

HIGHPERFORMANCEPOLYMERS FOR THE ELECTRICAL & ELECTRONIC MARKETS

Based on its extensive experience with flame retardant technologies, RadiciGroup High Performance Polymers offers a wide range of semi-crystalline products specifically for electrical and electronic applications.

The E&E materials portfolio includes Radiflam® and Radilon® polyamide, PBT and PPA compounds.



Introduction

RadiciGroup High Performance Polymers provides both standard and innovative solutions for Electrical and Electronic (E&E) market needs and is constantly working to meet the most stringent requirements of this industry sector. Health and environmental protection, product safety and performance requirements, together with cost efficiency, are always priorities for the company when developing a new grade. More in detail, the four main drivers below influence material development by RadiciGroup High Performance Polymers, according to the latest regulations and trends of the E&E industry.

HEALTH AND ENVIRONMENTAL PROTECTION Materials for the E&E market are required to comply with the **WEEE** Directive (EU Directive on waste electrical and electronic equipment), the **RoHS** Directive (EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment) and the **REACH** Regulation (EC Regulation on the registration, evaluation, authorisation and restriction of chemicals), in order to provide protection for human health and the environment.

PRODUCT SAFETY Fire behaviour, electrical properties, low smoke density and toxicity have great importance in the E&E market. Indeed, materials must comply with restrictive tests in conformity with the latest **IEC, VDE, UL and EN 45545-2** standards and others.

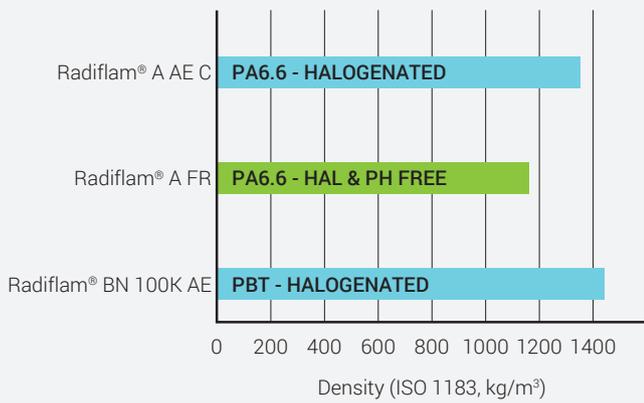
PERFORMANCE The development of new thermoplastic flame retardant grades aims at satisfying continuously increasing performance requirements. Excellent flame retardant behaviour and high **mechanical, chemical and thermal properties** are some of the typical demands of the E&E industry. A very important technical aspect is the ease of processing, especially in flame retardant products where particular attention must be paid to mould corrosion and deposit formation. For increasingly thinner components, such as connectors, the challenge is to offer very fluid materials with high mechanical properties.

GLOBAL OFFERING **Worldwide material availability** and global technical service support are key priorities at RadiciGroup High Performance Polymers. Computer-aided engineering **simulations** (CAE Service for process and structural simulation using an integrated approach) is also offered in order to speed up the component development phase.

Flame retardant technologies

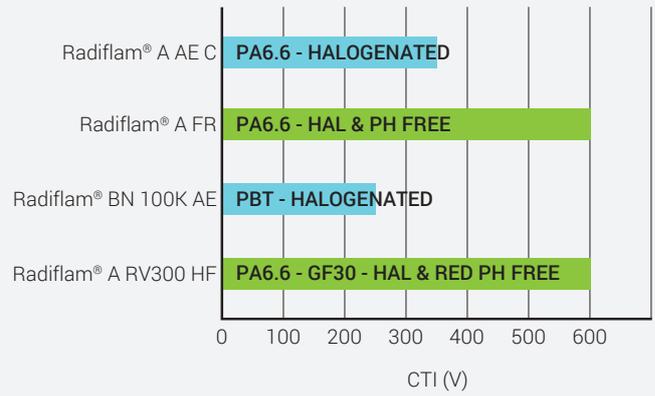
RadiciGroup High Performance Polymers uses three main flame retardant (FR) technologies: halogen- and (red) phosphorous-free, red phosphorous, and halogenated. Each type of flame retardant has its own advantages and peculiarities. RadiciGroup High Performance Polymers offers a complete material portfolio able to meet the requirements for diverse E&E market applications. As regards FR product development, special effort has been devoted to halogen-free compounds compliant with the WEEE Directive.

