Industrieverband
Halbzeuge und Konsumprodukte
aus Kunststoff e.V.

pro-K Fluoropolymergroup

pro-K compendium

Fluoropolymers

March 2016

Preamble

The completely fluorinated polymer PTFE is the most widely used fluoropolymer and based on its unique properties established as an undispensible construction material in modern industries.
The extraordinary properties of PTFE are due to its resistence to most chemicals, its broad service temperature range, the excelent electrical properties, the persisting to embrittlement, the ageing resistance and its high purity.

This technical brochure informs about the quality requirements and test conditions, which are necessary to assess semi ï finished goods made from PTFE resins, which are essential for high quality PTFE products.

This technical brochure is edited by the Fluoropolymergroup of pro-K and provides the present state of knowledge as by March 2016.

Important note

March 2016

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Part 1:

Principles for the description of PTFE products

GRUNDSÄTZE FÜR DIE BEZEICHNUNG VON PTFE-PRODUKTEN

1. Um die unterschiedlichen Anwendungsbereiche für Polytetrafluorethylene abdecken zu können, steht eine Vielzahl von Rohstoffen zur Verfügung.

Nach den Festlegungen der Fluoropolymergroup gelten zur Unterscheidung der verschiedenen Typen folgende Begriffsinhalte:

1.1	Virginales PTFE	=	Unbearbeitetes, noch nicht verarbeitetes, nicht durchgesintertes Ausgangsmaterial
1.2	Virginales, modifiziertes PTFE	=	Wie 1.1, jedoch mit fluorierten Comonomeren chemisch modifiziertes PTFE
1.3	Gefülltes PTFE (Compound)	=	Wie 1.1. und 1.2, jedoch mit Füllstoffen wie Glas, Kohle, Bronze usw. verstärkt
1.4	PTFE-Regenerat	=	Wieder aufbereitetes, gesintertes Ausgangsmaterial
1.5	Modifiziertes PTFE-Regenerat	=	Wieder aufbereitetes, gesintertes, modifiziertes Ausgangsmaterial
1.6	"Reines PTFE" oder "100 % PTFE" oder "Original-PTFEñ	=	Sind keine zulässigen Definitionen für den Qualitätsstandard des Materials

2. Es wird empfohlen, in Angeboten und in der technischen Beratung ausschließlich die eindeutigen Begriffe der Abschnitte 1.1 bis 1.5 zu verwenden, wenn eine Beschreibung der Rohstofftype erforderlich oder gewünscht wird.

3. Eine einfache Unterscheidung zwischen Halbzeugen aus ungefülltem virginalen und ungefülltem virginalen modifizierten PTFE ist die vergleichsweise höhere Transparenz von ungefülltem virginalen modifizierten PTFE im Vergleich bei dünnen Querschnitten.

PRINCIPLES FOR THE DESCRIPTION OF PTFE PRODUCTS

1. A multitude of raw material grades is available for covering the different application fields of polytetrafluor-ethylene.

According to the specification of the Technical Committee of the section "Fluoropolymer", the following definitions are used to classify the different grades:

1.1	Virgin PTFE	=	Raw, unprocessed, not sintered material
1.2	Virgin, modified PTFE	=	Like 1.1, but with perfluorinated comonomers that chemically modify PTFE
1.3	Filled PTFE	=	Like 1.1. and 1.2, but with fillers such as glass, coal, bronze etc.
1.4	PTFE-reprocessed	=	Processed, sintered raw material
1.5	Modified PTFE reprocessed	=	Processed, sintered, modified raw material
1.6	"Pure PTFE" or "100 % PTFE" or	=	Are not reliable definitions to identify the different "original PTFE" types.

2. It is recommended to use only the clear definitions of group 1.1 to 1.5 when a description of the raw material grade is required for offers or technical consultations.

3. An easy way to distinguish between semi-finished items made of virgin PTFE and semi-finished items made of virgin modified PTFE is the comparison of thin cross sections. The semi-finished items made of virgin, modified PTFE are more transparent than semi-finished items made of virgin PTFE .

CRITERES POUR LA DEFINITION DES DIFFERENTS TYPES DE PTFE

1. Pour couvrir les différents domaines d'applications du PTFE, il existe une grande variété de matières premières. Conformément aux spécification du Comité Technique de la section.

"Fluoropolymer" on utilise, pour classer les différents types ou grades de PTFE, les définitions suivantes:

1.1	PTFE vierge	=	Matériau de base non transformé, non fritté et non usin
1.2	PTFE modifié vierge	=	PTFE vierge contenant un comonomère perfluoré comme modifiant
1.3	PTFE chargé	=	PTFE vierge auquel ont été incorporées des charges telle que du verre, du carbone, du bronze, etc.
1.4	PTFE Régénérat	=	PTFE matière initiale retraitée et frittée
1.5	PTFE Régénérat, modifié	=	Matière initiale retraitée, frittée et modifiée
1.6	"PTFE pur" ou "100 %PTFE" ou "PTFE originel"	=	Ne sont pa des définitions suffisament précises pour qualifier le niveau de qualité de la matière.

2. Pour des offres commerciales et des informations techniques, il est conseillé d'utiliser seulement les définitions précises des groupes 1.1 à 1.5 si la description de la matière de base est nécessaire ou demandée.

3. Une différentiation entre le PTFE vierge non chargé et le PTFE vierge modifié non chargé peut être faite en comparant leurs transparences. En observant des coupes minces, le PTFE vierge non chargé a une transparence plus élevée.

PRINCIPI PER LA DEFINIZIONE DEI TIPI DI PTFE

1. Per soddisfare le molteplici esigenze nei differenti campi applicativi del polietrafluoroetilene, è disponibile una ampia gamma di prodotti.

