JMIF
JAPAN MEASURING INSTRUMENTS FEDERATION

Appendix

Uses and substitutions of Specialist Equipment

This document is the appendix of the general comment to the Restriction report on Per- and polyfluoroalkyl substances (PFAS)
from

Japan Measuring Instruments Federation (JMIF)

submitted on 21. September 2023

Table of content

The characteristics and functions of PFAS

Summary

PFASs have many functions. The characteristics and functions of PFAS which are mainly used in Specialist equipment are described in this section.

PFAS has excellent properties such as, chemical resistance, electric insulation, heat resistance, repellency from water and oil, non-adhesion, weatherability, and others. PFASs are used where multiple of these properties are required simultaneously. We recognize that the ability to provide these various properties in a single material is the most important property of PFAS, and at present we do not have information on any other substance with this function other than PFAS.

Chemical resistance

Fluoropolymers compared to other general-purpose resins.

	ETFE	FEP/TFE/FPA	FLPE	FLPP	HDPE	LDPE	PC	PETG	PP	PVC	TPE***
Acids, Dilute or Weak	E	E	E	E	E	E	E	G	E	E	G
Acids, **Strong/Concentrated	E	E	G	G	G	G	G	N	G	G	F
Alcohols, Aliphatic	E	E	E	E	E	E	G	G	E	G	E
Aldehydes	E	E	G	G	G	G	G	G	G	G	G
Bases/Alkali	E	E	F	E	E	E	N	N	E	E	F
Esters	G	E	G	G	G	G	N	G	G	N	N
Hydrocarbons, Aliphatic	E	E	E	G	G	F	G	G	G	G	E
Hydrocarbons, Aromatic	G	E	E	N	N	N	N	N	N	N	N
Hydrocarbons, Halogenated	G	E	G	F	N	N	N	N	N	N	F
Ketones, Aromatic	G	E	G	G	N	N	N	N	N	F	N
Oxidizing Agents, Strong	E	E	F	F	F	F	F	F	F	G	N

*Not for tubing chemical resistance (except PVC) **Except for oxidizing acids (See oxidizing agents, strong) ***TPE gaskets

Table 1 Classes of Substances at 20° C, Chemical Compatibility Chart - LDPE, HDPE, PP, Teflon Resistance (calpaclab.com) [1]

* Not for tubing chemical resistance (except PVC)
** Except for oxidizing acids (See oxidizing agents, strong)
*** TPE gaskets

Excellent: 30 days of constant exposure causes no damage. Plastic may tolerate for 30 years.
Good: Little or no damage after 30 days of constant exposure for the regent
Fair: Some effect after 7 days of constant exposure to the reagent. The effect may be crazing, cracking, loss of strength or discoloration.
Not recommended: Immediate damage may occur. Depending on the plastic, the effect may be severe crazing, cracking, loss of strength or dis coloration, deformation, dissolution or permeation loss.

[1] https://www.esaknowledgebase.com/wp-content/uploads/2022/06/PFAS-Article-Valve-World-May-2022.pdf last accessed on 14 July 2023

Type / Properties	Fluoroelastomer	Silicon rubber	Acrylic rubber	Nitrile rubber	Ethylene propylene rubber
	FKM	MQ, VMQ	ACM	NBR	EPDM
Specific gravity	1.8～2.0	1.0	1.0	1.0	0.9
Heat resistance	◎	◎	○	△	○
Low temperature resistance	△	◎	○	◎	◎
Electrical properties	○	○	△	△	◎
Solvent resistance	◎	◎	○	△	○
Flame resistance	◎	○	▲	▲	▲
Ozone resistance	◎	◎	◎	×	◎
Steam resistance	◎	○	×	△	○
Acid resistance	◎	○	△	○	◎
Alkaline resistance	◎	◎	△	○	◎
Oil resistance	◎	△	○	○	×
Permeability resistance	◎	▲	○	○	△

◎ : Excellent ○ : Good △ : Fair ▲ : Marginal × : Poor

Table 2 Property Comparison of Fluoroelastomers (FKM) with Other Rubbers[2]

“Cleanliness" is defined as the fact that fluoropolymers are not easily eluted by acids, alkalis, or solvents (chemical resistance), do not contain other materials such as plasticizers in the molding process, and do not contain products that would thermally decompose during the material molding process.

[2] https://www.daikinchemicals.com/library/pb_common/pdf/catalog/RC-1L.pdf translated from the document in Japanese. Last accessed on 14 July, 2023

Ozone resistance

Ozone is known to degrade plastic materials in two ways:
A: Substances with double bonds (C=C) in their structures (such as natural rubber, chloroprene rubber, butadiene rubber, etc.) undergo decomposition in which ozone reacts with the double bonds to produce ketones, when they come into contact with ozone.
B: When ozone exists in water, peroxy radicals are generated. Non-fluorine materials (eg. polyethylene, polypropylene, etc.) deteriorate even if they do not have double bonds.
Fluoropolymers does not have decomposition pathways such as A and B even if it comes into contact with ozone, so it can be used for a long time without deterioration.

Thermoplastic resin		Ozon Resistance
Soft vinyl chloride	PVC	○
Rigid vinyl chloride	PVC	○
Vinylidene chloride resin	PVdC	◎
ABS	ABS	△
Polyethylene	PE	△
Nylon	N	×
Acrylic resin	PMMA	△
Fluoropolymer resin	PTFE	◎
Phenolic resin	PF	△
Melamine resin	PVC	○
Furan resin	FF	○
Epoxy resin	EP	△
Unsaturated polyester resin	UP	×

Table 3 Comparison of ozone resistance properties of plastics[3]

[3] https://www.kk-kunii.co.jp/dcms_media/other/%E8%80%90%E6%B2%B9%E6%80%A7%E3%83%BB%E8%80%90%E6%BA%B6%E5%89%A4%E6%80%A7%E3%83%BB%E8%80%90%E8%96%AC%E5%93%81%E6%80%A7%E3%83%87%E3%83%BC%E3%82%BF.pdf Last accessed on 20 July, 2023

Repellency from water and oil / non-adhesion

Since the fluoropolymers have a small polarizability, the intermolecular force is small. Because of its characteristics, fluoropolymers have repellency and non-adhere properties on the surface. In general, the repellency from various liquids is evaluated by the contact angle, and the larger the contact angle, the higher the repellency.

Contact angle θ

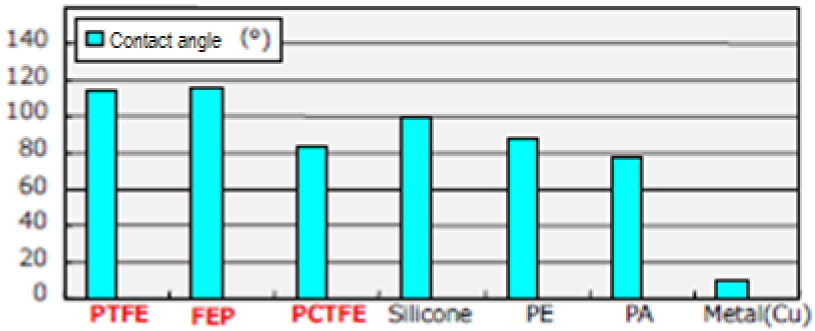


Figure 1 Contact angles with water

Adhesion energy refers to the amount of work required to pull a liquid contacting a solid away from the solid. The larger the contact angle, the smaller the adhesion energy. It means that a liquid in contact with a small adhesion energy solid easy to separate from the solid.[4]

Material name	Contact angle with water (°)	Adhesion energy (dyn/cm)
PTFE	114	43.1
FEP	115	42.0
Silicone resin	90-110	47.8-72.7
Paraffin	105-106	52.7-53.8
PE	88	75.2
PCTFE	83	-
PA	77	97.7
Phenolic resin	60	109.0
Copper(electropolishing)	9.6	144.2
Aluminium(electropolishing)	4.6	145.0

Table 4 Surface properties of various plastics and metals

[4] Japan Fluoropolymers Industry Association(2020), ふっ素樹脂ハンドブック 14th edition. Page 34 Translated from Japanese.

This characteristic is sometimes called "mold releasability". It can also be expressed as antifouling because it does not easy to adhere.

Heat resistance

Fluoropolymers have high heat resistance as follows. They have higher heat resistance compared to other general-use resins.

	Fluoropolymers						Other general-use resins	
Heat resistance : maximum operating temperature (C)	PTFE	PFA	FEP	ETFE	PCTFA	PVdF	PP	PVC
	260	260	205	150	120	120	100	60

Table 5 The heat resistance of Fluoropolymer [5]

Electric insulation

When the dielectric constant is low, the insulation in electrical components can be made thinner, leading to downsizing and weight reduction of the equipment. In applications where downsizing and weight reduction are necessary, it is an essential feature.

<table>
<tr><td rowspan="2"></td><td colspan="4">Fluoropolymer</td><td colspan="2">Fluororubber</td></tr>
<tr><td>PTFE</td><td>FEP</td><td>PFA</td><td>ETFE</td><td>FKM</td><td>FEPM</td></tr>
<tr><td>Dielectric constant</td><td colspan="3">◎
2.1</td><td>○
2.3-2.8</td><td>△
3-4</td><td>△-○
2.5-3.5</td></tr>
<tr><td rowspan="2"></td><td colspan="4">Non-fluoropolymer</td><td colspan="2">Non-fluororubber</td></tr>
<tr><td>PVC</td><td>PEEK</td><td>TPI
(Thermoplastic Polyimide)</td><td>Polyolefin</td><td>Silicone rubber</td><td>EPDM</td></tr>
<tr><td>Dielectric constant</td><td>△
4-6</td><td>△
3.2-4.5</td><td>△
2.8-3.2</td><td>△-○
2.3-4</td><td>△
3.2-10</td><td>△
2.5-3.5</td></tr>
</table>

Table 6 The dielectric constants of various resins

[5] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook，Page 4

Low friction, self lubrication

Friction coefficient of fluorine resin is lower than that of other resins. It is because polarizability. (Mobility of electrons in an electric field) of C-F bonding is low (0.68) and the intermolecular force is weak. (Reference: polarizability of C-Cl bonding is 2.59)[6]

Types of plastic	Plastic / Plastic	Plastic / Steel	Steel / Plastic
PTFE	0.04	0.04	0.10
PE	0.10	0.15	0.20
PS	0.50 *)	0.30	0.35
PMMA	0.80 *)	0.50 *)	0.45 *)

*) indicates occurrence of stick-slip motion.
Measurement condition: Bowden-Laden type measurement equipment, load: 9.8-39.2N, sliding speed: 0.01cm/s
Plastic/Steel indicates sample material/pin material
PE: polyethylene PS: polystyrene PMMA: polymethylmethacrylate

Table 7 Comparison of friction coefficient among PTFE and other materials[7]

As an example of low friction, Table 8 shows friction coefficient of PTFE.

Type	ASTM test method	Measurement condition	Unit	PFA	PTEF	FEP
Coefficient of static friction	-	Against polished steel	-	0.05	0.02	0.05

Table 8 Comparison of static friction coefficient among PFA, PTFE and FEP[8]

One of the characteristics related to friction is “self lubrication”. The molecules of PTFE separate from molding of PTFE due to friction. The molecules in crystals of PTFE separate easily because intermolecular forces are weak. PTFE moves and attaches to the friction mating surface and generates friction between them. It lowers friction coefficient[9].

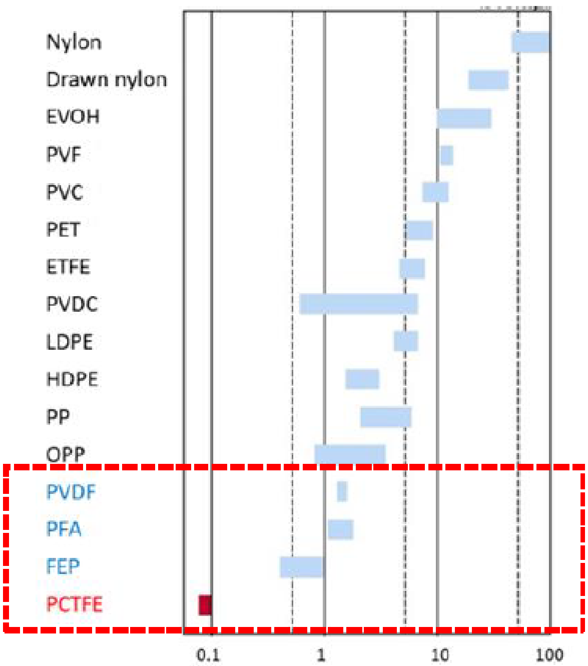
[6] Japan Fluoropolymers Industry Association(2020), Fluoropolymers Handbook, 14th edition. Page 9 Translated from Japanese.

[7] Japan Fluoropolymers Industry Association(2020), Fluoropolymers Handbook, 14th edition. Page 24 Translated from Japanese.

[8] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 53

Gas barrier properties/Gas permeation properties

Fluoropolymer film are less steam permeability.



steam permeability (g/m²/d)

Figure 2 The degree of steam permeability[9]

[9] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 109

Fluoroelastomers are less atmospheric (nitrogen, oxygen) permeability.

Material	Temperature degree Celsius	He	H_2	O_2	N_2	CO_2	CH_4	C_2H_2	C_3H_8
Vinyl methyl silicone rubber (VMQ)	25	N/A	400	400	200	1600	N/A	N/A	10000 or more
	50		570	500	280	1550			
Ethylene propylene rubber (EPDM)	25	N/A	N/A	16.5	5.90	79.2	N/A	N/A	91.2
	50			46.6	13.7	183			246
Perfluoro-elastomer (FFKM)	25	10.3	8.25	2.5	8.1	28.7	3.3	N/A	N/A
Styrene butadiene rubber (SBR)	25	17.5	30.5	13	4.8	94	N/A	N/A	N/A
	50	42	74	34.5	14.5	195			
Vinylidene fluoride fluororubber (binary FKM)	25	2.95	4.6	1.0	0.8	3.9	0.6	N/A	N/A
Vinylidene fluoride fluororubber (Ternary FKM)	25	2.64	4.13	1.7	0.7	1.6	0.4	N/A	N/A
Chloroprene Rubber (CR)	25	N/A	10.3	3.0	0.89	19.5	2.5	N/A	N/A
	50		28.5	10.1	3.55	56.5	9.8		
nitril-butadiene rubber (Mid-high NBR)	25	9.32	12.1	2.94	0.81	23.5	N/A	18.9	26.9
	50	23.4	33.7	10.5	3.58	67.9		68.3	78.3
nitril-butadiene rubber (High NBR)	25	5.2	5.42	0.73	0.18	5.67	N/A	8.25	11.2
	50	14.2	17.0	3.5	1.08	22.4		19.8	33.1
butyl rubber (IIR)	25	6.4	5.5	0.99	0.25	3.94	0.6	1.28	N/A
	50	17.3	17.2	4.03	1.27	14.3	3.2	5.82	

($\times 10^{-8}$cc, cm/cm^2, sec, atm)

Table 9 Comparison of gas permeability of elastomer[10]

[10] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 78

Property of Gas Permeability

Property			Standard Test method	Unit	FEP film
Gas Permeability	Gas permeability coefficient	N_2	ASTM D1434	㎤・cm/㎠・s・atm	120×10^{-10}
		O_2			370×10^{-10}
		H_2			$1,080\times10^{-10}$
		CO_2			970×10^{-10}
		CH_4			66×10^{-10}
		C_2H_4			44×10^{-10}
	Water-vapor permeability		JIS Z0208	g/㎡・24h	1.6
	Water Absorption		ASTM D570	%・24h	<0.01

Table 10 Gas Permeability of FEP film[11]

Fluoropolymers permeate small molecular gases, such as oxygen and nitrogen, conversely, large molecular gases do not permeate. Fluoropolymer properties are used in permeate membranes for measurement and analysis.

