PTFE in hose systems for the chemical, pharmaceutical and food industry

Markert Marsoflex PTFE hose assemblies:
Innovation through years of research and development

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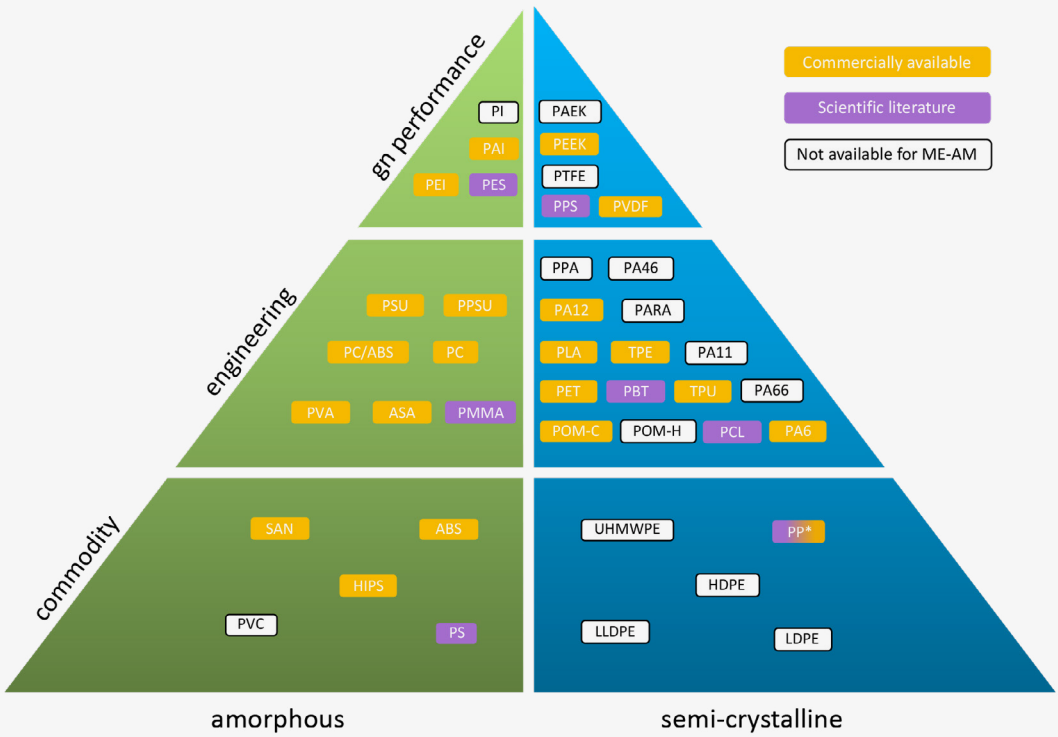
1. The material PTFE

The four letters PTFE stand for **polytetrafluoroethylene**, which was originally also known under the trade name "Teflon" from the DuPont company. PTFE is a partially crystalline polymer of fluorine and carbon. PTFE was discovered in 1938 by chemist Roy Plunkett when he experimented with tetrafluoroethylene (TFE) and converted it to "colorless crumbs" polymerized.
In the meantime, PTFE has become indispensable in many applications because of its outstanding properties:

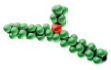
– PTFE is very inert and therefore has a very **high resistance** to almost all bases, alcohols, benzines, oils.
– PTFE has a very low coefficient of friction and is therefore an **ideal** lubricant.
– PTFE has an extremely low surface tension, so it is almost impossible to wet. There are almost no materials that stick to PTFE - also known as the **non-stick effect of** PTFE.
– PTFE has a high temperature resistance up to +260 °C.
– PTFE has very low electrical conductivity and therefore good insulation properties.

PTFE has clear advantages over almost all other plastics and is the best technical solution for many applications.



PTFE comes in two types:


–Non-modified PTFE (non modified)

