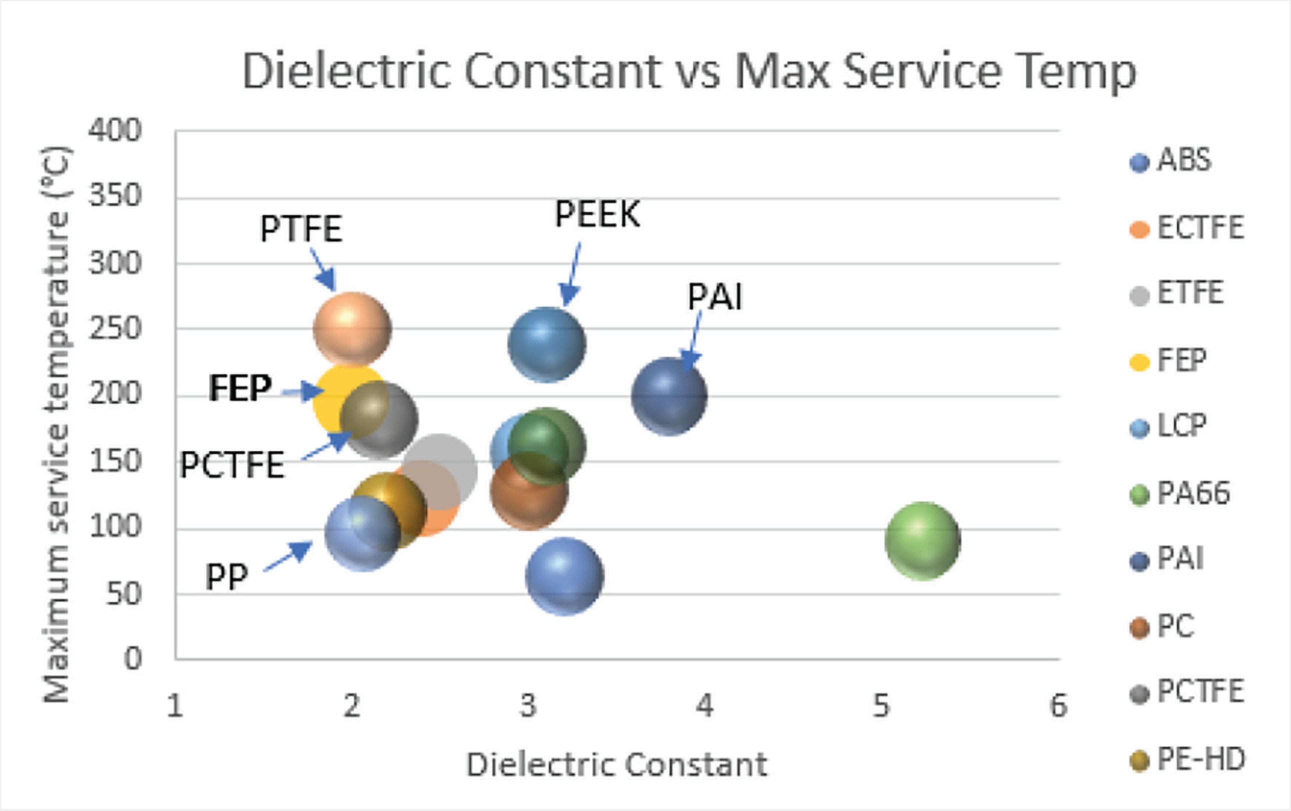


Source: Ansys Granta Materials Database

6.2.6 ELECTRONICS

Figure 6.3 below plots dielectric constant against maximum service temperature data from Ansys Granta's enterprise materials intelligence database. Alternatives such as PEEK do not fulfill all application requirements. Microwaves are heavily affected by water, that is the higher dielectric constant the more signal is reflected from the surface. Therefore, it is also important that the water does not "get stuck" on the surface of the antenna and that the water does not penetrate into the waveguide material. When PEEK is pressurized with steam, the water will penetrate into the waveguide and affect the reliability of the measurement and even block the signal of the measurement.

FIGURE 6.3 **Dielectric constant at different service temperatures for fluoropolymers and alternatives**



Source: Ansys Granta Materials Database

7

SOCIO-ECONOMIC IMPLICATIONS

7.1 Anticipated Reactions to the Proposed Restriction

The proposed REACH restriction on PFAS would ban the use of fluoropolymers in all IAMC applications containing PFAS from 18 months from entry into force of the restriction, except for those that are covered by the proposed time-limited derogations in the restriction proposal. As discussed in **Section 3**, Emerson expects that the vast majority of IAMC equipment contains fluoropolymers and are therefore affected by the proposed restriction. The main relevant proposed derogations, proposed in RO2 of the restriction report, that would cover IAMC applications are for:

- Fluoropolymer applications in petroleum and mining industry until 13.5 years after entry into force (paragraph 6.f. of the proposed restriction)
- Fluoropolymer food contact materials for the purpose of industrial and professional food and feed production until 6.5 years after entry into force (paragraph 6.a. of the proposed restriction)
- Potential derogation marked for reconsideration after the Annex XV report consultation: the semiconductor manufacturing process until 13.5 year after entry into force (paragraph 5.ee. of the proposed restriction)

Virtually all other IAMC uses are not expected to be covered by the proposed derogations, which IAMC suppliers expect to represent the vast majority of applications. For these applications, there are two main scenarios: Either alternatives are used to substitute fluoropolymers in these IAMC uses, or the IAMC equipment is withdrawn from the market in the European Union and the European Economic Area. The assessment of alternatives (**Section 6**) has shown that the potential alternatives identified so far cannot provide the same performance as fluoropolymers in the context of the specific combination of harsh conditions (e.g., extreme temperatures and corrosive chemicals) in many IAMC uses. Therefore, the use of alternatives would lead to a reduction in performance of IAMC equipment. In some cases, this would likely make the IAMC application technically and/or economically unfeasible, and the benefits associated with the use of IAMC the application would be lost. The socio-economic implications of both scenarios (use of alternatives, withdrawal from market) for the IAMC sector, downstream users, and the wider economy and society in Europe are discussed in more detail in the following sub-sections.

