3M Science. Applied to Life.™

▶ 3M™ Dynamar™ Polymer Processing Additives

Lucent solutions to achieve clear benefits.

Dynamar PPA Product Introduction Guide.

Easing processes to enhance results.

Discover the benefits of our 3M™ Dynamar™ Polymer Processing Additives (PPAs) – fluoropolymer based additives enhancing the processing of high viscosity polyethylene like linear low density polyethylene (LLDPE, mLLDPE). PPAs from 3M have been specially designed to improve the extrusion of various thermoplastic polymers, resulting in a highly beneficial combination of optimised product quality and increased manufacturing output. The addition of PPAs is commonly applied in extrusion processes like blown and cast film, pipe, sheet, cable, compounding, extrusion blow moulding, monofilament, tapes, and fibres. By reducing the apparent viscosity of these resins and hence facilitating increased use of the resulting higher performance resin types in the film processing industry, Dynamar PPAs have gained wide spread commercial acceptance.

This brochure informs you about the typical characteristics of our PPAs, points out possible fields of application and enables you to find the right PPAs for your purposes.

Mechanism of Action of Dynamar Polymer Processing Additives.

A PPA functions by creating a dynamic, temporary fluoropolymer coating on the die surface. This gives a low surface energy interface between the metal wall and the molten polymer stream, preventing drag, and allowing the melt to slip through the die more easily.

Stresses are reduced in the die and consequently melt fracture is eliminated. In addition, the lowered apparent viscosity allows the polymer melt to flow more freely through the die, providing easier flow and pressure reduction.

A major benefit when adding a PPA to an LLDPE extrusion process is the elimination of surface melt fracture. Additional processing benefits include reduction of die pressure and extrusion motor torque. The processing window when using PPAs is enhanced, allowing for a potential reduction in extrusion process temperatures, an increase in extrusion output, a delay to the onset of die build up at the die lip, increased flexibility in die geometry and the use of higher viscosity polymers.

LLDPE Blown Film.

Benefits of PPAs

- ✓ Elimination of melt fracture
- ✓ Alleviation of die build up
  - Reduction of production down time
- ✓ Reduction of operating pressures and amperage draw
  - Increase output
  - Energy savings
- ✓ Operation at lower processing temperatures
- ✓ Decrease degradation
- ✓ Increase gloss and surface smoothness
- ✓ Reduction of gel formation during extrusion
- ✓ Faster colour change
- ✓ Reduction (or elimination) of LDPE blending in LLDPE blown film

Elimination of melt fracture using a PPA

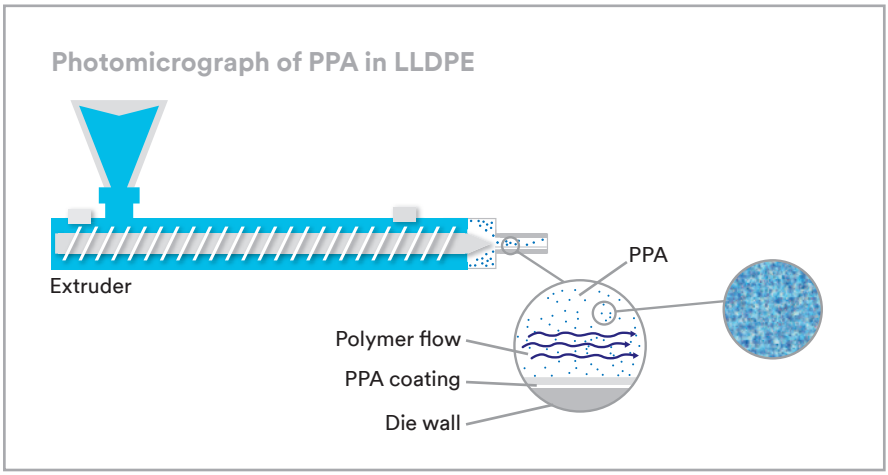
with PPA

When the die is coated, there is slip at the wall, giving a smooth flow profile.

Melt fracture or shark skin formation

without PPA

One of the proposed mechanisms: Upon die exit, the outer layer of the melt is stretched by the elastic recovery of the flow profile.



Fluoropolymers used as PPAs

Chemical structure.