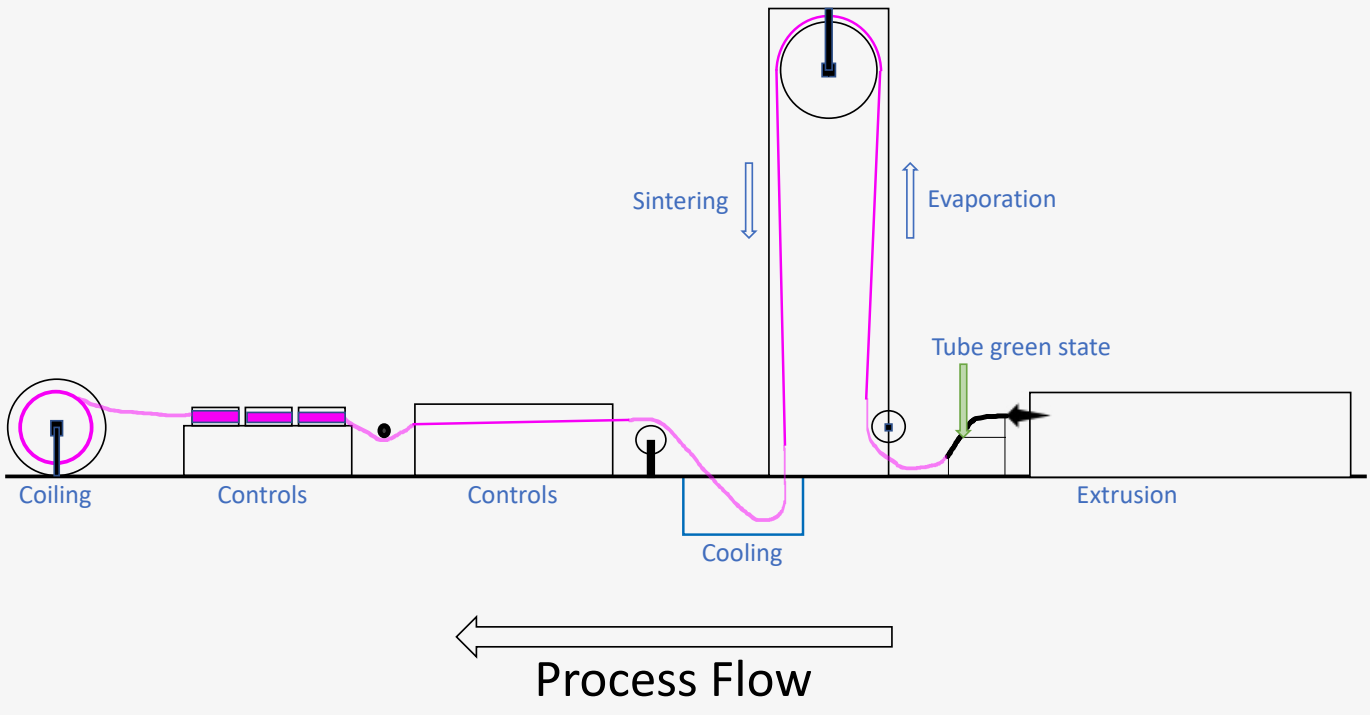

–Modified PTFE (modified) In modified PTFE, perfluoropropyl vinyl ether (PPVE) is added.

Hereby, the properties such as lower deformation, lower porosity, higher elongation at break and lower permeation are optimized. Markert uses only modified PTFE.

2. The production of PTFE hoses

Polymerization produces a white PTFE powder. This produces the raw material for the manufacture of PTFE products. Market leaders in the production of PTFE include DuPont (now Chemours), DOW (3M™ Dyneon™) and Daikin.

The PTFE powder is mixed with a binder (e.g. ISOPAR) for further processing and thus becomes processable. In the production of PTFE hoses, the resulting emulsion is thermally heated in an extruder and pressed over a die. If the PTFE is to be conductive, carbon is added to the PTFE in the mixing process (this is the starting material for the so-called "black" PTFE). By means of extrusion, the PTFE emulsion is sintered to the desired shape. In the final cooling and cutting process, the final PTFE hose liner is produced.



The extrusion process is extremely complex, as only balanced tempering phases can ensure complete polymerization of the PTFE powder. Furthermore, the die and the PTFE guide must be matched to each other with high precision; only in this way PTFE liners can be produced reliable. The smallest inclusions or tolerance deviations in the PTFE liner can drastically influence the strength.

Only raw materials of the highest quality may be used for industrial hose lines. Therefore, only the PTFE compound Teflon T-62 (Chemours formerly Dupont) is used for Markert Marsoflex hoses.

