Teflon™ FEP, PFA, Tefzel™ ETFE Product Overview

FPS
Fluorocarbon Polymer Solutions

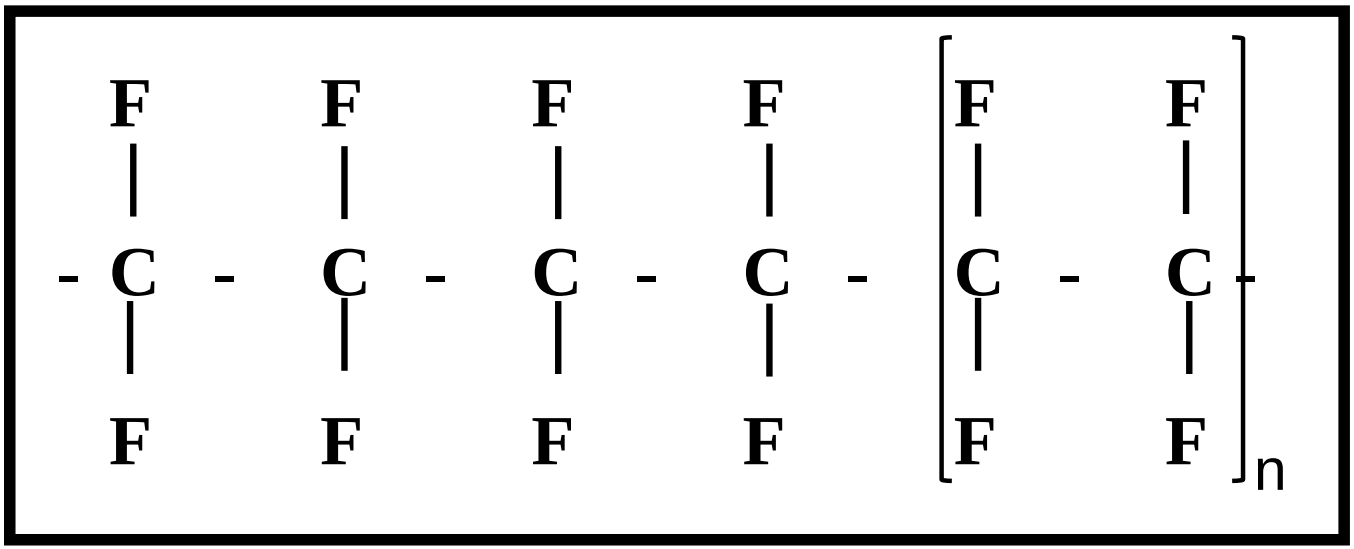
pro
Industrieverband Halbzeuge und Konsumprodukte aus Kunststoff e.V.

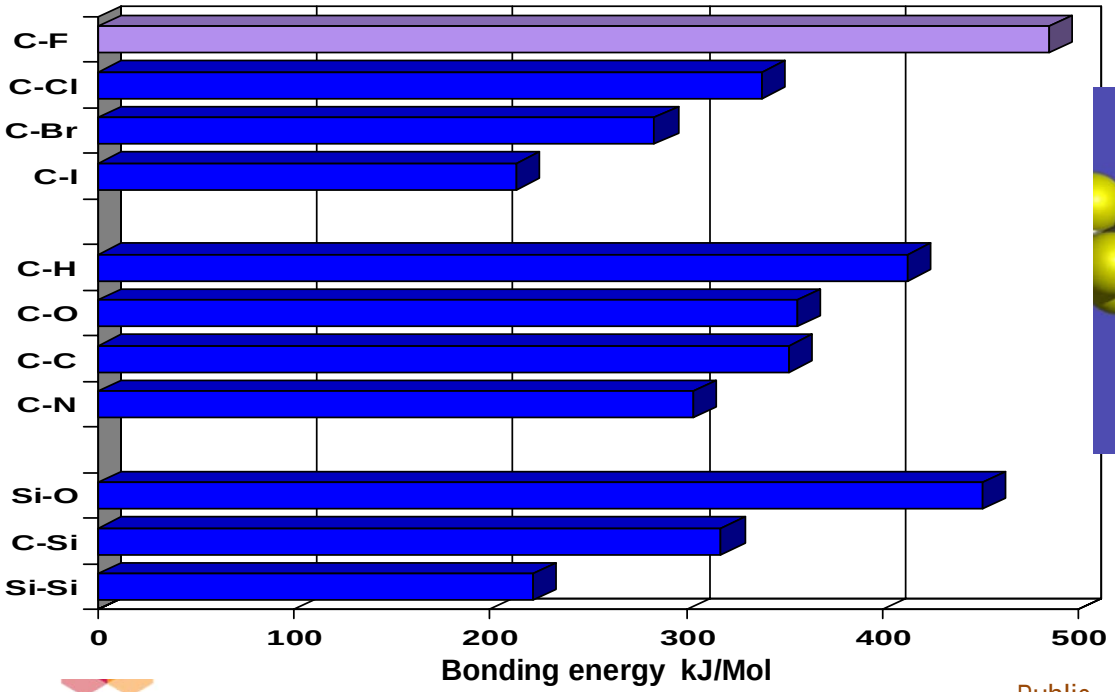
Time limited derogations to fluoropolymers

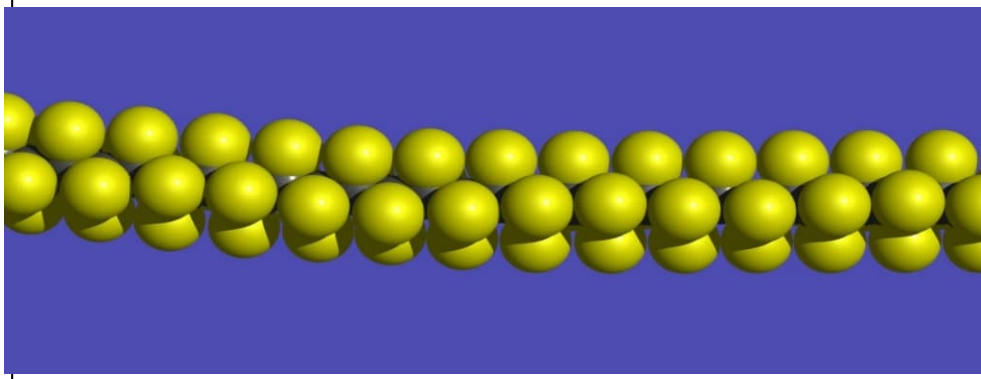
PROPOSED

	6,5 YEARS AFTER EIF	13,5 YEARS AFTER EIF
Time limited derogations	food contact materials for the purpose of industrial and professional food and feed production	implantable medical devices (not including meshes, wound treatment products, tubes and catheters)
	proton-exchange membrane (PEM) fuel cells	tubes and catheters in medical devices
	textiles for the use in filtration and separation media	coatings of Metered Dose Inhalers (MDIs)
		applications in petroleum and mining industry
		additives to hydraulic fluids in aircraft and aerospace industry
		Lubricants in certain categories
		diagnostic laboratory testing
		textiles used in personal protective equipment (PPE)
Potential derogations marked for reconsideration	non-stick coatings in industrial and professional bakeware	hernia meshes
		wound treatment products
		coating applications for medical devices other than Metered Dose Inhalers
		Rigid gas permeable contact lenses and ophthalmic lenses, PTFE in ophthalmic solutions packaging
		PCTFE-based packaging for medicinal preparations, medical devices and medical molecular diagnostics
		packaging of terminally sterilized medical devices
		applications affecting the proper functioning related to the safety of transport vehicles, and affecting the safety of operators, passengers or goods
		textiles for the use in engine bays for noise and vibration insulation used in the automotive industry
		membranes used for venting of medical devices
		the semiconductor manufacturing process

POLYTETRAFLUOROETHYLENE - PTFE







OUTSTANDING PROPERTIES

- CHEMICAL INERTNESS
- NON-STICK
- LOW FRICTION / SELF-LUBRICATING
- DIELECTRIC PROPERTIES
- WEATHER RESISTANCE / NON-AGEING
- INSENSITIVE TO UV
- NON-TOXIC
- BROAD TEMPERATURE RANGE (- 200 °C / + 260 °C)
- NON-FLAMMABLE

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DOES PTFE MELT ?

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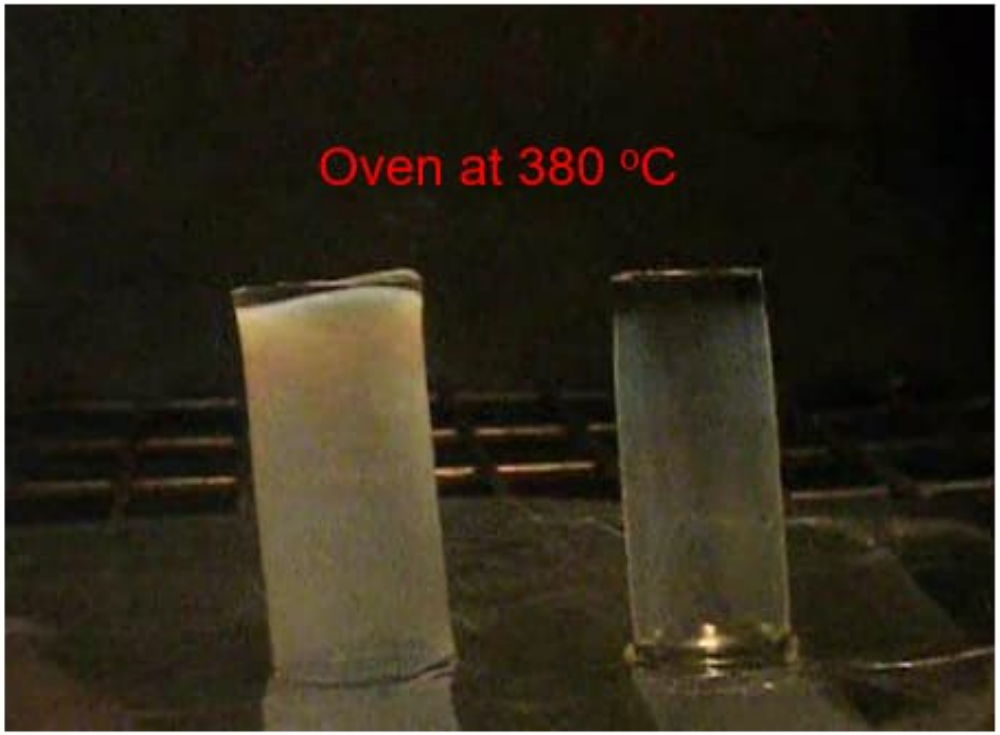
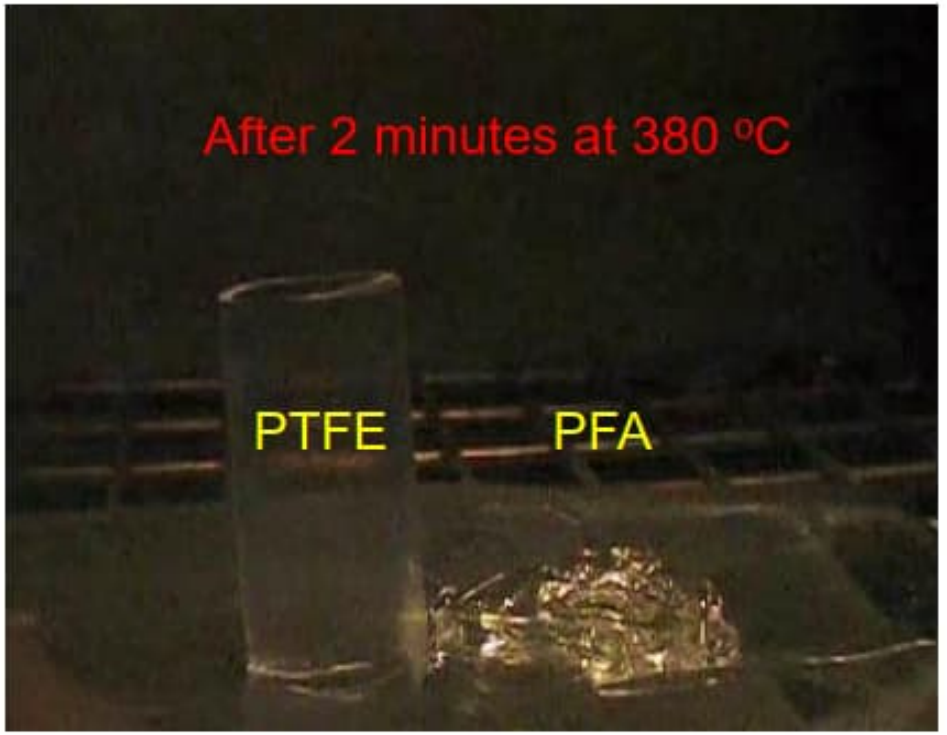
DOES PTFE MELT ?





YES, PTFE melts, but it does not flow.

FEP, PFA and ETFE melt and flow and therefore can be thermoformed

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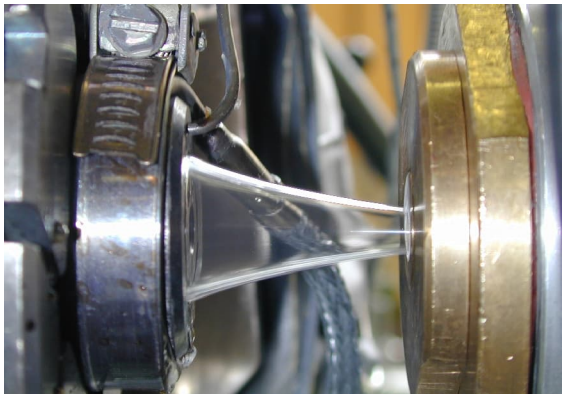
Melt extrusion processing for FEP, PFA and ETFE Safety

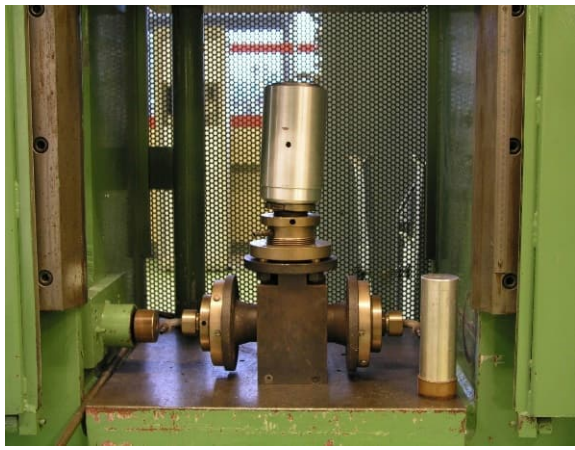
MELT PROCESSING

Roto-moulding/lining

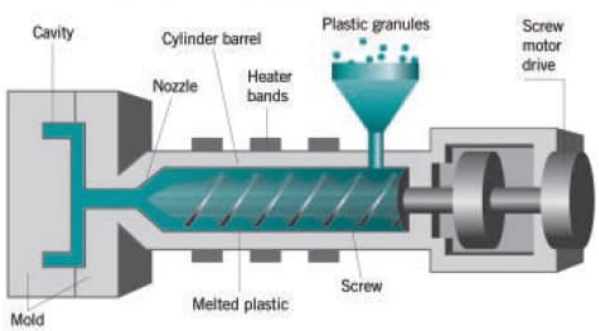
Compounding



Tube extrusion

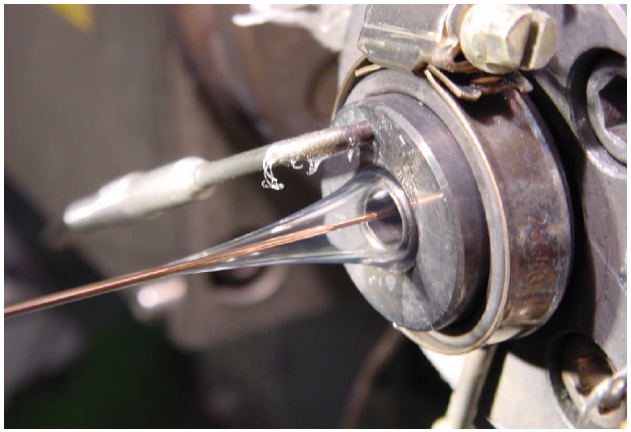


Transfer moulding



Injection moulding

Blow molding



Wire extrusion

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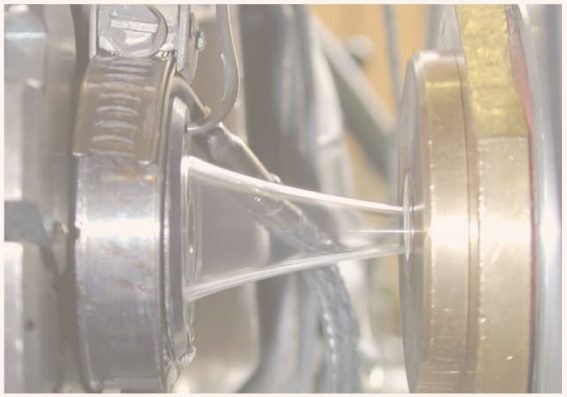
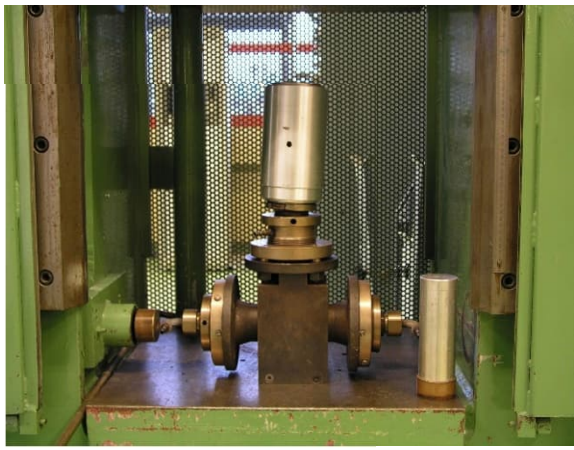
MELT PROCESSING

