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INTER-TPE COMPETITION IN AN EXPANDING, GLOBAL AUTOMOTIVE MARKET

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Abstract – TPE demand is increasing and the range of applications is broadening in the automotive sector, but intense price pressure is segmenting the market into commodity and specialty applications. This paper will examine the technical and market implications of:

- New super TPV technologies
- Super-TPVs
- The potential implications of nano-mineral fillers
- Supply side and path-to-market shifts
- Price pressure from global sourcing
- New high propylene plastomers
- The current and likely future potential for rubber replacement
- Foams and fiber growth opportunities.

The presentation is based on REA's:

- Recent automotive TPE research in Europe, North America and Japan
- Recently completed automotive interior soft trim study (1)
- (In process) second global TPE multiclient study (2)
- Multiclient analysis of advanced technology nonwovens in the automotive sector (3).

References and abbreviations are included at the end of the paper.

Impact of New Technologies on TPE Families – As illustrated in Exhibit 1, new technologies are impacting TPE families differently. The super-TPVs have reached the market and begun penetration. Nano-TPOs have also started penetration in both interior and exterior markets.

Driving Forces for Automotive TPE Growth – Many of the requirements driving TPE growth remain the same as we have previously presented (systems cost savings opportunities, scratch/mar resistance, etc.) (see Reference 8). Price reduction pressures have intensified as a result of global sourcing. Some of the TPE growth and value opportunities from recent automotive requirements are shown in Exhibit 2, illustrated in Exhibit 3, and categorized by TPE type in Exhibit 4. Value-added opportunities occur when new fabrication technologies are applied to TPEs. Examples of process technology shifts include:

- Two-shot molding of large parts
- Suck blow molding of thin, highly shaped tubing (e.g., for fuel systems)
- 3D blow molding of high performance boots/bellows (in s-TPV)
- Sequential valve gating (for bumper fascia, interior trim, glazing seals).

Profitability Erosion – While there has been some recovery in TPE prices from the 2002/2003 softening, profitability remains elusive due to increased raw materials costs and continuing price pressure in the commodity TPE sectors. Global parts pricing, the entry by Asian TPE producers, proliferation of TPE compounding technology amongst a broader range of compounders, cascading from higher to lower value TPEs in some applications, pressure from new metallocene plastomers, and improved reactor grades are all pressuring TPE profitability in the automotive sector.

Nanocomposites -- Mineral fillers have been incorporated into thermoplastic matrices to increase heat resistance and stiffness since the earliest days of automotive plastics. The physics of incorporating relatively large particles (often with agglomerates) dictate a conflict between the positive benefits of improved stiffness and heat resistance and the deterioration of other properties (impact strength, processability, surface characteristics, etc.).

Nano-sized mineral fillers offer the capability of making mineral-TPEs (nano-TPEs) that achieve the benefits of filler addition at lower concentrations (e.g., 3-5% vs. 12-20%), thereby:

- Avoiding the damage to the composite morphology that results from conventional-sized filler particles

- Gaining the benefits of lower density and lower filler concentration
    - (Potentially) lower volumetric costs
    - Easier processability (higher polymer content, less viscosity increase)
    - Wider processing window (reduces scrap rate)
    - Thin wall molding capability

- Improved scratch/mar resistance

- Lower CLTE, better dimensional tolerance (important for zero gap or close tolerance moldings, e.g., bumper fascia).

Clay/TPO nano-composites (nano-TPOs) have begun to penetrate the North American fleet. Four well-known parts are already on cars at GM, including:

- Body side moldings (note competition with PVC and LGF-TPs)
- Step assist (note competition with LGF-PP)
- Exterior components (on the Hummer H-2).

Clay is the dominant incumbent nano-mineral at present, but nano-talc offerings are reaching the market (from Nanova and possibly others) and may offer competitive advantages (for example, less energy for exfoliation of the filler lamellae).

Commodity TPOs are currently the major TPE in which the benefits for applications such as body panels and fascia are being targeted. Some of the target applications for nano-TPOs are listed in Exhibit 4. The ability to increase stiffness, and therefore make thinner walls with closer dimensional tolerances, is an advantage in many TPE applications (especially bumper fascia). The current generation of nano-TPEs are capable of meeting the higher (1600–1800 MPa) European stiffness requirements for European bumper fascia. (North American bumper fascia require only about 1000 MPa.) The improved stiffness is also valuable because it facilitates assembly operations. (It is difficult to attach floppy fascia.) The nano-TPOs also offer the benefit of reduced CLTE (while maintaining good surface characteristics) for obtaining zero gap fascia moldings. It should be noted, however, that there are alternative, non nano-TPO approaches to obtaining zero gap. For example, the BMW Series 1 bumper and rocker panels will use a zero gap, close tolerance TPO from Borealis.

Nano-fillers in TPVs – Clay fillers are used in TPV formulations. A key objective of dynamic vulcanization is to control and reduce the size of the elastomer dispersed phase.

