HIGH PERFORMANCE POLYMERS

RADILON® D SUSTAINABLE

The Radilon® D trade name identifies the long molecular chain PA6.10 grades that have been developed for injection moulding and extrusion. These products, made with 64% renewable source materials, are polymerized from hexamethylenediamine and sebacic acid at RadiciGroup Specialty Chemicals plants and then compounded at various RadiciGroup High Performance Polymers production sites located all over the world. Sebacic acid is a substance of biological origin obtained from castor oil plant (Ricinus communis) seeds. The plant is cultivated, mostly in China and India, in arid environments and, for this reason, does not compete with agricultural products for human consumption.

Radilon® D grades

	PRODUCT NAME	PRODUCT DESCRIPTION	MAIN CHARACTERISTICS
FOR INJECTION MOULDING	**RADILON® D HS 105M**	Unfilled general purpose.	Good dimensional stability and chemical resistance.
	RADILON® D HSKC	Unfilled, hydrolysis stabilized.	Suitable for heating and plumbing applications.
	RADILON® D HS 3032	Unfilled, high gloss.	Suitable for automotive interior parts. Excellent chemical resistance.
	RADILON® D RV300W	30% glass-fibre filled, heat stabilized.	Good mechanical properties, excellent dimensional stability and chemical resistance.
	RADILON® D RV300K	30% glass-fibre filled, heat stabilized.	Good mechanical properties, excellent dimensional stability and chemical resistance.
	RADILON® D ERV300W	30% glass-fibre filled, heat stabilized, impact modified.	Designed for tube connectors (including fuel lines).
	RADILON® D RV600RKC	60% glass-fibre filled, heat and hydrolysis stabilized.	High stiffness. Suitable for heating and plumbing applications. KTW approved 60°C.
	RADILON® D RV300RG	30% glass-fibre filled, heat stabilized, resistant to automotive coolants.	Suitable for parts in contact with cooling fluid, especially in the automotive field.
FOR EXTRUSION	**RADILON® D 24D**	Unfilled general purpose, low viscosity.	Suitable for monofilament extrusion and injection moulding.
	RADILON® D 27D	Unfilled general purpose, standard viscosity.	Suitable for monofilament extrusion and injection moulding.
	RADILON® D 40P50K	Plasticized, heat stabilized.	Suitable for pipes. Specific for in-tank fuel lines.
	RADILON® D 40EP50XK1C	Plasticized, impact modified and heat stabilized. Lower electrical resistivity (antistatic).	Designed for the internal antistatic layer of fuel lines.
	RADILON® D 40K	High viscosity, heat stabilized.	Suitable for the extrusion of pipes and profiles.
	RADILON® D 40E75K	High viscosity, impact modified, heat stabilized.	Rigid. Suitable for oil and gas sector applications and cooling pipes.
	RADILON® D 40E75W	High viscosity, impact modified, heat stabilized.	Rigid. Suitable for pipes, including oil transmission pipes.
	RADILON® D EP25ZK	Heat stabilized, plasticized and impact modified.	Flexible grade for pneumatic pipes.
	RADILON® D EP35XUK100M	Heat stabilized, impact modified and UV stabilized.	Semi-flexible. Suitable for outdoor exposed parts and for injection moulding.
	RADILON® D 40EP25ZW	High viscosity, heat stabilized, plasticized and impact modified.	Semi-flexible. Designed for air pipes and tank breather hoses.
	RADILON® D E35ZW	Heat stabilized, impact modified.	Semi-flexible. For air and oil pipes.

