FREUDENBERG
SEALING TECHNOLOGIES

FREUDENBERG
INNOVATING TOGETHER

Freudenberg FST GmbH
Hoehnerweg 2-4, 69469 Weinheim

Weinheim, August 8, 2023

Statement on PFAS - EU restriction proposal

Content:

1. Introduction

Freudenberg Sealing Technologies (FST) is a leading supplier of advanced sealing products for customers in the automotive and general industry. In researching, developing, and introducing innovative product and process solutions, the company benefits from more than 170 years of engineering and materials experience. The focus has always been on the technological demands and requirements of our customers.

Since the development of the Simmerring® rotary shaft seal in 1929, FST has continuously expanded its portfolio of industrial seals and components, offering a large variety of technological solutions that address critical factors such as performance, durability, friction, emissions, and material compatibility. In addition to a wide range of in-house developed, high-quality, engineered sealing solutions, the company also works with its customers to design and validate their specific sealing systems.

With the world's largest range of seals, FST offers sealing products for everything from dental drills and filling lines to wind turbines, aircraft, and automotive transmissions. Seals are often small components, usually invisible but essential for the smooth functioning and long service life of the system in which they are installed. In all application areas and industries, the company's unique materials expertise and continuous innovation create the basis for continued customer satisfaction. The company operates at 60 locations worldwide with appr. 13,000 employees. Sales in 2022 amounted to 2,455 million euros.

FST fully supports the goals of the European Green Deal and the Chemicals Strategy for Sustainability to improve protection of human health and the environment from risks posed by chemicals. Preventive health care, environmental protection, occupational safety, the safety of machines, production lines and processes, and product safety as well as good corporate citizenship are of great importance at FST.

FST aims to continuously reduce its environmental impact throughout the entire value chain. While developing new products and technologies safe and environmentally sound manufacturing, utilization, and disposal practices are adopted. In addition to this, FST is constantly focusing its efforts on reducing the environmental impact by using natural resources more efficiently, lowering emissions, saving energy, water, and other operating materials, as well as optimizing transportation processes. Waste is handled in accordance with the principle that prevention is better than recycling is better than disposal. Residual substances that can neither be avoided nor recycled are disposed of in a responsible manner and in accordance with national regulations. FST's management systems comply with internationally recognized standards such as the environmental protection standard ISO 14001 and the EU Eco-management guidelines.

2. Why Fluoropolymers are important for sealing applications

Fluoropolymers, especially the fluorinated elastomers FKM and FFKM, the fluorinated silicones FVMQ as well as Polytetrafluoroethylene PTFE have unique properties as base materials for gaskets and seals, most importantly high temperature stability and media resistance (e.g. against fuels, acids, bases, high performance lubricants such as motor and gear box oils, hydraulic fluids), excellent wear resistance and low friction properties, corrosion resistance and permeation tightness.

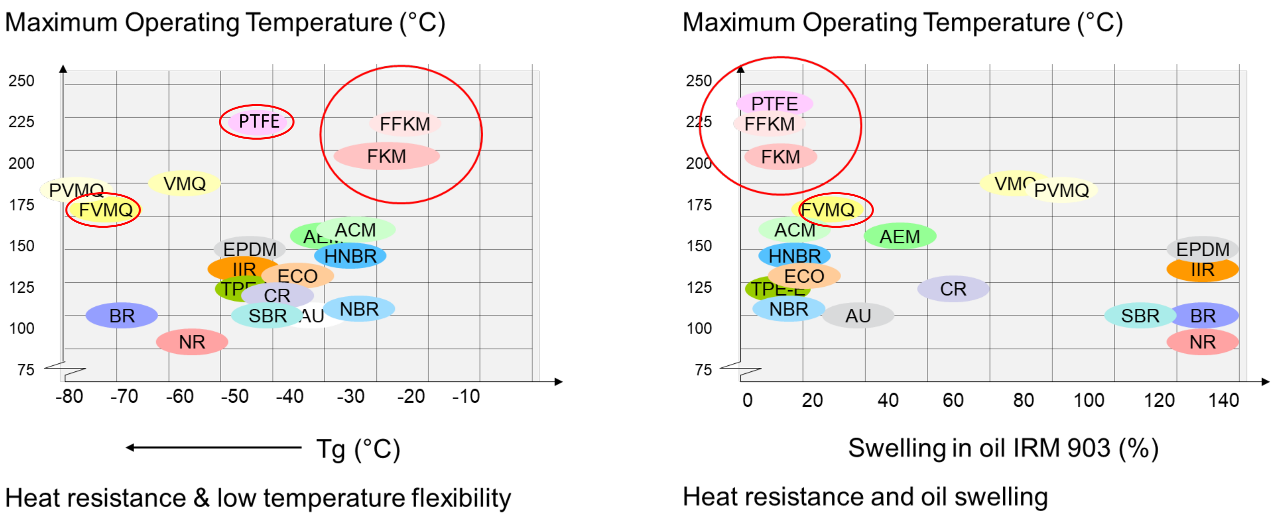

Figure 1: *Classification of elastomer materials according to ASTM D2000 / SAE J200*

