

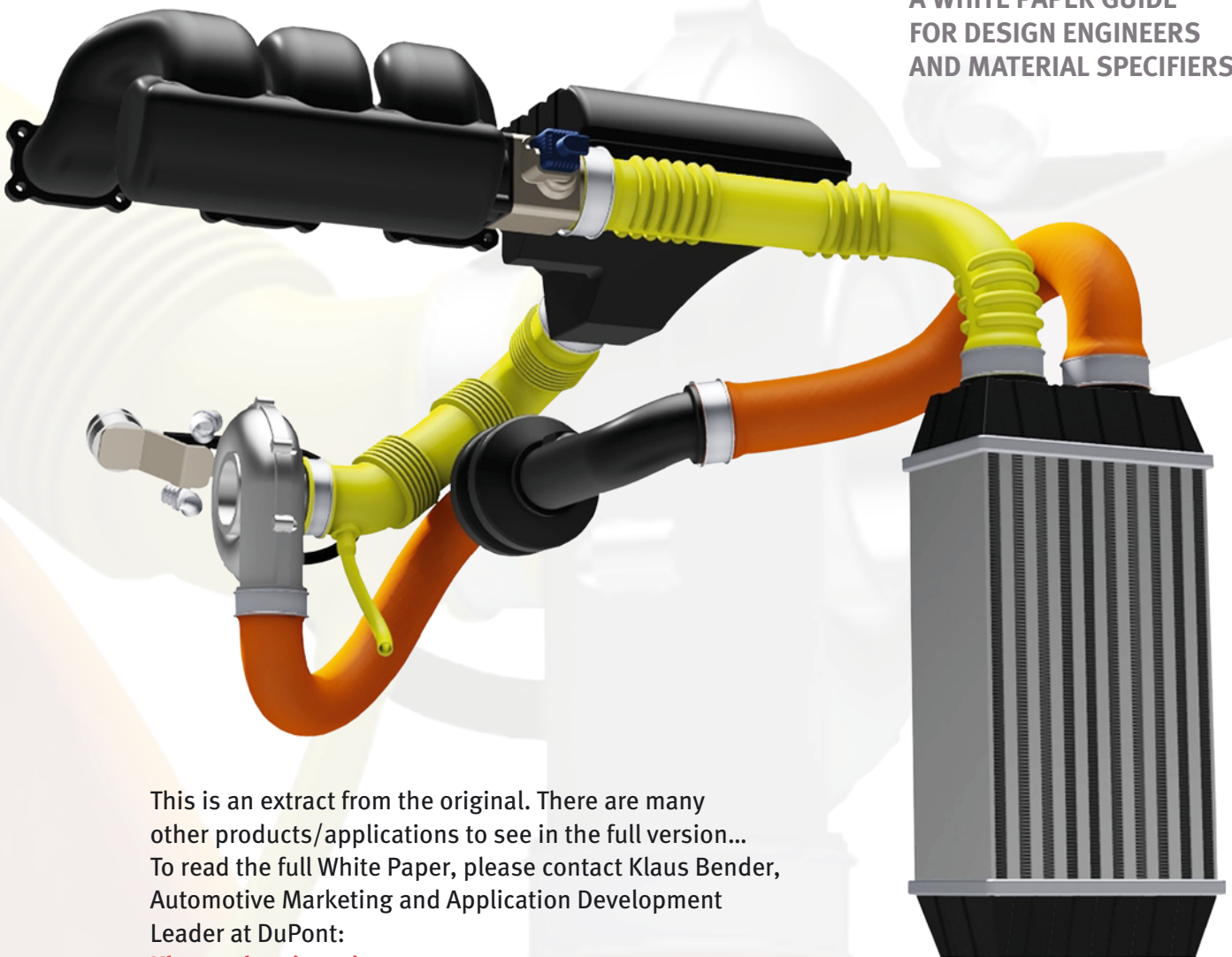


AIR MANAGEMENT WHITE PAPER

DUPONT HIGH-PERFORMANCE POLYMERS FOR AUTOMOTIVE AIR MANAGEMENT APPLICATIONS

HOW TO MEET THE LATEST ENGINE PERFORMANCE,
EMISSIONS AND LIGHTWEIGHTING CHALLENGES
WITH DUPONT RIGID AND FLEXIBLE POLYMERS

A WHITE PAPER GUIDE
FOR DESIGN ENGINEERS
AND MATERIAL SPECIFIERS



This is an extract from the original. There are many other products/applications to see in the full version...
To read the full White Paper, please contact Klaus Bender,
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Introduction

