Response to the public consultation on the global PFAS restriction project

September 2023

Five connector manufacturers - Amphenol Socapex, Eaton Souriau ITD, ITT Cannon GmbH, Radiall SA and TE Connectivity- have decided to call on **EcoMundo** as an independent third party to collect, aggregate and anonymise data for their response to the public consultation on the global PFAS restriction project.

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CONTENTS

Figures

Tables

1. CONTEXT AND INTRODUCTION TO CONNECTORS' INDUSTRY AND ACTIVITIES

The comments and observations of five connector manufacturers - Amphenol Socapex, Eaton Souriau ITD, ITT Cannon GmbH (representing Cannon and Veam Products), Radiall SA and TE Connectivity- are here presented regarding the restriction proposal on the manufacture, placing on the market and use of PFAS. Those companies design and manufacture high performance connectors intended for EU critical applications (i.e military, aeronautics, space or heavy industry sectors), subject to strong safety requirements, where thousands of inter-dependent connectors can be used for the high performances transmission of signals vital for the functioning and the safety of these systems. The connectors' industry is part of the "Global technology industries" segment, also comprising computers and electronics, which support its high interdependence with EU's related key sectors (energy; defense; aerospace…) and other "R&D" and "high-tech" related production networks.

The companies represent a significant partof the worldwide multi-contact connectors industry. Their statements and activities will significantly impact the connector sector and multi-contact connector end-customers applications.

The term "connector" refers to the entire component composed by several subcomponents (Fig 1), requiring specialized skills and equipment for their manufacturing. Connectors are entrenched in a worldwide system of interconnected qualification and certification standards. Component manufacturersoccupy a strategic position within critical EU supply chains. Both upstream and downstream industries define the functional requirements of connectors but also depend on connectors manufacturers for their deployment within their applications.

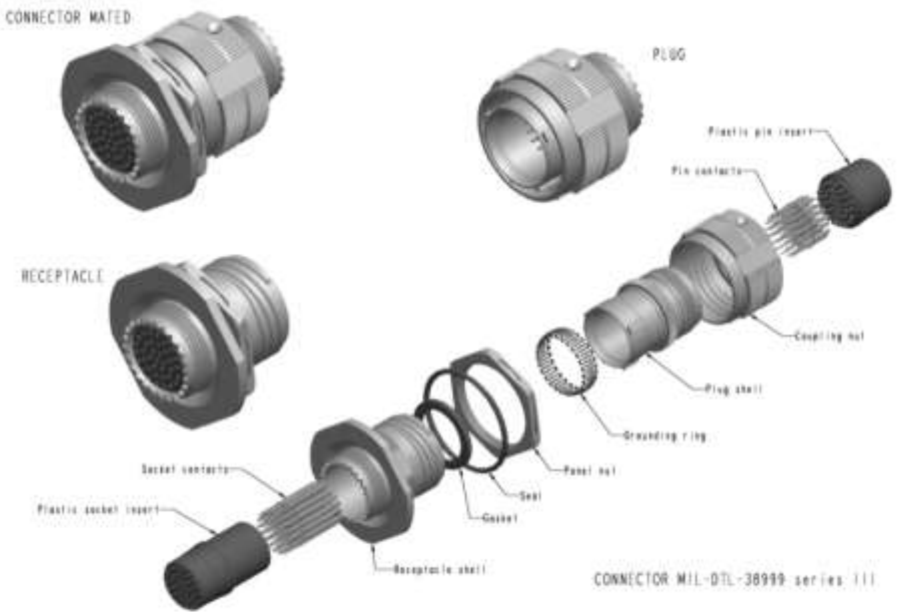

Figure 1 Schematic view of a connector and its sub-components

Inter-dependent process steps are necessary to obtain key performances of connectors (Fig. 2) and compliance with European and International normative requirements for customers' systems.

Figure 2 Simplified global manufacturing process of connectors

The key manufacturing processes are fully internalized in order to ensure the supply of any high-quality connector reference associated to specific normative and customer requirements in a brief timescale. Due to the wide range of their customers' applications, the companies presenting their views herein, design and manufacture more than 150 000 references of specific connectors that differ in shape, size, number and position of pins.

The harsh environment (humidity, temperature, vibrations, corrosion) to which connectors are subject combined with the normative and specific customer requirements in terms of signal transmission quality, define the highly technical nature of these products. To date, PFAS or PFAS-containing mixtures and materials are still used by the companies presenting their views herein or their supply-chain in the different manufacturing steps of sub-components required for the production of a connector in its entirety.