Figure 1 | Castor oil seeds used to make sebacic acid, one of the raw materials in the production of PA6.10

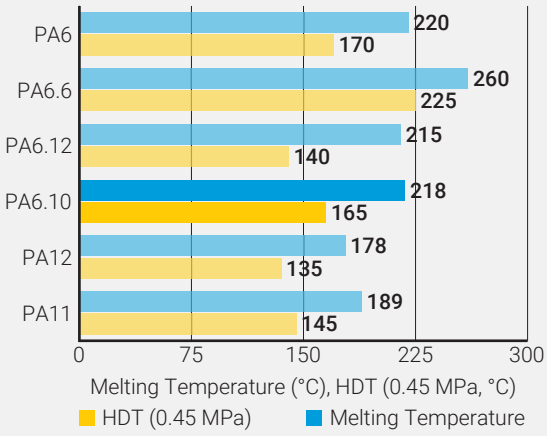
Figure 2 | Castor oil plant (Ricinus communis)

Properties comparison

Radilon® D polyamide 6.10 is a semi-crystalline polymer suited to highly technical applications. Among its main characteristics are:

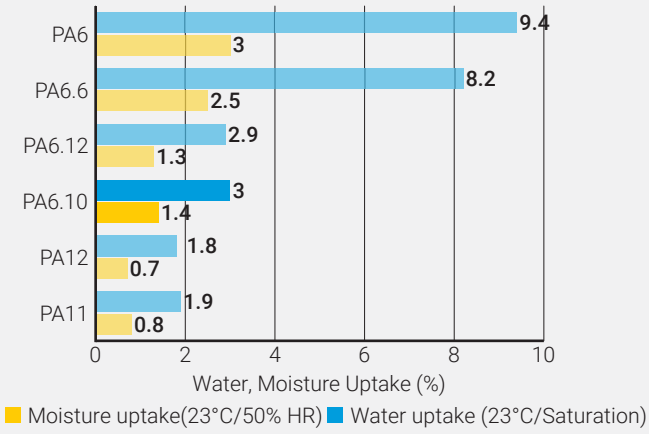
- Greater dimensional stability compared to PA6 and PA6.6, due to less water and moisture uptake
- Higher chemical resistance compared to PA6 and PA6.6
- Greater resistance at high temperatures than PA12
- Excellent hydrolysis resistance

The following graphs compare some of the important characteristics of Radilon® D, PA11, PA12, PA6.12, PA6 and PA6.6. The values were obtained for base polymers. Adding modifiers, stabilizers and fillers may change the behaviour of the materials significantly.



Melting Temperature and HDT

Chart 1 | PA6.10 HDTs and melting points are higher than the corresponding values for PA11 and PA12. These characteristics can be valuable indicators for determining the usability of a polymer at high temperatures. The trend in car fuel systems is clearly towards higher temperatures, particularly in diesel engines. A material such as PA6.10 can be a valid alternative, especially for those applications in which PA12 seems to have reached its intrinsic thermal resistance limit.



Water and Moisture Uptake Comparison (ISO 62)

Chart 2 | Polyamide 6.10 is slightly more hygroscopic compared to both PA11 and PA12. However, the dimensional stability of PA6.10 has proven to be more than adequate for many applications. Moreover, water uptake at saturation is only a third of the value for PA6 and PA6.6.

Applications

Radilon® D has been tested and approved for many applications, among which:

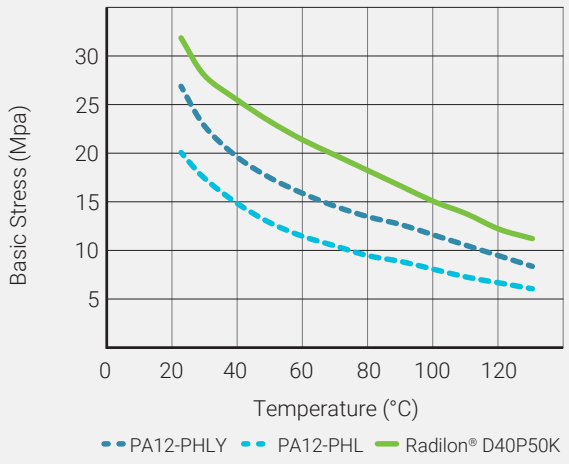
- Pneumatic tubing
- In-tank fuel lines
- Tank breather hoses
- Truck air brake pipes
- Fuel line connectors

Additionally, RadiciGroup High Performance Polymers has developed special materials targeted at applications such as in-tank fuel lines (Figure 7), fittings for the heating and plumbing sector (thanks to Radilon® D's excellent glycolysis resistance) and air tubing for high temperature applications, as well as special materials with excep- tionally high impact resistance and weather resistance for the sports sector.

