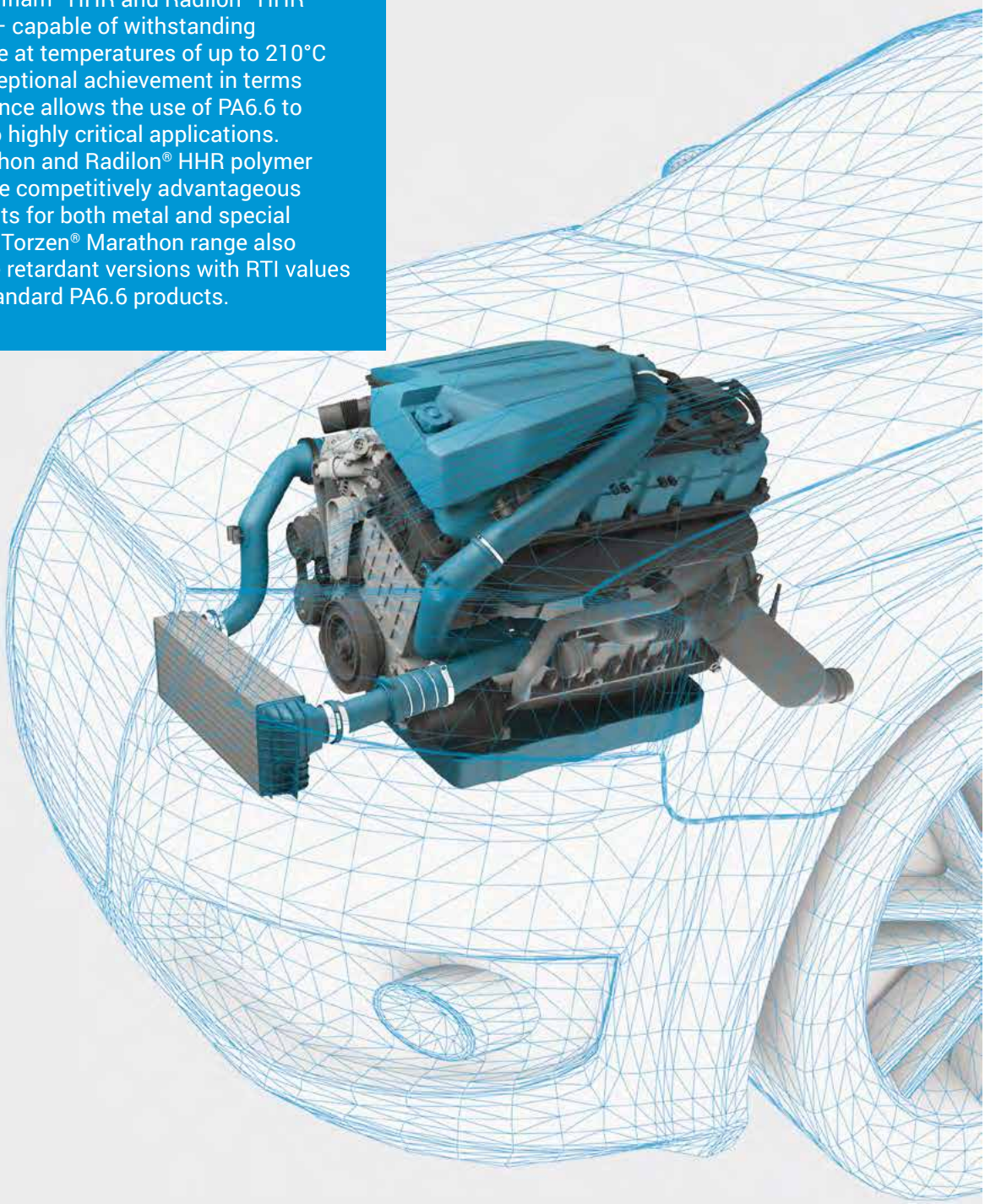
HIGH PERFORMANCE POLYMERS
HIGH TEMPERATURE PA

