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“Opportunities for Plastics Materials/Processes for Under-The-Hood Applications”

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Thermal System Division
Delphi Corporation

At
2008 SPE ACCE Conference
Troy Michigan

- ◆ **Introduction**
 - Under-the-hood Key Applications
 - Driving Forces For Material And Process Innovations
- ◆ **Innovations In Plastics Materials**
- ◆ **Innovations In Process Technologies**
- ◆ **Application Innovations (Examples)**
 - HVAC System
 - PowerTrain Cooling
 - Induction Systems
 - Engine Covers
- ◆ **Future Trends**

◆ Introduction

- Under-the-hood Key Applications
- Driving Forces For Material And Process Innovations

◆ Innovations In Plastics Materials

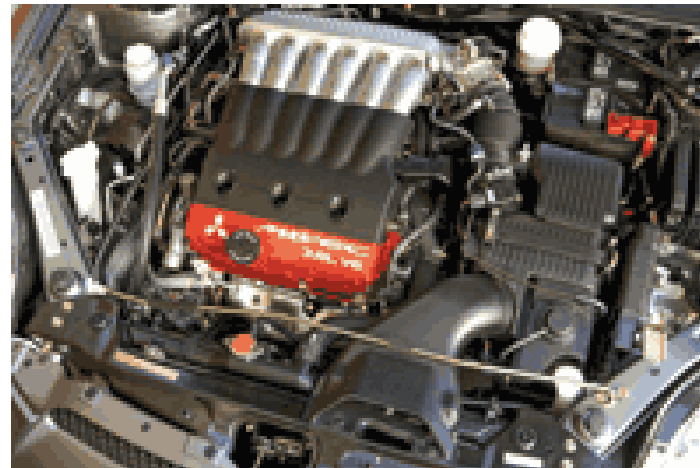
◆ Innovations In Process Technologies

◆ Application Innovations (Examples)

- HVAC System
- Power Train Cooling
- Induction Systems
- Engine Covers

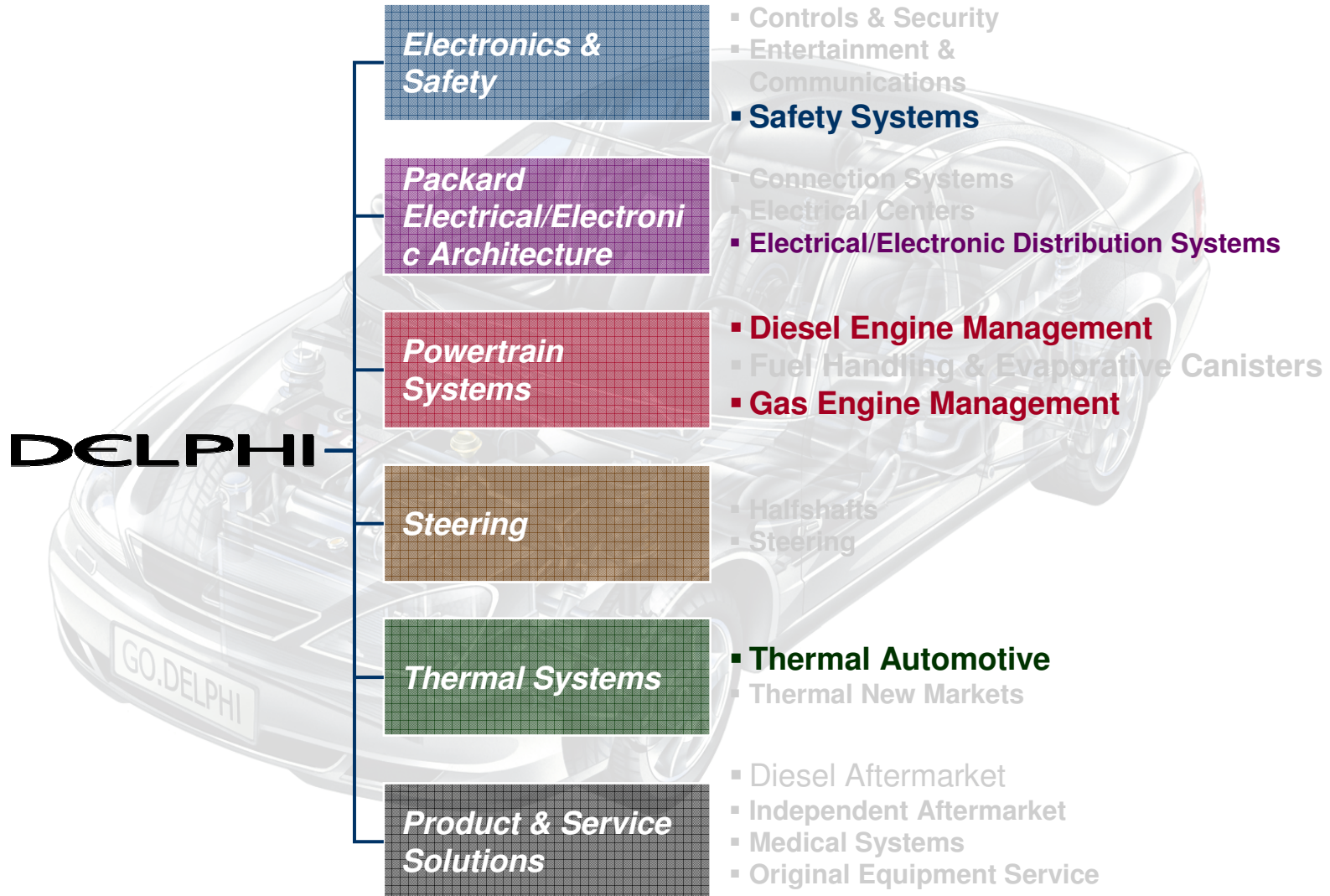
◆ Future Trends

- ◆ **HVAC System**
 - HVAC Housing
 - HVAC valve
 - Ducting
 - Filters
 - Fan
 - HVAC Controls
- ◆ **Power Train Cooling**
 - Fan and Shroud
 - Radiator
 - Thermostat Housing
 - Pipes/Hoses
- ◆ **Engine Covers**
 - Cosmetic and functional
 - Rocker box
- ◆ **Induction System**
 - Intake Manifold, filters and pipe works
- ◆ **Electrical**



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Delphi Divisions



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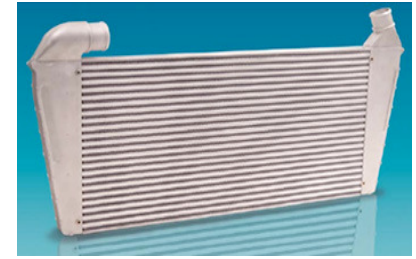
Delphi Thermal Systems Automotive Products Portfolio



Radiator



Condenser



Charge Air Cooler



HVAC Control



HVAC Module



Evaporator



Variable



Electronic Control



Fixed

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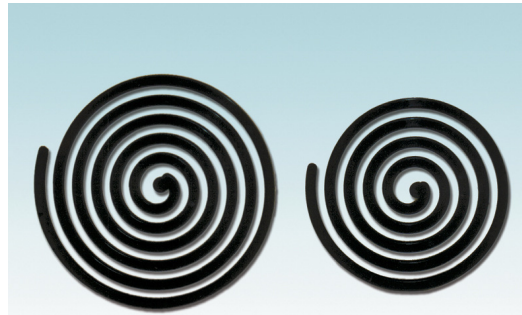
Driving Forces for Material Innovations

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- ◆ Low Weight – strongest driver (improved fuel economy requires vehicles to be lighter)
 - ◆ Low Cost
 - ◆ High temperature need (due to more sophisticated engine designs and continuing reduction in installation space)
 - ◆ Superior resistance to harsh and corrosive chemicals, even at high temperature (Under the hood of an automobile is one of the most severe environments in the world)
 - ◆ High strength and dimensional stability
 - ◆ Flame retardant properties
 - ◆ Modular design, integration of functionality
 - ◆ Added functionality (sensors, accessories, electronics)
 - ◆ Legislation: emission reduction and safety requirements
- Innovative Solutions is the only way for major plastics growth**

- ◆ PA 6 or 6,6 unfilled and filled (short glass and/or mineral fillers)
- ◆ PET, PBT
- ◆ Other high temperature plastics such as PPA, PPS etc.
- ◆ Thermosets such as SMC and BMC
- ◆ PP Compounds (talc filled/short glass filled/mineral filled)
- ◆ PP Long glass fiber
- ◆ Flexible Elastomers (TPEs, Engineering TPEs and TPVs)

1. Need: Ultra High Flow



- ◆ **Solution: UltraFlow Polyamide – Akulon PA6 (DSM)**
- ◆ Extremely easy to process material that offers up to 80% improved flow and corresponding reduction in injection moulding cycle times in comparison to standard PA6 grades, without significant loss of mechanical properties.
- ◆ Recent tests at multiple engine cover producers have resulted in significantly (25%+) reduced cycle times with equal or better dimensional stability.
- ◆ **Now with Improved Surface Aesthetics**

Source: DSM

http://www.omnexus.com/sds/PA6-air-inlet/index.aspx?lr=push_1_32067

1. Need: Ultra High Flow (Contd..)

BASF:

- ◆ High Flow Nylon using Nanoparticles
- ◆ Flow is enhanced by up to 100%
- ◆ Also improves heat-aging
- ◆ Target Applications: Large components in the engine compartment such as cylinder-head covers or intercooler end caps,



Source: BASF

SABIC:

- ◆ New super-high-flow **PBTs** permit molding thinner, larger, and more intricate automotive parts at lower injection pressures.
- ◆ Suitable for power-distribution boxes, high-pin-density connectors, and HVAC vanes.

