SHPP's Inputs to the Public Consultation Comments to Annex XV PFAS Restriction Proposal

Question number 6: Missing uses: PTFE Used in Internally Lubricated Thermoplastic Compounds for Electrical Applications

Previous ECHA submission Ref. (ECHA comment ID): 3980

Executive Summary

SABIC's Specialties business (SHPP) produces a range of highly differentiated products, including high-performance thermoplastics, compounds, and additives that meet complex thermal, mechanical, optical, and electrical property requirements.

PTFE internally lubricated engineering thermoplastic (ETP) compounds are widely utilized in safety-critical electrical applications, such as high voltage safety switches, circuit breakers, electrical outlet safety shutters, and more. These compounds offer differentiated properties, such as low friction and high wear resistance, resulting in self-healing and improved tribological properties. They extend the life span of devices or components, reducing plastic waste. In general, these compounds are more expensive than non-internally lubricated compounds and are only used when other materials fail to meet application requirements.

A recent review published by the Society of Environmental Toxicology and Chemistry (SETAC) in 2023 states that emissions of PTFE during the use phase of final products are negligible because PTFE is bound within the polymer. The emissions in the waste stage depend on the pre-treatment method. PTFE does not release substances of toxicological or environmental concern, and fluoropolymers are stable and not expected to transform to dispersive nonpolymeric PFAS.

Evaluating the possible alternatives shows that no known alternatives provide the same performance functions and the same/better safety and socio-environmental benefits. Finding an alternative to PTFE in internally lubricated ETP compounds is challenging and would require at least 5-7 years of research and invention. Additionally, numerous tiers, OEMs and moulders across the globe would need to re-design and re-test their tooling, components, and systems, which could take 7-10 years for electrical customers to fully replace. Therefore, it could take at least 12-17 years to develop a new material solution with the same performance and environmental benefits as PTFE, and to replace it in existing applications.

Therefore, SHPP requests a 12-year derogation for PTFE used in internally lubricated engineering thermoplastic (ETP) compounds for electrical applications.

Substance Information:

Substance Name: Poly(1,1,2,2-tetrafluoroethylene)
Synonyms/Abbreviations: PTFE
Molecular formula: $(C_2F_4)_n$
EC/List no.: 618-337-2
CAS number: 9002-84-0
Type: Solid
Application: PTFE used in internally lubricated engineering thermoplastic (ETP) compounds for electrical applications

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1. Technical description

1.1 Application description

SABIC's Specialties business, SHPP B.V. (hereafter "SHPP"), produces a range of highly differentiated products, including high-performance thermoplastics, compounds, and additives that meet complex thermal, mechanical, optical, and electrical property requirements.

PTFE internally lubricated engineering thermoplastic (ETP) compounds are designed to be converted by injection moulding and extrusion for use in components in electrical applications such as high voltage safety switches, circuit breakers, electrical outlet safety shutters, etc. These compounds typically comprise a base thermoplastic polymer and a fully or partially fluorinated polymer, such as PTFE, which serves the purpose of providing lubrication in the final moulded part. Additionally, these polymer formulations may include other additives and pigments, such as glass fibre reinforcements and/or mineral fillers.

ETP compounds containing PTFE are semi-finished products (plastic pellet) that are subsequently injection moulded or extruded into shapes or final parts. The main purpose of these ETP compounds containing PTFE is to reduce wear and friction between moving components and objects to ensure safe, reliable, and cost-effective functioning of the final product over its lifetime. As they are typically more expensive than compounds containing other lubricants or non-internally lubricated compounds, they are only applied by fabricators of parts when solutions or parts made from other materials fail to meet the application requirements.

These compounds are in many cases optimized for the specific requirements of the final applications. Some examples are:

- Wear and friction properties
- Mechanical properties
- Weight
- Noise reduction
- Vibration
- Chemical resistance
- Temperature resistance
- Cost

PTFE internally lubricated ETP compounds have been produced and sold over the last 40+ years. The differentiated properties of these materials have led to them being used in many different markets and have many different applications. In many cases, the PTFE-containing compounds and the application-specific parts, like structural and safety critical components, must go through complex extended life testing to ensure the devices or components safely function over the expected or mandatory lifetime of the electrical devices and applications.