Sulla base delle specifiche del Comitato Tecnico dei Fluoropolimeri, per la classificazione dei vari tipi valgono le seguenti definizioni:

1.1	PTFE vergine	=	Materiale base non lavorato, non trasformato e non sinterizzato.
1.2	PTFE vergine modificato	=	Come 1.1 ma con comonomeri fluorurati che modificano chimicamente il PTFE
1.3	PTFE caricato (Compound)	=	Come 1.1 e 1.2 ma addizionati di cariche tipo vetro, carbone, bronzo, etc.
1.4	PTFE rigenerato	=	PTFE processato, sinterizzato e rilavorato
1.5	PTFE rigenerato modificato	=	PTFE modificato processato, sinterizzato e rilavorato
1.6	Le definizioni "PTFE puro", "PTFE al 100 %" e "PTFE originale"	=	Non descrivono in modo univoco il tipo di prodotto e pertanto possono includere sia materiali del gruppo 1.1 che del gruppo 1.2 .

2. Nel caso di offerte o consulenze tecniche in cui fosse necessaria una descrizione del tipo di materiale, si consiglia di utilizzare solamente le definizioni dal gruppo 1.1 al 1.5.

3. Un metodo semplice per distinguere semilavorati di PTFE vergine da semilavorati di PTFE vergine modificato, consiste nella comparazione di sezioni sottili. Il semilavorato da PTFE vergine modificato è più trasparente rispetto al semilavorato da PTFE Vergine.

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Part 2:

Quality requirements and test guidelines for PTFE-products

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1. Field of application

These quality requirements and test conditions help to assess semi-finished goods made from PTFE. The requirements listed below define the minimum requirements that are necessary for high quality PTFE products.

In the practical experience you can sometimes find so called Ämean valuesñ whose variations of deviance may be quite high. In such cases it is necessary to define limits for the requested tolerance to be able to compare physical properties.

The tests described below have to be performed at a so called Ämormal climateñ this means at a temperature of 23 °C
(± 2°C), and an air humidity of 50 % (± 10%) (according to DIN EN ISO 291 "Plastics ï normal climate for conditioning and testing").

These requirements are valid including chapter 6 for all products made of pure/unfilled PTFE.

2. Standard Specific gravity

2.1 Test method

DIN EN ISO 12086 Plastics - Fluorpolymerdispersions, and moulding and extrusion materials - part 2: Preparation of test specimen and determination of properties (Subclause 8.4).

2.2 Requirements

Figures: 2,12 - 2,20 g/cm^3

2.3 Comment

Semi-finished goods made from low molecular PTFE show a a higher specific gravity than those made from PTFE of higher molecular weight. This means that the influence of the used resin has to be taken into account when the PTFE-product is evaluated.

Low specific gravity indicates a low crystalline and hence flexible material. Figures below 2,12 g/cm^3 define low compression and a high porosity.
High specific gravity is typical for a high crystalline and hence stiff material. Values above the tolerance indicate changed physical properties , that may be caused either by the used resin or from ñover-sinteringñ which may be due to a thermal degradation.
Compounds which contain glass, graphite, carbon or bronze show specific gravities that are defined by the used filler.

3. Tensile strength and elongation

3.1 Test method

DIN EN ISO 527-1:1996-04 Plastics ï determination of tensile strength - part 1: general principles

The determination of the tensile strength at break according to the above mentioned ISO standard is used to evaluate the behaviour of fluoropolymers during elongation in one axis. The test is performed on specific specimen under defined conditions for the preparation, the test climate and the speed of elongation. This test method is mainly used for quality control purposes using the following recommended specimen parameters:

Thickness: 1,0 mm for PTFE und 1,5 mm for Compounds.
Elongation speed: 50 mm/min
Specimen for the testing of skived films and plates :

For skived films of 0,5 to 3 mm thickness: specimen according or similar to SPI-Standard FD-105 (figure 1).

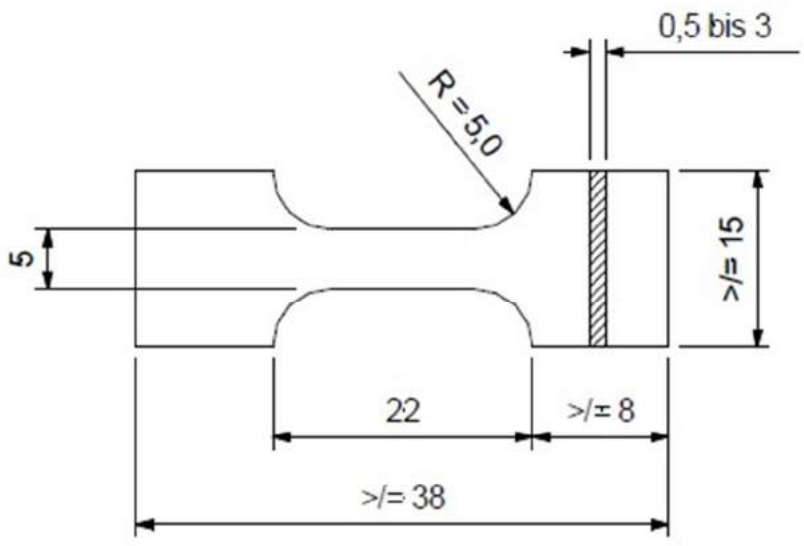


Figure 1: Specimen according to SPI-Standard FD-105.

For skived films 0,5 to 3 mm thickness: Specimen according to Standard FD-105 (picture 1) or DIN EN ISO 527-2 (figure 2).

