

Position of the EFRC e.V. with regard to the PFAS Restriction Proposal

1 Executive Summary

The current state of the energy system depends on the reliable operation of reciprocating compressors. An immediate ban on all polymeric PFAS uses within the industry would force shutdowns that put the energy supply at risk. The compressor operation will suffer from increased energy consumption due to inefficient operation, higher wear and higher leakages. The latter will offset the environmental protection achieved by banning forever chemicals through emitting more greenhouse gases. The state of the art for dynamic and static sealing and valve applications will be set back for decades. The goals of climate neutrality would be at stake as reciprocating compressors back the energy transition and the hydrogen economy towards climate neutrality.

Our industry and the EFRC support regulation that promotes the well-being of the people and the environment and is willing to invest in R&D on substitutes. However, a significant concern is the likelihood of a successful identification of replacement material(s) with similar properties to polymeric PFAS. The contribution of the reciprocating compressor industry to PFAS production and emission is considerably small, as shown below. However, polymeric PFAS are significant for today's and tomorrow's energy systems. The EFRC asks for exemption from restrictions on polymeric PFAS applications in dynamic sealing, static sealing and compressor valves.

2 Comment on the Annex XV Restriction Report

2.1 The European Forum for Reciprocating Compressors (EFRC)

The European Forum for Reciprocating Compressors (EFRC) was founded 1999 as a non-profit association. It supports users, manufacturers and universities working with reciprocating compressors (in short "recip community") regarding technology, exchange of experience, initiation and collaboration on precompetitive research, standards and guidelines, training and student exchange. The association is currently composed of 42 members from Europe and the US. Table 1 provides an overview of the members and employees.

*Table 1: Overview of EFRC members and employees**

	Amount	Employees
OEMs	12	> 12.350 (79.900)
Suppliers (excl. OEMs)	7	> 2.830
Operators	9	> 423.100

(*Only industry members are listed here. See a complete list of members on the [EFRC website](#). The numbers in brackets account for companies outside EEA¹)

¹ EEA – Euorpen Economic Area

2.2 Background to the Annex XV Restriction Report

Per- and polyfluoroalkyl substances (PFAS) are found throughout various applications. PFAS are considered “forever chemicals” due to their high persistence in the environment. Hence, concerns are raised regarding bioaccumulation, its effects on human health and ecosystems and endocrine activity. Five national authorities have therefore submitted a proposal to the European Chemicals Agency (ECHA). The restriction proposal published by the ECHA aims to reduce PFAS emissions into the environment under the regulation on the registration, evaluation, authorization and restriction of chemicals (REACH). The proposal considers two restriction options: A full ban or a ban with time-limited and use-specific derogations. The conditions of the ban include the ban on the manufacture, placing on the market of PFAS as such or as a constituent in other substances, as well as in articles.

In the further restriction process, ECHA’s scientific committees for Risk Assessment (RAC) and Socio–Economic Analysis (SEAC) will conduct a scientific evaluation of the proposal. In the meantime, a public consultation period is held. The committees’ opinions will be based on the restriction proposal's information and the comments received during the consultation. The opinion will be sent to the European Commission and scrutinized by the European Parliament and the European Council [1].

Since the restriction proposal has implications for the recip industry represented in the EFRC, the latter has decided to submit a joint comment about the consultation questions. For that, the EFRC surveyed its industry members about their points of view regarding PFAS and related issues. The feedback is incorporated into the present comment. Therefore, the following aggregation is considered a view of the recip community on the Annex XV Restriction Report.

2.3 Sectors of the Recip Industry

The members assign themselves to several sectors and (sub-) uses. Those include Energy, Petroleum and Mining, Transport, Lubricants, Manufacture, Chemical Products, Other Niche Applications and sectors not mentioned in the proposal: Defense and Compressor Manufacturer. Some do not assign themselves to a sector due to the broad application of their products.

The reason may be that they cover applications found throughout many uses mentioned in the restriction proposal. For instance, Annex A mentions in Table A.61 the use of polymeric PFAS for compressors and valve bodies in the petroleum industry, in Table A.41. as shaft and piston seals in transport applications. Other described sectors do not incorporate compressor-related products. Overall, it can be concluded that the restriction proposal does not comprehensively cover the recip industry.

The compressors used within the recip industry are mainly composed of a rotating drive whose rotating movement is converted into an oscillating movement through a conrod and a crosshead. The oscillating movement moves a piston rod and the piston, compressing the gas. The distinctive crosshead gives these compressors their name, “crosshead-type compressor”. The crosshead, the compressor's size, megawatt power input and ability to provide high discharge pressures are distinctive and distinguish them from other compressors, such as mobile and stationary refrigeration or turbo compressors.

2.4 Uses of PFAS in the Recip Industry

The uses of PFASs in the recip industry focus on fluoropolymers. Their use is divided into dynamic sealing, static sealing and valve parts.