2. OVERVIEW OF MAIN PROCESSES AND PARTS CURRENTLY REQUIRING THE USE OF PFAS IN CONNECTORS MANUFACTURING

The signatory companies are notably manufacturers of hermetic connectors, also known as waterproof or sealed connectors, used on systems or subsystems submitted to harsh environments during their life cycle. The sealing is therefore essential to protect internal components from moisture, dust, chemicals, or other contaminants contributing to the overall reliability, durability, and performance of the connector itself.

A connector can be divided into four main sub-components (Fig. 3):

- **The Shell**, a metallic or plastic component, ensures contact's alignment during mating operation and the protection of inserts. A surface protection can be applied on the shell to maintain the performance and integrity of the connector in harsh environment (eg. prevent wearing during mechanical endurance and pooling of corrosive moisture);
- **The Insert** (or isolators), a plastic or rubber component identified by its contact arrangement, provides mechanical support and positioning for the various contacts, which are generally clipped in place internally. Inserts are intended to prevent electrical short circuits, reduce the risk of electrical shocks, and maintain the integrity of the electrical signal or power transmission;
- **Seals,** plastic components of variable sizes and shapes, ensure the sealing of connectors or connectors' sub-components. A proper sealing is essential in connectors to ensure reliable electrical connections, preventing corrosion, and maintaining the performance and integrity of the connected devices or systems. Gaskets, rear grommets, interfacial seals, O-rings, panel seals, membranes or sealing plugs are different types of seals used in different connectors systems;
- **The contact,** a metallic component held inside the insert by retention clips, conveys a signal between connectors mating halves. The contacts are generally PFAS-free, except for RF coaxial contacts and High-speed data contacts such as quadrax or triax or twinax contacts: PFAS insulators hold the center contact(s) in the outer contact while guaranteeing the integrity of the RF or High speed data signal transmission.

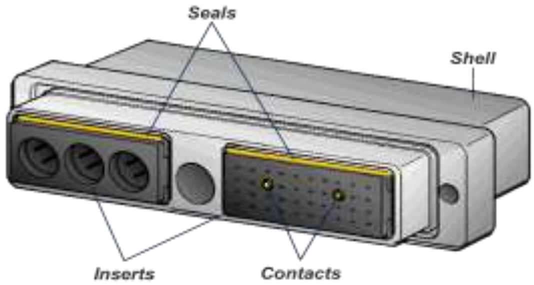

Figure 3 Schematic representation of main connectors' sub-components

Figure 4 Example of contacts

PFAS are involved directly or indirectly in the manufacturing of those connector sub-components. The following table summarizes the different main uses of PFAS for the signatory companies:

Use identified	Sub-component concerned	Manufacture Step
Raw material for Manufacture of components	**Insert** **Seal** **RF &High-Speed Contact**	**Molding** **Machining**
Anti-adhesive agent	**Shell** **Contact** **Mold**	**Surface treatment**
Lubricants	Insert Seal Connector	Moulding Assembly
Cleaning/degreasing agent	Contact Insulator Mold	Assembly Moulding Surface treatment
Cleaning and drying agent	Shell Insert	Surface treatment

Table 1 Overview of parts and processes impacted by the use of PFAS

In terms of tonnage, overall under 20 tons of PFAS are used across all companies annually.

It is to be noted that PFAS are mainly involved as raw materials for the production of inserts and sealing sub-components of connectors. Additionally, PFAS have been identified to be used as lubricants and as cleaning, degreasing and anti-adhesive agents (Fig 4). However, these uses are critical for the manufacturing processes despite their relatively low PFAS tonnages. Moreover, the PFAS used under those both uses are contained in purchased mixtures or articles and thus the alternative research is dependent on suppliers. In both cases of use as lubricant and as cleaning, degreasing and anti-adhesive agents, PFAS are used during the surface treatment process of contacts and molds but also during the molding, the machining and the assembly of sub-components.