The 3M™ Dynamar™ Processing Additives product portfolio includes many additives based on fluoroelastomers or fluorothermoplastics. They are manufactured from the co-polymerisation of the following monomers:

VF2 Vinylidene fluoride	$CH_2 = CF_2$
HFP Hexafluoropropylene	$CF_3CF = CF_2$
TFE Tetrafluoroethylene	$CF_2 = CF_2$
Ethylene	$C_2 H_4$

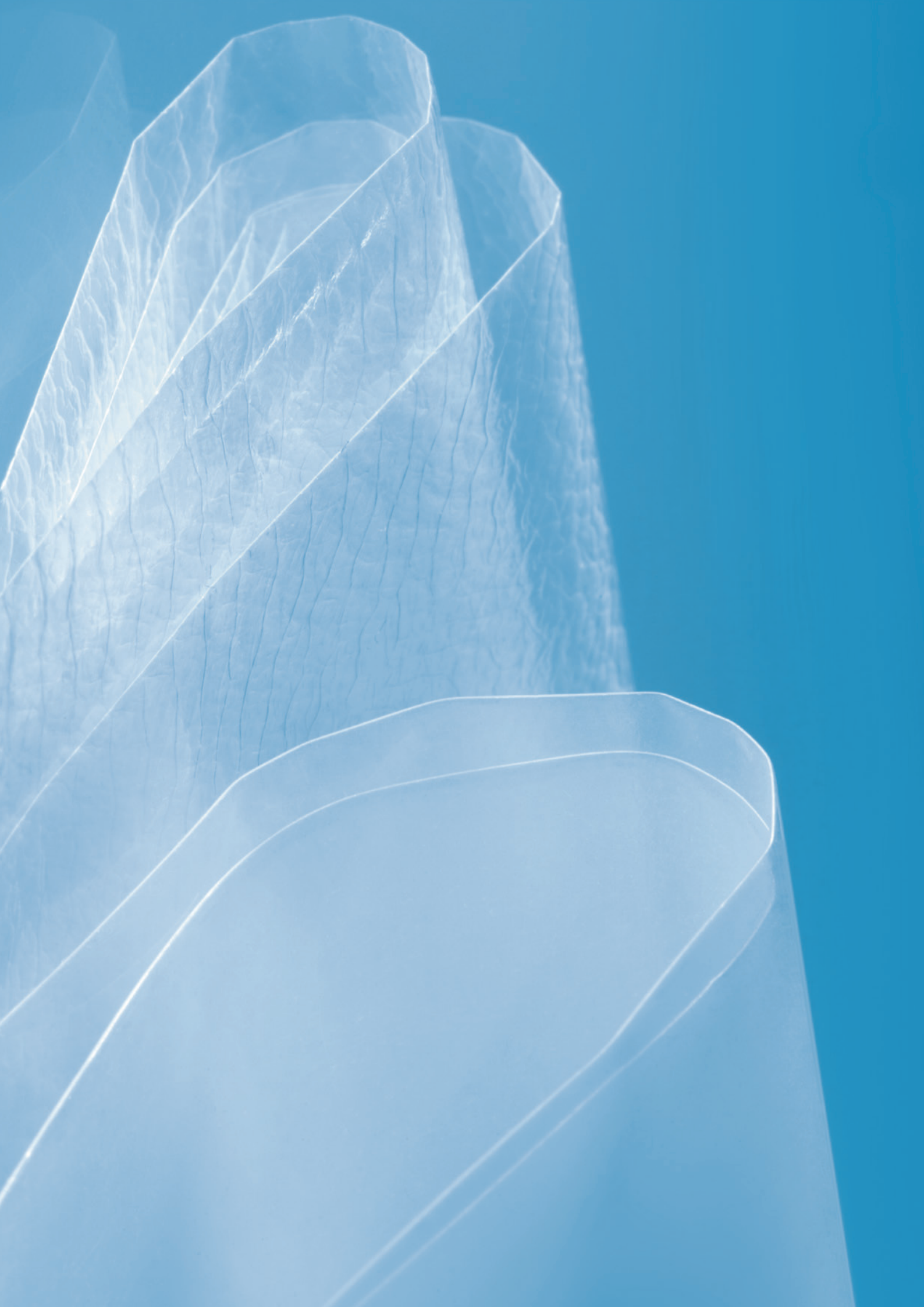
Fluoropolymers are characterised by high inertness towards chemical reactions, excellent thermal stability, low surface energy and are mostly immiscible with other polymers.

