ENGINEERING TOMORROW

February 2024

Danfoss position on the restriction of per- and polyfluoroalkyl substances (PFAS)

Danfoss is a global leader of components and solutions directly contributing to achieving global climate and energy goals. Danfoss develops technologies to increase machine productivity, reduce emissions, lower energy consumption, and enable electrification within many product sectors, including: heating and cooling, food supply and cold chain, industrial processing, and construction and agricultural machinery.

At Danfoss, we take our responsibility to provide safe and sustainable solutions very seriously. We are committed to delivering products that meet the highest standards of quality and safety and we support the global initiatives intending to restrict the use of PFAS. However, a blanket ban of PFAS could jeopardize global climate and energy goals, and PFAS restrictions should only be implemented when:
1) they reference scientifically confirmed health risks; and
2) viable alternatives for indispensable products are available.

Specifically, the impact of a blanket ban on PFAS to Danfoss products would be twofold:
1) Direct, via the use of fluoropolymers; and
2) Indirect, via fluorinated refrigerants (f-gases).

1. **Fluoropolymers:**

Danfoss' product portfolio has been developed and optimized over decades, using PFAS, such as PTFE, FKM and PFA for their performance and longevity. Mechanical products generally operate within systems at high pressures over a large temperature range, and are exposed to operating fluids such as refrigerants, oil, and water which can lead to chemical deterioration of the components' materials. Those systems inherently need to be tight for reasons relating to environment, safety, and energy efficiency. Fluoropolymers are essential in maintaining tight seals and low friction due to their chemical durability, offering safe and energy efficient solutions.

➔ **Given the lack of viable alternatives, Danfoss recommends a trial-and-error timeline or process for new product development to replace unsafe use of PFAS.**

2. **Fluorinated gases (f-gases):**

Danfoss does not produce or directly use refrigerant gases, but as a leading supplier to the Heating, Ventilation, Air-Conditioning and Refrigeration (HVACR) sector, our components need to be fit for the refrigerants used by our customers. Many of these refrigerants are f-gases and classified as PFAS. The classification as PFAS mainly relates to the formation of trifluoroacetic acid (TFA) as a breakdown product. According to the EEAP Report 2022, TFA as a breakdown product is not expected to pose significant risk to humans or the environment. In addition, f-gases are currently regulated on a global scale, mitigating the risk of exposure of PFAS to the environment to a large extent.

➔ **Given the importance of f-gases for several applications in the HVACR sector, playing a key role in the phase-out of fossil fuel-based solutions and for achieving climate and energy targets, Danfoss recommends exempting f-gases from the PFAS restriction scope.**

Danfoss A/S

Kim Fausing
President & CEO

ANNEX

Use of PFAS in Danfoss

Danfoss delivers an extensive range of products and solutions across our three business segments:
Danfoss Climate Solutions, Danfoss Power Solutions and Danfoss Power Electronics and Drives. The following section shows the impact of a PFAS restriction in each of these segments.

Danfoss Climate Solutions

Danfoss Climate Solutions is the leading global supplier of HVACR components for food and medical supply and conservation, health and well-being. The sectors we serve account for approx. 60% of final energy use and include cold chain, air conditioning, heat pumps, process cooling, hydronic heating flows in buildings, and district energy.