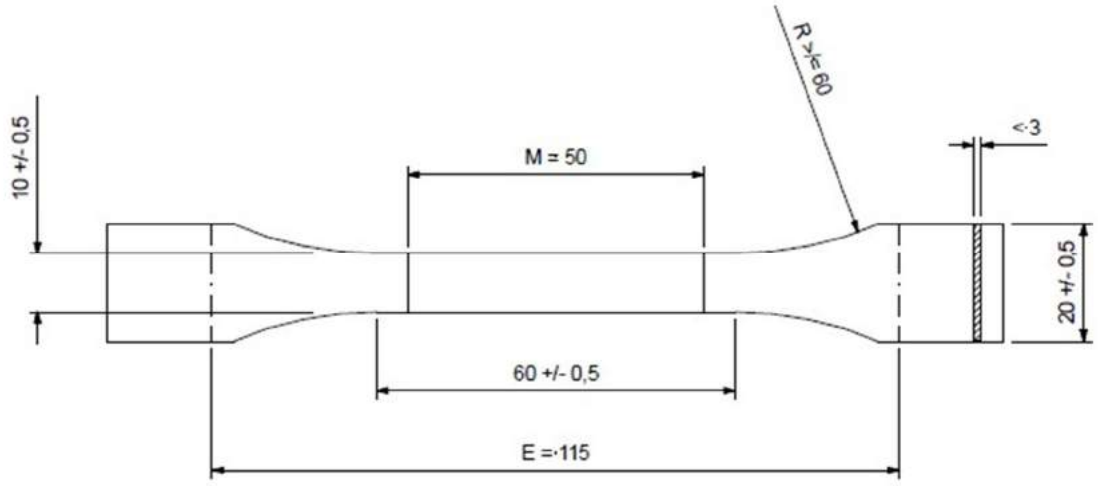


Figure 2: specimen 1B according to DIN EN ISO 527-2.
M = length of measurement
E = length in the test device

3.1.1 Machining of test specimen

Please use the specifications of DIN EN ISO 2818:1996, Plastics ï Preparation of test specimen by machining.

3.2 Tensile strength and elongation ï Minimum requirements

Note: pro-K Fluoropolymergroup recommends to use the following thickness for specimen :
1,0 mm for PTFE and 1,5 mm for Compounds.

	Films and plates moulded PTFE		Ram-extruded PTFE						Paste extruded PTFE (measured Across to Extrusion direction)
			virgin PTFE-powder		Pre-sintered PTFE-powder		Regrind		
	free flowing granules	non free flowing powder	extrusion direction		extrusion direction		extrusion direction		
			along	across	along	across	along	across	
Tensile strength N/mm²	23,0	28,5	22,0	25,5	19,0	20,0	11,0	13,0	26,0
Elongation %	260	300	230	265	190	210	90	110	275

4. Ball hardness H 132/30 and Shore-hardness D

4.1 Test method

Ball indentation hardness **according to** ISO 2039
Thickness of specimen: minimum 4 mm; distance to edge above 10 mm. test time: 30 sec.

Shore-hardness D according to DIN 53505:2000-08

Determination of plastics - test of hardness according to Shore D
Thickness of specimen: minimum 6 mm. test time: 3 sec.

Requirement: The following values are valid only for unlaminated samples.
Thickness of specimen: minimum 4 mm
Distance to edge : above 10 mm
Ball hardness: minimum 22,0 N/mm^2
Shore-hardness D: minimum 54

5. Voids

5.1 Test method

*5.1.1 Stabilized DC-voltage**

The testing is performed with a suitable device for detecting voids with stabilized DC-voltage. For this purpose pro-K re-commends to use brush like electrodes. The test voltage depends on the thickness of the specimen.
For thicknesses between 0,4 mm and 4,2 mm it should be calculated according to the below algorithm:

Thickness (in mm) time 2,5 kV plus a bias of 1,5 kV.

*In agreement with the user the test can be performed also with AC-voltage.

Please note:

For a thickness of 0,4 mm the testing voltage would account to 1,5 kV + 0,4 x 2,5 kV = 2,5 kV,
for 1mm thickness accordingly 4,0 kV.

See also VDE-standards and ATEX-guidelines.

5.1.2 Requirement (based on experience):

$$\text{max. number of voids per } m^2 = \frac{1{,}0}{\text{thickness (mm)} \times 2}$$

(please use only complete figures)

5.1.3 Please note

The thickness of films should not be less than the average particle size of the used resin.

5.1.4 Indicator for voids

To detect voids and/or cracks the complete surface is cleaned respectively decreased with a cleaning agent. After drying the surface is treated with a commercial penetrating colour by spraying or dipping. After 5 minutes this substance is removed by wiping or rinsing. As soon as the surface is dry it is detected for voids or cracks.

6. Dielectric strength, volume resistivity and surface resistivity

6.1 Test method

DIN EN ISO 12086
Plastics - Fluoropolymer dispersions and moulding and extrusion materials.
Part 2: Subclauses 8.1.1, 8.1.2 and 8.1.3

IEC 60093
Test method for electric insolator, volume resistivity and surface resistivity of solid, electrically isolating construction materials.

The test results shall contain the shape of the used electrodes.

The dielectric strength shall additionally contain the thickness of the test specimen used for the measurement.
Due to the excellent insolating properties of PTFE products the dielectric strength used to be very high. To avoid ambiance the tests shall be performed with specimen of a thickness >0,5 mm in a halocarbon medium.

6.2 Requirement

Minimum 50 kV/mm (measured with a specimen thickness of minimum 0,5 mm).

6.3 Please note

The value of the dielectric strength decreases significantly with increasing thickness of the film.

7. Semi-finished goods made of filled PTFE

For semi-finished goods made of filled PTFE the following minimum parameters are required in addition to chapter
2. (specific gravity), 3. (tensile and elongation) and 4. (ball indentation hardness). The results for carbon compounds refer to a filler called Ăsoft carbonñ For reasons of comparison the following table only contains results made of free flowing resins.