Due to their unique property profile, fluoroelastomers and PTFE are used in high-performance sealing materials in wide-spread applications from transportation, general industry, process industry, food & beverage as well as in future technologies like fuel cells or batteries.

Replacing fluoroelastomers or PTFE in sealing applications with other polymer classes always comes with a considerable loss of performance resulting in reduced lifetime of the respective component or system. This loss of functionality leads to premature failure of the seal, which can cause leakage, leading to emissions of the respective fluids to the environment and associated safety issues and result in major damage or complete destruction of the entire system (e.g. a valve, engine, gearbox, hydraulic system).

Seals used in dynamic applications which renounce the use of fluoroelastomers and PTFE are subject to premature wear due to higher abrasion and cause increased fuel/energy consumption due to increased friction.

To avoid unexpected leakage and major damages, seals made of other polymers would have to be replaced frequently and preventively, necessitating extra down times and expensive maintenance intervals. In many applications a premature and unplanned replacement of a seal is not possible at all (e.g. in offshore wind turbines or ship engines)

It is important to note that fluoroelastomers and PTFE-based materials are expensive and show a significant price gap to other classes of elastomers. They are therefore primarily used when no other polymer class provides the necessary performance and customer specifications cannot be met with other materials. (1)

The following examples of fluoropolymers used in demanding sealing applications demonstrate this:

Engine & Power Transmission Industry:

Today's power transmission industry faces ever-growing challenges when it comes to increased lifetimes, reduced maintenance costs and increased fluid compatibility. Only enhanced fluoropolymer materials adequately perform in state-of-the-art synthetic and biodegradable lubricants while delivering superior high-temperature resistance. These materials get specifically designed to extend for example the service life of a gearbox with significant lower wear band and shaft run.

Aviation Industry:

Seals for the aerospace industry must withstand extreme heat and cold, wide temperature fluctuations, pressure, humidity, ozone, and UV radiation. Emerging trends such as increased fuel efficiency, reduced emissions and lightweight can only be realized with state-of-the-art materials. The International Air Transport Association's (IATA) goal of zero carbon emissions is slated to be in effect by the year 2050, thus requiring many airports to start using alternate fuels such as kerosene and biofuel. As the aviation industry evolves, efforts to manufacture aircrafts with leading-edge technology will continue. Only high-performance fluoropolymer materials combine the multitude of properties needed for seals in such a demanding environment.

Chemical Industry:

During chemical processing it is highly important that no harmful or toxic substances are released to the environment. Thus, sealing materials must resist particularly aggressive, at times highly toxic chemicals as well as high pressures and high temperatures. The infrastructure in the chemical industry is unthinkable without fluoroelastomers and PTFE.

Pharmaceutical and Medical Industry:

Fluoropolymer seals are used in a wide range of pharmaceutical and medical applications, for example in dosing units for the filling of vaccines or other medications. Since the purity requirements for processes and products in the pharmaceutical industry are particularly stringent, materials must meet the highest requirements of international standards. Seals must be resistant to the product media that are needed to manufacture an active pharmaceutical ingredient. In addition, they must withstand cleaning cycles with the appropriate media for cleaning and sterilization processes, in combination with the difficult conditions of a hygienic plant design. Therefore, fluoropolymer seals have to pass cytotoxicity tests according to internationally acknowledged guidelines by the United States Pharmacopeia and National Formulary (USP) as well as additional standards e.g. EN ISO 10993-5:2009.

Food and Beverage Industry:

A variety of seals are installed in bottling plants, such as O-rings, valve seals, seals in sensors, pumps, heat exchangers & filters. To meet the demanding requirements of the F&B industry, sealing solutions and specially developed materials must withstand aggressive cleaning processes, food media as well as extreme temperatures, high pressure, flavors, and other chemically problematic media. Most importantly the seals must not change the food composition, influence its organoleptic properties, or endanger human health. Therefore, fluoropolymer seals used today fulfill European food regulations EU1935/2004 and EU10/2011.