Indirect Impact: f-Gases in the vapor compression process

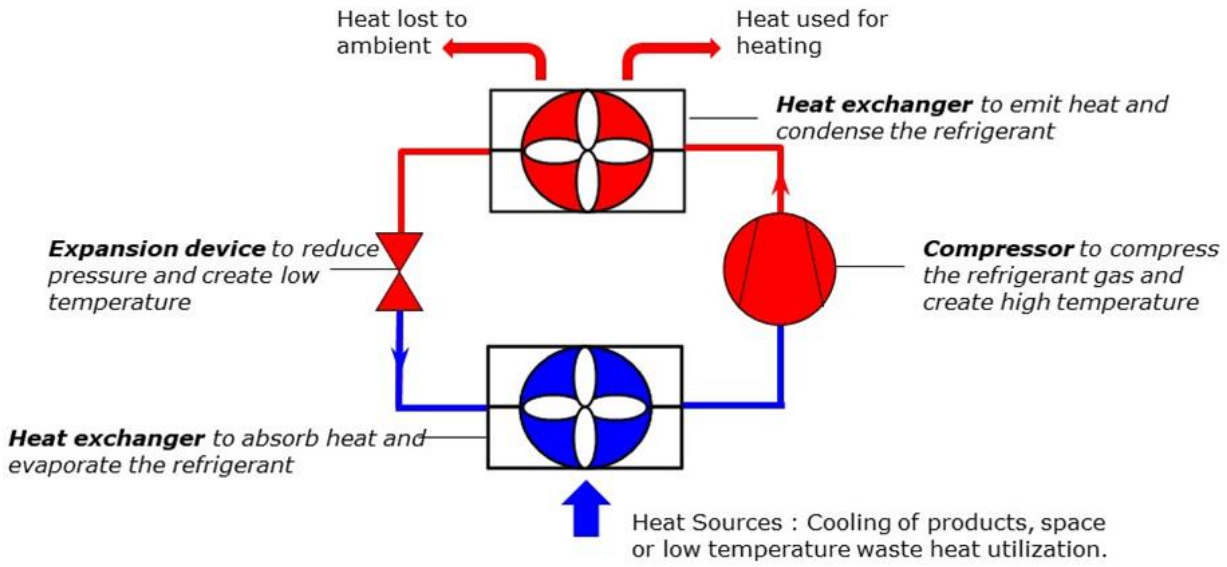

Figure 1: Basic principle of vapor compression system comprising the energy flows and the basic components.

The system relies on 'refrigerant' fluids, which, in case of most of the fluorinated gases (f-gases) are classified as PFAS as well as their breakdown products known as TFA. Refrigerants can also be non-fluorinated substances, such as naturally occurring gases like CO_2, ammonia, or propane. Danfoss delivers full product programs for natural refrigerants as well as for f-gases. Even though Danfoss is not a direct user of f-gases, components need to be designed to contain f-gases in the use phase. The main reason for using f-gases is safety. Safety is a concern if gases are toxic or flammable and usage is regulated through complex safety standards.

Not all f-gases are PFAS-classified as they break down into HF (no CF_3 part). Some of the PFAS-classified f-gases have very small TFA yields from breakdown, while others have 100 % TFA formation.

It is important to differentiate between f-gases. The newly applied HFO gases like R1234ze and R1336zd, for example, break down into a negligible amount of TFA [Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change ; UNEP 2022 Assessment Report of the Environmental Effects Assessment Panel]. It would therefore be disproportionate and hampering the green transition to include a blanket ban on f-gases.

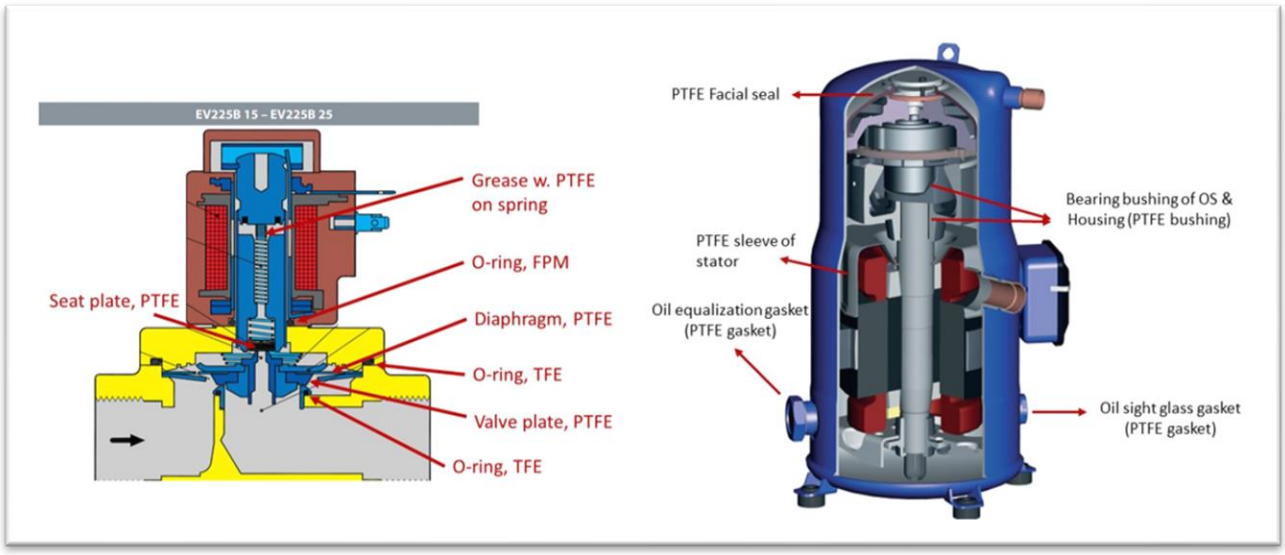

Figure 2: Solenoid valve (left) and compressor (right) exemplifying various critical fluoropolymer elements.