				Moulded semi finished goods		Ram extruded semi finished goods			
	Standard Specific gravity	**Deformation under load 15 N/mm² 100h**		**Tensile strength**	**Elongation**	**Tensile strength**	**Elongation-**	**Ball-indentation hardnesse**	**Shore D hardness**
Test method	**DIN 53479**	**equivalent pro-K***		**DIN EN ISO 527**	**DIN EN ISO 527**	**DIN EN ISO 527**	**DIN EN ISO 527**	**ISO 2039**	**DIN 53505**
Dimension	**[g/cm³]**	**[%]**	**[%]**	**[N/mm²]**	**[%]**	**[N/mm²]**	**[%]**	**[N/mm²]**	
		23° C	**100° C**						
PTFE virgin	2,16 ± 0,04	18	33	23	260	19	190	22	54
PTFE modified virgin	2,16 ± 0,04	9	23	22	360	18	300	23	56
PTFE + 10 % carbon	2,14 ± 0,04	14	19	16	180	14	160	26	61
PTFE + 15 % carbon	2,13 ± 0,04	10	14	14	150	12	130	27	62
PTFE + 25 % carbon	2,09 ± 0,04	8	22	13	100	11	90	34	63
PTFE modified + 25 % carbon	2,09 ± 0,04	4	-	9	45	8	35	34	63
PTFE + 33 % carbon	2,09 ± 0,04	6	15	9	25	6	15	35	65
PTFE modified + 33 % carbon	2,09 ± 0,04	3	-	7	5	6	15	35	65
PTFE + 15 % graphite	2,16 ± 0,04	11	-	20	200	16	120	-	63
PTFE + 10 % glass	2,19 ± 0,04	19	26	17	210	16	200	23	57
PTFE + 15 % glass	2,21 ± 0,04	14	30	15	200	14	180	25	58
PTFE + 20 % glass	2,22 ± 0,04	16	21	14	180	12	160	26	58
PTFE + 25 % glass	2,23 ± 0,04	12	30	14	160	11	140	27	59
PTFE modified + 25 % glass	2,23 ± 0,04	6	-	16	220	18	200	-	59/54
PTFE + 40 % bronze	3,10 ± 0,10	13	26	13	150	10,5	140	27	63
PTFE + 60 % bronze	3,85 ± 0,15	8	20	12	120	9,5	100	30	65
PTFE + 55 % bronze + 5 % MoS_2	3,85 ± 0,15	-	-	14	55	-	-	-	72/68
PTFE + 50 % stainless steel	3,35 ± 0,10	4	-	16	200	20	200	-	69/65
PTFE + 20 % PEEK	1,92 ± 0,04	5	-	18	200	16	180	-	68/62
PTFE + 10 % aromatic Polyester	2,07 ± 0,04	11	-	24	340	20	270	-	63/57
PTFE + 20 % aromatic Polyester	1,95 ± 0,04	-	-	18	200	-	-	-	64/60
PTFE + 10 % carbon fibrer	2,09 ± 0,04	-	-	22	260	23	250	-	65/60
PTFE + 20 % carbon fibrer	1,98 ± 0,04	-	-	14	140	14	140	-	67/63
PTFE + 7 % PI	2,06 ± 0,04	-	-	22	250	26	280	-	60/54
PTFE + 10 % PI	2,03 ± 0,04	-	-	16	250	-	-	-	68/60

*according to ASTM D 621 the remaining deformation is detected after 100 h under load without relaxation time.

8. Detection of filler content in PTFE-compounds

The following test method describes one of the most common procedures to determine the filling content of PTFE-compounds made of glass, carbon, graphite or metals
It is recommended to use the TGA-method (**TGA** = **T**hermal **G**ravimetric **A**nalysis) applying inert or oxydizing atmosphere.
The use of the TGA-method typically applies after a DSC-analysis (**DSC** = **D**ifferential **S**canning **C**alorimetry).
The performance of the DSC-Analysis of PTFE-compounds applies according to ISO 11357-3:1999: (Plastics differential scanning calorimetry).

Recommended sample size: 5 ï 10 mg.
The analysis starts under a Nitrogen inert atmosphere.

When using the DSC-method the specimen is first heated to 390 °C. Doing so the melting behaviour at about 327 °C (sintered PTFE) resp. 345 °C (unsintered PTFE) characterizes the base resin. By this the melting tmeperature and the melting enthalpy (J/g) are determined. During this procedure the specific behaviour of the resin respectively of the sintering process can be recognized.
Afterwards the sample is cooled down at a defined cooling-rate below the melting point. Melting the sample a second time provides information about remaining changes of the product properties as they occur by oversintering.
When melting the sample the second time the temperature is increased up to 650 °C which causes the PTFE and some fillers to decompose.
Based on the detected weight loss the amount of PTFE and the amount of thermally non oxidizable fillers is determined.
Starting from 650 °C the atmosphere is switched to oxygen heating up to 850 °C. Based on the detected weight lossfound now the amount of oxydizable fillers is determined.
Oxidizable , thermically not decomposable fillers, e.g. bronze, can be recognized by an increase in weight due to oxydation.

Example for a combined DSC/TGA- procedure:

1. 1. Heating: 30 °C - >390 °C (10 K/min)
2. Isothermic segment 390 °C (5 min)
3. Cooling 390 °C - >150 °C (5 K/min)
4. Isothermic segment (5 min)
5. 2. Heating 150 °C - >650 °C (10 K/min)
6. Switch to O_2,-atmosphere heating 650 °C - >850 °C (10 K/min)

Please perform these measurements only under appropriate safety precautions like an efficient exhaustion.

9. Deformation under load

The determination of the deformation under load is not part of the general quality control. Therefore a special agreement between supplier and customer is necessary.