3. PTFE coextruded

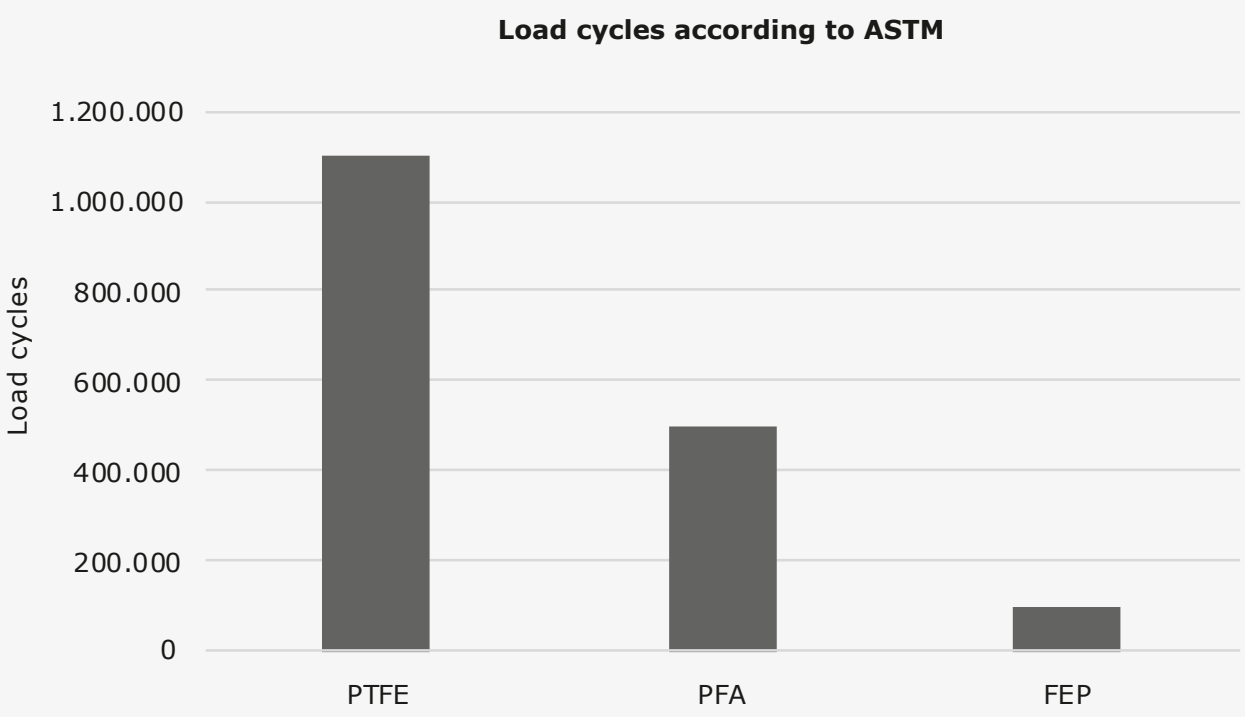
Pure PTFE is referred to as virgin PTFE. This PTFE forms tight linkage chains and has a very dense and thus smooth surface structure. White materials are often required, especially in pharmaceutical applications. For this purpose, pigments are added to PTFE to produce pure white PTFE. The pigmentation slightly changes the material structure, which is why unpigmented PTFE has fewer pores in the surface than pigmented PTFE. Transparent PTFE can be combined with pigmented PTFE by means of so-called coextrusion: Transparent virgin PTFE with a smooth surface on the inside - white pigmented PTFE on the outside: this combination provides a white appearance (since the white pigmented outer PTFE shines through the transparent inner layer) and a very smooth, transparent inner layer. Markert uses coextruded PTFE liners in all SIL300 PTFE tubing. These liners have a smoother (non-porous) surface with a lower absorption rate than pigmented white liners.

4. PTFE in comparison

PTFE can be considered the "all-purpose" material due to its excellent material properties, with a few exceptions. In the following, the properties of PTFE are compared with other highly resistant materials.

Material	Main material properties PTFE
PTFE vs. silicone	Durable resistance to steam cleaning Better cleanability Broader temperature/pressure spectrum Broader chemical resistance Higher purity
PTFE vs. PFA	Higher flexural fatigue strength Lower coefficient of friction Better temperature application range Better price/performance ratio PFA has better low-temperature properties
PTFE vs. FEP	Higher flexural fatigue strength Higher flexibility Broader chemical resistance Better temperature application range PTFE has a lower coefficient of friction than FEP (0.02 vs. 0.05) FEP has better low-temperature properties
PTFE vs. UPE	Broader temperature range Broader chemical resistance Better UV/ozone resistance Higher purity Less weight
PTFE vs. stainless steel	Higher flexural fatigue strength Broader chemical resistance Higher flexibility Better cleanability

Flexural fatigue strength is an important factor for the mechanical service life of a hose assembly. Here, PTFE offers significant advantages over PFA and FEP. According to bending tests in accordance with ASTM D2176, PTFE can withstand significantly more load cycles than PFA or FEP:



5. Requirement for PTFE

A large number of approvals, requirements and confirmed properties appear in connection with PTFE as a material. We shed light on this and explain what is really relevant for the application.

5.1 FDA approval

The FDA is the U.S. Food and Drug Administration, the government agency responsible for monitoring all goods marketed in the United States. This also includes all imports, which is why the guidelines and regulations of the US authority are also important for European manufacturers.