Direct Impact: Fluoropolymers

Vapor Compression Systems

- The market for vapor compression systems is enormous. According to the IEA, about 10% of the global electricity production is consumed by air conditioners and similar numbers apply for food refrigeration. That percentage will increase with the green transition towards heat pumps and the increasing need for a food cold chain. For example, phasing out fossil fuel boilers will result in the need for up to 60 million new heat pumps by 2030 ['Europe's Leap to Heat Pumps' ; European Climate Foundation].
- Compressors use bearings, sealings and gaskets based on fluoropolymers. The same is true for valves that control refrigerant flows. Besides the mechanical components, temperature sensors are necessary to avoid burnouts of the compressor. Likely, compressors would not last longer than a week without those temperature-detecting components. With the current state of technology, avoiding the use of fluoropolymers in compressors and controls is a problem if efficiencies and safety shall be maintained at high levels.
- Components for vapor compression systems for refrigeration, air conditioning and heat pumps are based on at least 40 years of incremental design improvements, where fluoropolymers have proven to be critical materials. Temperature demands inside the systems are dynamically varying from -50°C to 150°C, while pressures are ranging from 1 to 150 bar. The industrial usage of heat pumps has just started and will imply more extreme conditions on temperatures, resulting in the need for durable strong fluoropolymer materials.
- Containment of refrigerants is a major factor, and safety is ensured by numerous standards related to system location, human occupation and the charge size of specific refrigerants. Systems losing their refrigerant charge over time will underperform on energy efficiency. Tightness of systems is therefore a top priority and reliable (long-term) gaskets and sealings are necessary as many systems are not 'hermetically sealed'. Fluoropolymers are crucial in these applications (see table). For example, most valves are containing such sealings and gaskets.

Key components	**Key products**	**Key properties/requirements in relation to the materials used**	**PFAS materials**
Bearings Gaskets Seals Seal rings Coatings Bushings	Compressors Expansion valves Heat exchangers Solenoid valves Ball valves Service valves	Lifetime / reliability High to low temperature performance Lubricant resistance Dimensional stability	PTFE FEPM PFA FEP FKM PVDF

	Sight glasses Pressure regulating valves Non-return valves		PFPE FEPM

Table 1: List of fluoropolymers used in Danfoss vapor compression components.

Hydronic Systems

- In hydronic heating systems, water is used to move heat from heat sources to where it is needed, e.g., from heat pumps or boilers to radiators, heating mats, etc., while district energy systems are networks of hot and cold-water pipes used to efficiently heat–e.g. using waste heat–and cool buildings and using less energy than if the individual buildings were to each have their own boilers and chillers. The safety of transport of water through pipes in such systems are highly dependent on the stability and tightness of components to be energy-efficient; hence, temperature and pressure are of utmost importance. Components containing PFAS in sealings and bearings are an essential part of securing this.
- Heating and cooling of buildings represent 40% of global energy demand. Balancing and control valves ensure energy-efficient and reliable operation of such systems (district heating, HVAC, residential heating) by distributing energy from sources to consumers. The design life of such systems is 15-20 years. Today, there are no PFAS–free materials to provide products that enable comparable system efficiency and lifetime.
- Components for control valves and pressure regulators for heating and district heating are based on at least 40 years of incremental design improvements, where fluoropolymers have proven to be critical materials due to high operating demands. The temperature demand inside the systems is dynamically varying from -50°C to 180°C, while pressures range from 1 to 40 bar and higher. With the increased need for district heating comes an increasing need for more reliable control elements with lower hysteresis, ensured by durable, strong fluoropolymer materials.
- Safety and energy efficiency are major factors with emphasis on properties such as tightness, dimensional stability, wear resistance, and low friction. Safety is directly related to unintended leakage of high-temperature liquid or gas to the surroundings as a potential danger. Reliable guide gaskets and sealings are necessary to prevent these risks. For the energy efficiency of systems, low friction is critical. Friction in valves, especially in pressure regulators, leads to increasing hysteresis, resulting in reduced performance. Fluoropolymers are used for these applications (see table) and the majority of valves contain these guides and coated o-rings.

Key components	**Key products**	**Key properties/requirements in relation to the materials used**	**PFAS materials**
Bushings Guides/scrapers Coated o-rings Grease	Pressure regulators Pressure-independent control valves Control valves Pressure regulating valves	Lifetime/reliability High to low temperature performance Dimensional stability	PTFE
Lubricant	Gas filled self-acting radiator thermostats	Secure acceptable handle torque	PTFE-based dry-film lubricant
Seal rings Washer Greases	Ball valves	Lifetime/reliability High to low-temperature performance Lubricant resistance Dimensional stability	PTFE PTFE+C (compound)

Table 2: List of fluoropolymers used in Danfoss hydronic heating and district heating.