9.1 Test method

A cylindrical specimen with the following dimensions (diameter 10 mm, height 10 mm), which is free of internal stress, is fixed in the test-device (see figure 4) which is in the test-chamber. Please make sure the thickness is not above 10 mm. The specimen, which has been conditioned at normal climate (see chapter 1, ASTM D621/64), has to be fixed between the both pressure pistons. Be sure the lateral face is plane. At the normal climate the test-pressure accounts to 15 ± 0,5 N/mm^2. In case the temperature is different please correct the pressure appropriately.
The deformation is measured at (23 ± 2) °C and at (100 ± 2) °C; different temperatures have to be recorded.

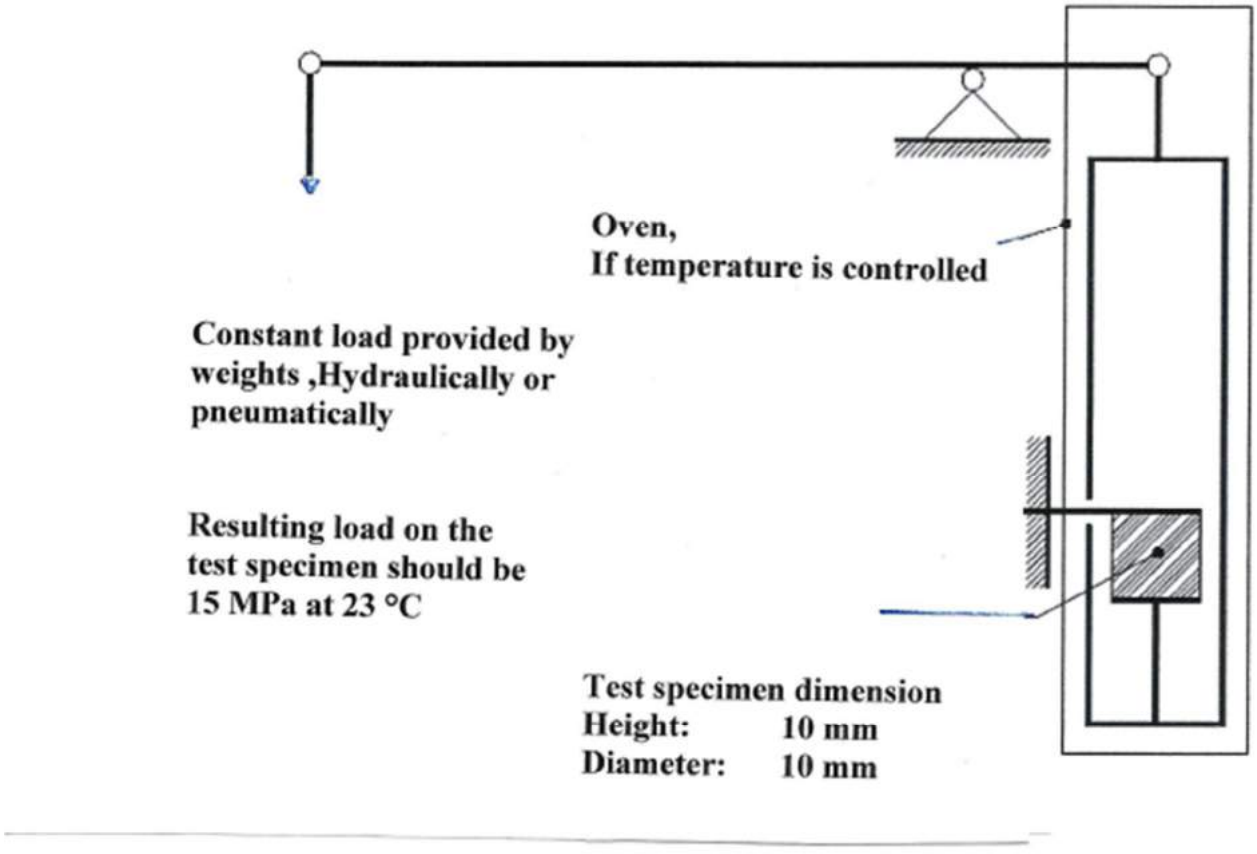
The determination can be done after 100 h under load or at 100h under load and subsequent 24h of relaxation.

9.2 Analysis

The deformation under load is calculated as follows:

$$\frac{B-A}{B} \quad X\ 100\ (\%)$$

Please not the exactness amounts to 1/100 mm:
A = Height of test specimen after test cycles
B = original height of specimen



Picture 4: Test device for the determination of deformation under load.

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Part 3:

Tolerances for sintered PTFE-products

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1. Field of application

The tolerances listed in this technical brochure are valid for filled and unfilled PTFE products as well as for reprocessed PTFE.

2. General

All measurements shall be performed at a Ăstandard atmosphereòat 23°C and 50 % air humidity.

2.1. Skived films and sheets

Thickness	Tolerance
< 0,1 mm	+0,01 mm/ -0 mm
Ó0,1 mm	+10 % / -0 %

The standard tolerance for width is +3 %/ -0 %, maximum 30 mm.
The standard tolerance for length is +2 %/ -0 %.
For surface roughness the tolerance is Ò0,8 εm

Edge waviness

A PTFE-skived film of the length L and the width B is placed on a support plate.
A parallel flat plate is placed over the highest point of the sheet. For practical purposes this can also be done by spanning of two cords.
The determination of the maximal tolerated waviness of the edge is performed according to the test method described in DIN ISO 1101.