Application: Pneumatic pipes tubing

Chart 3 shows a graph of the basic stress values taken at temperatures of up to 130°C according to the DIN 73378 standard. It can be seen that, in the case of Radilon® D 40P50K (semi-transparent), the basic stress valuesare higher than required by the standard and greater than the values measured for two types of PA12 used in the same applications.

Figure 3 | Spiral-shaped pneumatic tubing manufactured using Radilon® D 40P50K 100 Nat. The material is partly transparent and can be dyed different colours.



DIN 73378: Basic stress comparison

Chart 3 | Basic stress plotted as a function of operating temperature for two Radilon® D 40P50K products used for pneumatic tubing.

Applications: In-tank fuel lines, tank breather hoses

Figure 4 shows in-tank fuel line hoses made of Radilon® D 40P50K. A second version for the same application was designed with two layers. The internal layer was made of Radilon® D 40EP50XK1C 333 BK, a slightly conductive material that prevents electrostatic charge buildup.

Figure 4 | In-tank fuel line hoses made of natural and black Radilon® D 40P50K.

Figure 5 shows a tank breather hose made of blue Radilon® D 40EP25ZW.

This application requires:
- Burst pressure retention after fuel ageing
- Impact resistance at -40 °C, also after heat ageing
- Resistance to zinc chloride and calcium chloride (SAE J844)
- Strict dimensional tolerances on the corrugated hose
- Excellent processability by extrusion

Figure 5 | Tank breather hose made of Radilon® D 40EP25ZW 7037 BL.

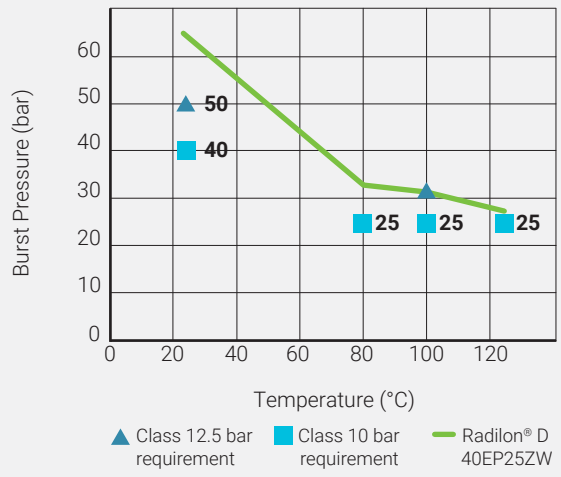
Figure 6 | Truck brake pipes made of Radilon® D 40EP25ZW 333 BK.

Applications: Truck air break lines and brake booster vacuum hoses

For truck air brake lines (Figure 6), RadiciGroup High Performance Polymers offers Radilon® D 40EP25ZW.

Key features of this flexible grade are:
- Stress cracking resistance
- UV resistance
- Compliance with requirements of standards ISO 7628, DIN 74324, SAE J844, FMVSS106
- Excellent processability by extrusion

Chart 4 shows the burst pressure measured on 6x8 mm pipes. Based on the burst pressure curve up to a temperature of 125°C, the material is suitable for applications at a nominal pressure of up to 10 bar and up to 12.5 bar (according to ISO 7628).



Radilon® D 40EP25ZW - Standard ISO 7628 burst pressure for 8X6 mm pipes

Chart 4 | Burst pressure values at different temperatures for Radilon® D 40EP25ZW (ISO 7628)

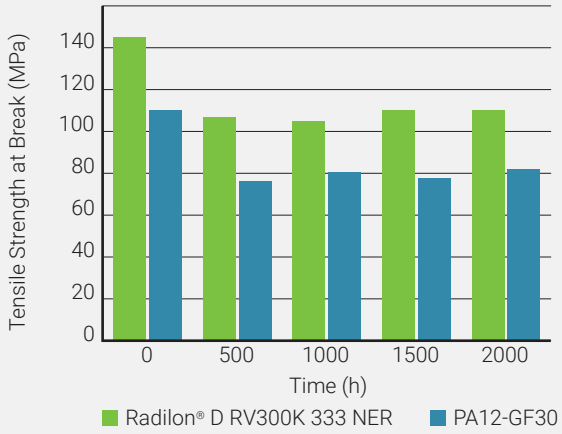
The physical and mechanical properties of various Radilon® Ds for tubes are summarized in the table below. RadiciGroup High Performance Polymers provides differentiated solutions that can meet the technical specifications of diverse applications.