Gas	Gas Permeability		
	FEP	PTFE	Low Density Polyethylene
N_2	1.2×10^{-8}	1.1×10^{-8}	0.74×10^{-8}
O_2	3.7×10^{-8}	3.2×10^{-8}	2.2×10^{-8}
CO_2	9.7×10^{-8}	8.9×10^{-8}	9.6×10^{-8}
CH_4	0.66×10^{-8}	―	2.2×10^{-8}
CH_3	0.66×10^{-8}	―	5.2×10^{-8}
C_3H_8	0.11×10^{-8}	―	7.2×10^{-8}
C_2H_4	0.48×10^{-8}	―	―

Temperature: 25℃(77°F) Units: cm^3 (ST P) cm/cm^2・atm

Table 11 Comparison of gas permeability of various materials[12]

Low refractive index

Amorphous fluoropolymer resin has high transmittance. This is utilized for optical components and optical fibers.

[11] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 78

[12] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 80

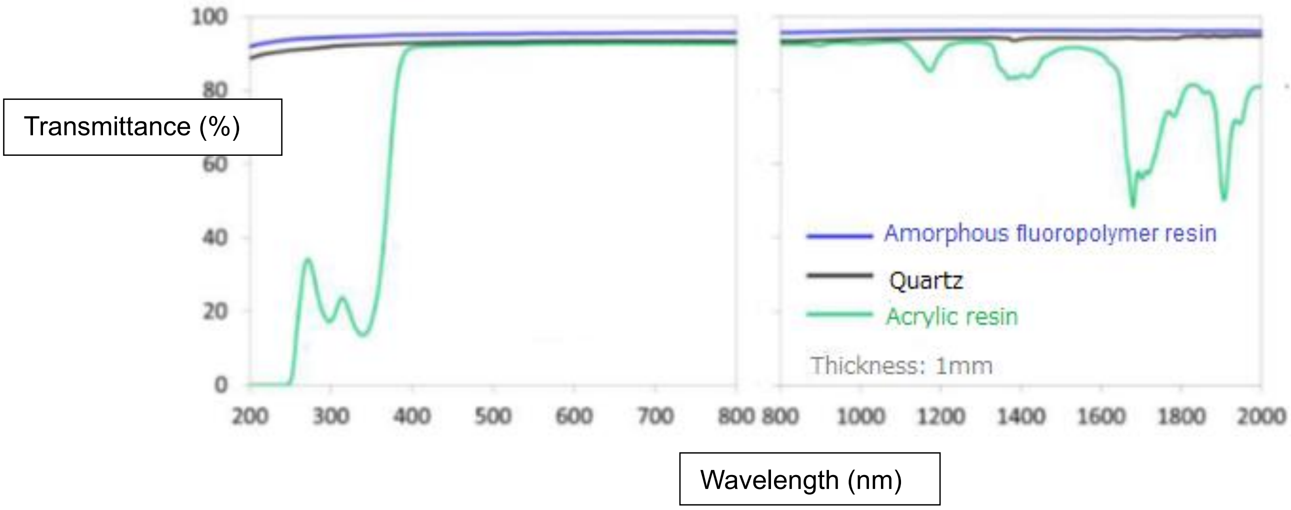


Figure 3 Comparison of transmittance[13]

Weatherability

Fluoropolymer resin has high weatherability and can be used outdoors. It does not react to sunlight such as ultraviolet rays. It is not susceptible to oxidizing effects of atmospheric oxygen and other substances (see "chemical resistance"). It can be used in a wide temperature range from low to high (see "heat resistance"). It has high water repellency and does not absorb water, so it is not affected by humidity changes. It can be said that fluoropolymer resin has high weather resistance because it has the above points.

	Fluoropolymer resin						General resin	
	PTFE	PFA	FEP	ETFE	PCTFE	PVdF	PP	PVC
Weatherability	◎	◎	◎	◎	◎	◎	×	×

◎ Excellent, ○ Good △ Not very good ▲ Needs attention × Not good

Table 12 Fluoropolymer resin weatherability comparison [14]

Regarding the graph below, it can be seen from the accelerated weatherability test with the Sunshine Weather Meter that the gloss retention rate decreases by no more than 10% even after 4000 hours of exposure.[15]

[13] https://www.agc-chemicals.com/file.jsp?id=file/Cytop_tech14_EN.pdf . Last accessed on 11 August, 2023
[14] DAIKIN INDUSTRIES, LTD. (2009) Daikin Fluoropolymers Handbook, Page 4
[15] https://www.kyoeishoji.co.jp/business/chemical/fusso_toryo.html translated from the document in Japanese. Last accessed on 21 July, 2023

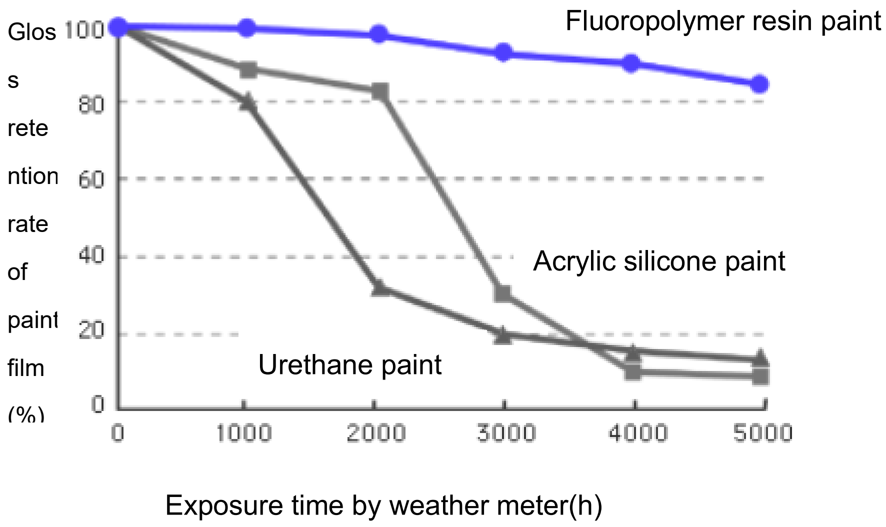


Figure 4 Accelerated weatherability test of paint

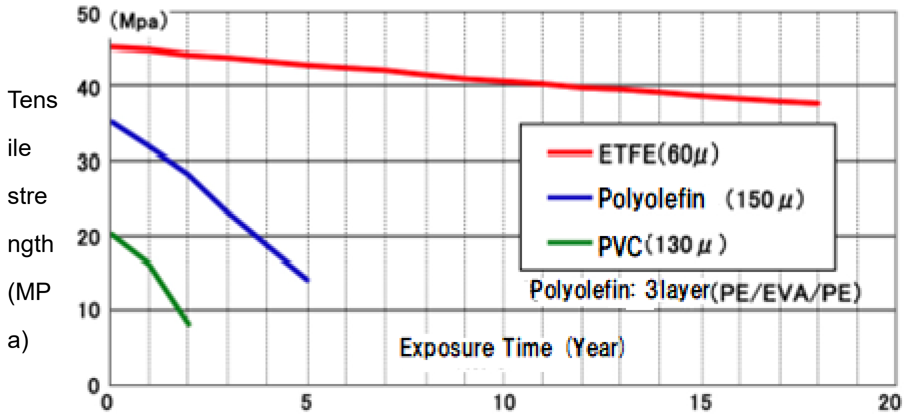


Figure 5 Outdoor exposure test Comparison of tensile strength between ETFE and other materials[16]

Durability

It means that it can be used for a long time. Due to its high chemical resistance and high weatherability, PFAS can achieve high durability.

Resistance to creep / Compression set

When a constant load is applied to a polymeric material, creep occurs, in which deformation progresses over time. Similarly, compression set occurs where the deformation does not recover

[16] https://www.taiyokogyo.co.jp/feature/etfe_film.html translated from the document in Japanese. Last accessed on 21 July, 2023

when the force is removed. Both properties are known to be correlated. When rubber materials are used in elastic applications such as packings or diaphragms, it is required to minimize the effects of both properties.

Experimental examples of "30% creep time (Hour)" for major rubber materials are shown below. Creep is known to be worse at higher temperatures, Experiments have shown that FKM and silicon exhibit good properties.

	50 degree Celsius	70 degree Celsius	100 degree Celsius	120 degree Celsius	150 degree Celsius
NR	190	103	3.8	–	–
SBR	1250	203	14	–	–
CR	4200	550	45	7.4	–
NBR	3900	380	41	12.2	–
IIR	–	–	2.7	–	–
FKM	–	–	1650	305	180
Silicon	–	–	–	1550	190

Table 13 Experimental examples of "30% creep time (Hour)" for major rubber materials

Quoted from the journal of “the Society of Rubber Science and Technology, Japan”, 1960(Vol33), P882-892, “Stress relaxation and creep properties of various vulcanized rubbers”.

Examples of compression set test results are shown below. In general, it is difficult to quantitatively compare materials because the measured values differ depending on the compounding and hardness of the rubber. Here, the compression set of the materials was compared by comparing the minimum value of each material in the database. FKM and silicon showed relatively good properties, showing the same tendency as creep.

	Compression set JISK6301 100℃×70h
NR	–
SBR	Min 20%
CR	Min 23%
NBR	Min 9%
IIR	–
EPDM	Min 23%
FKM	Min 11%
Silicon	Min 6%

Table 14 Examples of compression set test results

The minimum value of each material was quoted from the data described in "Material Database / Organic Materials" (1989), The Nikkan Kogyo Shimbun”.

Uses of PFAS in Specialist Equipment

Summary

PFAS are a very important group of substances for Specialist Equipment, which depends on these uses to maintain safety, as they are highly effective in chemical resistance, Repellency from water and oil, and electric insulation.

PFAS polymer resins are two to ten times more expensive than other commodity plastics. There is no use other than where the equipment does not work without the use of PFAS.

General electronics components are not covered in this document. However, since our equipment also uses common electronic circuit parts, we also use parts common to information equipment and general consumer EEE. For usage and non-substitutable information for such parts, please refer to Japan 4EE Opinion RCOM21, No.4543 and additional Opinion Information and Non-Substitutable Information to be submitted in September 2023. Semiconductors are also used in our products. Many PFASs are used in semiconductors and semiconductor manufacturing equipment Comments on most of the items in this section have been submitted by industry associations that specialize in the respective items. We hope that dossier submitters consider the manufacturer's opinions.

Electric wires and insulation

An electric wire is a linear member for transmitting electricity. Metal, which is a good conductor, is used for the part that transmits electricity, and plastic resin that has electric insulation is used around the wire in order to block the influence on anything other than the transmission destination of electricity.

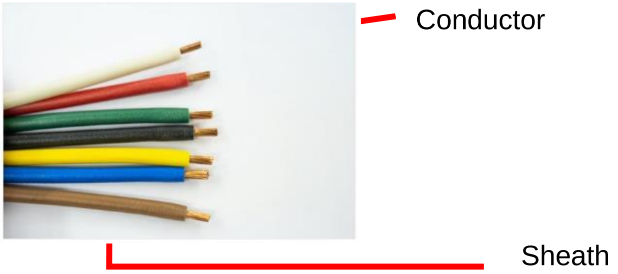


Figure 6 Electric wires

Polyvinyl chloride is generally used for covering parts where plastic resin is used, which is called as sheath, but PTFE, PFA, FTPE, etc. are selected depending on the suitability of use and electric insulation requirements. Since these are more expensive than polyvinyl chloride, they are used only when it is difficult to use other materials such as polyvinyl chloride.

PFAS functions required by PFAS wires and availability of alternatives.

Wires using PFAS for coating have high electrical insulation when the coating is thin (100 μm or less). PFAS also has a high heat resistance of 150-200°C. In addition, PFAS wires can be used even when there are chemicals around the device because PFAS has chemical resistance.

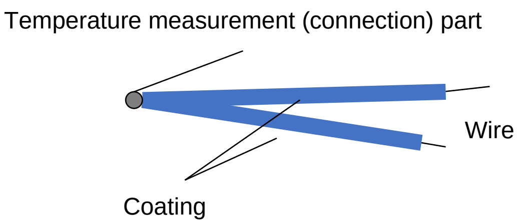
Examples of devices equipped with electric wire and insulation

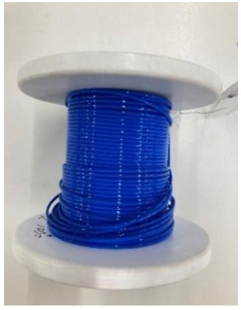
Temperature sensor（thermocouple)

A thermocouple is a temperature sensor that measures using the principle that a thermoelectromotive force is generated by connecting the tip of a metal wire made of different materials and the temperature difference between the tip and the other end.

Temperature sensors can measure a wide range of objects, including acids, alkalis, and organic solvents, and can also measure a wide range of temperatures, including applications that measure chemicals at 100°C or higher. The thermocouple wires are coated with FEP and PFA to ensure accurate measurement without negative effects from chemicals or high temperatures.

There is no material other than fluoropolymers that combines chemical resistance and heat resistance to realize such applications, and it is difficult to replace them.





Coated temperature sensor wire

Figure 7 Temperature sensor

Heat shrink tubing

By putting a thin and long object to be covered in a tube, heating it, and shrinking the tube, the object is covered. It prevents parts from coming off or falling off and strengthens the covered part. Fluoropolymer resin heat-shrink tubing is thin but has high electric insulation performance. PTFE and PFA are used as fluoropolymer resins.

Functions of PFAS required by heat-shrinkable tubing and availability of alternatives.
Fluoropolymer resin heat-shrink tubing is thin but has high electric insulation performance. It can be used in applications where there is not enough space for electric insulation, and there is no alternative material available for applications that require tight spaces.

Sealing materials

parts description

- Packings, gaskets, and O-rings

Packings and gaskets exist to connect and seal by placing/placing them between parts. As an example, they are used in piping and pipe connections. Gases and liquids that pass through pipes leak out through the smallest gaps, and packing gaskets exist to prevent this. Packing in the narrow sense is used for power system parts, and those used for non-moving parts are called gaskets. Various innovations have been made in molding and realizing functions, such as spiral gaskets made of alternating layers of thin metal strips and PTFE sheets, and wrapped gaskets made of 0.4-0.8 mm hot PTFE, covering gaskets of metal or other materials. Those with a circular/round cross section are called O-rings. In addition to PTFE, fluoropolymer rubbers such as FKM and FFKM are also used for this application.

Figure 8 Packings, gaskets, O-rings

- Bearings

A bearing reduces friction between two parts to make movement smoother. Bearings are classified into radial bearings, thrust bearings, and linear bearings, depending on whether rotational or linear motion is involved. A bush is also a type of bearing.

Fluoropolymer bearings such as PTFE have a low coefficient of friction and can maintain a constant torque within various tolerances, while minimizing rattling and noise. In particular, PTFE must be used for bearings near chemical fluids such as acids, alkalis, organic solvents, and ozone, and for food contact applications, where oil is not preferred.