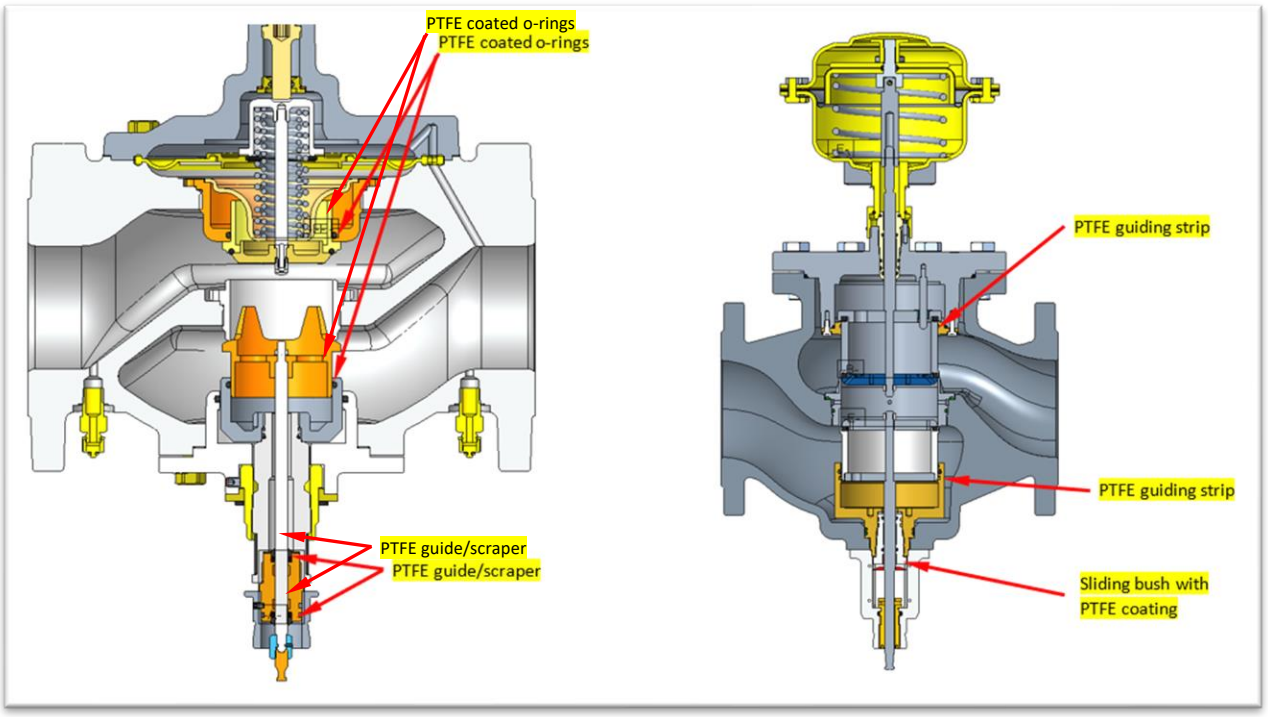

Figure 3: Pressure flow controllers ABQM (left) and AFQM (right) pressure-independent control valves exemplifying various critical fluoropolymer elements in hydronic heating and district energy system components.

