Focus on engine cooling –

DuPont has cool solutions to hot engines

In the quest for better fuel economy and cleaner emissions, the global auto industry is pushing designers, engineers and materials suppliers to come up with continuous improvements in engine efficiency, and new ways to take weight out of the vehicle. Replacement of metals by plastics is an important part of the solution.

However, there are trade offs, particularly in engines. To achieve both greater efficiency and weight savings, engines are downsizing — but they are also getting hotter, particularly with the growth of turbo charging. As a result, engine cooling is becoming more important than ever.

Modern engines are cooled by complex air and liquid cooling systems that manage the flow of high temperature air, gases and coolants, and house critical thermal management components. Plastics, many supplied by DuPont, are playing an increasingly important role in key cooling system parts including thermostat and heater housings, outlet and inlet ports, valves, cross-overs, coolant pumps, water jacket spacers, charged air coolers (CAC) and exhaust gas recirculation (EGR) coolers.

Materials requirements

Air and liquid engine cooling environments are tough on materials and components. Many standard plastics and elastomers struggle to meet new specifications for temperature and coolant resistance, mechanical strength, and life-of-vehicle durability coupled with industry expectations for weight saving and cost effectiveness.

Air systems with EGR coolers demand superior resistance to chemicals, aggressive gases and hot air at up to 210°C with excursions to 230°C — and the trend is higher temperatures, increased acidity, dirtier gases and rising pressures. Turbo air ducts and hot

and cold side charged air coolers operate in similar environments. These conditions combine to cause increased wear in moving component parts. Liquid systems require resistance to glycol based long life coolants (LLC) plus water at temperatures up to 130°C with excursions as high as 143°C, in addition to road salt resistance.

Increasingly, a system approach using high performance polymers and advanced technologies, such as those provided by DuPont, offers the best solution. In Europe, many OEMs use nylon 6.6 (polyamide/PA66) resins for coolant components, and polyphthalamide (PPA) or polyphenylene sulphide (PPS) for more demanding applications. In other regions PPA is still the material of choice for many key components.

Proven on the road

DuPont is not new to engine cooling. The company has a long commercial experience in applications development and can point to many successful programs in virtually all areas of liquid and air cooling. Thermal management components made from DuPont products have been in daily use on the road for over 15 years. The company continues to build on that proven track record with advanced technologies and enhanced product performance.

During that time, DuPont has carried out many studies for automotive industry customers, including comparative testing of DuPont and competitive products exposed to LLC and simulated EGR mixtures, and performance in injection, extrusion and blow molding processes.

DuPont capabilities

DuPont offers *material solutions* using a broad selection of high heat resistant lightweight polymers for air/gas and liquid engine cooling applications; *integration ideas* using the company's vast experience in elastomers, resins and parts, supported by global technical and development teams; and faster *'Concept to Part'* design, materials and processing expertise throughout the global value chain supported by DuPont Technical and Innovation Centers around the world.

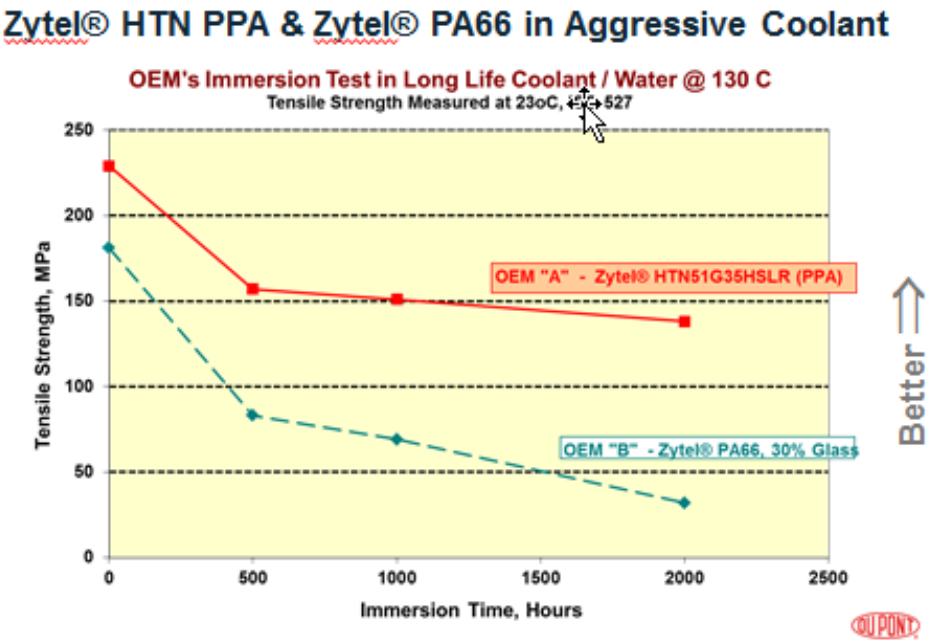
The company is unusual in being able to offer global systems capabilities in both PPA and PA66 polymers and in elastomers, backed by pilot production and assembly facilities, including in-house ultrasonic, vibration and laser welding, plus extrusion, injection and blow molding at its Technical Centers in Akron, Ohio, and Wilmington, Delaware, USA;