The moulds used to fabricate electrical components using the PTFE-containing compounds are often complex and designed to fabricate parts to very tight tolerances and to fulfil the applications' technical and regulatory requirements. Any significant change in composition/formulation of the compound, such as eliminating the PTFE and/or replacing it with a possible alternative, could result in needing to modify or replace the moulds to produce parts with the same final design and geometry. Also, a change in formulation or properties of the compound will likely trigger further mandatory design changes in adjacent parts that are not directly affected by this material change, because the parts must function together as a system in an assembly. Any of these changes could take months and years in electrical applications, depending on the complexity, materials used in fabrication and the number of tools per application.

Furthermore, the final assembly often needs to be completely re-tested and re-specified to ensure proper functioning over its lifetime. Regulated applications and safety critical devices require extensive and sometimes severe long-term testing, which often requires several years of testing and validation to complete a substitution. Safety-critical devices include fire detection and protection equipment, and parts of electrical equipment that could be contacted by a user. Given the re-testing and re-specifying coupled with changes in design and production, part substitution can easily take several years to complete. If the application is regulated, safety critical, or both, it may take even longer.

Injection mouldable, PTFE internally lubricated ETP compounds designed for use in electrical applications typically consist of a neat base polymer, PTFE, and in some cases also glass reinforcements and/or mineral fillers. These applications include high voltage safety switches, circuit breakers, electrical outlet safety shutters and more.

These PTFE internally lubricated compounds provide inherent wear and friction performance that eliminates the need for external lubrication (grease, etc.). This performance allows for increased electrical devices lifetimes and warranties, the elimination of the need for servicing (re-applying regular lubrication, e.g.), and reliable functioning of safety critical components. Some examples of current commercial applications of PTFE internally lubricated ETP compounds are described below.

Circuit breakers and safety switches are devices used for electrical safety. They automatically interrupt the current flow when an electric circuit is overloaded or when there are ground faults or short circuits. When protective relays detect a fault, circuit breakers "trip" or shut off current flow. This action protects the electrical installation and equipment from being exposed to high currents, which could result in overheating, damage, loss of function, and even fire.

Electrical outlet safety shutters are specifically designed to prevent any object other than plugs from being inserted into domestic sockets, thus reducing the risk of electrocution and potential injury or death. This safety feature also applies to adapters and electrical extension cords that may remain unused but still under tension (connected to a power source).

The preferred mechanism for opening outlet safety shutters is by simultaneously pressing in two pins. When used outdoors, these outlet safety shutters provide an additional barrier to prevent water and moisture from overloading the electric circuit, and to prevent ground faults. These products also help reduce short circuits, which can cause electrical devices and wiring to overheat and potentially result in damage, loss of function, or fire.

Some examples of above-mentioned devices:

Electrical Socket

General Electrical Devices

1.2 Function of material/article and PFAS content

Depending on the specific requirements for the application, the PTFE internally lubricated ETP compound provides a tailored combination of lubricating effects, electrical properties, mechanical properties, chemical resistance properties, heat resistance and in some cases flammability performance. These properties facilitate maintenance-free, reliable, and proper functioning of safety-critical moving parts in electrical installations and (sub-) components over a long lifetime that can be up to 20 years.

PTFE is used to optimize the tribological (wear and friction) properties of the compounds and articles that are made of it. PTFE, when used in self-lubricated engineering thermoplastic (ETP) compounds, is typically used in the range of 5-20% by weight.

PTFEs in self-lubricated polymer compounds provide a combination of high wear performance and chemical resistance. PTFE can also act as a drip suppressant for improved flammability performance as compared to other non-fluorinated internal lubricants [1].

PTFE has been utilized as an internal lubricant in a wide range of thermoplastic resin chemistries since the 1960s [2], resulting in an extensive understanding of PTFE grades, properties, and performance that is unmatched by other alternative internal lubricant systems. Additionally, PTFE's interactions with other fillers, including carbon fiber, glass fiber, mineral fillers, and flame-retardant additives, are well-known. This knowledge is difficult to replace.