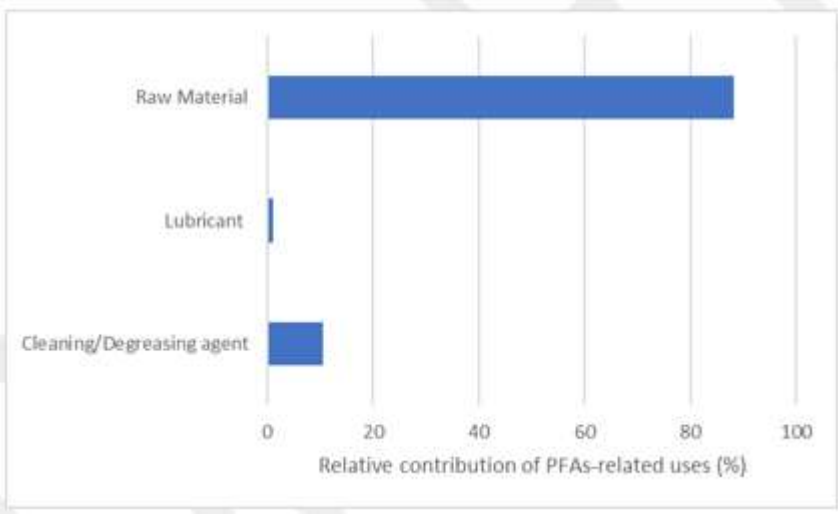

Figure 5 Relative contribution of PFA's uses amongst signatory companies

PTFE (CAS 9002-84-0) and FVMQ (CAS 63148-56-1/ 68037-87-6) contribute to almost 75% of the overall tonnage of PFAS used in the manufacturing of seals and inserts. The remaining 25% of PFAS used by signatory companies as raw material are indicated in the PFAS list in Annex I.

Hence, inserts and seals are for the vast majority manufactured by a molding process using PFAS-based raw materials. Sub-components (inserts and seals) are then assembled together with the contact and the shell to form the connector itself. Final products delivered to consumers therefore contain PFAS-based sub-articles.

Connectors are **used in critical EU sectors and destined to complex systems** entrenched in a **worldwide system of interconnected standards**. Thousands of connectors can be used in a given system (aerospace, defense, energy, nuclear for instance) and are **vital for the very functioning and therefore the safety of these applications. The main PFAS' use in signatory companies processes is related to the PTFE- or FVMQ- and FKM-based manufacture of inserts and seals sub-components.** Technical functions provided by PFAS and sought for in the manufacture of those inserts and seals sub-components are detailed below.

3. TECHNICAL FUNCTIONS OF PFAS & ALTERNATIVES IDENTIFIED

3.1 Technical functions

Defense, aerospace and energy sectors are the main recipients for the signatory companies' connectors. **The harsh environment to which these connectors are subjected, as well as the normative and specific requirements of those sectors in terms of signal transmission quality, are the conditions illustrating their high technical nature and also the constraints linked to the alternative research.** Articles need to withstand global performances of products as described in military European and international standards and norms precisely defined for such extreme conditions of use.

Harsh environment in electronics could be defined as a range of challenging conditions that cause significant operational limitations to electronic products. Factors that can be used to characterise harsh environments within the electronic industry include temperature, chemical, mechanical and radiative stresses. Extremely high or low temperatures, high pressures, aggressive fluids, or inflammability risks are examples of these stresses. Each of the mentioned stresses contributes to components' decay limiting the lifespan and integrity of electronic products.

In the electronics industry, the use of PFAS as raw material in the manufacturing of electrical subcomponents has significant effects on the longevity and safety of products. It also contributes to meeting the normative and specific requirements of various application sectors in which harsh environments are encountered such as defense, civil aerospace, and space industries. Therefore, achieving strong technical performance in terms of signal transmission quality, is a main requirement in the design of the signatory companies' electronic products.

In order to maintain their proper function (data and/or energy transmission) throughout their entire life cycle and through all conditions, two main requirements apply in the design of connectors: intermate-ability and technical performances.

PFAS have properties which make them important for applications in signatory companies connectors, where high temperatures and voltages apply. Those PFAS' key functionalities are as follows:

- **Excellent dielectric and electromagnetic characteristics,** insulator provides insulation between the inner and outer conductors of the RF and high-speed data contacts, a consistent dielectric constant and mechanical support with the lowest possible electromagnetic impact. As a matter of fact, PTFE and PFA, thanks to a low dielectric constant (2.1) and a low loss tangent ($<10^{-4}$), ensure efficient RF signal transmission and minimal energy loss. This material in such contacts is essential for maintaining the integrity of the transmitted signal by ensuring system characteristic impedance over the full frequency range, with greater temperature stability and over a very large temperature domain. Therefore, the selection of an appropriate material is imperative, leading to the utilization of PFAS for this specific purpose.