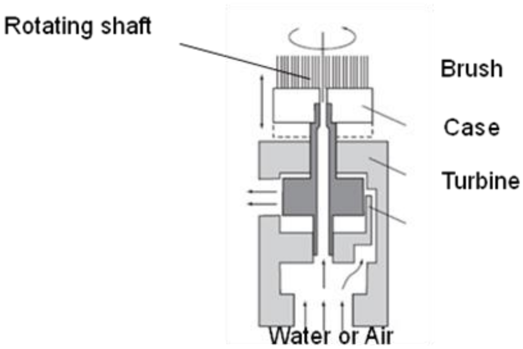


Figure 9 Bearing used for the rotating shaft sliding part of the sensor cleaning brush

- Sealing tape

Sealing tape, made of PTFE material, is an adhesive tape used to secure parts within equipment. It is employed to fasten parts that could pose safety risks if dislodged, as well as to seal mounting parts. Additionally, the tape serves as a filler to address gaps in the joints or connections of pipes for flowing liquids or gases, such as water pipes, air pipes, and hydraulic pipes. Notably, the tape can establish liquid- or gas-tight connections with tapered pipe threads by directly filling the voids between the threads.

Figure 10 Sealing tape

Functions of PFAS Required by Sealing Materials and the Feasibility of Alternatives to PFAS

・ Required Functions for Sealing Materials

Liquids and gases flowing in pipes, or near parts, often consist of strong acids, alkalis, or organic solvents. Therefore, the sealing materials used must be resistant to these chemicals. Fluoropolymer is highly resistant to such chemicals, and additionally, it is ozone-resistant, making it an ideal choice when ozone is present in the piping.

If the liquid or gas in the piping, or the equipment itself, operates at high temperatures, PTFE or PFA are good options due to their high heat resistance of up to 260°C—a limit higher than other resins. FFKM and FKM rubbers also exhibit high heat resistance, withstanding temperatures up to 250-300°C.

For applications where sealing materials, such as gaskets, are used on sliding surfaces, where lubricating oil is unsuitable (particularly in contact with food), or where play and noise must be avoided, sealing materials must also possess low friction and self lubrication properties.

・ Feasibility of alternatives to PFAS for Sealing Applications

In the restriction report on seal tape, paste-like sealing materials are mentioned as alternative materials. However, if these sealing materials contain hydrocarbon substances, reactive functional groups may decompose. This could pose a risk of contamination in the surrounding area due to the produced decomposition products. For sealing tape used for equipment operating in clean environments, where such contamination is unacceptable, paste-like sealing materials cannot be used as alternatives to PFAS.

As a sealing material that combines outstanding chemical resistance, ozone resistance, heat resistance, water and oil repellency, low friction, self-lubrication, and cleanliness, there is no substitute for fluoropolymers. The substitution of fluoropolymers with other materials poses a significant challenge.

Non fluorine elastomers might be considered as potential replacements for fluorine rubbers like FKM rubber. However, their heat resistance, low friction, and chemical resistance do not measure up to those of fluorine-rubbers like FKM rubber. Therefore, substituting fluorine - rubbers with non fluorine elastomers is unfeasible.

Examples of the products which uses sealing materials

Mass Flow Controller/ Mass Flow Meter

Mass flow controllers and mass flow meters are used for flow control and flow measurement of various industrial gases. O-rings are used as sealing parts to prevent external leakage at joints between different parts.

<Mass flow controller usage example>

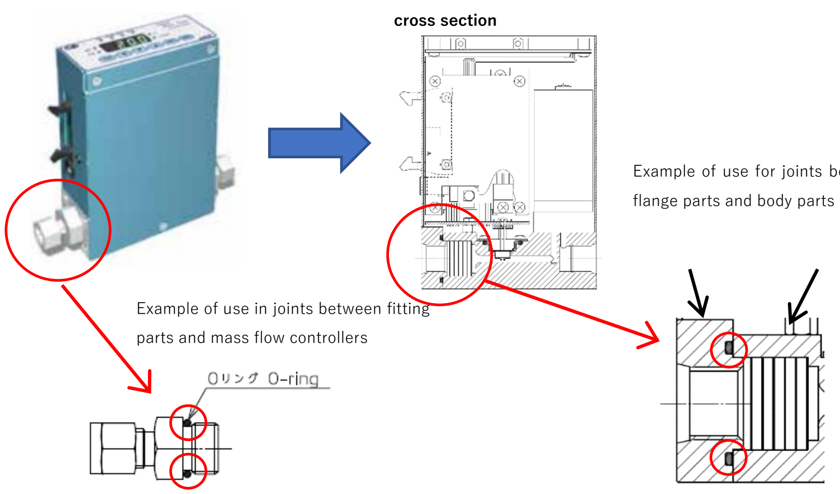


Figure 11 Mass flow controller usage example

FKM is used for various gases with excellent heat resistance, chemical resistance, ozone resistance, etc., especially when using flammable oxygen gas, it is used due to its high heat resistance and ozone resistance, and the alternative product is a special rubber material, but it becomes a fluorine-based rubber material, and the use of fluorine-based substances is unavoidable. If fluorine-based materials are not used, safety is significantly impaired.

Packings or diaphragms of Measuring Instruments

Fluororubber is often used as a cover for moving parts of measuring instrument that handle food or liquids. Such environments expose equipment to water and oil. In addition, frequent cleaning is carried out for the purpose of preventing the occurrence of various bacteria.

In weighing instrument used in food factories, rubber bellows-shaped cover called a diaphragm and packings such as O-rings or V-rings are used between the external moving parts and the inside of the instrument. The following performance is required for these parts.

・Resistance to creep / Compression set
・Chemical resistance (Acid resistance, Alkali resistance, Oil resistance, Ozon resistance)
・Heat resistance
・Repellency from water and oil / non-adhesion
・Tear resistance

Especially for the diaphragm between the internal weighing sensor and the external moving part that holds the weighing products, for creep resistance is critical for accurate weighing.

Table 15 summarizes the performance of major alternative materials with respect to the required performance.

Material		FKM	Silicon rubber	EPDM	NBR
Resistance to creep / Compression set	No impact for Weighing	◎	◎	similar to NBR	○
Oil resistance	Contained in food	◎	◎	△	◎
Acid resistance	Contained in food	◎	○-△	◎	○
Alkali resistance	Contained in detergents, etc.	△-×	◎	◎-○	○
Ozon resistance	Special cleaning	◎	◎	◎	×

Heat resistance	Hot food	◎	◎	○	○
Tear resistance	High-pressure Washing	○	△-×	○	○

Table 15 Materials for packings or diaphragms of Measuring Instruments

Summarized by the author of this section based on multiple documents.

Appropriate materials are selected and used according to the required performance that varies depending on the work environment and target product. From the table, FKM shows good properties except Alkali resistance. For precision measurement applications where creep resistance is a priority, such as weighing instrument, FKM and silicone rubber are candidates. In addition, in factories where high-pressure washing using hot water is carried out, tear resistance is also required, and FKM is used as a material that cannot be substituted.

Instrument example (Weigher for food industries)

diaphragm example (sensor section)

diaphragm example (feeding section)

Figure 12 packings or diaphragms of Measuring Instruments

Plumbing

Plumbing is any system that convey fluids or energy for any application. Pipes, tubes, joints, fittings, are used for plumbing. Fluoropolymer resins, such as, PTFE, PFA, PVDF, are used. Some international standards mention uses of fluoropolymer resins for plumbing.[17]

- Tubes (not heat shrink tubes)

Tubes are used for convey fluids to the places.

[17] Example of international standards: ISO 12039:2019 mentions that the sampling line shall be made of PTFE, PFA.

Figure 13 Tubes

・ Joints / fittings

Joints / fittings are components to connect tubes to units and/or tubes to tubes.

Figure 14 Joints/ fittings

The functions and alternatives which plumbing requires:

The material of plumbing is determined by the types of fluids flowing through tubes. Fluoropolymers can be used as piping for fluids in the temperature range of -10°C to 200°C (PTFE) and about -40°C to 160°C (PFA), including acids, alkalis, organic solvents, ozone, and oils. Fluoropolymers (PTFE, PFA, PVDF) are the only plubming materials that can be used when the fluids of flowing the tubes meets one or more of these characteristics.

Fluoropolymer resins are the only materials that can simultaneously provide, and express multiple functions required for the proper functioning of chemical resistance/ cleanliness, repellency from water and oil, and heat resistance.

Examples of the products which incorporate plumbing

Magnetic Flowmeter

An Electromagnetic Flowmeter is a type of flow meter that applies a magnetic field in the perpendicular direction to the flow of the measured fluid. As a result of the flow and the magnetic field, an electromotive force is generated in directions perpendicular to both the flow and the magnetic field. This electromotive force is extracted by a pair of electrodes, and the output signal is sent to a converter. The electromagnetic flow meter is a flow meter that applies Faraday's law of electromagnetic induction to moving objects.

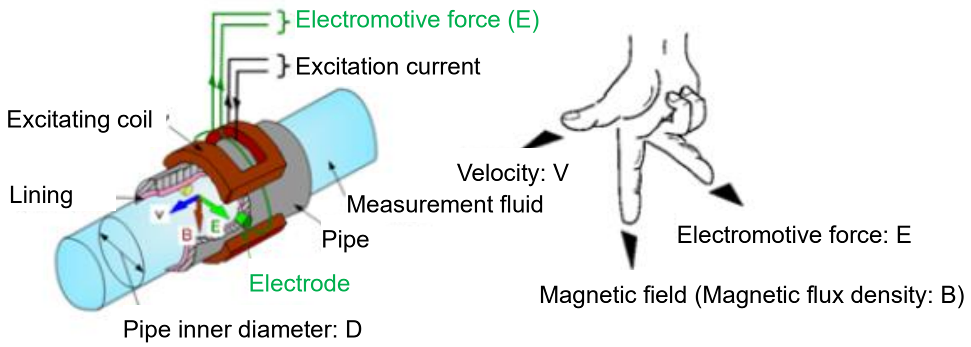


Figure 15 Magnetic Flowmeter

The resin lining, known as lining, is applied to pipes (metal piping), and materials such as PFA and PTFE are used.The purposes of this lining are as follows:

Electrical insulation: The lining ensures electrical insulation between the measured fluid and the electrodes or the pipe, preventing electrical short-circuiting of the signal electromotive force.

Chemical resistance: The lining provides resistance to chemical substances such as acids and alkalis when the measured fluid contains them. This prevents corrosion and degradation caused by the fluid's characteristics and the environment, thereby improving the accuracy and reliability of the measurement.

Wear protection: The lining plays a role in protecting the pipe from internal friction and impacts. It reduces wear and damage caused by solid particles and abrasives in the fluid, maintaining measurement performance over an extended period of use.

Heat resistance: The lining exhibits stable performance even in high-temperature environments. It resists degradation when exposed to high-temperature fluids and environments, ensuring consistency and reliability in the measurements.

Fuel Cell Performance Testing Equipment

Fuel cells generate electricity and heat through a chemical reaction between hydrogen and oxygen. Fuel cell performance testing equipment evaluates the performance and durability of fuel cells. Fuel cells contribute to carbon neutrality by improving energy efficiency and reducing CO2 emissions.

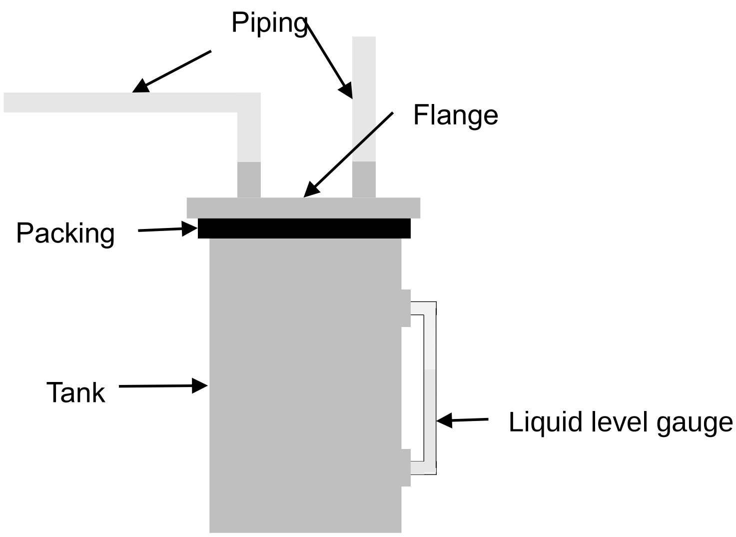


Figure 16 Fuel Cell Performance Testing Equipment

The following characteristics are required for the piping of the fuel cell performance testing equipment.
- The piping serves as a flow path for alkaline substances used as materials for hydrogen and acidic substances produced as a result of the reaction. (Chemical resistance)
- Since the polymer membrane used in the fuel cells requires wet condition, water vapor is added to the hydrogen. The flow path is heated to approximately 150°C to prevent condensation of water vapor in the piping. (Heat resistance)
- Hydrogen in the exhaust gas after the reaction may be reused, which requires an additional supply of hydrogen, resulting in large pressure changes inside the piping. Therefore, the piping needs to be strong. (Durability).

In case of condensation in the piping, the concentration of water vapor added to hydrogen cannot be maintained at the required level and normal operation will be disturbed. In addition, a transparent pipe with chemical resistance may be used as a liquid level gauge to check the liquid level in the tank where the alkali solution is stored.

For these reasons, the fuel cell performance testing equipment needs to be made of transparent, chemical (acid, alkali) resistant, heat resistant, and durable materials. Currently, PTFE and PFA are the only such materials available, and they are difficult to replace.

Valves

Valves are general for equipment with a movable mechanism that can open and close flow paths in order to go through, stop, and control the flow of fluids. They are used in a wide variety of products, from relatively small devices with flow paths and valves to large-scale manufacturing processes and chemical plants. There are many types of valves. Some valves, which are often incorporated in specialist equipment, are discussed. They are not exhaustive.

The functions and alternatives which valves require:

The chemical resistance against acids, alkalis, organic solvents oils, and ozone, which flows through valves, is essentially required. Valves, which opens and close frequently required the property of low friction, repellency from water and oils, non-adhesion. Any failure of valves can cause serious accidents. Therefore, the durability of fluoropolymer resin is required for valves PTFE and other fluoropolymer resins are frequently used. Fluoropolymer resins, such as, PTFE are the only materials that can simultaneously provide, and express multiple functions required for the proper functioning of valves.

- Solenoid valve

A solenoid valve is electromechanically operated. One of the operations is to open and close a valve using the principle that when an electric current is applied to an electromagnet (solenoid), an iron piece called a plunger is attracted and released when the electric current is cut off. Diaphragms divide into a valve compartment that opens and closes flow paths and a functioning compartment that drives. Fluoropolymer resins, such as, PTFE, FKM, FFKM, and FEPM, are frequently used for flow paths, diaphragms, and sealing materials in solenoid valves. Solenoid valves have wide variety of types, such as, liner action, pilot operated, the combination of liner action and pilot operated.

- Ball valves

A ball valve opens and closes a flow path by rotating a hollow ball. In automatic valves, an electric motor is used to rotate the ball. A large cross-sectional area of the flow path can be obtained, and the resistance of the path can be kept low. Fluoropolymer resins, such as, PTFE, are frequently used.

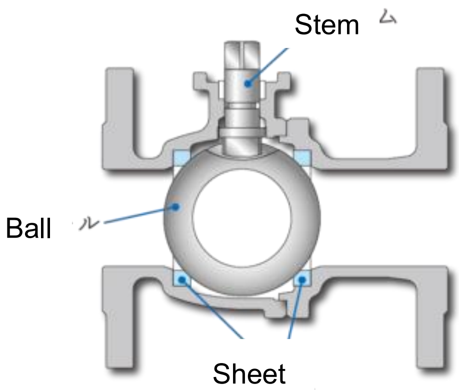


Figure 17 Ball Valve

- Check valves

A check valve is installed on gas or liquid piping where the fluid back pressure closes the valve plug to prevent reverse flow. A check valve is called as non-return valve, reflux valve, retention valve, foot valve, or one-way valve There are disc check valves that blocks backflow by closing the O-ring valve with a disc and duckbill check valves that uses a valve plug shaped like a duck's beak. Fluorinated materials such as PTFE, FKM, FFKM and FEPM are used for the valve plug and the sealing materials of the housing.