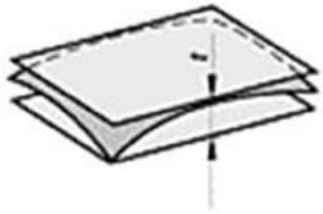

Figure 1 Edge waviness (from DIN ISO 1101 (University Essen / Duisburg, ipe)

Flatness tolerance

The film must lie between two parallel planes with a separation ñt.òThe following maximum values of t are allowed:

	Thickness of film (mm)	width (mm)	t (mm) normal film
Standard PTFE	≤ 2,5	600	30
		1000	50
		1200	60
		1500	80
	≤ 5,0	600	40
		1000	60
		1200	70
		1500	90
Modified PTFE	≤ 2,5	600	30
		1000	60
		1200	70
		1500	90
	≤ 5,0	600	55
		1000	70
		1200	85
		1500	110

Option: Straightness of edge

The PTFE-skived film of length L is placed without strain on a plane support.
The starting point and end point of the film are connected by a straight line. Parallel to this line a second parallel line is drawn at a distance of C.
The bent edge of the film must always be between the two lines.

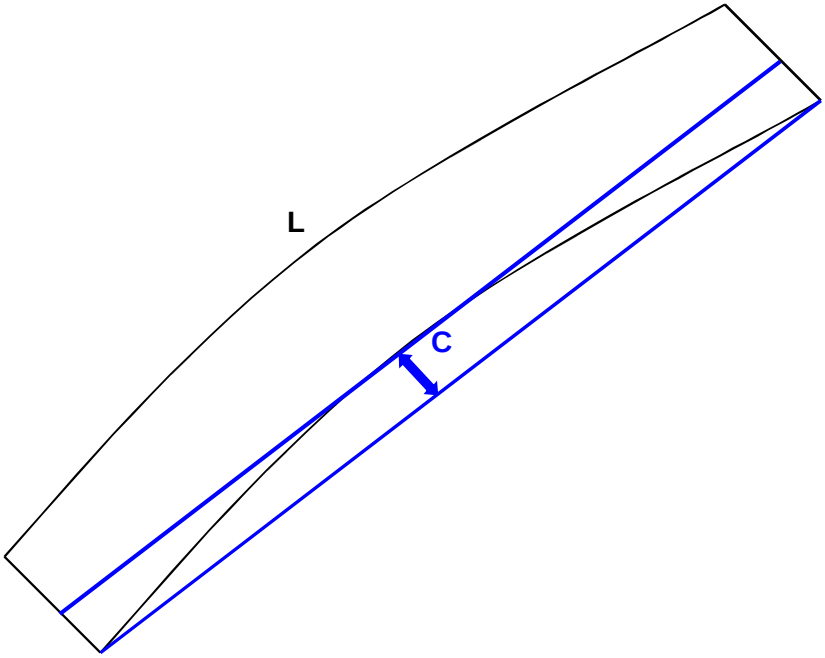

Figure 2: Straightness of edge

The straightness of edge is usually not part of general quality specifications.
For films of the thickness ≤ 5 mm the following guideline may be applied:

	C in % of L
Standard PTFE	3
Modified PTFE	5

Contamination

The determination of the contamination is done by a visual inspection of the surface. Contaminations adhering to the surface caused by the machining are not taken into account.

The following criteria may be regarded as a recommendation for the assessment.

Moulded sheets and thick films

The quality of semi-finished goods is defined by the following table:

Sheet/film dimensions	Description
600 x 600 mm	2 inclusions per side With a maximum diameter of 1 mm
1000 x 1000 mm	3 inclusions per side With a maximum diameter of 2 mm
1200 x 1200 mm 1220 x 1220 mm	4 inclusions per side With a maximum diameter of 2 mm
1500 x 1500 mm	5 inclusions per side With a maximum diameter of 2 mm

Thin skived films

For this kind of films higher requirements apply. These have to be agreed on between the customer and the supplier.

Moulded parts

The quality of semi-finished products is defined in the following table:
The number of contaminants applies to mouldings up to a diameter of 400 mm and to a length of 300 mm or mouldings above Ø 400 mm and a length of 100 mm.

Dimensions	Description
up to Ø 100 mm. (Ø D);	2 inclusions With a maximum diameter of 1 mm
above Ø 100 to 300 mm (Ø D)	3 inclusions With a maximum diameter of 1 mm
above Ø 300 mm (Ø D)	3 inclusions With a maximum diameter of 1 mm

Extruded parts

The quality of semi-finished products is defined in the following table:
(Length 1000 mm)

Dimensions	Description
from Ø 4 to Ø 40 mm (Ø OD)	2 inclusions With a maximum diameter of 1 mm per rod / pipe
above Ø 40 to Ø 80 mm (Ø OD)	3 inclusions With a maximum diameter of 1 mm per rod / pipe
above Ø 80 mm (Ø OD)	4 inclusions With a maximum diameter of 1 mm per rod / pipe

Quality control via determination of the mechanical properties

Information about the mechanical properties is provided in the technical brochure 4 ĂQuality requirements and test guidelines for PTFE productsñ edited in December 2012 by pro K.

2.2. Moulded sheets

Thickness	Tolerance
< 5 mm	+0,75 / -0 mm
Ó5 mm	+15 / -0 %

The tolerance with regard to length and width is +3 / -0 %, maximum 35 mm.
The surface roughness shall be Ò10 ε m.

Requirements regarding the **planeness** of moulded sheets are not defined.
If necessary these parameters have to be agreed on between the customer and the supplier.

2.3. Extruded and moulded rods, extruded tubes (Ram-Extrusion)

For this process only a plus-tolerance on diameter of rods is defined, which is 10 % independent from the diameter. The standard tolerance for extruded and moulded rods as well as for extruded tubes (Ram-Extrusion) with respect to length is:

Length	Tolerance
< 500 mm	+10 / -0 mm
Ó500 mm	+2 / -0 %

The tolerance for diameter for ground rods requires a separate agreement.