TECHNOLOGY	RADICIGROUP HIGH PERFORMANCE GRADES	ADVANTAGES	DISADVANTAGES
NITROGENATED	RADIFLAM® FR (unfilled) RADILON® FR2 (filled)	Halogen- and phosphorous-free Good electrical properties CTI (600 V) Lower density compared to other systems	GWIT 775°C difficult to achieve on some formulations For glass/mineral filled grades, only UL V-2 achievable Mechanical properties on filled grades Fumes may contain HCN
INORGANIC HYDROXIDE	RADIFLAM® FR (filled)	Halogen- and phosphorous-free High CTI (600 V) All colours High LOI Low smoke density and toxicity High stiffness	Impact resistance Density Part surface appearance GWIT 775°C difficult to achieve on some formulations
ORGANIC PHOSPHINATES	RADIFLAM® HF	Halogen- and red phosphorous-free All colours Good mechanical properties Good electrical properties WEEE compliant	GWIT 775°C difficult to achieve on some formulations
RED PHOSPHOROUS	RADIFLAM® AF	Good mechanical properties Good CTI Cost competitive	Only black and natural (brownish) colours Risk of circuit corrosion, especially in hot and humid environments Fumes toxicity due to the presence of phosphine GWIT 775°C difficult to achieve on some formulations
HALOGENATED	RADIFLAM® AE	Excellent GWFI, GWIT (>775°C), GWEPT All colours Good mechanical properties	Lower CTI Smoke density and toxicity Density WEEE conflict



Density comparison

Chart 1 | Halogenated PA6.6 and PBT have a higher density than halogen- and phosphorous-free PA6.6



CTI comparison (IEC 60112)

Chart 2 | PA6.6-GF 30 and halogen- and (red) phosphorous-free PA6.6 have a higher CTI than halogenated PA6.6 and PBT

Polyamide and PBT success factors

Radilon® and Radiflam® A (PA6.6) and S (PA6) polyamides successfully meet the requirements of the E&E market and are widely used in numerous applications. Their success factors are their excellent mechanical, thermal and electrical properties. Moreover, in line with the E&E market drivers and trends, polyamides can be modified with different flame retardants, show good performance even after long exposure to heat, withstand the most severe operating conditions and are characterized by ease of processing and high productivity.

To complete the product range for the E&E sector, Raditer® B and Radiflam® B PBT-based materials have also been developed, including special hydrolysis-resistant materials. Raditer® B and Radiflam® B products exhibit constantly good electrical, mechanical and dimensional properties, as well as long-term thermal performance.

RadiciGroup High Performance Polymers product range

The RadiciGroup High Performance Polymers E&E portfolio includes a wide range of thermoplastic semi-crystalline products modified using different FR technologies. More specifically, Radilon® and Radiflam® polyamides are available with each of the three types of flame retardants; Radiflam® PBT compounds are available only in the halogenated form; and Radiflam® Aestus partially aromatic polyphthalamide (PPA) compounds, only in halogen- and red phosphorous-free.

Radiflam® is the brand name for PA, PPA and PBT compounds with excellent flame retardant properties and the highest UL ratings (V-0 and 5VA). Depending on the E&E application, Radilon® PA and Raditer® PBT compounds, which have lower UL V-2 or HB ratings, may also be suitable.

These grades can be modified with different kind of fillers and additives and, depending on the FR technology, are available in different colours.

Yellow cards are available for many grades.

Below is the full range of RadiciGroup High Performance Polymers E&E materials.