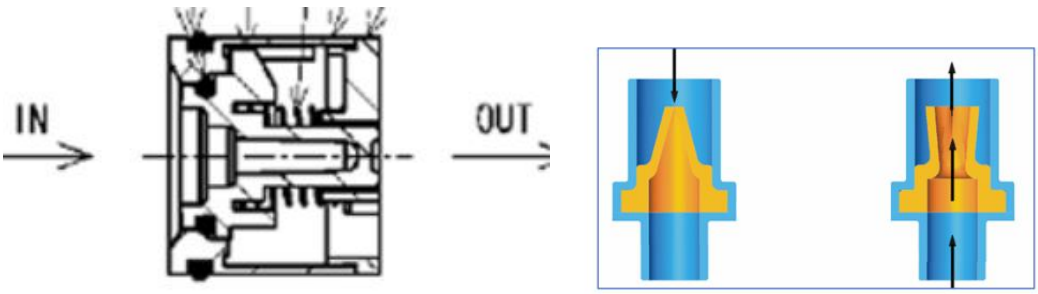


Figure 18 Check Valve

- Relief valves/safety valves

A relief valve is a valve that automatically releases pressure when excessive pressure occurs in the pipes. A spring keeps the valve plug such as O-rings or diaphragms closed, and it opens (released) when a pressure exceeding the spring force occurs. Fluorinated materials such as PTFE, FKM, FFKM and FEPM are used for the valve plug and the sealing materials of the housing.

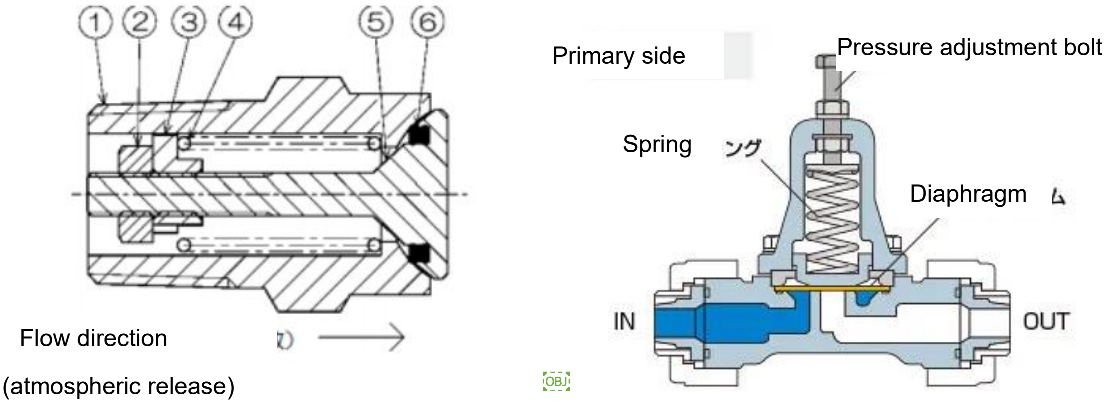


Figure 19 Relief valve / safety valve

Examples of the products which incorporates valves

<u>Mass Flow Controller</u>

Elemental analysis is a method of complete combustion of organic compound samples, and high-purity oxygen gas and argon gas are introduced. (see Figure 20)

The switching valve of the mass flow controller is a diaphragm type, and PTFE is used to provide flexibility to withstand repeated operation and durability against oxygen gases. PTFE is difficult to find replacement. Because it is highly non-adhesion and the substance does not stick to it like other fluoropolymers, and it has overwhelmingly low friction and excellent durability compared to other resins.

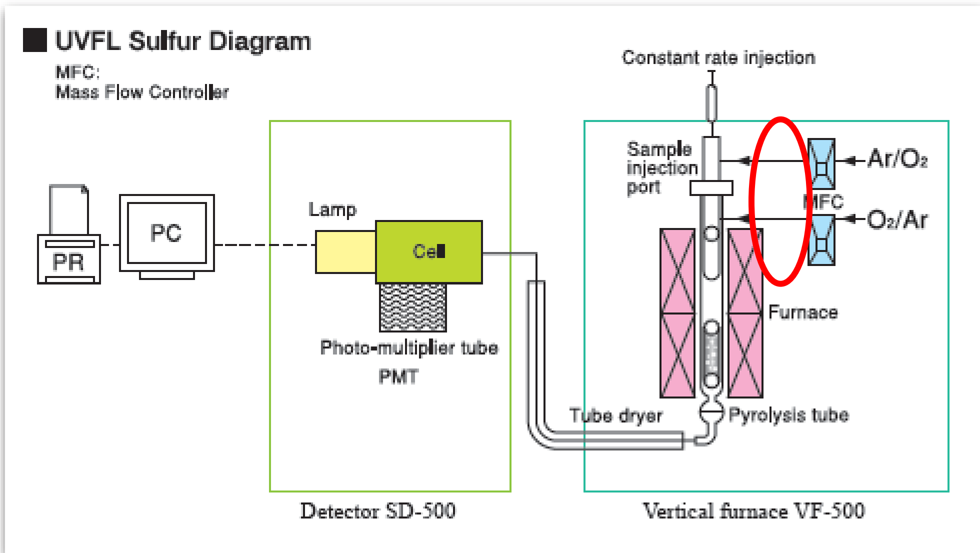


Figure 20 Mass Flow Controller

Control valve of mass Flow Controller

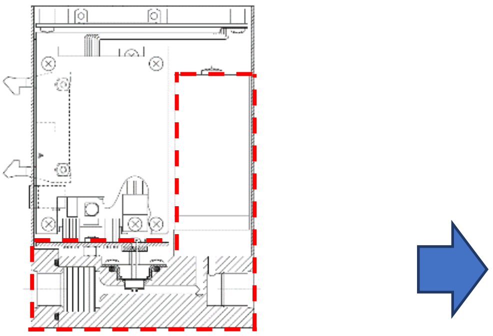
Mass flow controllers are used for flow control of various industrial gases. PTFE is used as the material of the valve body of the flow control valve of mass flow controller. See part (10) in the Figure 21 (the right is a partial enlarged view).

Performance requirements for materials.

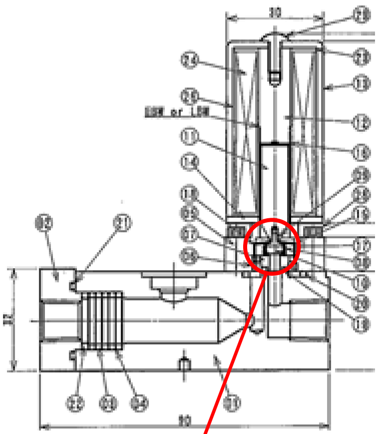
・Heat resistant to withstand operation from -10°C to +60°C.

・Chemical resistance to withstand components contained in combustible gases.

・Resistant to ozone gas.



Cross-sectional view of the product



Cross-sectional view of the valve

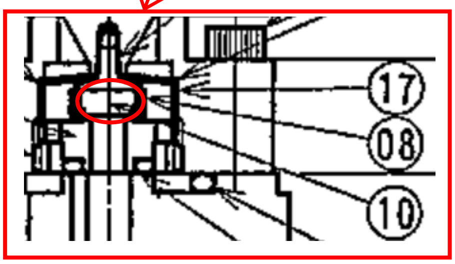


Figure 21 Control valve of mass Flow Controller

Control valves

Control valves are used in a variety of different markets that controls fluid flows in plumbing installed in air conditioning system of building, and Industrial plants, for example petrochemical and power plant.

Examples of control valve products

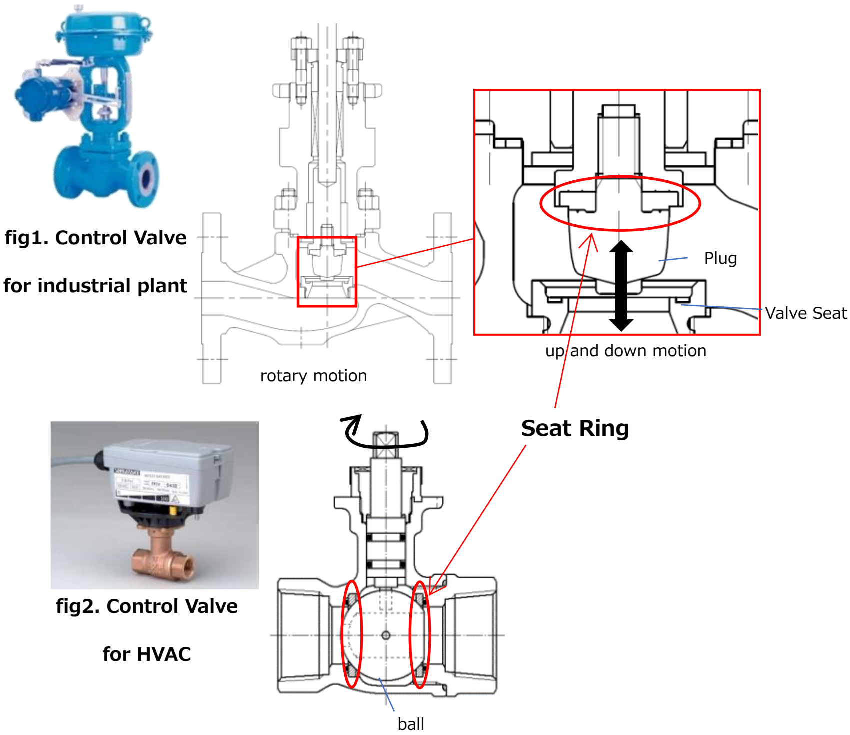


fig1. Control Valve for industrial plant

fig2. Control Valve for HVAC

Figure 22 Control valves

PTFE seat ring is a component of control valves that has a function of stopping the flow by contacting with the plug when it is fully closed. In general, the friction coefficient of PTFE (0.1 or less) is approximately 1/5 that of metal (approximately 0.5), and the torque required to rotate the plug is approximately 1/5 in proportion to the friction coefficient. Add that, corrosive and high temperature fluid flows through control valves. So, excellent chemical and heat resistance are required to control valves. PTFE fills all of characteristics aforementioned. Furthermore, it has proven track record of long-term use in various fields.

Material for scraper rings in industrial control valves

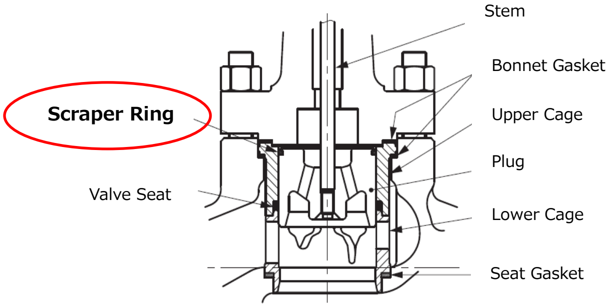


Figure 23 Material for scraper rings in industrial control valves

The PTFE scraper ring scrapes off the fluid adhering to the cage of the control valve and prevents sticking of the plug and cage. Industrial control valves are used to control corrosive fluids such as chemicals and are required to have performance that can withstand the control of corrosive fluids.

On the other hand, in identifying corrosive fluids, there are many fluids that are difficult to determine physical properties such as intermediates of chemical substances, and materials that have a wide range of chemical resistance are required.

In order to control corrosive fluids with industrial control valves, scraper rings made of PTFE are required in the flow passages where corrosive fluids come into contact. Other polymer materials, such as rubber and resin, might be able to substitute for PTFE as the material of scraper rings. However, it is considered that the alternative materials are not suitable, because they do not have enough resistance to various chemicals of chemical plants.

Lining and throttling mechanism materials for industrial control valves

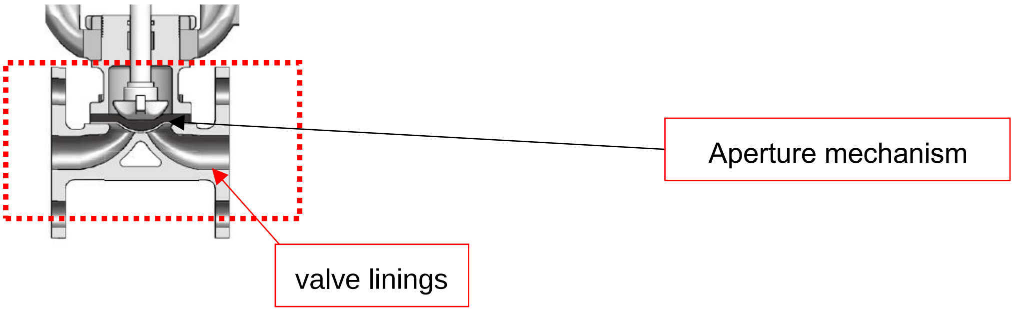


Figure 24 Lining and throttling mechanism materials for industrial control valves

Industrial control valves are installed in pipes of various industrial plants, that are used to control flow of fluids. Industrial control valves are used to control corrosive fluids such as chemicals. Industrial control valves are required to be able to withstand the control of corrosive fluids at high temperatures (approximately 140°C).

In order to control corrosive fluids with industrial control valves, main body linings and throttle mechanisms made of PFA, ETFE and PTFE are required in the flow passages where corrosive fluids come into contact.

Depending on the fluid used, PFA and ETFE are used in the body lining, and PTFE is used in the throttle mechanism.

・ It is possible that other polymer materials such as rubber and resin can be used as alternative materials for body lining and throttle mechanism using PFA, ETFE, and PTFE. However, alternative materials have poor resistance to a wide variety of chemicals in industrial chemical plants and cannot withstand corrosive fluids.

・ If it is assumed that metal materials such as chromium and nickel alloys will be substituted, it is necessary to periodically stop the equipment and check the corrosion status of the control valves connected to the pipes. When corrosion occurs, fluid control becomes impossible, so it is necessary to replace the industrial control valve itself.

Pumps

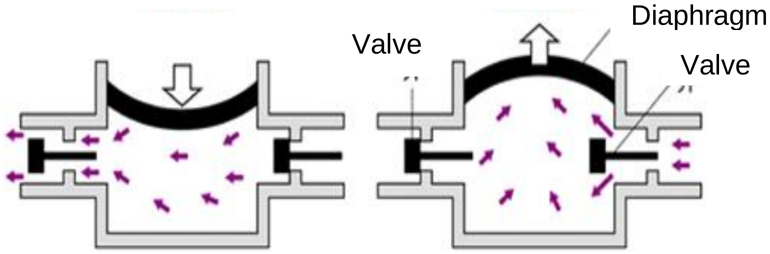


Figure 25 Explanation in Pumps [18]

A pump is a device that transfers, pumps, and stirs liquids and gases under the action of pressure. It is divided into two types according to the difference in structure: non-positive displacement pumps and positive displacement pumps. Non-positive displacement pumps are pumps that impart energy to liquids by rotating impellers, and include centrifugal pumps, propeller pumps, and viscous pumps. A positive displacement pump is a pump that pressurizes and energizes a liquid that is within a certain volume, and there are plunger pumps, diaphragm pumps, gear pumps, etc. In pumps, fluorine rubber such as FKM, FFKM, and FEPM is used for the sealing members and diaphragms of the housing. PTFE is used for the impeller bearings.