Shanghai, China; Utsunomiya, Japan, and Meyrin, Switzerland. Customers can also connect to more than 9 500 DuPont scientists and engineers located in new automotive-focused Innovation Centers in the USA and Switzerland, in Brazil, India, Japan, Korea, and Mexico, and at more than 150 research and development centers worldwide.

DuPont products for engine cooling

Through the company's "One DuPont" enterprise interoperability initiative, DuPont can offer strength in depth across all its products, technologies and facilities. Following are the principal DuPont product grades currently specified for automotive thermal management applications:

For liquid systems:



Immersion testing in aggressive long life coolant/water mixture at 130°C for 2000 hours demonstrates the excellent retained tensile strength of DuPont™ Zytel® HTN PPA

• Zytel® HTN 51 Series PPA has been developed for more demanding liquid cooling components, and offers excellent chemical resistance to LLC fluids, high mechanical strength, and longer durability

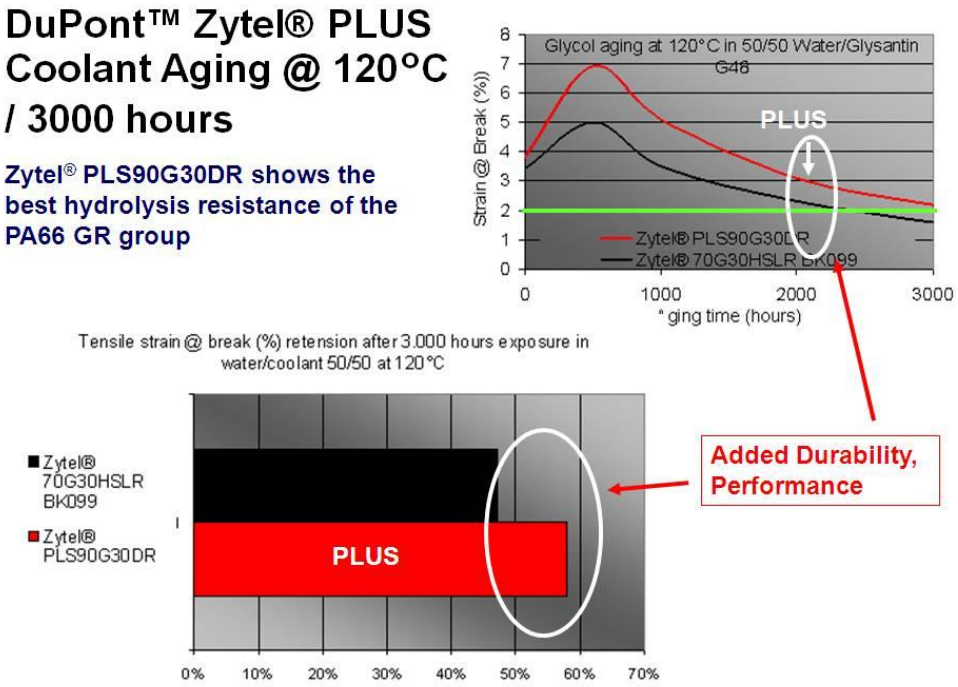
• Zytel® 70 Series PA66 is the "work-horse" resin specified for less demanding liquid cooling components

• Zytel® PLUS 90 Series offers improved chemical resistance to hot LLC fluids, and longer durability than PA66

• Zytel® Long Chain Polyamides offer excellent performance in coolant environments up to 120°C

• Zytel® LC6200 PA612 offers excellent chemical resistance and weight saving for coolant tubes

• Viton® GFLT-S and GF-S Series peroxide cured fluoroelastomers are suitable for water pump seals at 125+°C, and offer improved heat resistance over HNBR.