Carbon dioxide (CO₂) emissions reduction is arguably the most significant challenge faced by car manufacturers today. As CO₂ levels in the atmosphere rise, so the bar in global CO₂ auto emissions limits is being set lower and lower. Mandatory CO₂ emission reduction targets set by European Union legislation required that new cars registered in the EU by 2021 should not emit more than an average of 95 grams CO₂ per kilometer (g CO₂/km) for the fleet average of all new cars. The progression of emissions legislation in the USA, Japan and other high car density nations is just as tough. Pressure on auto OEMs to reduce nitrogen oxides (NOx) emissions from diesel cars is also set to increase in 2018 in the wake of events that throw into question the true pollution level of diesel cars. The emissions control pressures on auto manufacturers, whether for petrol or diesel cars, will thus continue to intensify.

It is generally accepted that one of the most effective ways to reduce CO₂ and NOx emissions is to reduce fuel consumption — and reducing engine size, or “rightsizing”, and vehicle weight are arguably the most effective and immediate paths to achieving that goal. Replacement of metals by plastics is the most effective way to make a vehicle lighter while gaining in easier processing, integration of functions and lower cost.

This White Paper specifically looks at air management lines of turbo charged engines that control the flow of high-temperature air, aggressive gases and fluids under high pressure. Modern turbo charged engines are cooled by complex air and liquid cooling systems that manage the intake and exhaust flow of high-temperature air, gases and coolants, and integrate many vital elements including the air filter, air intake manifold, turbocharger, resonator, charge air cooler or intercooler, exhaust gas recirculation unit, closed positive crankcase ventilation.



Fig 3. High performance plastics and elastomers are taking over from traditional materials such as metal in air management systems in the quest for lighter weight, lower fuel consumption and reduced emissions. DuPont is at the forefront of development and testing of polymers that have proved more than capable of replacing metals while enabling lightweighting. Source DuPont / PSA

What follows demonstrates how DuPont is responding to demanding CO₂/NOx emissions reduction legislation. Highlighted in particular is how the company helps OEMs meet stringent requirements by developing materials that are resistant to higher temperature exposure and acid condensates such as exhaust gas recirculation (EGR) or Blow-by gas (BBG). It will explain how thermoplastics and elastomers allow for vehicle emission reduction, hence playing a key role in meeting targets. The White Paper then highlights how DuPont finds solutions by working together with customers throughout the value chain. Finally, you will find examples of DuPont’s latest offerings, tailored to the industry’s needs.



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1) Meeting the exhaust gas recirculation challenge

Coping with EGR gases can be a nightmare for the design engineer. EGR systems generate an unpredictable and variable cocktail of gases and acid condensates that create challenges for polymer suppliers, and very difficult operating conditions for plastics and elastomers.

DuPont has developed a better understanding of the issues as a result of extensive studies into the effects of EGR chemicals on materials. The result is the development and commercialization of new plastics and elastomers that can withstand severe chemical environments.

As it is difficult to characterize all materials under all OEM conditions, DuPont has selected a representative mixture of formic, acetic, hydrochloric, sulfuric and nitric acids to evaluate the performance of materials in EGR simulation tests: the “DuPont EGR cocktail”.

	Chemical	DuPont EGR cocktail [g/l]
Organic acids	Formic acid	1
	Acetic acid	1
Mineral acids	Nitric acid	0.4
	Hydrochloric acid	0.1
	Sulfuric acid	0.1
Solution pH		2

Fig 1: DuPont EGR cocktail – chemical composition. Source DuPont.

A new grade of DuPont™ Hytrel® thermoplastic elastomer demonstrates superior resistance to the acidic solution. Figure 2 illustrates the effect of immersion of a “standard” TPC-ET and the new “acid resistant” Hytrel® Gen II thermoplastic elastomer in a mixture of organic and mineral acids representative of OEM test requirements, including pH ≈ 2 at 100°C.