Diameter tolerance (inside and outside) for extruded tubes

Outside- Ø	Tolerance	
	Inside- Ø	Outside- Ø
< 10 mm	+0 / -0,6 mm	+0,6 / -0 mm
Ó10 mm	+0 / -6 %	+6 / -0 %

2.4 Diameter - and wall thickness-tolerances for moulded, free sintered tubes

The tolerances for the diameter and wall thickness depend essentially on the length and thickness of the moulded product. The plus tolerance for the outside diameter and the minus tolerance for the inside diameter are higher than in extruded tubes. Only limited lengths can be moulded due to the process and the properties of the resin used. The conditions for processing agreed on between the customer and the supplier have to be met for the complete length of the pipe.

2.5. Paste extruded parts, hoses and pipes

The standard tolerance for the inside- Ø and the wall thickness is:

Dimension	Tolerance
Inside- Ø < 5 mm	± 0,25 mm
Inside- Ø Ó5 mm	± 5 %
Wall thickness < 1,0 mm	± 0,1 mm
Wall thickness Ó1,0 mm	± 10 %

The standard tolerance for the length is +2 / -0 %.

Deviation from the center	
Thickness (mm)	Tolerance (mm)
Up to 5 above 5 to 20 above 20 to 40 above 40	0,3 0,5 1,0 Depending on agreement

Paste extruded tubes

Outside diameter (mm)	Tolerance (mm)
Up to 50 above 50 to 80 above 80 to 125 above 125 to 150 above 150 to 200 above 200 to 250 above 250 to 350 above 350 to 300 above 400	± 2,0 ± 2,5 ± 3,0 ± 3,5 ± 4,0 ± 5,0 ± 5,5 ± 6,0 Depending on agreement

Tolerances for the wall thickness

Thickness (mm)	Tolerance (mm)
Up to 3,0	± 0,3
above 3,0 to 4,0	± 0,40
above 4,0 to 5,0	± 0,50
above 5,0 to 7,5	± 0,6
above 7,5	Depending on agreement

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Part 4:

Tolerances for the machining of PTFE-parts

Table of Content

1. PTFE-turned parts

1.1 Area of application

Chapter 1 deals with the maintainable tolerances that can be achieved with chipping of a length 5 ã d, maximum 50 mm machined length (Ädñ= outer diameter to be machined). The measurement is done at a normal climate[1]. The samples have to be in a thermal equilibrium.

1.2 Selection of tolerances

The following table is consistent with the geometric product specification (GPS) ISO tolerance system for lengths part 1. Basics for tolerances , deviances and fits (ISO/DIS 286-1:2007); German Version EN ISO 286-1:2007

Following tolerances apply (in µm):

Up to 50 mm:	for the wall thickness	IT 10
	for the diameter	IT 11
above 50 to 180 mm:		
	for the wall thickness	IT 11
	for the diameter	IT 12
above 180 to 500 mm:		
	for the wall thickness	IT 12
	for the diameter	IT 12

[1] According to DIN EN ISO 291 there are different normal climates. First normal climate 23/50 (for non tropic countries) and the normal climate 27/65 (for tropic countries). For both climates there are two classes 1 and 2. Class 1 iequires a temperature tolerance of +- 1 °C and a moisture tolerance of +- 5%. Class 2 requires a temperature tolerance of +- 2 °C and a moisture tolerance of +- 10 %.

	Radial wall thickness							Diameter						
Nominal-measure-ment range mm	8	9	10	11	12	13	14	8	9	10	11	12	13	14
from 1 to 3	14	25	40	60	100	140	250	14	25	40	60	100	140	250
from 3 To 6	18	30	48	75	120	180	300	18	30	48	75	120	180	300
From 6 To 10	22	36	58	90	150	220	360	22	36	58	90	150	220	360
From 10 To 18	27	43	70	110	180	270	430	27	43	70	110	180	270	430
From 18 To 30	33	52	84	130	210	330	520	33	52	84	130	210	330	520
From 30 To 50	39	62	100	160	250	390	620	39	62	100	160	250	390	620
From 50 To 80	46	74	120	190	300	460	740	46	74	120	190	300	460	740
From 80 To 20	54	87	140	220	350	540	870	54	87	140	220	350	540	870
From 20 To 80	63	100	160	250	400	630	1000	63	100	160	250	400	630	1000
From 80 To 50	72	115	185	290	460	720	1150	72	115	185	290	460	720	1150
From 50 To 15	81	130	210	320	520	810	1300	81	130	210	320	520	810	1300
From 15 To 400	89	140	230	360	570	890	1400	89	140	230	360	570	890	1400
From 400 To 500	97	155	250	400	630	970	1550	97	155	250	400	630	970	1550

1.3 Admissable deviations for length

According to ISO 2768 (Page 1), Table 1: upper and lower limit for length, exactness grade Ăfineñ

Exactness	Measurement range (mm)		
	0,5 to 6	above 6 to 30	above 30 to 120
Fine	± 0,05	± 0,1	± 0,15

The measurements are performed at normal climate 23/50 according to DIN 50014.

In case it is necessary for the correct operation to have a lower tolerance, which would require higher efforts, a product related commitment has to be agreed on between the customer and the PTFE-supplier.
Chipless formed turned parts require bigger tolerances than machined ones. They have to be agreed on between customer and PTFE supplier.

2 PTFE-milled parts

2.1 Area of application

Chapter 2 deals with the tolerances that can be achieved with normal production efforts. The peculiar behaviour of the face machining of PTFE often requires higher tolerances for complicated shaped parts or forms.

2.2 Selection of tolerances

The table of tolerances is consistent with the ISO tolerance (IT) according to ISO 286-1. It contains a limitation of the fineness with respect to the basic tolerances of the IT chapters 13, 14 and 15.