Thakker and Goettler (Reference 7) have evaluated the substitution of nano-clays in TPV formulations. They found that the use of nano-clay reinforcement in the EPDM rubber phase:

- Reduced tan δ values (e.g., less “lossy”)
- Increased elasticity (increased storage modulus)
- Improved rheological properties to give better processability (e.g., in blow molding and profile extrusion).

The high surface area coverage obtained with nano-minerals results in an increase in vapor barrier properties. Nano-TPEs are likely to play a role in the anticipated growth of improved fuel system components with reduced vapor permeability to meet the new fuel emission requirements evolving in the U.S. and Europe.

Super TPVs – At this year's RAPRA TPE Conference, the big news is the emergence of a broadened offering of super TPVs (s-TPVs). The upper right-hand portion of the widely used temperature vs. oil swell plot (see Exhibit 5) has not had a TPE contender to bring the inherent advantages of thermoplastic processing (blow molding, multi-materials parts, recyclability) to parts in the high temperature/oil resistant applications. As shown in Exhibit 1, the s-TPV class of TPEs has been expanded.

The traditional olefinic TPEs consist of crosslinked elastomer islands in a (usually) polyolefin matrix. The composition of both the crosslinked elastomeric islands and the resin matrix can be varied to improve properties beyond that possible with crosslinked EPDM in a polypropylene sea.

The s-TPVs represent variations on this approach. The current generation of candidates and their compositions are shown in Exhibit 6. The s-TPVs are of interest not only because they open a new market segment to the benefits of thermoplastic processing but also because this first generation of candidates will open the path to other island/sea combinations.

In addition to thermoplastic processing capabilities, the driving forces for TPE substitution in this high performance rubber automotive market segment include:

- Increased under-hood temperatures (especially in Europe where under-body shields are common)
- Increased fuel emissions control regulations (changing the materials palette being considered for fuel system components)
- Increased requirements for dynamic seal performance as warranty periods are extended
- Potential cost savings via integration of the connector function with the body of the part.

Silicone-based s-TPVs – Dow Corning's silicone-based s-TPV (TPSiV) introduced in 2002, consists of crosslinked silicone elastomer islands in a polyamide or TPU matrix. In addition to oil and temperature resistance and the ability to make butt joints via thermoplastic processing (e.g., in hose applications), the TPSiVs offer a dry, "silky" touch, which has allowed them to gain applications in high end, two-shot molded cell phones and suggests their potential use in automotive interior soft touch applications.

Acrylic Elastomer-based Super-TPVs – DuPont's candidate in the s-TPV category is based on a modified ethylene-acrylate rubber (AEM) in a copolyester (COPE) matrix. Heat resistances up to 3000 hrs. in a hot (150ºC) oil environment are possible with DuPont's E-TPVs.

Zeon's super TPV candidate utilizes polyacrylate rubber (ACM) in a polyamide (Nylon 6) or a COPE matrix.

Styrenic Elastomers – Styrene-butadiene rubber (SSBR) or hydrogenated styrene block copolymer (H-SBC) can also be used as the elastomeric island. Goodyear's Serel super TPVs are based on SSBR islands; Teknor Apex uses H-SBC. Both approaches use a polypropylene matrix to produce hybrid TPVs with improved oil resistance, wet coefficient of friction, and good long-term compression set.

The styrenic rubber approaches are offered in masterbatch form for blending with either styrenic or olefinic TPEs and provide substantial performance improvement over styrenic TPEs and intermediate performance between olefinic TPVs and the super TPVs. They may also operate in the competitive range targeted by reactive or crosslinked SEBS compounds.

Super TPV Targets – The target automotive applications for the super TPVs include:

- Spark plug boots
- Brake and fuel hose (especially trucks)
- Fuel vent hose
- Ducting in high temperature positions (note competition with olefinic TPV ducting)
- High performance body plugs
- Ignition seals/ignition coil boots
- CVJ boots (especially for high temperature, multi-axial stress applications where the current generation of o-TPVs and COPEs do not provide adequate performance)
- Connectors
- Extruded tubing
- Glazing seals
- Electrical insulation
- Soft touch interiors.

Body Seals – While TPEs (TPVs and SEBS) have gained in secondary body seals and glazing seal applications as previously forecast (Reference 8), they have yet to make a significant penetration in dynamic primary seals.

Role for High Propylene Plastomers – The new generation of high propylene plastomers from Exxon, Dow, Mitsui, and others offers the potential for high elasticity TPOs either alone or as an ingredient in TPO/TPV formulations. They have the potential to be used in elastic fiber applications in advanced nonwovens (References 4, 6) and in TPO coated fabrics.

Two-shot Molding and Sequential Valve Gating – Auto interiors continue to be a major growth opportunity for TPEs. (See References 1, 4, 6) Key among these interior growth opportunities are skin/foam laminates, coated fabrics, airbag doors, and non-carpet flooring. Growth of TPO skins for instrument panels has lost some momentum but has continued in door trim panels and will be accelerated by the benefits of negative forming.