3. Use cases: Availability of suitable alternatives

Fluoropolymer seals are used in applications under harsh conditions with high temperatures (> 200 °C) and/or in combination with aggressive chemicals where other elastomer materials fail. The following examples demonstrate the unique performance of fluoropolymers under relevant working conditions in industries such as chemical, transportation and food processing. The comparison with other classes of elastomers like Ethylene-Propylene-Diene-rubber EPDM or hydrogenated Nitrile rubber HNBR demonstrates the lack of available alternatives to replace fluoropolymers.

3.1 Heat resistance and effects on physical properties

Fluoropolymers like PTFE and fluoroelastomers like FKM or FFKM have excellent heat resistance properties. This is an advantage that reliably safeguards applications in e.g. the chemical and pharmaceutical industries with process temperatures exceeding 140 °C and aggressive media that materials such as EPDM or HNBR cannot cope with. In applications with continuously high temperatures, irreversible chemical and physical processes such as polymer chain cleavage, post-crosslinking or re-combination lead to degradation of unsuitable elastomer materials. This results in an increase in hardness and a deterioration in mechanical properties such as tensile strength, elongation and ultimately loss of elasticity. Additional formation of microcracks limits the service life of the elastomer material. Table 1 provides exemplary data which demonstrates the superior heat resistance of FKM materials compared to EPDM or HNBR.

Table 1: *Change of mechanical properties after heat aging for EPDM, HNBR and FKM in comparison*

		EPDM	HNBR	FKM
Heat aging – 1 week @ 180°C				
Change in hardness	Point	2	11	1
Change in tensile strength	%	-68	-60	19
Change in elongation at break	%	-77	-88	1
Compression set (DIN 53517)	%	28	58	31

3.2 Swelling in different media (mineral and biodegradable fluids)

The degree of swelling of an elastomer material in contact with a given fluid over time is of highest importance for the proper functioning of a seal. (2) Excessive swelling leads to complete deterioration of the seal causing severe leakage and in the worst case complete destruction of the system in which the seal is mounted (e.g. pump, gearbox, engine, compressor, hydraulic system). Topics such as miniaturization, increasing temperature ranges and highly corrosive media are just a few of the ongoing challenges in fluid handling, besides the constant threats of contamination of the interior part of the system and leakage. For quite a number of fluids and applications robust and durable seals can only be made from FKM- or PTFE-based materials.

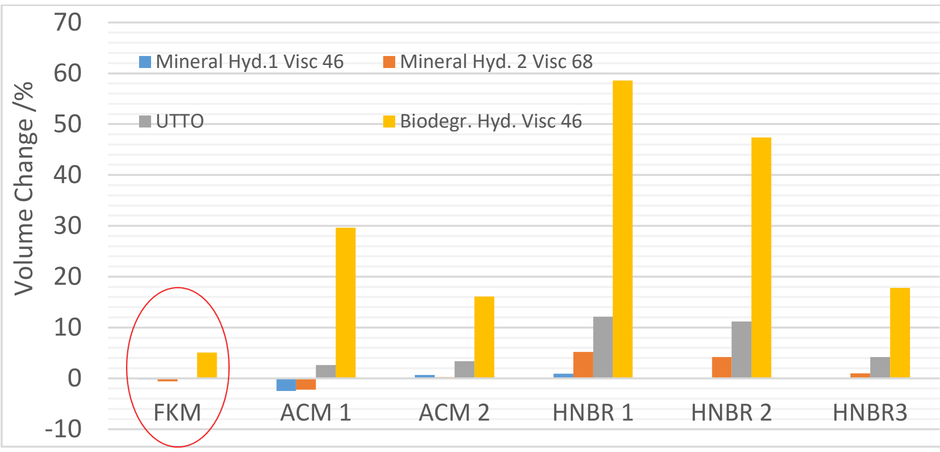

Figure 2: *Comparison of swelling behavior of different elastomer materials in mineral and biodegradable fluids (UTTO = Universal Tractor Transmission Oil)*

3.3 Friction and wear

Many fluoropolymers, above all Polytetrafluoroethylene (PTFE) are indispensable for dynamic sealing applications, where the seal is in constant contact with a moving surface against which it needs to permanently seal (e.g. a moving rod in hydraulics, a rotating shaft in engines or transmissions, a valve). (3) When rubbed or slid against a hard surface, suitable PTFE compounds exhibit a very low coefficient of friction and low rates of wear. At the same time PTFE compounds are highly temperature stable and resistant to fuels and lubricants such as engine or gearbox oils. Especially without the presence of a lubricant, PTFE exhibits low friction values and less wear than other thermoplastics as shown in Figures 3 and 4.