Zytel® PLUS 90 Series demonstrates best hydrolysis resistance of PA66 resins and superior tensile strength and durability following 3 000 hours exposure to 50/50 water/Glysantin G48 coolant at 120°C

For air and EGR systems:

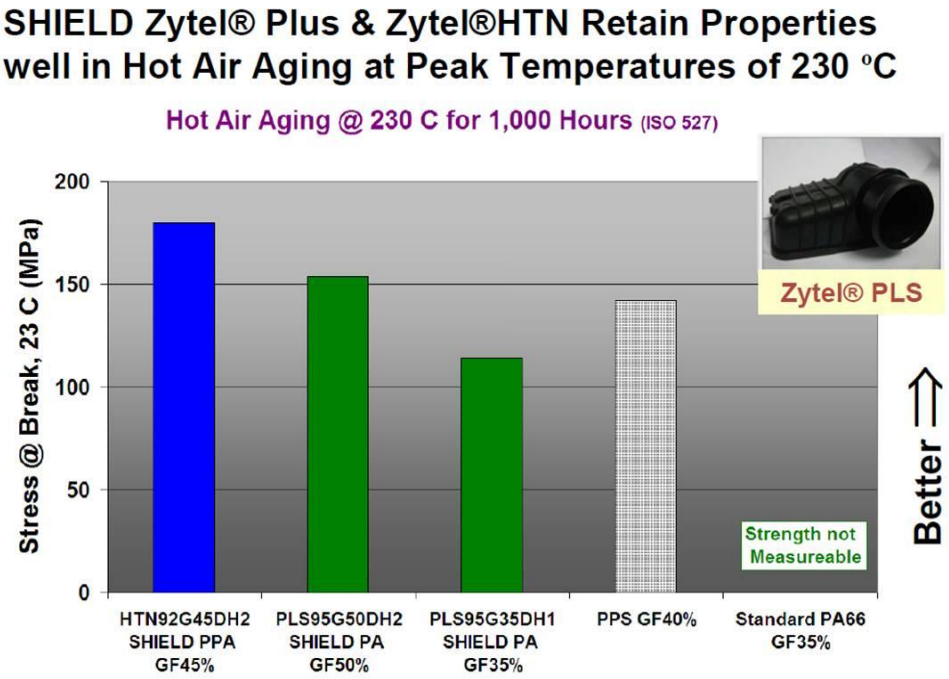


Chart illustrates excellent property retention performance of Zytel® PLUS and Zytel® HTN polymers versus standard PA66 following exposure to hot air aging testing at 230°C for 1 000 hours

• Zytel® HTN 92, 51 and 52 Series PPA offer high-level temperature resistance and mechanical properties, plus good chemical and thermo-oxidation resistance to EGR gases

• Zytel® PLUS 95 Series PA66 copolymer is based on innovative DuPont™ SHIELD Technology to enhance long-term resistance to heat, thermo-oxidation and EGR gases