Two-shot molding is widely used for small, soft touch components. Innovations in two-shot molding (larger area parts, e.g., skinned door trim panels) and sequential valve gating will stimulate the growth of TPEs in interiors and rigid/flexible body/glazing seals.

Coated Fabrics -- PVC coated fabrics in seating have gained share as leather's share has grown. TPO and styrenic TPO coated fabric penetration has started in European vehicles. The high propylene plastomers may have a role in this application, but TPE coated fabrics must compete with polyurethane dispersion (PUD) coatings and TPU coatings.

Role of Foams -- As described previously (Reference 8), the limited capabilities of the first generation of TPE foaming technology have restricted the realization of the potential of foamed TPEs in applications such as sheet, acoustic barriers, injection moldings, foam ducting, body seals, and glazing seals. Because of the favorable viscosity characteristics, TPVs appeared earlier on the market. Because of their low viscosity, SEBS foams have been more difficult to foam. The limitation of first generation TPV foams, in particular, has limited the penetration of TPVs into body seals. Foaming technologies based on the use of supercritical blowing agents, offer the potential for very fine particle dispersion in extruded profiles. The recent licensing of the Trexel MuCell® process to AES, Nishikawa Rubber, and Jyco suggests that the use of this technology could accelerate the penetration of TPV into the body seals sector. JCI is using the MuCell® technology for door trim panels in Korea.

Role of Masterbatch – Masterbatches have found a role in LGF-PP production, TPVs, and s-TPVs. They represent a shift in the path to market for TPE compounders and the potential for cost savings by processors.

Markets – A summary of market segment size of olefinic TPVs, specialty TPOs, and SEBS TPEs is shown in Exhibit 7. The relative TPE market segment size will shift substantially in the next five years as:

- TPVs penetrate interior applications
- Nano-TPOs broaden their penetration of exterior (exterior panels, rocker panels, etc.) and interior trim applications
- Glazing seals and body seal penetration by TPVs (and SEBS) is enhanced via improved foaming methods, better dynamic performance
- Super-TPVs penetrate high performance rubber sectors
- TPEs broaden their range in coated fabrics and interior soft touch applications.

SUMMARY

The specialty portion of the auto TPE market is expanding with the introduction of s-TPVs whose potential for rubber replacement is starting to be realized.

Nano-mineral fillers appear to offer an extended performance range to commodity TPOs, which could strongly stimulate growth in exterior panels as well as interior trim and substrates and put TPOs in competition with reinforced PPs in some applications. Preliminary findings also suggest that the use of nano-fillers in TPV formulations offers processing and performance advantages.

The ability to produce improved foam profiles could stimulate the rapid growth of TPVs in body seals if the compression set characteristics can be improved.

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2. Multiclient Study, “Olefinic TPVs, Styrenic TPEs, and High Performance TPVs: Global Markets, Economics, Technology, Intermaterials Competition,” Robert Eller Associates, Inc. (2005)

3. “Global Trends in Olefinic TPEs;” SPE Polyolefins 2004, Houston TX; Robert Eller (February 2004)

4. Multiclient Study, "Advanced Nonwovens in Automotive Applications," Robert Eller Associates, Inc./John R. Starr Associates, Inc. (August 2004)

5. “Overview of TPE Technology, Markets, Industry Structure and Value Added Growth Opportunities;” Thermoplastic Elastomers Asia; Bangkok, Thailand (March 18, 2004)

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7. “The Effects of Dynamic Vulcanization on the Morphology and Rheology of TPVs and their Nano-composites;” H. Thakkar, Lloyd A. Goettler; *Rubber World*, pg. 44, (October 2003)

8. “TPE Value and Growth Opportunities: Markets, Economics, Intermaterials Competition, and the Role of Plastomers;” RAPRA TPE 2003, Brussels; Robert Eller (September 2003)