While this is difficult to predict over the wide range of IAMC applications, **Table 7.1** provides examples of IAMC applications that are expected to be withdrawn as a result of the restriction, and IAMC applications in which Emerson expects fluoropolymers to be replaced with alternatives.

TABLE 7.1 **Anticipated reaction to a restriction of fluoropolymers in IAMC equipment**

USES/PRODUCTS EXPECTED TO BE WITHDRAWN AS A RESULT OF THE RESTRICTION	USES/PRODUCTS IN WHICH PFAS ARE EXPECTED TO BE REPLACED WITH ALTERNATIVES
› Electromagnetic flow meters used in harsh environments › Valves used in harsh environments › Regulators used in semiconductor applications › Level measurement devices used in harsh environments › Regulators, valves and/or actuators with PCTFE valve seat used in oxygen applications › Valves (solenoid, others), actuators, and regulators with PTFE seals for cryogenic applications › Measurement equipment with PTFE or PFA liners in media that is highly corrosive and will attack the un-lined surface › Measurement equipment used in harsh environments	› Wire insulation in flow meters - possibly changing to polyimide or mica, application dependent › Measurement equipment liners – possibly switching to cross-linked polyethylene for less-benign chemical processing applications › Control valves - switching to graphite or metal bellows packing

7.2 Implications for IAMC Suppliers

As a significant portion of IAMC applications would likely be withdrawn from the European market, Emerson expects that devastating cuts at IAMC suppliers would likely be experienced. Emerson employs over 16,500 people at 51 manufacturing sites and 50 sales / service center locations across 21 EU Member States. Emerson estimates that there are around 1,000 IAMC suppliers in Europe. As shown in **Section 2**, IAMC generates revenues of €56 billion annually in Europe. A portion of this economic activity could be lost to the European economy.

In those cases where fluoropolymers can be replaced with alternatives, there could be savings for material costs (as alternatives are often cheaper than fluoropolymers), but due to the decrease in performance and the competitiveness of the market, the prices that suppliers can sell IAMC equipment for would likely also be reduced. However, more importantly, there would be significant substitution costs for redesigning IAMC equipment and manufacturing processes (see also **Section 6.1.4**.). Emerson expects substitution costs to be in the order of hundreds of thousands of Euros for a single IAMC product. Considering there are around 1,000 different suppliers and assuming each supplier has at least tens to hundreds of different products, total substitution costs could be in the order of billions to tens of billions of Euros. Additional substitution costs would likely arise for downstream users, as discussed further below.

7.3 Implications for Downstream Users

Downstream user sectors relying on industrial automation and the products and services it enables account for economic activities and benefits that are likely orders of magnitude larger than the IAMC sector itself. If a significant part of IAMC applications were lost due to the proposed restriction, this could severely affect industrial automation, increase the costs of industrial processes, and put the benefits provided by applications in downstream user sectors at risk. Examples of potential impacts in downstream user sectors include:

- Water treatment and food processing: The production of chlorine in Europe could be affected, and chlorine could therefore become more expensive or scarce, as it needs to be imported from outside Europe. Besides the loss of the economic activity from chlorine production in Europe, the costs and safety of water treatment and food processing could also be affected. Chlorine is the most common type of drinking water disinfectant and used to clean and sterilize food processing equipment to prevent bacteria growth.
- Semiconductors: The production of semiconductors in Europe could become less effective and efficient, and therefore more costly or even technically and economically unfeasible. The associated economic activity would be lost and previously domestically produced semiconductors would need to be imported instead.
- Pharmaceutical and food manufacturing, power generation: The loss of valves using fluoropolymers could reduce the efficiency and safety of many industrial processes such as the processing and storage of chemical feedstocks, pharmaceuticals, petroleum, hydrogen and food, as well as power generation.

In those cases where fluoropolymers are replaced with alternatives, there could be savings resulting from the lower material prices of alternatives compared to fluoropolymers, but this would likely be far outweighed by substitution costs and the implications of the reduced performance of the IAMC equipment. Substitution costs would involve the costs for substituting IAMC equipment before the end of its lifecycle, and potentially also redesigning the downstream application to take into account the changes to the IAMC equipment. However, more importantly, due to the lower performance of alternatives, their use could lead to more frequent failures, maintenance and replacement, with associated downtime and costs. Emerson expects that the cost of downtime/shutdowns is likely most significant (depending on the application, in the millions of Euros per shut down). Considering the wide range of downstream uses of IAMC equipment, the total costs to downstream users associated with substitution and reduced performance cannot be estimated, but would likely be orders of magnitude larger than the costs to IAMC suppliers.

7.4 Wider Impacts

The potentially significant negative implications for the IAMC sector and especially the many downstream user sectors could lead to wider impacts for the European economy and society. For example:

- Emerson is concerned that the EU could fall behind other countries on technology competitiveness, especially in the area of chemical processing. Potential outcomes include reduction in manufacturing operations resulting in higher imports for everything from food to pharmaceuticals.
- Many of the affected downstream user sectors play important roles in policies and strategies vital to Europe's future, such as for example alternative energy, transportation, and battery manufacturing. **Table 7.2** provides a detailed overview of key sectors that will be impacted, and highlighting the impacts (both economic and environmental) and the EU- and global- level policies and strategies that could be jeopardized as a result – this covers for example:

- Access to clean drinking water
- Food supply
- Semi-conductor manufacture
- Production of chemicals and pharmaceuticals
- Clean energy, e.g. hydrogen production
- Wider sustainability initiatives

In those cases where fluoropolymers are replaced with alternatives, the carbon footprint of the affected products could worsen as certain alternatives also exhibit higher density (increased weight), and higher life-cycle carbon emissions associated with the production process. More frequent replacement of parts due to the lower performance of alternatives would lead to more waste. Furthermore, many downstream user applications involve hazardous fluids or gases, so if alternatives cannot properly contain them, there is a significant health, safety and environmental risk (see also **Section 6.1.5**). Due to the potential severity of a failure, significant caution is expressed regarding the removal of fluoropolymers, a material that has performed so reliably for over six decades. One prevailing concern is that industry standard bodies like ATEX may need to lower their bar for hazardous location equipment to accommodate replacement materials that currently cannot deliver the required performance.