PFAS functions which pumps require and alternatives

Pumps used to transfer fluids such as acids, alkalis, organic solvents, oils, and ozone require high chemical resistance for each member in contact with the fluid. Especially in the case of diaphragms, durability that can withstand repeated bending are also required. Fluorine materials such as FKM, FFKM, and FEPM are used as materials to satisfy these requirements, and it is difficult to replace them with other materials.

In the case of bearings, low friction, self-lubrication, and wear resistance are also required. Fluorine materials such as PTFE are used as materials to satisfy these requirements, and it is difficult to replace them with other materials.

Coating/Lining

Part Description

[18] https://www.monotaro.com/note/cocomite/525/

A surface treatment in which the surface or inner surface of a base material is covered with a fluoropolymer is called a coating or lining. A relatively thick covering is often referred to as a lining, while a thin covering is often referred to as a coating. There are various methods such as molding, bonding a sheet to the base material, bonding powder, or covering with a liquid. Fluoropolymers used include PTFE, PFA, PCTFE, FEP, and ETFE.

Metal plating and surface treatment containing fluoropolymer resins are used to adhere to metals. Coatings and linings are applied to parts in contact with fluids. The parts include the inner surface of the piping and parts in contact with the fluid. Metal plating and surface treatment containing fluoropolymer resins are used to adhere to metals.

Examples of coating / lining

Piping inner surface

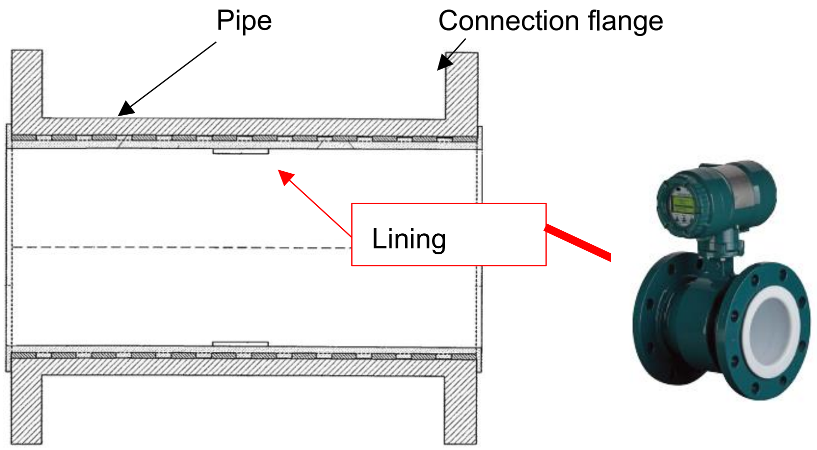


Figure 26 Coating: Piping inner surface

Coating and lining section of parts (diaphragm) in contact with fluid

Figure 27 Coating and lining section of parts (diaphragm) in contact with fluid

PFAS functionality required by coating/lining and possible substitutions

By covering the surface with a fluoropolymer, PFAS gains chemical resistance/cleanliness and mold-releasing properties that the base material does not have. Coatings and linings in contact with fluids can withstand corrosion and operate stably without maintenance for long periods of time (10 years). For example, fluorine coatings and linings on low-hardness rubber materials provide both high flexibility and chemical resistance. When the fluid is a powder, it is difficult for the fluid to adhere to the coating/lining area due to non-adhesion of fluoropolymers.

Examples of Parts and Equipment Using Lining and Coating

There are a great many devices that coat base materials that come in contact with fluids.

Lining for fluid contact parts of electromagnetic flowmeters and pressure transmitters

Equipment around piping such as electromagnetic flowmeters and pressure transmitters cannot maintain their performance without fluoropolymer resin linings and coatings in order to withstand various fluids such as acids and alkalis. Linings using ETFE or PFA can operate stably for 10 years without maintenance. Accidents may occur if the equipment continues to operate with the fluid flowing through the piping without noticing that it has been corroded by the fluid. In order to maintain the work environment and safety management, it is necessary to use fluoropolymers that can be safely used for a long period of time without replacement for devices that pass corrosive fluids.

Environment-resistant photoelectric switch with built-in amplifier

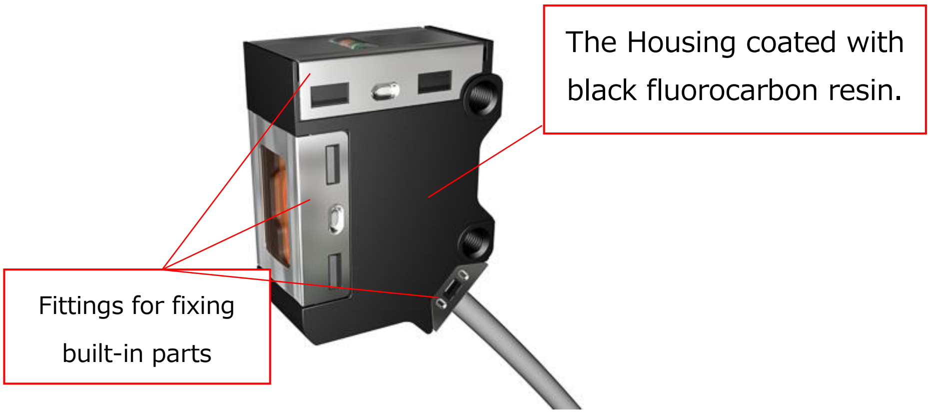


Figure 28 External View/ Detection of workpiece seating in machine tool

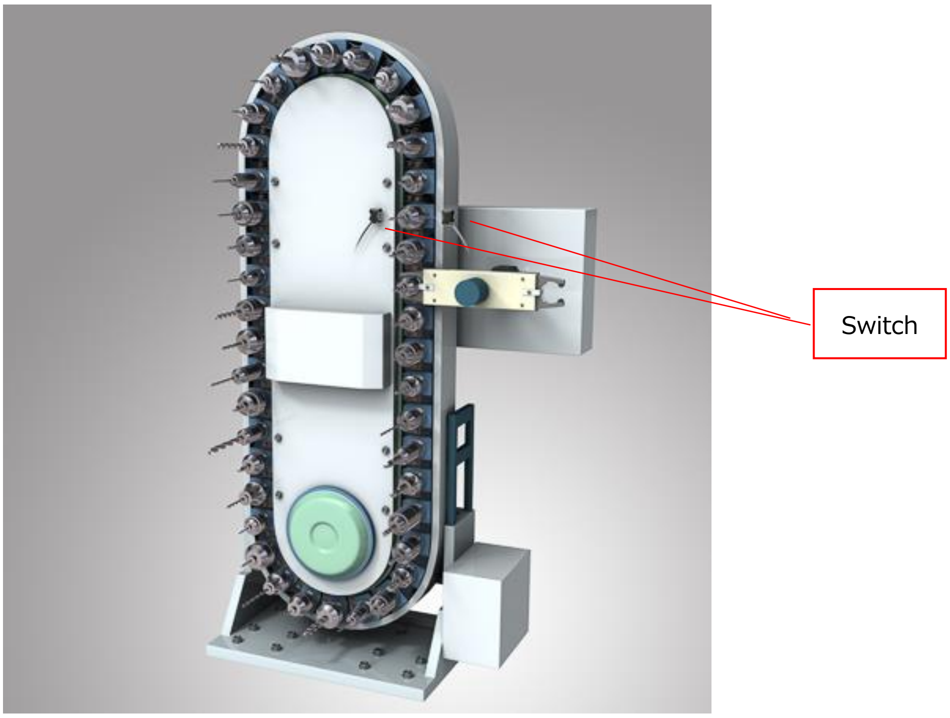


Figure 29 Confirmation of Existence of Tool in Machine Tool

1) Improved corrosion resistance of housing

The housing of Environment-resistant photoelectric switch is made of zinc die-cast. Zinc die-casting has advantages such as high fluidity, easy dimensional accuracy, low molding temperature, and long service life of metal mold, but it has low chemical resistance. Therefore, it cannot be used in machine tools and automobile parts machining lines, which are users of this switch, unless corrosion resistance is improved by painting and plating. Water-soluble coolant (basic) is often used in machine tools and automobile parts machining lines, and zinc die-cast housing is highly likely to be corroded unless surface treatment such as painting is performed (Figure 28).

2) Prevention of crevice corrosion and dissimilar metal contact corrosion
The H2B housing is assembled with a metal stopper (SUS plate (zinc plated)) (Figure 28) and attached to an accessory SUS bracket or the mounting surface of the user side (metal, resin, etc., materials cannot be specified) (Figure 29). Therefore, it is necessary that the metal surface of the housing is not exposed in order to prevent electrolytic corrosion due to gap corrosion and contact between different metals.

The former model number of this switch had adopted acrylic coating, but it was changed to fluorine coating due to low resistance to water-soluble coolant. The surface of the housing must be free from exposed metal. Therefore, coating by coating is necessary instead of plating. For the same reason, coating is necessary even if the housing is changed to a highly chemical resistant metal material such as SUS.

There are concerns about the following impacts due to the unavailability of this technology.
・Affects machining with machine tools that use water-soluble coolant and parts machining and production on automotive parts production lines.
・There is no alternative technology. When a switch without fluorine coating is used, corrosion of the switch causes contamination of corrosion products (foreign matter) into parts, generation of rust in processed parts, and increase of stoppage period of machine tools and production lines due to increase of sensor replacement frequency.

For the above-mentioned reasons, the prohibition of coatings with fluorine-based paints should be exempted indefinitely from this restriction because of the economic burden due to the increased frequency of replacement and the serious degradation to the finished product. In terms of disposal, restrictions should not be applied as coatings by fluorinated paints generally lead to a reduction in waste.

Fuel Cell Performance Testing Equipment: Coating of tank

Fuel cells generate electricity and heat through a chemical reaction between hydrogen and oxygen. Fuel cell performance testing equipment evaluates the performance and durability of fuel cells. Fuel cells contribute to carbon neutrality by improving energy efficiency and reducing CO2 emissions.

The Fuel cell performance testing equipment supplies hydrogen obtained from an alkaline substance to the fuel cell. It stores the alkaline liquid to obtain hydrogen in a stainless steel tank, which cannot be used for a long period of time because the stainless steel is corroded by the alkali. Therefore, the tank surface is protected by coating with PTFE. Moreover, hydrogen gas used for fuel cell is necessary to add water vapor. The tanks for to control the dew point of the added water vapor can reach temperatures above 150°C. Thus the coating material must be heat resistant. So far, PTFE is the only material which has both chemical and heat resistance.

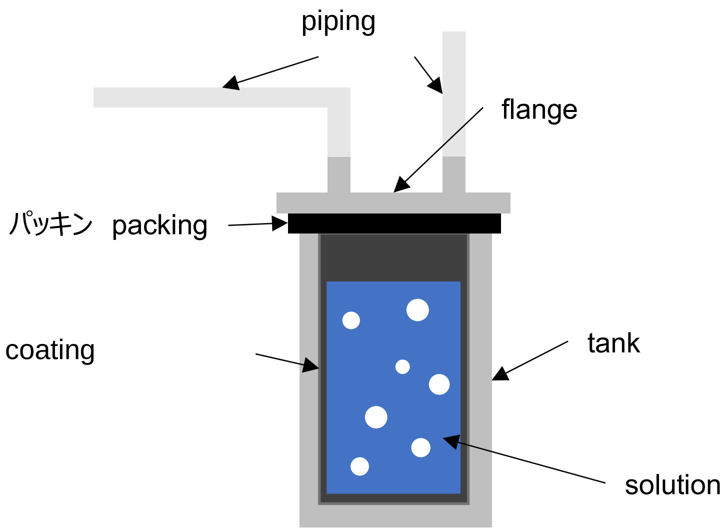


Figure 30 Fuel Cell Performance Testing Equipment:Coating of tank

Temperature sensor

Contact type temperature sensors can measure temperature by contacting the object to be measured and reaching to the same temperature. The sensor measures the temperature using the element itself or an element inserted into a protective tube for strength.

Temperature sensors can measure a wide range of objects, including acids, alkalis, and organic solvents, and can also measure a wide range of temperatures, including applications that measure chemicals at 100°C or higher. Therefore, sensor elements, wires themselves, and protective tubes are coated with FEP or PFA to eliminate the adverse effects of chemicals and high temperatures and realize accurate measurement.

There is no material other than fluoropolymers that combines chemical resistance and heat resistance to realize such applications, and it is difficult to replace them.

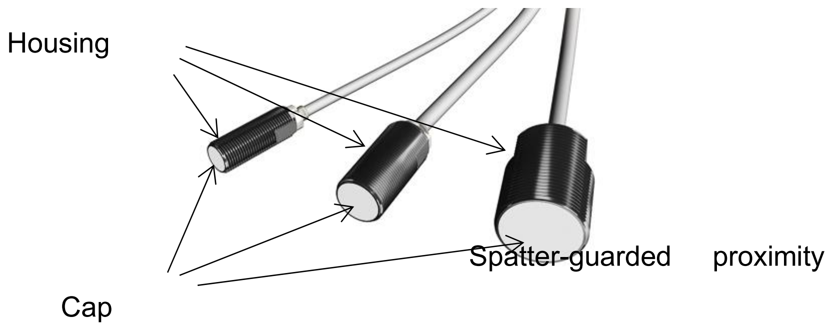


Figure 31 Temperature sensor

Membrane filters

Membrane filters are to remove and separate specific substances or objects from fluids. A wide variety of materials are used. If fluorine compounds are necessary, PTFE, FEP, ETPE and PFA are frequently used.

Membrane — Electrolyte

Dissolved oxygen electrode — Electrochemical gas sensor

Figure 32 Membrane filter

Measurement method of pH meter and diagram of membrane filter

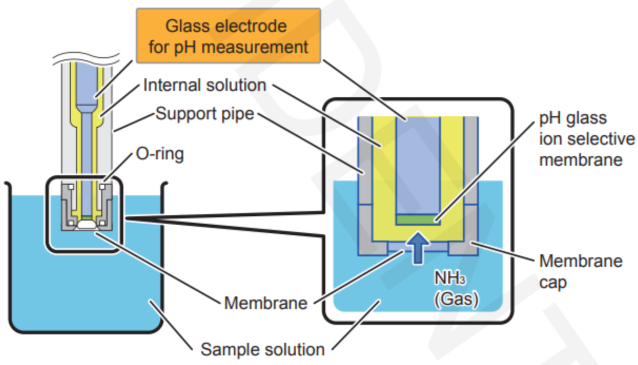


Figure 33 pH meter and diagram of membrane filter

1. Gas components in the sample are go into the electrode through the membrane.
2. The pH of the internal solution changes according to the amount of the gas taken in, and the change of pH is read by a glass pH electrode.
3. The pH change of the internal solution is converted to gas concentration in the sample.

The following properties are required for the membrane used in this application. There is currently no other material that possesses these properties at a level that can be used in products.

・Gas permeability

Membrane must have sufficient gas permeability even under conditions of no pressure.

・Chemical resistance

Membrane must have sufficient chemical resistance that will not deteriorate after immersion in various samples.

・Repellency from water

Repellency from water is required in order not to permeable water.

PVC, glass and PEEK are too high much gas barrier property to separate gases. PE is weak for acids. Glass is melt down by hydrogen fluoride and some gases. Fluorine compounds such as PFAS are the only materials that can simultaneously provide, and express multiple functions required for the proper functioning of membrane filters.