Properties of 3M™ Dynamar™ Polymer Processing Additives.

Table with typical properties

	Unit	FX 5920A	FX 5922	FX 5927	FX 9613	FX 5911	FX 5912	FX 5914	FX 5917
Physical Form		Free flowing powder	Free flowing powder	Free flowing powder	Free flowing powder	Free flowing powder	Free flowing powder	Free flowing powder	Pellet
Colour		white to off white	white to off white	white to off white	off white	clear to off white	clear to off white	clear to off white	white to off white
Active Ingredients	%	97	97	96	90	100	100	100	100
Inorganic Additives	%	3	3	4	10	na	na	na	na
Particle Size		less than 10 mesh	less than 10 mesh	less than 10 mesh	less than 10 mesh	98 % less than 2400 µm	98 % less than 2400 µm		
Bulk Density	g/cm³	0.7	0.7	0.7	0.9				
Specific Gravity	g/cm³					1.9 to 1.96	1.9 to 1.96	1.76	1.78
Melting Point	°C	na				110 to 126	110 to 126	195 to 215	160
Melt Flow Index (265 °C, 5 kg)	g/10 min					5 to 14	15 to 25		
Melt Flow Index (230 °C, 2,16 kg)	g/10 min								2
Range of extrusion temperature	°C	below 245	below 245	below 245	up to 350	up to 350	up to 350	up to 350	up to 350
Typical use level	ppm	200 - 1000	100 - 800	100 - 800	100 - 1000	100 - 1000	100 - 1000	300 - 500	200 - 1000
European Food Contact		+	+	+	+	+	+	+	+
FDA food contact		+	+	+	+	+			+

*(not for specification purposes)



Selecting the right PPA for different applications.

Guide to select the right PPA.

A key decision factor in PPA selection is the specific process (e.g. blown film) and related process parameters. Typically, the polymer type, rheology and processing temperatures will be important considerations in the choice of PPA type.

In any given process, the total additive package needs to be taken into account in order to avoid or minimise potential interactions which could affect the performance of the PPA.

Selection of the PPA also depends on the target benefit, such as melt fracture elimination, pressure reduction, or die build-up reduction.

1. Blown Film Extrusion.

With the advent of high performance polyolefins such as LLDPE, and mLLDPE, leading to exceptional film characteristics, a variety of process issues became evident: melt fracture (or “sharkskin”), die build up, gel formation, bubble instability, surface defects etc. PPAs provide a solution for the majority of these processing problems.

A typical LLDPE resin formulation containing antiblock and slip agents, benefits from the use of a synergist containing PPA, such as FX 5920A, FX 5922, or FX 5927 (at a loading range of between 300 to 1000 ppm). This PPA series has been developed to provide improved efficiency and reduced tendency to interact with inorganic additives.

Another more specific example would be the extrusion of HDPE blown film, formulated with high titanium dioxide content (e.g. synthetic paper), where pressure and die build up are critical issues. Here, the most suitable PPAs are FX 9613 and FX 5911.

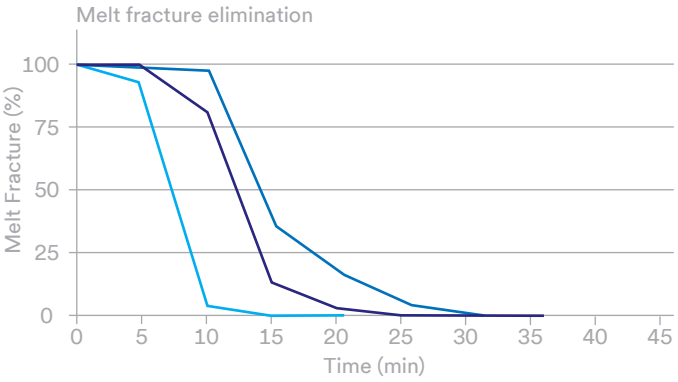
Best Performance	Good Performance
LLPDE without antiblocking and slip agents	
▶ FX 5920A / FX 5922 / FX 5927	▶ FX 9613
LLPDE with antiblocking and slip agents	
▶ FX 5920A / FX 5922 / FX 5927	
LLPDE with HALS	
▶ FX 9613	▶ FX 5920A / FX 5922 / FX 5927
HDPE with TiO_2 or Carbon Black, pigments	
▶ FX 5911	▶ FX 9613