Roto-moulding/lining

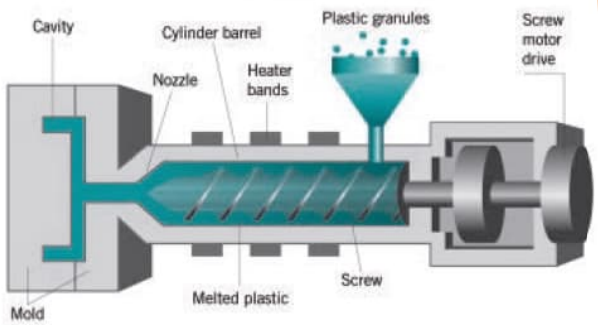
~10 %



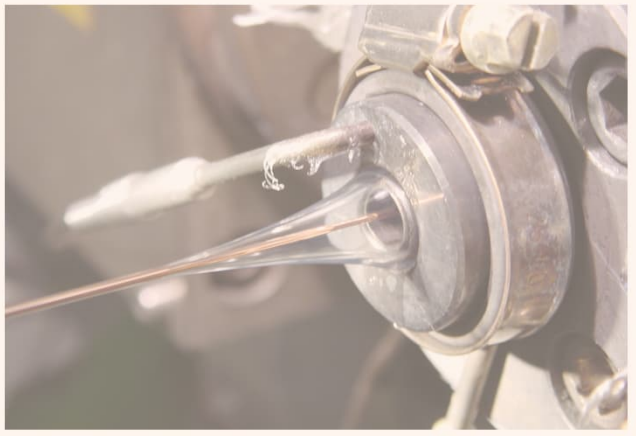
Tube extrusion



Transfer moulding



Injection moulding



Wire extrusion

~70 %

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Fluoroplastics process SAFETY

- Fumes during melt processing can cause polymer fever
- Molten fluoroplastics are corrosive
- High processing temperatures
- High viscosity
- Shear sensitive

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Safety

- Appropriate ventilation
- Follow the PlasticsEurope guide-lines

https://fluoropolymers.plasticseurope.org/application/files/6216/3178/0517/Fluoropolymers_Safe_Hand_EN__June_2021.pdf

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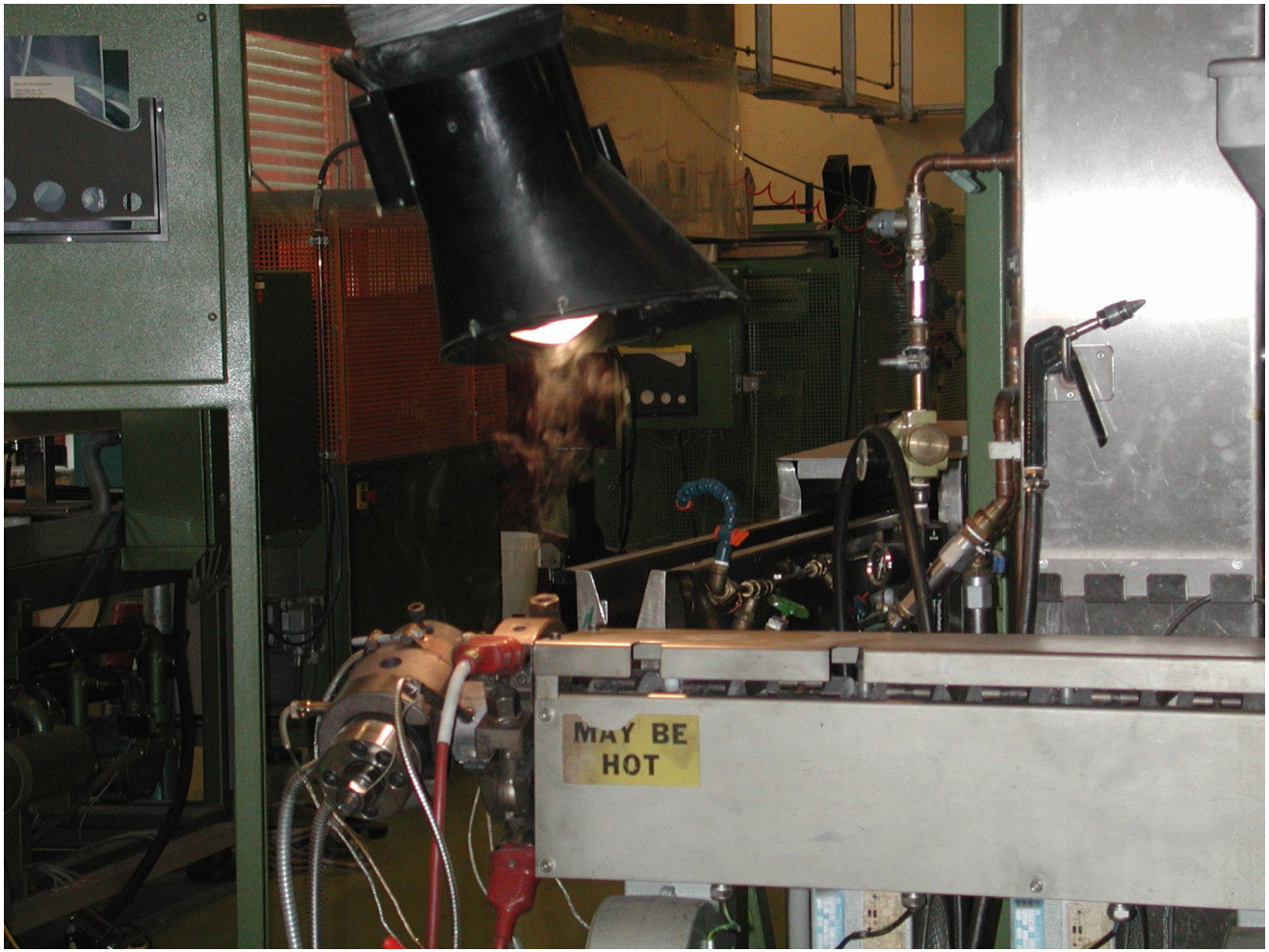
Local exhaust ventilation



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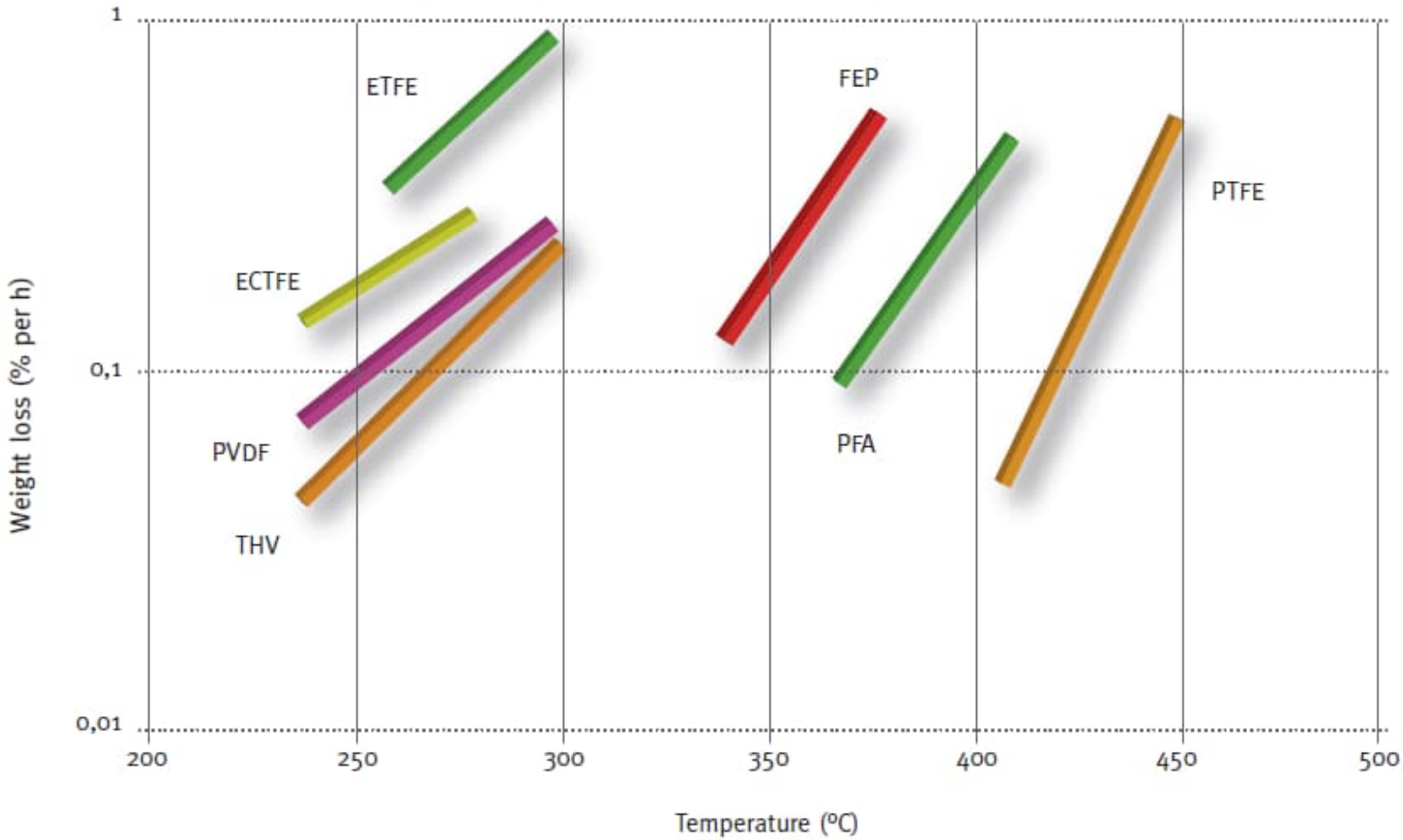
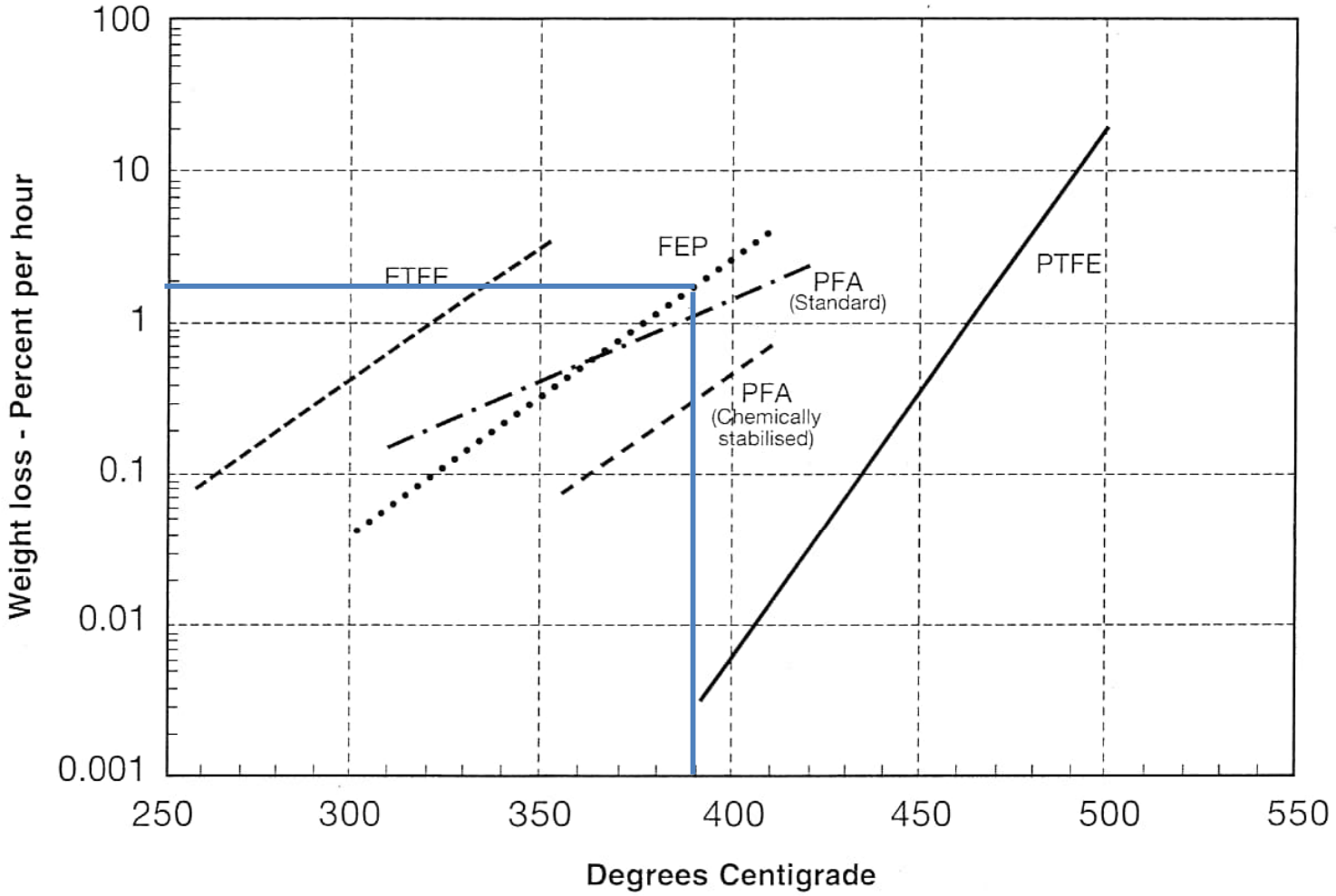
Typical weight loss of fluoropolymers vs. temperature

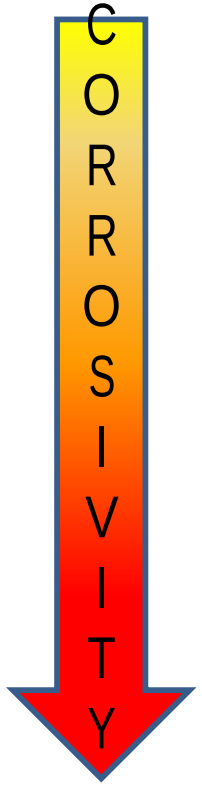
Figure 1 : Typical weight loss of Fluoropolymers heated in air



Typical weight loss of fluoropolymers vs. temperature



POLYMER	CONTINUOUS SERVICE TEMPERATURE	MELT TEMPERATURE	PROCESSING TEMPERATURE
ETFE	155 °C	~265 °C	340 °C
FEP	205 °C	~260 °C	390 °C
PFA	260 °C	~305 °C	400 °C



High nickel alloys are A MUST

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Equipment Materials of construction

PROTECT YOUR EQUIPMENT TO AVOID THAT IT IS EATEN AWAY BY CORROSION

Screw, adapters, tooling, head, filters

- Hasteloy® C-276 / Haynes® 242
- Inconel® 625
- Monel® 400 or 500

Bi-metallic cylinder liner

- Reiloy® 115
- Bernex® C 250
- Xaloy® 306
- Xaloy® 800 with Inconel® flange

Kanigen nickel plating (for non continuous process)

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Equipment Materials of construction