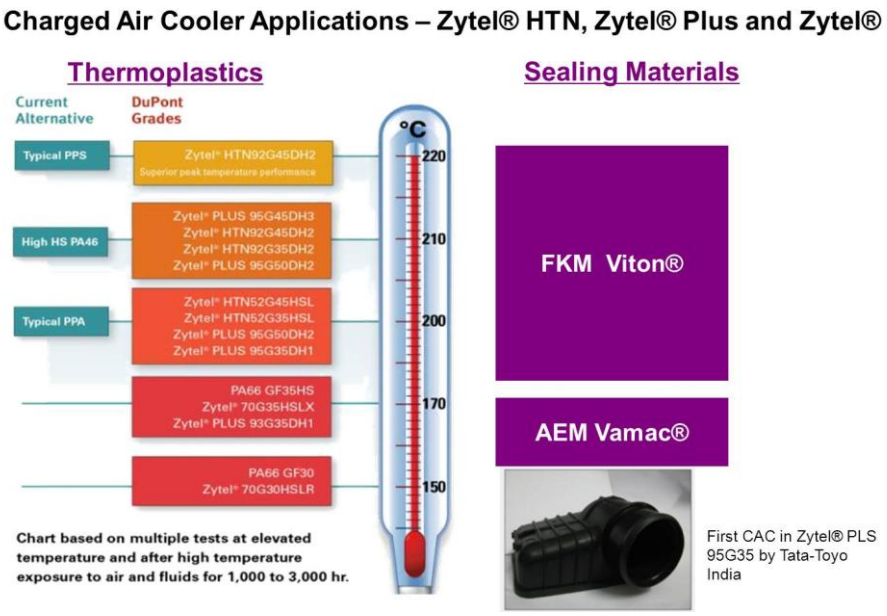


Chart ranks temperature resistance of DuPont™ Zytel®, Vamac®, Viton® and Kalrez® perfluoroelastomer for engine coolers and EGR components following exposure to air and fluids for 1 000 to 3 000 hours

In addition to the above resins, other DuPont thermoplastics, elastomers and fibers used in moving turbocharging loop, air duct and hose components include:

- DuPont™ Viton® fluoroelastomer
- DuPont™ Vamac® ethylene acrylic elastomer
- DuPont™ Kevlar® para-aramid
- DuPont™ Nomex® meta-aramid
- DuPont™ Hytrel® TPC-ET thermoplastic polyester elastomer
- DuPont™ Vespel® polyimide parts and shapes

These materials offer many benefits in engine cooling applications including:

- Opportunities to reduce weight up to 50% and cost up to 30% in replacement of traditional metal/rubber components
- Design flexibility to meet tight underhood packaging constraints
- Full plastics integration in multi-layer ducts and hoses, and opportunities for reduced part count
- High temperature resistance, proven chemical durability, improved NVH performance, enhanced wear resistance and reduced friction.

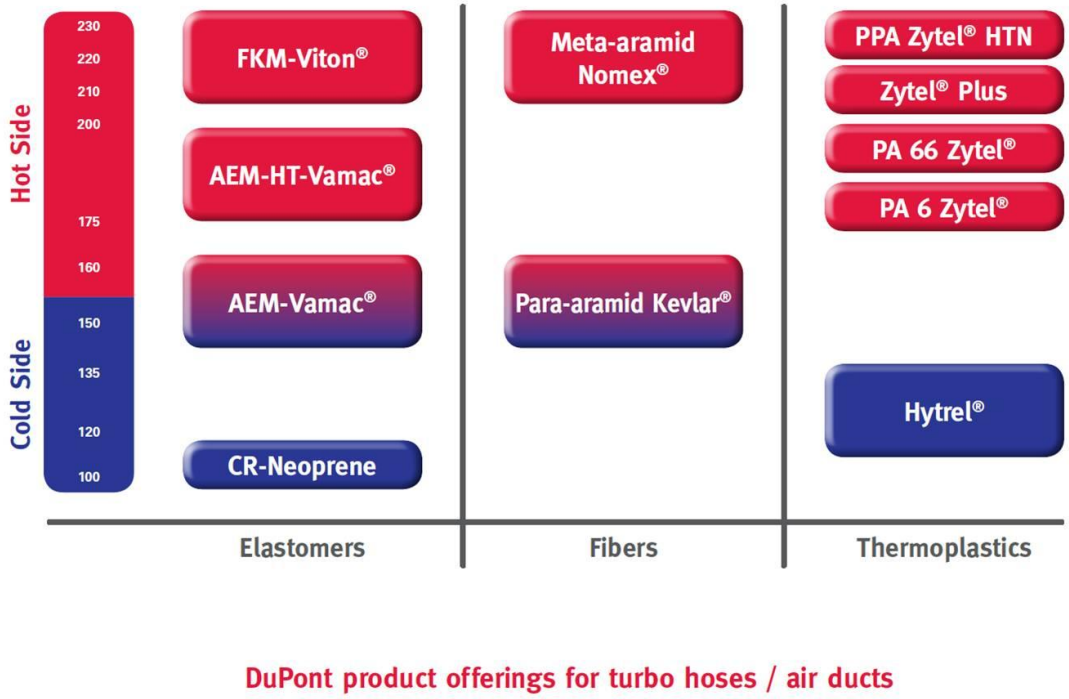


Figure 3: Upper hot side/cold side temperature capabilities of key DuPont and other generic materials used in engine cooling applications

Figure 3 illustrates the upper temperature capabilities of the most frequently specified DuPont products used in hot side and cold side engine cooling system components, led by three high performance Zytel® grades, and Viton® fluoroelastomer.