RADICIGROUP HIGH PERFORMANCE GRADES	FLAME RETARDANT TECHNOLOGY	UL 94
RADIFLAM® FR (unfilled)	NITROGENATED	Self-extinguishing V-0
RADILON® FR2 (filled)	NITROGENATED	Self-extinguishing V-2
RADIFLAM® FR (filled)	INORGANIC HYDROXIDE	Self-extinguishing V-0
RADIFLAM® HF	ORGANIC PHOSPHINATES	Self-extinguishing V-0
RADIFLAM® AF	RED PHOSPHOROUS	Self-extinguishing V-0
RADIFLAM® AE	HALOGENATED	Self-extinguishing V-0
RADILON®	HALOGENATED, NITROGENATED, OTHERS	Self-extinguishing V-2, HB

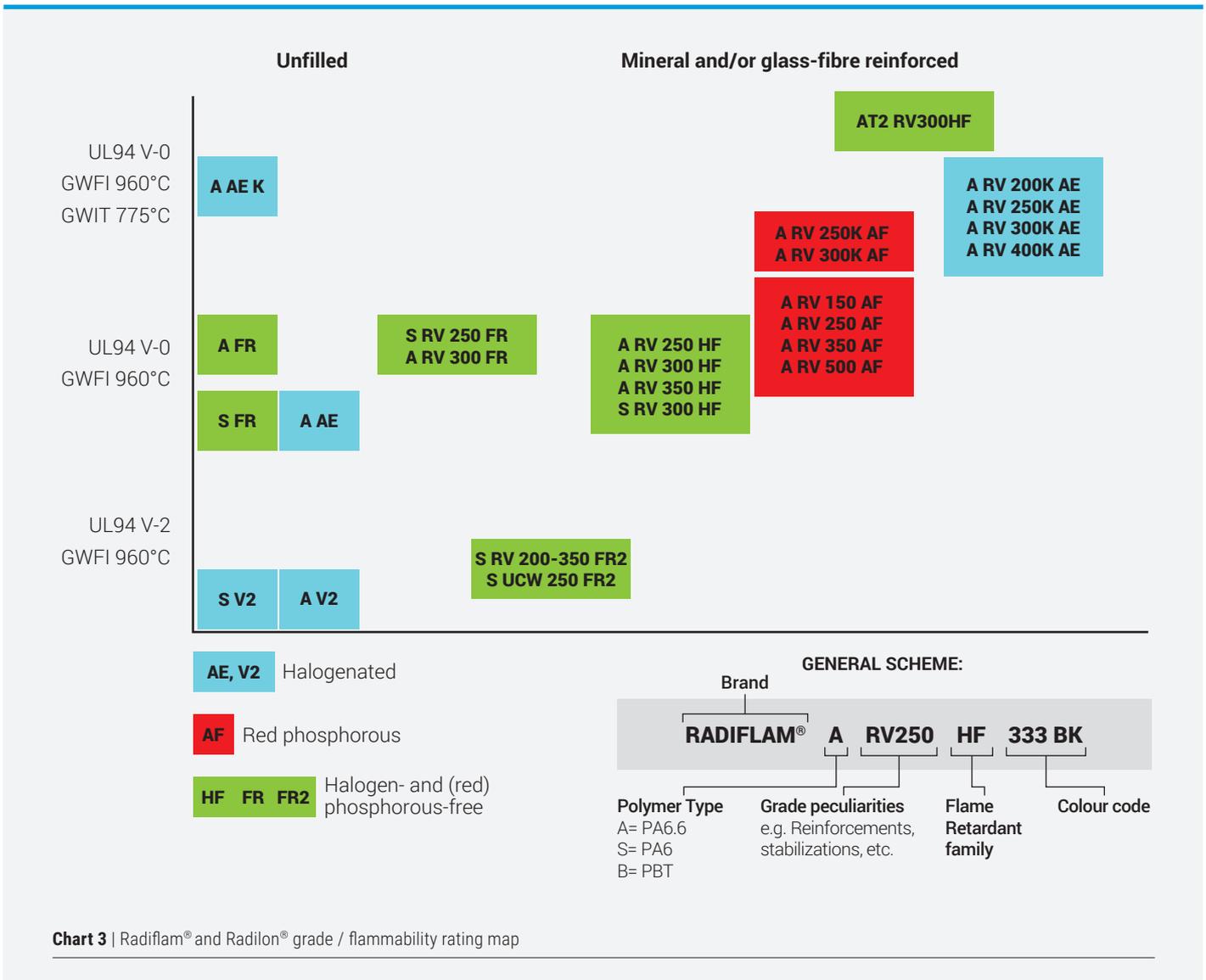


Chart 3 | Radiflam® and Radilon® grade / flammability rating map

Typical segment applications

RadiciGroup High Performance Polymers aims to meet the specific material needs for every E&E market segment. The most important application areas are power distribution and industrial control, insulation systems, connectivity systems and cable ties.