Extruding with equipment without the right corrosion protection

is like

you can do it once …
but no guarantees that you will be able to do it again

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TEFLON™ FEP

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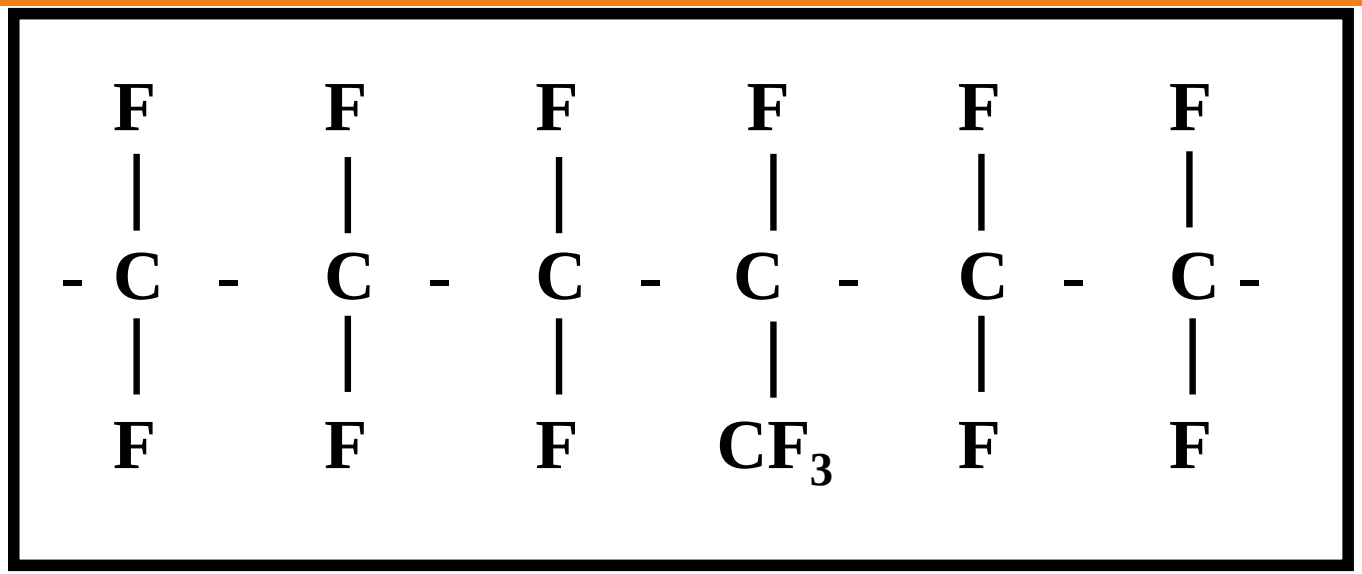
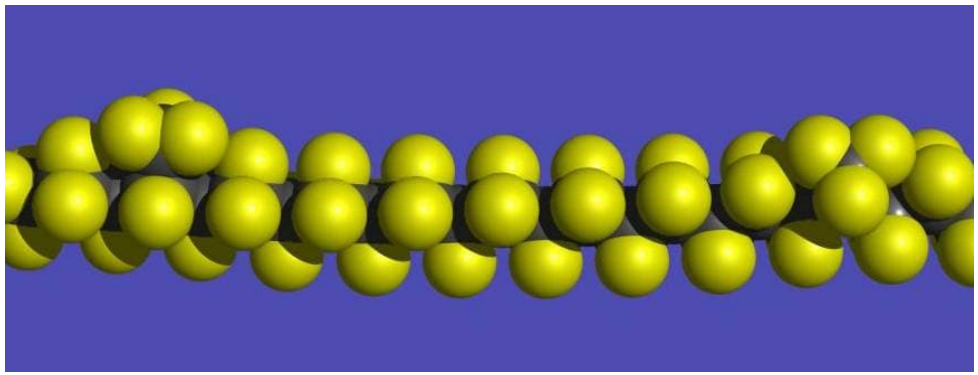
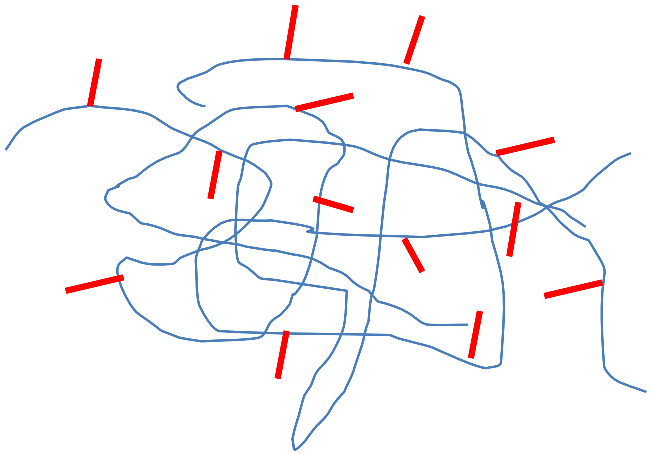
FLUORINATED ETHYLENE PROPYLENE - FEP



ASTM D 2116
ISO 12086
UL Yellow Card





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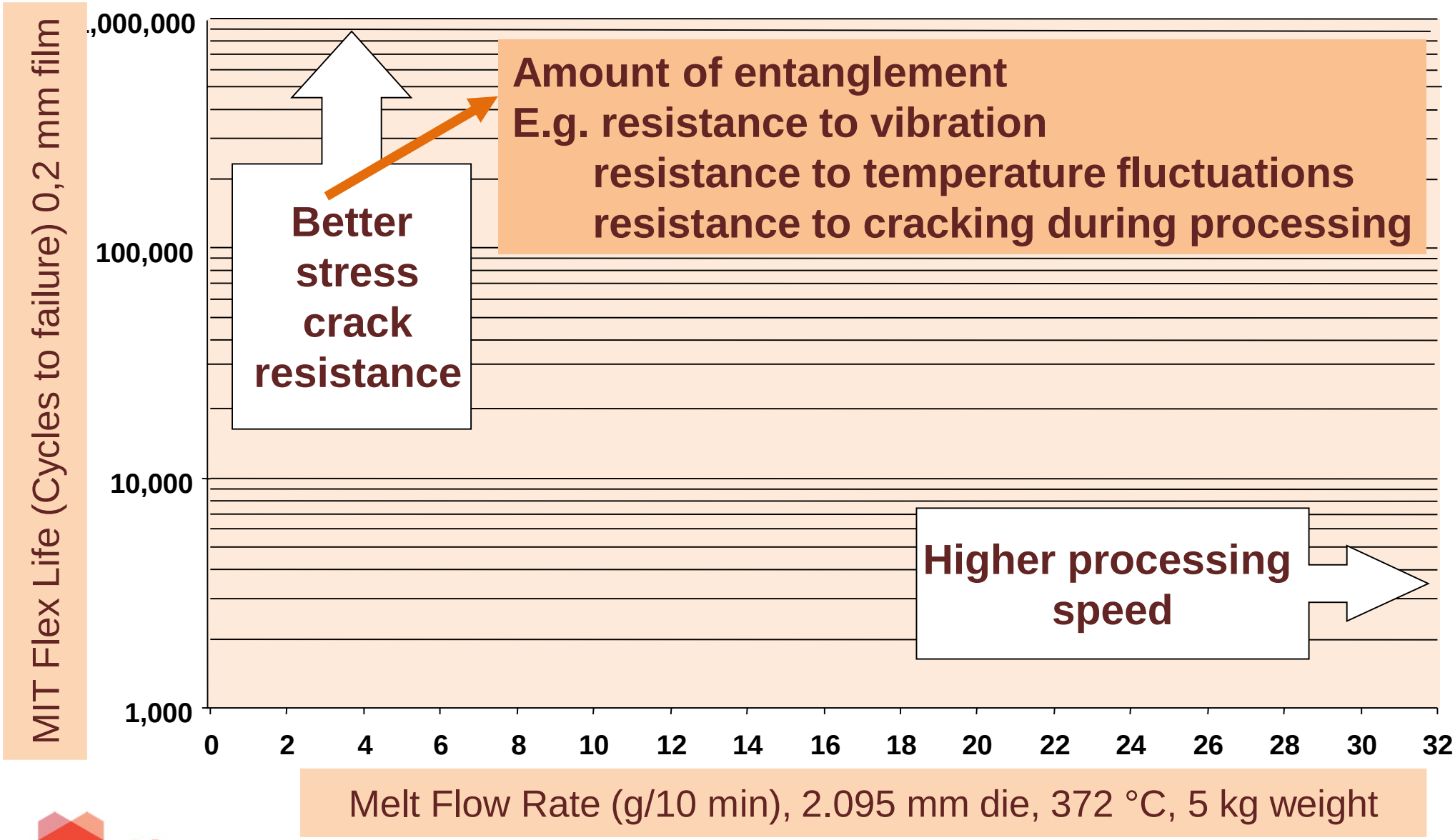
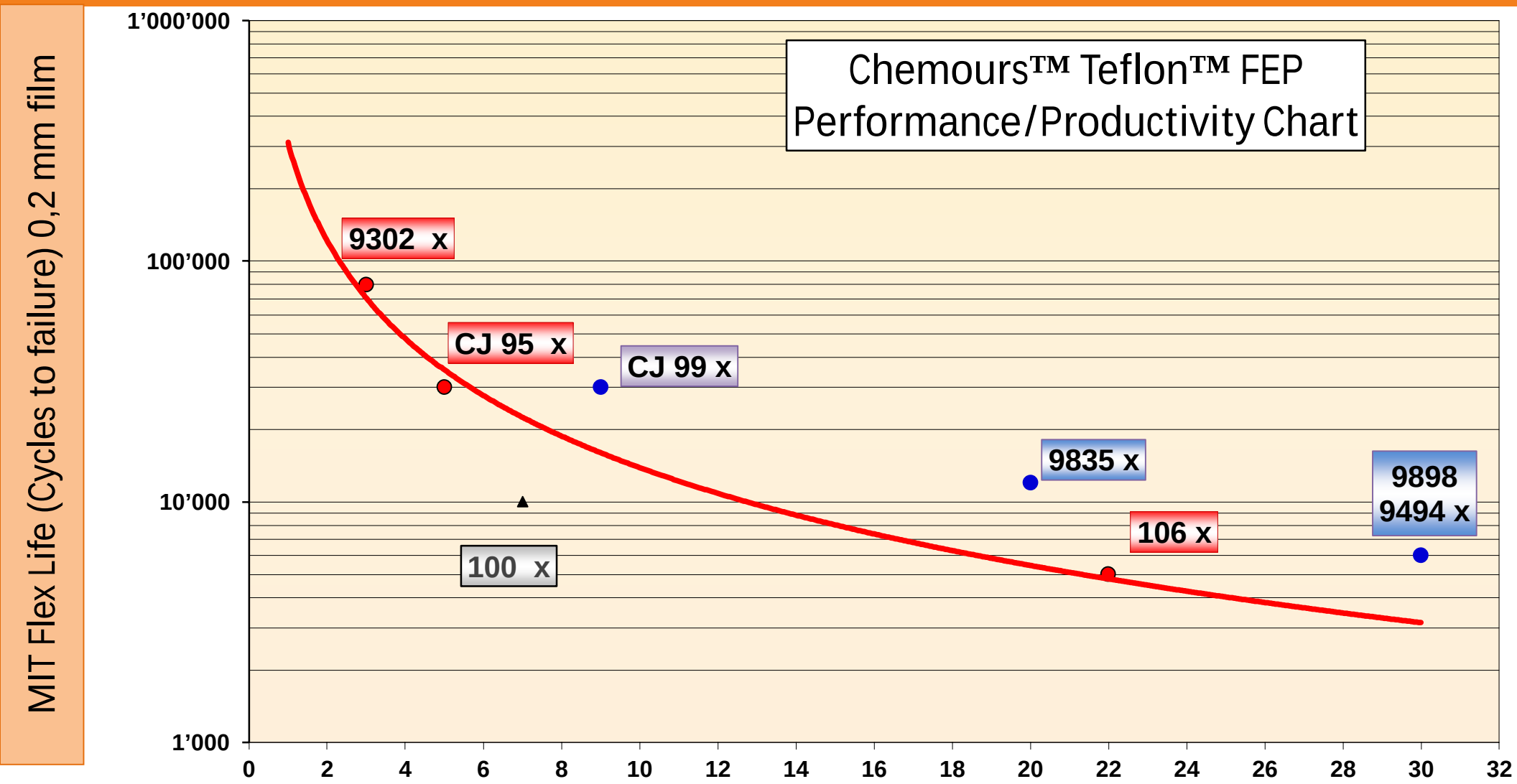
Teflon™ “MELTS” Positioning chart



Chemours™



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Cable design :
Grade selection suggestion vs cable diameter

AWG	CONS-TRUCTION	Ø (mm)	AREA (mm²)	FEP 9302	FEP CJ 95	FEP 100	FEP CJ 99	FEP 9835	FEP 106	FEP 9494	
				3	5	6.8	9	20	22	30	MFR
				80000	30000	10000	30000	12000	5000	4000	MIT
4	133 x 0.455	6.48	21.62								
6	133 x 0.361	5.14	13.61								
8	133 x 0.287	4.09	8.6								
10	37 x 0.404	2.8	4.77								
12	37 x 0.320	2.22	2.98								
14	37 x 0.254	1.78	1.88								
16	19 x 0.287	1.36	1.23								
18	19 x 0.254	1.27	0.962								
20	37 x 0.142	0.97	0.586								
22	37 x 0.114	0.78	0.38								
24	19 x 0.127	0.634	0.241								
26	19 x 0.102	0.504	0.155								
28	19 x 0.079	0.395	0.093								
30	19 x 0.063	0.315	0.059								

Note: for heavy wall constructions, select a grade with higher stress crack resistance if needed
FEP 9835 and 9494 have lower dissipation factors at higher frequencies

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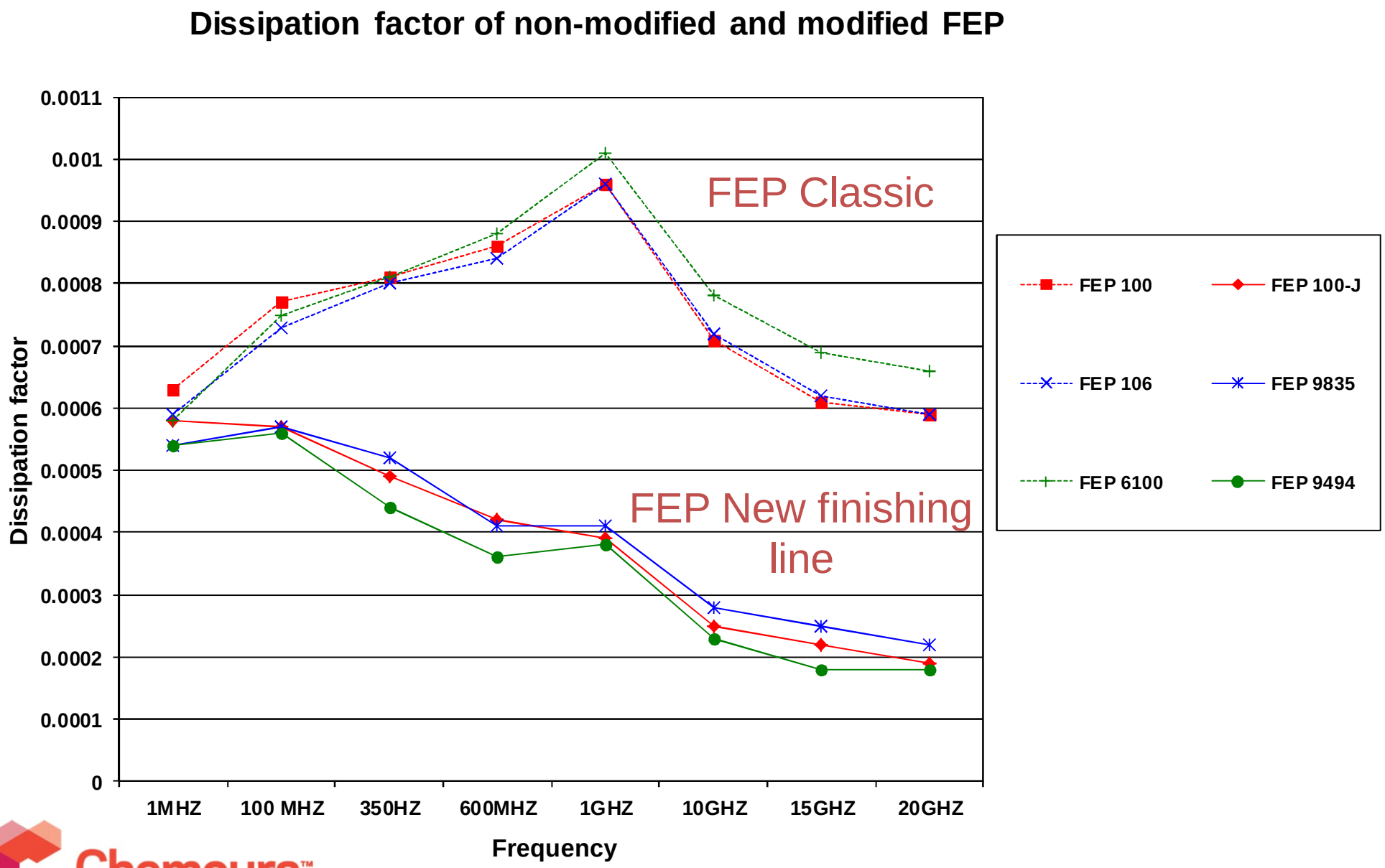
DATA CABLES
Looking for improved signal return loss at high frequencies ?