TABLE 7.2 **Overview of EU- and global-level policies and strategies, where use of PFAS in IAMC equipment is potentially significant**

TYPE OF USE	USE OF PFAS / WHY PFAS ARE IMPORTANT	KEY EU ACTIONS	KEY GLOBAL ACTIONS
Provision of safe drinking water	PTFE & PFA liners in measurement equipment and valves for the production of chlorine. Highly concentrated chlorine is corrosive and highly toxic to people and the environment. PTFE & PFA liners can withstand the corrosive environment, are lightweight and have a relatively low carbon footprint associated with their manufacturing processes. Chlorine is able to reduce the chance of pathogen regrowth in water storage tanks or distribution systems. It also oxidizes iron, manganese, taste and odor compounds, remove color in the water, destroy hydrogen sulphide, and aid other water treatment processes, such as sedimentation and filtration. Highly concentrated chlorine is corrosive to metals and highly toxic to people and the environment. Exotic metals that might withstand the corrosive environment are not viable due to the high weight and increased CO2 associated with their manufacturing processes.	At EU-level a key pillar of drinking water policy is to *"protect human health by ensuring the quality of water intended for human consumption"*. The recast Drinking Water Directive is the EU's main law on drinking water. It concerns the access to and the quality of water intended for human consumption to protect human health.	World Health organisation (2017) Guidelines for drinking-water quality (4th edition) – sets specific guidelines for chemical and microbial levels in drinking water. The UN Sustainable Development Goals include a target for the provision of clean/safe drinking water (SDG6) – Target 6.1: "*By 2030, achieve universal and equitable access to safe and affordable drinking water for all*".
Provision of safe food supply	Chlorine is used to clean and sterilize food processing equipment to prevent bacteria growth. › Highly concentrated chlorine is corrosive to metals and highly toxic to people and the environment. › Exotic metals that might withstand the corrosive environment are not viable due to the high weight and increased CO2 associated with their manufacturing processes.	An extensive body of EU-wide law covers the entire food production and processing chain within the EU. This includes maintaining good food hygiene, by controlling contaminants and residues. For example, maximum acceptable limits apply to domestic and imported food and feed products.	The UN Sustainable Development Goals include a target for the provision to "*End hunger, achieve food security and improved nutrition*" The WHO Global Strategy for Food Safety 2022-2030 aims to ensure that all people, everywhere, consume safe and healthy food so as to reduce the burden of foodborne diseases
Semi-conductor manufacture	Use in semiconductors and microchips manufacturing ensuring that highly corrosive chemicals do not contaminate ultra-clean fabrication environment. Pressure regulators utilize PTFE and PCTFE in valve seats to control the pressure of media used in etching and chemical vapor deposition processes for semiconductor manufacturing, providing high purity and compatibility with the processed gases to prevent a reaction with the media. PCTFE also delivers an ideal compressive modulus and creep resistance for maintaining sealability.	The European Chips Act aims to double European production capacity (from 10% to 20%) of the global market by 2030. The goal is to address semiconductor shortages and strengthen Europe's technological leadership. More than €43 billion of policy-driven investment will support the Chips Act until 2030.	The rapid vertical and horizontal expansion in chips applications means the market for semiconductors is expected to double from €512.5 million presently to over €931.9 billion by 2030[10], indicting there will be a rapid increase in global demand and production.

10 https://espas.eu/files/Global-Semiconductor-Trends-and-the-Future-of-EU-Chip-Capabilities-2022.pdf

TYPE OF USE	USE OF PFAS / WHY PFAS ARE IMPORTANT	KEY EU ACTIONS	KEY GLOBAL ACTIONS
Processing and/or Storage of Chemical Feedstocks, Pharmaceuticals, Petroleum, Hydrogen	Control and isolation valves utilize PTFE valve packing in the production of pharmaceuticals, chemicals, hydrogen processing, etc. › PTFE valve packing is better at sealing gases than graphite, is inert and delivers performance at extreme temperatures, -200°C to +260°C › PTFE waveguides are used in non-contact, radar level measurement applications for safe storage of harsh chemicals. › PTFE and PFA liners are used in flow meters to control process conditions. Liners protect metal from corrosive media.	The Pharmaceutical Strategy for EuropeEN••• and associated roadmap aims at creating a future proof regulatory framework and at supporting the industry in promoting research and technologies. One of the key pillars of this is to *"supporting competitiveness, innovation and sustainability of the EU's pharmaceutical industry and the development of high quality, safe, effective and greener medicines"*.	N/A
Pressure Vessels for processing of pharmaceuticals, power, and food	Across all pressure vessels – from a home pressure cooker to a three-story pressurizer in a nuclear reactor – a relief valve is required by law for safety. › Industrial relief valves use PTFE, FKM & FFKM in valve seats at high temperatures (>150°C) and high pressures (>100 bar). › Pressure vessels include boilers, heat exchangers, chemical reactors, etc. › Alternative materials do not provide adequate properties for reliable seals on these devices.	The EU Hydrogen strategy includes key actions around boosting demand for and scaling up production and designing an enabling and supportive framework for hydrogen production in Europe.	
Slower Adoption of Sustainability Initiatives	Fluoropolymers such as PTFE are utilized in most decarbonization activities such as H2 production and storage, mobility, wind and solar. Fluoropolymers are used as protective films in solar, coatings, for offshore wind turbines, and membranes for transportation activities involving H2 and battery manufacturing.	The European Green Deal (2019) aims to make Europe climate neutral by 2050. To make this objective legally binding, the Commission proposed the European Climate Law, which also sets a new, more ambitious net greenhouse gas emissions reduction target of at least -55% by 2030, compared to 1990 levels. The Net-Zero Industry Act[11] proposal sets a benchmark for the manufacturing capacity of strategic net-zero technologies to meet at least 40% of the EU's annual deployment needs by 2030.	EU policies are linked to global action, principally the 2015 legally binding international treaty on climate change by UNFCCC, the Paris Agreement. The UN Sustainable Development Goals include a target for the provision of affordable and clean energy (SDG7) – including: › 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services. › 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix. › 7.3 By 2030, double the global rate of improvement in energy efficiency. › 7.B By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.