DuPont:

- ◆ **Nano-composites**
 - High strength, low mass and easy flow
- ◆ Experimenting with a proprietary nanoclay

www.modplas.com/inc/mparticle.php?section=techtrends&thefilename=techtrends02012008_01

2. Need – High Temperature Resistance Material

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- ◆ Chevrolet's new ZR1 Corvette exemplifies the trend toward tighter and hotter engine compartments
- ◆ This in turn is driving a switch to higher-temperature polyamides, PPS, and bulk molding compound.

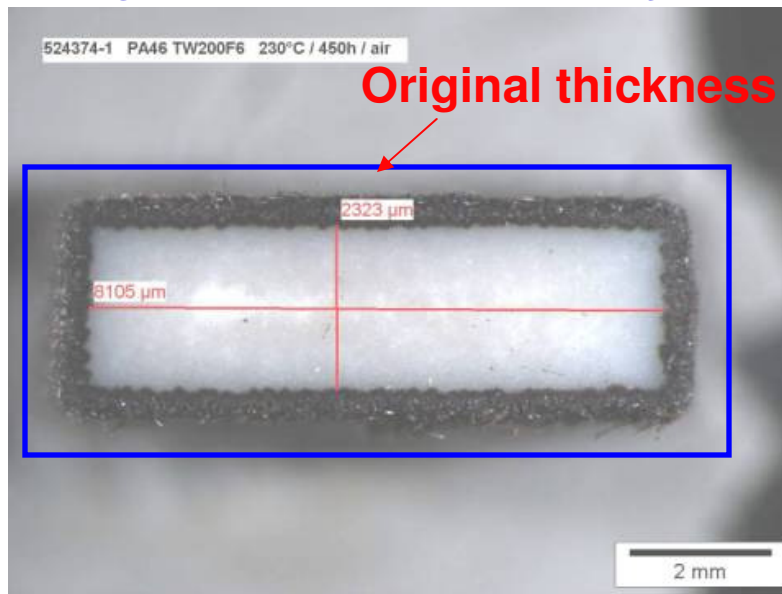


<http://www.immnet.com/articles?article=3584>

2. Need – High Temperature Resistance Material

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Degradation Mechanism of Nylon at High Temperature



- A degradation layer progressively builds up with consequences on tensile strength. The remaining, non-degraded, white colored core, carries the load.

(TW200F6 = PA46GF30HS)

Solution from DSM : High Temperature Material Stanyl® Diablo

- High Heat aging at 210°C with good properties retention such as:
 - Tensile Modulus.
 - Tensile Strength.
 - Elongation
- Vibration Welding – No issue
- Good Surface Appearance after aging at 210°C
- Turbo Diesel Applications

2. Need – High Temperature Resistance Material (Contd.)

◆ Solution: Technyl HP - Rhodia

- This material innovation broadens the field of polyamide usage to higher-heat environments where previously only PPA (polyphthalamide) could offer an answer.
- Rising underhood temperatures (up to 230C) are precluding the utilization of PA 6 and even, in some cases, standard PA 66 in the engine bay.
- Technyl HP, however, retains its properties well, even with extended usage at 200 °C. After 2000 hours at 200 °C, Technyl HP tensile strength falls by only 12% compared to 57% for conventional PA.
- Technyl HP grades are available with glass fiber loadings of 35% and 50%.

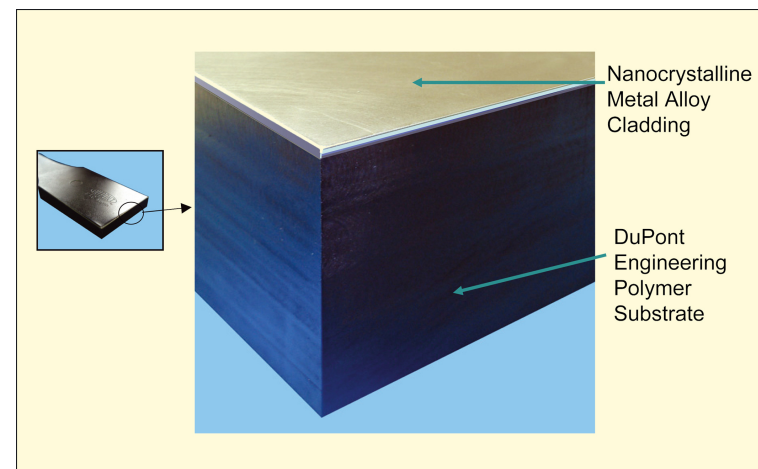
◆ Growth of Thermoset materials: BMC and SMC, due to high temperature needs

http://www.modplas.com/inc/mparticle.php?section=techtrends&thefilename=techtrends02012008_01

3. Need: Higher Strength With Light Weight To Replace Metal

◆ Solution: MetaFuse “Nanometal/Polymer Hybrids

- It combines the strength and stiffness of metals with the light weight and design freedom of plastics
- Nanometal - Nanocrystalline nickel or nickel-iron alloy (wet electrodeposition process)
- Nylon 66 and HTN (current work)
- A metallic layer only 25 to 200 microns thick (1000 times smaller grain than conventional metal) can double or quadruple stiffness, strength, and impact toughness of Engineering Plastics



Source: DuPont

<http://www.ptonline.com/articles/200711ed.html>

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Driving Forces for Process Innovations

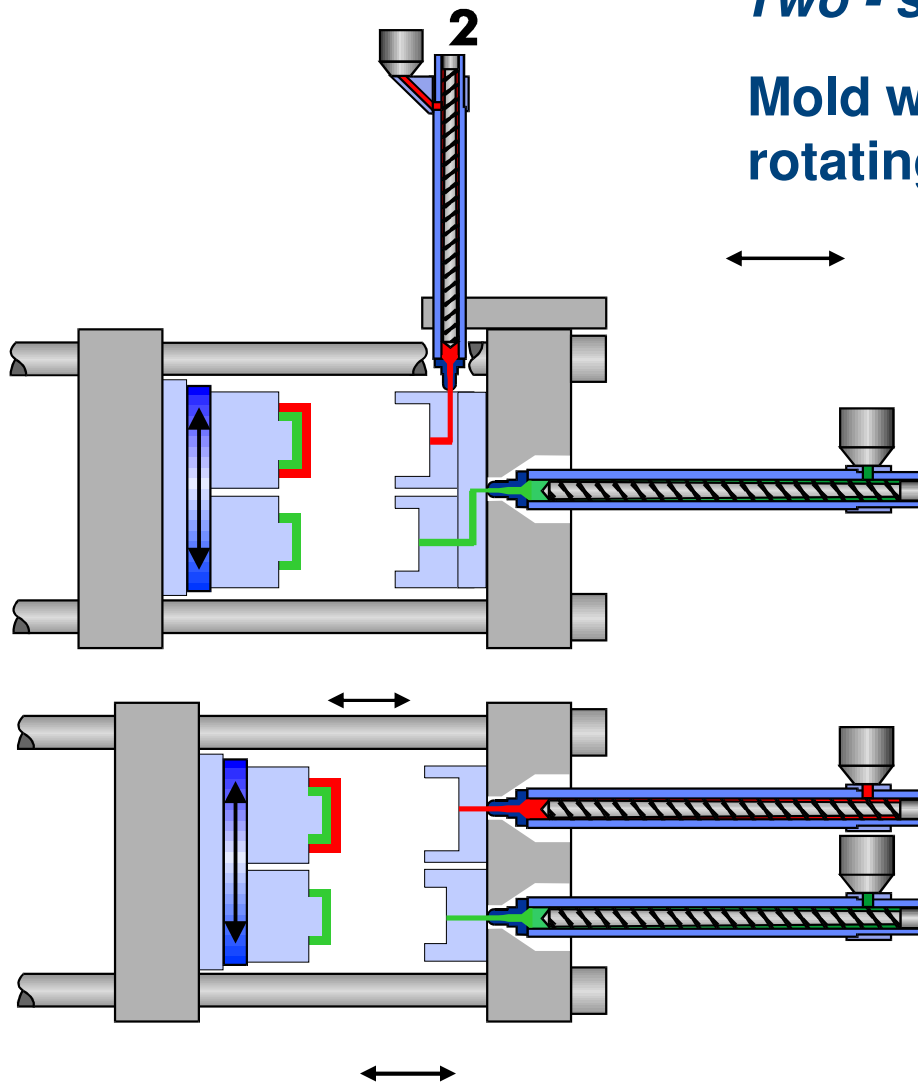
- ◆ Low Weight
- ◆ Low Cost
- ◆ Cycle time reduction
- ◆ Lean Engineering
- ◆ High strength and dimensional stability
- ◆ Modular design, integration of functionality
- ◆ Safety requirements