Zytel® polyamide resins are inherently lighter than metals and offer high performance combinations of temperature, pressure, chemical and moisture resistance, and significant opportunities for cost and weight savings. Viton® is the most specified fluoroelastomer for automotive seals, hoses and O-rings and gaskets.

Trends in engine cooling –

DuPont products for thermal management

Modern engines are cooled by complex air and liquid cooling systems that manage the flow of high temperature air, gases and coolants, and house critical thermal management components. To achieve both greater efficiency and weight savings, engines are downsizing — but they are also getting hotter, particularly with the growth of turbo charging. As a result, engine cooling is becoming more important than ever.

In Europe, close to 100% of diesel engines are now turbo charged, and this trend is taking place in the other major automotive markets. Gasoline powered engines are also following the move to turbocharging, particularly in the Americas and Asia-Pacific regions. While turbocharging improves engine efficiency, it also generates more heat that must be managed by the air-cooling system (*see Figure 1.*).

In a parallel trend, charged air and EGR coolers are increasingly used in turbocharged engines as automakers strive to meet Euro 6, PZEV, CARB, and other global emissions and fuel efficiency requirements. But increased use of EGR produces more acidic and aggressive exhaust gases, necessitating the use of lower pH resistant component materials.

These demanding turbocharger operating environments, especially those combining air intake manifold, EGR and CAC components, present significant opportunities for the integration of plastics.

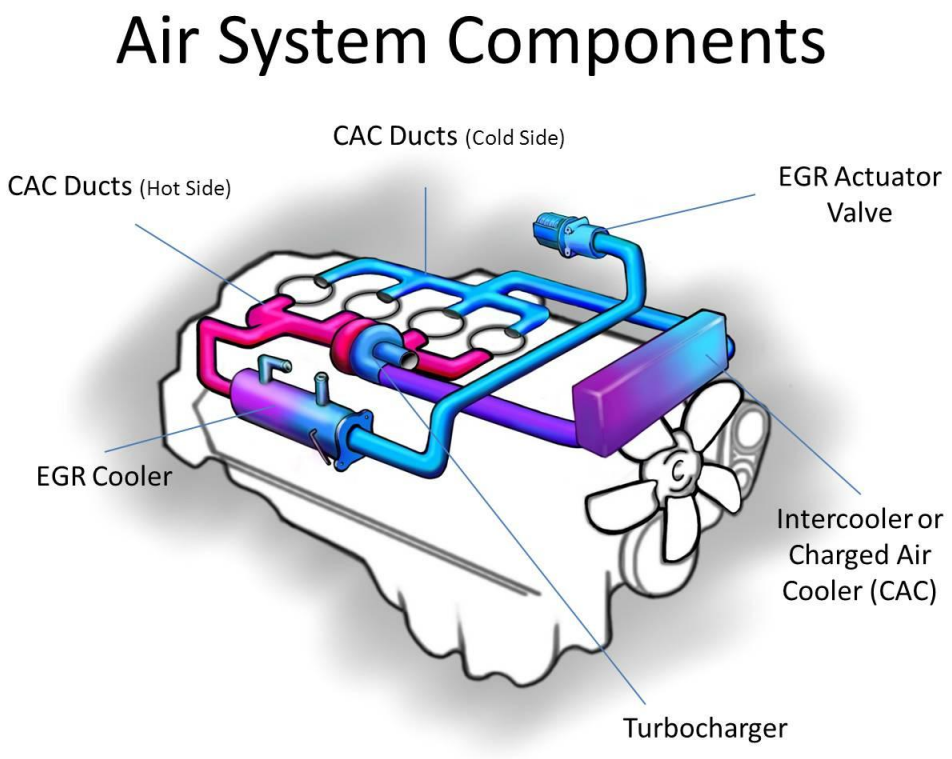


Figure 1: Plastics play an increasingly important role in air system components

Smaller turbocharged engines also place greater demands on liquid cooling systems (*see Figure 2.)*. As a result, the latest engines tend to have more and increasingly complex inlet and outlet ports to boost water circulation. Smart coolant control valves are beginning to replace traditional on-off thermostats for better control of coolant temperature and enhanced fuel economy. Electrical pumps are becoming more evident as hybrid and electric-powered cars grow in popularity. In Japan, several OEMs have been extending the use of water jacket spacers to improve fuel economy since first introduced in 2004.