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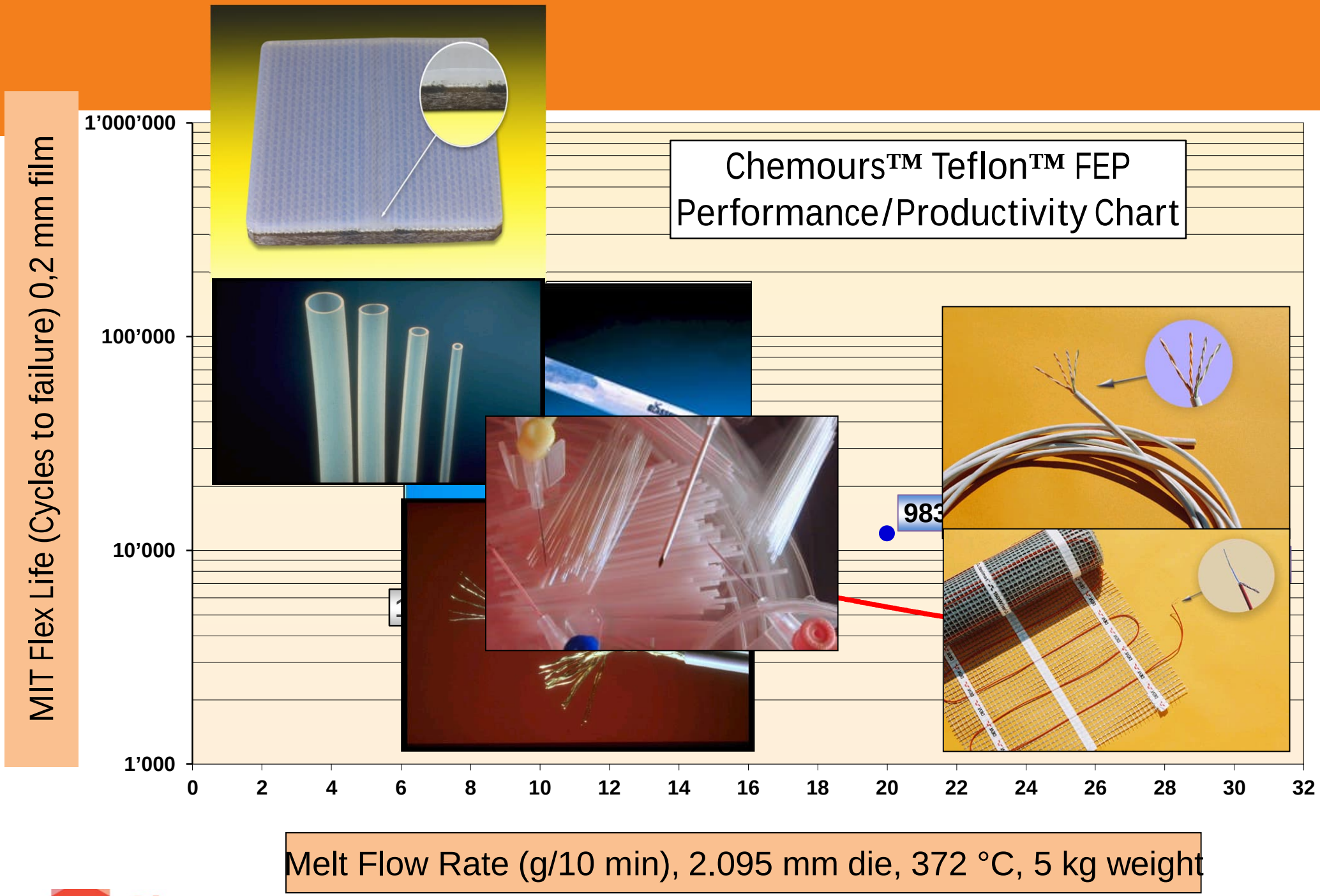
Chemours™ Teflon™ FEP
Performance/Productivity Chart
MIT Flex Life (Cycles to failure) 0,2 mm film
1'000'000
100'000
10'000
1'000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
983
Melt Flow Rate (g/10 min), 2.095 mm die, 372 °C, 5 kg weight

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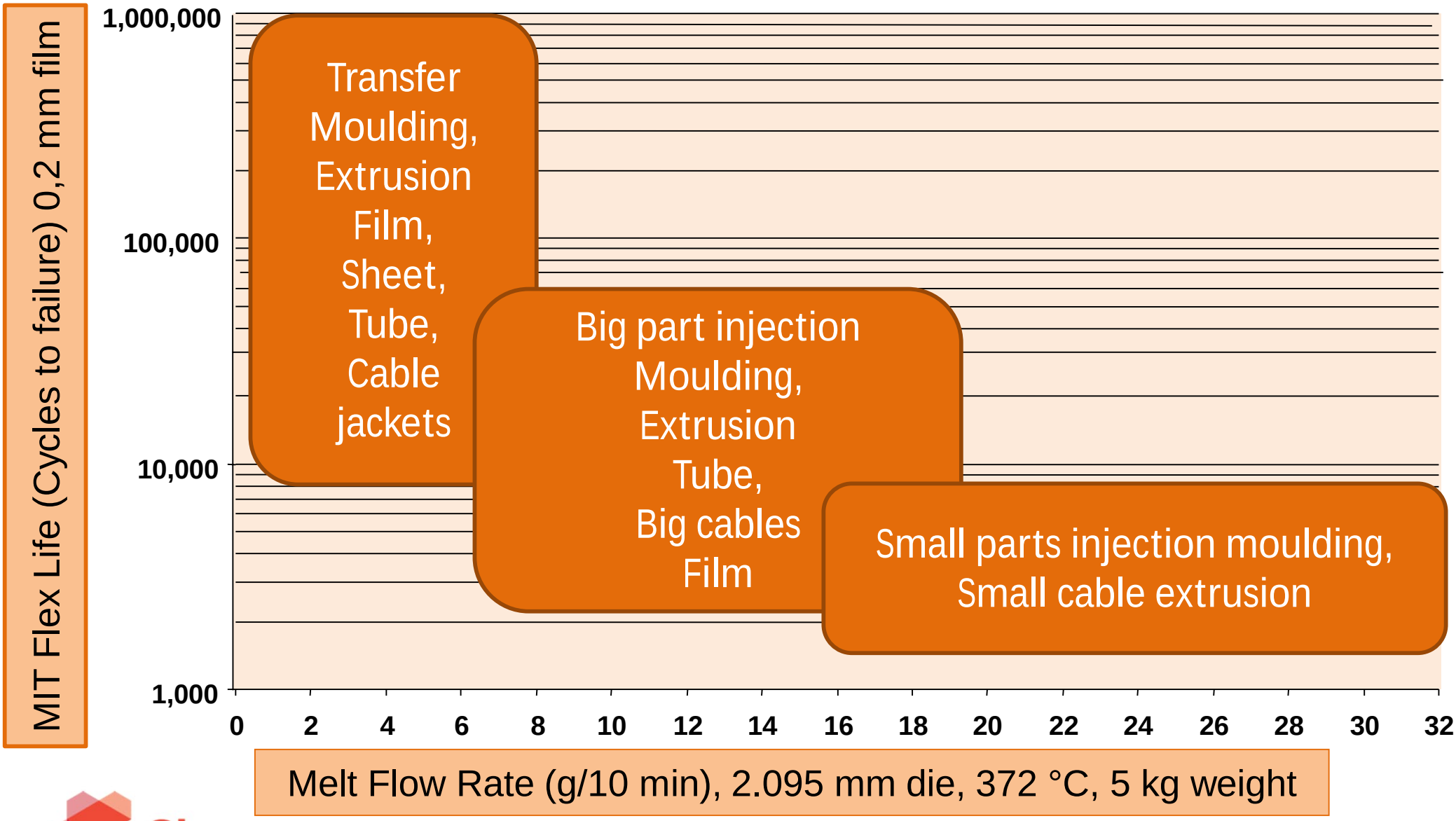
“MELTS” Positioning chart linked to Processing



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TEFLON™ FEP

Questions ?

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TEFLON™ PFA

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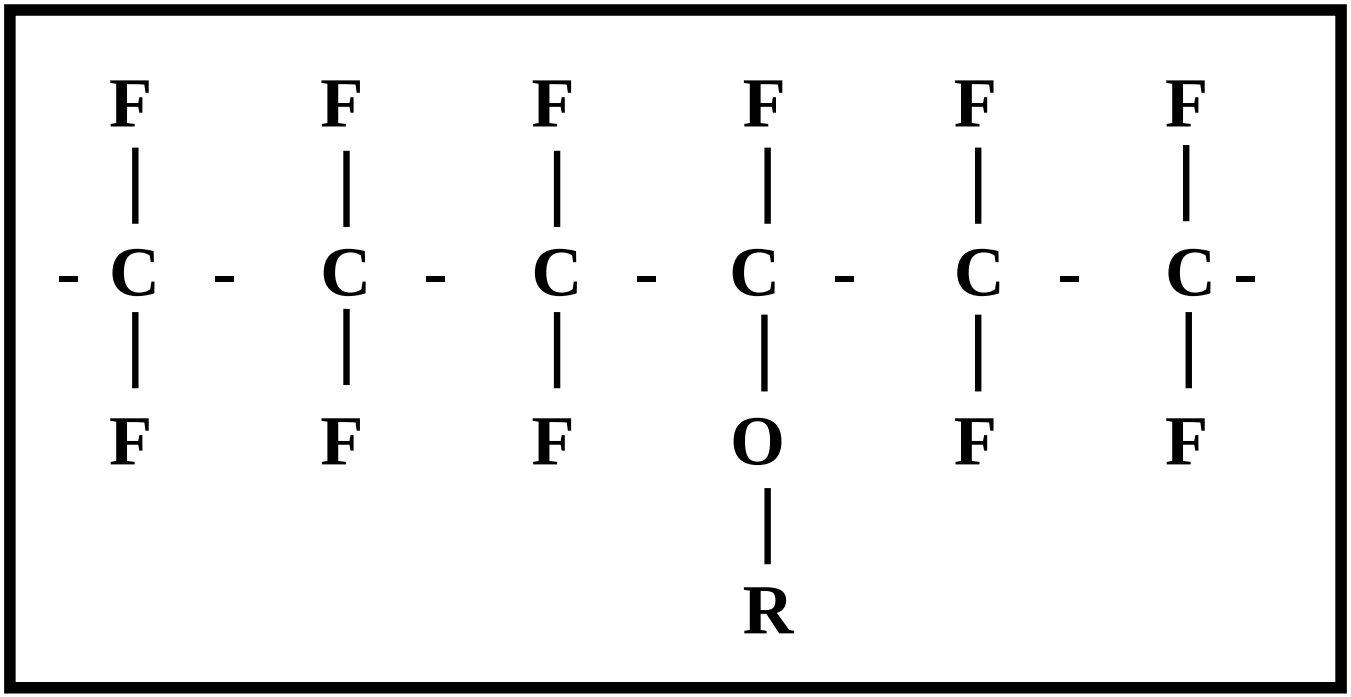
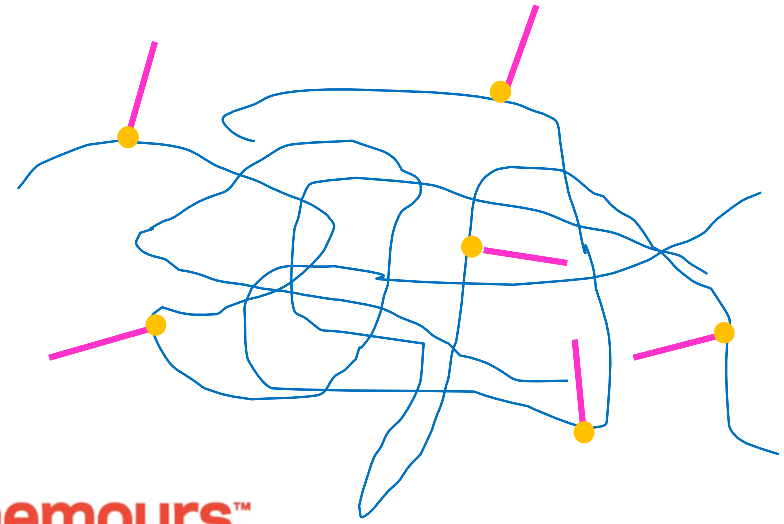
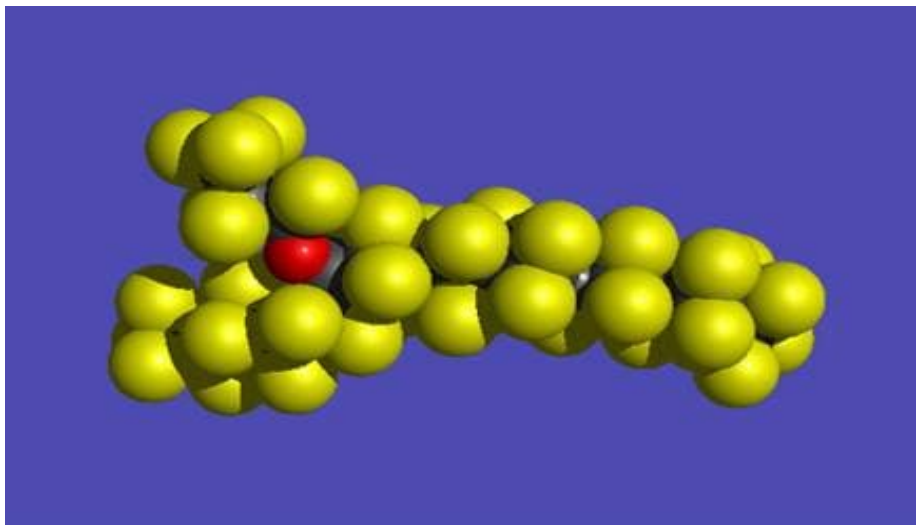
PERFLUOROALKOXY - PFA







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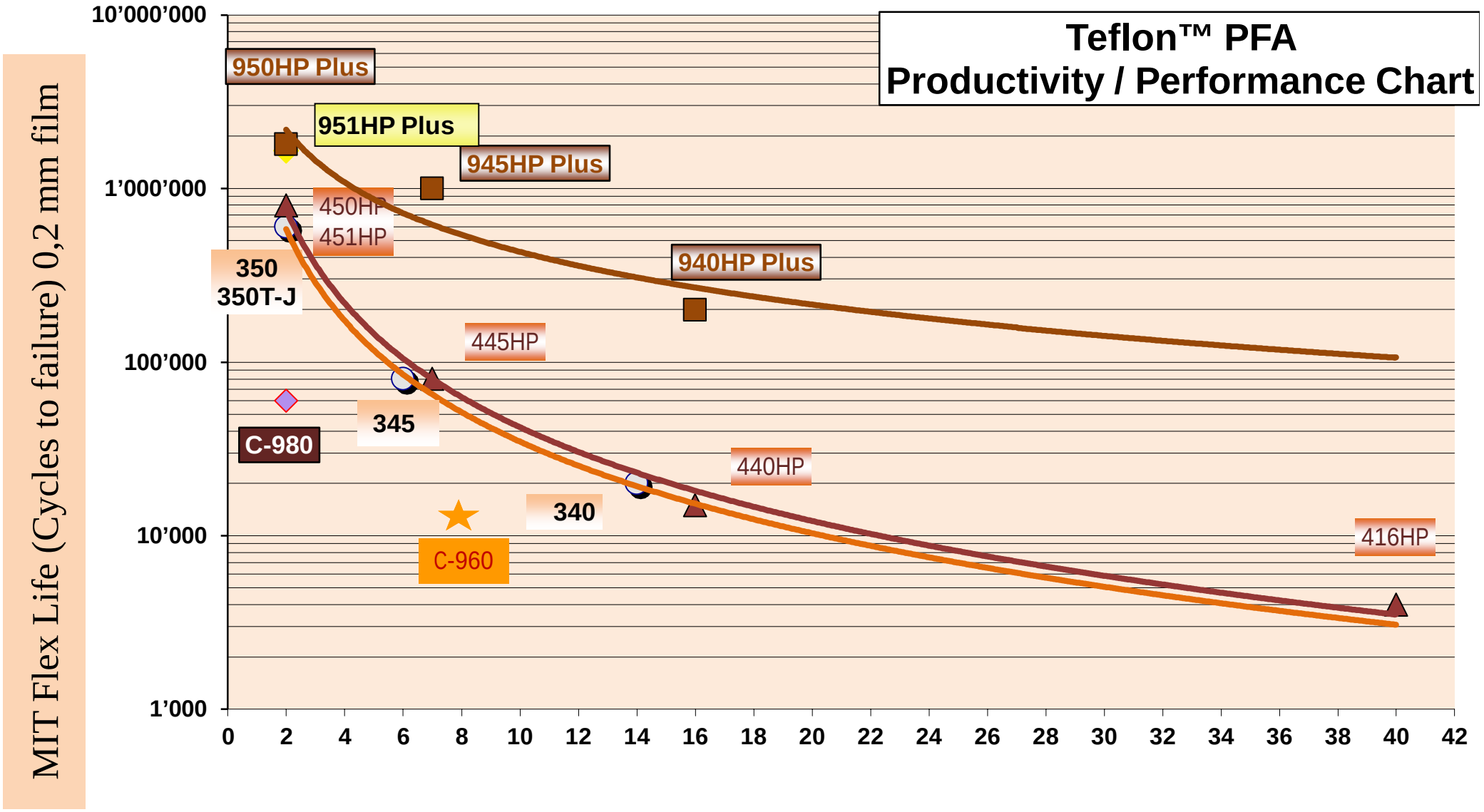