Multi-Material Molding

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Two - shot molding

Mold with integrated rotating device



Benefits—

- Design Enabler – Flexibility
- Improved Fit and Finish
- Reduce buzz, squeak and rattle

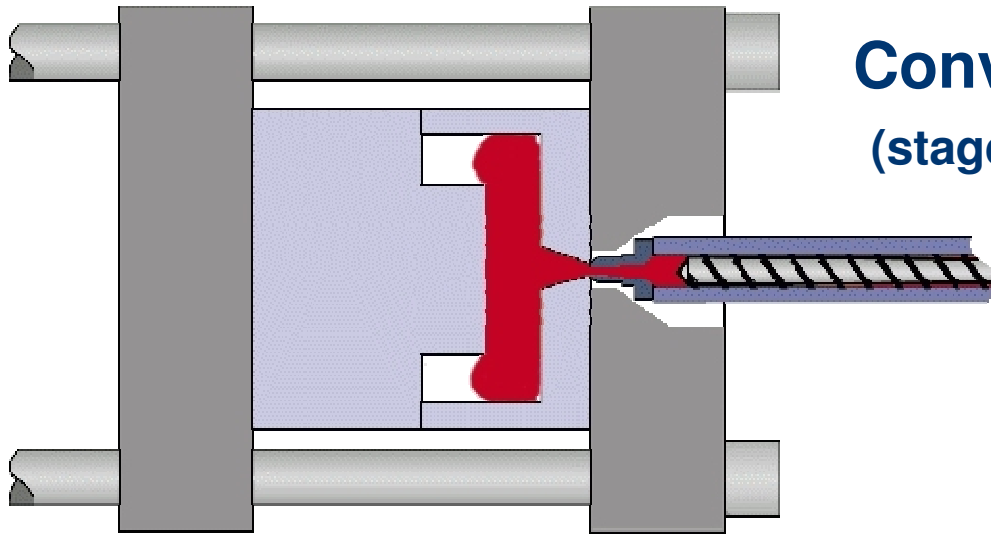
Examples:

- HVAC valves (flappers)
- Possible LIM gasket for radiator

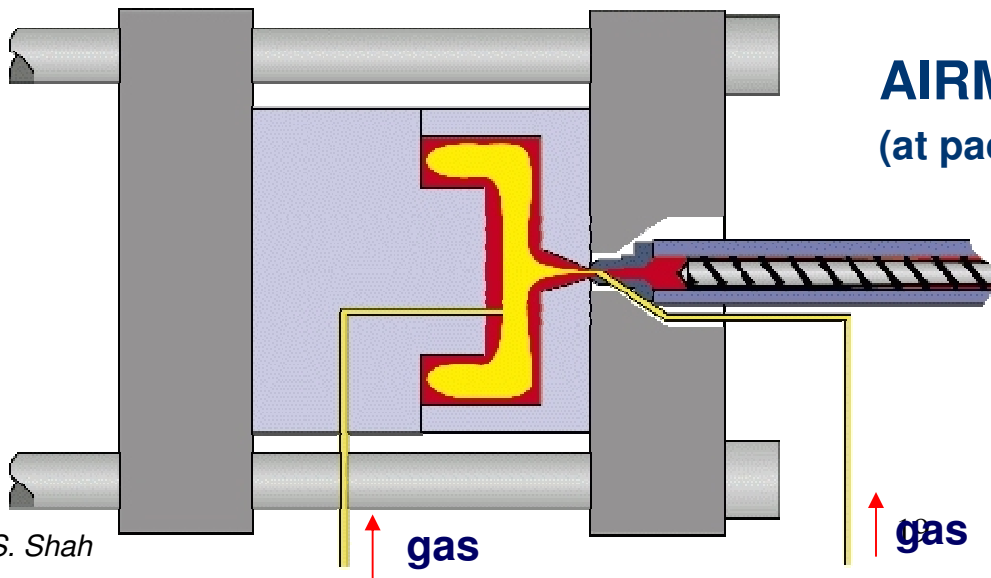
Source: Battenfeld

Gas Assisted injection Molding

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Conventional Injection Molding
(stage before gas have been introduced)