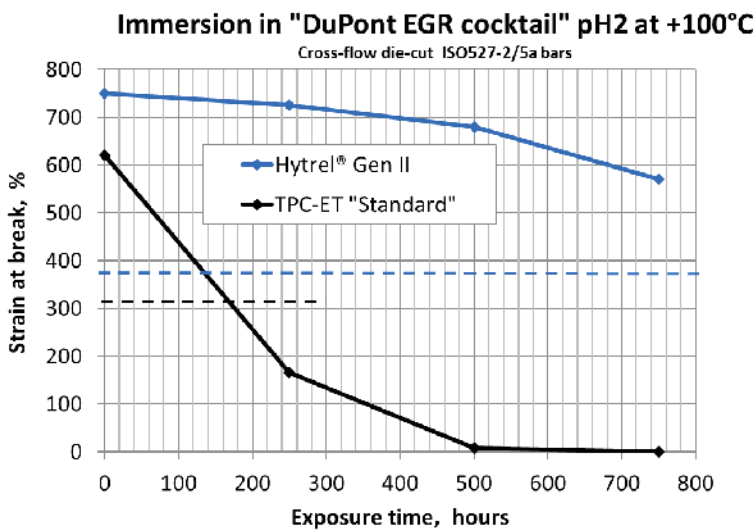


Fig 2. Effect of immersion of a “standard” TPC-ET and the new “acid resistant” Hytrel® Gen II thermoplastic elastomer into a mixture of organic and mineral acids representative of OEM test requirements, pH ≈ 2. Source DuPont.



a) Elastomers for EGR acid resistance

An ethylene acrylic elastomer, such as DuPont™ Vamac®, is the rubber material of choice for EGR applications because it resists EGR acid condensates and Blow-By Gases up to 150°C far better than conventional chlorinated elastomers (CPE, CR, ECO). AEM polymers are also superior in acid resistance to ACM and HT-ACM due to their different ethylene + methyl acrylate containing polymer chemistry. FKM and FFKM will be the ultimate rubber material of choice for exposure to temperatures above 150°C and to high acidity EGR condensates (pH < 2). The choice of mineral fillers added to rubber compounds can significantly impact the acid resistance performance of finished elastomer parts, including also high-performance elastomers such as AEM and FKM.

b) New NOx emissions limiting technologies

DuPont has developed an extensive data collection of the performance of DuPont polymers in blow-by and exhaust gases and condensates, plus in-depth knowledge of the three principal NOx emission limitation technologies: EGR systems, Selective Catalytic Reduction (SCR), and lean-burn NOx Traps (LNT).

2) How DuPont adds value: Customer support and Technical capabilities

DuPont is not just a raw materials supplier. The company collaborates with the customer right through to successful commercialization of the part and is one of the very few market leaders that can provide sophisticated tailor-made services comprising of the selection of thermoplastic, elastomer and fiber-filled materials, as well as dedicated design, process, prototyping and lab testing for automotive air management ducts and hoses.

DuPont is also unique in being able to offer global systems capabilities in both thermoplastic and elastomers, backed by in-house processing facilities including extrusion, injection and blow moulding plus welding combined with design support & lab testing. These processing capabilities replicate customers' own processing conditions, speeding up prototyping and the production of finished parts for testing and qualification.

Customers can connect to thousands of DuPont scientists and engineers located in Technical Centers and automotive-focused Innovation Centers in Brazil, China, India, Japan, Mexico, Russia, South Korea, Switzerland, Taiwan, Thailand, Turkey and the USA, and at more than 100 research and development centers worldwide. Through the DuPont Centers of expertise all over the world, customers can benefit from world-class technical support and application development.