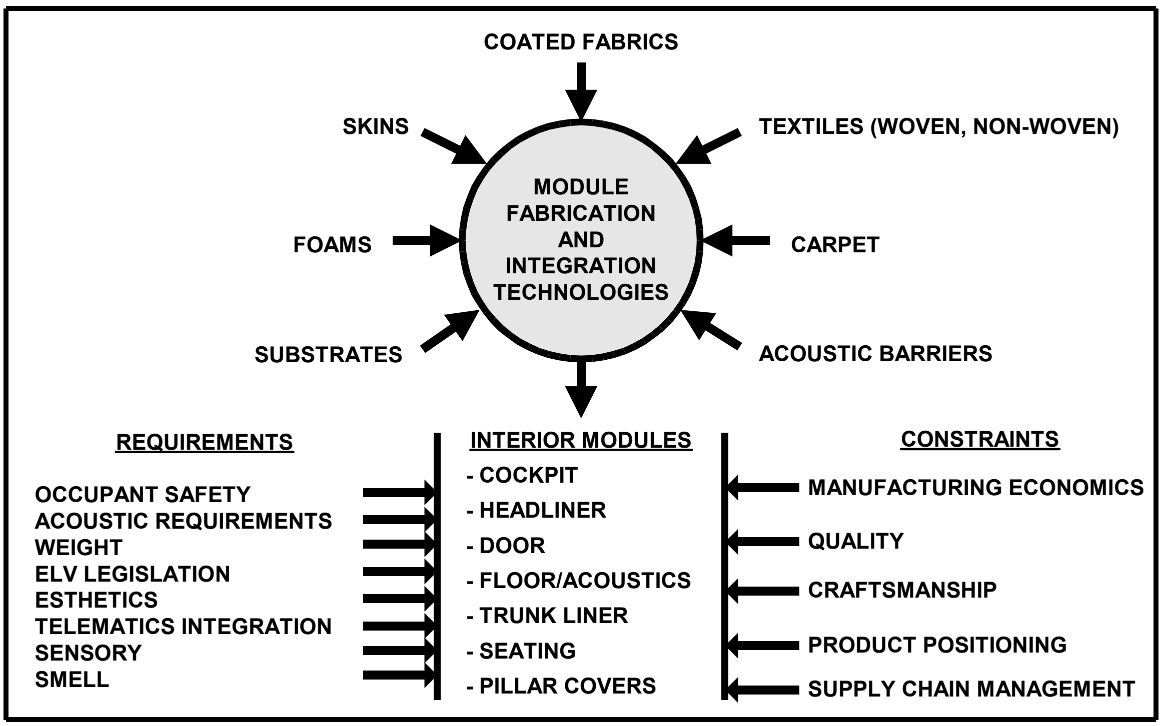
See other publications and study prospectuses on REA web site:
www.robertellerassoc.com

GLOSSARY OF ABBREVIATIONS

ACM	- Polyacrylate rubber
AEM	- Ethylene-acrylate rubber
CLTE	- Coefficient of linear thermal expansion
COPE	- Copolyester type TPEs
E-TPV	- DuPont's super-TPV
EPDM	- 1. Ethylene-propylene-diene monomer; 2. Ethylene propylene rubber
H-SBC	- Hydrogenated styrene block copolymer
HI-P-M-TPO	- High propylene metallo TPOs (plastomers)
LGF-PP	- Long-glass fiber reinforced PP
LGF-TP	- Long-glass fiber thermoplastics
m-PO	- Metallocene polyolefin
MPa	- Megapascals
o-TPV	- Olefinic TPV
PUD	- Polyurethane dispersion (used in coated fabrics)
RF	- Radio frequency
SBC	- Styrene block copolymer TPEs (SEBS, SBC)
SEBS	- Styrene-ethylene-butadiene-styrene TPEs
SSBR	- Styrene-butadiene rubber
s-TPV	- Super-TPV
TPE	- Thermoplastic elastomer
TPO	- Thermoplastic polyolefin
TPSiV	- Dow Corning's silicone-based s-TPV
TPU	- Thermoplastic polyurethane
TPV	- Thermoplastic vulcanizate

Automotive Interior Soft Trim:

Skins, Foams, Coated Fabrics, Textiles, and Acoustic Barriers



A Europe / North America Multiclient Analysis (March, 2003)