The even dispersion of the lubricant additive into the base resin is critical in ensuring optimal performance in a thermoplastic compound. Poor dispersion can lead to a significant decline in critical mechanical properties, such as impact strength, and delamination of the moulded part. Furthermore, PTFE's hydrophobic nature provides distinct surface interactions when combined with other additives. Basically, an alternative internal lubricant, such as those discussed in Section 3.2, cannot be directly substituted to replace a PTFE-containing formulation and expect equivalent performance.

1.3 PFAS properties required in material/article

The PFAS used in these types of formulations is a fully fluorinated polymer - Polytetrafluoroethylene (PTFE). PTFE possesses distinct tribological properties. Due to its melt temperature and rheological character, neat PTFE cannot be processed by injection moulding. Instead, it must be sintered (compression moulded) at high temperatures to form shaped stock pieces, which are then machined into final parts. These parts are generally used in environments that require high chemical resistance at temperature and pressure, such as in the chemical process industry. Although neat PTFE exhibits very low coefficients of friction, it also exhibits high rates of wear due to its soft surface hardness.

When used as an internal lubricant in a thermoplastic resin, PTFE forms a layer on the wear surfaces, reducing friction between the wear parts and leading to reduced heat build-up and wear. In high-wear applications where a PTFE lubricated resin moulded part is used against steel, the PTFE layer forms on the steel as well. The PTFE chemically bonds to the steel surface through a reaction with the metal oxides present on the steel surface. This wear counterface film is continuously renewed through the wear process[3][4].

Figure 1 below shows how significant the improvement in wear is for PTFE containing thermoplastics across a range of resin types. Wear factor (K) is one measurement of the amount of wear resulting from contact and relative motion to another surface. This data was generated using ASTM D3702. If the result of the test is no wear the K value would be 0, so the larger the K value, the greater the wear.