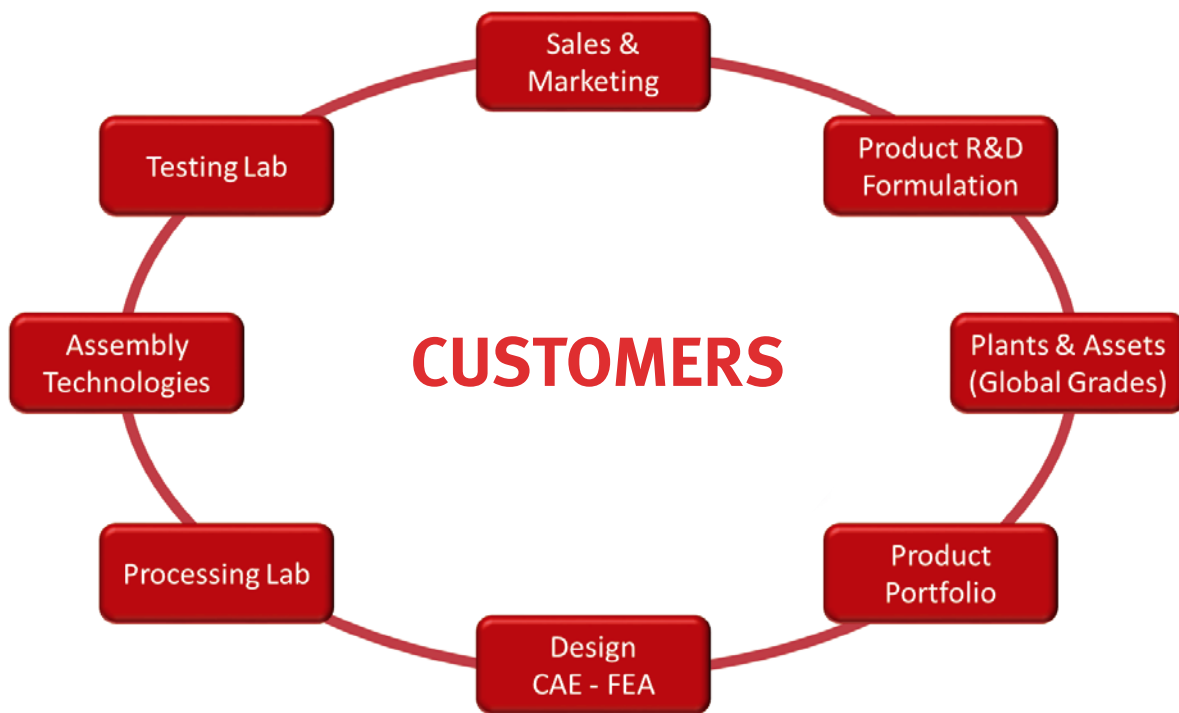


Fig. 3: The customer is at the center of the DuPont global network that brings all of the company's assets and expertise together to exceed expectations. Source DuPont.

Design support and Computer Aided Engineering (CAE)

Through its specialized centers of excellence (for example the DuPont European Technical Center in Geneva, Switzerland), DuPont supports customers with advanced Finite Element Analysis (FEA) and Computer Aided Design (CAD) expertise. The Center offers all the key welding techniques (hot plate, infrared, vibration) with machines on site, and full pilot 3D suction blow moulding and injection moulding production capabilities that replicate their own processing conditions in order to speed prototyping and produce finished parts for testing and qualification.

Successful part commercialization is the result of detailed attention to design in plastics, selection of material, processing technique, laboratory testing and post mold processes including machining, painting, and assembly. Please find more information of DuPont capabilities in design, processing, prototyping and laboratory testing in the detailed version of the White Paper by contacting *Klaus Bender*, Automotive Marketing and Application Development Leader at DuPont: Klaus.w.bender@dupont.com

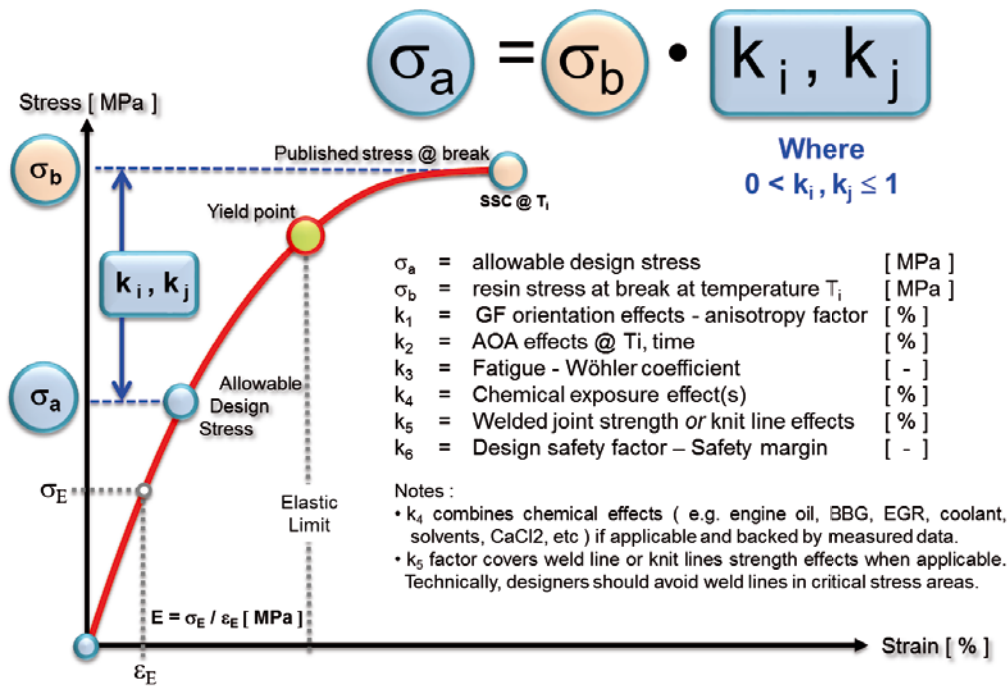


Fig. 35. Known as the k Factor, the formula is applied to the design of ducts, hoses, bellows, and demonstrates DuPont's in-depth knowledge and expertise in prototyping air management parts for customers. Source DuPont.