- **Good electrical insulation properties**: insulator provides insulation between the conductors. PFAS involve good electrical insulating or elevated dielectric strength. This has led to their use in insulation, where they help prevent electrical leakage and maintain stable electrical performance in harsh environments (fluids, temperature, low pressure etc.).
- **Mechanical resistance:** PFAS have high tensile strength, meaning they can resist substantial stretching or pulling forces without breaking or deforming. This makes them suitable for applications where mechanical durability is essential, like the manufacture of mechanical seals used in electronic connectors.
- **Pressure resistance:** In applications such as gaskets, seals, and O-rings, PFAS can maintain their integrity, sealing capabilities (and chemical resistance) under high-pressure environments, where other materials might fail or degrade.
- **Thermal Stability:** PFAS have high thermal stability, allowing them to withstand elevated temperatures without degradation, as needed in connector applications. This property makes them suitable for applications that involve exposure to high temperature environments (e.g. from -65°C up to 260°C). They also have excellent low temperature performances.
- **Chemical inertness:** PFAS compounds are chemically inert, meaning they are not easily reactive with other substances. This characteristic allows them to remain stable and effective even in harsh environments with exposure to chemicals, solvents, specific liquids like hydrocarbon fuels, oxidation, extreme temperatures, varying pressures, corrosion, flammability, ionizing radiation, etc.

Most of these properties must be combined to meet product requirements. Other desirable properties are also considered for the use of PFAS such as:

- **Compatibility with metals, plastics, seals and elastomers**,
- **Flame retardancy,**
- **Water and oil repellency,**
- **Low Friction,**
- **Non-stick properties.**

These highly severe and combined functional requirements ensure proper operation of the connectors but also – and mainly – the safety of the operators and equipment in the various conditions they are designed to withstand. Please note that such performances depend to a great extent on standards and on the specific requirements of signatory companies' customers.

3.2 Efforts on searches for alternatives

All signatory companies have carried out and continue to carry out strong research works in order to identify alternatives for the different PFAS applications. The maturity of alternatives varies with each signatory company, but the order of magnitude is the same.

There are many specialized uses of PFAS for which no viable alternatives have been identified. These include: raw materials for manufacture of components like inserts and sealing sub-components of connectors or some specific surface treatment applications.

To date, there are no existing alternatives for the signatory companie's specific connector manufacturing related uses with the same level of performance as PFAS substances. Even with lower-performance materials, the impact on current tooling and requalification in terms of cost and requalification will be extensive. For instance, the solutions proposed for coating mold parts do not allow to reach the same level of performance and need therefore to be reworked to improve them. New tools will have to be built, and the unit price is likely to increase. Research and development work are therefore needed to develop alternative solutions that can safely produce high-quality surfaces.

The development of alternative solutions will not only depend on signatory companies but also on raw material manufacturers and standards requirements. Signatory companies will support development of alternative solutions by raw material manufacturers and contribute to update standards or customer specifications.

Moreover, some subcomponents such as seals are also procured from suppliers. The alternatives research is then dependent on their research works. Today, no alternatives with the same harsh requirements are proposed nor even considered by the suppliers which have been contacted by the signatory companies.

Alternatives available on the market, depending on the type of application, may offer promising technical properties in terms of temperature range and substrate compatibility, while other alternatives may offer lesser technical performance, such as lower resistance to high pressure or to fuels and oils combined to high temperatures, resulting in reduced durability and therefore more frequent maintenance. These potential alternatives, will however in any case not reach the industrialization stage before the end of the transition period since several testing, development, industrial deployment and qualification are still necessary before being able to be placed on the market. Indeed, they still have not reached a TRL4[1] validation and are far from this level. **Furthermore, it is to be stressed that those alternatives currently do not fit the requirements of use of PFAS in the manufacture of inserts and seals sub-components.**

[1] Technology Readiness Levels (TRL) are a method of estimating maturity of technology elements and helps in measuring the progress of a project and the maturity of technology components for a system. TRL is based on a scale going from 1 to 9 with 9 being the most mature technology. European Commission, G. Technology readiness levels (TRL), Horizon 2020 – WORK Programme 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.

Connectors are manufactured with specific requirements for each customer. Consequently, there are many different profiles of customers' requirements and it is therefore difficult to identify a single suitable alternative covering them all.