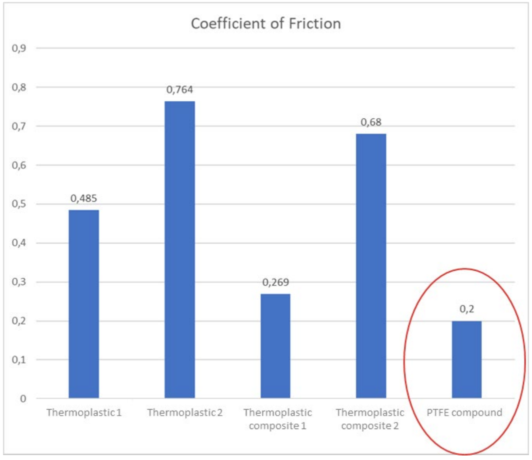

Figure 3: *Comparison of coefficient of friction for different thermoplastics under dry friction conditions; counter surface stainless steel Ra ~ 0,3 µm, Rz 2.5 µm*

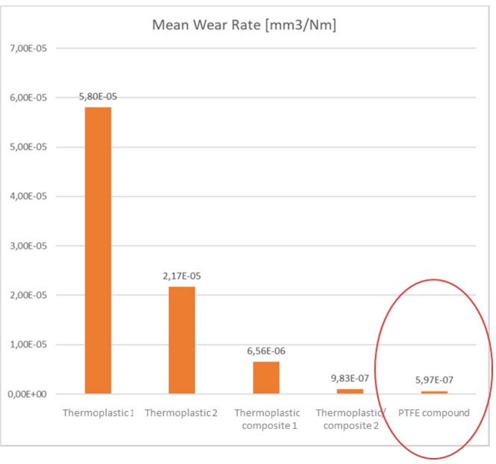

Figure 4: *Comparison of the mean wear rate for different thermoplastics under dry friction conditions; counter surface; stainless steel Ra ~ 0,3 µm, Rz 2.5 µm*

Low friction of a dynamic seal not only means extended lifetime and safety for the system in which the seal is mounted, but also considerably lower drive energy resulting in lower fuel consumption and significant energy savings in operation. The aspect of low CO_2 emissions is becoming increasingly important and will become another differentiator in the sealing industry in the not-too-distant future. Up to 99% of the CO_2 emissions associated with a dynamic seal are generated during its service life.

3.4 Permeation

In many applications it is essential to guarantee the lowest possible permeation of gases and liquids through the elastomeric sealing material to ensure safe operation of the system (i.e., no loss of pressure, no loss of protective gas, no loss of any liquids) and to avoid any loss of harmful fluids to the environment.

The permeation tightness of a seal is essentially determined by the base polymer used. Depending on the application (temperature, pressure, type of fluid) the choice of suitable materials is limited and the use of FKM or PTFE is particularly essential when high temperatures, aggressive media and requirements for minimal abrasion and maximum tightness come together in use.

As seen in Figure 5 permeation coefficients of different base rubbers differ by orders of magnitude with FKM and PTFE being at the low end.