FDA-compliant requirements need materials that have a long shelf life while not releasing ingredients into the food.

The FDA is divided into various substructures. FDA21 stands for Food and Drugs, CFR for Code of Federal Regulations and Part 177 for Indirect Food additives: Polymers. This specific area of the FDA describes the approved polymers.

FDA-approved PTFE is required whenever the hose assembly is used in applications and/or equipment subject to FDA approval.

Markert Marsoflex PTFE tubing systems use only PTFE liners with FDA 21 CFR 177.1550 approval.

The **hose cover** and any **intermediate layers** are generally not designed in accordance with FDA, since they are not in contact with the medium in the intended use.

5.2 USP Class VI

Plastics used in medical technology and pharmaceuticals are divided into six biocompatibility classes in the United States Pharmacopeia (USP). To assign elastomers and other polymer materials to one of the classes, they are subjected to various tests to determine their biological reactivity in living organisms.

Based on binding guidelines for the manufacture of medicinal products and medical devices, the quality of the substances tested is to be guaranteed. The correct identity of the drug substance, active ingredient strength, quality, purity and composition are evaluated. In order to obtain a USP Class VI classification, the following tests are carried out on the material itself and on various extracts of this material in external testing laboratories. Roughly, three test fields can be distinguished:

– Acute systemic toxicity:
  The determination of acute irritant effect by skin contact, inhalation and ingestion is carried out.
– intracutaneous reactivity:
  The test material is placed in direct contact with the tissue for which it is intended in normal use.
– Implantation test:
  The reaction after implantation into the tissue of a living organism is studied. The duration is usually five days.

These tests are performed at set exposure times and temperatures to ensure comparability of results. Although biocompatibility testing must take place on the finished medical device, it is important for the manufacturer that all starting materials used are also tested and meet the requirements of the final product.

USP Class XI is further subgrouped in detail according to EP 3.1.9. This subcategory specifies specific tests on silicone elastomers, such as the residual peroxide content.

Strictly speaking, USP Class VI approval is only required if the tubing is in continuous contact with human tissue.

Markert Marsoflex PTFE hose systems use only PTFE liners with USP Class VI approval.

5.3 Freedom from GMO/BSE/TSE

In the pharmaceutical industry, it may be necessary to confirm freedom from GMO/BSE/ TSE. This is a declaration that the products are free from animal ingredients and materials of animal or cell culture origin:

– **BSE** (Bovine Spongiform Encephalopathy -' spongy change of the brain substance occurring in cattle)
– **TSE** (Transmissible Spongiform Encephalopathy -' transmissible spongiform brain disease).
– **GMO** (Genetically Modified Organism)

The **ADI-free** certificate confirms that raw materials used in the manufacture of the elastomer do not contain any animal derived ingredients (ADI).

Markert Marsoflex PTFE hose systems use only PTFE liners that are free of BSE, TSE, GMU and ADI.

5.4 Regenerate-free

Sometimes the property "regenerate-free" appears in connection with the material PTFE. This is completely irrelevant for industrial hose assemblies. Regenerate-free means that no PTFE residues with any toxic substances are reused in the manufacture of the PTFE liner. This may occur with low-quality elastomers (e.g. pond liners).

Markert Marsoflex PTFE liners are always extruded from virgin PTFE (i.e. pure PTFE) or PTFE-carbon compounds (a fixed proportion of carbon is added to the virgin PTFE for this purpose).

5.5 Virginity/Conductivity

As described above, a distinction is made between virgin PTFE and PTFE compounds. Virginal PTFE is pure PTFE without further additives. PTFE compounds can usually contain carbon (to increase conductivity) or glass (to increase strength).

6. Technical properties of PTFE

The main technical properties of PTFE and, where regulated by standards, the associated standards are listed below.

Technical property	Norm	Unit	Values for PTFE
Density	ISO 1183	g/cm²	ca. 2,13-2,23
Yield stress	ISO 527	MPa	10
Tensile strength	ISO 527	MPa	–
Elongation at break	ISO 527	%	350
Bending E-modulus	ISO 527	MPa	420
Melting temperature	–	°C	325-335
Thermal conductivity	ISO 22007	W/K m	0,24
Hardness			
Coefficient of friction			
Maximum operating temperature		°C	260 °C
Minimum operating temperature		°C	-270
Fire class		–	V-0
Electr. surface resistance	IEC 60093	Ohm	10^{17}
Volume resistivity	IEC 60093	Ohm m	10^{16}
Flammability	IEC 60695-11-10	–	incombustible

Higher temperatures have a relevant influence on the compressive strength of PTFE.

The following table gives a rough guide as to which reduction factors apply at temperatures >20 °C.