Power distribution and industrial control

The RadiciGroup high-performance polyamide portfolio perfectly suits the requirements of the highly demanding applications in power distribution and industrial control.

Radilon® S RV200FR2 is a polyamide 6 grade with 20% GF (glass fibers) for **MCBs** (mini circuit breakers). The special features of this product are: UL 94 V-2 rating, GWFI 960°C and laser markability.

Radiflam® A RV 250 HF, a halogen- and red phosphorous-free flame retardant UL V-0 PA6.6–GF 25, is currently used for **MCCBs** (moulded case circuit breakers), contactor housings, refrigerator electronic power module housings and similar products. This material combines excellent flame resistance for reduced wall thickness (UL V-0



Figure 1 | MCB



Figure 2 | Industrial plug



Figure 3 | Switch & socket

at 0.75 mm; UL 5VA at 1.5 mm) and good electrical insulating properties; it exhibits high mechanical performance even at elevated temperatures. **Radiflam® Aestus T2 RV 300 HF**, a halogen- and red phosphorous-free PPA-GF 30, is an ideal high-end material solution for new MCCBs and is particularly suitable for **thermoset replacement**, due to its fire retardancy (UL V-0 at 0.4 mm), high melting temperature and good mechanical property retention.

The PA6 **Radilon® S HSUK 213 WT** is currently successfully used for **domestic switches** and **sockets** due to its excellent surface appearance and white colour stability. **Radilon® S HS 9210 GY** is another example of a PA6 compound meeting all the material requirements for the production of **industrial sockets**: UL V-2 rated, CTI (comparative tracking index) 600 V, GWFI (glow wire flammability index) 875°C at 1.5 to 2 mm and impact resistance at low temperatures.

Insulation systems

Adequate electrical insulation is extremely important for E&E applications and must be ensured to prevent material failure resulting in free current flow and potentially serious injuries.

To guarantee the safe handling of products, RadiciGroup High Performance Polymers has paid great attention to the research and development of thermoplastic semi-crystalline compounds with improved insulating properties.

Typical characteristics are: low dielectric constant for a better insulating effect, high CTI (comparative tracking index) for better electrical breakdown properties, flame resistance and mechanical performance.

Radiflam® A RV250AF, a PA6.6-GF 25 red phosphorous-based compound, is currently employed as the preferred material for the production of **coil bobbins**, thanks to its high flammability rating (UL V-0 at 0.75 mm and 5VA at 1.5 mm) in combination with good mechanical properties.

A product proven to be highly effective for **electrical engine insulation parts** exposed to severe operating conditions is **Radilon® A RV350HHR 3800 BK**, an insulation class H (180°C) PA6.6-GF 35 characterized by superior heat ageing resistance.

Other solutions presently offered by RadiciGroup High Performance Polymers are for **stator housings** and **stator coils**. The requirements of such applications can be fully met by the Radilon® product family: **Radilon® S V2 181C NT** (UL V-2) PA6 halogenated for stator housings and **Radilon® A RV300K NT** (UL HB) heat stabilized PA6.6-GF30 for stator coils.

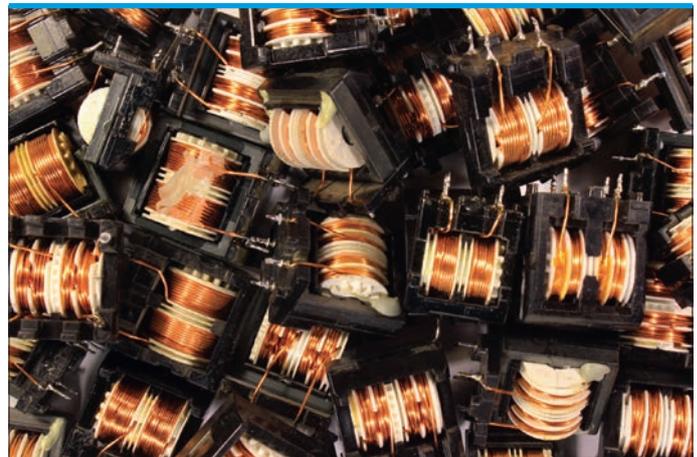


Figure 4 | Coil bobbin

Connectivity systems

Connection technology is definitely a growing market, and thus RadiciGroup High Performance Polymers has formulated specialized grades to fulfill the key requirements. The development of new high performance connectors is driven by the need for higher power, higher speed and small part size (miniaturization), in addition to easy processing.