Dynamic sealing and lubrication consist of piston rod packings and piston sealing elements. The piston rod packing seals the crank side cylinder of double-acting compressors, whereas piston rings seal the cylinders from each other. Furthermore, rider bands ensure the guidance of the rod and piston. A material that is used in particular for those purposes is polytetrafluoroethylene (PTFE). Depending on the application, the material use in compounds is roughly 10-90 %. The main reason for the use is the good sliding property, including self-lubrication, that leads to low friction. Another reason is the excellent shape adaptability through high flexibility and low hardness, which yield good sealing properties and ease the installation process. Those properties, in combination with a high chemical resistance against aggressive gases and high-temperature resistance, lead to its unique set of properties. Applications are compressors that require chemical resistance against highly reactive gases like oxygen, hydrogen fluoride or hydrogen sulfide. Special requirements for gas purity, such as in PET bottle blowing or hydrogen compression, are further applications.

Static seals are mainly O-rings and gaskets. They are used where the adjacent parts are not in relative motion. Here, PTFE is also used through its good adaptability, temperature resistance, chemical resistance and dielectric properties. Further, PFAS used are the per- and fluoroelastomers FFKM and FKM. Usually, the share of PFAS in those products is 100%.

Compressor valves control the gas flow into and out of the cylinder. Valves that use polymeric PFAS are plate valves and ring valves. The plates and rings use PTFE and perfluoroalkoxy alkane (PFA). Again, chemical and temperature resistance and the high impact resistance of the latter are essential factors for this use. The share of PFAS in valve plates varies between 70-90 %.

Information on the annual tonnage for the previously mentioned uses within the recip industry is not available to the public domain. The presented information was gathered through the survey. The annual tonnage of polymeric PFAS processed throughout the recip industry is presented in the first row of Table 2. Four manufacturers of compressor parts such as rod packings, piston rings and valves account for the provided annual tonnage of PTFE. One manufacturer accounts for the number of PFA and three for FKM/FFKM. The numbers in the table are based only on the input of members who provided relevant data. For comparison, the table also provides annual tonnages of polymeric PFAS given in Annex A of the restriction report.

Table 2: Annual tonnages and for comparison production volumes of polymeric PFAS

	PTFE	PFA	FKM/FFKM	Total
Tonnage in 2021 recip industry	96,1 t	8 t	1,11 t	106 t
EEA [2], Table A.6	37.500 t			49.000 t
Global [2], Table A.6	150.000 – 170.000 t			405.000 t

Among the members, it is expected that there will be a growth of business throughout the upcoming years of 5-50 %. For PTFE, an increase in tonnage of 2 t/a is expected, and a slight decrease of 0.5 % for valve materials. This is explained through the planned transition to other polymers. Mentioned

drivers are an increased demand in the chemical and refining industry. A primary driver is the ramp-up of renewable energies.

Hydrogen will play a significant role in meeting the targets of the European Green Deal's climate neutrality [3]. As the common electrolysis technologies provide hydrogen on low-pressure levels, compressors step in to increase the pressure, e.g., to increase the energy density of hydrogen for storage in tanks and underground and transport via pipelines. The need for self-lubricating compressors and fluoropolymers is found in the high requirements for hydrogen purity in downstream applications, e.g., fuel cells.

2.5 Emission of PFAS in the Recip Industry

Emissions can occur throughout fluoropolymer-containing products' production, use and end-of-use phase. Processing, e.g., machining, happens on the manufacturer's site. Furthermore, compressors are not subject to widespread use and are usually operated in industrial sites.

The production phase includes blending polymers, compression molding and machining. Data on emissions during that phase are also unavailable in the public domain. In the manufacturing phase, particle emissions to air are monitored and machines are equipped with advanced filtration to filter airborne emissions. During processing of PTFE, no significant emissions of hydrogen fluorides, fluorides and perfluoroisobutylene could be detected if the specified process parameters, in particular the temperature, were maintained. During processing, approx. one-third of the semi-finished polymeric part is generated as waste. Measures have been taken to incinerate the waste or regrind it for recycling. Efforts to decrease the share of waste, including new molds with thinner wall thicknesses and different sealing designs, have also been introduced.

In the case of piston rod sealing, piston rings and rider bands wear occurs. Due to the applied frictional load, wear debris is produced. There are two possible paths for that debris: The first is through the piston rod packing into the crankcase of the compressor and then to air. Rod packings have been developed to mitigate or suppress venting into the crankcase. For the other path, debris uptake by the compressed gas is possible. Usually, the gas is filtered after the compressor. If not, the debris is transported downstream. The downstream process then defines the disposal route. If not prohibited by law for many applications, venting into the air is possible. Overall, roughly 80 % of the sealing material wears, leading to the formation of particles. The debris is expected to be contained in the compressor's closed system or the downstream system.

Valves form cracks due to the high frequency of impacts and are replaced during maintenance. Static sealing is replaced once removed from their joint during maintenance. Neither valves nor static sealing contribute to emissions during the use.