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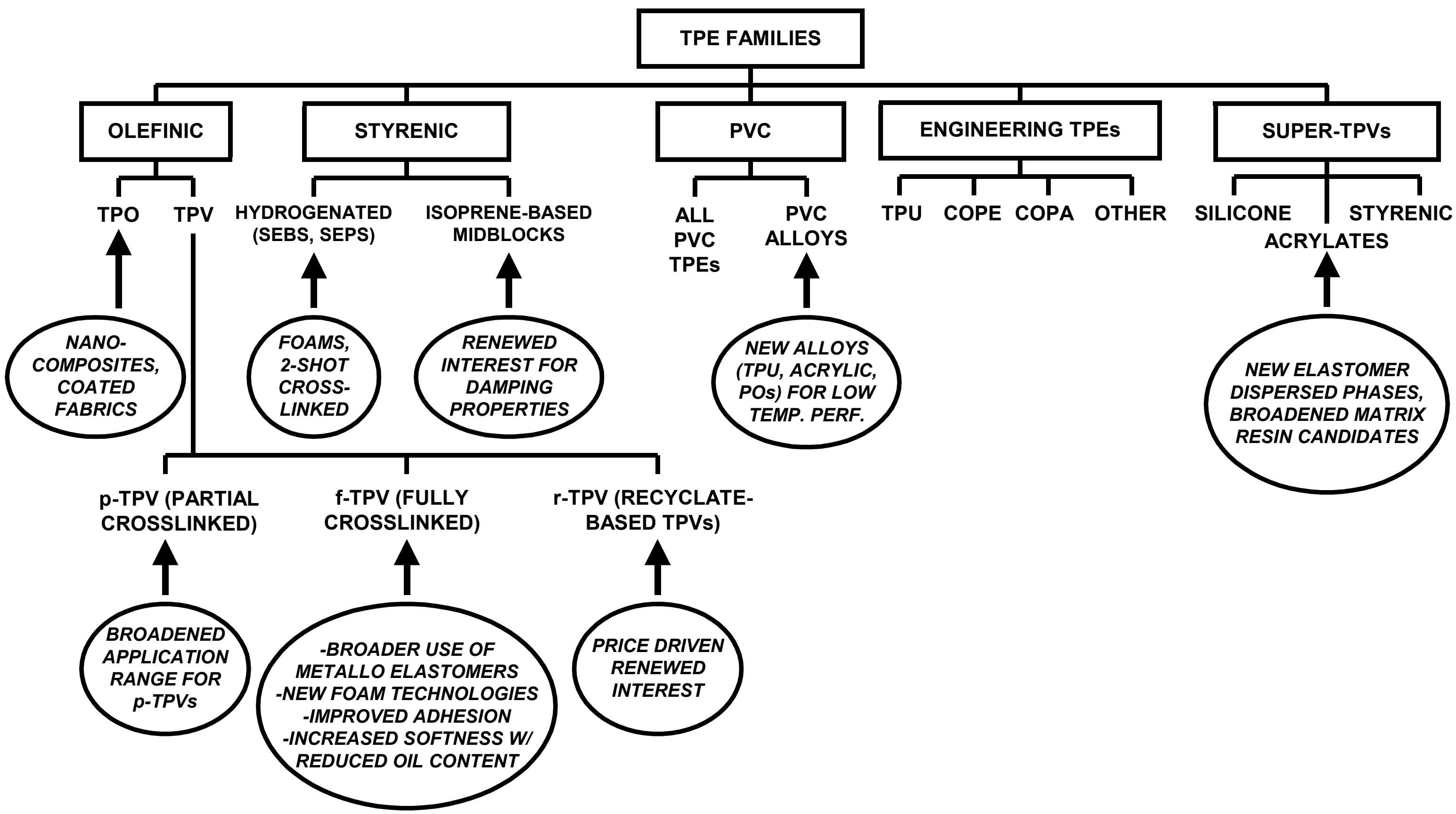
EXHIBIT 1

TPE FAMILIES: BROADENED PERFORMANCE ENVELOPE



SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

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EXHIBIT 2

TPE GROWTH/VALUE OPPORTUNITIES FROM SHIFTING AUTOMOTIVE REQUIREMENTS

AUTOMOTIVE REQUIREMENT	TPE GROWTH/VALUE OPPORTUNITY
WEIGHT SAVINGS	-FOAMING OF SEBS -RAPID GROWTH OF NANO-TPOs
SYSTEMS COST SAVINGS	-RIGID/FLEXIBLE COMBINATIONS -TPE BODY SEALS -TWO-SHOT MOLDING OF LARGE PARTS
IMPROVED FIT/FINISH	-NANO TPEs WITH LOW CLTE -PROCESS CRAFTSMANSHIP SOLUTIONS
ZERO-GAP (EXTERIOR/INTERIOR)	-FAVORS NANO-TPOs
SOFT TOUCH	-TWO-SHOT MOLDING (LARGE PARTS) -CO-EXTRUSION OF SOFT TOUCH SURFACED TPEs -MORE IMPORTANT WITH INCREASED HARD SURFACE USE (IP AND DOOR TRIM)
IMPROVED SCRATCH/MAR RESISTANCE	-NANO-TPOs
LOW GLOSS INTERIORS FOR "EUROPEAN LOOK"	-A TPE BENEFIT FOR SEBS -NEGATIVE FOR NANO-TPOs
REDUCED FUEL VAPOR LOSS	-GROWTH OF NANO-TPES? -s-TPVs
OIL RESISTANCE	-STRONG GROWTH FOR S-TPVs
INVISIBLE AIRBAG DOORS	-MAJOR DRIVER FOR p-TPV SKINS
ODOR-FREE INTERIORS	-PLASTICIZER REDUCTION -SUBSTITUTE OLEFINS FOR OTHER FAMILIES
ELIMINATION OF COATINGS	-IMPROVED SCRATCH/MAR TPE GRADES -IN-MOLD DECORATION -INCREASED CO-EXTRUSION
BODY COLOR MATCH	-EPDM REPLACEMENT IN BODY SEALS
MOLDED-IN COLOR	-TPEs WITH IMPROVED COLOR CONTROL -LOWER FILLER LEVELS
IMPROVED NOISE, VIBRATION, HARSHNESS CONTROL	-TPEs WITH INTEGRAL FOAM LAYERS -ISOPRENE-BASED GRADES
ACOUSTIC PERFORMANCE	-ISOPRENE-BASED GRADES -CONTROLLED DENSITY FOAMS -ELIMNATION OF HEAVY LAYER CONSTRUCTIONS
ENERGY ABSORPTION (OCCUPANT SAFETY)	-ON-BOARD FOAM CONSTRUCTIONS
RECYCLABILITY	-TPE ROLE IN ALL-POLYOLEFIN CONSTRUCTIONS