11 The European Commission proposed the Net-Zero Industry Act (NZIA) on 16 March 2023

7.5 Potential Impacts of a 12-Year Derogation for Fluoropolymers in IAMC Equipment

A 12-year derogation period could provide material suppliers time to develop suitable alternatives, and IAMC suppliers and downstream users time to re-design their products and processes, and/or test the alternative materials to ensure their function, safety, and compliance with applicable standards and regulations (see also performance requirements outlined in **Section 5**). Emerson expects that these activities will need to be executed concurrently as estimated timelines overlap, with the possible emergence of a suitable alternative estimated at 4-6 years and re-designing the IAMC portfolio at 8-10 years. In addition, for many applications, feasible alternatives are currently not available, and so substitution plans involve a high degree of uncertainty and risk. A suitably long derogation period would help reduce this risk of not successfully identifying suitable alternatives and completing substitution before the entry into force of the restriction, and therefore mitigate some of the worst potential socio-economic implications discussed above.

8 EMISSIONS (INCLUDING END-OF-LIFE)

8.1 Introduction

This section includes consideration of the possible emissions to environment. In developing the evidence for this section, we have taken into consideration our own uses to provide information in a format as consistent to the REACH restriction dossier as possible. We therefore note the following important details:

- Based on the definition of PFAS used under REACH and different reference documents it is estimated that between 4,700 and 6,300 unique substances exist. Developing emission estimates on a substance-by-substance basis is hugely challenging and therefore the restriction dossier has used grouping approaches, largely based on emissions of total non-polymeric PFAS, total polymeric PFAS, and total side-chain fluoropolymers. The same grouping approach has been used in this section with only 'total PFAS emissions' provided.
- IAMC suppliers use only fluoropolymer based PFAS within its products with the vast majority meeting the OECD's 13 criteria for polymers of low concern[1]. The sector does not intentionally make use of any non-polymeric PFAS or side-chain fluorinated polymers. During the Q&A session held by ECHA in June 2023[12] it was highlighted that the concerns for fluoropolymer inclusion within the REACH restriction was related specifically to emissions during manufacture of fluoropolymer and end-of-life waste management. On that basis fluoropolymers could be viewed in terms of the full life cycle in a more holistic way. We have therefore structured this section in terms of estimating emissions across the life cycle in terms of manufacturing, service-life, and end-of-life. This is intended to help determine the key stage of release and management measures to limit release. We have also divided our applications into fully closed, partially closed, and open[13] to further help characterize the service life stage.
- IAMC suppliers do not directly manufacture fluoropolymers, but purchase the finalized fluoropolymer components (e.g., O-rings) for assembly within its own manufacturing processes to produce a range of articles for the IAMC sector. There are a small number of cases where it is necessary to cut down or reduce the size of fluoropolymer components to fit within IAMC equipment, which requires machining (grinding/cutting processes). These activities are completed within environmental settings to protect the health and safety of workers and aims to meet the standards set out by best practice under the Industrial Emissions Directive. Furthermore, since the nomination of PFAS for restriction under REACH, options are being explored to phase out this activity.
- The aim, as far as possible, is to provide estimates in a quantitative fashion based on available data and our own investigations. However, this has still been very challenging, due in part to the very robust nature of fluoropolymers and situations in which they have been used. In the cases where it has not been possible to provide quantitative values, the aim has been to still provide a qualitative description of use and potential emission. Again, the ultimate aim of this section is to provide direction on the magnitude of emissions, key points of release during the life cycle, and steps to limit emissions.

12 All Webinars - ECHA (europa.eu)

13 As further comment on this specific aspect we make the following assumptions. 'fully closed' relates to applications where the fluoropolymer component is used within a fully sealed article for the entire duration of its service life. A good example of this might be valve packing or valve seats within sealed units. 'Partially closed' relates to applications which are largely sealed with some potential release. The best example of this relates to liners used in pipework. The pipework itself is fully sealed for the full service-life, however, where the liner forms the inner most layer it means that there *could* be releases into the liquids/gases passing through the pipe with later release to environment. 'open' relates to applications used without containment in both indoor and outdoor environments. The best example of this would be insulating sheaths used on power cables.

As a further comment on developing emission estimates it is noted that developing precise IAMC fluoropolymer emissions are more difficult to assess because they primarily take place at the end of a 15+ year life. Both the benefits and impacts must be considered. On the positive side, fluoropolymer valve packing prevents emissions to the environment due to increased seal efficiency over competing materials. On the negative side, negligible and non-toxic emissions may be released over the entire life cycle of the fluoropolymer product. Despite the relatively small emissions in the IAMC sector, there are further mitigating factors that tend to reduce the concern about emissions even more. The useful lives of IAMC equipment and components are very long, often greater than 15 years. This is in contrast to single use and/or limited lifetime consumer products that reach their end-of-life stage more quickly. Moreover, due to the closed-loop and sealed structure of IAMC equipment, the risk of environmental or human exposure is very limited during the use phase. Even equipment operators are unlikely to come in contact with the fluoropolymers in the system, as the fluoropolymers are utilized in discrete, solid plastic parts that are embedded or lined inside the components of the final end-products.