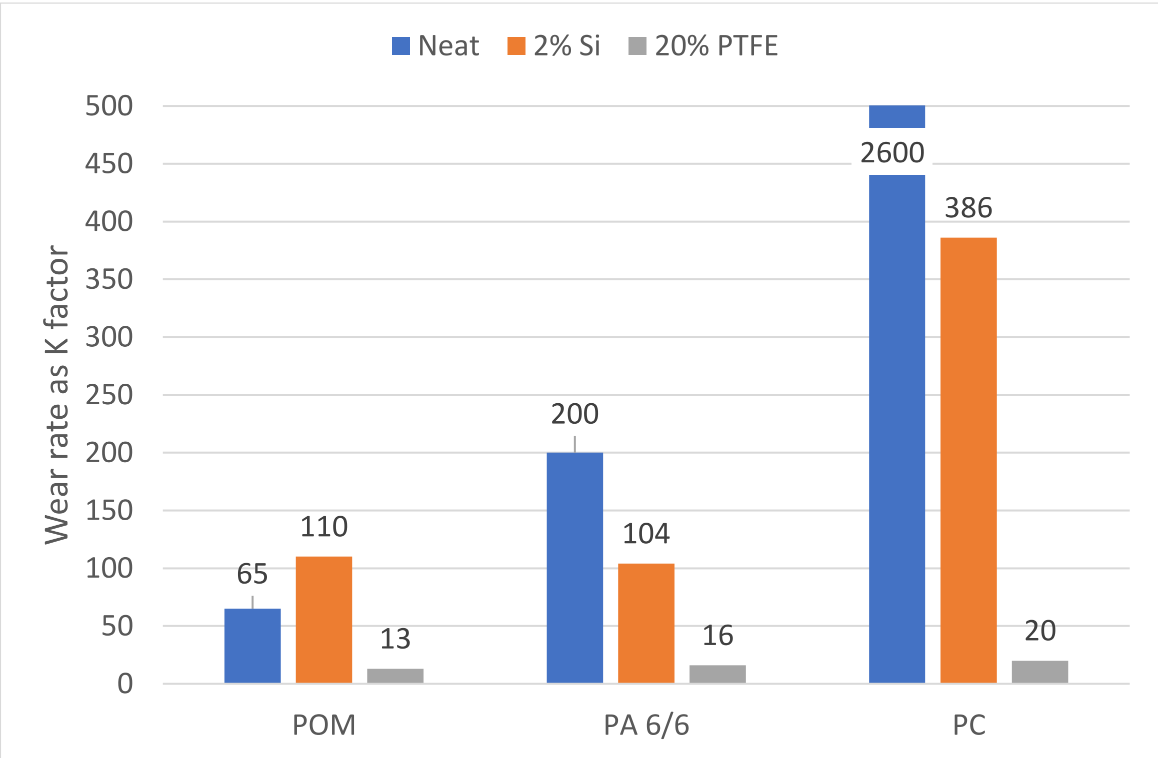

Figure 1 Change in wear of thermoplastic resin by adding PTFE or Silicone as internal lubricant.

For electrical application, a non-exhaustive list of other properties that make PTFE a differentiated material as an internally lubricating additive in ETP compounds are its:

- high melting point
- high resistance to thermal degradation
- very high resistance to chemicals
- very low surface energy
- non-electrically conductive
- inert reactivity due to perfluorinated structure and high molecular weight.

PTFE is a class of polymer that encompasses a wide range of products, which mainly differ in molecular weight, molecular weight distribution, and final particle size of the powdered product. Over the last two decades, the process of producing these PTFE powders has been significantly modified to eliminate the use of PFOA and PFCA fluorinated surfactants as dispersants in aqueous phase emulsion polymerization. These surfactants were found to be environmentally persistent due to their relatively low molecular weight and high surface activity. PTFE suppliers have invested heavily in research to develop more environmentally benign surfactants [5], resulting in many REACH and POPs [6] compliant grades of PTFE.

The powdered form of PTFE is used as an internal lubricant in thermoplastic resin formulations. The powder is dispersed into the base resin, along with other formulation components, using a twin-screw extruder. The temperature, extruder/screw design, and extrusion conditions are optimized based on the specific formulation composition. The high shear environment of the twin-screw extruder is crucial to effectively disperse the PTFE and other additives into the base resin, resulting in a product mainly produced in pellet form.

This pelletized compounded material is subsequently used in injection moulding and/or extrusion processes with or without subsequent secondary operations such as machining of stock forms, assembly, bonding, etc.

The combination of the polymer and PTFE compounded together results in unique tribological properties versus the individual components: the compound immediately exhibits improved wear and friction properties and over time will display self-healing and further improved tribological properties. As a result, these types of PTFE internally lubricated ETP compounds significantly increase the lifespan of devices or components, thereby, reducing the number of new devices or parts needed and minimizing the amount of plastic waste generated during manufacturing and at the devices' end of life.

As PTFE wears, it leads to the formation of a strongly adherent and coherent transfer film. This film forms in the high shear/pressure/temperature environment at the wear interface between the internally lubricated part and the companion part in the wear pairing, which can be plastic or metal. The PTFE at this interface undergoes unique morphological and chemical changes to form films on both wear surfaces. When used against metals, the film can actually chemically bond into the metal oxide surface of the metal part. These films are continuously re-formed at the wear interface during use, making PTFE internally lubricated resins unique in many applications.

By reducing wear in these applications, PTFE lubricated resins reduce the energy required to power the assemblies in which they are used and increase the functional lifespan of these products. This, in turn, reduces replacement costs and the landfilling of these spent parts and assemblies. This trade-off needs to be considered when restricting the use of PTFEs. As an additive in a lubricated formulation, PTFE is generally used in loadings of 5-20 wt% of the bulk compounded product. Since the density of a perfluorinated polymer is higher than that of the base resin, the volume fraction of PTFE is lower than the weight percentage cited.

In contrast, externally applied lubricants, including those containing PTFE micro-powders, have a higher risk of ending up in the environment. This is because externally applied lubricants are often in a lower molecular weight grease base, which makes them more transitory. On the other hand, components or parts manufactured from internally PTFE lubricated plastic compounds can be and are recycled together with the rest of the assembly or application, which can prevent the PTFE from ending up in the environment.