Melt Flow Rate (g/10 min), 2.095 mm die, 372 °C, 5 kg weight

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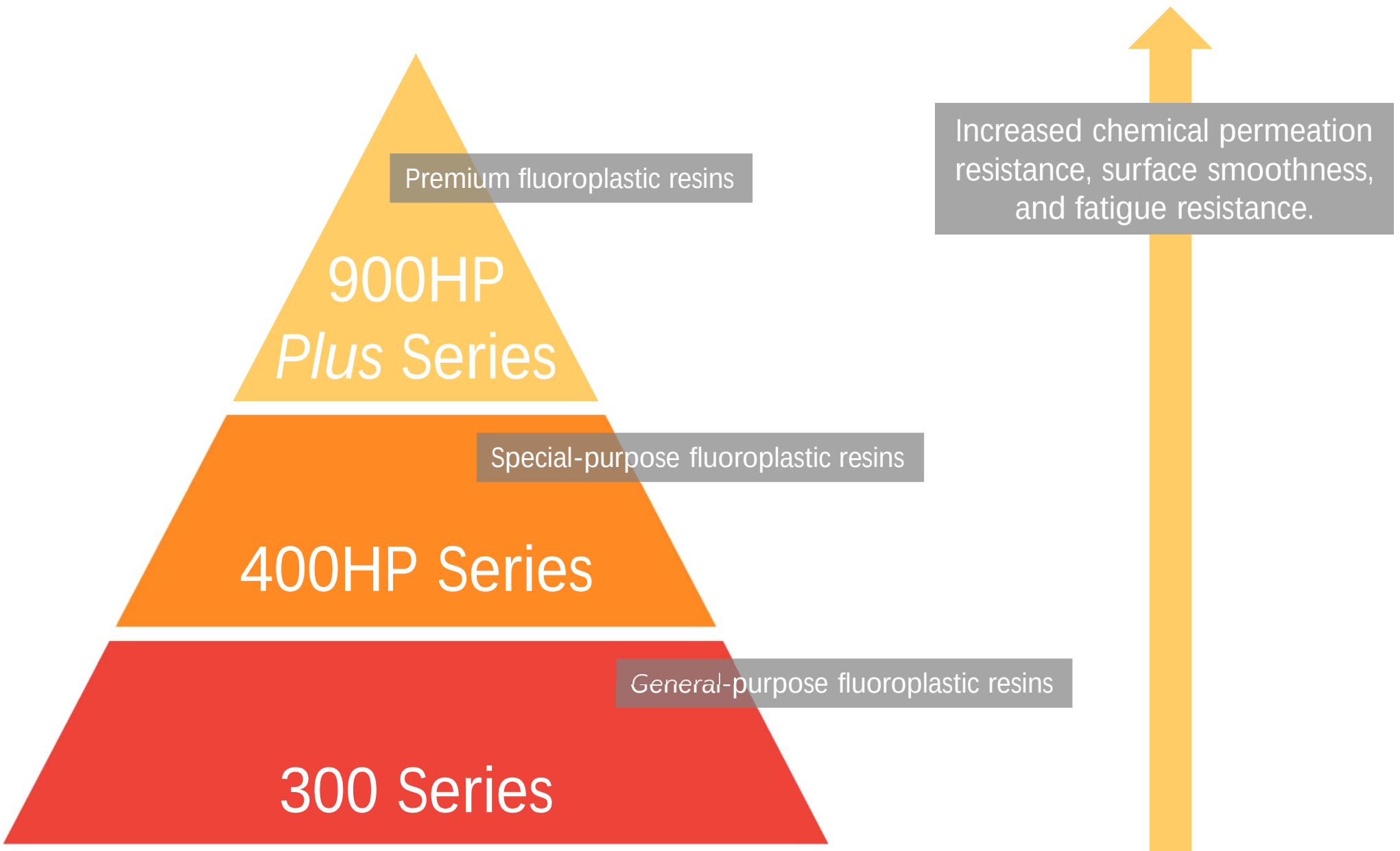
All grades may be followed by «x»

Teflon™ PFA Product Line Evolution



Teflon™ PFA Product Selection Guide

High Melt Flow Rate = Greater processing ease
LOW Stress Crack Resistance

Low Melt Flow Rate = High Melt Strength
HIGH *Stress Crack Resistance*

GENERAL PURPOSE

- Excellent chemical resistance
- High thermal stability

PFA 340
MFR = 12-19

PFA 345
MFR = 5

PFA 350
MFR = 2

HIGH PURITY

- Fully fluorinated version of 300 series
- No reactive end-groups
- Excellent chemical resistance
- High thermal stability
- Excellent electrical properties

PFA 416HP
MFR = 42

PFA 440HP
MFR = 12-19

PFA 445HP
MFR = 5

PFA 450HP
MFR = 2

PFA 451HP
MFR = 2

HIGH PURITY + STRESS CRACK RESISTANCE

- Superior optical clarity
- Superior flex life to 400 series
- Similar to 400 series electrical performance

PFA 940HP *Plus*
MFR = 12-19

PFA 945HP *Plus*
MFR = 5

PFA 950HP *Plus*
MFR = 2

PFA 951HP *Plus*
MFR = 2

Highest permeation resistance

- Purity = no reactive end groups → 400 & 900 series are <u>equivalent</u> in purity
- 900 series has added stress-crack resistance to 400 series NOT added purity
- 451 & 951 have 'spherulite size control technology' that leads to smoother surfaces
- 951 has highest chemical permeation resistance

SUPERIOR SURFACE SMOOTHNESS
- LOWER PERMEATION
- FASTER FLUSHING TIMES
- LESS PARTICLE SHEDDING

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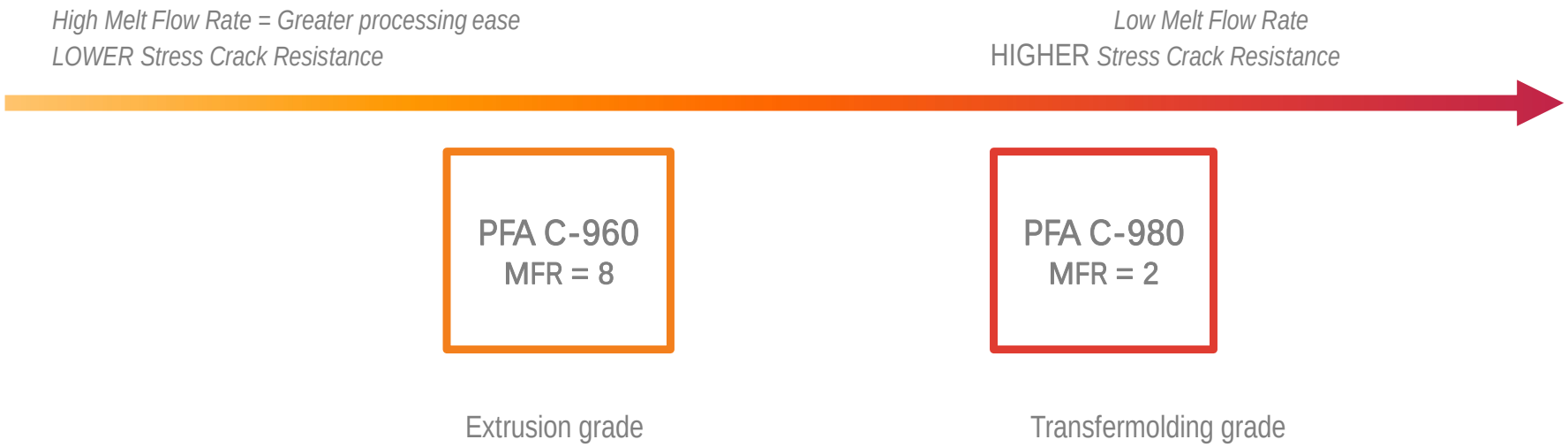
Teflon™ PFA special grades -> Semi-conductive

Resistivity < 14Ω.cm



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Teflon™ PFA C-960,
a semi-conductive PFA for W&C

		PFA C-980	PFA C-960
Property	UoM	Historical Average	Typical results
MFR	g/10 min	2.8	8.3
MP (1st)	°C	284	287
Vol. Res.	Ohm.cm	11.3	10.8
Tens. St. @ break	MPa	35.0	29.3
Elong. @ break	%	302	519
MIT Flex	MCycles	84.7	13.9
Bulk Dens.	g/l	1196	1183

- Mid range MFR
- Resistivity well within the requested range (< 14 Ω.cm)
- Tensile strength in the range of normal PFA's
- Sufficient stress crack resistance ; MIT flex results are comparable with an FEP 100
- NOTE : This new compound is not targeted for food contact applications ;
  No food approval statements

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Cable design :
Grade selection suggestion vs cable diameter

AWG	CONS-TRUCTION	Ø (mm)	AREA (mm^2)	PFA 350	PFA 450HP	PFA 345	PFA 445HP	PFA 340	PFA 440HP B	PFA 440HP A	PFA 416HP	
				2	2	5	5	14	13.5	16.5	42	MFR
				500000	500000	50000	50000	15000	15000	12000	4000	MIT
4	133 x 0.455	6.48	21.62									
6	133 x 0.361	5.14	13.61									
8	133 x 0.287	4.09	8.6									
10	37 x 0.404	2.8	4.77									
12	37 x 0.320	2.22	2.98									
14	37 x 0.254	1.78	1.88									
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28	19 x 0.079	0.395	0.093									
30	19 x 0.063	0.315	0.059									

Note: for heavy wall constructions, select a grade with higher stress crack resistance if needed

PFA 4xx HP : lower Dissipation factor

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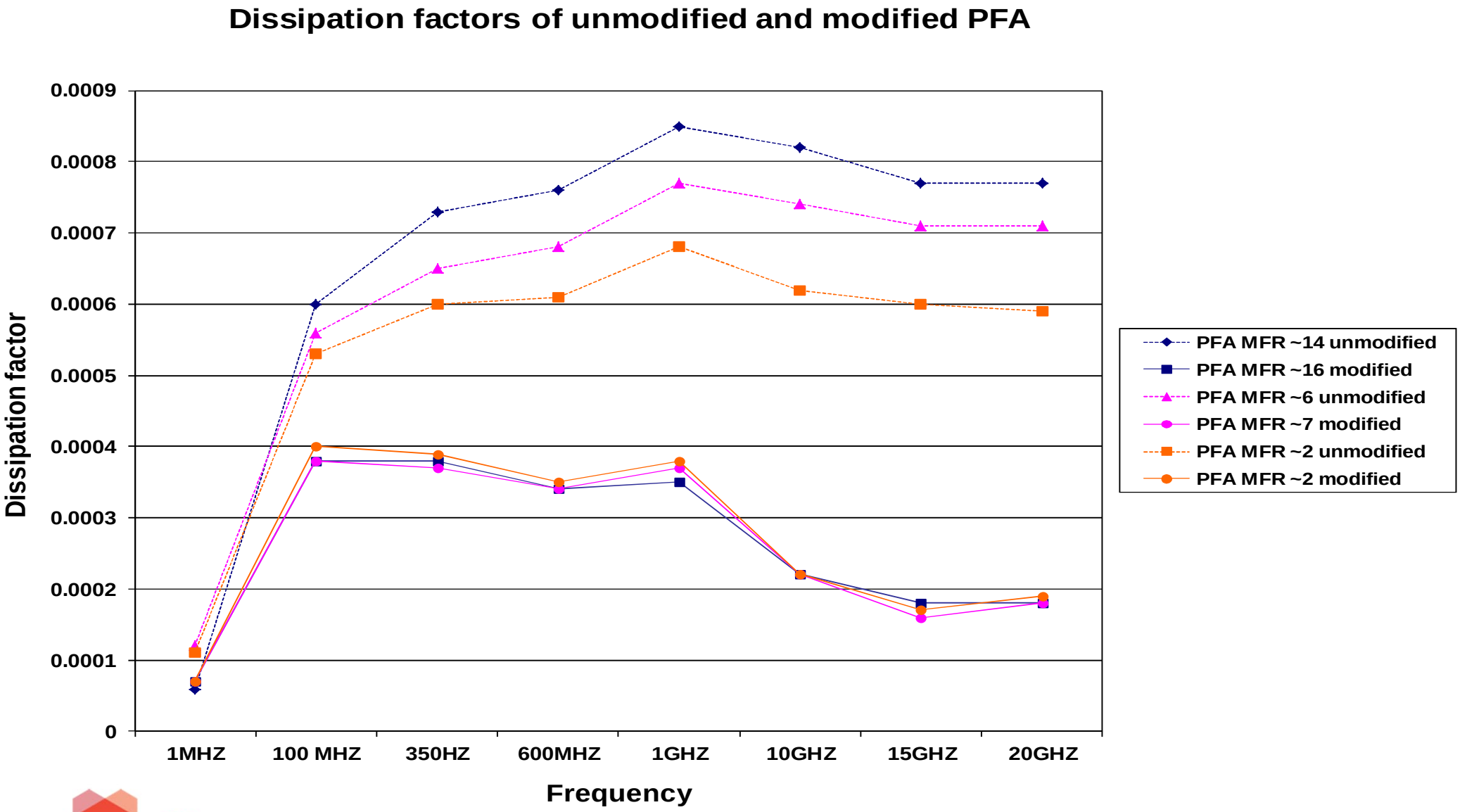
Looking for improved signal return loss at high frequencies ?



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TEFLON™ PFA

Questions ?