Another option for estimating IAMC emissions is to leverage the similarities to the Petroleum and Mining use sector and assign values that are on the same order of magnitude.

8.2 Manufacturing

IAMC suppliers do not directly manufacture fluoropolymers. All components made of fluoropolymers or containing fluoropolymers are pre-manufactured by upstream suppliers and provided as final components (i.e., O-rings). Based on the Q&A held by ECHA in June 2023 we understand the major concerns for fluoropolymers as a source of PFAS emissions relates to the manufacture of fluoropolymer (particularly using non-polymeric PFAS as a processing aid) and to the waste management aspects, particularly incineration. Where IAMC suppliers sit within a wider supply chain, they have more limited influence on upstream activities. However, options are being explored with suppliers to better understand whether the fluoropolymer components will be made using non-polymeric PFAS as processing aids.

The aim is to source as far as possible fluoropolymer components that were made with non-polymeric PFAS processing aids. If this is not possible, we will also work with our suppliers to help support the transition to PFAS-free processing aids.

The manufacturing stage of the process covers the assembly of components into finished articles for use by downstream customers. In a very limited number of cases, it is necessary to machine certain components to reduce their size in order to facilitate assembly. This includes cutting/grinding processes to reduce the size of the component. In these cases suitable abatement technologies are utilized to limit direct exposure of workers to any dusts, and collect the dusts for waste management.

These dusts currently go to waste disposal (landfill) but could be further managed. We note that Daikin[14] has recently launched 'the group basic environmental policy' which includes the collection of debris from production processes (PTFE, PFA, FEP) whether manufactured in-house or otherwise. The quantity of debris created by machining processes is low (0.5 - 2.5% w.w. equivalent to 11 - 55 tonnes per annum) but could be sent to Daikin for repelletization. This is an aspect we would be willing to explore further in the future if economically reasonable.

On this basis we expect the total emission of fluoropolymer to air, land, water to be negligible and waste generation to be less than 55 tonnes per annum.

14 https://www.daikinchemicals.com/company/sustainability/fluoropolymer-recycle.html#:~:text=These%20waste%20materials%20are%20turned,materials%20for%20tubes%20and%20pipes.

8.3 Service Life

As noted in the introduction to this section, fluoropolymer components within an article are considered in fully closed, partially closed, or open systems. For a component within a fully closed system, the fluoropolymer emissions during the component's service life are negligible, as the component is fully encapsulated within the article. Fluoropolymer degradation can occur during the component's service life, however as the system is fully closed, there is no opportunity for environmental emissions from this degradation.

For partially closed and open systems, fluoropolymer emissions are non-zero, with the extent of the emissions depending on the conditions to which the component is exposed. In the case of partially closed systems, such as liners, repetitive, abrasive mechanical degradation can take place. In general, it has been found that surface abrasion on a fluoropolymer is highly dependent on the fluoropolymer type, as well as the particle size and type[15]. Surface abrasion is an opportunity for mechanical degradation of micro-particulates of the fluoropolymer which become emission sources when leaving the partially closed system. Surface abrasion also alters the hardness and the hydrophobicity of the fluoropolymer, further increasing the opportunities for emissions in partially closed systems. Precautionary measures are taken for partially closed systems by conducting particle counts on regulators with fluoropolymer value seatings and adding an inline filter to remove further particulates.

In an open system, the extent of emissions further increases, as the external conditions can be variable and unpredictable. For example, the cable sheathings are typically used in the following environmental conditions:

- Low Temperature: -55°C
- High Temperature: 200°C
- Indoor/Outdoor proportionality: 70% Indoor/30% Outdoor
- Humidity: Ambient
- Dust: No issues

In open systems, there are more opportunities for fluoropolymer emissions. While the environmental conditions for IAMC products are not considered extreme for fluoropolymers, repetitive significant changes in operating conditions over time lead to polymer aging, and an increased opportunity for fluoropolymer emissions[16]. As mentioned for partially closed systems, fluoropolymer abrasion during service life can occur, however in the case of the open system, there are no measures in place to contain the particulates.

The summary of IAMC's main product categories and anticipated emissions for fluoropolymers within the categories can be found in **Table 8.1**.

15 Guerrero-Vaca, G. and Rodriguez-Alabanda, O. Analysis of Wear Phenomena Produced by Erosion with Abrasive Particles against Fluoropolymeric Coatings. Polymers (14) 21, 2022. https://www.mdpi.com/2073-4360/14/21/4617

16 Zepp, R., et al. Fragmentation of polymer nanocomposites: modulation by dry and wet weathering, fractionation, and nanomaterial filler. Environ. Sci.: Nano, 2020, 7, 1742-1758. https://pubs.rsc.org/en/content/articlehtml/2020/en/c9en01360a

TABLE 8.1 **Anticipated emissions of fluoropolymers in IAMC equipment**

	LINERS	SEALS	VALVE PACKING	VALVE SEATS	CABLE & WIRE INSULATION	ELECTRONICS
	Pressure, Flow, Level, Temp	**All IAMC Equipment**	**Control & Isolation Valves**	**Valves, Regulators, Actuators** **Semiconductor Application**	**All IAMC Equipment**	**All IAMC Equipment**
System Type	Partially closed	Fully closed	Fully closed	Partially closed	Open	Partially closed
Emissions of fluoropolymers from IAMC equipment (e.g., weight of new and worn components to determine material loss).	Not an appreciable amount	None	None	Not an appreciable amount, especially in semiconductor manufacturing where the only plastic part in the regulator is the valve seat. The seat is not overloaded so friction stress is low. Particle count is conducted on regulators before release (often zero). Also, a filter is in line to prevent contamination throughout the process. If particulate is shed, it won't be seen. SEMI F70 particle count standard is followed for particle count evaluation (mostly zeros) on all regulators before they are shipped from Emerson. ASTM F1394 is also followed for determination of particle count.	Material is robust and inert, zero emissions expected.	No data available

8.4 End-of-Life

8.4.1 WASTE MANAGEMENT

Once the equipment containing fluoropolymers reaches the end of the service life phase there are effectively three waste management options. This covers the potential for recovery and recycling, disposal in landfill, and destruction through incineration at Energy from Waste (EfW) plant. IAMC equipment is designed so that it can be disassembled and separated at the end-of-life for processing or re-use in a circularity methodology. Based on discussion with customers, information is provided in **Table 8.2** to provide best estimates for the current disposal pathways for IAMC products that contain fluoropolymer. It should be considered that supply chains can be complex and we have collated the data available to us. This may mean some deviation from the estimates for any missing respondents / changes on day-to-day demands.