In summary, PTFE internally lubricated Engineering Thermoplastic (ETP) compounds create a durable low-friction and low wearing layer on wear surfaces, improving the long-term reliability and performance of the contacting wear parts. The even distribution of PTFE within the resin ensures continuous re-forming of the high-performance film layer at the wear surfaces during use, effectively increasing the functional lifespan of all parts in the wear environment. The thermal and chemical resistance of PTFE also make it uniquely applicable for use in high temperature and chemically aggressive environments and applications when compounded into high temperature base resins such as PEEK and PPS[7][8]. These high-performance formulations are essential to industries requiring high temperature operations, high dielectric strength, and high chemical resistance.

Compared to the use of external lubricants, internally lubricated polymers are less likely to release fluorinated components into the environment, require less maintenance, and provide longer-lasting parts, ultimately reducing costs and waste.

2. End-of-Life

Emissions during the use phase of final articles are negligible, because PTFE is bound within the polymer. However, it is understood that anti-wear/anti-friction PTFE in products will eventually enter the waste stage with levels in the polymer matrix at 5-20% by weight.

2.1 Concerning Exposure to the Environment

A recent review published by the Society of Environmental Toxicology and Chemistry (SETAC) in 2023 states that emissions of PTFE during the use phase of final products are negligible because PTFE is bound within ETP compounds. The emissions in the waste stage depend on the pre-treatment method. PTFE does not release substances of toxicological or environmental concern, and fluoropolymers are stable and not expected to transform to dispersive nonpolymeric PFAS.

When these internally lubricated articles reach their end-of-life, various waste (pre-) treatment methods are commonly practiced by the industry, e.g., recycling/re-use, landfilling and incineration. Thorough incineration will decompose PTFE without formation of non-polymeric PFAS. When recycling/reuse and landfilling are chosen, polymeric PTFE remains as a fluoropolymer that is not water soluble or mobile and therefore, does not present the specific risks nor hazards as those of non-polymeric PFAS. There is considerable data demonstrating that PTFE do not release substances of toxicological or environmental concerns[9].

In contrast to non-polymeric PFAS, PTFE being a polymeric material is chemically, thermally, and biologically stable and therefore is not expected to transform to dispersive nonpolymeric PFAS when disposed of in landfill. A recent study presented results from OECD guideline biodegradation studies demonstrating that PTFE is stable under environmentally relevant conditions. Furthermore, fluoropolymers that meet the criteria to be considered Polymer of Low Concern (PLC), have negligible leachables, unreacted monomers, and oligomers most likely destroyed in fluoropolymer use processing and would therefore not be expected to significantly contribute to landfill leachate.

Available data reveal that fluoropolymers are mineralized (i.e., all C–F bonds broken, hydrofluoric acid generated, and scrubbed to calcium fluoride) under commercial Waste-to-Energy (WtE) incineration operating conditions. In recent pilot scale studies representative of full-scale WtE facilities, the most common form of end-of-life destruction conducted on PTFE found that combustion converted the fluorine into controllable hydrogen fluoride gas and that, of the 31 PFAS studied, no fluorine-containing products of incomplete combustion were produced above background levels. Further, a recent study investigating the presence of PFAS in waste incinerator flue gas stated: "based on a literature review, RIVM (the Dutch National Institute for Public Health and the Environment) expects that most of the PFASs will largely degrade during the incineration process and then be removed when the flue gases are cleaned. The remaining PFASs are expected to be removed during the recovery of the carbon dioxide". The RIVM report [10] affirmed that PTFE is the most stable fluorine-containing polymer. The RIVM report concluded that complete thermal decomposition of PTFE is achieved at a temperature of approximately 800 °C.

3. Availability of substitutes

3.1 Alternative applications

There are no known alternatives to PTFE used in internally lubricated plastics that result in the same differentiated tribological properties and application performance. Alternative formulations/compositions would require re-design and re-qualification of parts and would significantly risk not meeting the safety and performance requirements needed.