Several fields of applications of connectors are critical for safety such as for aeronautic, nuclear, space and submarine application. **As an example, regarding sealing sub-components for aeronautic applications**, the use of non-PFAS substances can compromise the safety of an aircraft. Indeed, sealing defects lead to a number of malfunctions, including short circuits, breakdowns and loss of connection between sensors and computers. As a result, there will be a loss of signal transmission between the various electronic components, and hence a deterioration in flight controls. Therefore, failure of such connectors may jeopardize the whole plane's airworthiness.

Some connectors, requiring the use of PFAS, are dedicated to the nuclear domain and installed the closest to the reactor building. Applications of these connectors can include pressure transmitters, motors, reactor coolant pump controls, monitoring systems etc. One specificity of such range of products is to be qualified for "Loss Of Coolant Accident" (LOCA). In case of failure or accident that would happen in the nuclear core, the connectors are supposed to be able to maintain their characteristics to guarantee the monitoring of the installation. Nuclear connectors are able to withstand the most severe radiation, temperature and pressure operating conditions to guarantee the safety of the installation.

Further connectors are dedicated to rail applications, rolling stock or railway infrastructure. When it comes to the use in power distribution or converters/inverters or intervehicle connection the ability to withstand temperatures of 800° C for 30 minutes ensures these connectors can maintain critical control signals and allow trains to move away from a fire.

Other connectors are specially designed for various space applications, covering a wide range of systems from launchers to satellites. A typical product is the umbilical connection between the launcher and its platform prior to rocket launch. The system provides on-board power before the booster ignites. Connectors are also directly involved in controlling the separation system between the different stages of the launcher during flight. Any failure of the connection would affect safety and airworthiness.

As a consequence, no alternative, capable of meeting all the standard and customers' requirements for the manufacturing of inserts and seals sub-components, used by signatory companies, and where PFAS are currently used, can at this point in time be deemed as technically suitable for substitution. Additional work and time are required to identify potential alternatives and carry out all associated R&D work, as well as to implement it for substituting the use of PFAS.

4. JUSTIFICATION FOR A DEROGATION REQUEST

Industrialization is a long and complex step-by-step methodology followed to implement a qualified material or process throughout the manufacturing, supply chain and maintenance operations, leading to the item final certification. This includes renegotiation with suppliers, investment in process implementation and the final audit to qualify the new process throughout the supply chain. Any change in the process or in the components concerned can take several years to requalify and ensure that the level of performance achieved is as good as the previous one. To allow industrial deployment, the following milestones must be applied:

1. Companies individual **research projects**: identification, testing and development of alternatives (5y);
2. **Industrial validation** (3-5y);
3. **Internal qualification** (1-1,5y);
4. Qualified Products List **(QPL) qualification** (certification process used in military standardization in the United States) (1-1,5y based on the possibility of updating MIL specifications that require the use of PFAS);
5. **Customer qualification** (1-2 y).

It is not uncommon to iterate several times before a solution passes selection. The expected timeframe for qualification alone is 3 to 5 years, depending on the field of application.

Moreover**, it is important to keep in mind that connectors are implemented in long-lasting applications**, such as aeronautics for which the average lifespan of an airplane is 30 years. During such a period, connector manufacturers are contractually required to supply parts that are identical to those legacy connectors, for maintenance purposes.

The modification of standards to include future alternative processes is a mandatory step for the manufacture and marketing of connectors, as it conditions external and customer qualification. A period of three to five years is envisaged for the integration of alternative processes into the content of standards alone.

As a synthesis, a general scheme for substitution can be outlined as follows:

Figure 6 General substitution process

It has to be further noted that, regarding the manufacture of sealings and insert sub-components requiring the use of PFAS, any modification of the raw material will have an impact on the existing moulds. The moulds used to manufacture sealings and insulators will have to be redesigned, modified or remanufactured, then tested and industrially deployed. The alternative will also have to be evaluated, tested and qualified, as will the connectors. It may also be necessary to re-qualify the equipment for the connector manufacturers customers.

Overall, **a ban on PFAS would impact signatory companies' worldwide connector production.** PFAS are widely used throughout the products portfolio. Most connectors are qualified by customers (OEMs in the aerospace, nuclear, marine and space industries, etc.) or by certification bodies (EN, MIL, ...).