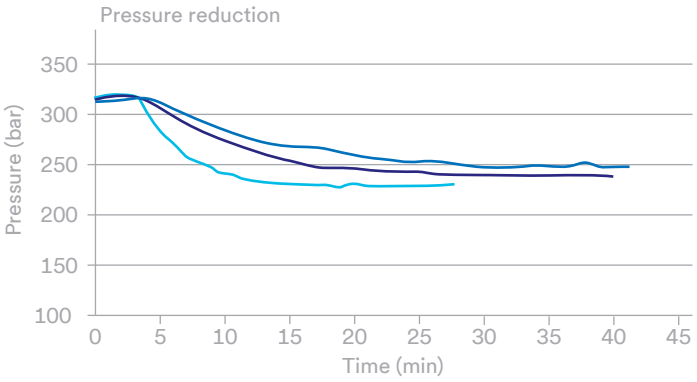
3M™ Dynamar™ Polymer Processing Additives.

Blown film line evaluation with C6 mLLDPE

mLLDPE: C6, MFI: 1.2, Density: 0.920, 200 ppm Dynamar PPA, no antiblock

FX 5920A FX 5922 FX 5927

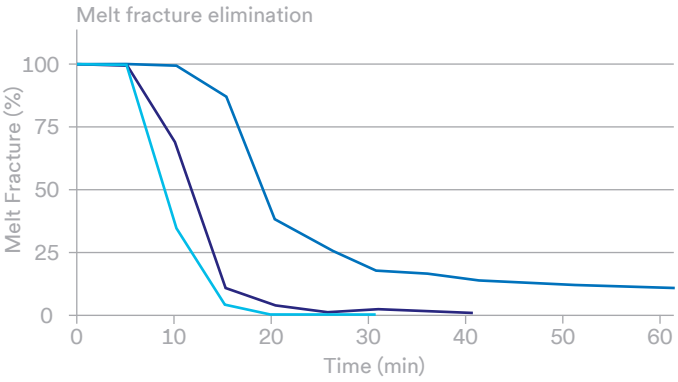


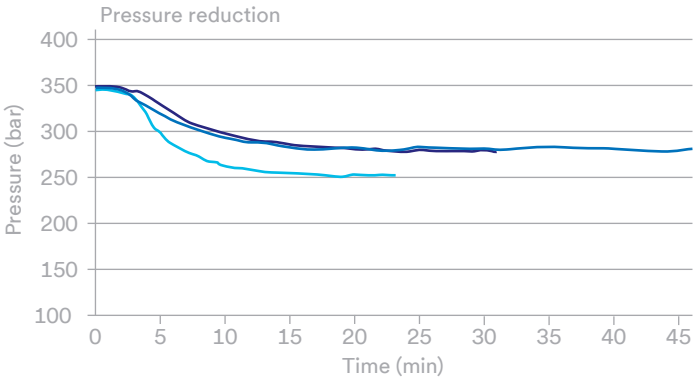


Blown film line evaluation with C4 LLDPE

LLDPE: C4, MFI 0.7; density 0.925, 1000 slip, 2000 ppm antiblock, 400 ppm PPA

FX 5920A FX 5922 FX 5927





2. Cast Film.

In this process, typically higher processing temperatures and/or shear rates are employed. Consequently, die build-up and resulting film defects can be an issue, leading to excessive machine down-time.

The addition of small amounts of FX 9613 or FX 5917, typically at lower loadings than used for blown film, will delay the onset of deposition at the die exit. Levels of 300 ppm or lower can provide significant productivity improvements.

In special applications, such as breathable film, with high loadings of inorganic fillers, there can be a rapid deposit formation at the die lip, as well as a higher torque loading, which can affect product quality and output. In this case, the most suitable PPA is FX 5911, at up to 1000 ppm.

Best Performance — Good Performance

Transparent LLDPE

▶ FX 5917 ▶ FX 9613

LLPDE with high inorganics content

▶ FX 5911 ▶ FX 5917 ▶ FX 9613

PP raffia, tapes

▶ FX 5911 ▶ FX 5917 ▶ FX 9613

BOPP

▶ FX 9613

3. Multilayer Film Extrusion.

With today's growing trend towards multilayer film architecture, which may be blown or cast, novel problems can arise. Due to the differing layer thicknesses and variety of polymers used, having differing rheologies, and providing a range of functionalities, such as barrier properties, adhesion, mechanical properties, and cost reduction, it is possible that the layers will meet at conflicting rates. This velocity gradient can cause turbulence at the interface, disrupting the optical clarity – a key criterion in food packaging, e.g. meat and poultry barrier films. This phenomenon is known as "interfacial instability".