3) DuPont cool solutions for hot engines

DuPont has long commercial experience in applications development and can point to many successful commercial programs in virtually all areas of air cooling. DuPont offers *material solutions* drawn from the broadest portfolio of high heat, pressure, chemically resistant and lightweight polymers for engine air management applications including:

- **Crastin®** polybutylene terephthalate (PBT) for resonators, small connectors, brackets, spigots, nipples, mass air flow sensors, etc.
- **Hytrel®** thermoplastic polyester elastomer (TPC-ET) for air ducts.
- **Vamac®** ethylene acrylic elastomer (AEM) for hoses and ducts, seals and gaskets, sensor tubes.
- **Zytel®** polyamide resins PA6, PA66, PA66/6, PPA, PA612 for resonators, air ducts, air intake manifolds, sensor tubes, EGR components, connectors, air filters, charge air cooler end caps.
- **Kalrez®** perfluoroelastomer (FFKM) custom parts, seals and O-rings.

These DuPont products offer valuable lightweighting opportunities, and often enable one integrated part to replace several metal/rubber/plastic components. All grades are process friendly for use with existing blow molding, injection molding and/or extrusion equipment, and can typically be reground up to 30-50% with little impact on final properties and productivity.

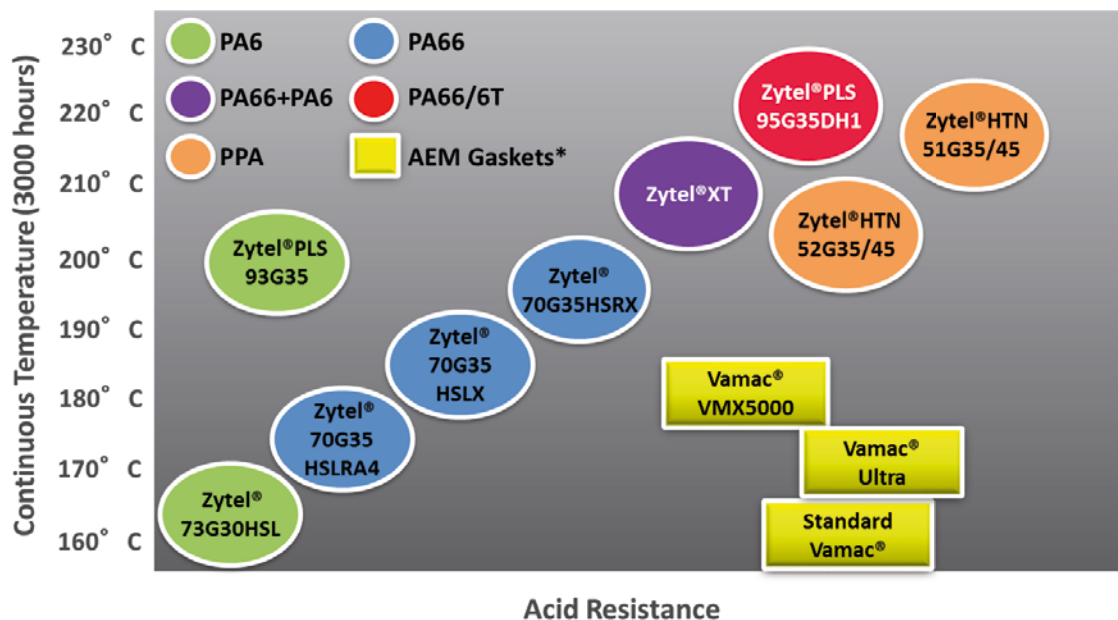


a) What's new from DuPont?

The company continues to broaden its Zytel® PA range to respond to the demands of increasing temperature and chemical resistance by tailoring offerings to the needs of the industry. Continual development of the Crastin®, Hytrel®, and Vamac® product families is also generating new grades with special performance characteristics. DuPont is also working on developing new offerings to address the most severe combinations of temperature and chemical resistance for EGR applications. What follows highlights some examples of DuPont's latest offerings within its product families.

b) What's new in Zytel®?

Glass fiber reinforced Zytel® polyamide grades have been used in air management systems for many years. Two new product lines — Zytel® PLUS and Zytel® XT — have been developed to meet higher temperature needs. Both products can withstand temperatures of more than 200°C with little change in technical properties even after more than 3000 hours of exposure time.