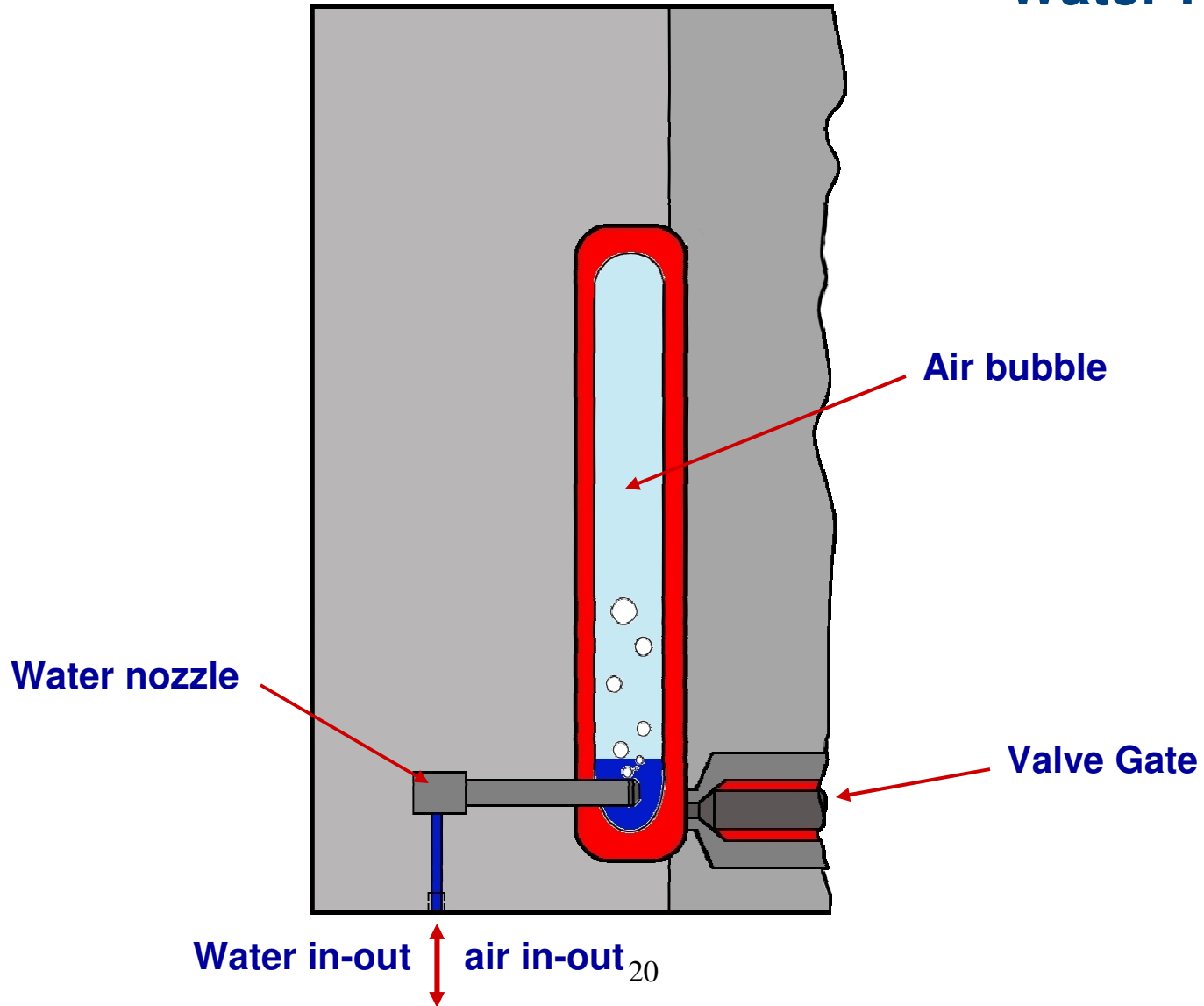


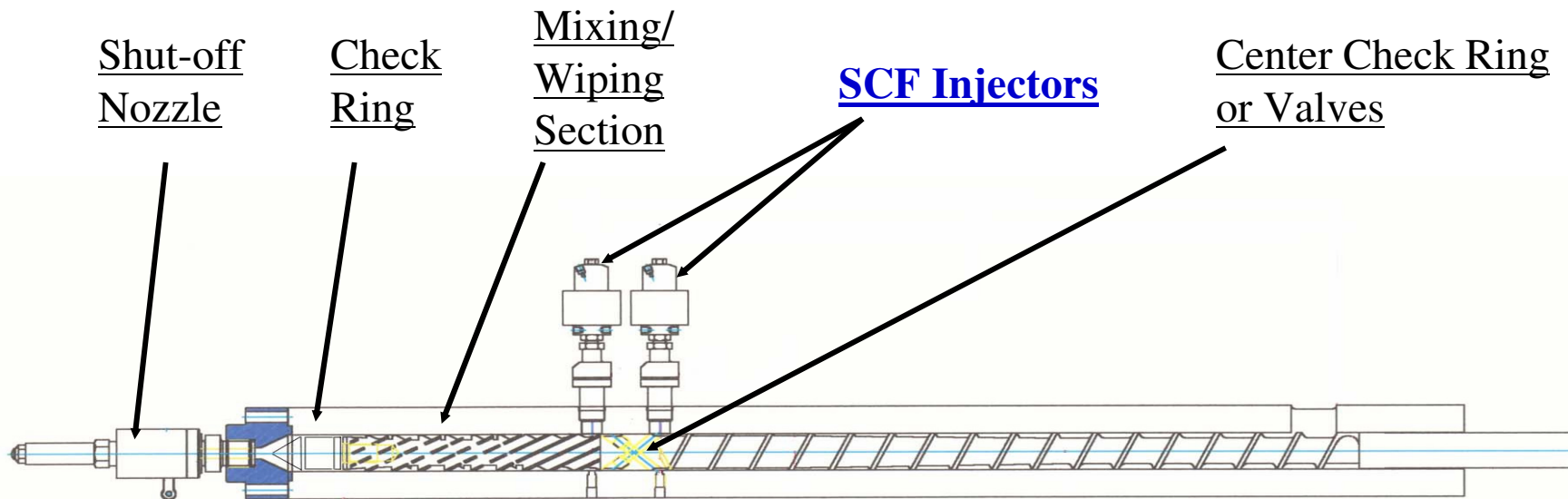
AIRMOULD® Gas assist
(at packing stage)

S. Shah

Water Injection Molding (WIT)

Water Relief

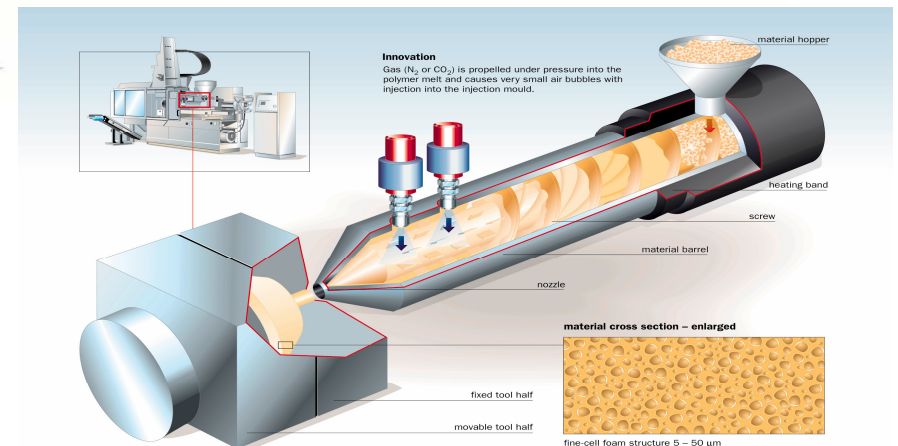


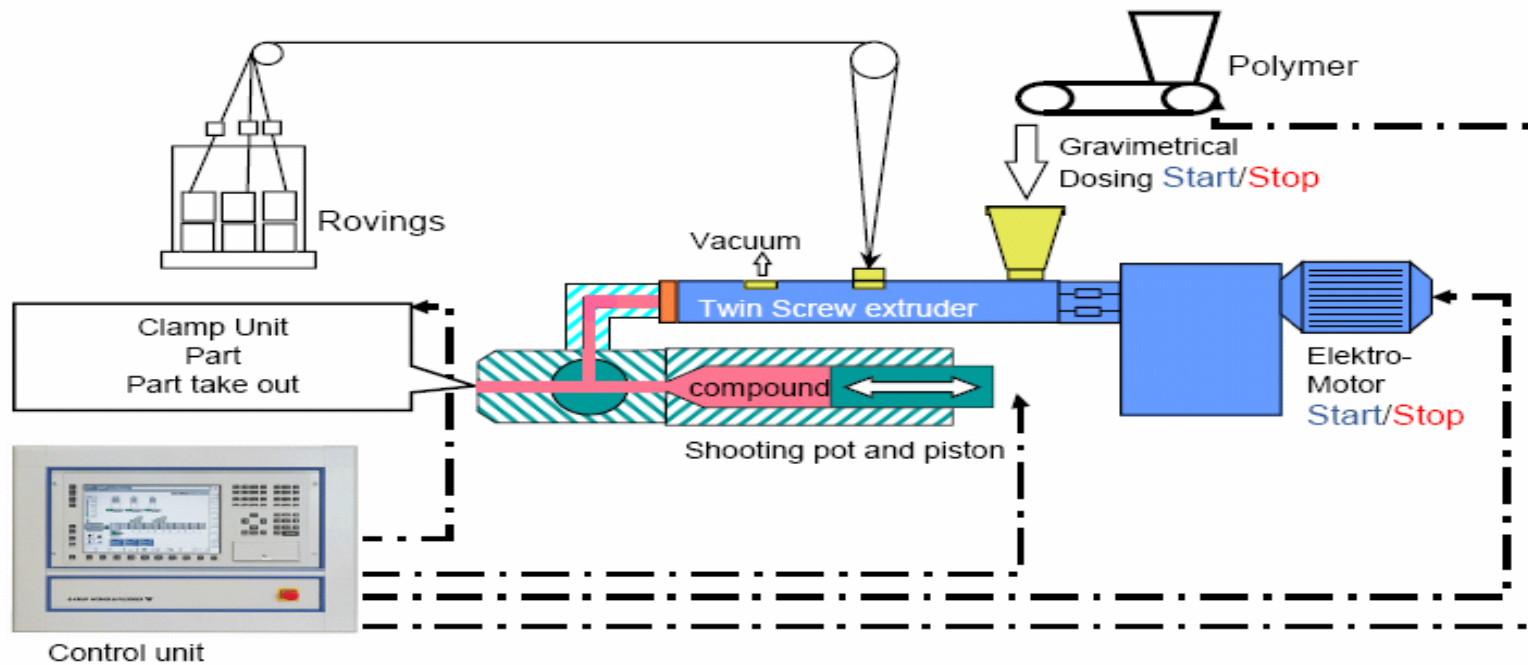


Benefits:

- **Low mass**
- **Cycle time reduction**
- **Uniform shrinkage**
- **Significantly low warpage**