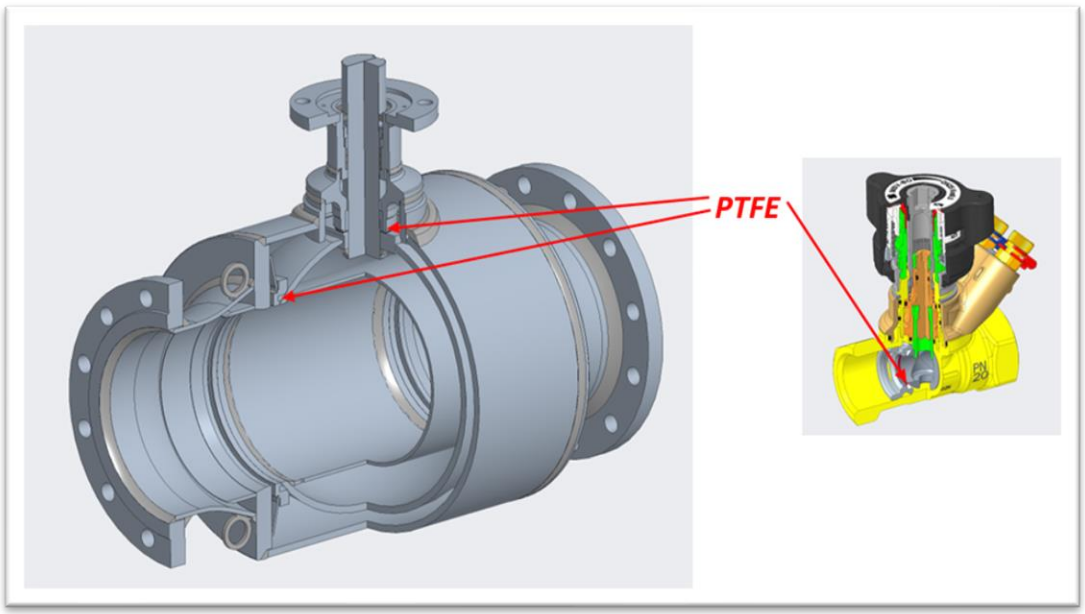

Figure 4: Ball valve for district heating and manual balancing ball valve (LENO) with critical fluoropolymer component.

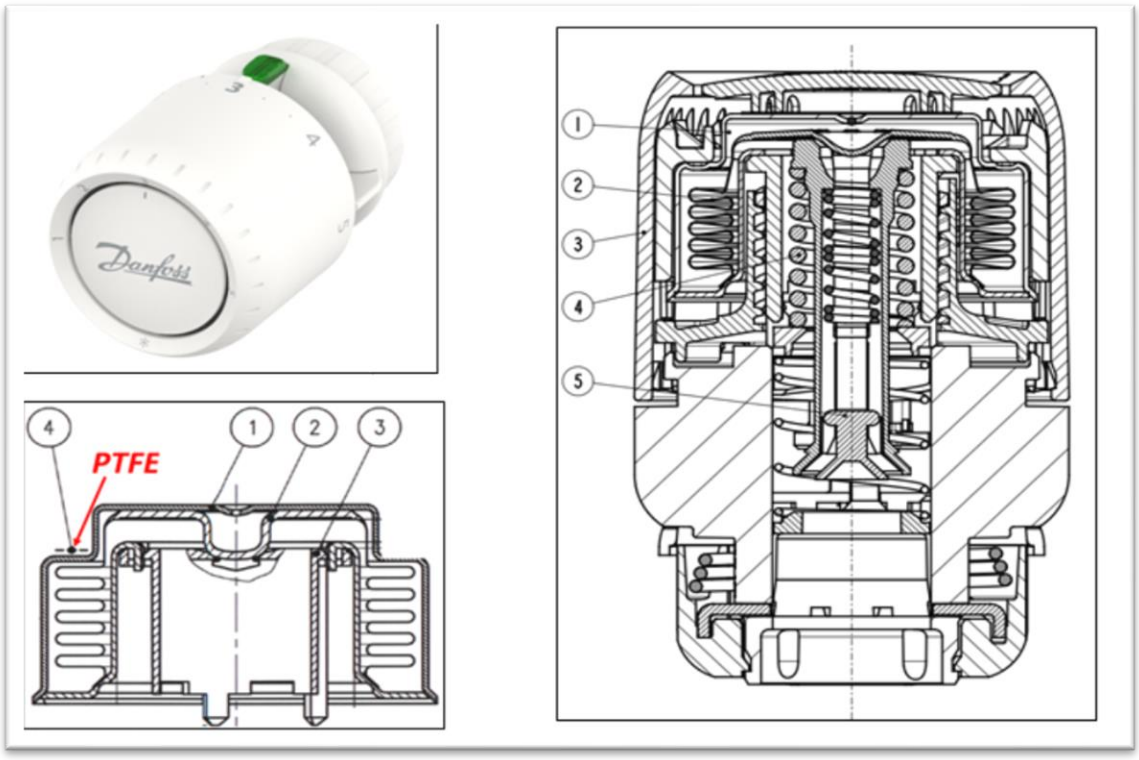

Figure 5: Radiator thermostat exemplifying critical fluoropolymer element.

Danfoss Power Solutions

Danfoss Power Solutions is the global leader in mobile and industrial hydraulics, fluid conveyance, electrification, and software. The business segment designs, manufactures, and provides a complete range of engineered components and integrated solutions to various industries in off-highway, on-highway, marine, offshore, and industrial.
The product portfolio includes motors, pumps, valves, steering components and systems, electronic controls, electrical systems, PLUS+1 software, former Eaton Hydraulics products, and hydrostatic drive systems.