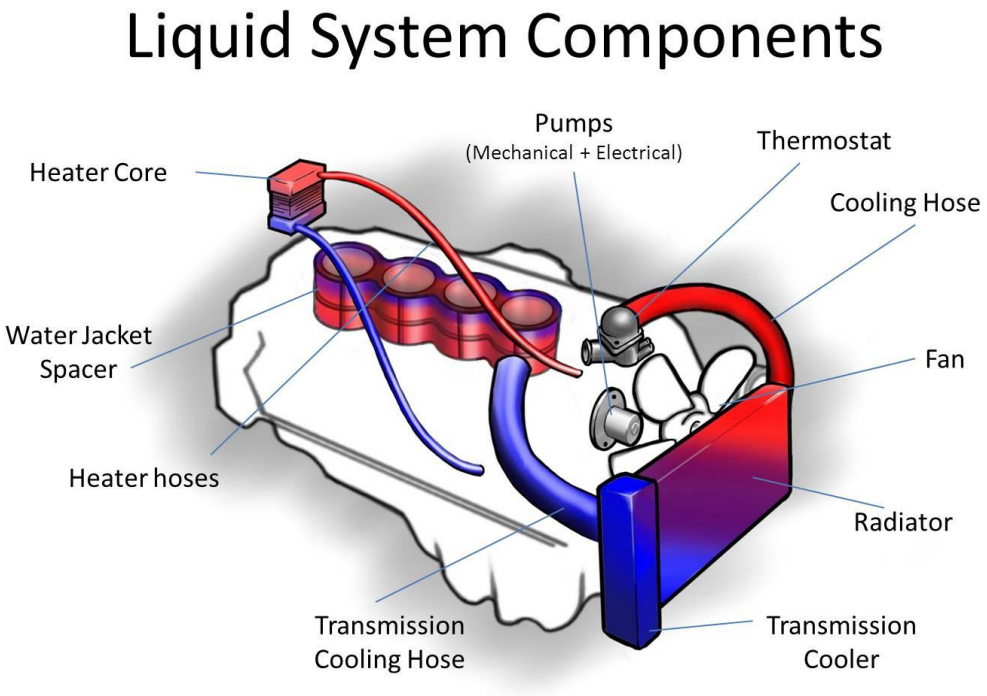


Figure 2: Liquid cooling systems are becoming more complex, and must manage increasing coolant temperatures

Underlying these cooling system trends is a significant move to plastics on a global level. Plastics, many supplied by DuPont, are playing an increasingly important role in key cooling system parts including thermostat and heater housings, outlet and inlet ports, valves, cross-overs, coolant pumps, water jacket spacers, charged air coolers (CAC) and exhaust gas recirculation (EGR) coolers.

DuPont products for engine cooling

Key DuPont thermoplastics, elastomers and fibers used in many automotive liquid and air/gas cooling system applications include:

- DuPont™ Zytel® HTN, Zytel® PLUS, Zytel® Long Chain Polyamides and Zytel® PA66 nylon resins
- DuPont™ Viton® fluoroelastomer
- DuPont™ Vamac® ethylene acrylic elastomer
- DuPont™ Kevlar® para-aramid
- DuPont™ Nomex® meta-aramid
- DuPont™ Hytrel® TPC-ET thermoplastic polyester elastomer
- DuPont™ Vespel® polyimide parts and shapes

These materials offer many benefits in engine cooling applications including:

- Opportunities to reduce weight up to 50% and cost up to 30% in replacement of traditional metal/rubber components
- Design flexibility to meet tight underhood packaging constraints
- Full integration of plastic components including multi-layer ducts and hoses, and opportunities for reduced part count
- High temperature resistance, proven chemical durability, improved NVH performance, improved wear resistance and reduced friction.

Focus on engine cooling –

DuPont product applications for next generation engine efficiency

Modern engines are cooled by complex air and liquid cooling systems that manage the flow of high temperature air, gases and coolants, and house critical thermal management components. To achieve both greater efficiency and weight savings, engines are downsizing — but they are also getting hotter, particularly with the growth of turbo charging. As a result, engine cooling is becoming more important than ever.

