KRAIBURG TPE

CUSTOM-ENGINEERED **TPE** AND MORE

KEEPING EMISSION AND ODOR UNDER CONTROL

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THERMOPLASTIC ELASTOMERS FOR AUTOMOTIVE INTERIOR APPLICATIONS KEEPING EMISSION AND ODOR UNDER CONTROL

1. INTRODUCTION

Sensitivity to emissions in automotive interiors has been a topic since the early 1980s. This was in particular caused by the formation of undesired condensation on the inside of windshields of new vehicles. As a result, the focus was initially on achieving specific fogging values. The requirements for interior components have been extended and have become more sophisticated over the years. Various analytical test standards were gradually developed to ensure compliance with emission standards. Odor has become a more critical issue for both automotive manufacturers and consumers. The general opinion on regional differences relating to the issue of odor that has been expressed during conferences and meetings coincides with KRAIBURG TPE's internal experiences: While odor, or rather the requirement to have no odor, has top priority in Asia, in Europe the focus is primarily on single substances and total emissions inside motor vehicles' cabins. In North America, the debate about odor and emission is led with lower dynamism.

Due to the material properties of thermoplastic elastomers (TPEs), a wide variety of potential applications and cost-effective processing, these materials have developed rapidly since the 1990s. This is reflected in a large number of applications including components for automotive interiors. As a consequence, it was important for KRAIBURG TPE to be able to meet the requirements of automotive manufacturers. A project was started more than three years ago to acquire comprehensive knowledge about emission and odor values of materials for automotive interiors and gain a thorough understanding of their influencing factors.

2. EMISSION MEASUREMENT AND ODOR ASSESSMENT – A COMPLEX CHALLENGE

Testing the emission behavior of materials differs significantly from determining common materials data like mechanical properties. In addition to various standards such as DIN or VDA methods, automotive manufacturers have established many standards of their own. Some of them are very similar in their specifications. There are over 15 company standards for determining fogging behavior, but all are related to DIN 75201. Along with a large number of similar methods, it is necessary to take into account, that depending on the measuring parameters, each emission test gives different results of emitted substances. Therefore, the dynamic thermal desorption analysis in accordance with VDA 278, the static headspace analysis VDA 277 and various chamber methods specified in the ISO 12219 versions cannot be compared to each other nor should the test values be converted in any way. Test methods that seem to be similar often differ in the type of conditioning, testing temperatures or duration providing results that are not comparable. In some tests, calibration of equipment and sampling play a decisive role and have a significant influence on the measurement results.

Assessing odor is even more critical than measuring emissions. All efforts to replace the purely subjective, human olfactory perception by other more objective methods have not been very effective so far. The evaluation by trained panels in accordance with VDA 270 remains state of the art. Despite intensive training and a precise selection of panels, there may be significant differences in odor assessments. It is not unusual that various laboratories or automotive manufacturers determine different odor rating for the same materials. To some extent this can be explained by local and gender-specific senses of smell. What makes the qualification of TPEs for automotive interiors even more difficult is that automotive manufacturers do not use the same specifications.

The basic findings of KRAIBURG TPE's work include that the results of the various tests do not allow correlation between emission and odor. It is not recommended to draw inferences from emission results about odor results and vice versa. However, what emission results and odor results have in common is that they depend on the sample history. It plays a major role, along with the selection of the test method and has been specified by the ISO 12219-8 standard since January 2019. To generate comparable results, we have to ask the following questions: Are plastics granules, sample plates, single components or component groups tested? How is the sample packed? How was it stored and