50 °C	75 °C	100 °C	150 °C	200 °C	250 °C
0,87	0,77	0,68	0,53	0,39	0,28

The factors are to be understood as an indication, the exact temperature/pressure ranges depend heavily on the hose design. We will be happy to advise you on checking the application condition and selecting the optimum hose design.

7. Connection of the hose fitting

For the use of a hose assembly in the process industry, the hose is usually integrated with connection fittings.

In this process, a hose nozzle located in the hose is firmly connected from the outside with clamping shells or furrules. The combination of connection fittings and the hose creates a hose line - a pressurized component that is subject to the Pressure Equipment Directive.

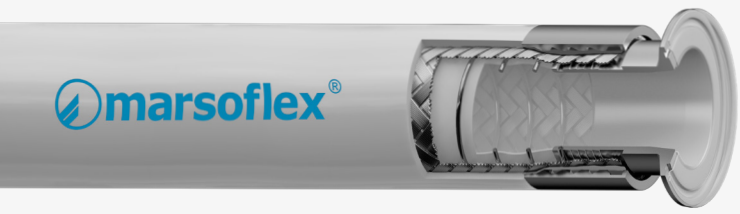
When integrating the fitting, there are basically two design options for PTFE liners:

– Flanged connections
– Crimped connections

In the case of flanged connections, the PTFE liner is passed through the connection fitting and brought onto the sealing surface of the fitting by means of thermal deformation (lining or flaring). This results in a hose line that is 100% lined with PTFE: completely gap-free and with full protection against the medium. This is often used for highly corrosive media or processes with dead space free requirements (pharmaceutical/food applications).

In the case of crimped connections, the hose fitting nozzle inserted into the hose is crimped to the hose from outside with a ferrule by means of a crimping sleeve. This creates a transition inside the hose line between the PTFE liner and the material of the hose fitting nozzle (usually stainless steel).

Crimped Tri-Clamp connection



Lined / Flared Tri-Clamp Connection

↑
Liner flared to the sealing surface of the tri-clamp.

8. Selection of the hose cover

The outer cover protects the liner from external mechanical stress and ensures sufficient pressure- and bending strength. For the correct selection of the best hose cover, the following cirterias apply (✓ = excellent properties, ○ =satisfactory properties, ✗ = conditionally suitable depending on the application):

Cover	Cover Application	Clean-ability	Resistancy	Weight	Flexibility	Conduc-tivity
Stainless steel braid B1	The stainless steel braid of 1.4301 is the most common design for the protection of the liner. On the one hand, it offers high conductivity and has a high mechanical stress resistancy. However, smooth covers made of e.g. silicone or EPDM are recommended, to avoid that external particles accumulate in the braiding.	✗	✓	✗	○	✓
Silicone (in conjunction with B1)	Due to its smooth surface, a silicone cover is the right choice when the hose must also be easy to clean on the outside. In addition, the silicone has a wide chemical resistance. The silicone is usually extruded onto a metal braid.	✓	○	○	○	✗
EPDM/CR (in conjunction with B1)	Compared to a silicone cover, an EPDM/CR cover offers the ad-vantage that EPDM/CR has a higher abrasion resistance. In the case of a high abrasion load (dragging the hose across the floor), EPDM/CR is preferable to silicone. Likewise is dirt less visible on black surfaces compared to white silicone surfaces. The EPDM/ CR cover is the standard in the chemical and food industry.	○	○	○	✓	✓
Modified plastic braid B3	The hose cover has an singificant impact on the overall hose weight anf the flexibility. With the use of a plastic braid, a very light and flexible cover is achieved. In addition, the braid has a high tensile strength and chemical resistance and can be used up to 230 °. Thanks to woven-in metal filaments, the braid is electrically conductive (M conductivity) and can be used in hazardous areas.	✗	✗	✓	✓	✓
Polypropylene braid B6	The B6 braid has comparable properties to the B3 braid and can be used where the conductivity requirements are lower (Ω conductivity) is required.	✗	✗	✓	✓	✓

9. The PTFE liner in detail

From the starting powder material, extrusion produces a smooth cylindrical PTFE liner.