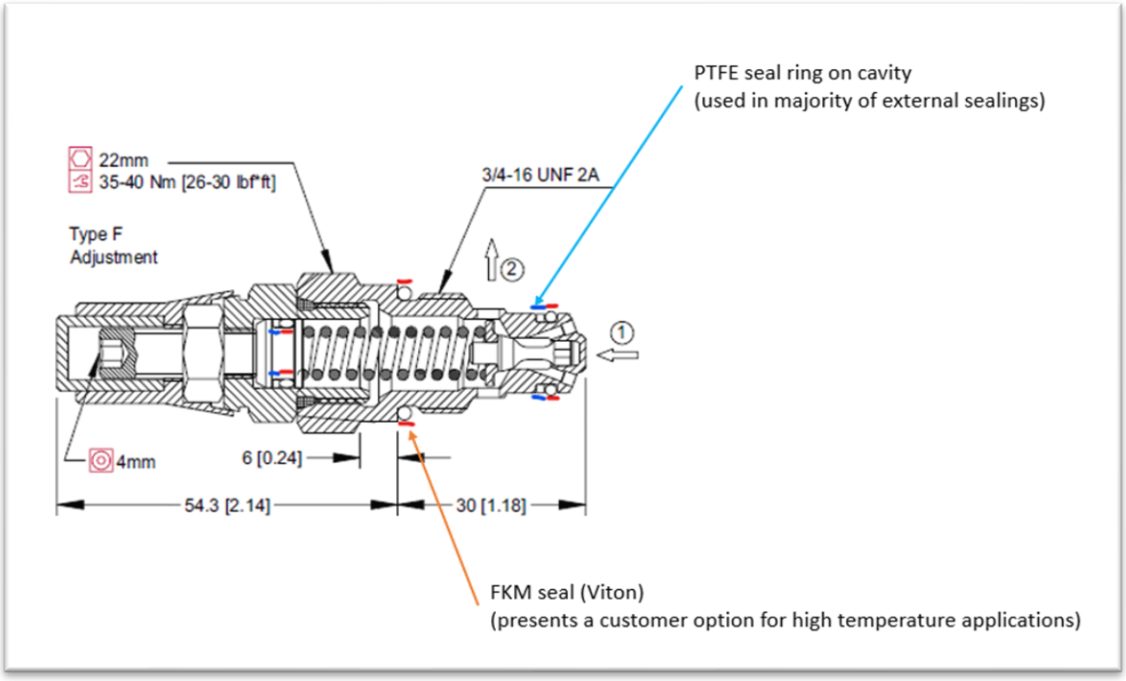

Figure 6: Example – Relief valve with PTFE and FKM.

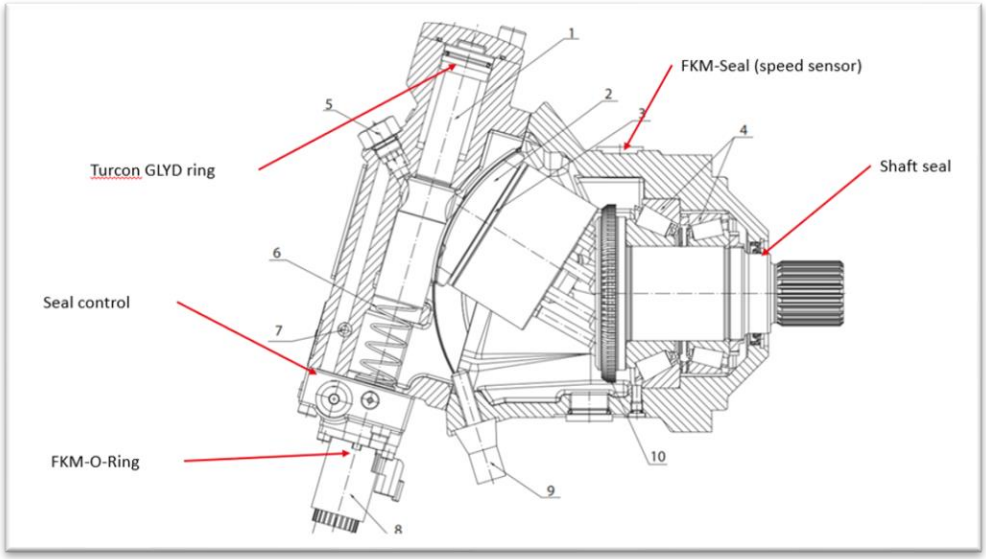

Figure 7: Example – Hydrostatic variable displacement axial piston motor with PTFE and FKM.