DuPont plastics are playing an increasingly important role in key cooling system parts including thermostat and heater housings, outlet and inlet ports, valves, cross-overs, coolant pumps, water jacket spacers, charged air coolers (CAC) and exhaust gas recirculation (EGR) coolers, demonstrating life-of-the-vehicle durability and reliability in many commercial programs. Following are selected applications from the global automotive industry:

Air system components

Air systems with EGR coolers, turbo air ducts and hot and cold side charged air coolers demand plastics that provide superior resistance to chemicals, aggressive gases and hot air at up to 210°C, with excursions to 230°C. High performance DuPont plastics and

elastomers have been proven in many commercial air system components. Following is a selection of current applications:

Tata Toyo adopts Zytel® PLUS for added durability in charge air coolers

Hot and cold-side charged air coolers of DuPont™ Zytel® PLUS nylon by Tata Toyo

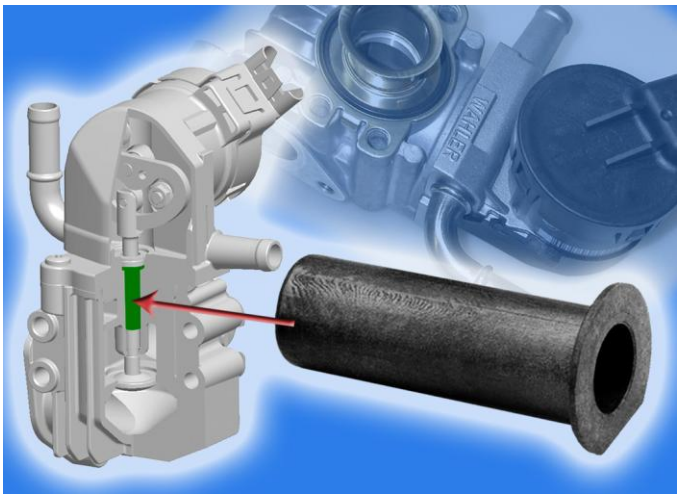
Tata Toyo of India chose DuPont™ Zytel® PLUS nylon to deliver long-term resistance to heat, chemicals and pressure in three hot- and cold-side charged air coolers for turbo-diesel engines powering passenger, utility and light commercial vehicles.

TCH/airduct of Zytel®, Vamac® and Viton® for Mazda Skyactiv-D diesel

Turbocharger airducts of DuPont™ Zytel® HTN and hoses of Viton® FKM and Vamac® AEM for Mazda's new SKYACTIV –D diesel engine

Turbocharger airducts of DuPont™ Zytel® HTN and hoses of Viton® FKM and Vamac® AEM resist charged air temperatures reaching 200°C at pressures up to 200kPa, and a wet, corrosive environment in Mazda's new SKYACTIV –D diesel engine.

Low wear low friction Vespel® polyimide parts aid performance of Wahler EGR valve bushings



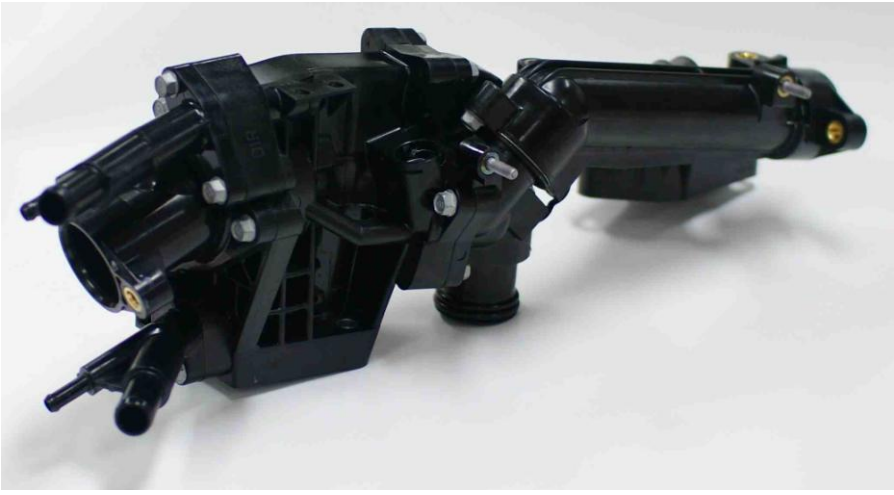
Low wear, low friction injection molded DuPont™ Vespel® EGR valve bushings manufactured by Gustav Wahler

