

PFAS applications in Fluid Power

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Components	PFAS types Examples	Key functionalities provided by PFAS	Relevant uses	Emission risk to the environment	Alternatives	Socio-economic impacts
Seals	Elastomers: FKM FFKM FEP FVMQ PTFE PCTFE TFM PVDF PFA FEP O-rings Gaskets Piston and rod seals Wipers Circlips Radial shaft seals Guide bands Support rings Stuffing boxes, i. e. in industrial valves	Thermal resistance especially greater than 150 °C Long term proofed and well documented chemical resistance Combination of thermal and chemical resistance Abrasion resistance Sliding and emergency dry- running properties Low friction Low wear Less leakage Long lifetime	Automotive Aerospace Power Generation Renewable energy Rail Oil & Gas Hydrogen Earth Moving & Construction Farming Medical Hydraulics Overall mechanical engineering Cooling lubricants in machine tools (as biocides are increasingly restricted, the pH values of the substances are	Besides abrasion no risk to the environment. Disposal through recycling process of the parent (metallic) assembly Long time usage in machinery, professional disposal at the end of the machine's life, Thermal disposal for oil-smeared seals	No alternative elastomer chemistry in sealing technology is available. Alternatives are currently in research and development stage. PFAS seal manufacturers have spent decades of research and development to reach the current state. There are no alternatives for high temperature applications. For low temperature applications, there exist alternatives with significantly worse	There is no alternative elastomer chemistry in sealing technology that allows temperatures > 150 °C. The characteristics of fluoropolymer sealings are crucial for the safety of humans and the environment. Any research, development, qualification and validation of suitable alternative materials requires longer transitional periods as foreseen in the restriction proposal. E. g. for very high temperatures and required flexible material, it is most likely that no alternative will be found at all in the future.

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			increased. This requires PFAS seals).		tribological properties and worse energy efficiency.	In consequence, all risk assessments of machines and plants would have to be revised with alternative materials not providing the same properties as the used fluoropolymer sealings. Experience with other materials does not exist as with fluoropolymers. This means that assessments need a long time. This would lead to interruptions in the supply chains in all industrial sectors including in the medical, food or energy sector. In the EU, risks can be reduced by legislation. If the production would be in other parts of the world, the EU would have no influence on the safety requirements. Parts of the industry would go outside of the EU. Workplaces in the whole industry are in danger. The technological development in the EU would be obstructed. Prices would rise. Environmental risks include e. g. agricultural machines that could lead to contamination of soil and

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						groundwater with hydraulic fluid. Sealing solutions with fluoropolymers contribute significantly to plant and machinery safety and thus to human and environmental safety. They give an additional safeguard when normal operating conditions are exceeded in case of failures.
Sliding coatings Guides	PTFE	Low friction, low wear, increased lifetime	Whole industry	Besides neglectable abrasion no risk to the environment. Disposal through recycling process of the parent (metallic) assembly	For guides and sliding coatings alternatives do not exist. PTFE-sliding coatings are used to replace environmentally incompatible lubricants in sliding surfaces. This prevents them from entering the environment.	
Surface treatment	PTFE PFA FEP PVDF Pistons, wipers, inner tube surfaces, guide rods	Non-stick coating, low friction, smooth running properties, chemical resistance, wear protection	General mechanical engineering, treatment of compressed air, chemical industry	Emission of wear, abrasion. Disposal via industrial waste stream	No known alternatives	Reduced operating time, Increase of safety risks in chemical processes
Membrane filter materials	Filter materials with PTFE membrane	Filter materials with PTFE membrane are characterised by very good	Air Filtration	Emission risk is low. The cutting process of the filter material is	No alternative exists with similar filtration performance	

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		cleaning, high filtration performance (fine filtration), use in the food and pharmaceutical sector with FDA and EU 1935 approval.		extracted. No emission occurs during filtration if used properly.		
Plain bearings Thrust washers	PTFE, FKM, FVMQ Gearboxes, pumps, axial pistons, foil bearings for lifting magnets, automatic filters	Sliding properties, high temperature and chemical resistance, withstanding heavy loads (dynamic loads, contaminated oil, mixed friction)	Most hydraulic applications, e. g. automatic filters	Use phase: Emission only by abrasion possible End of life: Low risk, since oil-smeared operating materials are disposed separately		
Hoses	PTFE, PFA Tubular goods	Chemical resistance against aggressive media High temperature resistance (Sterilisation) Low permeation Smooth non-adhesive surfaces to avoid sticking in hoses Germ-free	Food processing (FDA approved) e. g. dairy processing (pasteurisation, cleaning of the hose assemblies, sterilisation) Vulcanisation Tyre presses, Adhesive application: Hotmelt adhesive Processing Chemical and petrochemical industry: refineries, chemical processing plants, polymerisation			Higher germ load on food due to biofilm adhesion and/or inadequate cleaning/sterilization of hose assemblies. Hot medium escapes due to premature failure of the hoses. Leakage of adhesive. In the case of alternative adhesives with solvents, higher emissions of greenhouse gases. Leaks can lead to the escape of toxic gases or vapours