By volume (see **Table 4.1** with tonnages), the highest usage of fluoropolymer within IAMC products is for seals, which makes up 70% of all fluoropolymer used within this sector. This category also has the highest rates of recovery and recycling (65%). In terms of total fluoropolymer used annually in IAMC products (2,140 tonnes), just under 55% (1,170 tonnes) is sent for recovering and recycling, with a further 32% (677 tonnes) sent to landfill and 13% (285 tonnes) sent for thermal destruction. Further commentary on recycling and the types of recycling process is provided in **Section 8.4.2**.

During the ECHA Q&A held in June 2023, the primary concerns for release of PFAS from fluoropolymers was highlighted as being during the manufacture of fluoropolymer (particularly where non-polymeric PFAS is used as a processing aid), and during the end-of-life management, particularly incineration.

Based on the data gathered and waste disposal options, the lion share of the fluoropolymer sent for thermal destruction will be PTFE (40-50%), with the next major substances being PCTFE, FKM, FFKM, and EFTE. The remaining substances which make up a minor contribution (5% or less) are PFA and FEP. The stability of fluoropolymers varies depending on the specific fluoropolymer, with PTFE being the most stable. NILU, 2009[17] documents a literature review for the fate and behavior of fluoropolymers during thermal destruction. At 800°C, the NILU study notes that the major breakdown metabolite is hexafluoropropylene (HFP). HFP is a colorless gas, which has also been identified as having uses as a raw material in other manufacturing processes, particularly the pharmaceutical industry[18]. Within the correct management process capture of flue gas could be used to prevent release and present a more circular management of PTFE waste.

Based on NILU's study for the remaining fluoropolymers the major breakdown products during thermal destruction up to 800 Celsius include, tetrafluoroethylene (TFE, the monomer of PTFE), perfluorobutylethylene (PFBE), perfluoroisobutene (PFIB), chloropentafluorpropene (CPFP), chlorodifluoroacetic acid (CDFA), and carbonyl fluoride (COF_2).

Monitoring data from the Environment Agency of England[19] based on municipal incinerators estimated that per tonne of solid waste thermally destroyed approximately 30kg of air pollution control residues (fly-ash) are generated and a further 250kg of grate ash (bottom ash). It is assumed that bottom ash fraction exceeds the 5mm diameter definition of 'microplastics'. However, the fly ash fraction is likely within the scope of the definition. Based on 285 tonnes of fluoropolymer waste thermally destroyed per annum this equates to around 8.5 tonnes of microplastic based fluoropolymer. However, it is also noted that fly ash is extremely toxic and is managed as a hazardous waste, with additional controls that would limit release to the environment.

17 NILU, 2009, Emissions from incineration of fluoropolymer materials, a literature survey.
18 Hexafluoropropylene Market Size, Trends & Share - 2028 | FMI (futuremarketinsights.com)
19 Environment Agency (2002) Solid Residues from municipal waste incinerators in England Wales Published by the Environment Agency (UK)

Aside from incineration, the second most important disposal option (by volume) is landfill, with an estimated 32% of all fluoropolymers used within IAMC products consigned to landfill. As a general statement, manufacturers are committed to achieving the sustainability goals outlined within the EU Green Deal and continuing to improve upon recovery and recycling rates. As a comment on waste fluoropolymer consigned to landfill, it can be noted that fluoropolymers are inherently safe, non-mobile, non-bio accumulative and non-toxic. Waste is chemically inert and therefore, fluoropolymers disposed in landfills do not pose any substantive threat to human health and the environment.

TABLE 8.2 Best estimate for end-of-life processing pathways for IAMC products containing fluoropolymer

	LINERS	SEALS	VALVE PACKING	VALVE SEATS	CABLE & WIRE INSULATION	ELECTRONICS
Recovery & Recycling	25%, flow meters are likely recycled as a unit so the liner is included and would be a contaminant	65%, flow meters are likely recycled as a unit so the seals are included and would be a contaminant	25%, valve packing is likely recycled as a unit so the valve packing would be a contaminant	50%, regulators are likely recycled as a unit so the PCTFE valve seat is included in the unit and would be a contaminant.	0%	No data available
Incineration	25%	10%	25%	10%	0%	No data available
Landfill	50%	25%	50%	35%	100%	No data available
Additional end-of-life details	The manufacturing equipment will be recycled (scrap metal), but the liner is likely to be recycled with the electromagnetic flow meter or thrown in the landfill with the meter	The manufacturing equipment will be recycled (scrap metal), but the seal is tiny and likely to be recycled with the device or thrown in the landfill with the device	Sensors are generally recycled for the raw metal at end-of-life, rest of sensor is landfill	The manufacturing equipment will be recycled (scrap metal), but the valve seat is tiny and likely to be recycled with the regulator or thrown in the landfill with the regulator	Sensors are generally recycled for the raw metal at end-of-life, rest of sensor is landfill	No data available

8.4.2 RECYCLING

Polymer recycling has become increasingly popular as an end-of-life option over the past few years, and is done either mechanically or chemically. Fluoropolymers can be chemically returned back to their building blocks for reconstruction without damage to their properties.