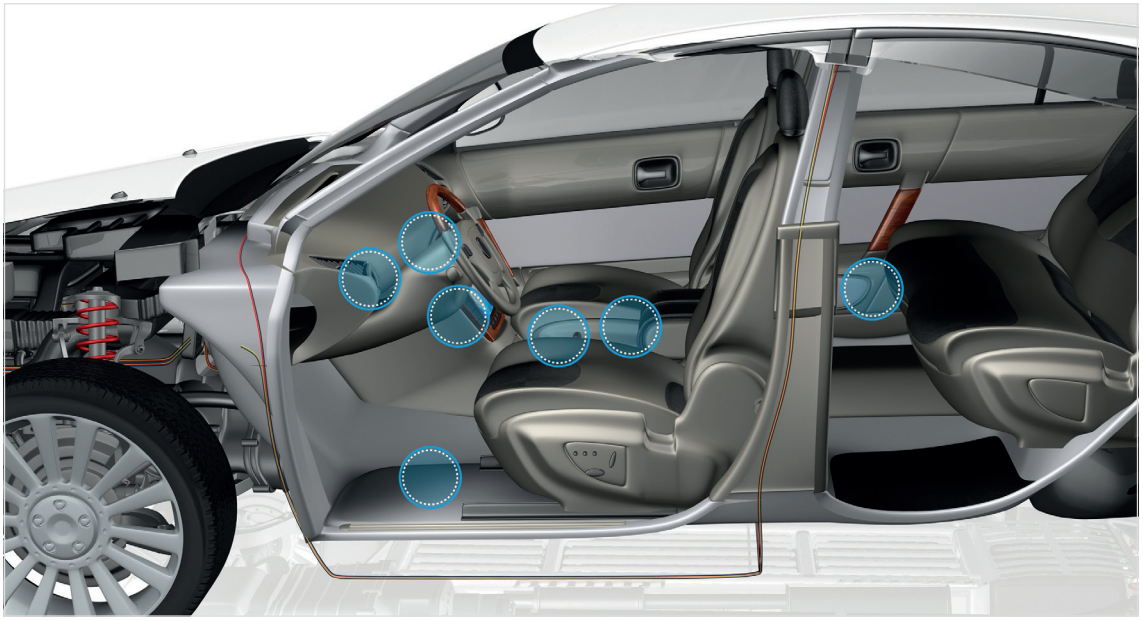
under which conditions was it processed to become a sample or component part? The reproducibility and comparability of the measured results are depending primarily on the sample history.

3. JOINT COMPETENCE – IMAT-UVE AND KRAIBURG TPE

KRAIBURG TPE chose to thoroughly analyze the subject of automotive interior emission and odor a few years ago. Due to the complexity of this special field, the company decided to collaborate with an external partner. Together with imat-uve, an independent testing institute, we fundamentally examined and analyzed the issue. imat-uve is an innovative development and engineering company, which also supports its customers throughout the entire process chain. This includes project identification, design, and development through to testing materials, components and systems. The collaboration between imat-uve and KRAIBURG TPE made it possible to look at emission and odor influences holistically from a perspective of materials and processing including measuring devices and methods. The results and findings yielded a win-win situation for both companies.

imat-uve's expertise was and still is essential, in particular for interpreting complex tests and test results. This enabled us to find effective solutions and eliminate incorrect interpretations. In close collaboration with imat-uve, the factors influencing emission and odor have been identified, and the specific TPE portfolio has been tested using standardized test conditions. In this process, materials from all KRAIBURG TPE production sites in Germany, the United States and Malaysia were compared. The testing sites of imat-uve in Germany and China were also compared with each other.

In addition to generating well-founded emission data for KRAIBURG TPE interior materials, the cooperation also resulted in a detailed understanding of various test methods and test results in combination with the raw materials used.



Picture 1: Possible TPE applications in automotive interiors

Profound knowledge of emission and odor behavior of thermoplastic elastomers for automotive interior applications (fig. 1) was generated. In addition to approved products for interiors, providing specific customer support in this complex subject area is a real added value that can save time and costs.

4. ANALYSIS OF ALL INFLUENCING FACTORS

An essential result of the efforts is that the emission and odor levels of the raw materials used for a TPE material and the manufactured component can vary over the entire value-added chain. This means that everyone involved has a great responsibility, starting from the raw material supplier to the TPE manufacturer through to the component supplier and also the test laboratories of automotive manufacturers that perform the approval process. This awareness along the value-added chain is required to ensure that high-quality materials with low emission and odor levels can be reliably provided. KRAIBURG TPE, therefore, uses a holistic approach. It includes the analysis of raw materials, the screening of globally produced materials, the processing of parts on customers side and the release by the respective automotive manufacturer.

4.1. THE INFLUENCE OF RAW MATERIALS

KRAIBURG TPE materials for applications in automotive interiors are mainly TPS, i.e. thermoplastic elastomers based on styrene block copolymers (SBC). TPS are compounds made of raw material mixtures that are composed of various materials such as elastomers (SEBS), thermoplastics (PP), fillers, colorants, and stabilizers. Each of these raw materials has specific properties and influences the emission and odor behavior of the finished TPS compound. In a first step, we analyzed the single raw materials to be able to draw conclusions about the finished TPS compounds. Styrene block copolymers and polypropylene, as well as the colorants used, have a significant influence. Based on this profound analysis, KRAIBURG TPE now has detailed knowledge about the emission and odor levels of its raw materials.

For instance, the results from microchamber testing according to ISO 12219-3 for emissions of different types of styrene-ethylene-butadiene-styrene (SEBS) and polypropylene (PP) vary significantly. The correct choice of SEBS in a TPS compound can influence the total carbon emission (TVOC) as well as the styrene emission of the TPS material. The PP used also influences the TVOC value. Critical substances like formaldehyde or aromatic hydrocarbons such as benzene, toluene, xylene and ethylbenzene (summarized as BTXE) can be determined in microchamber tests. In general, TPS materials from KRAIBURG TPE contain very low levels of these substances.