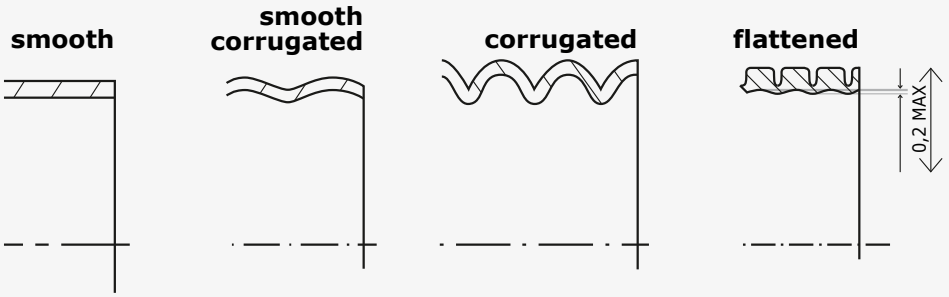
The cylindrical liner can be corrugated on one or both sides (inside/outside) by further processing. The corrugated shape increases the flexibility and the bending radius. What sounds simple is a complex process and patented at Markert Marsoflex HygienicPureFlex®. Generally there are four possible surface structures of a PTFE liner.

Inner surface	Outer surface	Application	marsoflex®
Smooth	Smooth	Smooth non-stick inner surface with maximum cleanability. Limited flexibility and limited bending radius. Optimal use for fixed connections with little bending of the hose assembly.	Type G
Smooth corru-gated	Smooth corru-gated	The type GC/GA has a small corrugation to reduce the bending radius compared to the relatively rigid type G tube.	Type GC/GA
Corru-gated*1	Corru-gated	Corrugated non-stick inner surface. Maximum flexibility and maximum bending radius for applications where a small bending radius and high flexibility is required.	Type C/CA
Flatte-ned*2	Profiled	Smooth, flattened non-stick inner surface with flex outer flex profile, combines a smooth inner surface with profiled, flexible outer surface. The perfect combination of high flexibility and easy to clean inner surface.	Type Hygienic PureFlex®

*1 Corrugated: Markert Marsoflex PTFE corrugated hoses feature a high-flow design, which guarantees a significantly higher throughput cross-section than competitor products (e.g. 35% more line throughput area for 1") due to the combination of corrugated design and wall thickness.

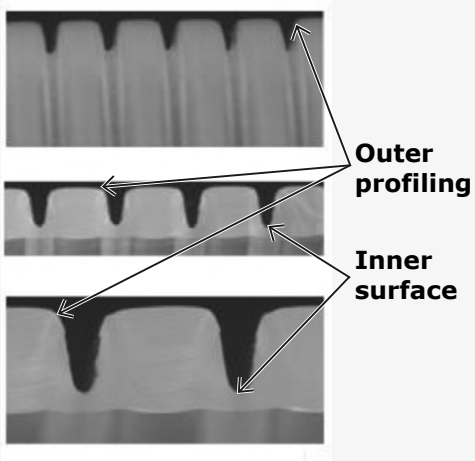
*2 "Flattened" means that the hose liner has a flexible, profiled outer surface, with a smoothed inner surface.

The PTFE liners offered by Markert with the various surface structures are shown below.



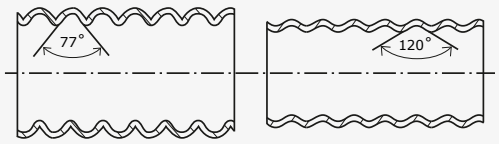
On the left you can see the Hygienic PureFlex liner in detail. The outer profile provides the flexibility of the liner, on the inside you can see the slight corrugation, which is max. 0.2 mm. The outer profiling also provides vacuum resistance and this without additional metal siprals. On the right you can see our highflow design type GC/GA in detail, which guarantees up to 35% higher flow rates.

Hygienic PureFlex under the microscope



The Highflow Design

The high-flow design of the corrugated hose type GC/GA compared to the design of competitors on the market. Nominal size 1" is shown here schematically. Due to the corrugation design, a significantly larger cross-sectional throughput is achieved with the same nominal size.

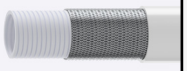


Markert offers the widest range of PTFE hose assemblies on the market: Hose liners in Teflon T62 quality and PTFE with Non-stick effect - perfectly smooth, with highly flexible corrugated structure, with flattened inner surface and profiled flex outer surface. In addition, there are five different hose cover qualities or just the liner - with or without vacuum spiral, with lined connection fitting and in other designs.

→ The Markert Marsoflex PTFE product range guarantees the best solution for your application with over 40 different product base variants.