The service life of compressor parts containing fluoropolymers is depicted in Table 3. The numbers in brackets show positive outliers. The service life depends on the operation conditions, maintenance practices and the condition of the compressor. By the end of the lifetime, worn parts are disposed of according to local law and the manufacturer's instructions. Measures to collect used products for recycling have been considered but not implemented. The worn parts are contaminated with the

processed gas, which complicates recycling. Furthermore, incineration is considered to be an effective measure for the destruction of fluoropolymers [4].

Table 3: Lifetime of compressor parts containing fluoropolymers

	Dynamic sealing	Static sealing	Valves
Lifetime	4.000 h – 3,5 y (< 5 y)	4.000 – 16.000 h (50.000 h)	4.000 – 16.000 h

2.6 Alternatives for Fluoropolymers for the Recip Industry

It is agreed that R&D on alternatives is in the early stages and will take years to find substitutes for every application. To gain the confidence of the customer, it could further take at least five years of testing and validation of substitutes. The technical and economic feasibility of substitutes depends on the compressor's applications and operation.

In general, for few applications, substitutes are already available. For instance, valve plates but not for chemically aggressive gases. Furthermore, HNBR² or EPDM³ as FKM⁴ substitutes for static sealing but cannot substitute applications that combine thermal and chemical stability.

Other technical polymers such as PEEK⁵, PI⁶, UHMW-PE⁷, graphite and ceramics are considered possible substitutes for dynamic sealing and have been investigated. In all cases, it is expected that service requirements concerning compressor efficiency, reliability and availability due to increased downtime cannot be fulfilled anymore. Plastics yield low-temperature stability and poor tribological behavior and become too brittle when combined with inorganic filler to increase tribological properties. Graphite shows high wear, especially with very dry gases and is too brittle to seal appropriately. Ceramics show high wear themselves and further abrasive behavior to the mating surface.

As for gases like hydrogen sulfide (H₂S), hydrogen chloride (HCl), oxygen (O₂) and chlorine (Cl₂) no materials with similar chemical resistance like PTFE are available. The same accounts for applications above 120 °C or below -50 °C. Expectations for substitute developments are therefore, low.

Some dry-running applications may be converted into oil-lubricated operations. This needs further investments in oil separation. The estimated share of possible applications is less than 5%.

In addition, decreased sealing capability can increase the leakage of greenhouse gases like CO₂ from breweries or methane from biogas plants.

The time and investments needed for R&D to develop depends on the application. Table 4 gives an overview of the estimated times required for the development. A likelihood of successful completion for all applications is not given. Higher customer costs accompany the expenses due to increased operational maintenance costs, leakage loss and more expensive substitutes.

² HNBR – Hydrogenated nitrile-butadiene rubber

³ EPDM – Ethylene propylene diene monomer rubber

⁴ FKM – Fluorocarbon-based fluoroelastomer

⁵ PEEK – Polyether ether ketone

⁶ Polyimide

⁷ UHMW-PE – Ultra-high-molecular-weight polyethylene

Table 4: Estimated time to develop substitutes

	Dynamic sealing	Static Sealing	Valves
Years for development	8 – 20 y	2-3 y	10 y
Costs	1.150 – 1.250 T€/a	1.120 T€/a	500 T€/a

3 Conclusions

The use of PFAS in the recip industry are mainly fluoropolymers in dynamic sealing, static sealing and valves. They are valued for their unique properties in a broad range of applications. They play a necessary role where harsh conditions are present or high gas purity is needed and deliver uninterrupted service for long service intervals. Lastly, the estimated numbers for annual polymeric PFAS tonnages within the industry are small compared to the European production, but their significance to the energy supply is significant.

Emissions during processing are monitored and air with possible contamination through machining is filtered. During use, only dynamic sealing elements are subject to possible emission. The produced debris is contained within the system or filtered after the compressor. Once fluoropolymer parts are worn out, they are correctly disposed of. Thus, if present, emissions are considered as low throughout the life cycle. In addition, emissions are only expected to occur within the industrial area where the compressor operates.

Alternatives are available for only few applications. In particular, substitutes for dynamic sealing are expected to increase downtime due to shorter service intervals, cost, emission of compressed gases and decreased compressor efficiency. They are not expected to perform equally well in all applications. Even though the costs of R&D on alternatives are estimated to be high, a broad success is not likely. Lastly, it will become increasingly challenging to safeguard the environment due to the ban of PFAS.

To sum up, the EFRC advises using polymeric PFAS in industrial settings and taking steps to prevent the material from entering the environment. This can be achieved by properly disposing of it through incineration or, when feasible, implementing a recycling process.

4 References

- [1] *ECHA publishes PFAS restriction proposal*. [Online]. Available: <https://echa.europa.eu/de/-/echa-publishes-pfas-restriction-proposal> (accessed: Sep. 5 2023).
- [2] *Annex XV Restriction Report - Annex A: Manufacture and Uses*, 2023.
- [3] European Commission, *Delivering the European Green Deal*. [Online]. Available: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en (accessed: Sep. 15 2023).
- [4] K. Aleksandrov *et al.*, "Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas," *Chemosphere*, vol. 226, pp. 898–906, 2019, doi: 10.1016/j.chemosphere.2019.03.191.