* Aging time for elastomers 1000 hours

Additional requirements such as chemical resistance, fatigue, pressure pulsation, stiffness at service temperature, dimensional stability may affect the positioning.

Fig. 4: The DuPont™ Zytel® polyamide family includes PA6, PA66, PA66/6, PA612 and PPA, and covers the spectrum of air management price/performance needs from stiffness to flexibility, with optimum combinations of heat, chemical and mechanical resistance, and cost-effectiveness. Vamac® is the material of choice for rubber seals and gaskets in combination with parts made of Zytel®. Source DuPont

Zytel® XT70G35HSL and Zytel® XT74G35HSL

The Zytel® XT series is DuPont's latest high temperature PA66 and PA66+PA6 product family complementing existing the Zytel® PLUS product range. They have been developed to address specifically the increasing needs for air management systems. Zytel® XT offers an excellent balance in processing (injection molding and welding) and maintains mechanical properties at continuous temperatures



up to 200°C, with peaks as high as 220°C. In addition, the new product family delivers outstanding fatigue resistance and stiffness at the in-use temperatures of turbo charged engine environments.

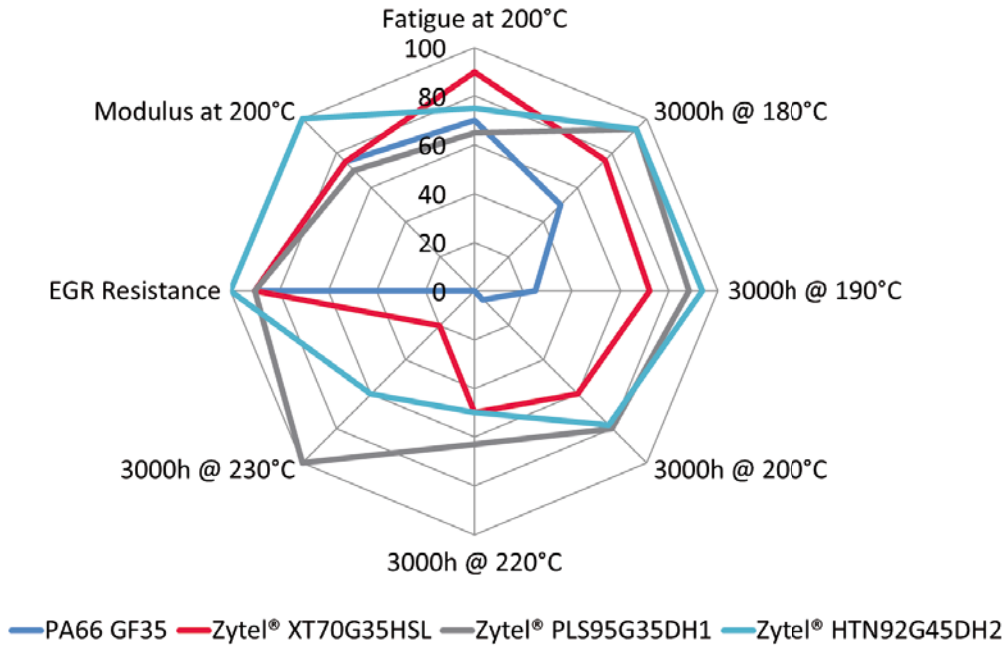


Fig. 6: The Zytel® XT product family has been developed to provide an excellent balance of mechanicals such as fatigue and performance at end use temperature. Source DuPont.

Already well known for its ability to resist heat, chemicals and moisture, the use of SHIELD Technology for this polymer family helps ensure ‘step-above’ performance at 230°C, and superior protection for components exposed to 210°C for long periods.

Zytel® BM74G18HS is the latest addition to the DuPont polyamide PA66+PA6 glass filled blow molded portfolio for hot side rigid air ducts, focusing on turbo charged engines. The grade has excellent heat ageing resistance at continuous temperatures up to 210°C and peaks at 230°C, combined with outstanding durability, but differentiates itself in easy 3D suction blow molding processing thanks to its good parison strength, low crystallization speed, and good die swell in comparison to other high temperature polyamide glass filled blow molded materials.