10. Which hose for which application

The combination of the various PTFE liners with the different hose cover designs results in a wide range of products. The following table provides a simple overview of the main product properties of the respective design. The respective properties are rated as follows: ✓ =excellent properties, ○ =satisfactory properties, ✗ = conditionally suitable depending on the application

Picture	Product description	Flatness inner surface	Flexibility[1]	gap free lined fitting
	**Type G:** Smooth inner surface, no media residues possible. Limited flexibility for generally fixed installation situations. For low volume flows (max DN 25).	✓	✗	✓
	**Type GC/GA:** Slightly corrugated surface structure, which excludes media residues and improves flexibility. I.d.R. for fixed installation situations and large volume flows.		○	
	**Type C/CA:** Corrugated surface structure ensures maximum flexibility and thus easy handling.	○	✓	✓
	**HygienicPureFlex®** Combination of profiled outer surface and smoothed inner surface provides high flexibility with smooth inner surface.	○	✓	✓
	**Type SIL 300/350:** Smooth inner surface, no media residues possible. Good flexibility. For large volume flows. Firmly etched silicone cover with ultra-smooth surface ensures maximum cleanability from the outside.	✓	○	✗
	**Type 50HW:** Smooth inner surface, no media residues possible. Good flexibility. For large volume flows. Solid EPDM cover with wide resistance and high load capacity.			

[*1] This is a simple indication. In the application case, it must be evaluated whether the bending capacity (bending force) or the bending radius is decisive.

11. What can happen

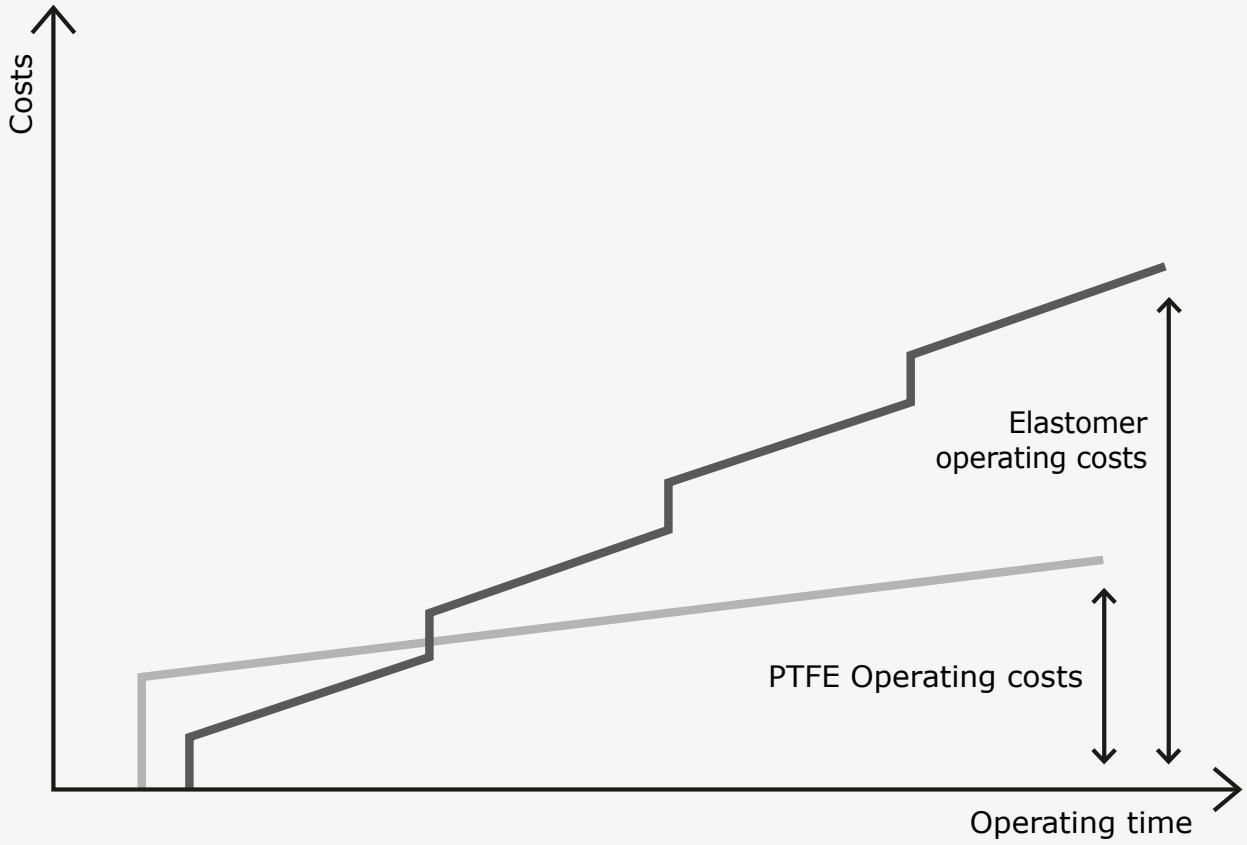
The use of high-quality PTFE raw materials, the precise manufacture and testing of the hose liner, the correct selection of the hose design together with the configuration of the hose cover, and finally the high-quality manufacture and testing of the hose assembly are essential to ensure that the hose assembly has a long service life. This is the only way to exclude damage to machinery and equipment as well as to the process and ultimately to people and the environment. Incorrect product selection, the smallest material defects and manufacturing errors in the production of the hose line can quickly cause great damage. Even small defects in the PTFE liner can cause the liner to detach from the hose cover, which may mean that the production process has to be stopped - or even entire production batches become unusable.