Source: MuCell, Engel

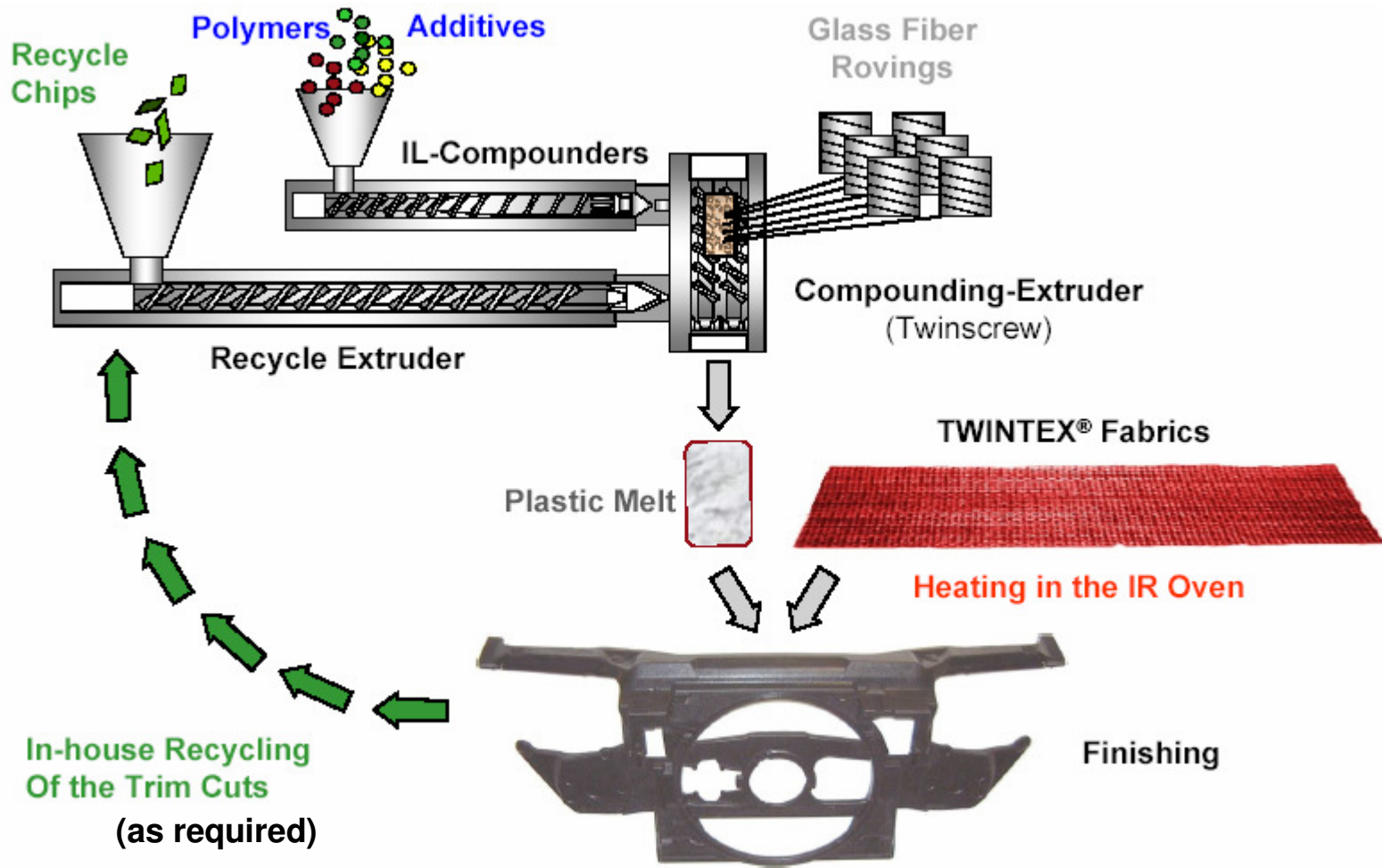




Source: Husky

ECM w/ILC & Continuous Fiber Reinforcement

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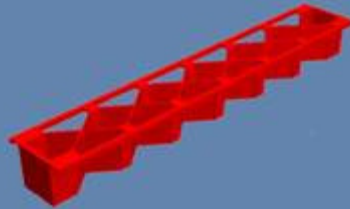


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Plastics Metal Hybrid (PMH) technique. Best of Both Worlds

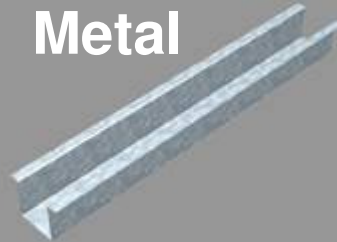
- High design flexibility
- Good flow properties
- Low density
- Good rigidity and toughness
- Good fatigue performance
- Stable at underhood temps
- Resistant to oil, grease and cleaning agents

Durethan® BKV 30

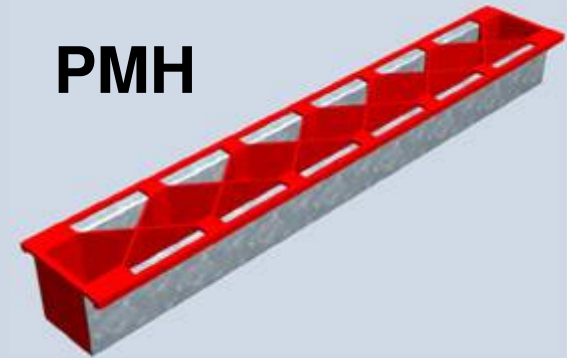


- High strength and rigidity
- Ductile failure behaviour
- Low thermal expansion
- Good deep draw behavior

Metal



PMH

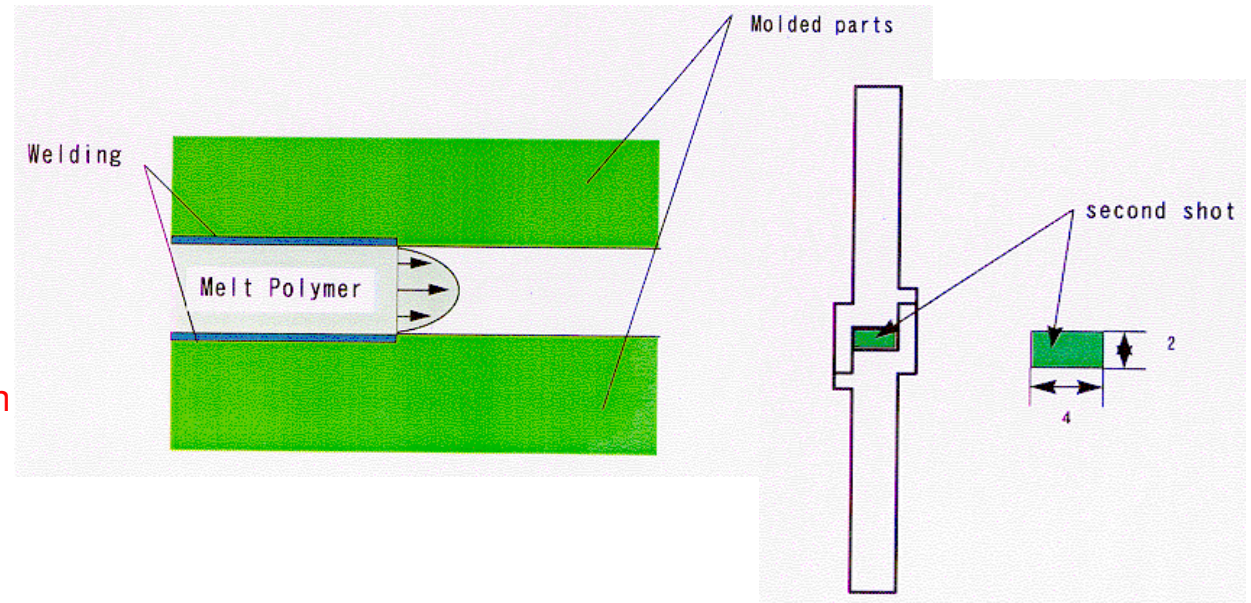


- Delayed buckling behaviour using thin sheet metal
- High energy absorption
- High temperature stability (E-Coatable, Paintline capable)
- Low part weight
- High repeatability in manufacturing and assembly
- Easy integration of functional elements

LANXESS

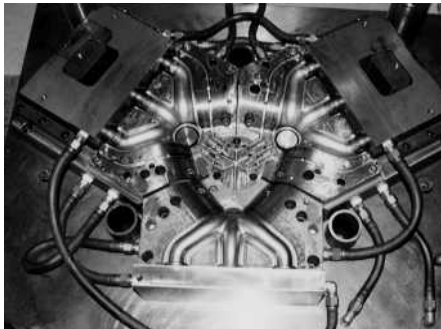
Method Description:

Two halves of the part are injection molded separately in the same tool
Tool rotates 120° (or slides) to bring the two halves together
Second shot of polymer is injected into a channel between the two halves to fuse them together

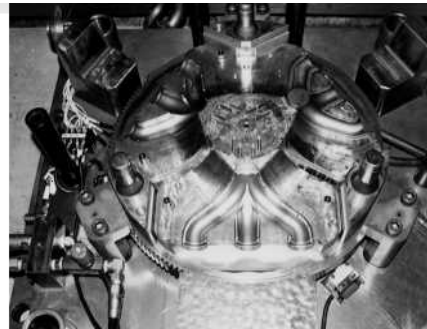


Variables:

Melt temperature for second shot



DIE OF FIXED SIDE



DIE OF ROTATABLE SIDE

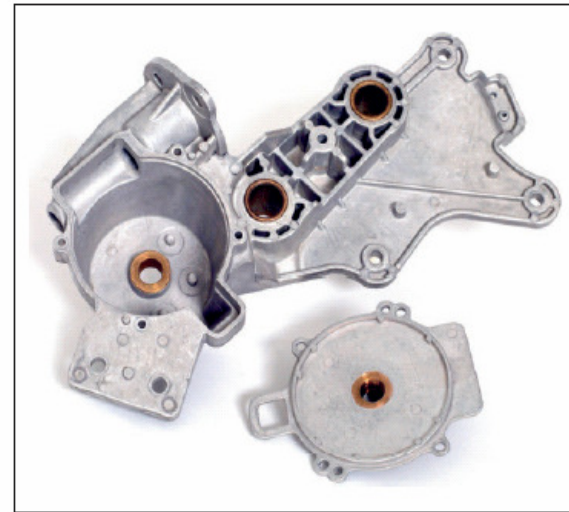
◆ Summary

- Requires resin compatibility
- Requires good flow to fill channel completely
- High weld strength
- Complex joint line capability
- Joint subject to molding pressure

Magnesium Injection Molding (Thixomolding-TXM)

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- ◆ Several parts that are not possible in die-casting because of precision tolerances for mating surfaces with the engine block are net-shape ready with this TMX process.
- ◆ Thixomolding allows molding parts with very high tolerances
- ◆ Magnesium is 36% lighter than aluminum by volume and, when alloyed, has the highest strength-to-weight ratio of any structural metal.
- ◆ It compares favorably with plastics as well, magnesium alloys have the potential to reduce weight by 30% compared with plastics in dynamic applications and up to 60% in static loads.