Table 1: Emission values of various raw materials measured on granules in accordance with ISO 12219-3

Test	Microchamber ISO12219-3		
	TVOC	Styrene	BTXE
Unit	µg/kg·h	µg/kg·h	µg/kg·h
SEBS 1	8,910	29	81
SEBS 2	27,800	4,920	451
PP 1	11,500	<10	17
PP 2	4,350	<10	<10

KRAIBURG TPE gives special attention using SBC raw materials that contain virtually no free monomeric styrene. Compounds with a styrene content of 1% and above must be identified as hazardous substances. The traces of monomeric styrene remaining in SBC raw materials typically are 0.0001% (1 ppm), which is a ten-thousandth of the proportion specified for mandatory identification as a hazardous substance. The use of nearly styrene-free SBC raw materials results in very pure finished TPS products, as can be seen in table 2. Styrene is rarely detected, with its proportions being far below the specified emission limits.

Table 2: The styrene content in TPS compounds in accordance with ISO 12219-4 and VDA 278, limit values from DBL 5430 (2017-12)

Method	Emission limit	Styrene content in TPS compounds			
		TC6COZ	TC7MLB	TC6MLB	TC6GPN
ISO 12219-4 in µg/m³	≤ 100	4	12	2	ND*
VDA 278 in µg/g	≤ 8	ND*	ND*	ND*	ND*

* ND: not detectable, below the detection limit

In addition, various SEBS and PP types were tested in accordance with VDA 278, VDA 270 and DIN 75201-B (Table 3). These methods are part of many specifications of well-known automotive manufacturers.

The VDA 278 test method shows significant differences for the polymers tested. The fogging behavior of SEBS is clearly better if compared to PP. The VDA 270 B-3 odor test produces a noticeable odor value of 4.0 for both PP types. Particularly the production method of the PP types plays a decisive role, which consequently has a significant influence on both performance and price. The SEBS raw materials were not tested for odor, as they cannot be processed in the form of pure polymers. Evaluating the individual raw material in powder form makes little to no sense due to its porous structure.

Table 3: The emission values of raw materials measured on granules in accordance with VDA 278, DIN 75201-B and VDA 270 B-3

Test	VDA 278		DIN 75201-B	VDA 270 B-3
	VOC	Fog	Fogging	Odor
Unit	µg/g	µg/g	mg	Rating
SEBS 1	464	260	<0.2	-
SEBS 3	459	44	<0.2	-
PP 3	226	548	1.5	4.0
PP 4	190	428	1.4	4.0

4.2. THE INFLUENCE OF THE COMPOUNDING PROCESS

Along with the raw materials used for a TPS compound, which usually have the most significant influence on the odor and emission levels, the compounding process also plays a major role. During the compounding process the different raw materials are mixed homogeneously under the influence of shear and temperature to form a TPS compound. This is usually done using twin screw extruders. Ideally, no chemical reaction occurs in the production of TPS compounds. However, a high energy input during the compounding process may cause non-controlled chemical reactions and thus can potentially be a source for emission and odor. This knowledge can also be applied to other TPE classes. The configuration of the production line and the selection of the process parameters can affect the odor and emission levels both positively and negatively.

A TPS manufacturer faces the challenge to find the optimal process settings combined with the best raw materials for each specific formulation while meeting all of the material properties required. That is precisely the task KRAIBURG TPE has been dedicated to in recent years and were able to identify important influencing factors and relevant parameters. Based on this know-how, KRAIBURG TPE has built up a market-oriented portfolio for interior applications. In addition to optimizing the existing series, the acquired knowledge was used to develop a new, customized TPS series (FG/SF series) for automotive interior applications.

Table 4 illustrates the impact of throughput and energy input on a typical TPS material for automotive interiors. A smaller throughput positively influences the emission (VDA 278 and VDA 277) and odor (VDA 270 B-3) of the tested material. The measuring tolerance of the odor evaluation is at a minimum half of an odor grade.

The energy input that affects raw materials during productions has a considerable influence on the emission behavior. It is necessary to ensure that degradation of the raw materials during compounding is avoided. Increasing the energy input reduces the emission level measured according to VDA 278 and VDA 277. Although the variation in fogging values is within the range of the measuring equipment, the values in combination with the other results clearly show the impact and influence of specific process parameters.