PTFE filter used in the ozone decomposition catalyst unit of NOx measuring equipment

A NOx meter needs to generate ozone to measure NOx by the chemiluminescence method. For accurate measurements, ozone is generated in excess of NOx in the sample. An ozone decomposition catalyst is used to decompose ozone remaining after NOx measurement, and a PTFE filter is used to remove the catalyst powder. PTFE filter is a filter with little adsorption and decomposition. Use is recommended in the business promotion manual for a procedure of monitoring for ambient air developed by Ministry of the Environment of Japan[19]. It also has better ozone-resistance than PVC and PE and is less priced than PEEK.

PTFE porous membrane Electrochemical gas sensor

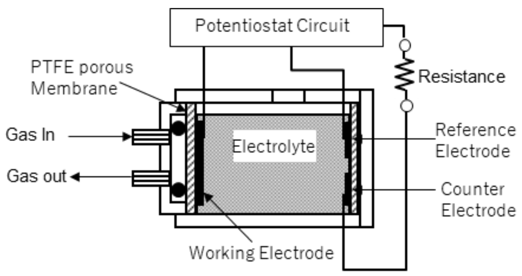


Figure 34 PTFE porous membrane Electrochemical gas sensor

1. Electrochemical gas sensor is constituted by a working electrode formed on a PTFE porous membrane, a reference electrode, a counter electrode, electrolyte and a housing which is holding other components.
2. Every electrode is connected to a potentiostat circuit and the working electrode is implied

[19] The Business Promotion Manual of Continuous Monitoring for Ambient Air Quality (Japan Environmental Technology Association, https://www.jeta.or.jp/publish/manual)

fixed potential to that of the reference electrode.

3. The PTFE porous membrane is in contact with atmosphere which may contain intended gas to be detected.

4. The gas to be detected goes through by diffusion in the membrane and reaches the interface of the working electrode and the electrolyte.

5. The gas is electrochemically oxidized or reduced.

6. The oxidized or reduced reaction involves transfer of electrons between chemical species and the working electrode, hence current flows in the circuit.

7. The current is measured to determine the concentration of the gas to be detected.

The following properties are required for the membrane used in this application.

There is currently no other material that possesses these properties at a level that can be used in products.

・Gas permeability

The membrane must have gas permeability at atmospheric pressure.

・Water resistance

The membrane must have sufficient water resistance not to leak electrolyte.

・Corrosion resistance

The membrane must have corrosion resistance. Examples of corrosive gases are NOx, SOx, halogen and halogen halide.

・Chemical resistance

・Heat resistance

The membrane must have sufficient heat resistance over 150℃ to coat electrocatalyst.

・Non-adsorptive

The membrane must have sufficient non-adsorptive. If the gas to be detected is adsorbed on the membrane, the gas can’t go through the membrane, or it takes time to go through the membrane.

Galvanic oxygen sensor

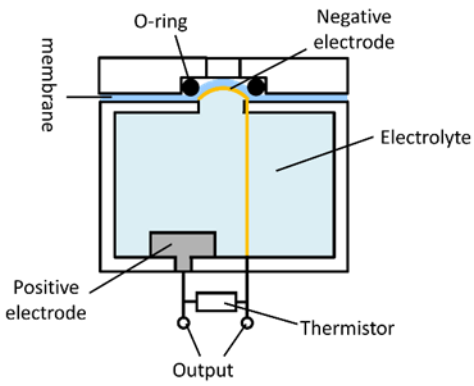


Figure 35 Galvanic oxygen sensor

1. Oxygen gas in the sample reaches through the membrane into the sensor.
2. The oxygen gas taken in is reductively decomposed at the cathode. A current flows according to the oxygen amount taken in.
3. The current is read as a voltage through a resistor such as a thermistor.

The following properties are required for the diaphragm used in this application.

Gas permeability

The gas to be measured is taken into the electrode. This measurement is not possible without sufficient oxygen permeability even under conditions of no pressure. Among fluorine compounds, FEP has superior oxygen permeability compared to other polymer membranes.

Chemical Resistance

FEP is used in environments where it is in constant contact with various gases (acids, alkalis, organic solvents, etc.). The membrane filter does not deteriorate in these environments, does not elute components of the membrane filter when in contact with any sample, and must be resistant to chemicals.

Water repellency and water resistance

The membrane filter must be hydrophobic and water resistant to prevent water from permeating into the electrode.

The material must not change after 10 years of exposure test as a material.

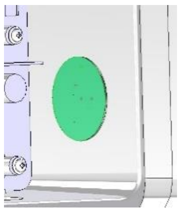
Other examples

Porous membranes filters used in Weighing and Measuring Instruments

Weighing and Measuring instruments that handle chemicals, foods or drugs are used in environments exposed to dusts, oils and liquids. In addition, frequent cleaning is carried out for the purpose of preventing cross contamination, preventing occurrence of various bacteria, occupational health and safety, or maintenance of normal operation and accuracy of the instruments. These instruments often employ ingress protection structure such as IP6X and IPX5 or higher to prevent dusts, oils and liquids from entering the interior. If the instrument is completely sealed, a difference in air pressure will occur between the inside and outside of the instrument, which can cause measurement errors or malfunctions. In addition, the transmission of the buzzer sound from inside the device is disturbed, adversely affecting safety and operation.

Therefore, in order to prevent dusts, oils and liquids from entering the instrument while allowing air to permeate through, filters with porous membranes made of PTFE with fine pores are used in the above applications. Due to PTFE's water and oil repellency, non-adhesiveness and chemical resistance, high filtering performance and the prevention of filter clogging and chemical damage can be achieved.

ıment example (Operating
e for Weigher)



filter example

Figure 36 Porous membranes filters used in Weighing and Measuring Instruments

Electrode

Parts in contact with liquid other than electrodes in electrode structure (of instrument that measures the physical quantity of a liquid by electrical means)-

An electrode in a measuring instrument is a part that is electrically connected to an object to be measured for the purpose of measuring the electrical signal of the measurement object. The instrument that measures the physical quantity of a liquid by electrical means has electrodes. In that type of instrument, the purpose of the electrodes is to acquire the electrical potential or charge at limited area in the liquid. Therefore, （In the electrode and surrounding structure,）parts in contact with liquid other than electrodes must be non-conducting. As the non-conducting material, high hardness materials such as glass and ceramics can be used only very limitedly. because these high-hardness materials are inferior in workability and impact resistance. Therefore, in many cases, resin is used for parts in contact with liquid other than electrodes. And there is no resin material other than PFAS that can withstand the temperature and corrosiveness of liquids.

Optical coating

A water-repellent coating layer which contains Perfluoroalkyl or perfluoropolyether compounds is formed with a thickness of less than tens of nm on the outermost surface of coating layers of the ophthalmic lens surfaces. The water repellent coating provides superior properties such as water repellency, oil repellency, lubricity, smoothness and chemical resistance to the ophthalmic lens. These properties improve prevention of water discoloration on anti-reflection coatings, scratch resistance, ease of wiping off stains (fingerprints, sebum, etc.) on the lens surface and maintainability. As the results, these high performances enable to extend substantially the product life of lenses. And the water-repellent coating layer is coated on anti-reflection coating layers to eliminate the ghost and flare phenomena in lens optical systems. The one of valuable features is having both properties of low refractive index (n<=1.40) and high transparency of the coating layer which composed of perfluoroalkyl or perfluoropolyether compounds.

*1 Ghosting/flare: Reflected light generated on the lens surface is repeatedly reflected in complex ways, resulting in the appearance of light images that are not actually there. The higher the reflectivity of the lens surface, the more likely it is to appear.

*2 Anti-reflection coating: A film with a function to reduce reflected light. In ophthalmic lenses, reflection is reduced by alternately layering materials with different refractive indices to utilize light interference.

*3 Low refractive index: Since the lower the refractive index of the film of the top surface layer of an antireflection coating, the greater the effect of reducing reflections from the lens surface, a film material with a lower refractive index is required. The refractive index of general glass is 1.52, and the refractive index of base materials for eyeglass lenses is 1.50-1.90 (including plastic and glass).

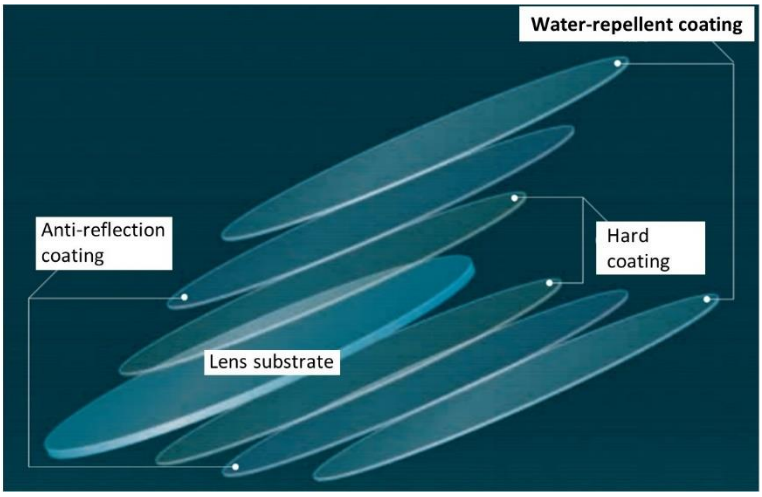


Figure 37 Optical coating

Functions of PFAS that required for lens coating and their alternatives.

Ophthalmic lenses

Ophthalmic lenses are daily exposed to sunlight, rain, sweat, and washed with detergents. So, high level repellency from water and oil are required for the coating of ophthalmic lenses. PFAS-based coatings are widely used because of their excellent weatherability, low friction, and repellency from water and oil. The water-repellent coatings have been developed since the 1980s, but it is still very difficult to achieve the target performances with non-fluorine compounds. Even after more than 30 years effort, no coating without PFAS, which can pass abrasion resistance, chemical resistance, and weather resistance tests assuming everyday use, has been developed yet.

As the proposal alternatives, silicone-based water repellents are representative material, though they can achieve fluorine-based equivalents in terms of contact angle to water, they have not been able to achieve fluorine-based equivalents in terms of contact angle to oil, chemical resistance, and low refractive index.

＜Test results＞

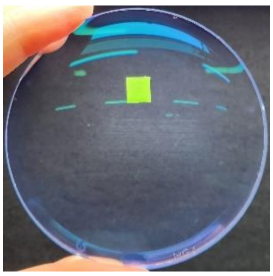
Performance comparison of fluorine-based perfluorinated polyether water-repellent coating and silicone-based polydimethylsiloxane water-repellent coating

		Perfluorinated polyether	Polydimethylsiloxane
Contact angle	To water (H_2O)	108°	104°
	To oil (Oleic acid $C_{18}H_{34}O_2$)	80°	52°
Scratch resistance	Steel wool load 500g 50 round-trip	Good	Bad
Chemical resistance	After 6hr dipping in alkali（NaOH aq. pH:11）	Good	Bad
	After 6hr dipping in acid（HNO_3 aq. pH:1）	Good	Bad

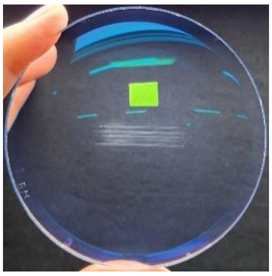
Table 16 Performance comparison of fluorine-based perfluorinated polyether water-repellent coating and silicone-based polydimethylsiloxane water-repellent coating

＜Details＞

Pictures of appearance after scratch test



perfluorinated polyether



polydimethylsiloxane

Contact angle change in chemical resistance test

		Alkali		Acid	
		Water	Oleic acid	Water	Oleic acid
Perfluorinated polyether	Before	108°	80°	108°	80°
	After	105°	70°	104°	70°
Polydimethylsiloxane	Before	105°	52°	105°	52°
	After	42°	40°	48°	31°

Table 17 Contact angle change in chemical resistance test

Water repellent effect by coating

Without coating With Coating

Figure 38 Difference among lens with coating and without coating [20]

Period required for replacement: About 1.5 to 2 years, if a non-fluorine material with PFAS-equivalent performance is produced.
Volume of PFAS to be placed on the EU market : car camera 0.32μg/year
Amount of PFAS entering in the EU as water-repellent coating materials on ophthalmic lenses

The amount of PFAS entering the EU as water-repellent coatings on ophthalmic lenses is estimated to be 300 kg/year[21]. The amount of PFAS entering the EU through water coating[22]

[20] Cannon optron https://optron.canon/ja/evaporation/pickup01.html accessed on 31 May 2023.
[21] WORLD LENS AND FRAME DEMAND STUDY 2022, SWV, https://www.ewintelligence.com/world-lens-and-frame-demand-study-2022/98489.article
[22] Spectacle Lenses – Europe, https://www.statista.com/outlook/cmo/eyewear/spectacle-lenses/europe

is much smaller (1 ppm to 2 ppm) than the total amount of PFAS entering the EU through all applications (140,000 to 310,000 ton/year).

<Explanation for estimating the amount of PFAS entering the EU as water-repellent coating materials of ophthalmic lenses>

The amount of PFAS entered in the EU as ophthalmic lenses was calculated from the product of the annual sales volume of eyeglass lenses in the EU and the amount of PFAS coated as hydrophobic coating film per lens.

1. Hypothesis
・Assume that all vision corrective spectacle lenses sold in the EU have a hydrophobic coating on both sides

2. Estimate
1) Annual sales volume of eyeglass lenses in the EU: 200,000,000 pcs/year [21, 22]
2) Amount of PFAS per lens (both sides)*: 1.5 x 10^{-3} g/pcs[23]
3) Amount of PFAS entering the EU through spectacle lenses: 1) × 2) = 300 kg/year
4) Total amount of PFAS entering the EU: 40,000 to 310,000 tons/year [23]
5) PFAS content ratio by spectacle lens: 9.7E-07-2.1E-06 (1ppm-2ppm)

**The net PFAS amount a is the solid content coated as the water-repellent coatings on both sides of the lens, excluding the solvent. Assuming that the total amount a is deposited on the total number of lenses b that are put in. The amount of PFAS per lens is calculated as a/b.

Therefore, The PFASs amount entering in EU countries as water-repellent coating materials for ophthalmic lenses is much smaller than that entered in EU as other industrial application.

Examples of devices with lenses

PFAS is mainly used for outdoor sensors, lenses of surveillance cameras, etc., and protective panels on the surface of smartphones and other devices. Without the use of PFAS, it would not be possible to meet the required specification of water contact angle (100° or more). As a result, the visibility of the image will be poor, and the function of the sensor or surveillance camera will not be established.

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[23] ANNEX XV RESTRICTION REPORT PROPOSAL FOR A RESTRICTION, P.22/224, Socio-economic analysis, “For the EU, this resulted in an estimated amount of 140 000 to 310 000 t of PFASs introduced to the market in 2020," https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea

Examples

Fiber unit for Measurement use

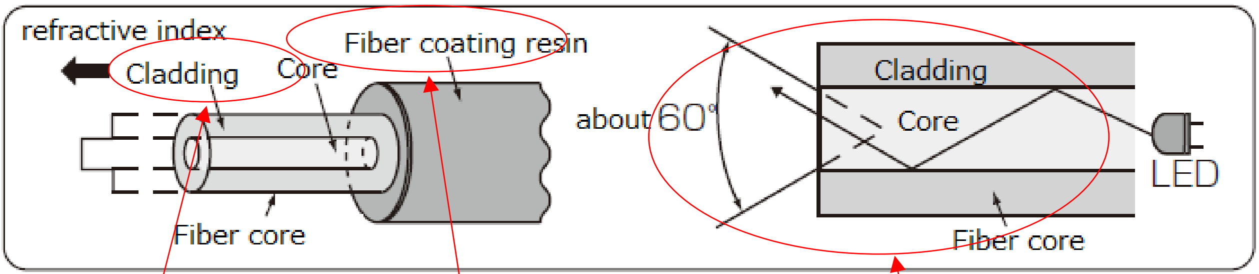
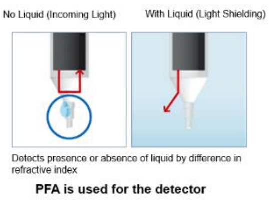


Figure 39 Fiber unit for Measurement use

This is a step index type multimode fiber (using the refractive index difference between core and clad). Fluorine resin is used for the clad. No alternative material has been proposed by the manufacturer at present. In this type of fiber, the basic optical characteristics of the fiber are determined by the refractive index difference between core material and clad material, and the material is selected by the manufacturer in consideration of the manufacturing method. Users use commercially available fiber. FEP is used for the clad and jacket, and PFA is used for the jacket and outer coating.