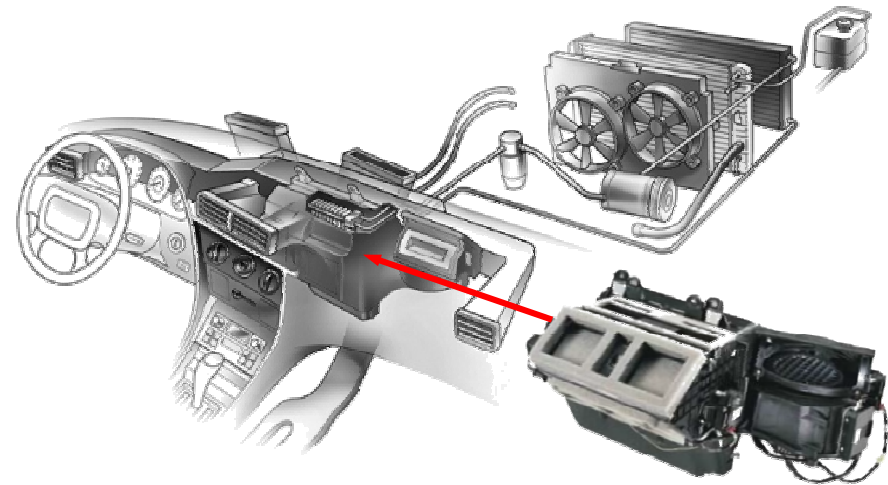


Source: Husky

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◆ Challenges:

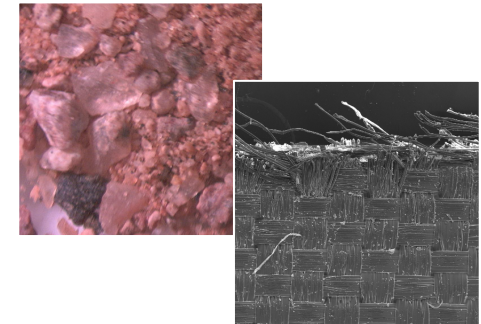
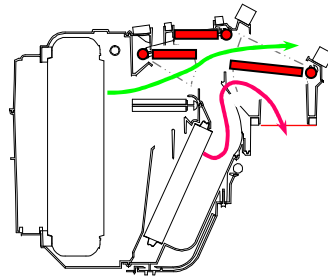
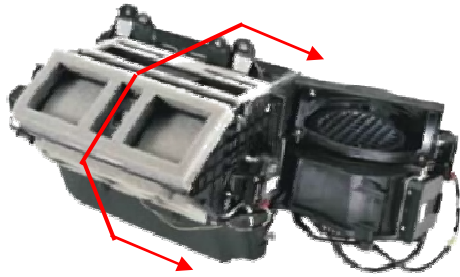
- Low mass and cost
- NVH control
- Warpage reduction with PP materials
- Functional integration with simplified tool design
- Air quality
- Increased demand for comfort level
- Cooling and heating performance at lower cost
- Zone conditioning



Sub-components

- HVAC Housing
- HVAC valve
- Ducting
- Filters
- Fan
- HVAC Controls

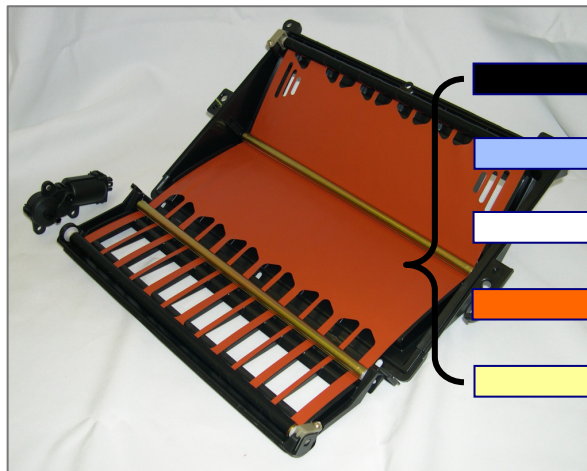
Conventional Valve



This is the 1st application of PTFE & silicone on the same substrate

2006 SPE Award Winner

Delphi's Film Valve



Film:

- PTFE coating
 - Low COF
 - Static dissipative
 - Black
- Binder
 - Adhere PTFE to fiberglass
- Woven fiberglass
 - Minimal creep
 - Minimal change in stiffness
 - Sufficient tensile & tear strength
- Silicone rubber coating
 - Noise damping
- Anti-stick coating
 - No Blocking
 - Eliminates "stick" of silicone rubber layer

Precise control of airflow, compact design

- ◆ For rear HVAC systems on the Nissan Quest.
- ◆ It incorporates 11 discrete components into one integrated assembly, streamlines packaging significantly
- ◆ First brushless pump with MMT motor-control technology and overmolded integrated brackets
- ◆ Material -DuPont™ Zytel® HTN PPA
- ◆ Increased life expectancy for pump and brackets by reducing corrosion thanks to special hydrolysis and ethylene glycol resistant resin.
- ◆ The pump delivers 8% higher performance in flow at 53% of the size, 33% of the mass (vs. metal brush pumps), and at lower cost while increasing cabin comfort
- ◆ 2007 SPE award winner



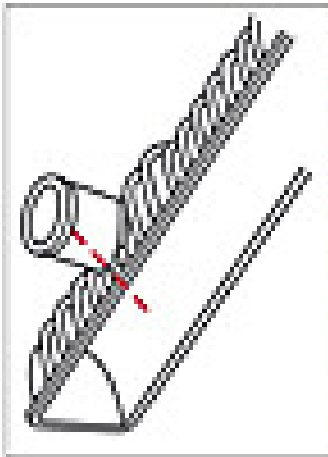
http://www.speawards.com/2007Awards/chassis_hardware/21.htm

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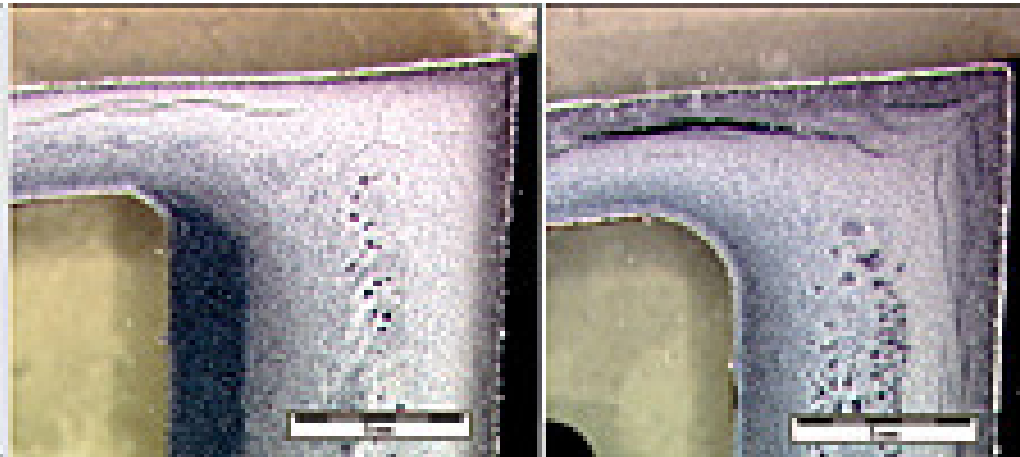
Radiator End Tank: Improved Hydrolysis and Crack Resistance

DELPHI

- ◆ **Solution: new A3WG6 and A3WG7 HRX Polyamide - BASF**
- ◆ Lower tendency to form cracks - a very advantageous aspect for components with weld lines (glass filled material)
- ◆ Also this is confirmed in the swelling test in pure glycol at high temperatures
- ◆ Tests were carried out on welded containers that had been exposed on one side and on both sides to hot coolant at a temperature of 130 °C [266 °F]



Radiator End Tank



Source: BASF

Plastic Coolant Tube – Complex Design by Gas and Water Assist Injection Molding and Blow Molding

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- ◆ Demand for lower fuel consumption leads to modified engine concepts. As a result, demands on all the pipe systems for air management, fuel supply, and oil and cooling circuits are rising

GAIM-

- ◆ Metal tubes cannot achieve the bend radii
- ◆ This is the first PPS coolant tube of complex geometry produced by GAIM for '07 MY Ford F250 pickup engine to withstand long life coolant and high engine temperatures.