With the increased push for circular economy, a number of recycling programs and methods have been developed. 3M and Invertec, along with others, partnered from 2005-2014 to develop a recycling process for PTFE[20]. Companies such as Daikin[21] and Performance Plastics[22] currently offer recycling for excess fluoropolymer waste from the production process, with both companies accepting fluoropolymers (such as PTFE, PFA, and FEP) from any production stream. Within the manufacturing industry, the mechanical recycling of some fluoropolymers, such as PTFE, is built into the overall process by creating a PTFE micropowder from excess polymer[23]. Industrial high temperature pilot scale work is also being done to use vacuum pyrolysis to regenerate gas-phase monomers from end-of-life industrial fluoropolymer applications[26].

20 https://www.invertec-ev.de/en/projects/environmental-care/ptfe-recycling/
21 https://www.daikinchemicals.com/company/sustainability/fluoropolymer-recycle.html
22 https://hpp.arkema.com/files/live/sites/hpp_extremematerials/files/downloads/article-reprints/kynar-article-reprints/2022-06-kynar-ar-pvdf-a-recyclable-fluoropolymers-and-polyolefin-processing-recycling-aid.pdf
23 https://pubs.acs.org/doi/full/10.1021/acs.est.0c03244

In the case of fluoropolymers or co-polymers that have fluoropolymer components, recycling is a more straightforward process. Melt-processable fluoropolymers, can be recycled through traditional mechanical methodologies. The thermal reprocessing of PFA has shown negligible decrease in the physical properties of the polymer, and the use of extrusion chemistry decreases manufacturing emissions[24].

Recycling however becomes more difficult as the fluoropolymer and end use application become more complex. Some fluoropolymer applications, such as coatings for metals on non-stick cookware, present a unique challenge for recycling as the fluoropolymer needs vastly different recycling conditions than the metal does. However, in some cases layered products can be separated. For example, in electronic applications, the fluoropolymer sheets can often be separated from the other polymer laminate layers through the use of solvents and reused in manufacturing[25].

For thermal recycling of melt-processable fluoropolymers, the recycling emissions are negligible. For mechanical grinding to recycle non melt-processable fluoropolymers, the recycling emissions are dependent on the system used for grinding, such as the particle containment and dust mitigation. In the cases of chemical recycling, the emissions are again dependent on the technique and tools used to accomplish the recycling. If fluoropolymers are not treated on their own but rather recycled with the overall article, the entire recycling stream will be subject to fluoropolymer emissions.

8.5 Summary

This section has presented to our best knowledge the data available on the manufacture, use, and waste management of components containing fluoropolymer utilized in IAMC products. The results of the analysis suggest that the bulk of the potential emission occur during manufacturing and end-of-life, with very low to near negligible releases during service life.

In terms of manufacturing and waste, the key issues relate to waste generation and management of that waste to prevent environmental release. Total fluoropolymer waste generation during manufacturing processes utilised in IAMC products equates to 0.5 – 2.5% w/w of total fluoropolymer used. Note that this is not direct environmental release but rather dust generation to be managed. During waste handling 55% of all end-of-life fluoropolymer is recovered and recycled, with the next biggest disposal option being landfill (32% by volume). The remainder (13%) is sent for thermal destruction. This is likely the biggest potential release of PFAS from fluoropolymer during incineration. It has not been possible to estimate this release, other than to note 28% (280kg per tonne) ends up as fly ash or bottom ash. The bottom ash fraction likely exceeds the definition of microplastics (i.e., particles will be bigger than 5mm), while fly ash (estimated as 8.5 tonnes per annum) is managed as a hazardous waste to limit release as far as possible.

24 Romoaldo, C.H., et al. Recycling Tetrafluoroethylene–Perfluoroalkyl Vinylether Copolymer (PFA) Using Extrusion Process. Materials and Engineering, 2023. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1002/mame.202200458

25 https://link.springer.com/article/10.1007/s10163-023-01609-8

9 ENDING STATEMENT

In closing, our derogation request is two-fold, as follows:

1. **Incorporation of IAMC equipment as a use sector, and**
2. **A 12-year derogation of fluoropolymers for use in IAMC equipment.**

Fluoropolymers are clearly differentiated from other substances in this very broad group of PFAS chemicals. There is strong evidence that suggests that these materials will not give rise to situations of concern for human health or the environment, acknowledging as well that industry needs to continue making significant progress to limit the use of PFAS polymerization aids and to introduce adequate abatement techniques to keep emissions of potentially harmful fluorinated by-products under adequate control.

Fluoropolymers are known for providing many beneficial properties simultaneously (combined in single products) that allow the continued development of applications critical to society, not only related to technological progress, but specifically in terms of safety to the population and development of green energy alternatives.

In conclusion, Emerson recommends incorporation of IAMC as a new use sector and a 12-year derogation for fluoropolymers for use in IAMC equipment as part of the upcoming REACH PFAS restriction, as outlined in Restriction Option 2 (RO2). This position is consistent with Emerson's continued commitment to preserving environmental sustainability and human health and as an advocate of restricting the use of harmful substances. Emerson is also committed to compliance with all relevant environmental laws and regulations in the countries in which we operate.

This submission was preceded by Emerson's summary derogation request, which was submitted on 9 May 2023.

We appreciate the opportunity to provide this information and thank you for your time and consideration of our requests. We invite you to reach out to us for additional information or discussion regarding our request.