RadiciGroup High Performance Polymers offers PA6.6 materials – sold under the Torzen® Marathon, Radiflam® HHR and Radilon® HHR brand names – capable of withstanding continuous use at temperatures of up to 210°C in air. This exceptional achievement in terms of heat resistance allows the use of PA6.6 to be extended to highly critical applications. Torzen® Marathon and Radilon® HHR polymer compounds are competitively advantageous as replacements for both metal and special polymers. The Torzen® Marathon range also includes flame retardant versions with RTI values higher than standard PA6.6 products.



Ready to take on demanding challenges

The evolution towards greater engine efficiency, reduced dimensions and engines fitted into a more limited space requires the use of high performance materials in terms of heat resistance and life.

In Euro 6 engines, which are designed to comply with ever more stringent norms and regulations on the environment and fuel consumption, increased pressure is generated in the turbo system and the recirculated exhaust gas (EGR) causes an increase in under-the-bonnet temperature. All this requires the development and use of materials with enhanced performance and greater reliability during the entire life of the vehicle.

In the electrical and electronics industry, components must be capable of withstanding increasingly more severe service conditions, while meeting the need for further miniaturization. Moreover, to improve economic and environmental sustainability, the demand for the use of alternatives to replace thermoset materials in medium-voltage electrical equipment is constantly rising.

The continual increase in temperature poses a major challenge for engineering polymer manufacturers but, at the same time, creates a great opportunity for the research and development of special products that meet the new specification requirements, which are always much more stringent than the previous ones. Working from this perspective, RadiciGroup High Performance Polymers has developed a range of polyamides for the automotive market that can meet temperature requirements of up to 210°C and special materials for the EE sector with RTIs of up to 160°C.

The innovative technologies used on Torzen® Marathon, Radiflam® HHR and Radilon® HHR ensure that these high temperature materials still maintain the ease of processability that is typical of PA6.6, by keeping the moulding temperature at 100°C or lower. The moulding parameters are practically unchanged compared to standard glass-fibre filled PA6.6.

	PRODUCT NAME	PRODUCT DESCRIPTION	MAIN CHARACTERISTICS
RADILON® HHR	**A RV150HHR**	High temperature PA6.6-GF15	Suitable for parts exposed to continuous operating temperatures of up to 210°C. Medium stiffness.
	A RV350HHR	High temperature PA6.6-GF35	Suitable for parts exposed to continuous operating temperatures of up to 210°C. Good stiffness.
	A RV500HHR	High temperature PA6.6-GF50	Suitable for parts exposed to continuous operating temperatures of up to 210°C. High stiffness.
	A BMV150HHR 3800 BK	High temperature PA6.6-GF15 for blow moulding	Suitable for ducts exposed to continuous operating temperatures of up to 210°C. Good melt strength.
	A BMV200HHR 3800 BK	High temperature PA6.6-GF20 for blow moulding	Suitable for ducts exposed to continuous operating temperatures of up to 210°C. Good melt strength and stiffness.
RADIFLAM® HHR	**A RV150HHR AF 3700 BK**	High temperature PA6.6-GF15, flame retardant	Red phosphorous FR technology. Rated UL V-0 at 0.75 mm. Good surface appearance. For covers.
	A RV150HHR HF 3739 BK	High temperature PA6.6- GF15, flame retardant	Halogen and red phosphorous free. Rated UL V-0. Excellent surface appearance. For covers.
TORZEN® MARATHON	**Marathon G3500XHL**	High temperature PA6.6-GF35	Suitable for parts exposed to continuous operating temperatures of up to 190°C. Good stiffness and improved flowability.
	Marathon G5000XHL	High temperature PA6.6-GF50	Suitable for parts exposed to continuous operating temperatures of up to 190°C. High stiffness.
	Marathon FRU4800XHL BK01	High temperature PA6.6, unfilled, flame retardant	Halogen and red phosphorous free. Rated UL V-0 at 0.4 mm. Suitable for EE applications (e.g., connectors) with higher thermal exposure.
	Marathon FRG2500XHL NC01	High temperature PA6.6-GF25, flame retardant	Halogenated. Product rated UL V-0 at 0.4 mm. Suitable for EE applications with higher thermal exposure.