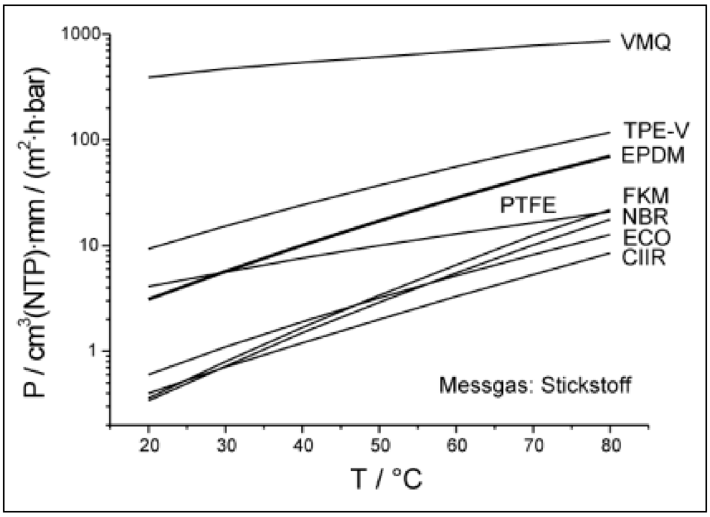

***Figure 5**: Comparison of permeation coefficients of elastomer material in nitrogen* (4)

In this context also the failure mechanism of explosive decompression, which is caused by the rapid drop in pressure of a gaseous medium needs to be mentioned. Gas that has permeated into the elastomeric seal will expand violently when the pressure is quickly released, resulting in cracking and failure of the seal. This phenomenon is well known in all applications where gases under high pressures have to be sealed (e.g. in the petroleum & mining industry, in submarine applications and in the emerging Hydrogen industry). Fluoropolymers are often used in these applications because they offer a unique combination of superior physical and chemical properties, as well as excellent compressive strength. The stringent requirements for permeation resistance are tested according to Norsok M-710 RGD, Norsok M-710 sour gas and ISO 10423 (API 6A) chemical aging, immersion, and fixture testing.

3.5 Flavor transfer

In the food & beverage industry, a variety of seals are installed in bottling plants, such as O-rings, valve seals, seals in sensors, pumps, heat exchangers & filters. The seals are in permanent contact with food products, so that in some instances aroma substances (terpenes, esters, aldehydes…) can migrate into the elastomer due to a similar solubility of the aroma substance with the elastomer. This poses the danger of carryover of the flavoring substances to the next filled food product. Even with thorough standardized cleaning processes, no complete removal of the flavor out of the seal is possible. The consequence is disposal of contaminated food batches. While it would be possible for food processors to increase their machinery fleet to have designated bottling equipment for single food products to prevent cross-contamination, it would mean a much higher invest and running costs. Performing additional more aggressive cleaning cycles (higher temperatures, higher concentrated chemical cleaners) would mean an overall reduction of a sustainable production process. The solution to reducing flavor transfer is advanced fluoropolymer seals. An independent study by Dienstleistungszentrum Ländlicher Raum (DLR) Rheinpfalz, Institute for Viticulture and Oenology shows how fluoropolymer seals significantly reduce flavor transfer compared to seals made of commonly used EPDM. Tests were done with mulled wine containing the flavor substances like Eugenol and Cinnamic aldehyde. (5)

Terpenes like limonene, which are present in citrus fruit oils, are highly soluble in various elastomers such as EPDM, HNBR and Silicones VMQ and cause extensive swelling and subsequently failure of the elastomer seal. Fluorinated elastomers exhibit significantly lower swelling as is demonstrated in Figure 6.

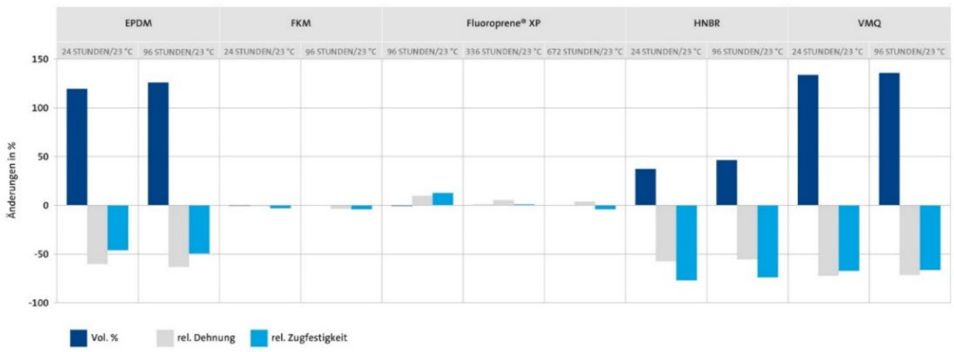

Figure 6: *Immersion tests of EPDM, HNBR, VMQ, standard FKM and special fluoropolymer (Fluoroprene® XP) in orange oil*

4. Emissions & waste

4.1 Emissions

According to leading fluoropolymer manufacturers, that supply the base polymers such as FKM and PTFE to the sealing industry, emissions of fluorinated surfactants are today almost 100% eliminated by using the latest production technologies. All emissions from fluoropolymer production are already subject to strict regulations and controls in Europe. Several pieces of EU legislation, both existing and revised, for example on industrial emissions, water and environmental quality standards set even stricter limits. To our knowledge, all the major fluoropolymer manufacturers that still use fluorinated surfactants in their fluoropolymer manufacturing processes today are working to phase them out in the next few years.

To evaluate potential emissions during our manufacturing process and in our products, FST conducted various analyses according to available standards. The main challenge is the highly sophisticated trace analysis required to detect and quantify substances in products in the ppb level and the lack of harmonized analytical methods e.g. for air emissions of PFAS. Reference limits for individual substances (10 $\mu g/m^3$ PFOA and 5 $\mu g/m^3$ PFOS) already exist (6) and we found emissions at our production sites are several orders of magnitude below the limits.