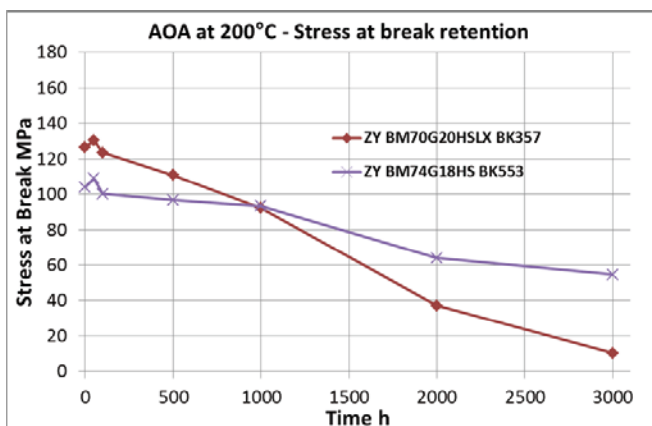


Fig. 8: Graph illustrates the excellent retention of mechanical properties, including over 50% stress retention, of Zytel® BM74G18HS following long term Air Oven Aging after 3000 h at 200°. Source DuPont.



c) What's new in Hytrel®?

Hytrel® HTR8797 is a flexible, blow-moldable grade that more than doubles the 130°C - 150°C Air Oven Aging (AOA) durability of previous Hytrel® grades. It is already specified for flexible cold side air ducts.

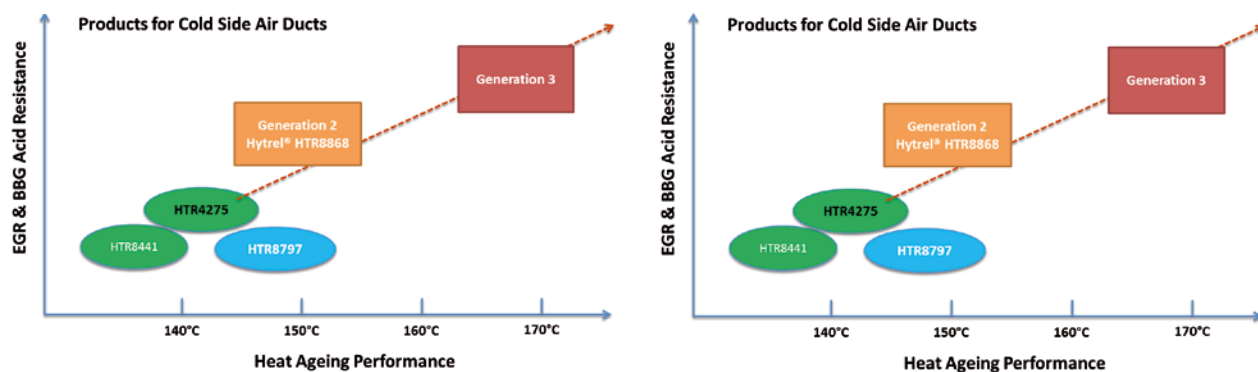


Fig. 11: The evolution of Hytrel® grades for cold side blow molded air ducts includes significantly improved resistance to aggressive acid condensates in EGR and Blow-By Gases and more than twice the Air Oven Aging durability of first generation TPC-ET grades.

The high temperature Hytrel® blow molding grade for hot side air ducts enables customers to create one fully integrated and flexible blow molded duct, replacing rigid air ducts of metal or glass filled polyamide 6, and turbo hoses of rubber/textile reinforcement. Result is potential for up to 50% in weight saving, up to 30% cost reduction, and opportunities to reduce the number of components and mating surfaces. Source DuPont.

Hytrel® Generation 2 delivers higher resistance to acid condensates in Exhaust Gas Recirculation (EGR) and Blow-By Gases (BBG) than many other commercial TPC-ET blow moulding grades. It has been developed as a solution to increased acid exposure in air ducts, turbo hoses and other air management lines generated by some new turbo engines using EGR low-pressure loops.

Hytrel® HTR8808, DuPont's new developmental TPC-ET thermoplastic elastomer blow molding high temperature grade, was developed to produce pressurized hot side air ducts for small turbo gasoline engines. It enables customers to create one fully integrated and flexible blow molded duct, replacing the conventional rigid air duct made of metal or polyamide 6 glass filled material and turbo hoses made of rubber/textile reinforcement. Benefits include the potential to save 20 - 50% in weight and reduce costs by up to 30%, and also the opportunity to reduce the number of components and mating surfaces. Hytrel® HTR8808 offers an optimal balance of stiffness and heat resistance at continuous temperatures up to 160°C resulting in good pressure resistance and design flexibility.

d) What's new in Vamac®?