PROPERTY	UNIT	D 40P50K PLASTICIZED TRANSLUCENT	D 40EP35XK IMPACTMODIFIED ANDPLASTICIZED ANTISTATIC	D 40EP25ZW IMPACTMODIFIED ANDPLASTICIZED FLEXIBLE	D E35ZW IMPACTMODIFIED FLEXIBLE	D 40E75W IMPACTMODIFIED RIGID
Density	g/cm³	1.09	1.13	1.04	1.00	1.03
Melting point	°C	215	217	215	220	220
Water uptake (24h-23°C/Saturation)	%	1.1/2.5	0.7/1.5	0.9/2.0	0.8/1.9	
Yield strength (DAM/RH50)	MPa	42/30	34/28	30	23/19	40
Elongation at break (DAM/RH50)	%	>100/>100	70/>100	>100/>100	>50/>100	>100
Tensile modulus (DAM/RH50)	MPa	920/550	1000/680	580	800/580	1400
Charpy notched impact strength at 23°C (DAM/RH50)	KJ/m²	25/40	55/	85	80/90	63
Charpy notched impact strength at -30°C	KJ/m²	6	-	-	75	-
Charpy unnotched impact strength at 30°C	KJ/m²	NB	-	NB	NB	NB

Applications: Fuel system connectors

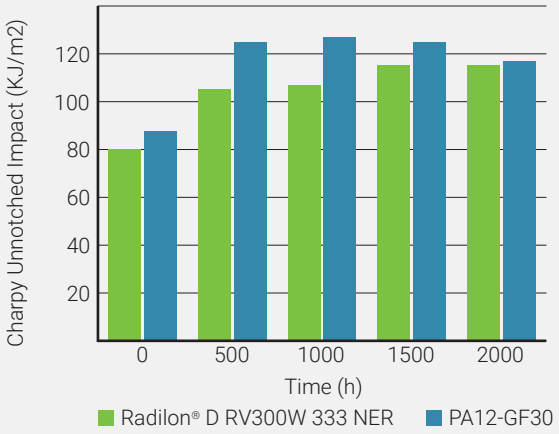
The materials proposed by RadiciGroup High Performance Polymers for fuel system connectors (Figure 7) are Radilon® D RV300W 333 BK and Radilon® D ER- V300W 333 BK (improved deformation at break version). Components manufactured with these materials have exhibited excellent dimensional stability and impact resistance characteristics in circulation tests using E10 and E24 fuels and B10 and B30 diesel fuels. The graphs below show how some of the mechanical properties of the materials change over time after immersion in zinc chloride solutions, after ageing in fuel and after thermal ageing in air.

Figure 7 | Fuel connector made with Radilon® D RV300W 333 Ner.



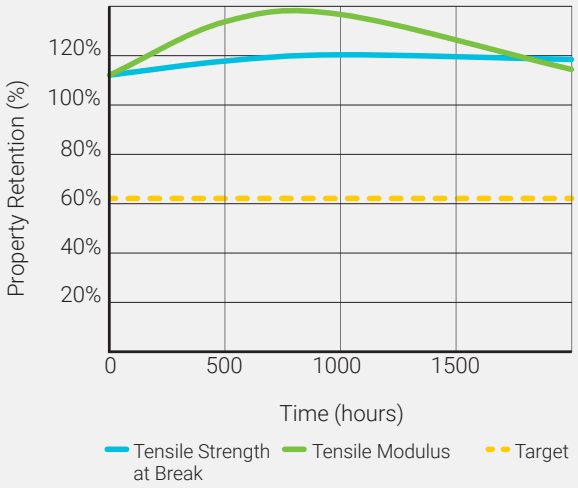
Ageing in E24 fuel at 90°C.