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TEFZEL™ ETFE

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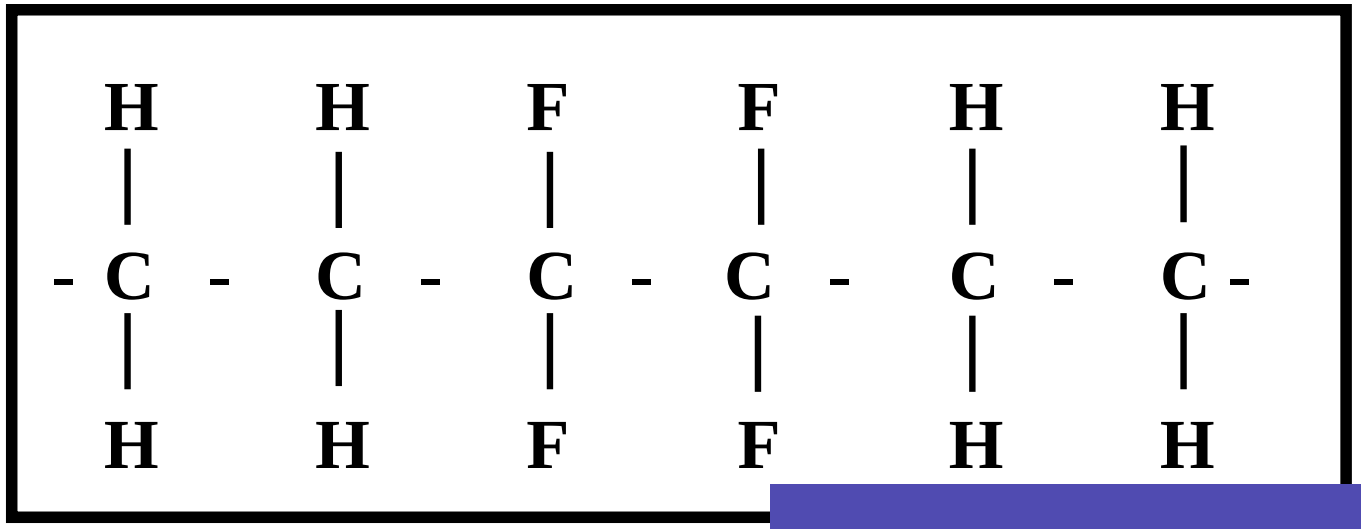
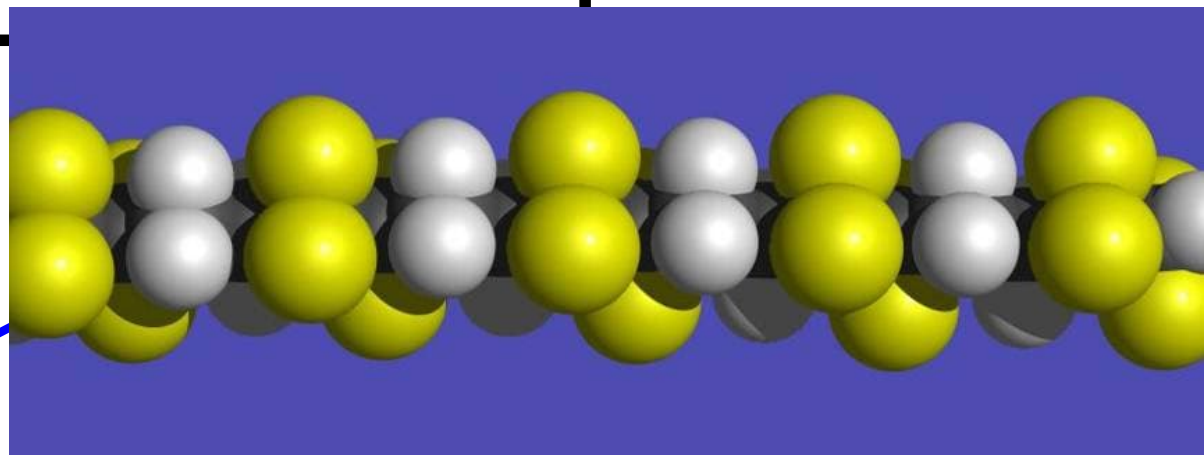
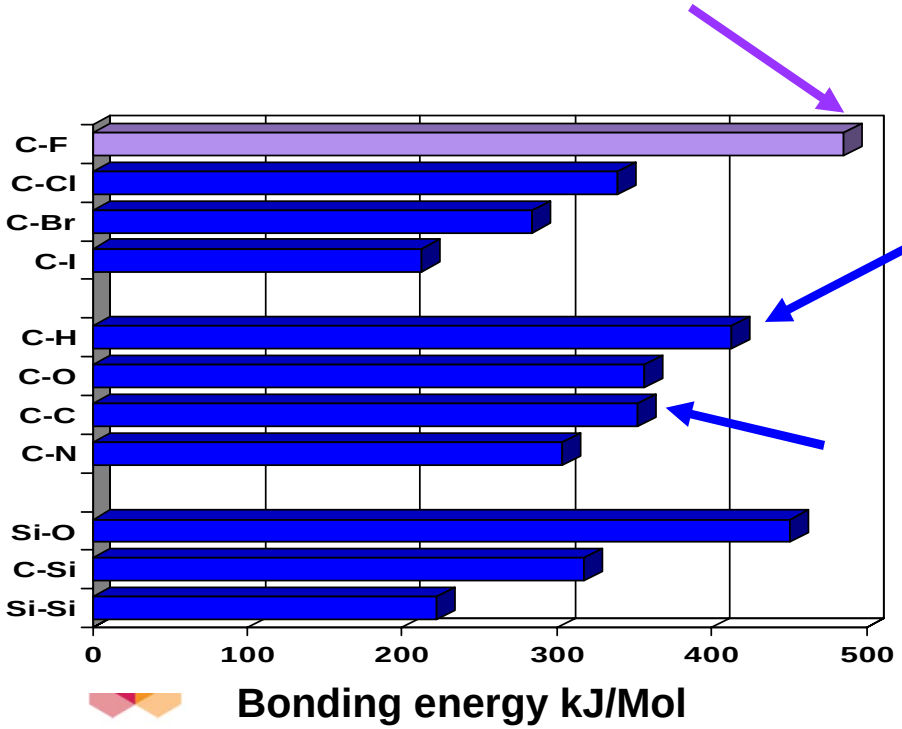
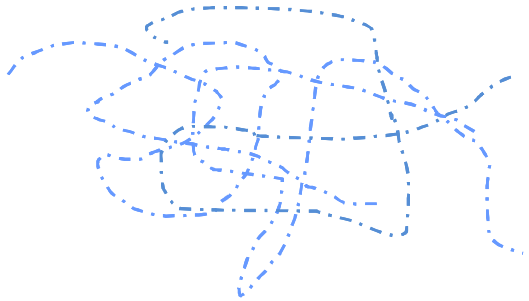
ETHYLENE – TETRAFLUOROETHYLENE COPOLYMER - ETFE



ASTM D 3159
ISO 12086
UL Yellow Card







Typical Properties

Property	Units	PTFE	FEP	PFA	ETFE
Molecular Weight		10^6 - 10^7	250 - 600 x 10^3	250 - 450 x 10^3	250 - 400 x 10^3
Comonomer Content	% Weight	< 1	10 - 12	2,8 - 4,0	20
Melting Point (ASTM D 4591)	°C	327 - 342	260	305	265
Melt Viscosity	Pa.s	10^{10} - 10^{11}	3 - 55 x 10^4	3 - 35 x 10^4	0,5 - 13 x 10^4
Melt Flow Rate(*) (ASTM D 1238)	g/10 min.	No Flow	1 - 30	1,5 - 40	*2,5 - 64*

(*) Measured at 372 °C for FEP and PFA and 297 °C for ETFE

Thermal Properties

Property	Units	PTFE	FEP	PFA	ETFE
PEAK MELTING TEMP. (ASTM D 4591)	°C	327	260	305	265
SERVICE TEMP. (ISO 2578, 20.000 h)	°C	260	?	260	?
FLAME CLASS (UL94)		94V-0	94V-0	94V-0	94V-0
LIMITING OXYGEN INDEX (ISO 4589)	%	>95	>95	>95	30 - 32
HEAT OF COMBUSTION (ISO 1716)	MJ/kg	4,9 - 5,0	4,8 - 5,1	4,7 - 4,9	12,4 - 12,6

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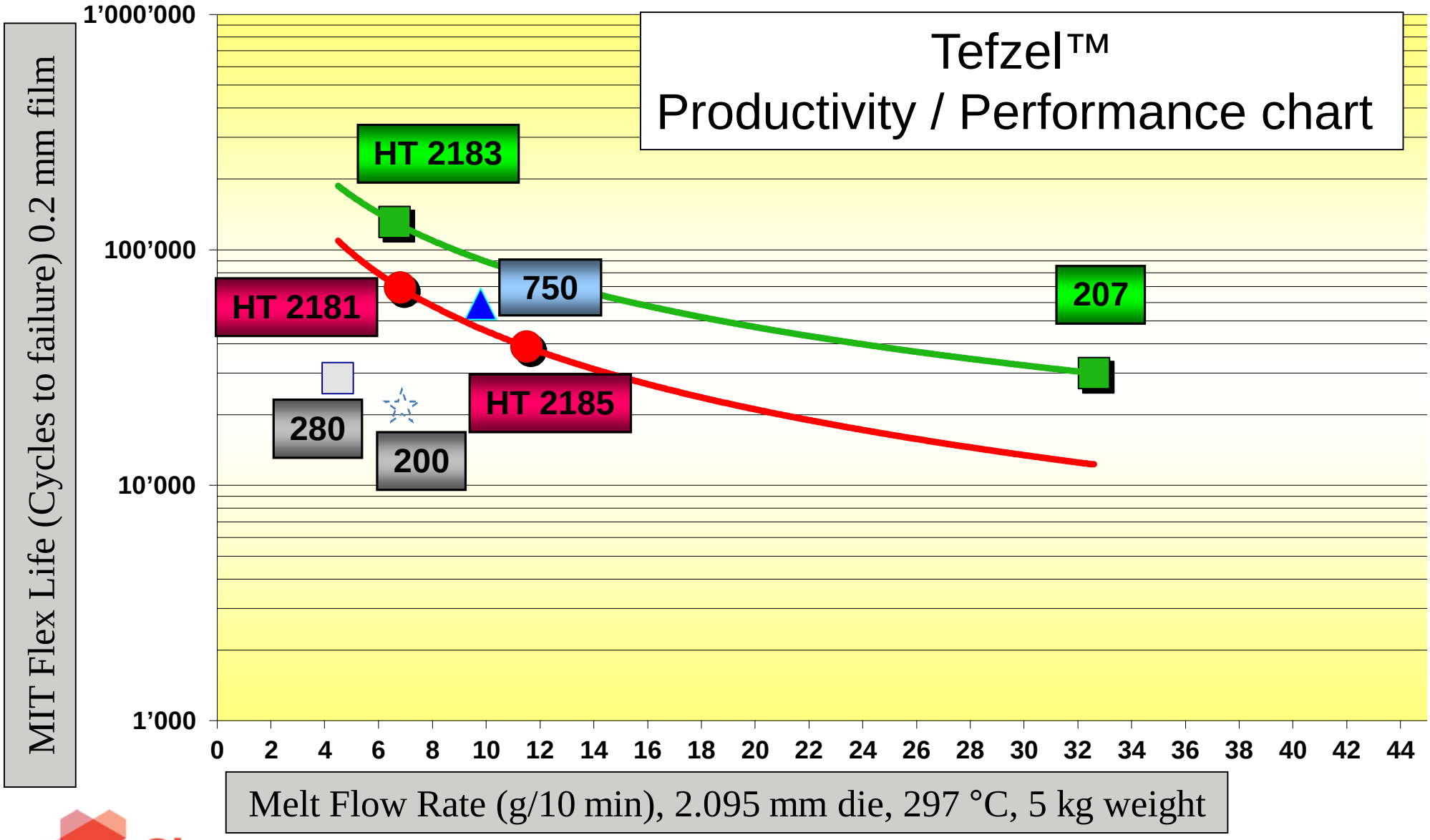
Thermal Properties

Property	Units	PTFE	FEP	PFA	ETFE
PEAK MELTING TEMP. (ASTM D 4591)	°C	327	260	305	265
SERVICE TEMP. (ISO 2578, 20.000 h)	°C	260	205	260	155
FLAME CLASS (UL94)		94V-0	94V-0	94V-0	94V-0
LIMITING OXYGEN INDEX (ISO 4589)	%	>95	>95	>95	30 - 32
HEAT OF COMBUSTION (ISO 1716)	MJ/kg	4,9 - 5,0	4,8 - 5,1	4,7 - 4,9	12,4 - 12,6



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Revised MIT flex results based on 2016 data

Cable design :
Grade selection suggestion vs cable diameter

AWG	CONS-TRUCTION	Ø (mm)	AREA (mm²)	ETFE 280	ETFE 200	ETFE HT-2183	ETFE 750	ETFE HT-2181	ETFE HT-2185	ETFE 207	
				4	7	6	7	6	11.5	30	MFR
				7500	*5500*	*35000*	*30000*	*25000*	*15000*	*15000*	*MIT*
4	133 x 0.455	6.48	21.62								
6	133 x 0.361	5.14	13.61								
8	133 x 0.287	4.09	8.6								
10	37 x 0.404	2.8	4.77								
12	37 x 0.320	2.22	2.98								
14	37 x 0.254	1.78	1.88								
16	19 x 0.287	1.36	1.23								
18	19 x 0.254	1.27	0.962								
20	37 x 0.142	0.97	0.586								
22	37 x 0.114	0.78	0.38								
24	19 x 0.127	0.634	0.241								
26	19 x 0.102	0.504	0.155								
28	19 x 0.079	0.395	0.093								
30	19 x 0.063	0.315	0.059								

Note: for heavy wall constructions, select a grade with higher stress crack resistance if needed

ETFE 200 Pressure extrusion & Aircraft cable specified ;

ETFE 750 UL Subject 758 and CSA 210 rated at 200 °C

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Tefzel™ ETFE Product Selection Guide

Chemours is a leading producer of fluoroplastics, including Tefzel™ ETFE resins. Our products combine superior mechanical toughness with outstanding chemical inertness and high radiation resistance. Tefzel™ ETFE is the preferred fluoroplastic electrical components, wire insulation, and molding applications.

GENERAL PURPOSE

- Electrical components
- Chemical service items – valves, liners
- Film
- Injection molding

ETFE 280 MFR = 4

ETFE HT2183 MFR = 6

ETFE HT2185 MFR = 11

ETFE 207 MFR = 30

ETFE 200 MFR = 7

ETFE HT2181 MFR = 6

Improved processing — Improved stress crack resistance

HIGH TEMPERATURE

- Appliance wire

ETFE 750 MFR = 7

SPECIALTY RESINS

- Range of melting points
- Tubes and liners
- Injection and blow molding

ETFE HT2195 MFR = 20

- Rotomolding and rotolining

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TEFZEL™ ETFE

Questions ?

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TEFLON™ FFR

Fluoropolymer Foam Resin

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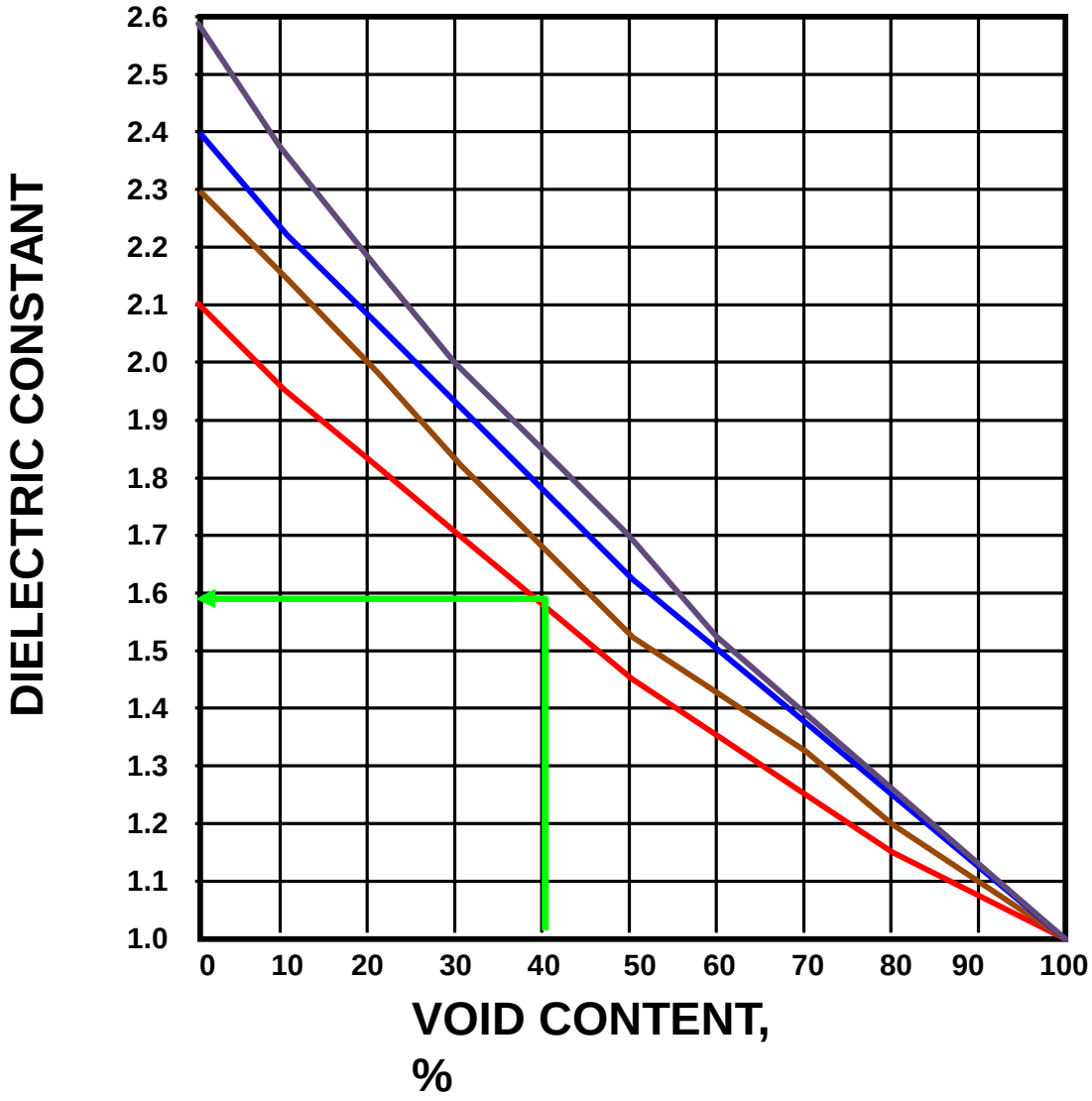
FOAM RESINS

WHY FOAM ? DIELECTRIC CONSTANT VERSUS VOID CONTENT

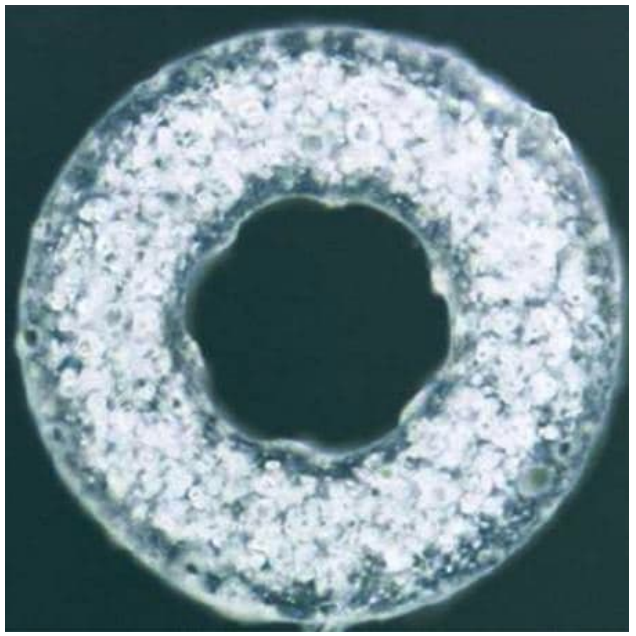


TEFLON™ FEP

POLYETHYLENE

SURLYN™

TEFZEL™



OD 0.61 mm, 40%void content

Similar effect for dissipation factor versus voids

ECCtreme™ ECA

CURRENTLY NOT AVAILABLE !!!