<u>More details can be found in the confidential part of this statement.</u>

4.2 Waste

<u>Recycling of Fluoroelastomers and PTFE</u>

The concentration of fluoropolymers in mixtures & articles can vary between 40-100%. The manufacturing process of elastomeric products leads to scrap rates of fluoroelastomer-based compounds in the range of 20-40%, depending on the manufacturing process. Much of the waste consists of vulcanized or partially vulcanized rubber resulting from the molding process, residual flash and scrap parts. The very nature of the fluoroelastomer cure system prevents effective devulcanization. No efficient method of reuse is currently available. There are limited options for recycling of these materials (7) (8).

Different mechanical grinding processes can break down vulcanized or partially vulcanized fluoroelastomer materials into powders which can then be re-incorporated into virgin polymer or rubber compound with little or no adverse effects. However, this recycling method will obtain fluoroelastomers of the same performance only if certain thresholds of regrind are not exceeded. Current specifications prohibit the use of recyclate for many applications, such as those that are considered safety critical.

For pure PTFE adequate recycling processes have already been developed. Most PTFE compounds consist of virgin PTFE and inorganic or organic fillers. While established recycling processes exist for virgin PTFE many processors of PTFE compounds must dispose of their processing waste via landfill or incineration. It is not possible to separate the individual components - neither in the compound powder nor in the processed end product. In the case of unmixed material, mainly virgin PTFE powder, a re-use of the waste is possible. (9)

FREUDENBERG FST GMBH
Hoehnerweg 2-4,
69469 Weinheim,
Germany

Phone: +49 6201 960-6666
www.fst.com

Commercial Register:
District Court of Mannheim
HRB 736340
VAT Id no.: DE811879378

Managing Directors:
Claus Möhlenkamp,
Ludger Neuwinger-Heimes,
Matthias Andres,
Dr. Matthias Sckuhr

Chairwoman of the Supervisory Board:
Esther M. Loidl

Disposal

Fluoropolymers are often incinerated, the resulting fluorine compounds are decomposed and the evolving hydrogen fluoride gas is separated in gas scrubbers; no PFAS are released into the environment. (10) Fluoropolymers such as PTFE are also recyclable, the technology for this is available. (8) The typical disposal route for fluoropolymers in Germany is incineration with energy recovery, while in other European countries products get disposed of in landfills in accordance with national standards. (11)

FST follows internationally recognized requirements such as ISO 14001 environmental protection standard and the EU Eco-management guidelines. The following principle is always applied when dealing with waste: prevention is better than recycling is better than disposal. Residual waste that is neither avoidable nor recyclable is disposed of in a responsible manner in accordance with the applicable national standards of the respective countries.

More details can be found in the confidential part of this statement.

If seals are used as intended, no fluoropolymers are released into the environment. Releases of fluoropolymers are limited to accidents and incidents.

After end of life of the system (valve, engine, gearbox, hydraulic system) or the broader entity (pump, vehicle), the seals are typically not separated from the systems in which they have been installed. Disposal follows the same disposal route as for metals, i.e., the seals go with the metals into the melting furnaces, where they are completely burned, and any toxic gases are separated in gas scrubbers.

A recent study by Conversio demonstrated that the incineration of fluoropolymers at 860°C entirely convert these materials to inorganic fluorides and carbon dioxide. The inorganic fluorides detected were Hydrogen Fluoride. The results confirm that fluoropolymers at their end of life when incinerated under representative European municipal incinerator conditions do not generate any measurable levels of PFAS emissions and therefore pose no risk to human health and the environment. (12)

5. Socio-economic impact

5.1 REACh regulation

Art. 68 (1) of the REACh Regulation requires that any chemical restriction must always be substance-related and risk-based and is only possible if the substance in question poses an "unacceptable risk to human health or the environment". Far from all PFAS pose an unacceptable risk that would justify a total ban. PFAS can be divided into different subgroups based on their physical, chemical and toxicological properties (e.g. polymers, functionalized PFAS, non-functionalized PFAS, state of aggregation, solubility; mobility, etc.).