Better part performance at high hot air temperatures

In the automotive market there has been continual growth in demand for engineering polymers capable of withstanding very high temperatures. This trend is directly related to the mass introduction, during the last few years, of turbocharged engines that develop greater power with smaller displacement. In this area, Torzen® Marathon and Radilon® HHR products can be used in the manufacture of components that, in some cases, are still made of metal, such as:

- Turbo air ducts
- Turbo resonators
- EGR valve housings
- Intercooler end caps
- EE components exposed to high temperatures

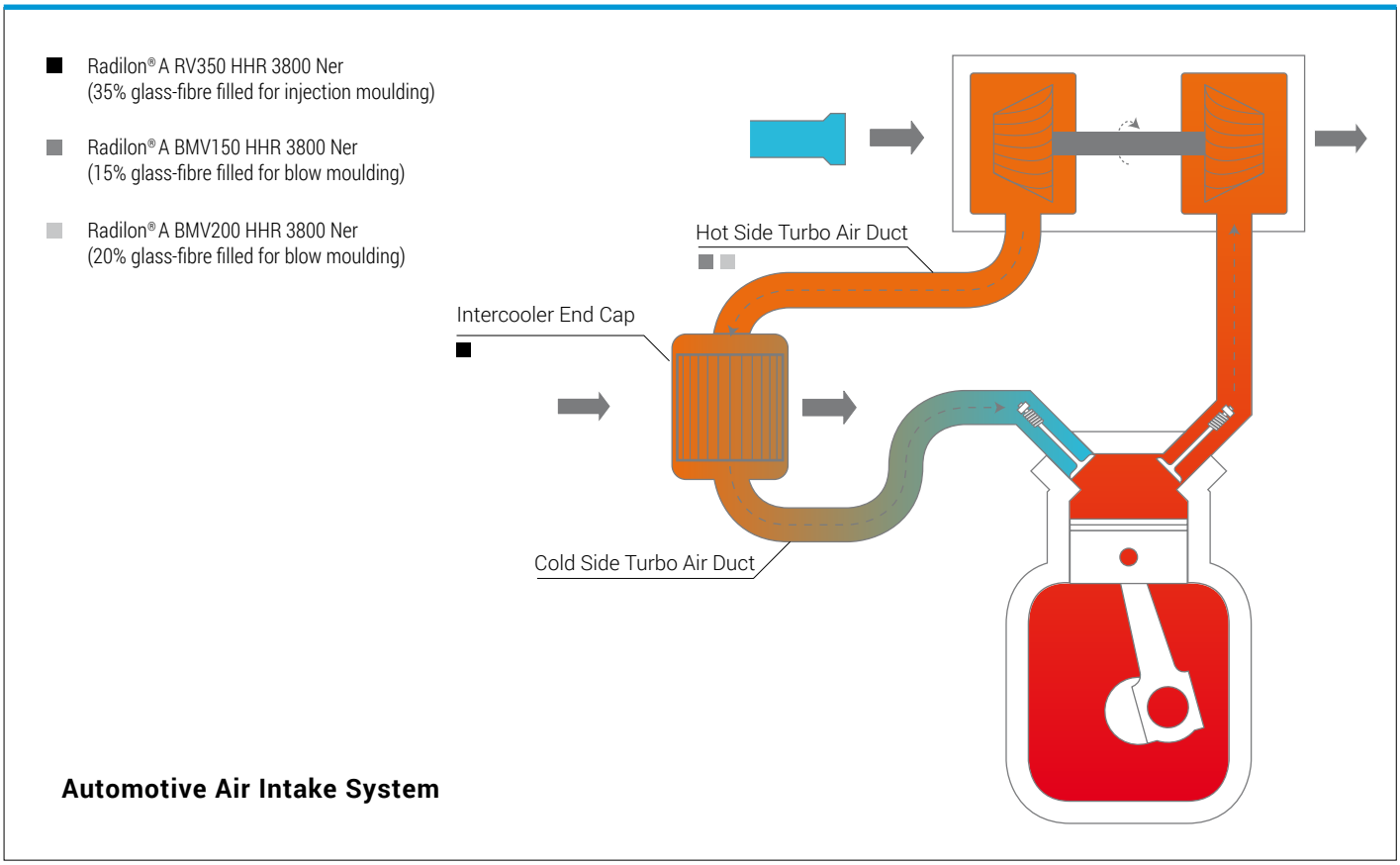


Figure 1 | Turbo air ducts, turbo resonators and CACs are typical applications for Torzen® Marathon and Radilon® HHR.

Cost-effective improved PA matrix

Figure 2 (right-hand side): Radilon® A RV350HHR (high heat stabilized polyamide). As observed in the cross-section, after heat ageing at a high temperature (2000 h at 210°C) the specimen has remained practically intact, except for slight degradation on the surface.