The level of performance provided by PFAS substances is an essential condition to the competitiveness of connectors industry. Therefore, its banning without derogation will impact a major share of the companies' activities. Given the strategic importance of the components concerned by the use of PFAS, and its importance for signatory companies in terms of activity, know-how and competitiveness, the consequences of a simple ban of PFAS without any temporary derogation would be wide with economic, social and distributive impacts:

- **Distributional End customers and OEMs impacts** would mainly concern the aerospace, civil and defense industry, which would suffer dramatic impacts, ranging from supply chain disruptions, to practical security impacts during aeroplane flights notably, as it will not be possible to transmit critical signals for lift-off, landing and during the flights, meaning that the mere existence of all industry sectors requiring, notably for safety reasons, to use connectors for signal transmission, would be at risk. This is also notably the case during rocket launch, where connectors are used in the umbilical connection between the launcher and its platform prior to rocket launch. Any failure of the connection would affect safety and airworthiness.

- **Economic impacts** on signatory companies' business will include loss of profits, rupture in the supply chain, loss of activity and partial or complete shutdown of production. **All signatory companies would be impacted by a global PFAS restriction on more than 70% of their annual sales, representing more than 600M€ business value in 2023**. **Therefore, such scenario would as a consequence inevitably lead to the closure of some plants.**

- **Social impacts** are difficult to evaluate throughout the supply chain, considering however the End-customers and OEMs impacts mentioned above, social impacts in case of no-derogation PFAS restriction are expected to be very far reaching. **Considering only the signatory companies, the social impact on employment will mean that more than 5.000 persons would be at risk of losing their employment due to plant closures.**

5. PROPOSED DEROGATIONS

The relevance to include Fluoropolymers in a global EU restriction is questioned because of a possibly lower impact than other PFAS on the environment[2]. Nevertheless, in any case, based on technical, economical, qualification and certification considerations, previously explained, signatory companies have identified the need for proposed at least 12-year derogations for connectors manufacturing and connector uses, as well as some uses for which a substitution is expected to be possible in a shorter timeframe, as listed in the table below.

Type of Use	Duration of derogation request
Use of PFAS (notably Fluoropolymers (like FVMQ, FKM or PTFE)) as a raw material for the manufacture and the subsequent use in the supply chain of PFAS-containing inserts and seals sub-components in connectors destined to harsh environment (defined in §3	At least 12 years
Use of PFAS (PTFE, PCTFE and ETFE) as a raw material for the manufacture and the subsequent use in the supply chain use of PFAS-containing insulation bodies in RF coaxial contacts and High-Speed Signal contacts	12 years
Use of PFAS as an antiadhesive agent for the surface treatment of molds required for the manufacture of inserts and seals sub-components for connectors	5 years
Use of PFAS as additive for lubrication in surface treatment of connector shell	5 years
Use of PFAS as a lubricant agent required for the assembly of inserts and seals sub-components into connectors and subsequent use in the supply chain of those PFAS containing connectors	5 years
Use of PFAS as cleaning and drying agent during surface treatment process of connectors	5 years

Table 2 Proposed derogations

[2] Bruno Ameduri, Jaime Sales and Michael Schlipf, *Developments in Fluoropolymer Manufacturing Technology to Remove Intentional Use of PFAS as Polymerization Aids* (2023)

6. ANNEX

6.1 PFAS involved in signatory companies' activities

- **List of all PFAS used**

CAS number	PFAS name
9002-83-9	Chlorotrifluoroethylene polymer (PCTFE)
9002-84-0	Polytetrafluoroethylene (PTFE)
63148-56-1/ 68037-87-6	Fluorosilicone (FVMQ)
64706-30-5/ 64706-30-6	Fluoroelastomers
2374-14-3	2,4,6-trimethyl-2,4,6-tris(3,3,3-trifluoropropyl)cyclotrisiloxane
68952-02-3	Siloxanes and silicones, methyl 3,3,3-trifluoropropyl, methyl vinyl, hydroxy terminated
25067-11-2	Tetrafluoroethylene-hexafluoropropene copolymer
1478-61-1	4,4'-[2,2,2-trifluoro-1-(trifluoromethyl)ethylidene]diphenol
75768-65-9	benzyltriphenylphosphonium, salt with 4,4'-[2,2,2-trifluoro-1-(trifluoromethyl) ethylidene]bis[phenol] (1:1)
25190-89-0	1-Propene, 1,1,2,3,3,3- hexafluoro-, polymer with 1,1- difluoroethene and 1,1,2,2- tetrafluoroethene
9011-17-0	1-Propene, 1,1,2,3,3,3- hexafluoro-, polymer with 1,1- difluoroethene
26425-79-6	Perfluoro(methyl vinyl ether)-tetrafluoroethylene copolymer
26655-00-5	Poly (tetrafluoroethylene-co-perfluoro(propylvinyl ether))
67925-82-2	Perfluoroalkoxy alkanes (PFA)
69991-67-9	1-Propene, 1,1,2,3,3,3-hexafluoro-, oxidized, polymd.
161075-00-9	hexafluoropropene
15290-77-4	1,1,2,2,3,3,4-heptafluorocyclopentane
138495-42-8	Reaction mass of (3R,4R)-1,1,1,2,2,3,4,5,5,5-decafluoropentane and (3S,4S)-1,1,1,2,2,3,4,5,5,5-decafluoropentane
56773-42-3	Tetraethylammonium heptadecafluorooctanesulphonate