To avoid this, our team of experts is always ready to help you find the best solution for your application in our comprehensive product range.

Figure: PTFE liner detached from hose cover

12. Sustainability

In addition to the many outstanding properties of PTFE, there is one major problem: sustainability. On the one hand, the manufacturing process of PTFE is not entirely harmless, as long-lasting perfluorinated alkyl compounds are produced that can hardly be degraded naturally. On the other hand, PTFE can only be recycled to a limited extent. Small quantities of PTFE can be reused in lubricants, for example. However, the majority must be disposed of thermally. In this process, fluorine compounds can be released into the environment.
However, PTFE scores points in its sustainability balance sheet for its service life, since alternative products have a significantly shorter service life and thus lead to significantly higher energy and operating costs. The following graphic provides a simplified comparison.



13. Why Markert Marsoflex

The Markert Group endeavours to be the number one in filter and hose technology, with leadership in quality and innovation. These two pillars of our company vision make us who we are.

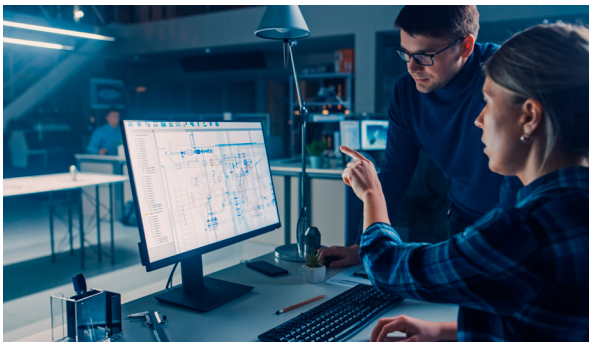
For us, innovation means offering the broadest range of approved products on the market and extensive product features for hose assemblies.

Quality is reflected in the materials we use for hoses, their design, their connections and our comprehensive testing of the final product.

Markert Marsoflex in this context stands for:

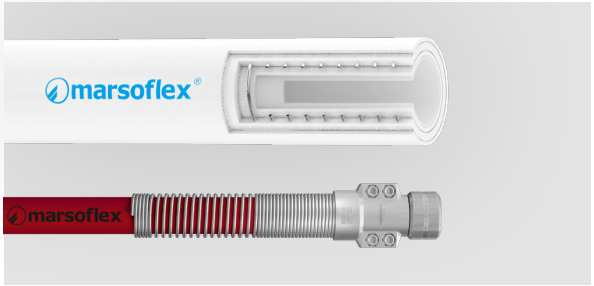
Expertise
Experienced specialists with comprehensive product and applications knowledge ensure technically outstanding products. In the jungle of extractables studies and standards such as EN1761/EN12115, EN10204 3.1, DNV, TRbF-131/2, USP XXXVI class VI, FDA 21 CFR 177 and 3a Sanitary Standard and platinum cross-linked silicone, we provide clarity. And we draw up the best solution for you.

Your advantage: all the answers on industrial hose lines from a single source



Flexibility
From dry coupling and special materials to custom hose assemblies, we offer a comprehensive product range, engineered for your application by competent specialists.

Your advantage: flexible and fast product solutions



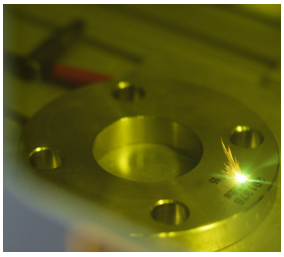
Stock availability
With several million euros worth of product in stock, multiple decentral PTFE lining warehouses close to customers and automated forming facilities, we combine our high quality with short delivery times.

Your advantage: rapid availability

Quality
The hazard potential of hose assemblies is frequently underestimated. To ensure our hoses meet all relevant requirements such as the PED Pressure Equipment Directive, leave our plant with all technical properties inspected, and provide reliable service in their intended applications, we provide:

- Our own pressing, tightness and laser technology
- 100% pressure and seal testing
- 100% material traceability

Your advantage: quality you can rely on



Customer proximity
Whether for examining your system, working out technical solutions or the regular inspection of your installed hose assemblies:

We are close by, either through our regional sales and applications specialists or with our own service team.

Your advantage: specialists in your area

14. Contacts

Do you have questions about any of the matters discussed,
or are you looking for specialist consulting on hoses and fittings?
Contact our field representatives at any time.

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