Contact Details:

Amy Neal | [redacted]@emerson.com

Wes Childers | [redacted]@emerson.com

EMERSON
http://www.emerson.com/

Appendix A:
CASE STUDIES

TITLE	DESCRIPTION OF USE	IAMC EQUIPMENT USED	COMPONENTS	FLUOROPOLYMERS USED	FUNCTION	PERFORMANCE PROVIDED
Improved Chlorine Analysis for Effective Disinfection Reduces Water Treatment Costs[26]	Water must be properly treated before it can be used by the public as a safe and reliable source for drinking. Chlorine has commonly been used as a chemical disinfectant of drinking water for over a century. Water treatment plants have struggled with the question of how to best measure free chlorine in drinking water. IAMC equipment is helping to measure free chlorine, total chlorine and monochloramine to ensure clean water.	Chlorine Sensor	Membrane Seal	PTFE ; FKM	Amperometric chlorine sensors use a membrane to allow chlorine species to diffuse through to the electrodes while protecting the electrode from fouling. Key function provided by the fluoropolymer: Chemical resistance and membrane permeation	Sensors with amperometric technology provide the following performance: › Reagent free - no costly consumables replacement › Very low maintenance › Freedom from interference › Low error, and no errors due to reagent depletion › Consistent, constant, and accurate analysis › No hidden components or added chemicals that need checking and replacement, providing substantial benefits to water plants.
Emerson Solution Accelerates Fermentation Facility Start-Up at Pharmaceutical Plant[27]	A pharmaceutical company built a new fermentation facility that was controlled by an Emerson DeltaV™ distributed control system (DCS). The company wanted an Emerson process control solution that was easy to configure within the Delta V environment and offered complete interoperability with the production system. The fermentation process involves the use of bacteria, yeast or fungi to produce a specific active ingredient or intermediate, which is then extracted and purified to create the pharmaceutical product.	Valve and Distributed Control System	Valve: Seal DCS: Electronics	Seal: FKM Electronics: PTFE	Chemical resistance, temperature	With the compact solution the customer had easy access to the valves and saved time and cost.

26 https://www.emerson.com/documents/automation/white-paper-effective-chlorine-analysis-for-disinfection-en-5463798.pdf
27 https://www.emerson.com/documents/automation/wln1016-pharmaceutical-preparations-web-en-7509780.pdf

TITLE	DESCRIPTION OF USE	IAMC EQUIPMENT USED	COMPONENTS	FLUOROPOLYMERS USED	FUNCTION	PERFORMANCE PROVIDED
The Role of Hydrogen in Carbon Reduction / TESCOM Air Operated Valve Helps H2 Refueling Stations Handle More Pressure and Reduce Fill-up Times  	Recent years have seen a rapid growth in hydrogen electrolysis plants. Companies across the hydrogen value chain are working on large-scale projects to advance hydrogen fuel's availability, its ease of use, and expand its contribution to decarbonization. Scaling up each area presents major challenges, in terms of efficiency, process control, safety, and reliability. It is critical to identify technologies that can reliably and efficiently control hydrogen fuel, from production through end use. The portfolio of IAMC equipment that supports the H2 economy is vast. For an electrolyzer to work effectively and safely, the flow of water, hydrogen, and oxygen must be precisely controlled.	Multiple	Liners, o-rings, valve packing, valve seats, electronics, etc.	Multiple (incl. FFKM, Perfluoroelastomer (Kalrez®), FKM)	High temperature, chemical resistance, and surface wetting and diffusion through Proton Exchange Membrane (PEM) membrane.	Reliable valves, back-pressure regulators, and an intelligent programmable logic controller (PLC) with Supervisory Control and Data Acquisition (SCADA) can provide four layers of media control, preventing leaks and minimizing maintenance time and costs while protecting the plant at large. Improving the pressure rate — and thus the fill rate — of a hydrogen refueling system, and reduced refuelling times.

TITLE	DESCRIPTION OF USE	IAMC EQUIPMENT USED	COMPONENTS	FLUOROPOLYMERS USED	FUNCTION	PERFORMANCE PROVIDED
Innovations in Pressure Regulators Support Yield Optimization in Semiconductor Manufacturing[29]  	There is growing pressure (in Europe and globally) to increase chip production: Yields, pushing manufacturers to search for solutions that will increase productivity while allowing them to take tighter control of quality. Modernizing an operation with cutting edge automation and data analysis tools to speed up production is costly, particularly for those manufacturers who have long-established and deeply rooted systems and controls. New innovations in gas delivery components are emerging. Because there are so many gas delivery systems involved in semiconductor manufacturing, the pressure regulators that use control gas flow have taken center stage as a critical component in the pursuit of better yields. The more precise pressure and flow control and improved cycle times afforded by newer pressure regulator designs are helping manufacturers more tightly control gas delivery, which is directly tied to higher product quality and higher yield. Regulators control the flow rate and pressure in precise gas delivery systems used in semiconductor manufacturing, including H2 for plasma cleaning and etching, surface passivation, and reducing oxide layers, oxygen for the oxidation of silicon and argon for sputter of metals.	Regulators TESCOM™ 64-5000 Series Subatmospheric Pressure Regulator TESCOM™ ACS3200 Series Changeover Pressure Regulator	Valve Seat	PCTFE	High purity, chemical resistance, mechanical properties (compressive modulus)	Allow pressure regulators to deliver safer and more reliable performance and contamination control in many types of ultrahigh-purity gas delivery systems. High purity regulators ensure no impurities / control of contamination into the process once the regulator is installed, as well as leak integrity within the regulator body. Advances in the pressure regulator's internal design, such as reductions in volumes and modifications to the diaphragm, have improved cycle times by reducing the amount of required to purge the regulator during changeover.

29 https://www.emersonautomationexperts.com/2022/fluid-control-pneumatics/the-chip-shortage-continues-how-semiconductor-manufacturers-are-responding/#:~:text=Innovations%20in%20Pressure%20Regulators%20Support,and%20yield%20in%20semiconductor%20manufacturing.

Endnotes

1 Korzeniowski, S.H., Buck, R. C., Newkold, R. M., El kassmi, A., Laganis, E., Matsuoka, Y., Dinelli, B., Beauchet, S., Adamsky, F., Weilandt, K., Soni, V. K., Kapoor, D., Gunasekar, P., Malvasi, M., Brinati, G. Musio, S. (2022) A Critical Review Of The Application Of Polymer Of Low Concern Regulatory Criteria To fluoropolymers II: Fluoroplastics, and fluoroelastomers, Integrated Environmental Assessment and Management, 19(2), 326. https://doi.org/10.1002/ieam.4646