25628-08-4	Tetraethylazanium nonafluorobutane-1-sulfonate
163702-05-4	1-ethoxynonafluorobutane
163702-06-5	1-ethoxy-1,1,2,3,3,3-hexafluoro-2-(trifluoromethyl)propane
69991-61-3	Fluoropolymer oil: Ethene, 1,1,2,2-tetrafluoro-, oxidized, polymd.
24937-79-9	Polyvinylidene fluoride (PVDF)
335-67-1	Pentadecafluorooctanoic acid
68258-85-5	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene (ETFE)

- **List of PFAS used as raw material for the manufacturing of sealing and insulating subcomponents**

CAS number	PFAS name
9002-83-9	Chlorotrifluoroethylene polymer (PCTFE)
9002-84-0	PTFE
63148-56-1/ 68037-87-6	Fluorosilicone (FVMQ)
64706-30-5/ 64706-30-6	Fluoroelastomers
2374-14-3	2,4,6-trimethyl-2,4,6-tris(3,3,3-trifluoropropyl)cyclotrisiloxane
68952-02-3	Siloxanes and silicones, methyl 3,3,3-trifluoropropyl, methyl vinyl, hydroxy terminated
25067-11-2	Tetrafluoroethylene-hexafluoropropene copolymer
1478-61-1	4,4'-[2,2,2-trifluoro-1-(trifluoromethyl)ethylidene]diphenol
75768-65-9	benzyltriphenylphosphonium, salt with 4,4'-[2,2,2-trifluoro-1-(trifluoromethyl) ethylidene]bis[phenol] (1:1)
25190-89-0	1-Propene, 1,1,2,3,3,3- hexafluoro-, polymer with 1,1- difluoroethene and 1,1,2,2- tetrafluoroethene
9011-17-0	1-Propene, 1,1,2,3,3,3- hexafluoro-, polymer with 1,1- difluoroethene
26425-79-6	Perfluoro(methyl vinyl ether)-tetrafluoroethylene copolymer
26655-00-5	Poly (tetrafluoroethylene-co-perfluoro(propylvinyl ether))
67925-82-2	Perfluoroalkoxy alkanes (PFA)

68258-85-5	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene (ETFE)

- **List of PFAS used in surface treatment processes**

CAS Number	PFAS name
56773-42-3	Tetraethylammonium heptadecafluorooctanesulphonate
25628-08-4	Tetraethylazanium nonafluorobutane-1-sulfonate
9002-84-0	Polytetrafluoroethylene (PTFE)
24937-79-9	Polyvinylidene fluoride (PVDF)
68258-85-5	1-Hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with ethene and tetrafluoroethene

- **List of PFAS used in lubricant agents**

CAS Number	PFAS name
163702-07-6	Butane, 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-
163702-08-7	Propane,2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoro-
811-97-2	1,1,1,2-Tetrafluoroethane
9002-84-0	Polytetrafluoroethylene (PTFE)
63148-56-1/ 68037-87-6	Fluorosilicone (FVMQ)
69991-67-9	1-Propene, 1,1,2,3,3,3-hexafluoro-, oxidized, polymd.
69991-61-3	Fluoropolymer oil: Ethene, 1,1,2,2-tetrafluoro-, oxidized, polymd.
335-67-1	Pentadecafluorooctanoic acid