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

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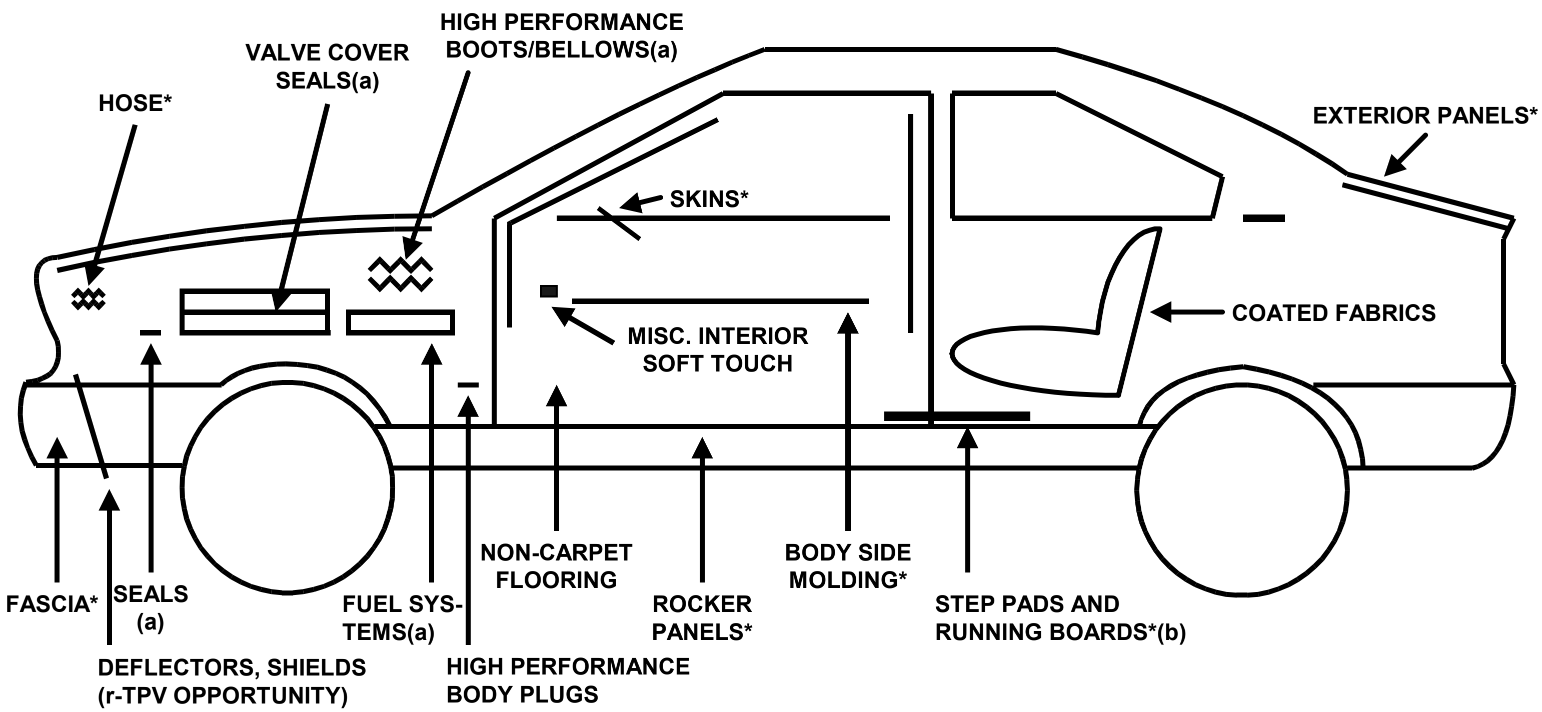
EXHIBIT 3

EXAMPLE APPLICATIONS FOR RECENTLY DEVELOPED TPEs



NOTES:
-DOES NOT SHOW BODY/GLAZING SEALS, A CONTINUING GROWTH OPPORTUNITY
* INDICATES NANO-TPE OPPORTUNITY
(a) s-TPV TARGET
(b) NOTE COMPETITION WITH LGF-PP

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

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EXHIBIT 4

EXAMPLE APPLICATION OPPORTUNITIES FOR RECENTLY DEVELOPED TPEs

APPLICATION	TPE TYPE			
	NANO-TPO	s-TPV	PVC ALLOYS	HI-P M-TPOs
AIRBAG DOORS			X	
BODY SIDE MOLDINGS	X			
BUMPER FASCIA	X			
COATED FABRICS				X
DOOR TRIM/QUARTER PANELS	X			
ELASTIC FIBERS				X
EXTERIOR PANELS	X			
FUEL LINES/SYSTEMS		X		
IN-MOLD DECORATION FILMS	X?			
IP SUBSTRATES	X			
ROCKER PANELS	X			
RUNNING BOARDS	X			
SKINS	X		X	
STEP PADS	X			
HOSE		X(a)		