Vamac® VMX5000 is a versatile family of AEM pre-compounds that resist high heat (180°C to 190°C) and aggressive fluids for the toughest turbocharger hose, air duct, rubber sleeve and seal and gasket applications. The problem of accelerated oxidative degradation of carbon black or silica filled AEM



compounds is eliminated by utilizing a novel DuPont patented filler system that actively extends the life of AEM parts when exposed to hot air.

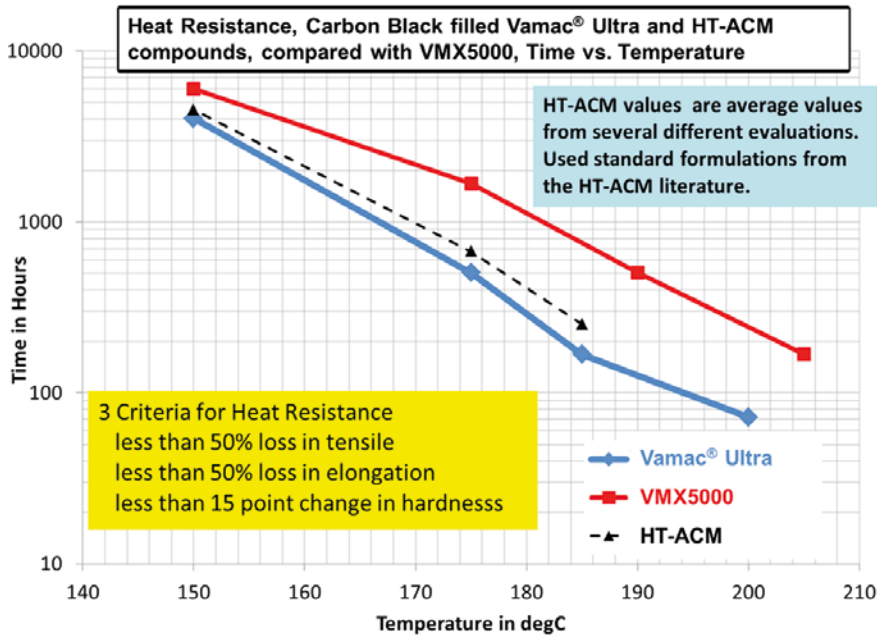


Fig. 13: Arrhenius curve shows superior heat aging performance of Vamac® VMX5000 including retention of tensile strength, resistance to elongation and hardness stability after nearly 7 000 hours at over 200°C, compared with Vamac® Ultra and standard HT-ACM.

e) What's new in Kalrez®?

DuPont™ Kalrez® perfluoroelastomer (FFKM) parts are available as O-rings and custom shapes, and resist over 1800 different chemicals while offering the high temperature stability of PTFE at 327°C. They are used in highly aggressive sealing applications demanding the highest elastomeric performance, and provide the ultimate solution if fluoroelastomers (FKM) fail in turbocharger and selective catalytic reduction (SCR) applications.

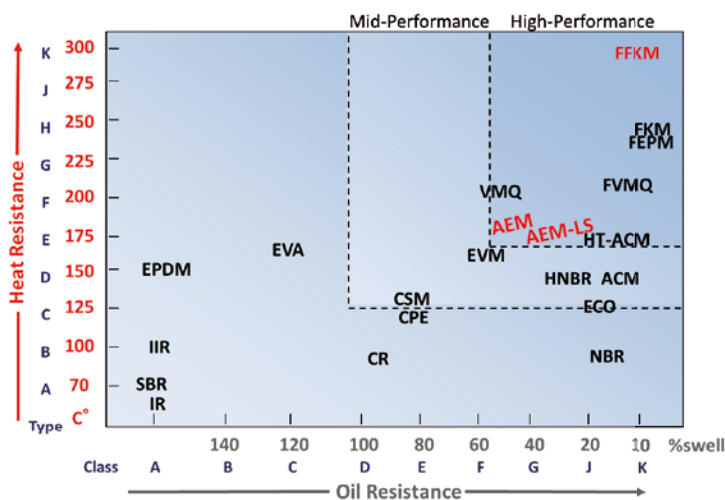


Fig. 20. Kalrez® FFKM is top of the ASTM 2000 classification, offering the highest temperature and chemical resistance of all rubber and elastomeric materials. Source DuPont.

- Classification inspired by ASTM D2000 standard
- Maximum temperature at which a vulcanizate can be aged for 70 hours and still retain at least 50% of its elongation
- % volume swell in ASTM IRM 903 Oil, 70 hours exposure
- Fig. 20. Kalrez® FFKM is top of the ASTM 2000 classification, offering the highest temperature and chemical resistance of all rubber and elastomeric materials. Source DuPont.



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