Chart 5 | Change over time in tensile strength after immersion of the materials in fuel containing 24% ethanol. Radilon® D RV300W 333 Ner follows the same trend as PA12-GF30, which has been used to manufacture fuel connectors up to now.



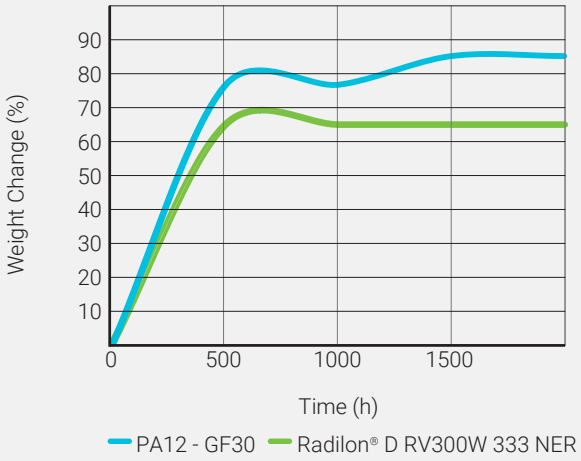
Ageing in E24 fuel at 90°C

Chart 6 | Change over time in Charpy unnotched impact strength after immersion of the materials in fuel containing 24% ethanol. For Radilon® D RV300W 333 Ner, the graph shows that Charpy unnotched impact strength steadily increases with immersion time and, after 2000 hours, becomes greater than its initial value. On the other hand, for PA12-GF30, after 1000 hours, Charpy unnotched impact strength begins to decrease, which could be a sign of the onset of material degradation. No decline in impact strength is observed for Radilon® D RV300W 333 Ner.



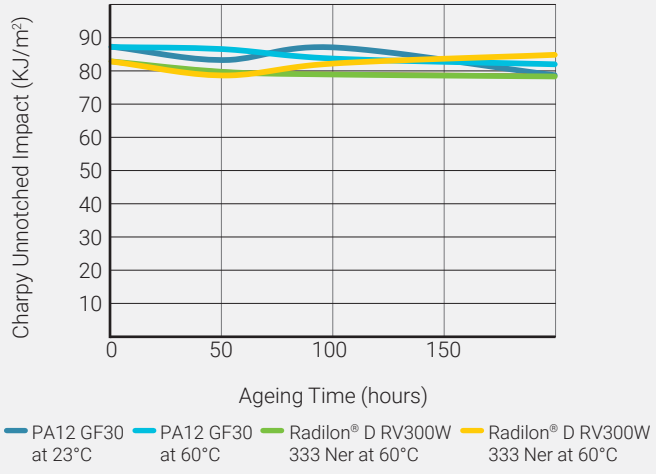
Ageing in air at 130°C

Chart 7 | Change over time in the mechanical properties of the materials after ageing of up to 2000 hours.
After 2000 hours, Radilon® D RV300W 333 Ner shows no decline in either tensile strength at break or tensile deformation at break compared to the initial values. This product, which is heat stabilized to ensure component integrity against deterioration from thermal ageing, is well within the limit set forth in many technical specifications that the loss in mechanical properties be no greater than 50%.



Ageing in E24 fuel at 90°C

Chart 8 | Weight change over time after immersion of the materials in gasoline containing 24% ethanol.
The graph shows that, after 2000 hours of immersion, the change in weight for Radilon® D RV300W 333 Ner is 2% less than for PA12-GF30. This result demonstrates that Radilon® D has greater dimensional stability.



Ageing in a 50/50 zinc-chloride solution at 23°C and 60°C

Chart 9 | The graphs demonstrate that, after ageing in a 50/50 water/zinc chloride solution at 23°and 60°C, there is no significant change in the Charpy unnotched impact strength of Radilon® D RV300W 333 Ner. These results confirm the excellent chemical resistance of Radilon® D compared to PA12.

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