Figure 2 (left-hand side): Standard heat stabilized polyamide. The specimen exhibits a deeply degraded structure after the same heat ageing time.

Two performance options for parts in contact with air:
- Glass-filled Torzen® Marathon: continuous use temperature of 190°C in air
- Glass-filled Radilon® A HHR: continuous use temperature of 210°C in air

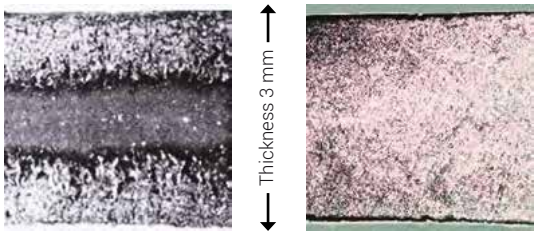
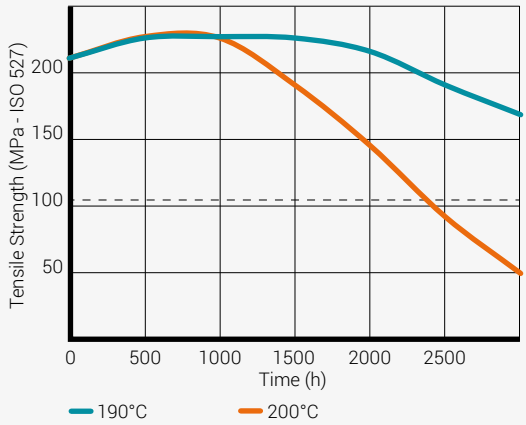


Figure 2 | Standard heat stabilized polyamide (left) vs. Radilon® A RV350HHR (right) after heat ageing at 210°C.

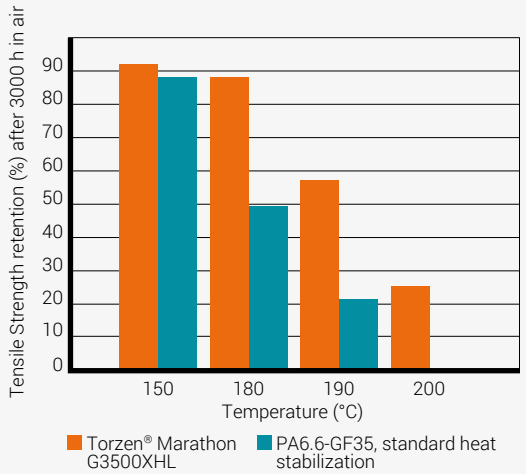
Torzen® Marathon key features

- Excellent property retention up to 190 °C in contact with hot air
- High electrical properties and RTI values for the flame retardant version
- Easy flow grade with high productivity
- Excellent weld line resistance



Torzen® Marathon G3500XHL

Chart 1 | Torzen® Marathon G3500XHL (HT PA6.6-GF35) exposed to a temperature of 190°C for up to 3000 hours. As the graph shows, tensile strength at break remains well above 50% of its initial value.