Low wear, low friction injection molded DuPont™ Vespel® EGR valve bushings manufactured by Gustav Wahler GmbH of Germany for 4 and 6-cylinder petrol engines offer increased design freedom, reduced weight, elimination of contact corrosion and increased resistance to aggressive exhaust gases when compared to similar metal bushings. Vespel® is also specified for bearing retainers, control arms, shaft seals and spacers.

Liquid system components

Liquid systems require resistance to glycol based long life coolants (LLC) plus water at temperatures up to 130°C with excursions as high as 143°C, in addition to road salt resistance. These are operating environments that fall well with the capabilities of DuPont high performance plastics and elastomers, as demonstrated by the following commercial examples:

INZI replaces aluminium by DuPont™ Zytel® HTN, saves 30% in weight



Integrated thermostat housing of DuPont™ Zytel® HTN PPA by INZI Controls.

An integrated thermostat housing of DuPont™ Zytel® HTN PPA by INZI Controls of South Korea for the Hyundai Theta and Lambda offers 20-30% weight reduction and longer component service life than the aluminium it replaces.

Wahler chooses thermostat housings of Zytel® HTN for BMW and Daimler

Thermostat housings of DuPont™ Zytel® HTN by Gustav Wahler

DuPont™ Zytel® HTN enables Gustav Wahler to save weight and enhance the performance of thermostat housings for BMW and Daimler. The housing parts for BMW were welded together, providing additional design flexibility.

Cooper Standard specifies Zytel® HTN PPA for all-plastic coolant pump

Series 4 Brushless Pump of DuPont™ Zytel® HTN PPA by Cooper Standard

Cooper Standard of USA chose DuPont™ Zytel® HTN PPA for its all-plastic Series 4 Brushless Pump to reduce weight, withstand 100g-force shocks, resist salt and lifetime contact with glycol coolants, and operate at high temperatures.

Bergstrom selects DuPont™ Zytel® PLUS for new coolant pump parts

Bergstrom selected DuPont™ Zytel® PLUS for the housing, impeller and cover of its next generation booster pump for the bus and specialty market.

New booster pump by Bergstrom, Inc, of USA, circulates coolant to auxiliary heaters, and is designed to be higher performing, more efficient, more durable and less prone to leaks than many existing booster pumps on the market. It uses DuPont™ Zytel® for the housing, impeller and cover, and offers severe service capability at temperatures of -40°F to 240°F and pressures of more than 60 psi. The result is better, more consistent heating in buses and specialty vehicles.

Water jacket spacer of Zytel® HTN

Water jacket spacer of DuPont™ Zytel® HTN PPA

A water jacket spacer of DuPont™ Zytel® HTN PPA helps improve cylinder bore temperature distribution in several engines manufactured by a leading OEM, improving fuel economy by nearly 1%, equivalent to reducing vehicle weight by 25 kg. Zytel® was chosen because of benefits in cost, performance, weight saving and ease of manufacturing — meeting engineering criteria including high temperature reliability, resistance to hot coolant, dimensional accuracy and ease of assembly.

Water pump seals of Viton® GFLT-600S resist aggressive coolants and greases where HNBR fails

Chart illustrates marginal loss of elongation at break of DuPont™ Viton® GF-600S and Viton® GFLT-S fluoroelastomers (FKM) versus dramatic loss of properties of a bisphenol grade of FKM after aging in aggressive monoethylene glycol coolant liquid for 2 000 hours at 125°C, conditions that caused traditional HNBR seals to leak

Seals of DuPont™ Viton® fluoroelastomer are widely specified for long-term service in automotive water pumps due to their resistance to high temperature coolants and grease containing polymeric urea.

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The company believes that by collaborating with customers, governments, NGOs, and thought leaders we can help find solutions to such global challenges as providing enough healthy food for people everywhere, decreasing dependence on fossil fuels, and protecting life and the environment. For additional information about DuPont and its commitment to inclusive innovation, please visit www.dupont.com.