Fluoropolymers:

- The use of PFAS substances in indispensable components such as seals is essential for the functionality of the products, especially in safety-related areas where resistance to high temperatures, pressure, abrasion, and to other extreme working conditions are required.
- PFAS-containing seals and coatings play an important role in many product lines that convey hydraulic fluids (e.g. pumps, hoses, etc.). These components are supplied individually or as advance solutions for integration into final machine applications with no direct exposure to the environment.
- The identified essential use of fluoropolymers in seals, coatings, and bushings is a stopgap situation in which replacements are actively sought. The essential use concept expects that PFAS uses considered essential today should be continually reviewed for potential removal or replacement by new technologies and be targeted by innovation toward alternatives. Unfortunately, fluoropolymers are the only comparable alternative to comply with a variety of official safety regulations applicable to Danfoss Power Solutions today.

Key components	**Key products**	**Key Properties/requirements in relation to the materials used**	**PFAS Materials**
Seals Seal rings Coatings Bushings	Axial piston pumps & motors Gear pumps & motors Steering Valves Electronic Controls Hoses	Resistance to physical effects (e.g. heat, pressure, resistance, abrasion, etc.) Safety in high-power and extreme work conditions	FKM PTFE

Table 3: List of fluoropolymers used in Danfoss Power Solutions.

Danfoss Power Electronics and Drives

As a result of the recent partnership between **Danfoss Power Electronics and Drives** and **SEMIKRON-Danfoss**, we have become a global technology leader in power electronics and AC/DC and DC/DC power conversion. Our innovative solutions for electric motors, automotive, industrial, and renewable applications enable the world to utilize energy more efficiently and sustainably, significantly reducing overall CO_2 emissions. With the world's largest portfolio of power converters, VLT® drives, and VACON® drives, we offer a comprehensive range of semiconductor devices, power modules, stacks, and systems. As the world goes electric, our technologies are more relevant than ever, and we are committed to helping our customers meet one of the biggest challenges of our time:

- Low-voltage single- and three-phase drives
- Medium-voltage drives
- Motion drives
- Low-harmonic drives
- Intelligent drives
- Decentral drives
- Semiconductor/chip production.

For the applications we are serving industries like HVAC (Heating, Ventilation, and Air Conditioning), Water - Wastewater treatments, Food & Beverage industries, Heavy industries, Textiles, Automotive, Electrification & Marine.

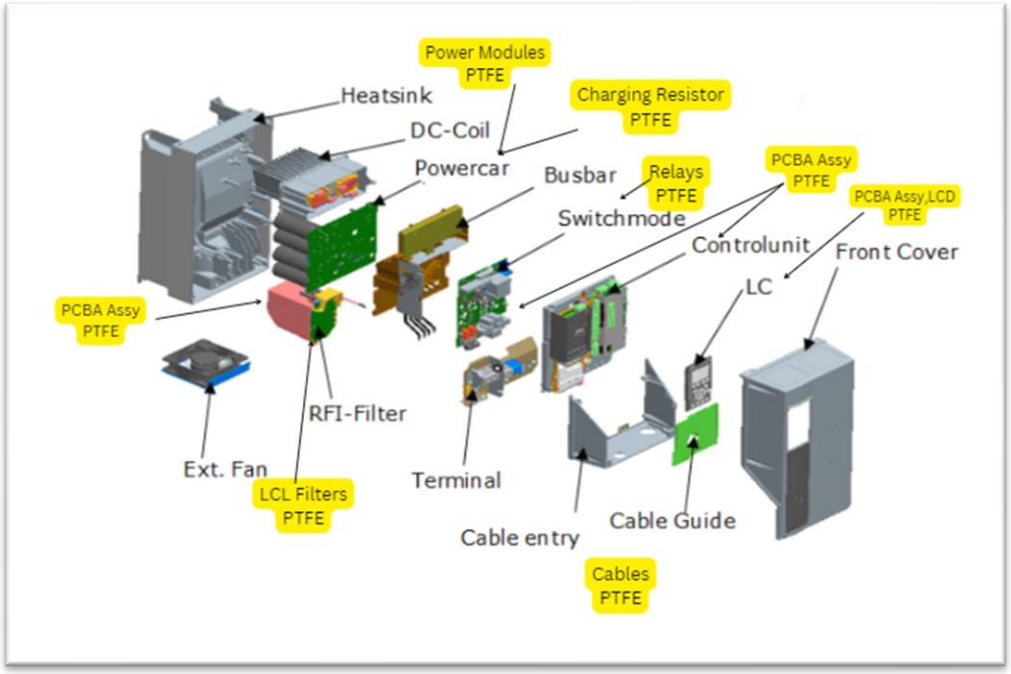

Figure 8: Example – Frequency Converter with PTFE-containing components.