Polyamide 6.6 is a perfect candidate for such applications. The halogen- and phosphorous-free PA6.6 **Radiflam® A FR** and **Radiflam® A FRX** are ideal for **connectors** and **terminal blocks**, as it shows excellent flame resistance (UL V-0 at 0.4 mm), good colourability and, among mechanical properties, good elongation at break. The halogenated version, **Radiflam® A AE 121C NT**, is also a suitable material for connectors. This grade is UL V-0 rated and, thanks to its robust glow wire performance, is compliant with IEC 60335-1.

Radiflam® red phosphorous-based compounds demonstrate excellent mechanical and electrical properties and, therefore, can be successfully used for connectors. A specific application example is **Radiflam® A RV250K AF**, a PA6.6-GF 25 that is currently the material of choice for the production of **oven connectors**.

For highly demanding new connectivity applications with the goal of higher power and speed yet smaller size, the PPA GF 30 **Radiflam® Aestus T2 RV300HF** (halogen- and red phosphorous-free) is the ideal material; it is suitable for lead-free soldering and displays excellent mechanical and thermal properties.

Cable ties

There are different kinds of cable ties in the market, which require specific properties, such as excellent productivity and mechanical performance. As concerns flame resistance, most often a UL V-2 rating is sufficient.

A number of Radilon® grades from the RadiciGroup High Performance Polymers range can be selected for this kind of application. For instance, PA6.6 **Radilon® A HS 164 NT** and **Radilon® A HSK 164 NT** have been successfully used for the production of **cable ties**, because they not only feature good colour stability and high productivity on multicavity tools but also can be heat stabilized. Another grade known for its good flowability is the impact modified and UV stabilized PA6.6 **Radilon® A LEP25XUK 3010 BK**, used for the production of **Colson cable ties**.