3.2 Alternative substances

Polymer compounds with silicone oil based lubricant vs PTFE internally lubricated polymer compounds have:

- Potential safety risk due to malfunctioning and shorter application lifetime because the silicone oil will naturally self-migrate from the polymer and from the contact surface due to physical movement of the parts and changes in viscosity due to temperature differences.
- Potential safety risk due to malfunctioning and shorter application lifetime because the silicone oil can damage other components in the devices (e.g., electrical components).
- Potential risk of manufacturing issues: painting and bonding operations can suffer from quality issues when silicone oil-based materials are used in the area.
- Waste and cost issues due to the need to guarantee application performance by undergoing periodic inspections, maintenance and/or replacement of the entire device/system.

Polymer compounds with Molybdenum disulphide (MoS_2)-based lubricant vs PTFE internally lubricated polymers have:

- Potential safety risk due to malfunctioning because the MoS_2 is a semi-conductor and generates a lot of fine debris when wearing so this makes it less suited as a lubricant especially where electrical insulation must be guaranteed.
- Potential safety risk due to malfunctioning and shorter application lifetime because the MoS_2 only offers very minor reduction in friction and increased wear of the compound especially at higher pressures, velocities, and/or temperatures.
- Waste and cost issues due to the need to guarantee application performance by applying periodic inspections, maintenance, and/or replacement of entire device/system.

Polymer compounds with graphite-based lubricant vs PTFE internally lubricated polymers have:

- Potential safety risk due to malfunctioning because the graphite is electrically conductive and generates a lot of fine electrically conductive debris when wearing.
- Potential safety risk due to malfunctioning and shorter application lifetime because the graphite only offers much less reduction in wear friction and is typically only suitable in aqueous environments because of increased wear of the compound especially at higher temperatures.
- Waste and cost issues due to the need to guarantee application performance by applying periodic inspections, maintenance, and/or replacement of entire device/system.

Polymer compounds with olefin-based lubricant vs PTFE internally lubricated polymers have:

- Compatibility and mechanical degradation issues. Various types of polyolefins have been developed as internal lubricants in thermoplastics[11]. Their incorporation into thermoplastic resins requires the use of compatibilizers and usually degrades the mechanical properties of the resultant compounded product. Their ability to be used is highly resin dependent and is also highly dependent on other additives in the formulation.
- Limited application space as they are only applicable in certain use cases. These compounds offer an alternative in some applications that do not require high wear and/or high temperature conditions. They will not be applicable for use in all applications currently using PTFE as an internal lubricant.
- Performance and property reduction issues. The temperature performance and chemical resistance may be reduced (compared to PTFE containing resins) and delamination in moulded parts may occur (dependent on part design).
- Waste and cost issues due to the need to guarantee application performance by applying periodic inspections, maintenance, and/or replacement of entire device/system.

Externally lubricated solutions (using greases, waxes, and oils) including those containing PTFE micro-powders vs PTFE internally lubricated polymer compounds have increased:

- Potential safety risk due to malfunctioning and shorter application lifetime caused by the loss of the external lubricant, which migrates away from the applied surface due to physical movement of the application and changes in viscosity due to temperature differences.

- Potential safety risk due to malfunctioning and shorter application lifetime because of debris, dirt, and contaminants getting caught in the external lubricant, causing excessive wear and/or blocking.
- Waste and cost issues due to the need to guarantee application performance by undergoing periodic inspections, maintenance, and/or replacement of the entire device/system.

Table 1: Comparison of the tribological performance differences of various internal lubrication additives in nylon 6/6 base resin. Data generated using ASTM D3702 at 50 fpm, 40 psi, 23C and a steel counterface.