NOTES:

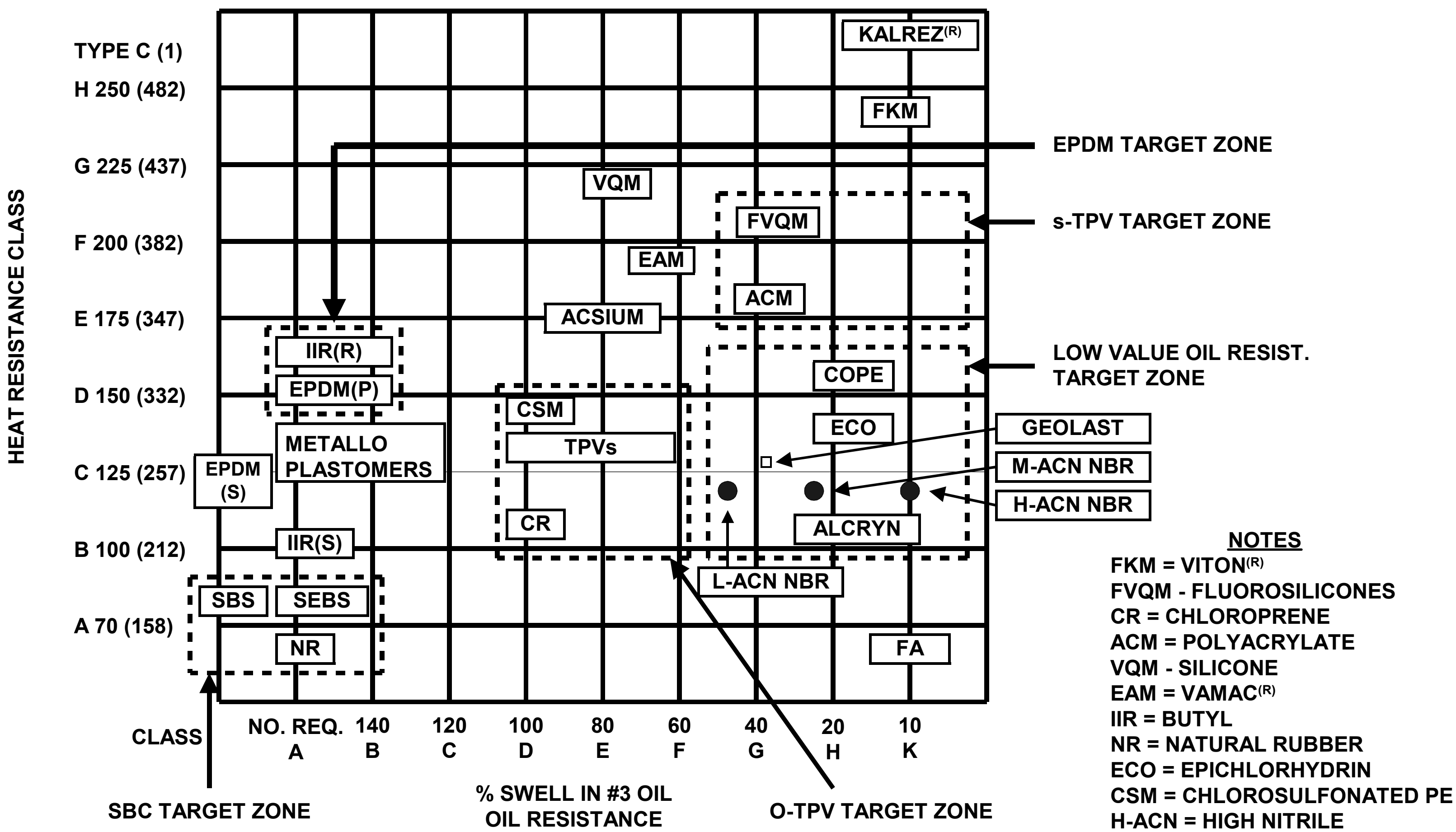
SEE GLOSSARY OF ABBREVIATIONS

(a) AN ANNOUNCED TARGET FOR DuPONT'S E-TPV

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004 (References 1 and 3)

EXHIBIT 5

OIL RESISTANCE/HEAT RESISTANCE OF TPEs AND THERMOSET RUBBERS



NOTES

FKM = VITON(R)
FVQM - FLUOROSILICONES
CR = CHLOROPRENE
ACM = POLYACRYLATE
VQM - SILICONE
EAM = VAMAC(R)
IIR = BUTYL
NR = NATURAL RUBBER
ECO = EPICHLORHYDRIN
CSM = CHLOROSULFONATED PE
H-ACN = HIGH NITRILE
FA = THIOKOL
(S) = SULFUR CURE
(P) = PEROXIDE CURE
(R) = RESIN CURE