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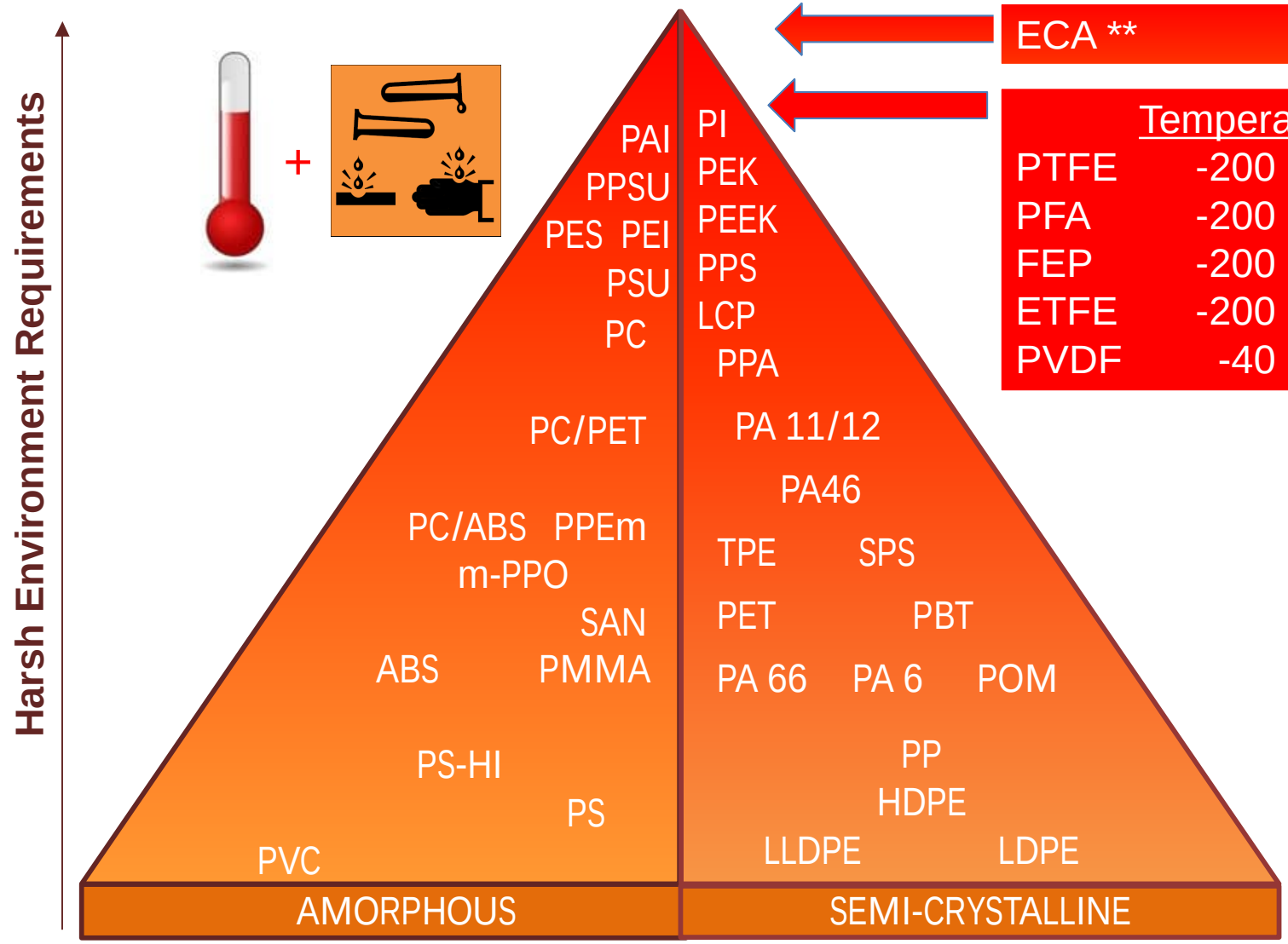
Introduction
Fluoroplastics positioning



ECA **

Temperature range *		
PTFE	-200 - 260	° C
PFA	-200 - 260	° C
FEP	-200 - 205	° C
ETFE	-200 - 155	° C
PVDF	-40 - 135	° C

(*) ISO 2578 20 000 h
(**) UL Yellow Card per E54681

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What is ECCtreme™ ECA

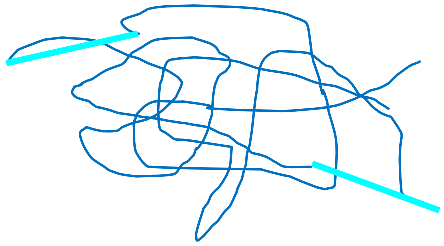
- ✓ This new class of perfluoroplastics is called ECA : Epitaxial Co-crystallized Alloys
- ✓ Melt processable, using the same equipment as for FEP and PFA
- ✓ ECA is recognized by UL as a new class of perfluoroplastic material, with RTI up to 300 °C*
- ✓ ~~3~~ 2Grades to suite different applications

**300˚C rating is result of long-term thermal aging tests per UL 746B*
NOTE : UL rating as-is; before heat aging

What makes ECCtreme™ ECA special ?

Unique combination of two effects during heat treatment:

- End Group Coupling

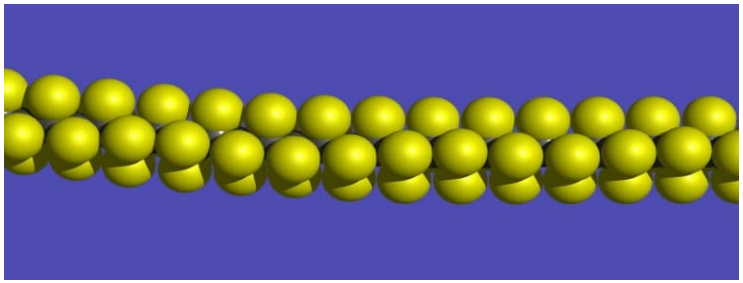


- Epitaxial Co-Crystallization
  - ✓ Epitaxial co-crystallization effect occurs when the resin is heated for a prolonged period close to the melting point
  - ✓ This effect helps stabilize product performance at high temperatures

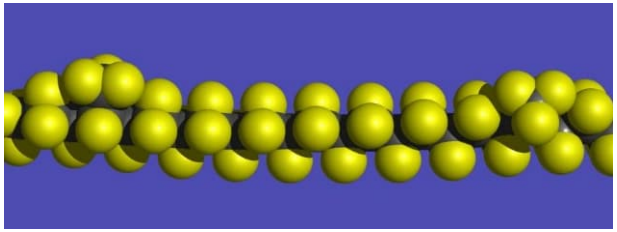
Heat treatment : Typically 1 week at 300 °C, IF improved properties are needed.

In Summary
Chemours™ Fluoropolymer Portfolio

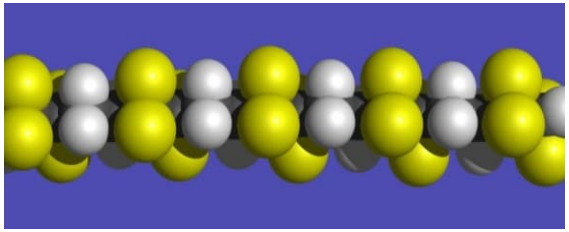
Teflon™ PTFE **(-CF2-CF2-)n**
(Polytetrafluorethylene)
Discovered 1938



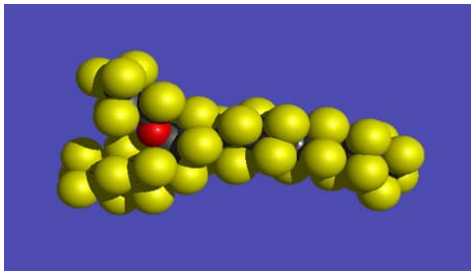
Teflon™ FEP **(-CF2-CF2-CF2-CFCF3-)n**
(Fluorinated Ethylene Propylene)
Dvlp. 1960



Tefzel™ ETFE **(-CH2-CH2-CF2-CF2-)n**
(Ethylene Tetrafluorethylene)
Dvlp. 1970



Teflon™ PFA **(-CF2-CF2-FCOC3F7-CF2-)n**
(Perfluoroalkoxy)
Dvlp. 1972



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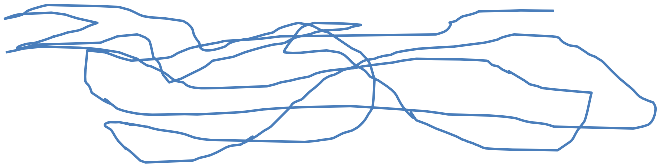
Schematic Summary
Chemours Fluoropolymer Portfolio

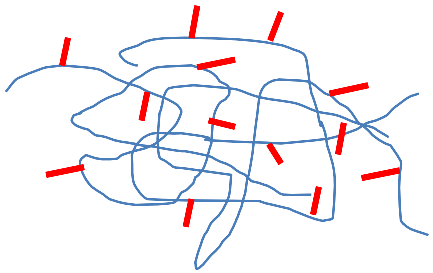
Teflon™ PTFE **(-CF2-CF2-)n**

Mechanical strenght from long chains



Teflon™ FEP **(-CF2-CF2-CF2-CFCF3-)n**

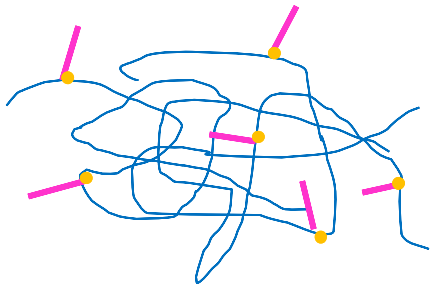
Mechanical strenght from
many short side chains



Teflon™ PFA **(-CF2-CF2-FCOC3F7-CF2-)n**

Mechanical strenght from

A few longer side chains



Tefzel™ ETFE **(-CH2-CH2-CF2-CF2-)n**

Mechanical strenght at from
Ethylene comonomer, less thermal resistance

ECCtreme™ ECA

Mechanical strenght at from co-coupling

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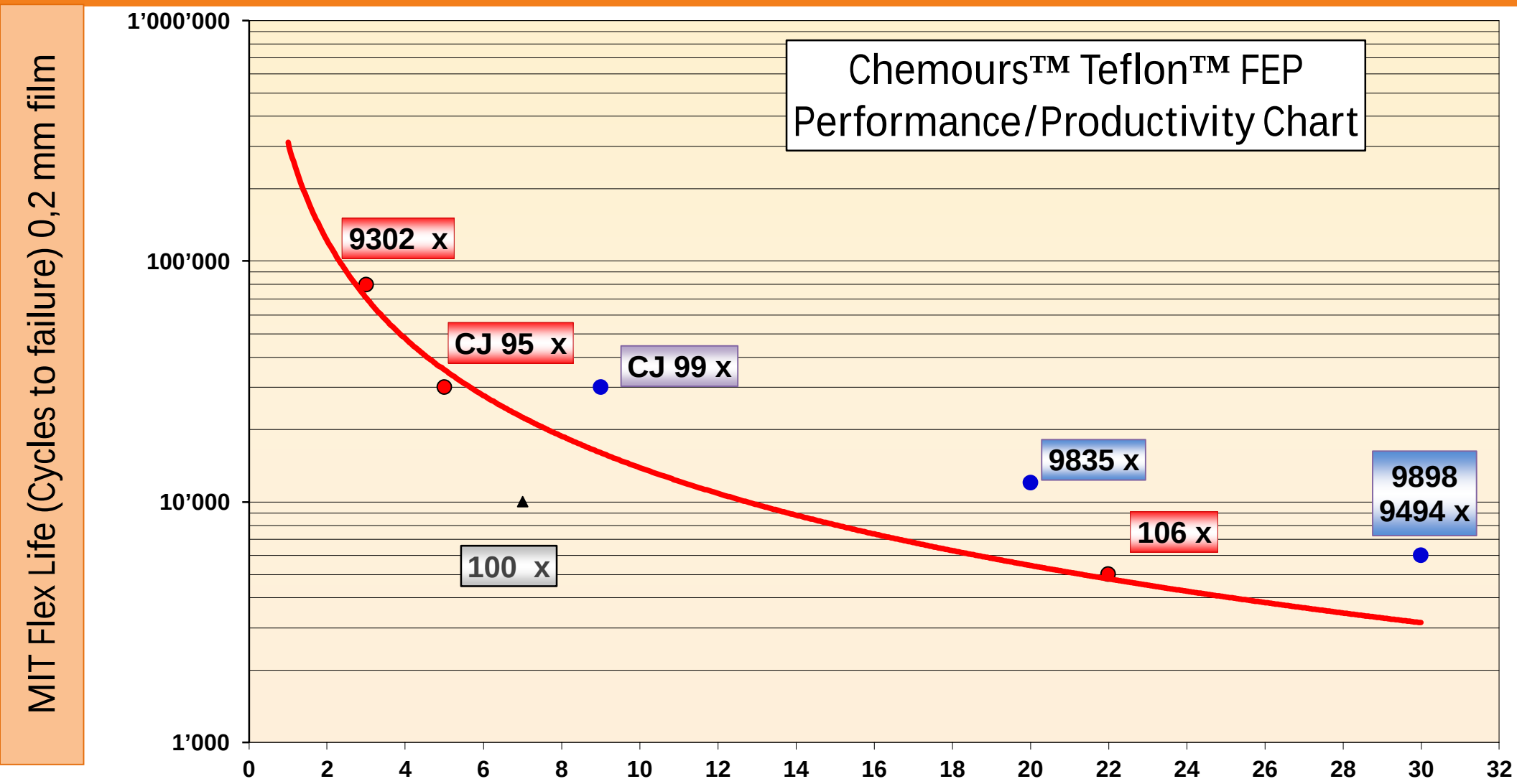
Melt Extrusion



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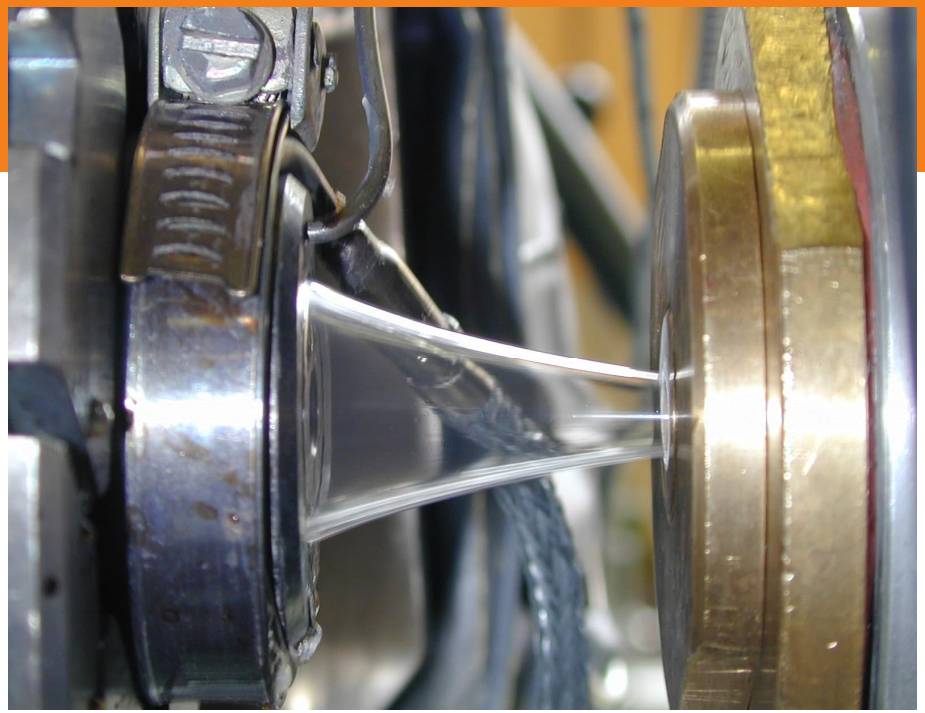
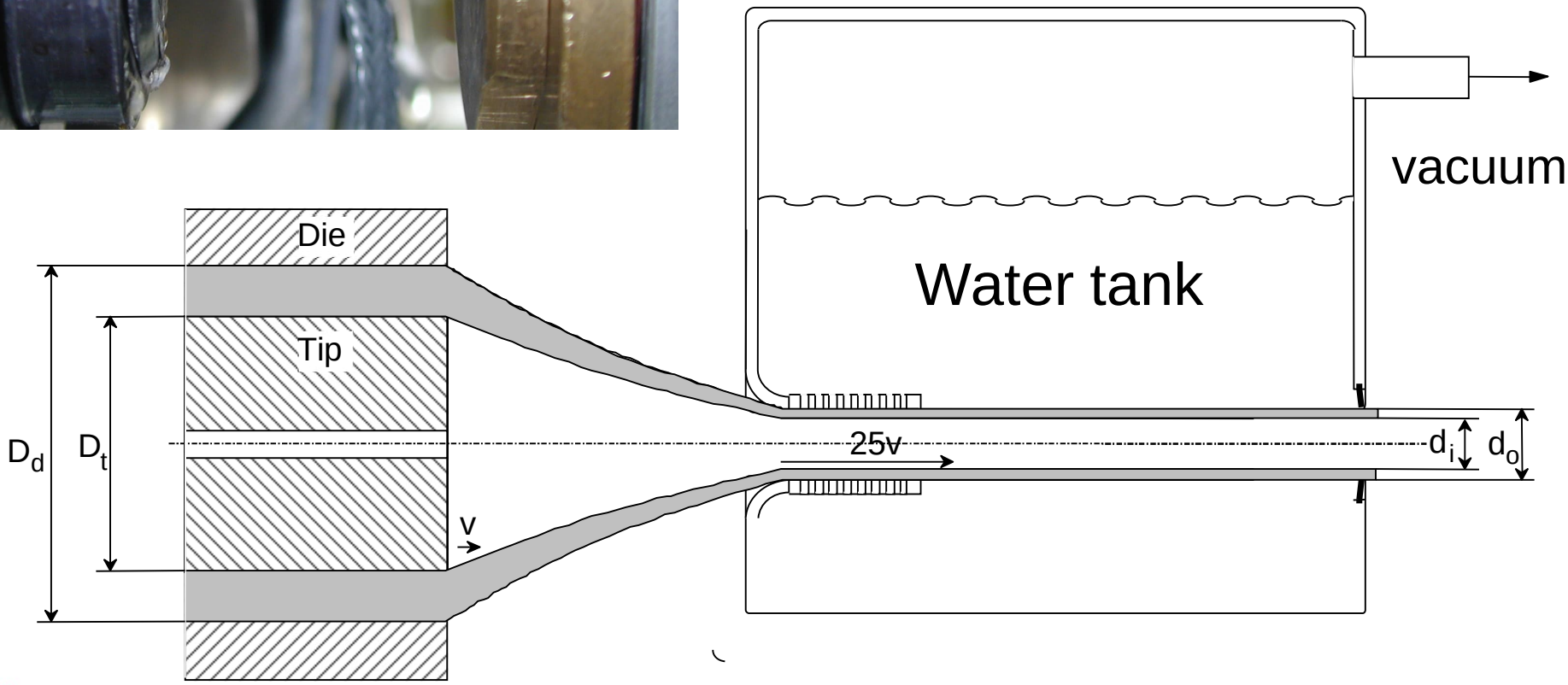
Tubing Extrusion