	Detection method and part of use	Purpose and materials used	Principle using PFA characteristics
Liquid level detection		The tip detection part is made of PFA, and the tube material which may come into contact with liquid is also covered with PFA, a material which is easily fused with the tip. In order to make the tip small and non-electric, a commercially available plastic optical fiber cable is used for guiding the detection light, and fluorine resin (specific material is not disclosed by the manufacturer) is also used as the clad material.	Use refractive index difference between PFA and liquid It uses the difference in refractive index between liquid and liquid.  Detection principle · It utilizes the return light difference due to the refractive index difference (hereinafter referred to as n) between the material of the tip cone and the external contact

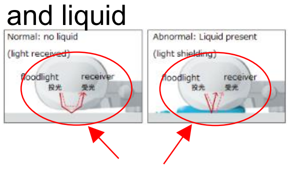
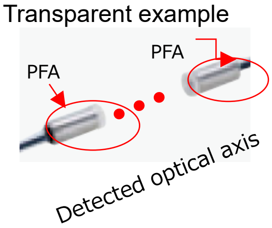
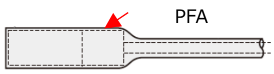
			material. ・ Without liquid : In a state of lower refractive index than PFA (n ≈ 1.35) (air n ≈ 1), most of the light emitted from the projection is reflected by the inner surface of the cone and returns to the light receiving portion to enter. ・ Liquid : The liquid has a large refractive index equal to or higher than that of PFA (water n ≈ 1.33, ethyl alcohol n ≈ 1.36), and the amount of light that is substantially transmitted through the conical surface and returns to the light receiving portion decreases. The presence or absence of liquid is determined by this light amount difference.
Leak detection		The detection head and cable, which may come into contact with liquid, are covered with PFA.	Use refractive index difference between PFA and liquid  Detection principle is the same as "liquid level detection"
Chemical resistance	Transparent example 	The detection head and cable, which may come into contact with liquid, are covered with PFA.	Sealing performance is ensured by fusing the tip of the PFA detection head and the tube. 

Figure 40 Fiber unit for Measurement use

Due to the housing made of PFA resin, this fiber unit has higher stability against organic solvents than other products.

・The following characteristics can be obtained by using PFA resin for the fiber unit.
- This fiber unit functions stably for the detection of organic solvents.
- There is no alternative to this function
・This leakage sensor is used for the following applications.
- Liquid leakage detection in semiconductor wafer cleaning and developing processes
- Detection of tank leakage
・There are concerns about the following effects due to the unavailability of this technology :
- Cleaning and development of a semiconductor wafer using an organic solvent cannot be carried out safely.
・For the above reasons, the prohibition of PFA resin in leakage sensors affects safety and should be exempted from this restriction indefinitely.

Optical fiber for data communication
(End products: LC, LCMS, protein sequencer protein sequencer, ICPMS, ICP, GC)

VDF plastic is used for the clad of optical fiber. VDF plastic has a lower refractive index than that of PMMA which is used for the core, and VDF is clear plastic.
https://www.pofeska.com/index.html

Its use is for data communication between devices. LED with a wavelength of 660 nm is used for the light emitting device for transmission.
https://www.broadcom.com/products/fiber-optic-modules-components/industrial/industrial-control-general-purpose/650nm/hfbr-1532etz

Figure 41 Optical fiber for data communication

Even if there is an alternative material that meets some of the properties, we believe that it is almost impossible to cover all the properties, including optical, mechanical and environmental properties.

Heat medium

Refrigerators, compressors, centrifuges

Refrigerators are used for the units require temperature control, and pretreatment for measurement and analysis. Fluorinated gases are the only materials that can simultaneously provide and express multiple functions required for the proper functioning of refrigerators, such as, thermodynamic efficiency, surface tension, electrical insulation, inactivity, heat conductivity, and a wide range of operating temperature.

HFCs as F-gas will be restricted by the EU F-gas regulation and international treaties. HFCs will be replaced by organic fluorine compounds that their GWP are smaller than carbon dioxide. In that case, the substituted organic fluorine compounds (GWP>1) will be further substituted.

A succession of substitutions in a short period shortens the lifetime of specialist equipment, which is originally long-life. Refrigerators, compressors, centrifuges are used as units of specialist equipment, the derogation as spare parts should be considered. Specialist equipment cannot be repaired, it will be discarded and its lifetime will be shortened.

Refrigerants must not leak from the unit, the units that uses refrigerants such as refrigerators, compressors, and centrifuges requires the sealing materials mentioned in this document. 5(f), (g), and (h) of proposal wordings are written in Annex A of the restriction report. Specialist equipment with a long Lifetime cannot be sufficient grace periods. The grace periods should be examined.

Lubricating oil

Lubricating oil is used to control friction and wear of metal contacting parts when machines are combined to rotate, reciprocate, or otherwise operate. In addition to suppressing friction and wear, this oil also suppresses corrosion and frictional heat, and its sealing and cleaning properties allow the machine to operate smoothly.

Features of fluorinated synthetic lubricants

Lubricating oil formulated with PFAS have the following characteristics

・Low friction: Reduces the adverse effects of friction on the lifetime and performance of components.

・Heat resistance: Resistance to chemical changes even when used in high-temperature environments. Resistance to ignition.

・Weatherability: Excellent oxidation stability and resistance to adverse effects of oxygen. Not decomposed by moisture.

・Chemical resistance: Resistant to chemicals such as acids and alkalis.

・Chemical resistance/cleanliness: Almost no deterioration of rubber and plastic materials.

There is no other lubricant besides fluorinated synthetic lubricants that can satisfy all of the above characteristics.

Lubricant oils in the products.

Mass Flow Controller/ Mass Flow Meter

Mass flow controllers and mass flow meters are used for flow control and flow measurement of various industrial gases. Lubricating oil is applied to joint screws and O-rings to prevent screw galling and improve the assembly of O-rings.

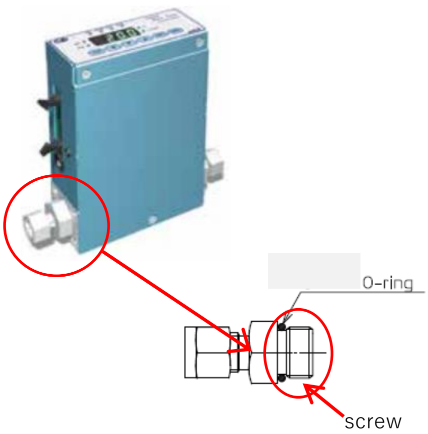


Figure 42 Mass Flow Controller

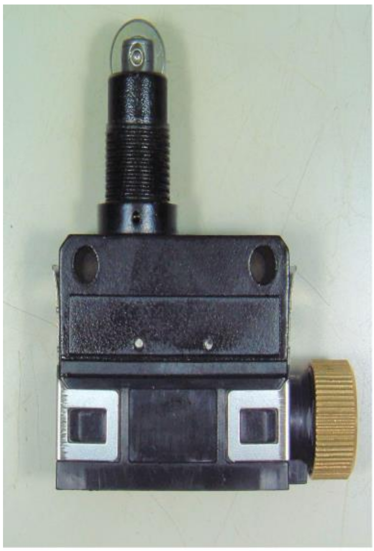
Ordinary grease and oil cannot be used because they may become a source of ignition when flammable oxygen gas is used, so their safety is significantly impaired.

Others

Limit switch button, housing and rubber seal

1. Internal switch button
2. Painting the housing
3. Used for each rubber seal of limit switch

Although the exterior coating can be changed to other coatings, fluorine is the lowest and most suitable for internal sliding properties.
Sliding : plunger and housing
Sliding: internal switch button and internal switch cover
Addition of fluorine improves slidability.



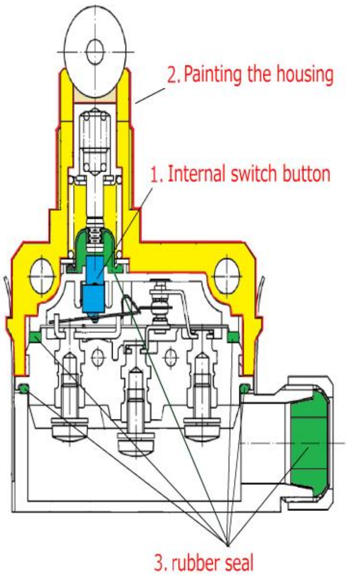


Figure 43 Limit switch

	Fluoropolymer	Resin	
	PTFE	PE	POM
Dynamic friction coefficient (ud)	0.09	0.13	0.18
Heat-resistant(℃)	260	70-110	80-120

Table 18 Limit switch[24]

[24] https://www.y-skt.co.jp/magazine/coating/lowfriction/

The retention of seals at high temperatures is superior to other rubbers. Switching to silicone rubber is difficult to adopt because of the risk of contact failure. In addition, it is often used for applications such as cutting fluid that damage silicon rubber, so it cannot be used.

High-Speed Impact Testing Machines

Strength, shock absorption capacity (speed 20 m/sec)
It is used in a thermostatic bath. It must withstand temperatures between -40 and 150 degrees Celsius.

To absorb shock

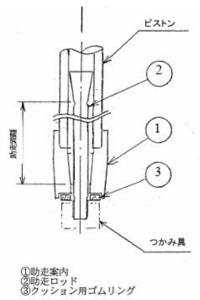


Figure 44 High-Speed Impact Testing Machines

Mold release coating for the injection molding of plastic lenses

In the injection molding of plastic lenses and lens unit housings, we use a mold release coating on the surface of the mold to prevent the plastic from sticking to the mold during removal from the mold (mold release) after filling the mold with plastic. Thereby, it can improve moldability. The type of PFAS for the release coating is not disclosed due to confidential information. If this release film is not coated, the yield of the molding process will be less than 10%.

The reasons why release coating is especially necessary for plastic lenses and lens unit housings are as follows.
1) Effect on lens optical performance
If the next injection molding is performed with plastic adhering to the mold, the part of the molded product corresponding to the part of the mold to which the plastic has adhered will be transferred in the shape of the adhered plastic, creating a dent in the molded product. Especially in the case of lenses, if even a part of the lens is dented, optical performance is greatly affected and the product becomes defective.

2) Decreased production efficiency

When resin adheres to the mold, molding must be stopped and the adhered resin removed from the mold. If this frequency is high, production efficiency will decrease. Plastic lenses also tend to adhere, mainly because of the following reasons:

2-1. Since the required shape accuracy is very strict, the pressure to transfer to the mold must be high. As a result, the resin tends to stick to the mold during mold release more than other plastic parts.

2-2. Dirty mold surfaces due to continuous molding make it easy for resin to adhere to the surface.

Cutting parts

(Example of finished products: diaphragm galvanic oxygen sensors, oxygen detectors)

It is a part manufactured by cutting a block of resin. Because it is a small-lot production product, it is produced by cutting that does not require mold costs. Another reason for cutting is that there are places where sealing properties are required.

Here, I will touch on the machined parts used in the casing of the galvanic oxygen sensor. There are various materials, but we will describe the case where PTFE and PFA, which have higher chemical resistance, are used.

Figure 45 Example of Fluoroplastic Cutting Parts

Please see “Membrane filters” for galvanic oxygen sensors.

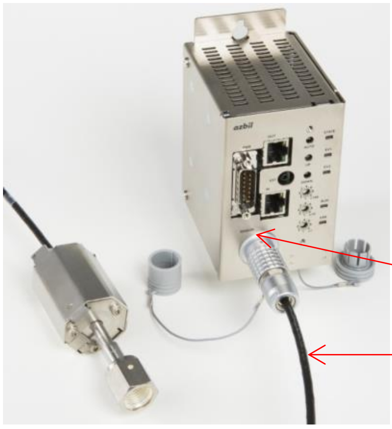
Fluoropolymer casing are required when parts require chemical resistance. There is a need to measure oxygen concentration even in places where acids, alkalis, and organic solvents are always present. In this application, it is necessary to have chemical resistance such that it does not deteriorate even when it comes into contact with various gases (acids, alkalis, organic solvents), does not elute components even when it comes in contact with any sample.

Also, as a material, it is necessary to have weather resistance properties such as not changing in a 10-year exposure test and not softening or deforming in the surrounding environment of -40 to 70 °C. If you try to perform the same function with other materials, for example, phenolic resins and polyamide resins can be mentioned as resins that are resistant to acetone as a general organic solvent, but phenolic resins are resistant to strong alkalis. Polyamide-based resins cannot be used as a substitute because they do not have durability against strong acids.

Sapphire Capacitance Diaphragm Gauge

Components corresponding to a heater operating temperature of MAX 250°C
For the picture of this products, please see the explanation in electric wires and insulation.

Components compatible with gauge head operating temperature of MAX 250°C



LEMO connector ⇔
Board connection cable
→
Cable jacket and dielectric
contain Perfluoroalkoxy alkane(PFA)

Sensor, Temperature sensor for control ⇔ Board connection cable
Sheath, insulator, etc.
contain Perfluoroalkoxy alkane(PFA)

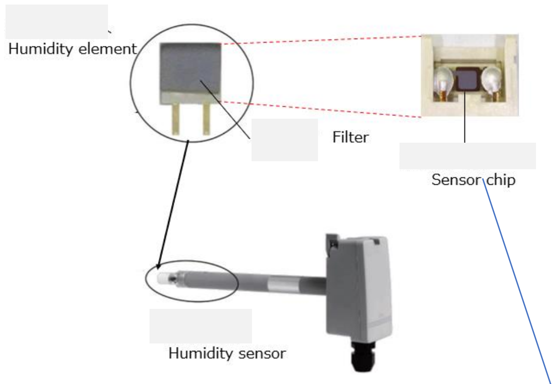
Figure 46 Sapphire Capacitance Diaphragm Gauge

Humidity element for humidity sensor and dew point temperature sensor

Sector: "Electronics and semiconductors (Annex E.2.11.)", "Construction products (E.2.13.)"
Sub-uses: Monitoring and control instruments, Heating, Ventilation and Air Conditioning(HVAC)
Polymeric PFAS /Fluorinated polyimide
Generic name for the final product: Humidity sensor, Dew point temperature sensor

Common name for application parts: Humidity element, Detailed application description

The humidity sensor chip used for a humidity sensor and a dew point temperature sensor measures humidity by capacitance change between electrodes sandwiching the moisture sensitive film. The thickness of the moisture sensitive film is several μm.



Schematic diagram of sensor chip structure
Polymer moisture-sensitive membrane is made of fluorinated polyimide

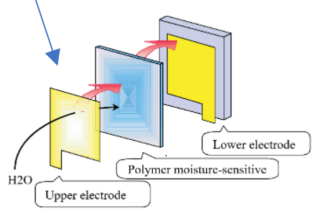


Figure 47 Humidity sensor

This humidity sensor is used for the following purposes

- Humidity sensor installed in an environment in which condensation appears on the sensor itself, such as inside the HVAC duct and the outside air intake section.