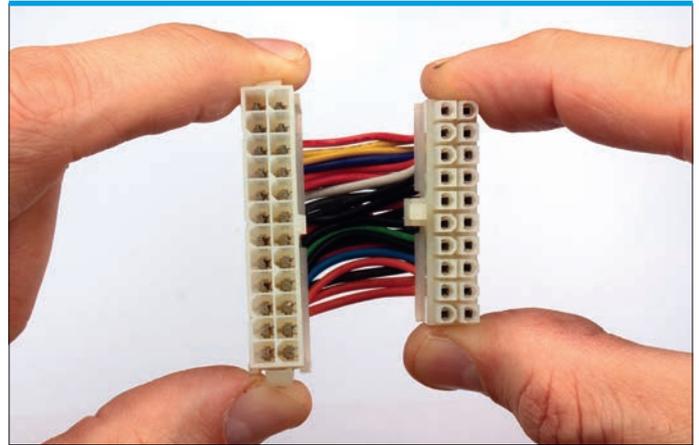


Figure 5 | Connector

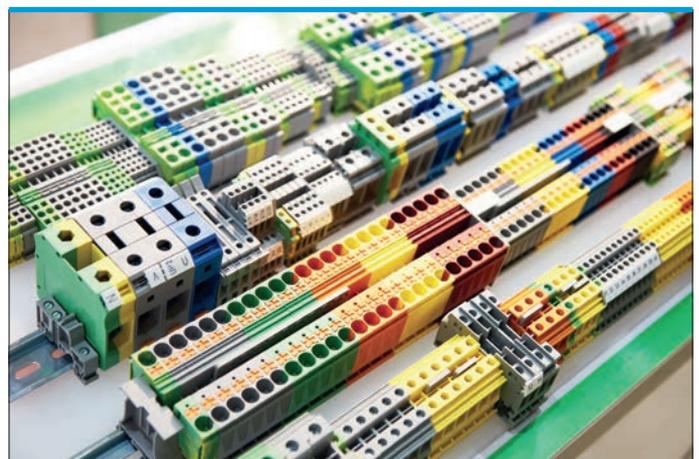


Figure 6 | Terminal block



Figure 7 | Cable ties

	MATERIAL FAMILY	GRADE	DENSITY [kg/cm ³]	** CHARPY NOTCHED, IMPACT STRENGTH, 23° [KJ/m ²]	** STRESS AT BREAK [MPa]	* STRAIN AT BREAK [%]	* TENSILE MODULUS [MPa]	HDT (1.80 MPa) [°C]	UL-94	GWIT [°C]	GWFI [°C]	*** CTI [V]
			ISO 1183	ISO 179/1eA	ISO 527-2/1A	ISO 527-2/1A	ISO 527-2/1A	ISO 75/2Af		IEC 60695-2-1/3	IEC 60695-2-1/2	IEC 60112
RADIFLAM® HF	PA6.6	ARV 250 HF	1360		135/-	2.8/-	8700/-	240	V0, 5VA	875 (3 mm)	960	600
		ARV 300 HF	1410	11/-	150/120	3/3.2	10050/8800	220	V0	875 (3 mm)	960	600
		ARV 350 HF	1470	12 /14	160/125	2.7/2.5	12200/10100	245	V0	875 (3 mm)	960	600
	PPA	AESTUS T2 RV 300 HF	1470	10/11	155/135	2.4/2.2	11100/11000	280	V0, 5VA	825 (3 mm)	960	600
	PA6	S RV 300 HF	1420	7/-	138/-	3/-	10700/-	190	V0	775 (2 mm)	960	550
RADIFLAM® FR	PA6.6	A FRX	1170	3/-	80/-	13/-	3700/-	85	V0	960 (0.4 mm)	960	600
		A FR	1160	4.5/6.5	77/50	12/ >50	3450/2600	70	V0	960 (0.4 mm)	960	600
	PA6	S FR 309 M	1160	5/-	75/-	12/-	3500/-	75	V0	960 (1 mm)	960	600
		S RV 250 FR	1770		150/-	1.85/-	14850/-	200	V0	725 (1 mm)	960	600
RADIFLAM® AF	PA6.6	A RV 250 AF	1380	7.8/11	130/90	2.8/3.2	7900/5150	230	V0, 5VA	800 (3 mm)	960	500
		A RV 300 AF	1420		135/85	2.5/2.5	9200/8000	230	V0	800 (3 mm)	960	550
		A RV 350 AF	1470	12/13	155/100	2.7/3	10900/9100	235	V0	800 (3 mm)	960	500
		A RV 500 AF	1550		175/-	2.2/-	14500/-	250	V0	825 (3 mm)	960	600
RADIFLAM® AE	PA6.6	A RV 250 K AE C	1550	10/12	125/-	1.9/-	9550/-	225	V0	930 (3 mm)	960	600
		A RV 300 K AE C	1610		130/-	1.8/-	11500/-		V0	930 (3 mm)	960	600
	PA6	S AE K C	1330	6.5/-	55/-	25/-	3000/-	80	V0	850 (1 mm)	960	300
		S RV 300 K AE C	1620	9/13	110/85	1.8/1.9	10900/9900		V0	875 (1 mm)	960	600
	PBT	B RV 200 K AE	1520	11	100	3	7000	190	V0		960	250
RADILON®	PA6.6	A HS 164	1140	5.0/15	80/50	4.6/30	3000/1300	70	V2		800 (2 mm)	600
	PA6	S RV 200 FR2	1310		70/-	8/-	5000/-	165	V2	775 (1.3 mm)	960	600
		S V2 181 C NT	1260	4.6/-	70/-	15/-	3250/-	95	V2	775 (1 mm)	850	300

* THE FIRST VALUE REFERS TO DAM (DRY AS MOULDED) STATE, THE SECOND TO CONDITIONED STATE ** FOR UNFILLED GRADES IS STRESS AT YIELD ***DAM STATE



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