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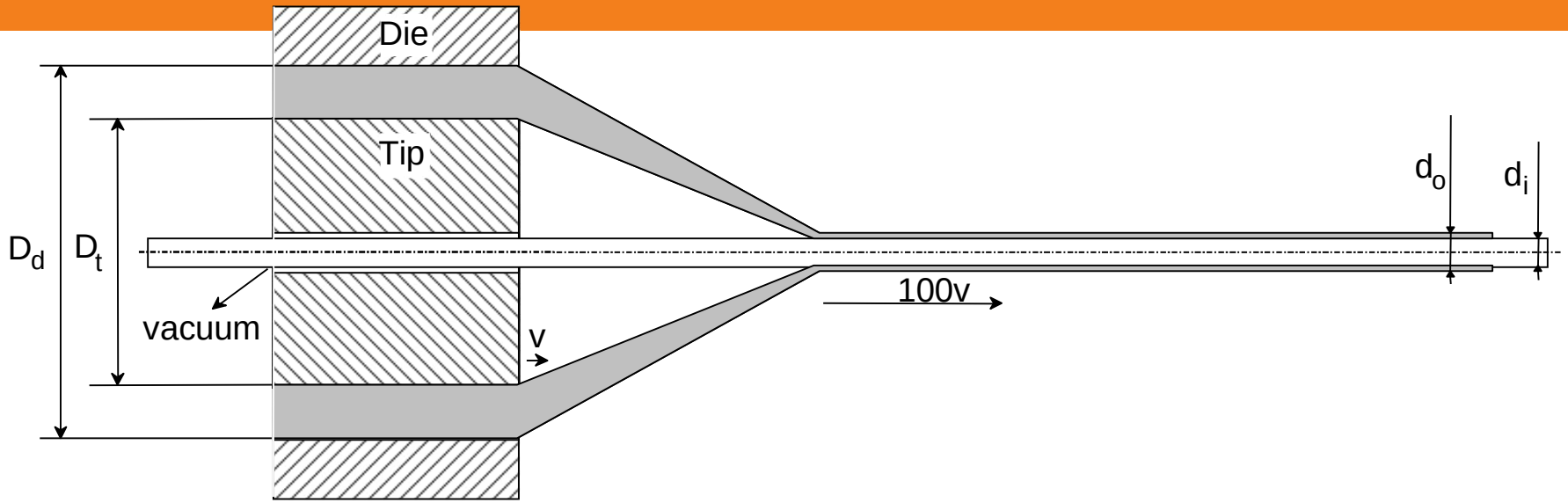
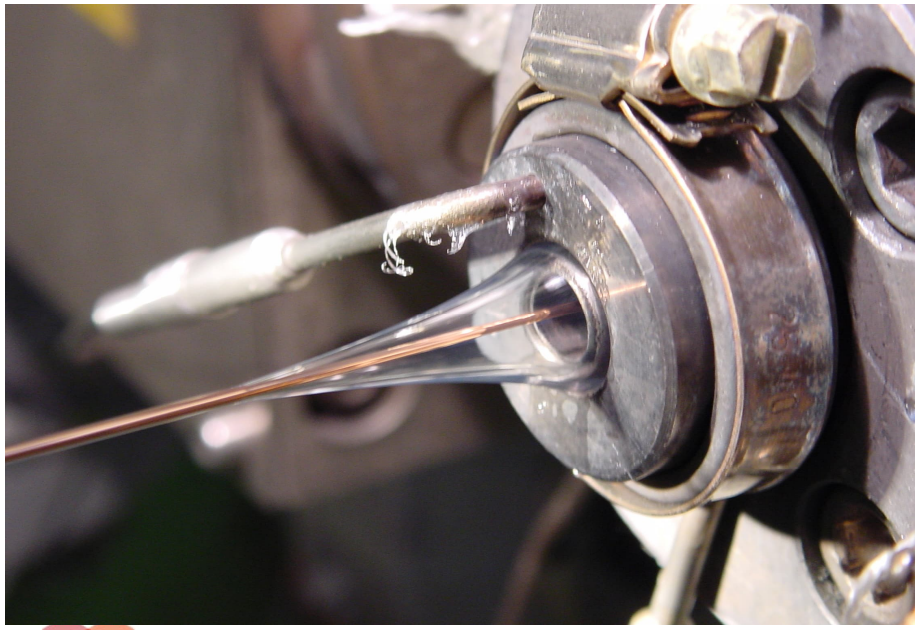
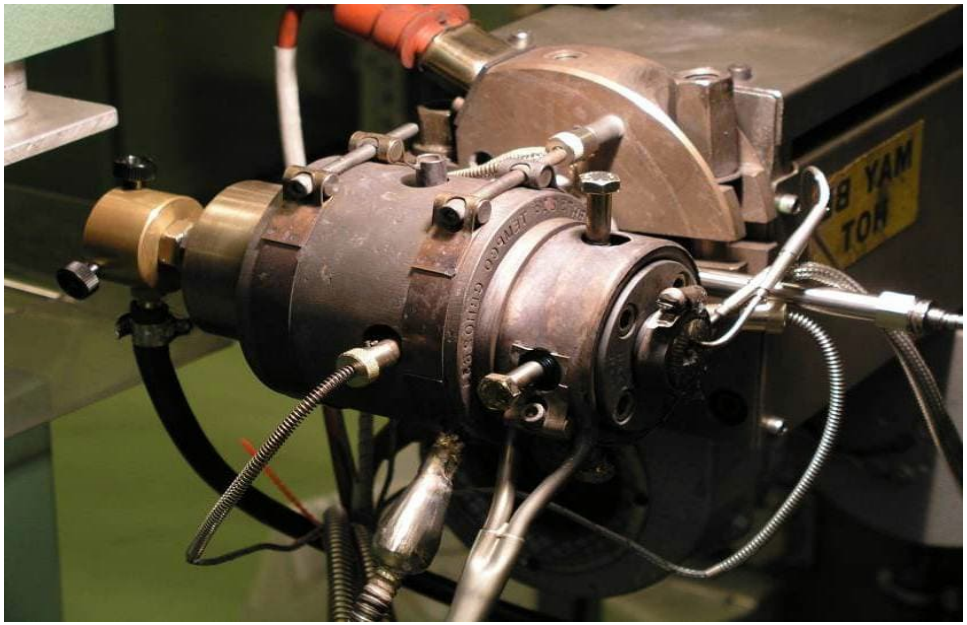
Wire coating Tube Extrusion

$$DDR = \frac{D_d^2 - D_t^2}{d_i^2 - d_o^2} \qquad DRB = \frac{\frac{D_d}{d_o}}{\frac{D_t}{d_i}}$$







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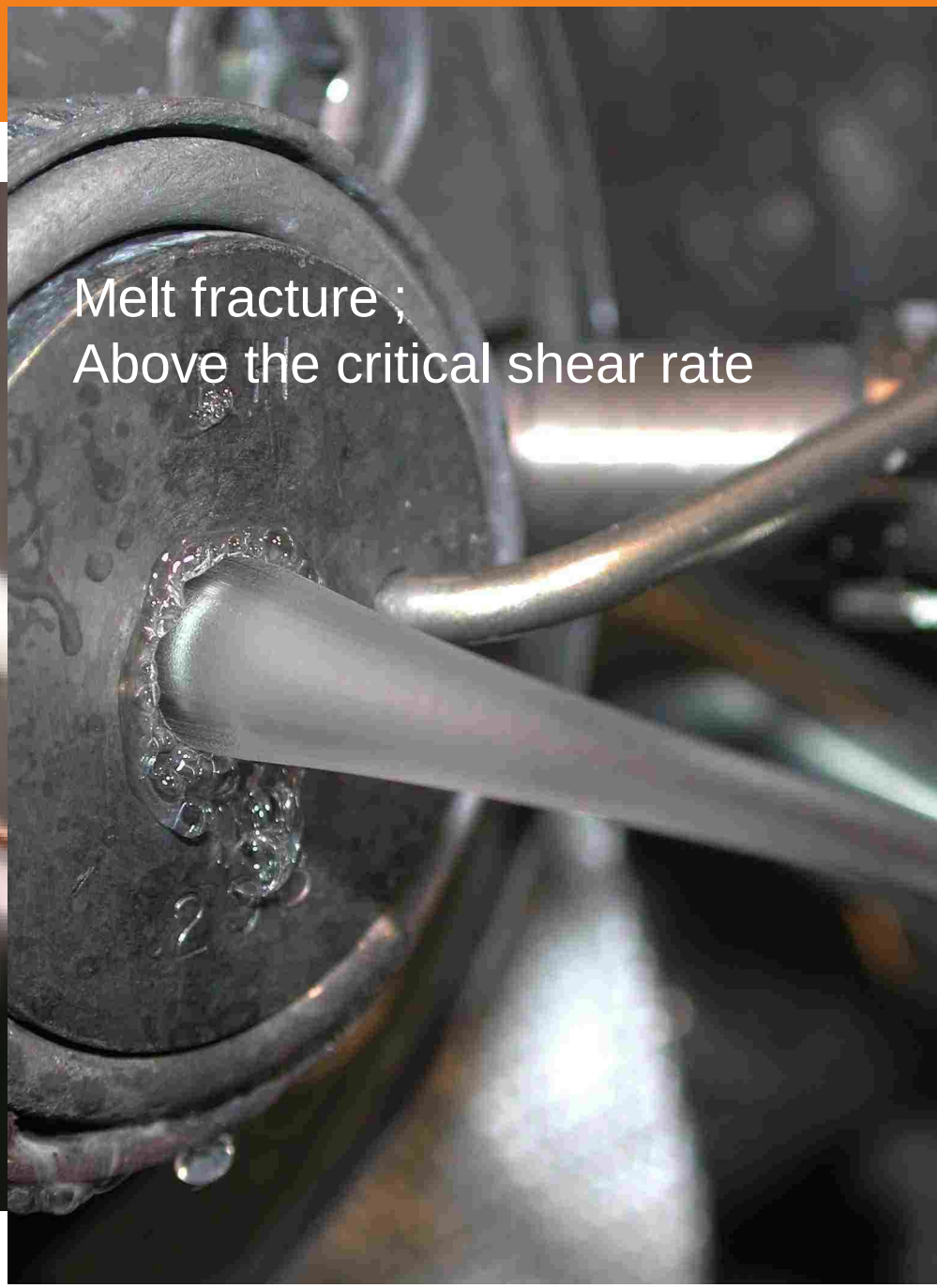

Melt fracture ;
Above the critical shear rate

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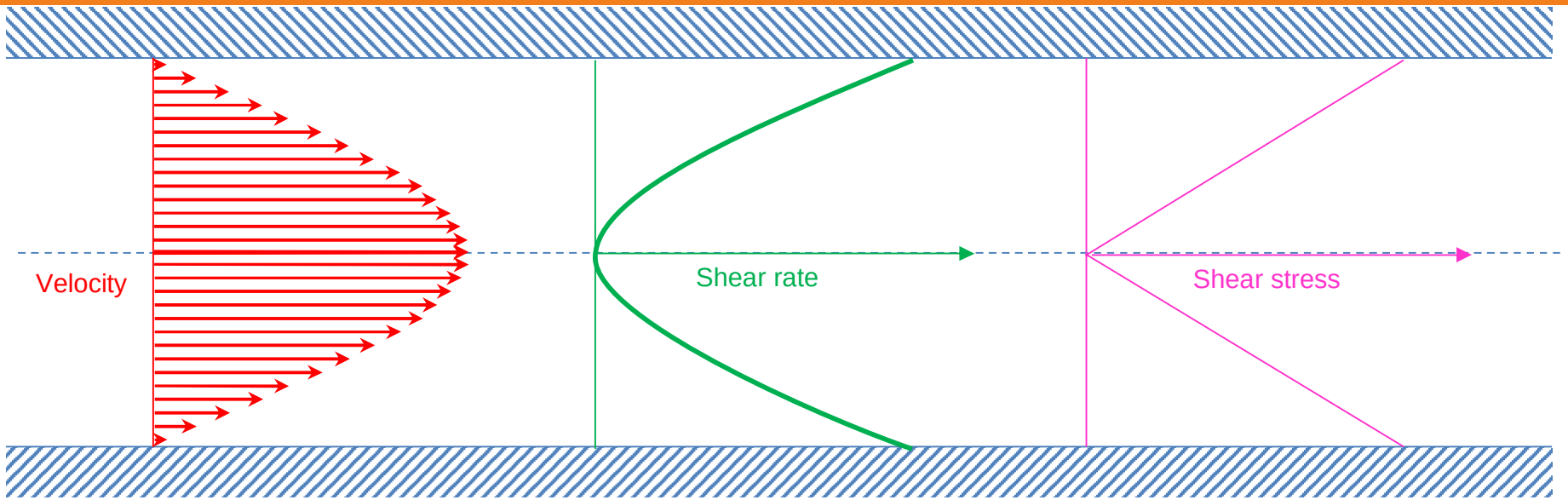

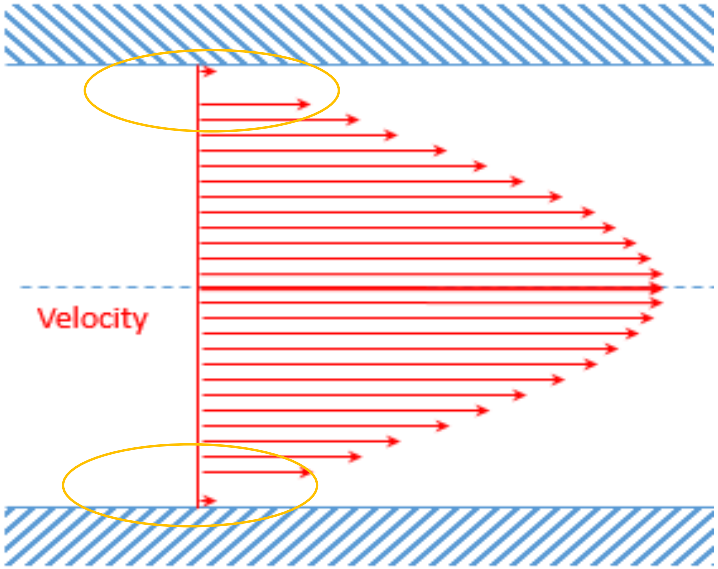

Too fast extrusion,
Connection between the layers traveling a
different speeds is broken
=> Surface defects

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Thank you for your attention

Chemours™