As a first approach to this more complex case, the same recommendations apply in accordance with the respective process. To determine the film layers that would require PPA addition and the appropriate concentration, technical support is available using 3M's own laboratory facilities and expertise.

Reduction of die build up in cast film

with PPA

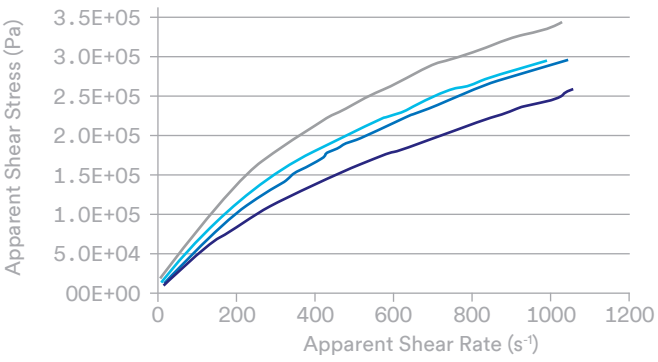
without PPA

Reduction of interfacial stability in cast film

with PPA *without PPA*
3-layer film (mLLPDE / MDPE / mLLPDE)

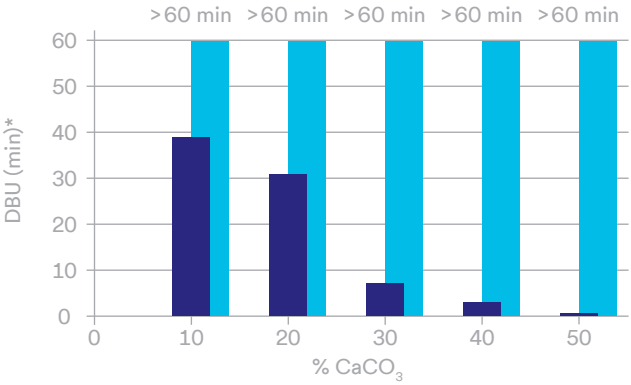
The influence of Dynamar PPA in the extrusion of breathable film.

Shear stress reduction



mLLDPE
mLLDPE + 50% $CaCO_3$
mLLDPE + 50% $CaCO_3$ + 1000 ppm FX 5911
mLLDPE + 1000 ppm FX 5911

Reduction of die build up



1000 ppm FX 5911
No PPA

*Time when die build up initially observed

4. Pipe Extrusion.

Plastic pipe has, to a large extent, replaced conventional construction materials such as metal, concrete and clay composites.

Polymers used include HDPE, MDPE, LLDPE, LDPE, PP and PVC for different end uses, such as gas and water high pressure pipes, floor heating, drainage, irrigation, and sewage systems.
Process issues encountered relate to overall pipe dimensions and rheological behaviour of the polymer, as well as the presence of other additives such as carbon black and pigments.

These issues include head pressure, die deposit, and surface defects, all of which can benefit by adding PPA at levels from 250 ppm up to 1000 ppm, resulting in quality and productivity improvement.

The addition of PPAs to HDPE, MDPE, LLDPE, LDPE, and PP resins in the manufacturing of high pressure pipes, cross-linked pipes for floor heating, and drainage and sewage pipes may result in overall higher productivity.

Benefits in pipe extrusion:
- ✓ Reduction of die build up
- ✓ Reduction of back pressure
- ✓ Reduction in processing temperatures
- ✓ Higher output
- ✓ Better surface