The following features can be obtained by using fluoride polyimide for humidity sensor

- The humidity sensor works stably for a long period in an environment where the sensor is condensed (100% humidity).
- Nothing to replace this function.

The humidity sensor has higher stability under high temperature, high humidity and condensation than other products due to the humidity sensitive membrane using fluorinated polyimide.

The prohibition of this technology is concerned about the following effects.

- It won't be able to properly measure and control humidity on HVAC system in an environment in which condensation appears on the sensor itself.

・ Other polymer materials such as methyl methacrylate resin (PMMA), polyimide, polysulfone, etc. can be candidates as alternative technologies and materials.

・ However alternative technology requires replacement of the sensor every time condensation occurs. For example, it is known that condensation appears on a humidity sensor which is inserted into an outside air intake duct several times a year depending on the weather. Humidity sensors without moisture sensitive membrane using fluorinated polyimide for this application will require replacement at least once a year. Moisture sensitive membranes using fluorinated polyimide can withstand at least 8 years of use.

Performance requirements for materials (PFAS)
Heat-resistant: 180 degree Celsius as a humidity sensitive element
Repellency from water: Electrical insulation in condensing environments
Chemical resistance: Resistant to organic solvent atmosphere
Alternative Considerations: No substitute material
Required derogation period: 13.5 years or more

Valve for air volume and room pressure control

Materials for ensuring sliding, **corrosion resistance**, chemical resistance, and solvent resistance for air volume valves.

Use sector: "Medical devices (Annex E.2.9.)", "Construction products (E.2.13.)"
sub-uses: Control valve, Heating, Ventilation and Air Conditioning(HVAC)
PFA：26655-00-5
PTFE：9002-84-0
PVDF：24937-79-9
ETFE：25038-71-5
Generic name for the final product: Valve for air volume and room pressure control
Common name for application parts: Body, Pivot arm, S-link, Shaft, Spring, Cone, Brackets, Seal), Tap, e-crip), Bush, Slider, Sleeve, Cap, Bolt

The two main applications of valves are below.

(1) To be installed as a local exhaust ventilation system to prevent workers from being exposed to substances harmful to the human body, such as in chemical manufacturers and biotechnology research laboratories.

For example, when a worker opens or closes the door of the local exhaust device (red dotted frame in Fig.1), the differential pressure across the valve suddenly changes, but by taking advantage of the good sliding property, the valve can be instantly changed to the appropriate valve opening position to maintain exhaust at a constant air volume.
In addition, since valves must control fluids containing various chemicals and solvents, they must be resistant to corrosion, chemicals, and solvents.

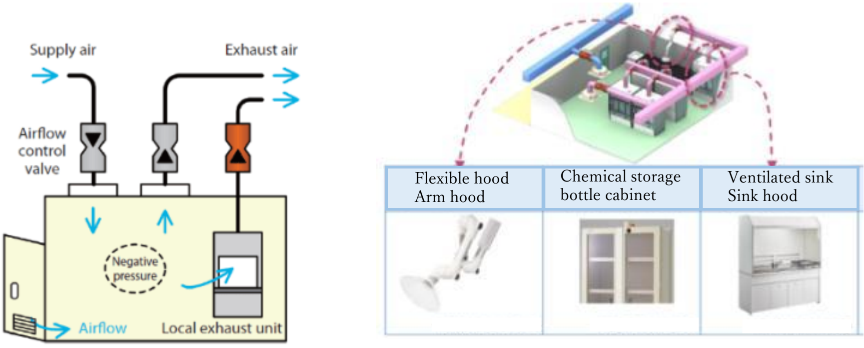


Figure 48 Example of air volume control in a chemical/ Other exhaust applications

(2) The device is installed in hospital rooms and wards as a negative-positive pressure control device to secure hospital beds for patients with infectious diseases and to protect healthcare workers from infection risk.

Even when the differential pressure across the valve suddenly changes due to the opening and closing of the hospital room entrance door, etc., the air supply and exhaust valves respond instantly by taking advantage of their good sliding characteristics and change to the appropriate opening position, thereby always maintaining the pressure difference between the room and outside.

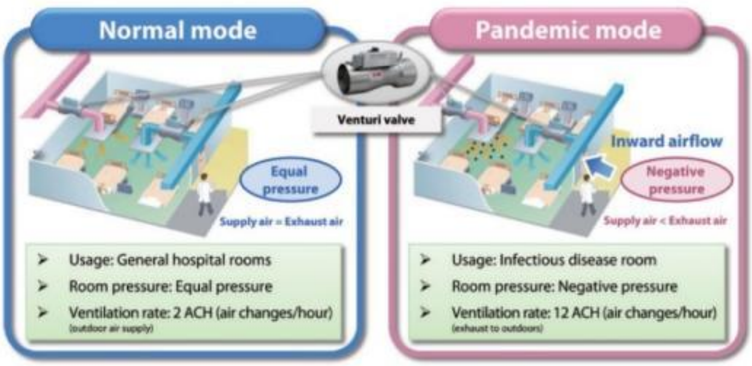


Figure 49 Image of negative and positive pressure control in a hospital room

The parts used in valves that include candidates for regulation are below.

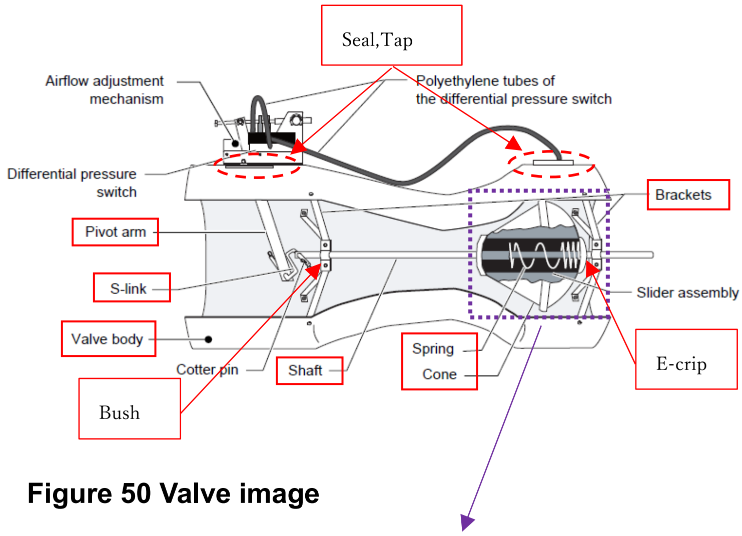


Figure 50 Valve image

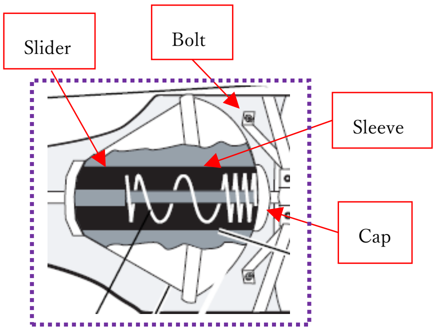


Figure 51 Slider assembly

(1) For valves that do not require corrosion resistance, chemical resistance, or solvent resistance, parts (Slider, Sleeve, Cap) containing PTFE should be used to ensure sliding properties.

(2) Valves that require corrosion resistance, chemical resistance, and solvent resistance use the following parts to ensur
e the above three functions and sliding properties.

・Parts containing PTFE (Slider, Sleeve, Cap, Bush, Seal, Tap)
・Parts containing PFA (Shaft, Spring)
・Parts containing PVDF or ETFE (Body, Pivot arm, S-link, Cone, E-crip, Bolt)

Technical Description of Essential Uses

As mentioned above in “Detailed application description”, valves must have the sliding property required to respond instantly to sudden disturbances, and the corrosion, chemical, and solvent resistance required to control fluids containing various chemicals and solvents. Therefore, it is necessary to place parts containing PTFE, PFA, PVDF, and ETFE for mechanisms that need to ensure sliding properties and for channel parts that are in contact with the control fluid.

(1) Ensure sliding properties
Other polymeric materials may be used as an alternative to PTFE for ensuring sliding properties. However, since there is no material with lower sliding resistance than PTFE, the sliding resistance force will increase and the sliding performance required for valves cannot be ensured.

(2) Ensure sliding properties, corrosion resistance, chemical resistance, and solvent resistance
Other polymeric materials, such as rubber and resin, may be used as alternatives to PFA, PTFE, PVDF, and ETFE for the purpose of ensuring the above four functions. However, the alternative materials cannot ensure the sliding properties, corrosion resistance, chemical resistance, and solvent resistance required for valves due to the deterioration of sliding properties as described in (1) and the lack of resistance to various chemicals and solvents.

The following effects are feared as a result of the unavailability of these technologies. The inability to use PFA, PTFE, PVDF, and ETFE for valves will make it impossible to carry out normal operations at chemical manufacturers, biotechnology research facilities, hospitals, and other facilities. This will have a profound impact on the production and supply of medicines, the progress of research in biotechnology, and isolated medical treatment, including coronas.

For the above reasons, the prohibition of the use of parts containing PFA, PTFE, PVDF, and ETFE in valves should be exempted from this restriction in terms of ensuring safety for the human body. In terms of disposal, the restriction should not be applied to valves containing PFA, PTFE, PVDF, and ETFE, since these components can be used until the product reaches its original service life, leading to a reduction of waste in general.

Performance requirements for materials (PFAS)
Heat-resistant: Heat-resistant max93 degree Celsius
chemical resistance: Resistant to chemicals, solvents and corrosive fluids
Sliding performance: Wear resistance due to sliding, sliding performance
Non-adhesion: Non-adhesion of foreign matter

Mechanical parts for sliding or releasing applications used in "Specialist equipment”.

Fluoropolymers with excellent low friction and self-lubrication and non-adhesion properties are often used in mechanisms that require sliding with plastic and metal parts or releasing from sticky materials. The following common characteristics are related to the reason why fluoropolymers are particularly selected for "Specialist equipment".
1) Some final products handled by "Specialist equipment" require use in special environments. For example, in facility environments where foods, liquids, powders, etc. are handled, consideration must be given to high temperature, high humidity, generation of dust, or hygiene management.
2) Equipment used in social infrastructure such as factories is required to have performance such as automatic operation, trouble-free operation, easy preparation and setup changes. This enables us to provide society with high-quality, low-cost products and services.
3) When handling products with equipment, it is required to minimize the impact on product quality, such as damage or adhesion of foreign matter.

From the above, the mechanical parts for sliding applications used in " Specialist equipment " are required to have the following properties.
・Repellency from water and oil / non-adhesion
・Low friction, self lubrication
・Heat resistance
・Chemical resistance (Acid resistance, Alkali resistance, Oil resistance, Ozon resistance)

Table 19 summarizes the performance of major alternative materials with respect to the required performance.

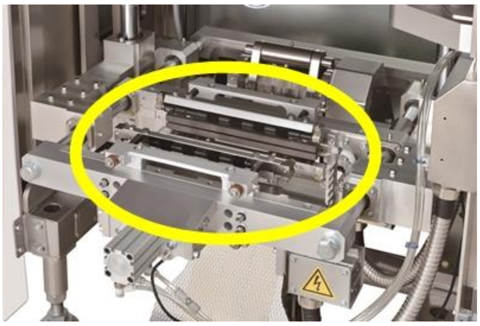
Appropriate materials are selected and used according to the required performance that varies depending on the work environment and target product. From the table, PFAS shows good properties with respect to water/oil repellency and heat resistance. Cases where PFAS is used as an irreplaceable material include, for example, use in environments where food and liquids are handled, as well as guide parts or blade surface coatings where adhesion is undesirable.

Material		PTFE	POM	HDPE	PA66
Material or Coating		Material /Coating	Material	Material /Coating	Material /Coating
Low friction	Coefficient of friction	0.04	0.2-0.3	0.2-0.3	0.18-0.4
Repellency from water and oil	Contact angle of water [deg]	114	(Same as PA66)	88	77
	adhesion energy [dyne/cm]	43.1		75.2	97.7
Oil resistance	Contained in food	◎	○	◎	◎
Acid resistance	Contained in food	◎	×	◎-○	△-×
Alkali resistance	Contained in detergents, etc.	◎	×	◎	◎
Ozon resistance	Special cleaning	◎		△	×
Heat resistance	Hot food	◎	△	△-×	△

Table 19 Material for Mechanical parts for sliding or releasing applications

* Non-adhesion and Repellency from water and oil are according to the above-mentioned property table. Others are summarized by the author of this section based on multiple documents.

Instrument example (Packaging machine for food industries)



Heating pressure bar with knife of packaging machine (with PTFE Coating)

Figure 52 Mechanical parts for sliding or releasing applications used in "Specialist equipment"

Food Contact Parts of Equipment and Measuring Instruments used at Sites where Food is handed (including parts that may come into contact with food)

The following hygienic performances are required for the food contact parts of equipment and measuring instruments used at sites where food is handed before packaging.
1) The materials used shall be safe for exposure to the body through food. These materials are therefore subject to regulations such as (EC) No 1935/2004, or (EU) No 10/2011.
2) In order to prevent the growth of bacteria and reduce food loss and the burden of cleaning, it is required that food does not adhere easily. Therefore, repellency from water and oil / non-adhesion and low friction are important for these materials.

Table 20 summarizes the performance of the main means currently in practical use for this purpose. (Each means is provided in the form of material or coating.)

Technical approach		(1)contact area	(2) water- and oil-repellent, non-adhesive materials		
Means		Stainless steel embossed structure	PFAS (PTFE,PFA)	Ceramic	HDPE
Material or Coating		Material	Material /Coating	Coating	Material
Repellency from water and oil	Does not adhere to water or oil	× Oil hardens and accumulates.	◎	◎-○	○
Non-adhesion (for hard foods)	Food does not remain on equipment.	◎-○	◎	○-△	○
Non-adhesion (for soft foods)		△-×	◎	○-△	○
Oil resistance	Contained in food	◎	◎	◎	◎
Acid resistance	Contained in food	◎	◎	◎	◎-○
Alkali resistance	Contained in detergents, etc.	◎	◎	○	◎
Ozon resistance	Special cleaning	◎	◎	◎	△
Heat resistance	Hot food	◎	◎	◎	○
Durability	Hard to wear	◎	△	○	△

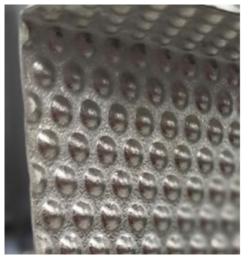
Table 20 Materials for Food Contact Parts

*PFAS and PE are according to the above-mentioned property table. SUS and ceramics are summarized by the author of this section based on multiple documents.

In terms of technology in the practical stage, PFAS is superior in all items except durability. Since the required performance differs depending on the type of food and the factory environment, means other than PFAS may be selected. However, it is clear from the above table that substitution is not possible in all cases, which is the reason why exclusion is necessary. Also, the determination of substitutability requires trials using actual food in actual working environment and confirm compliance with (EC) No 1935/2004, (EU) No 10/2011, etc. Therefore the substitution period is necessary.

Instrument example (Weigher for food industries)

Example of oil accumulation (Food contact part is a flat stainless steel without coating)



Example of stainless steel embossed structure

Instrument example (Label Printing Scale)

Instrument example (Wrapping Machine)

Figure 53 Food Contact Parts of Equipment and Measuring Instruments used at Sites where Food is handed