Machining dimension mm	IT										
	8	9	10	11	12	13	14	15	16	17	18
From 1 To 3	14	25	40	60	100	140	250	400	600	---	---
Above 3 To 6	18	30	48	75	120	180	300	480	750	---	---
Above 6 To 10	22	36	58	90	150	220	360	580	900	1500	---
Above 10 To 18	27	43	70	110	180	270	430	700	1100	1800	2700
Above 18 To 30	33	52	84	130	210	330	520	840	1300	2100	3300
Above 30 To 50	39	62	100	160	250	390	620	1000	1600	2500	3900
Above 50 To 80	46	74	120	190	300	460	740	1200	1900	3000	4600
Above 80 To 120	54	87	140	220	350	540	870	1400	2200	3500	5400
Above 120 To 180	63	100	160	250	400	630	1000	1600	2500	4000	6300
Above 180 To 250	72	115	185	290	460	720	1150	1850	2900	4600	7200
Above 250 To 315	81	130	210	320	520	810	1300	2100	3200	5200	8100
Above 315 To 400	89	140	230	360	570	890	1400	2300	3600	5700	8900
Above 400 To 500	97	155	250	400	630	970	1550	2500	4000	6300	9700

In case it is necessary for the correct operation to have a lower tolerance, which would require higher efforts, a product related commitment has to be agreed on between the customer and the PTFE-supplier.

3 PTFE-blanked parts

3.1 Area of application

The specified tolerances are valid for one side of the blanked part, the opposite side may differ by the conical shape of the cut face. For this reason the reference dimension for the tolerance is for the inside dimension the smallest size and for the outside dimension is the biggest size.

3.2 Selection of tolerances for the diameter and other dimensions (except thickness)

For blanked parts, that have been machined with precision tools (combination die, knife cut) the basic tolerances of the IT row 15 according to EN ISO 286-1: 2007 apply.

The values of tolerance are valid up to a thickness of max. 3 mm.

3.3 Admissable deviations for the thickness

Up to a nominal thickness of 2 mm: ± 10 %;
For a thickness above 2mm the defined tolerances for thickness of PTFE plates described in pro-K guidelines apply.

4. Admissable deviations for dimensions without defined tolerance of faced or rotation symmetric PTFE-parts

4.1 Diameter and length

According to ISO 2768 General tolerances: Length and angles, shape and position, not for new constructions, edition 4. 1991 (page 1) Table 1 upper and lower limits for lengths, exactness grade medium and coarse, identical to ISO 2768-1 general tolerances.

	Limit dimensions in mm for the nominal measurement range						
Exactness grade	0,5 to 3	Above 3 to 6	Above 6 to 30	Above 30 to 120	Above 120 to 400	Above 400 to 1000	Above 1000 to 2000
medium	± 0,1	± 0,1	± 0,2	± 0,3	0,5	0,8	1,2
coarse	± 0,2	± 0,3	± 0,5	± 0,8	± 1,2	± 2,0	± 3

For the nominal measurement range of 0,5 to 120 mm the exactness grade medium applies. For measurement ranges above 120 -2000 mm as well as for complicated (thin walled) parts the exactness grade coarse has to be applied, provided there is no specific agreement ion place.

4.2 Radius of curvature and cant (heel)

According to ISO 2768 (Page 1), Table 2, upper and lower limit for radius of curvature and heel hight the exactness grade fine/medium ï identical with DIN ISO 2768-1 general tolerances applies .

Exactness grade	Limit dimension in mm for the nominal measurement range				
	0,5 to 3	Above 3 to 6	Above 6 to 30	Above 30 to 120	Above 120 to 315
Fine/ medium	± 0,2	± 0,5	± 1,0	± 2,0	± 4,0

4.3 Angular dimension

According to ISO 2768 (Page 1), Table 3: Exactness grade Ăine/mediumñ

Exactness grade	Limit of angular dimensions for the nominal measurement range of the short arm in mm					
	to 10		Above 10 to 50		Above 50 to 120	
	Grad	mm per 100 mm	Grad	mm per 100 mm	Grad	mm jper100 mm
Fine medium	± 1°	1,8	± 30°	0,9	± 20°	± 0,6

4.4 Deviations in shape

PTFE hollow articles - especially those with thin walls - are difficult to measure with respect to deviations in shape. The following tolerances are valid only for massive shaped pieces or hollow articles with a diameter/thickness ratio < 5. These parts may utilize the tolerances of the particular nominal dimension given in table 4.1 to 4.3

5. Surface quality

5.1 Test method

DIN EB USI 3274 Geometric product specifications (GPS) ï surface quality: Code procedere ï Nominal properties of code tools (ISO 3274:1996); German Edition EN ISO 3274:1998.

It is recommended to use the reference area code system with a code radius of 0,005 mm.
Because of the softness of PTFE a very low measuring force of (0,7 mN) should be applied.

5.2 Requirements

The guidance levels for the acceptable roughness of face machined surfaces are as follows:

PTFE-grade	Roughness R_z
Virginal	< 16 µm
Filled*[2]	< 25 µm

Please ensure the necessary test length.
The surface quality can be improved by increased manufacturing effort.

6. Measuring equipment and test method for the surface measureent

It is recommended to use a spring loaded scanning system. The probe type is carried out as a cone with a rounded peak. The curve radius should amount maximum 5 µm. Especially when testing filled PTFE products a diamond needle is recommended.

[2] Is affected by the character and amount of filler as well as its particle size, fibre length e.g glass fibre typical values L_{50} = 60 µm, maximum fibre length about 150 µm.

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www.dyneon.com

www.elringklinger.com

www.fietz.com

www.heutecomp.de

www.kudernak.de

www.k-u-w.com

www.sglgroup.de

www.berghof.com

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