All fluoropolymers used in FST are classified as "polymers of low concern" according to OECD criteria (13), but their production, use, importing and placing on the market are now to be extensively restricted. Experts agree that 10,000 PFAS chemicals should not be grouped into one substance class, that persistence alone is not sufficient to group PFAS for the purpose of human health risk assessment, and that the definition of appropriate subgroups can only be defined on a case-by-case manner. It is not scientifically tenable to assume equal toxicity/potency across the diverse class of PFAS and specifically to include polymers of low concern such as fluoropolymers in the restriction. (14)

The restriction must therefore differentiate between the various PFAS subgroups and the risks of their use and exclude individual substance groups if there is no "unacceptable risk to human health or the environment" such as fluoropolymers. Proposals for practical categorization and regulation of PFAS which take into account the different stages of the life cycle of PFAS from their manufacture through their processing into intermediate materials, their formation into a final product, and their disposal at the end of life exist. (15) (16)

Risks in the manufacturing and waste phase must not lead to an immediate blanket ban on fluoropolymer uses but can be addressed through occupational health and safety measures and regulations of waste streams.

5.2 Derogations

If the current restriction proposal were to come into force fluoroelastomer an PTFE containing sealing systems which are widely used because of their unique properties when other polymer classes do not show adequate performance would not be available anymore. In the current restriction draft only very few time-limited derogations are proposed for specific applications which do not cover the wide-spread usage of fluoropolymers in the sealing industry.

***Table 2**: Selected industry sectors and their respective derogations in the Annex XV proposal where fluoropolymer seals are used*

Use sector	Application	Derogation [years after EIF]
Transport	*…applications affecting the proper functioning related to the safety of transport vehicles, and affecting the safety of operators, passengers or goods*	13.5
Food Contact Materials	*…for other equipment for food and feed production, recognising that PFAS seals, pipes, gaskets, tubes etc are deeply integrated into manufacturing and processing equipment.*	6.5
Energy	*…for PEM fuel cells to substitute instead of closing business, thereby limiting producer surplus losses, employment impacts and impacts on customers resulting from the unavailability of PEM fuel cells.*	6.5

FREUDENBERG FST GMBH
Hoehnerweg 2-4,
69469 Weinheim,
Germany

Phone: +49 6201 960-6666
www.fst.com

Commercial Register:
District Court of Mannheim
HRB 736340
VAT Id no.: DE811879378

Managing Directors:
Claus Möhlenkamp,
Ludger Neuwinger-Heimes,
Matthias Andres,
Dr. Matthias Sckuhr

Chairwoman of the Supervisory Board:
Esther M. Loidl

Petroleum & Mining	*… fluoropolymer applications to bear the costs related to product reformulation that can range from tens of thousands of euros to millions of euros for any single formulation. In addition, loss of functionality of products in this sector could have substantial economic implications, including shorter operational lifetime of components, increased frequency and costs of maintenance, and increased operational downtimes.*	13.5

If the current restriction proposal were to come into force, seals used in general stationary machinery would be entirely excluded from any potential derogation. This includes any seals made from fluoropolymers used in applications such as hydraulics, stationary engines, stationary gearboxes, pumps, valves, in the chemical process industry, in all types of power generation other than fuel cells, e.g. batteries, electrolysers, wind turbines to name but a few.

Even if derogations are foreseen for some use sectors, the conversion of processes and articles with an already available substitute (or a substitute that can easily be identified) requires longer periods of time. The development, release and approval periods for products such as seals in demanding applications must be taken into account (both in general and for derogations). Otherwise, there is a high risk of disproportionate consequences for supply chains in many key industries.

Depending on the complexity of the application and approval processes, the development of a new material, the complete redesign of a seal or the entire system as well as approval by the customer can take 5 to 10 years. The proposed derogation of either 6.5 or 13.5 years does not cover the time required to change an entire article portfolio for different market segments and customers. Sectors with no derogation will not be able to replace their portfolio within an 18-month transition period. The costs associated with reformulating materials, redesigning products or changing customer process environments can range from tens of thousands to millions of euros depending on the application.

5.3 Spare parts

If the current restriction proposal were to come into force, spare parts for existing machinery will no longer be available. Even if a non-fluoropolymer replacement solution were available, these new seals might not necessarily have the same dimensions and design to retain their function as the previous fluoropolymer seals. If e.g. existing housing designs or grooves of that machinery are not compatible with the new seals, the entire machine becomes unusable. This will result in either premature dismantling and disposal of fully functional equipment, or the relocation of machinery to non-EU countries.

5.4 Impact

The broad restriction of PFAS as currently proposed is putting the goals of the European Green Deal at risk and will severely impact European companies and the innovative capacity of European industry in different market segments. Ultimately it will lead to significant competitive disadvantages compared to the rest of the world.

Uncertainty in the European and global markets is created and risks disrupting the complex, not easily understood supply chains. The uncertainty about future investments will already trigger a migration process to non-EU countries now.