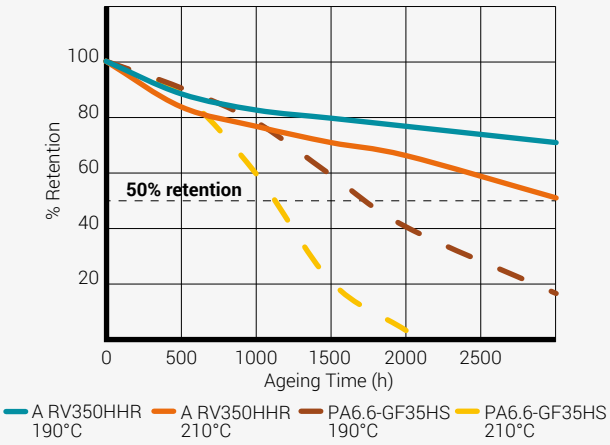
Heat ageing performance

Chart 2 | Hot air ageing of Torzen® Marathon (35%GF) versus a standard heat stabilized PA6.6-GF35 (3000 h in air).

Radilon® HHR key features

- Excellent property retention up to 210°C in contact with hot air
- Excellent weld line resistance

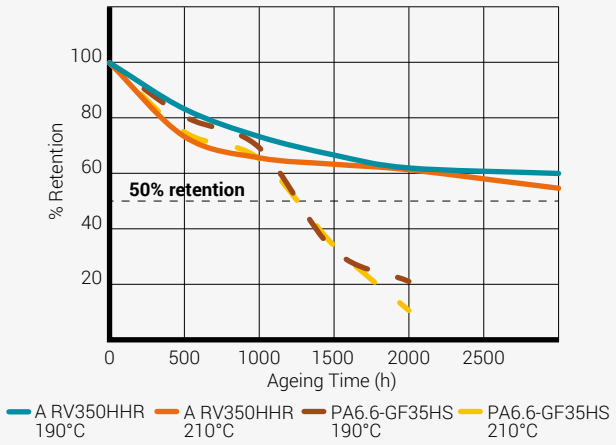
The Radilon® HHR family of products comprises: 15% to 50% glass-fibre reinforced materials for injection moulding; two grades, 15% and 20% glass-fibre filled, respectively, for blow moulding; and two 15% glass-fibre filled flame retardant versions. Chart 3 shows how tensile strength retention decreases as a function of time during heat ageing. The behaviour of Radilon® A RV350 HHR 3800 BK under heat ageing at 190°C and 210°C is compared to PA6.6-GF35 heat stabilized, taken as the benchmark reference commonly used at temperatures of up to 170-180°C. The graph illustrates that, after heat ageing, the tensile strength at break of Radilon® A RV350 HHR 3800 BK still remains above 50% of its initial value, while PA6.6-GF35 heat stabilized at the standard 190°C and 210°C temperatures, exhibits a fast decline in tensile strength at break caused by the thermal oxidation of the polymer base.



Tensile strength at break retention

Chart 3 | Radilon® A RV350 HHR tensile strength measured on ISO 527 specimens at temperatures of 190°C and 210°C. After 3000 hours, the tensile strength is still more than 50% of its initial value.

The same type of behaviour is seen in Chart 4, where Charpy notched impact strength retention is shown as a function of exposure time at 190°C and 210°C.