SOURCE: ROBERT ELLER ASSOCIATES, INC., TPE MULTICLIENT, 2004

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EXHIBIT 6

THE SUPER-TPV CANDIDATES

GRADE NAME	ELASTOMER TYPE	MATRIX RESIN(S)	SUPPLIER
TiPSiV	SILICONE	PA, TPU	DOW CORNING
ZEOTHERM	POLYACRYLATE (ACM)	PP, PA, POLYESTER	ZEON
E-TPV	ETHYLENE ACRYLATE (AEM)	COPE	DUPONT
UNIPRENE XL	HYDROGENATED SBC (H-SBC)	PP	TEKNOR APEX
SEREL(a)	STYRENE BUTADIENE (SSBR)	PP	GOODYEAR

NOTE:
(a) AVAILABLE IN MASTERBATCH FORM

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004 (Reference 2)

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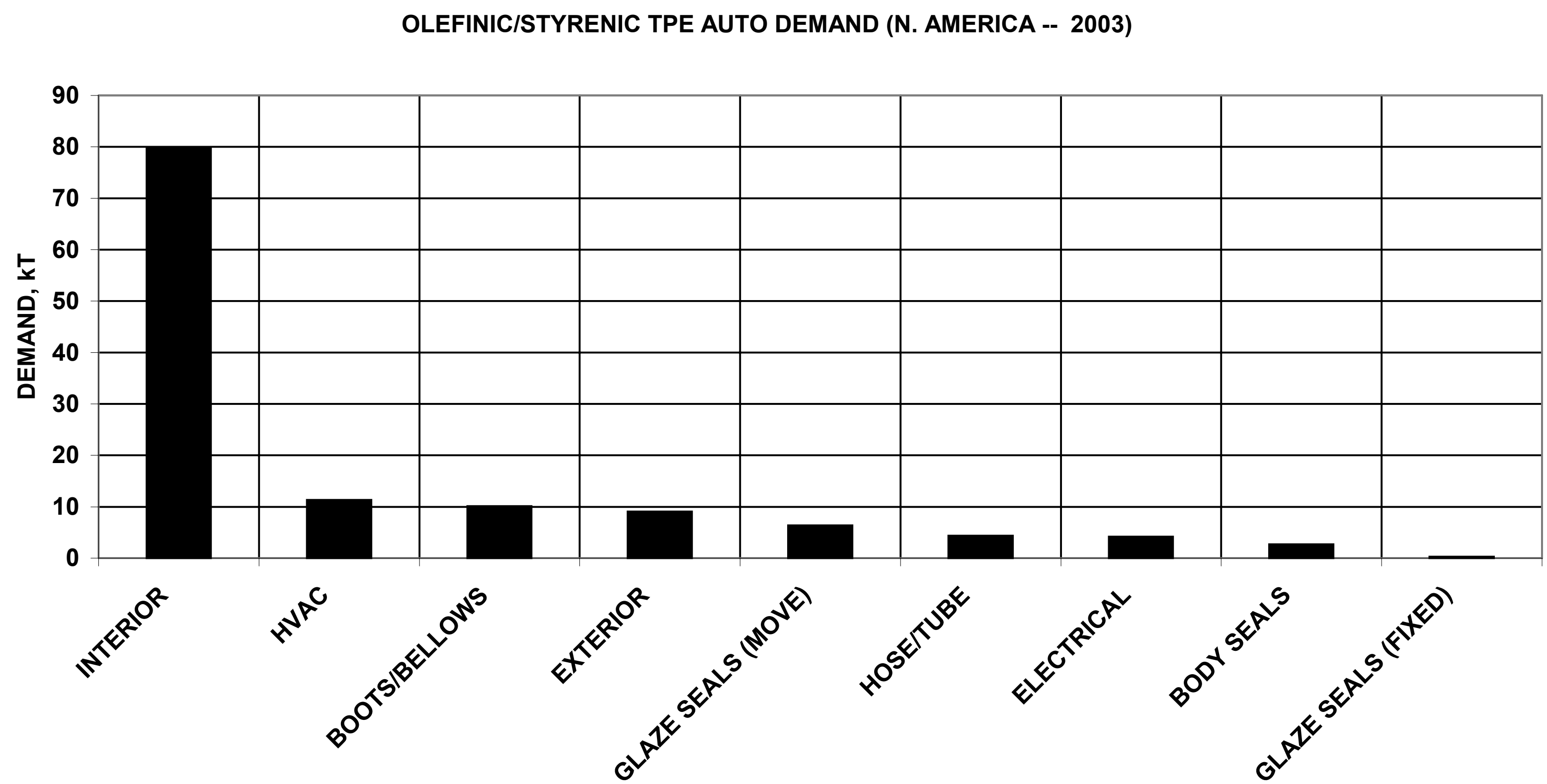
EXHIBIT 7



NOTE: DOES NOT INCLUDE COMMODITY TPO

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

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