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Tube and hose connectors Flanges Quick release couplings Tube line valves Measuring connectors	FKM seals PTFE back rings in tubes for: Vulcanisation processes Hot forging processes Injection moulding processes Air compressors Hydraulic fluids with reduced pH-value	Temperature resistance > 150 °C	Hydraulic tyre presses Hydraulic hot forging presses Hydraulic injection moulding machinery Pneumatics Compressors Mobile hydraulics (e. g. farming machinery)	Possible leakage of hot fluid or fluid vapours Increase of fire hazard due to contact of the escaping fluid with red-hot forged parts. Contamination of the injection moulded parts Fire hazard from vehicles with combustion engines, especially in summer. Contamination of farmland and grasslands	According to the seal manufacturers, no alternative elastomers are available for this temperature range, even in the long term. Possibly HNBR can be used, resistance tests required.	Increased machinery downtime due to the need for repair or shorter maintenance intervals. Impairment of occupational safety Impairment of breathing air Contamination of farmland and grasslands
Cables Wires Plugs	PTFE PFA Signal transmitter Pressure and flow switches Valves	Insulation Temperature resistance Resistant to corrosive environmental influences	Industrial control and monitoring instruments General mechanical engineering	No emission Industrial waste recycling at end of life		
Hydraulic components (e. g. pumps, motors, control blocks, valves, cylinders)	FKM, EPDM, PTFE, PVDF	Resistance against high pressures, high temperatures, various chemicals (hydraulic fluids, including bio-based fluids), harsh environmental conditions and combinations of those.	The whole machinery sector, stationary and mobile machinery. For example, storage devices for safety valves, lifting devices, sluice gates, presses, power plants, wind turbines, ropeways,	Exact waste data on products are not available. It is estimated that 90-98% of the components are made of recyclable metal alloys or plastics, the remaining 2% up to 8% are materials (of which PFAS is a small fraction)	No PFAS-free alternatives are available. When potential alternative PFAS-free elastomers or plastomers are available, tests and validations would be obligatory for all intended applications.	If PFAS polymers could not be used any more, hydraulic components and systems will no longer be manufactured. This would affect all industries where hydraulic components and systems are used, e. g. agricultural, construction and other mobile machines as well as all stationary machines, e.

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			aircrafts, vehicles and conveyor systems.	which would have to be sent for thermal recycling due to their contact with media. Current specifications for the service life of seals range from a minimum of 10 years to 30 years in the power plant sector. No emissions of PFAS during the manufacture of products. Gaskets after replacement are given to waste for thermal disposal. Products and the PFAS-containing sealings are not released into the environment when used as intended in closed hydraulic circuits.	This would be necessary for each manufacturer and each kind of product. Insofar, a lot of energy, human resources and costs would be needed to test all hydraulic components.	g. machine tools or wind turbines.
Hydraulic accumulators	PTFE, FKM	Resistance against high pressures, high temperatures, various chemicals (hydraulic fluids, including bio-based fluids), harsh environmental conditions and	The whole machinery sector/in stationary and mobile machinery. For example, storage devices for safety valves, lifting devices, sluice gates,	Exact waste data on products are not available. It is estimated that 90-98% of the components are made of recyclable metal alloys or plastics, the remaining 2% up to	No PFAS-free alternatives are available. When potential alternative PFAS-free elastomers or plastomers are available, tests, validations and	If PFAS polymers could not be used any more, accumulators will no longer be manufactured. This would affect all industries where hydraulic accumulators are used, e. g. agricultural, construction and other mobile machines as well as all stationary

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		combinations of those.	presses, power plants, wind turbines, ropeways, aircrafts, vehicles and conveyor systems.	8% are materials (of which PFAS is a small fraction) which would have to be sent for thermal recycling due to their contact with media. Current specifications for the service life of seals range from a minimum of 10 years to 30 years in the power plant sector. No emissions of PFAS during the manufacture of products. Gaskets after replacement are given to waste for thermal disposal. Products and the PFAS-containing sealings are not released into the environment when used as intended in closed hydraulic circuits.	conformity assessments would be obligatory (hydraulic accumulators fall under the Pressure Equipment Directive). This would be necessary for each manufacturer and each kind of product. Insofar, a lot of energy, human resources and costs would be needed to certify all accumulators with alternative sealings which are on the market.	machines, e. g. machine tools or wind turbines.
Pneumatic components (e. g. valves, regulators, actuators, tubes, fittings)	FKM, EPDM, PTFE, PVDF	Resistance against high pressures, high temperatures, various chemicals and combinations of those.	Components for automation and mechanical engineering used in various industries, e. g. in machines for	PFAS have a high resistance against wear. Insofar, there are neglectable amounts of abrasion particles	Rarely PFAS-free alternatives are available for specific applications only. For complex conditions, no	If PFAS polymers could not be used any more, pneumatic components and systems will no longer be manufactured. This would affect all industries where pneumatic

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			producing vaccines, medical products, automotive parts, semiconductors, food packaging, printing products, textiles, PV modules, etc.	only during the use phase. The used fluoropolymers are destroyed in recycling processes for metals and the thermal utilisation of plastics in waste incineration plants	alternatives are available. When potential alternative PFAS-free elastomers or plastomeres are available, tests and validations would be obligatory for all intended applications. This would be necessary for each manufacturer and each kind of product.	components and systems are used, e. g. in automation and mechanical engineering (see “Relevant uses”).