Charpy notched impact strength retention

Chart 4 | Radilon® A RV350 HHR Charpy notched impact strength measured on ISO 179 specimens at temperatures of 190°C and 210°C. After 3000 hours, Charpy notched impact strength is still more than 50% of its initial value.

Radilon® HHR for blow moulding

Two materials that can be processed using blow moulding and can withstand continuous use temperatures of up to 210°C are:

- Radilon® A BMV150 HHR 3800 BK (15% glass-fibre filled)
- Radilon® A BMV200 HHR 3800 BK (20% glass-fibre filled)

Besides their superior heat resistance, both materials are well suited to blow moulding. These materials are mainly used in manufacturing turbo manifolds/ducts, particularly when the shape of the components is complex or impossible to make using individual moulded parts welded together.

Figure 3 | Turbo duct made of Radilon® A BMV200 HHR using suction blow moulding.

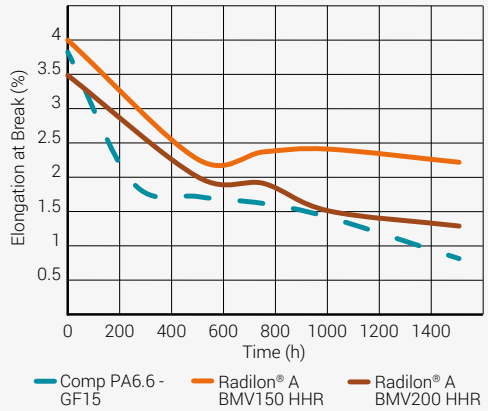
A 1.2-m duct with both an elbow and bellows, blow moulded using parison suction technology, is shown in Figure 3.The materials were designed to achieve the best rheological properties to make them suitable for 3D-blow moulding (materials with improved melt strength).

RadiciGroup High Performance Polymers offers two solutions: 15% and 20% glass-fibre filled. The best choice depends on the geometric configuration of the duct and the manufacturer's specifications. The main properties are listed in the table below.

PROPERTY	STANDARD	RADILON® A BMV150 HHR	RADILON® A BMV200 HHR
Tensile strength at break	ISO 527	86	98
Tensile modulus	ISO 527	4900	5900
Elongation at break	ISO 527	4	3.5
HDT (1.8 MPa)	ISO 75	215	225
Charpy unnotched impact strength	ISO 179	66	69
Density	ISO 1183	1.20	1.23

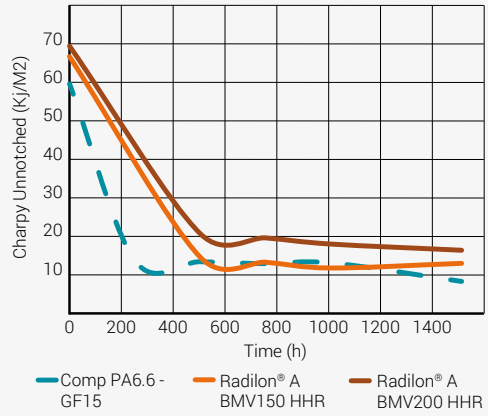
Considering the excellent chemical resistance of these materials to engine oil and cooling system liquids, even at high temperatures, they are highly recommended for the manufacture of water and oil ducts.

The heat ageing effect on elongation at break, Charpy unnotched impact strength and tensile strength at break is illustrated in Charts 5, 6 and 7. A clear improvement over the benchmark material is noted, particularly in the behaviour of tensile strength. After 1500 hours of heat ageing, the benchmark shows a property retention rate below 50%, while the two Radilon® HHRs for blow moulding still retain 70% and 90% of their initial values, respectively.