- **List of PFAS used in cleaning agents or degreasing agents**

CAS Number	PFAS name
29118-24-9	Propene, 1,3,3,3,-tetrafluoro-,(E)-
-	Reaction mass of 1,1,2,3,3,3-hexafluoro-1-methoxy-2-(trifluoromethyl) propane and 1,1,2,2,3,3,4,4,4 nonafluoro -1-methoxybutane
811-97-2	1,1,1,2-Tetrafluoroethane
132182-92-4	1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-(trifluoromethyl)pentane
161075-00-9	Hexafluoropropene, oxidized, oligomers, reduced, fluorinated
15290-77-4	1,1,2,2,3,3,4-heptafluorocyclopentane
138495-42-8	Décafluoropentane
163702-05-4	1-ethoxynonafluorobutane
163702-06-5	1-ethoxy-1,1,2,3,3,3-hexafluoro-2-(trifluoromethyl)propane
15290-77-4	1,1,2,2,3,3,4-heptafluorocyclopentane
138495-42-8	Reaction mass of (3R,4R)-1,1,1,2,2,3,4,5,5,5-decafluoropentane and (3S,4S)-1,1,1,2,2,3,4,5,5,5-decafluoropentane

6.2 Example of requirement listed in standards

The defense and aerospace industries have the strictest requirements for connector manufacturers in terms of product performance due to their exposure to harsh environmental conditions. These harsh environment conditions to which connector products are subjected, as well as the normative and specific requirements of those sectors in terms of signal transmission quality, are the conditions illustrating their high technical nature and also the constraints linked to the alternative research. Articles need to withstand global performances of products as described in military European and international standards and norms precisely defined for such extreme conditions of use.

Standards provide the framework within which electronic components are qualified, and are therefore a prerequisite for their placing on the market. The production and marketing of these electronic components treated by an alternative process are therefore subject to the inclusion of the said alternative process in the standards.

Examples of defense and aerospace standards:

European standards such as EN 3682 series or 3645 series specify the requirements of Aerospace multipin connectors. They are similar to the ones from the Military American standards used by the U.S. Department of Defense (DoD) to specify technical and quality requirements for various products and equipment. As an example, MIL-DTL specification defines detailed requirements for specific products and they are often used for military hardware components, parts, equipment and systems. A MIL-DTL specification provides precise information on materials, performance, tests, tolerances, dimensions, test methods, etc., needed to ensure a product's conformity to specific criteria. Key features include several elements :

REQUIREMENTS	
Materials	Humidity
Configuration interface and features	Shell spring finger forces
Interchangeability	EMI shielding
Maintenance aging	Ozone exposure
Thermal shock	Fluid immersion
Temperature cycling	Pin contact stability
Plating adhesion	Contact walkout
Air leakage	Installing and removal tool abuse
Coupling and uncoupling torque.	High temperature exposure
Durability	Electrolytic erosion

Table 3 Example of military standard requirements

- **MIL-DTL-38999N**

INCH-POUND

MIL-DTL-38999N
10 February 2023
SUPERSEDING
MIL-DTL-38999M
w/AMENDMENT 2
8 September 2017

DETAIL SPECIFICATION

CONNECTORS, ELECTRICAL, CIRCULAR, MINIATURE, HIGH DENSITY, QUICK DISCONNECT (BAYONET, THREADED OR BREECH COUPLING), ENVIRONMENT RESISTANT WITH CRIMP REMOVABLE CONTACTS OR HERMETICALLY SEALED WITH FIXED, SOLDERABLE CONTACTS, GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers four series of miniature, high density, circular, environment resistant electrical connectors with removable crimp contacts, or hermetically sealed electrical connectors with fixed, nonremovable contacts. Both environment resistant and hermetically sealed connectors are available with bayonet, threaded, or breech-coupled mating systems. Connectors are capable of operating within a temperature range of -65°C to +200°C maximum, or as specified herein (see 1.4). See 6.1 for intended use, application notes, application restrictions and derating factors.

MIL-DTL-25988/3 - Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, O-rings, Class 1, Grade 60.

3.4.4.2 Jam nut mounting receptacles, mounting nuts and O-rings. Series I and II jam nut mounting receptacles shall be provided with a mounting nut in accordance with MS3186. Series III and IV jam nut mounting receptacles shall be provided with a mounting nut in accordance with MIL-DTL-38999/28. All mounting nuts include provisions for locking. All jam nut mounting receptacles shall be provided with an O-ring in accordance with MIL-DTL-25988/3 except space grade classes G and H which shall be provided with an O-ring in accordance with AMS3302 or AMS7269 or an equivalent meeting all space grade class requirements.