Fluoropolymers:

- The use of PFAS substances in components such as relays, soft starters, power modules, capacitors, LCL filters, conformal coating PCBAs (Printed Circuit Boards Assembly), cables, batteries, semiconductors, chip, and charging resistors is essential for the functionality of Danfoss Drives products. These components are essential for safety-related areas where resistance to elevated temperatures, pressure, abrasion, and other extreme conditions are required.
- Semiconductor parts, cables, and coatings play a critical role in ensuring the reliability and performance of Danfoss Drives products - especially in heavy industry applications. While some of these components may contain PFAS, they are supplied individually or as advanced solutions for integration into final machine

applications, with no direct exposure to the environment. These components are essential to the success of the European Green Deal, as they enable the creation of essential technologies like PV systems and wind turbines.

- While fluoropolymers are currently the only comparable alternative for complying with official safety regulations applicable to Danfoss Drives, the company actively seeks replacements for identified essential uses of PFAS. The essential use concept expects that PFAS uses considered essential today should be continually reviewed for potential removal or replacement by innovative technologies and targeted by innovation towards alternatives.

Key components	**Key products**	**Key Properties/requirements in relation to the materials used**	**PFAS Materials**
Power module Relays Capacitors LCL filters Conformal coating in PCBAs Cables Batteries Charging resistor O-Rings Semiconductors Computer chips	Power modules Soft starter Variety range of drives Electric converters	Safety in high-power and extreme work conditions Resistance to physical effects (e.g. heat, pressure, resistance, abrasion, etc.)	PTFE ETFE Potassium nonafluoro-1-butanesulfonate Methyl perfluoroisobutyl ether Methyl nonafluorobutyl ether PFA (perfluoroalkoxy) PVDF (polyvinylidenfluorid) ECTFE (ethylenchlor-trifluorethylen) PFPE (perfluorpolyether)

Table 4: List of fluoropolymers used in Danfoss Power Electronics and Drives.

Conclusions

- At Danfoss, we take our responsibility to provide safe and sustainable solutions very seriously and we are committed to delivering products that meet the highest standards of quality and safety.

- Danfoss' current product portfolio has been developed and improved over decades and as described in previous sections, different types of PFAS, primarily fluoropolymers such as PTFE, FKM and PFA are key for the performance and lifetime of our products. There are currently no known, suitable alternatives to our PFAS applications, and substitution of PFAS from our products would require a complete re-design of thousands of parts in close collaboration with our complex, international supply chain: a very time-consuming, iterative process involving several rounds of testing, re-qualification and, in many cases, recertification of the new designs.

- Fluoropolymers: The validity periods of the derogations currently proposed vary between 4 and 12 years, and this is far from enough time for industry to make proper redesigns. We strongly recommend taking into consideration the trial-and-error nature of the redesign phase by granting long-term derogations for fluoropolymers with appropriate review clauses to ensure updated and technology aligned derogations.

- Refrigerants: The scientific evidence of the harmfulness of the breakdown products of f-gases seems very doubtful based on the official main institutions as the UN expert panels. Furthermore, there is a tremendously big span of the TFA amounts depending on the type of the f-gases. Very important refrigerants like R1234ze, R1233zd(E), R1336mzz(Z) are negligible in their TFA formation, and it would be disproportionate to ban them. We therefore ask to exempt refrigerants from the PFAS restriction scope.

- Correlation with existing regulations: The main concern for PFAS is their very high persistence and consequently their potential accumulation in the environment and in living organisms. We believe that the risk of exposure of PFAS to the environment can to a large extent be mitigated by ensuring well-established processes for handling products at end-of-life. We therefore strongly encourage policy makers to consider how restrictions of PFAS under REACH can be correlated with already existing and/or upcoming regulations. Refrigerants (f-gases) for example, are already controlled via the AIM Act in the USA or the F-Gas Regulation in Europe.

- Enforcement: At Danfoss we are concerned about the authorities' ability to enforce a very broad PFAS restriction covering more than 10.000 substances – in particular, we see the lack of laboratory capacity and suitable analytical methods as limiting factors for proper enforcement. Inefficient enforcement will make it easy for 'free riders' to place non-compliant products on the market, thereby distorting competition.