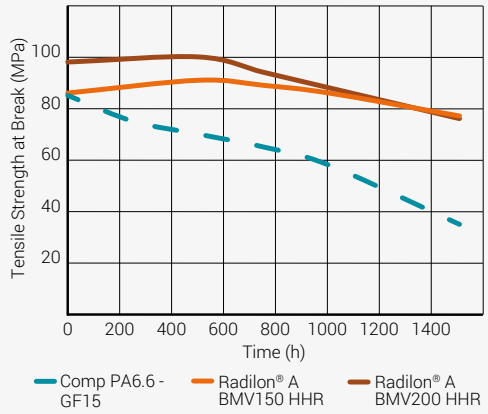
Heat ageing in air at 210°C

Chart 5 | After 1500 hours of heat ageing in air at 210°C, the degradation of elongation at break for the HHR (High Heat Resistance) blow moulding products is clearly less than for the benchmark.
- Radilon® A BMV150 HHR: 55% of initial value.
- Radilon® A BMV200 HHR: 37% of initial value.
- Benchmark: 21% of initial value.



Heat ageing in air at 210°C

Chart 6 | After 1500 hours of heat ageing in air at 210°C, the degradation of Charpy unnotched impact strength for the HHR (High Heat Resistance) blow moulding products is clearly less than for the benchmark.
- Radilon® A BMV150 HHR: 20% of initial value.
- Radilon® A BMV200 HHR: 23% of initial value.
- Benchmark: 14% of initial value.



Heat ageing in air at 210°C

Chart 7 | After 1500 hours of heat ageing in air at 210°C, the degradation of tensile strength at break for the HHR (High Heat Resistance) blow moulding products is dramatically less than for the benchmark.
- Radilon® A BMV150 HHR: 90% of initial value.
- Radilon® A BMV200 HHR: 78% of initial value.
- Benchmark: 41% of initial value.

Radiflam® HHR for engine covers

Figure 4 shows an engine cover made with Radiflam® A RV150HHR AF.

The main characteristics of this material are:
- Flame retardant properties (UL 94 V-0 rated at 0.8 mm)
- Mechanical property retention after 1000-hour exposure at 170°C (tensile strength retention > 65%)
- Flame retardancy retention after 3000-hour exposure in air at 170°C
- Excellent appearance and high fluidity

Figure 4 | Engine cover made of flame retardant grade Radiflam® A RV150HHR AF

Torzen® Marathon for the EE market

PROPERTY	STANDARD	TORZEN® MARATHON FRU4800XHL	TORZEN® MARATHON FRG2500XHL
Description	-	PA6.6-FR	PA6.6-GF25 FR
FR system	-	Halogen and red phosphorous free	Halogenated
Density	ISO 1183	1170 kg/m³	1600 kg/m³
Flame class	UL 94	V-0 at 0.25 mm	V-0, 5VB at 0.4 mm
RTI	UL 94	130, 95, 125 at 0.4 mm 140, 110, 140 at 0.71 mm	140, 140, 140 at 0.4 mm 160, 160, 160 at 0.7 mm
GWFI	IEC 60695-2-12	960°C at 0.4 mm	960°C at 0.4 mm
GWIT	IEC 60695-2-13	960°C at 0.4 mm	850°C at 0.4 mm
CTI	IEC 60112	600 V	325 V
Tensile strength at break	ISO 527	73 MPa	130 MPa
Tensile modulus	ISO 527	3900 MPa	9800 MPa
Tensile strain at break	ISO 527	13%	2.5%

RadiciGroup High Performance Polymers offers a range of polyamides that can withstand hot air temperatures of up to 210°C.

To complement the traditional PA6-GFs (Radilon® S RV300W for moulding and S BMV150K for blow moulding) and the heat stabilized PA6.6-GF (Radilon® A RV350W), RadiciGroup High Performance Polymers has introduced Torzen® Marathon and PA6.6-HHR with continuous use temperatures of up to 210°C.