Best Performance Good Performance

High Pressure Pipes

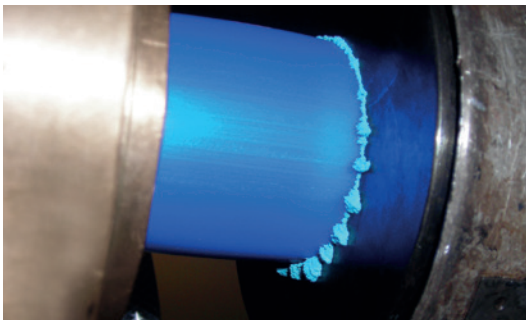
▶ FX 5911 ▶ FX 9613

Cross-linked Pipes

▶ FX 5911 ▶ FX 9613 ▶ FX 5920A

Corrugated Pipes

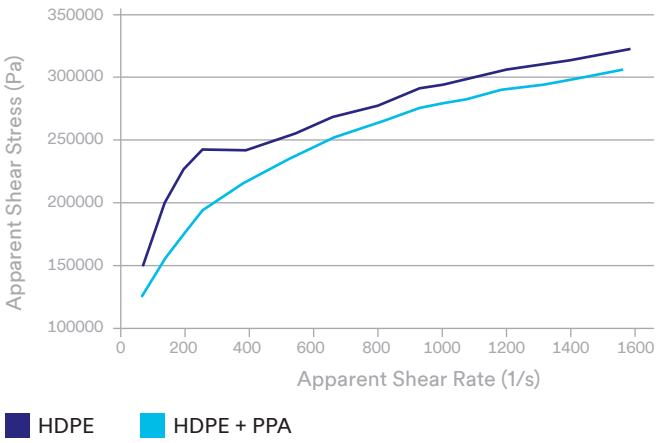
▶ FX 5911 ▶ FX 5917 ▶ FX 9613

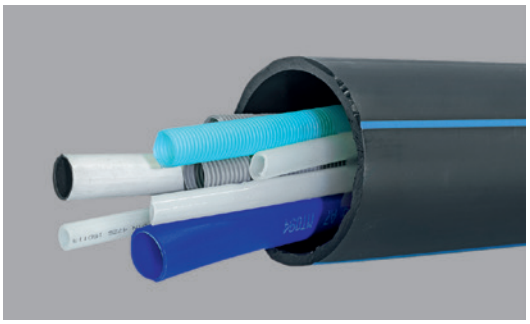


Die build up in HDPE pipes

Pressure reduction in HDPE Pipe extrusion

Capillary rheometry is a tool used to demonstrate the possible processing enhancements that can be achieved by addition of a 3M™ Dynamar™ PPA.





Long term aging data

Tests conducted by independent institutes, on pipes manufactured under real production circumstances, reveal that Dynamar PPA has no effect on the long term hoop stress (LTHS) properties of the pipe.

5. Other Extrusion Processes.

Any continuous extrusion process with shear rates in the range of 50 – 2000 sec-1 may be influenced by PPA. Typical extrusion benefits provided by PPA, depending upon formulation and processes, are:

- ✓ Reduction of die build up
- ✓ Pressure reduction
- ✓ Faster colour change over
- ✓ Energy savings
- ✓ Better surface quality

Best Performance	Good Performance
Sheet extrusion	
▶ FX 5912	▶ FX 5911 ▶ FX 9613
LDPE, HDPE & PP artificial grass	
▶ FX 5911	▶ FX 9613
PP carpet backing	
▶ FX 5911	
Cable extrusion	
▶ FX 5912	
Polyamide black compounds	
▶ FX 5914	▶ FX 5911
Polyamide for barrier film	
▶ FX 5914	
WPC, Wood Plastic Composites	
▶ FX 5911	
Other engineering resins	
▶ FX 5911	▶ FX 5914

Technical Information and Test Data

Technical information, test data, and advice provided by Dyneon personnel are based on information and tests we believe are reliable and are intended for persons with knowledge and technical skills sufficient to analyse test types and conditions, and to handle and use raw polymers and related compounding ingredients. No license under any Dyneon or third party intellectual rights is granted or implied by virtue of this information.

General recommendations on health and safety in processing, on work hygiene and on measures to be taken in the event of accident are detailed in our material safety data sheets.

You will find further notes on the safe handling of fluoropolymers in the brochure “Guide for the safe handling of Fluoropolymers Resins” by PlasticsEurope, Box 3, B-1160 Brussels, Tel. +32 (2) 676 17 32.

The present edition replaces all previous versions. Please make sure and inquire if in doubt whether you have the latest edition.

Important Notice

All information set forth herein is based on our present state of knowledge and is intended to provide general notes regarding products and their uses. It should not therefore be construed as a guarantee of specific properties of the products described or their suitability for a particular application. Because conditions of product use are outside Dyneon’s control and vary widely, user must evaluate and determine whether a Dyneon product will be suitable for user’s intended application before using it. The quality of our products is warranted under our General Terms and Conditions of Sale as now are or hereafter may be in force.

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