The import of PFAS-containing products will be formally banned, but monitoring will be difficult to impossible for fluoropolymers used in sealing applications as seals are usually hidden in complex products (machines, electronics, vehicles). Requiring importers to control the PFAS in articles will result in disproportionate costs and distortion of competition if EU- based companies are no longer allowed to produce fluoropolymer parts.

FST assumes that a far-reaching restriction of fluoropolymers in the next 5 to 10 years will have significant impact on its business; a significant drop in sales is expected.

More details can be found in the confidential part of this statement.

FST advocates a responsible, differentiated and risk-based approach to PFAS regulation

- Fluoropolymers which are classified as "polymers of low concern" according to OECD criteria and their base materials must be completely exempt from the restriction. (17) (18)
- REACH Annex XVII restriction process based on scientific evidence must be followed including provision of a list of relevant substances containing CAS numbers.
- PFAS that evidently pose a high risk to humans or the environment and for which there are substitution options with comparable properties need to be continuously substituted, as is common practice today.
- Occupational exposure limits and emission limits for volatile or water soluble PFAS as well as disposal routes at end-of-life need to be defined.
- Standardized methods for analyzing PFAS emissions in products or air need to be defined.

References

1. Sales, J. Critical Use of Fluoropolymers in the Functioning of Modern Society. *ICRL.* 2023, 1, p. 29.

2. Brandt Nielsen, Tenna. Elastomer swelling and Hansen solubility parameters. *Polymer Testing.* 2005, Vol. 24, 8, p. 1054.

3. Biswas, S.K. Friction and wear of PTFE — a review. *Wear.* 1992, Vol. 158, 1-2, p. 193.

4. Kreiselmaier, Rainer. Permeationsverhalten in Elastomerwerkstoffen. *KGK Kautschuk Gummi Kuntstoffe.* 2002, Vol. 55, 6, p. 316.

5. Gottmann, J. Improved sealing polymers and cleaning procedures to mitigate aroma carryover during bottling of aromatised and regular wines on the same filling line. *OENO One.* 2022, Vol. 56, 4, p. 41.

6. GESTIS Database. [Online] https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index.jsp.

7. Recycling of Cured Fluoroelastomer for Cost Control and Improved Performance. [Online] https://www.rubbernews.com/article/20050101/DATA01/301019987#:~:text=The%20very%20nature%20of%20the%20fluoroelastomer%20%28FKM%29%20curing,most%20costly%20of%20all%20rubber%20materials%20used%20today..

8. Schuster, J. Recycling of fluoro-carbon-elastomers – A review. *Advanced Industrial and Engineering Polymer Research.* 2022, Vol. 5, 4, p. 248.

9. pro-K Fluoropolymergroup. Recycling of fluoropolymers. *Technical Brochure.* 2018, 10.

10. Aleksandrov, Krasimir. Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas. *Chemosphere.* 2019, p. 898.

11. Beylage, H. Fluoropolymer waste in Europe 2022 - End-of-life analysis of fluoropolymer applications, products and associated waste streams. Final Report for Pro-K. 2022, p. S.41.

12. Gehrmann, Hans-Joachim. *Pilot-Scale Fluoropolymer Incineration Study: Thermal Treatment of a Mixture of Fluoropolymers .* Institute for Technical Chemistry (ITC) at Karlsruhe Institute of Technology (KIT); P Taylor & Associates, LLC, USA; Pro-K, Germany; ICGM, University of Montpellier, France; Gujarat Fluorochemicals. 2023.

13. OECD (2021), Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance. Series on Risk Management, 61. [Online] https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf.

14. Anderson, J.K. Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts. *Regulatory Toxicology and Pharmacology.* 2022, p. 105226.

15. Henry, Barbara J. INSIGHT: Finding a middle ground on PFAS using a four-step process. *https://news.bloomberglaw.com/environment-and-energy/insight-finding-a-middle-ground-on-pfas-using-a-four-step-process.* [Online] 2020.

16. Buck, Robert C. Identification and classification of commercially relevant per- and poly-fluoroalkyl substances (PFAS). *Integrated Environmental Assessment and Management.* 2021, p. 1045.

17. Henry, Barbara J. A Critical Review of the Application of Polymer of Low Concern and Regulatory Criteria to Fluoropolymers. *Integrated Environmental Assessment and Management.* 2018, p. 316.

18. Korzeniowski, Stephen H. A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers. *Integrated Environmental Assessment and Management.* 2022, p. 1.