Blow Molding



Water Assist



Gas Assist



<http://97.86.166.109/speawards/2006Awards/powertrain/22.html>

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Metal Replacement Accelerated for Valve Covers and Intake Manifolds

- ◆ Plastics have made significant inroads in valve covers and air-intake manifolds since 1990.
- ◆ In valve covers (also called rocker or cam covers), both newer glass-reinforced nylon 6 and 66 versions and the established thermoset vinyl ester composites are replacing metals by providing weight and cost savings and extended design freedom.
- ◆ **Delphi** has produced more than 37 million (Integrated Air/Fuel Modules) IAFMs and more than 21 million plastic manifolds since 1990.

Source: Delphi.com



Delphi Composite 8-cylinder Multi-piece Vibration Welded Integrated Air/Fuel Module

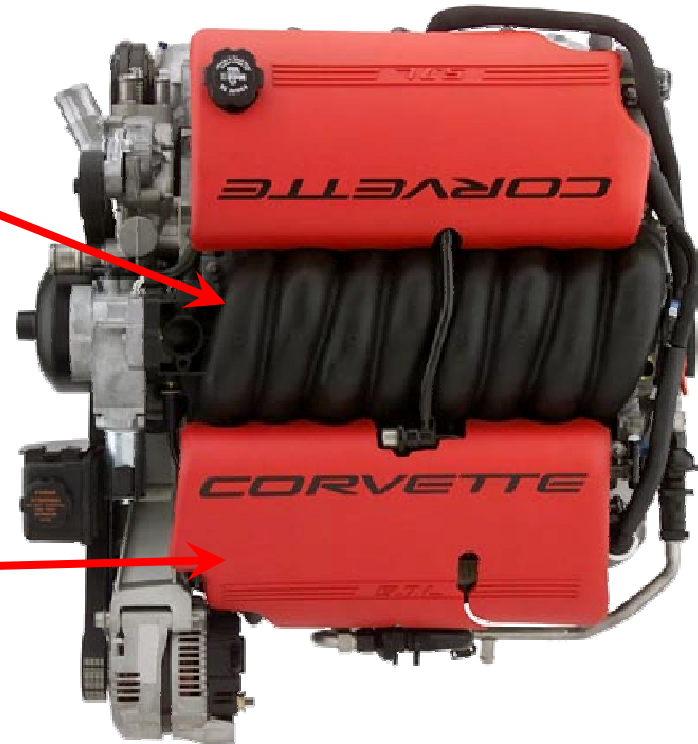


Delphi Composite 4-cylinder Integrated Air/Fuel Module

Current Plastic Gasoline Engine Components

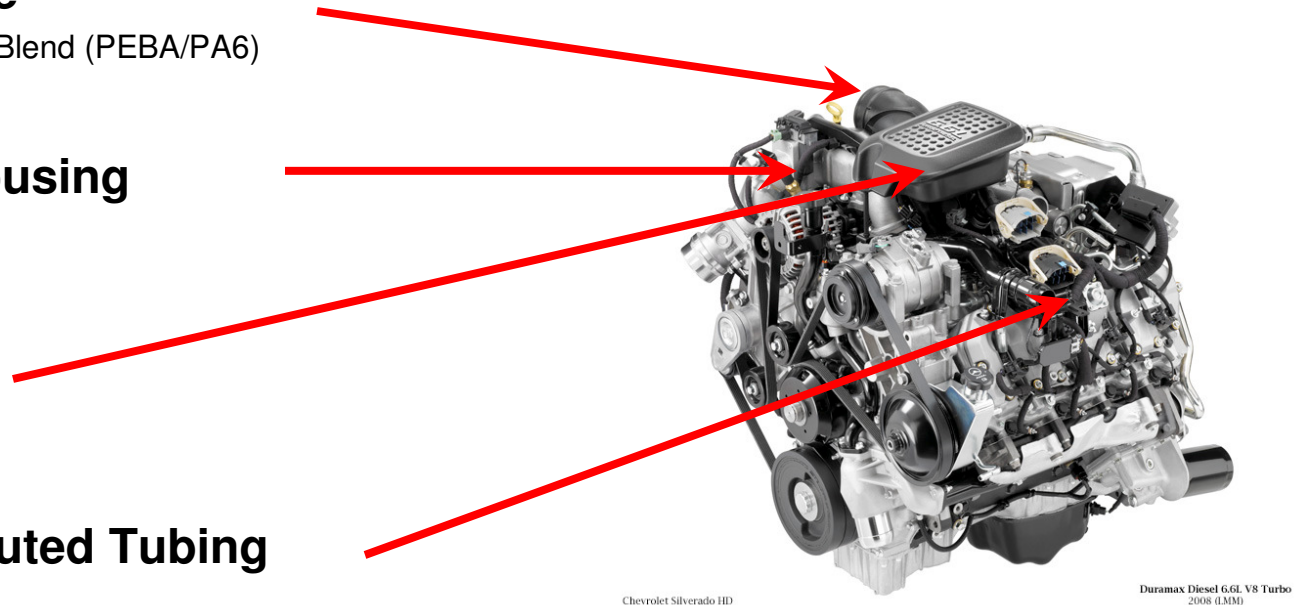
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- ◆ **Air Intake Manifolds**
 - Nylon 6 & 66
- ◆ **Chain Tensioners**
 - Nylon 46 & 66
- ◆ **Timing Belt Covers**
 - Polypropylene
- ◆ **Cam Covers**
 - Thermoset Polyester
- ◆ **Engine Acoustic Covers**
 - Nylon 6 & 66



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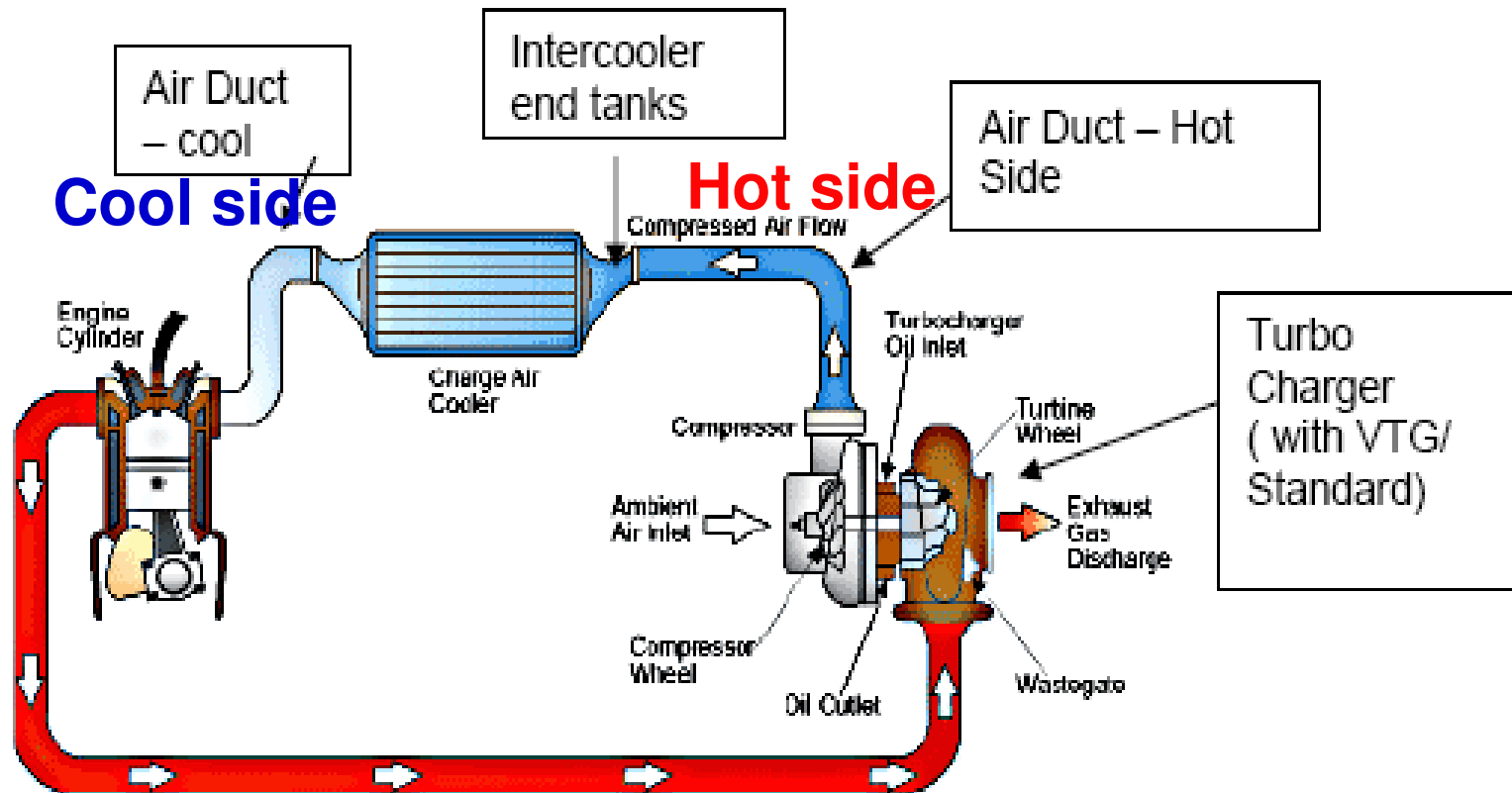
- ◆ **Turbocharger Inlet Tube**
 - Polyether Block Amide/Nylon 6 Blend (PEBA/PA6)
- ◆ **Throttle Body Motor Housing**
 - PBT 30% Glass Fiber
- ◆ **Air Intake Resonator**
 - Polypropylene (PP)
- ◆ **Wiring Harness Convoluted Tubing**
 - Nylon 66