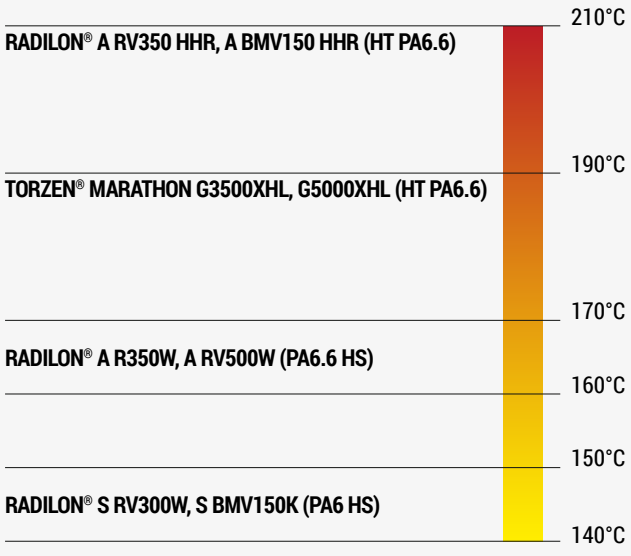


Chart 8 | Max CUT in air. Criteria: 50% TS retention after 3000 h exposure.

RADICI GROUP HIGH PERFORMANCE POLYMERS

Global Presence

RADICI NOVACIPS SpA
Via Bedeschi, 20 – 24040 Chignolo d'Isola (BG) – IT
Ph. +39 035 4991311 – Fax +39 035 994386
e-mail: italia.plastics@radicigroup.com

RADICI NOVACIPS SpA
Via Provinciale, 1331 – 24020 Villa d'Ogna (BG) – IT
Ph. +39 0346 22453 – Fax +39 0346 23730
e-mail: italia.plastics@radicigroup.com

RADICI PLASTICS GmbH
Glockengiesserwall 2 – 20095 Hamburg – DE
Ph. +49 40 3095410 – Fax +49 40 30954199
e-mail: rplde.info@radicigroup.com

RADICI PLASTICS IBERICA SL
Avda. Josep Tarradellas, 130 5º1ª
08029 Barcelona – ES
Ph. +34 93 5416500 – Fax +34 93 4943326
e-mail: iberica.plastics@radicigroup.com

RADICI PLASTICS UK Ltd.
7 Langham House - 148 Westgate
Wakefield, England WF2 9SR - UK
Ph. +44 (0)20 7431 4554
e-mail: uk.plastics@radicigroup.com

RADICI PLASTICS LTDA
Rua Giuseppe Marchiori, 497
CEP 18147-970 Araçariguama – São Paulo – BR
Ph. +55 11 4136 6500
e-mail: brasil.plastics@radicigroup.com

RADICI PLASTICS FRANCE SA
65, Rue du Dauphiné – 69800 St. Priest – FR
Ph. +33 4 72782090 – Fax +33 4 72782089
e-mail: france.plastics@radicigroup.com

RADICI PLASTICS B.V.
Verloren Van Themaatweg 9 – 6121RG, Born – NL
Ph. +31 464496221
e-mail: rplnl.info@radicigroup.com

RADICI PLASTICS USA Inc.
960 Seville Road, Wadsworth, OH 44281 – USA
Ph. +1 330 3367611 – Fax +1 330 3355029
e-mail: usa.plastics@radicigroup.com

RADICI PLASTICS (Suzhou) CO., LTD.
No. 49 Ping Sheng Road, SIP
215126 Suzhou, Jiangsu Province – PR China
Ph. +86 512 62952290 – Fax +86 512 62952291
e-mail: china.plastics@radicigroup.com

RADICI PLASTICS INDIA PVT. LTD.
501, DLF Tower, Shivaji Marg
New Delhi - 110015 – IN
Ph. +91 11 41638 170
e-mail: info.plastics@radicigroup.com

RADICI PLASTICS MEXICO S. DE R.L. DE C.V.
Av. Francisco Zarco 2688
C.P. 47810 - Col. Loma Bonita - Ocotlán Jalisco – MX
Ph. +52 392 923 2390
e-mail: info.plastics@radicigroup.com

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