Internal lubricant	Wear Factor (K), lower value is better	Coefficient of friction (dynamic), lower value is better
10% PTFE	Baseline (49)	Baseline (0.27)
2% MoS2	110% Increase (103)	178% Increase (0.75)
2% Silicone	112% Increase (1040)	63% Increase (0.44)
Unmodified nylon 6/6	306% Increase (199)	141% Increase (0.65)

3.3 Health and environmental hazards of alternative to PTFE

Table 2: Comparison of health and environmental hazards of some alternatives to PTFE

Substance name	Cas no	EC no	Hazard Category	CLP Notes1	LogKow	BCF	PBT/vPvB	Uses	Additional information
Silicone oil/Polydimethylsiloxanes	63148-62-9	613-156-5	*Not classified*		8.21	3 397	No data found	Base oil (silicone)	May contain residual amounts of cyclic methyl siloxanes (D4, D5 and/or D6)
Molybdenum disulphide (MoS2)	1317-33-5	215-263-9	*Acute Tox. 4*		2.23	13.73	Inorganic	Solid additive in lubricants	
Graphite	7782-42-5	231-955-3	Not classified				Not applicable	Solid additive in lubricants	
olefin-based lubricant			Not classified					Solid additive in lubricants	

Source: Appendix E2 – Annex XV PFAS Restriction Proposal.

4. Development of possible substitutes

4.1 Actions taken to develop alternative applications or alternative substances

Externally lubricated materials (plastics and metals) and other internally lubricated plastic compounds could be used in some cases but at a considerable:

- Increase of cost

- Decrease of lifetime of the parts and devices
- Increase of waste
- Decrease of functionality to the end-user

Where the original PTFE internally lubricated ETP compounds were used for safety reasons, replacement would also bring a significant increase in risk for the end-user caused by potential malfunctioning of the devices.

4.2 Stages and timeframes needed to establish possible substitutes

First, currently there are no known alternatives to PTFE used in internally lubricated ETP compounds that result in the same distinct tribological properties and application performance (please refer to 3.2). An invention, therefore, will be necessary to develop a new solution without the negative consequences mentioned above for alternatives. It would take at least 5-7 years to develop such a material solution. Second, there are a vast number of globally located individual OEMs and moulders that would need to re-design, re-test and re-certify their tooling, devices, assembly and systems made from PTFE internally lubricated ETP compounds to ensure the proper functioning of a new material solution and design. SHPP expects that our customers (actual parts/devices fabricators) would need at a minimum between 7 and 10 years to ensure all the PTFE internally lubricated ETP compounds are replaced in their electrical applications. In most cases, service/replacement parts for existing/in-use applications would need to be provided if the design cannot be modified, otherwise the entire application/device would need to be replaced.

Overall, it is estimated that to develop a new material solution with the same performance, safety, and environmental benefits, as well as for the moulders and OEMs to re-design and re-test their tooling, parts, and devices, will take at least 12-17 years.

5. Request for derogation for use of PTFE Used in Internally Lubricated Thermoplastic Compounds for Electrical Applications

Given the two derogation choices, SHPP respectfully requests a 12-year derogation. Since there are no PTFE alternatives available which can provide the same performance functions and the same/better safety and socio-environmental benefits, at least a 12-year derogation is absolutely needed. The material industry will need to develop a better solution (or equivalent) if possible, and all the moulders and OEMs from the electrical industry who use this type of material will need to re-design and re-test their parts, devices, and systems.

SHPP considers our derogation request as essentially different from the current derogation in the ECHA proposal for lubricants. Language in the proposal seems to indicate those PFAS-containing "lubricants" are traditional greases and oils (including those containing PTFE micro-powders in external lubricants) that are used in harsh industrial environments or for safety reasons.

Since the proposed derogation is only for PTFE, one additional point of reference is the UK's recently published PFAS regulation proposal. They limited their proposed restriction to certain and specific PFAS substances and did not apply the restrictions to an entire class of fluorine substances. Of particular note, they are excluding fluoroplastics and fluoroelastomers (such as

PTFE, PVDF, etc.), which they consider as low hazard groups, from their proposed regulation. Presumably, this is because fluoropolymers (such as PTFE) are not water soluble, are not mobile, and do not present the same level of environmental hazards as low-molecular-weight non-polymeric PFAS. SHPP believes this also provides a basis for a total exemption of PTFE from the potential REACH restrictions if one is to be considered.

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