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Charge Air Cooler (CAC) End Tank Function of CAC:



TO INCREASE THE O₂ CONTENT OF IN-TAKE AIR TO IMPROVE FUEL EFFICIENCY / GENERATE MORE POWER.

TURBOCHARGER IS DRIVEN BY EXHAUST GASES & COMPRESSES IN-TAKE AIR.

CHARGE AIR COOLER COOLS THE COMPRESSED AIR TO DENSIFY IT.

Source: DuPont

First Intercooler End Caps Made By Special GF PA 66

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- ◆ Charge air intercooler end caps made of Ultramid® A3W2 G10
- ◆ Highly heat-stabilized and highly filled (50% GF AP 66)
- ◆ Withstands the continuous temperatures of 190 °C [374 °F] and the excess-pressure fluctuations between 0.1 and 1.5 bar encountered in the intercooler system
- ◆ To be found in Ford Transit Connect and Tourneo Connect (diesel engine)



Electronic Throttle Control Module

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- ◆ Summary: This is the first plastic ETC housing, which replaces machined cast aluminum at mass savings of 28% and costs savings of 18%, while also reducing warranty costs and potential for ice freeze-up and potential throttle blade stick.
- ◆ Engine mounted
- ◆ A special zero-shrink BMC grade was used and the units tight concentricity better controls air flow at idle.



<http://www.speawards.com/2007Awards/powertrain/28.htm>

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- ◆ Nylon compounds with superior surface appearance are beautifying the engine compartment with engine covers, rocker panels, and air-intake manifolds.
- ◆ Since 2003, Resin suppliers like DSM, Rhodia, DuPont, Bayer, Albis, BASF etc., have come up with a cost-effective solution in novel high-flow nylon 6 grades that enhance surface quality and productivity.
- ◆ In US, car engines and rocker covers are larger and more demanding in terms of dimensional stability and seal integrity, possibly making thermosets highly cost-effective. But benefits of thermoplastics can not be ignored.

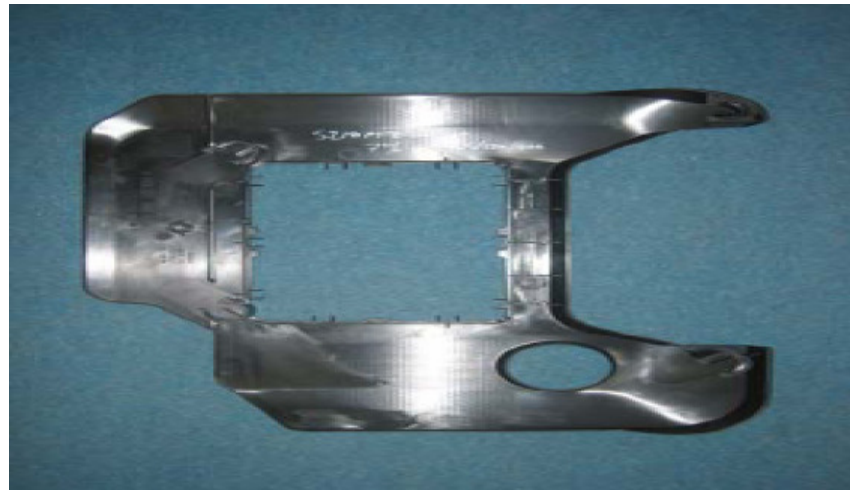


<http://www.ptonline.com/articles/200301fa1.html>

MuCell Engine Cover – Good Surface Appearance

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- ◆ Rhodia's special material for MuCell for better surface (ex: engine Beauty cover)
- ◆ Grade used: TechnylXcellS218MZ20V1 0 blk
- ◆ 10% weight reduction
- ◆ Surface aspect equal to solid
- ◆ No warpage issue
- ◆ Cycle time reduction: 20%
- ◆ Note: Other companies also have MuCell grades



Source: www.Rhodia.com

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Composite Valve Cover Assembly with Oil Trap

- ◆ This first metallic top-coated SMC valve-cover assembly with deep draw and die-locked features meets all requirements for Volvo Powertrain – North America.
- ◆ Use of SMC allowed for significantly reduced investment, with 30% mass saving and 50% piece-cost savings vs. a cast-aluminum design.



<http://97.86.166.109/speawards/2006Awards/powertrain/46.html>

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- ◆ An engine cover integrated with an air filter for DaimlerChrysler's V8 engines, molded from a 30% glass-filled PA 6 (Ultramid B3WG6 GP, BASF) with enhanced resistance to bursting pressure.
- ◆ A heat-stabilized PPA air-intake manifold in the 4.2L diesel motor on the Audi A8 that withstands intermittent temperatures of 250 °C, exhaust gases, and fuels (Zytel HTN 52G35HSL, a 35% glass-filled PPA from Dupont). It replaced a metal part weighing two times more.
- ◆ A 1m-long rocker cover with heavy ribs on the underside to reduce resonance and sound radiation, molded for a six-cylinder MAN truck engine using 15% mineral/25% glass-filled PA 66 (Technyl A218 MT15 V25, Rhodia Engineering Plastics).

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- ◆ A flexible engine shroud fan cover that resists oil and chemicals at engine compartment temperatures, consisting of a TPV (NexPrene 1087A, Solvay Engineering Plastics) overmolded onto a rigid nylon retaining ring.
- ◆ An integrated motor, impeller, and electronic control system housing for an electric water circulating pump for static heating systems and supplementary cooling of high-performance engines, molded from PPS (Fortron, Ticona) for its ability to resist antifreeze-water mixtures at operating temperatures up to 140 °C for extended periods.
- ◆ Of course, these are only the tip of the iceberg. Most breakthrough developments in the automotive industry go unreported, for the most part because automakers tend to be wary of releasing information due to competitive pressures.

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- ◆ Meet the Global Vehicle demands (BRIC nations - expected to reach 20 million vehicles, exceeding US and Europe).
- ◆ Weight Reduction – Major Need from OEMs (Fuel Efficiency)
- ◆ High Temperature up to 220 C for certain applications (Cost is still a major factor since these materials are costly)
- ◆ Rigorous dimensional and form tolerances requirements for Manifold
- ◆ Other than engineering plastics, three materials trends that can be found in the current automotive underhood market are:
 1. The use of Thixomolded (TXM; molded magnesium) parts,
 2. In-line compounding/injection molded thermoplastics, and
 3. Thermoset polyester (SMC), or bulk molding compounds (BMC) that are injection molded.
- ◆ NVH – Needs smart materials, innovative part design and better characterization methods
- ◆ Bio-polymers / Composites (Bio-based resins and Fibers)
- ◆ Nano-materials and Nano-composites
- ◆ Need for advanced predictive engineering techniques and molding processes capable of meeting the demanding tolerances

- ◆ More modular design concept for the fully automatic climate control system, which can be expanded from one climate zone to up to four
- ◆ There's no letup in cost pressure, but there is an increasing imperative to explore innovation and new technology that helps reduce cost
- ◆ Advanced Powertrain; electric vehicles; hybrid vehicles; fuel cell vehicles will force innovative design solutions for under the hood applications
 - Electric Vehicles (Totally new demands for HVAC and PTC, to accommodate electricity as the new primary power source)
- ◆ Need for Smaller, Lighter, Less-expensive Front-end Module (FEM) which contains the carrier, radiator, air conditioning condenser, washer tank, electric fan, motor, and duct, also a structure where the headlamp can be attached to the carrier and fender without the headlamp bracket
- ◆ Air integration with function integration (HVAC system integration)
- ◆ The OEM is looking for acoustic solutions that can fulfill three criteria: weight reduction; cost reduction and optimized, improved systems approach that gives better acoustic performance.

DELPHI

Thank You!