Table 4: Influence of process parameters on emission and odor behavior in compounding

Influence of the compounding process	VDA278	VDA278	VDA277	VDA 270	DIN75201-B
	VOC	Fog	VOC	B-3	Fogging
Unit	µg/g	µg/g	µg*C*/g	Grade	mg
Default parameter	66	793	0.6	3.0	0.26
Throughput ⇩	29	751	0.3	2.5	0.25
Throughput ⇧	111	969	2.4	3.0	0.57
Energy input ⇩	135	859	1.8	2.5	0.46
Energy input ⇧	34	807	0.4	3.0	0.36

4.3. THE INFLUENCE OF THE PART MANUFACTURING PROCESS

Another influencing factor for the production of low-emission and low-odor component parts is its production process. For TPE materials it is typically injection molding. Similar to the compounding process, the chosen processing parameters play a crucial role as well. So far, molders of TPE parts mainly focus on the optical quality of parts. The influence on emission and odor levels is mostly underestimated and only identified during subsequent testing. In this case, sample history again plays

a crucial role. KRAIBURG TPE can support its customers by providing recommendations and empirical data on processing. In order to achieve the best possible emission and odor behavior of the part, certain temperature settings, residence times and shear rates, for example, should be observed.

5. TESTED AND QUALIFIED INTERIOR PORTFOLIO OF KRAIBURG TPE

KRAIBURG TPE offers several product series for automotive interior applications that meet most automotive manufacturers' standards for emission and odor behavior. The globally available portfolio includes compounds that are suitable for multi-component injection molding. For example, there are custom-engineered series with adhesion to various thermoplastics such as PP, PC, ABS, and PA.

Table 5: Overview of KRAIBURG TPE's automotive interior portfolio

Series	Type designation	Description
GP/FG	TC5GPZ to TC8GPZ	Universal use Adhesion to PP
FG/SF	TC5FEZ to TC8FEZ	Improved surface finish Odor-optimized with adhesion to PP
AD1	TC5MLZ to TC8MLZ	Adhesion to polar thermoplastics such as PC, ABS, ASA, SAN
AD/PA	TC5PAZ to TC8PAZ	Adhesion to PA6, PA66, PA12
VS/AD/HM	TC6CEZ to TC8CEZ	Improved abrasion properties Adhesion to PC, ABS, ASA, SAN, PA6, PA12

In the course of the project, all of the globally available interior materials from our production sites in Germany, Malaysia, and the United States have been tested in accordance with VDA 278 and VDA 270 B-3 in imat-uve labs in Germany and China. The hardness range, including 50, 60, 70, and 80 Shore A (ShA), were tested for each product series. All tests were performed on test plaques produced in-house in accordance with a standardized injection molding process. The samples were shipped in standardized, emission-free sample bags. The samples were entirely conditioned at imat-uve laboratories. This way a consistent sample history was maintained to ensure the comparability and reproducibility of results.

The overview of the VDA 278 and VDA 270 B-3 tests in table 6 shows the results for all product series. In general, all interior product series from KRAIBURG TPE's three production sites, meet the emission behavior standards of most automotive manufacturers. Table 6 shows the minimum and maximum emission and odor values within the product series. Though the differences indicate a wide range of values at first glance, they are very reasonable considering they are derived from different production sites, a broad hardness range (50 to 80 ShA) and multiple colors (black and natural), and most important the maximum values are still below the emission limits currently required by automotive manufacturers.

An odor rating of 3.0 or 3.5 is usually approved, while odor ratings of 4.0 and above tend to be seen as critical values. Odor behavior essentially depends on the formulation and thus on the raw materials used. An aspect worth mentioning is the newly developed, surface optimized FG/SF series. At imat-uve all materials of this series have been rated with 3.0 for all hardnesses. Despite all evaluations and test results for TPS compounds, we have to bear in mind that the final size of the part always plays an important role as well. For example, a dashboard has a much bigger share (surface area) of the total odor level in a car's interior than inlay mats or thumb wheels.

Table 6: Global emission and odor range of KRAIBURG TPE's interior portfolio in black and natural for the whole hardness range between 50 ShA and 80 ShA (tested by imat-uve Germany)

Test		VDA 278	VDA 278	VDA 270 B-3
		VOC	Fog	Odor
Unit		µg/g	µg/g	Rating
Typical target values		<500	<2000	≤ 3.5
Series	GP/FG	47 - 257	297 - 1,300	3.0 - 4.0
	FG/SF	138 - 206	883 - 1,200	3.0
	AD1	26 - 82	151 - 1,190	3.0 - 4.0
	AD/PA	31 - 168	326 - 1,360	3.5 - 4.5
	VS/AD/HM	181 - 184	370 - 419	3.5

Another important aspect of the project was to test the comparability of results obtained from different test laboratories. For this purpose, materials made at the production site in Malaysia were tested at different laboratories. The overview in table 7 shows that tests performed according to VDA 278 can produce almost identical values, especially when a measurement tolerance of ± 20% is considered.

The assessment of odor in accordance with VDA 270 B-3 is entirely different. There are deviations of up ± 1.0, which shows that odor assessments always have to be treated with caution. For example, it is recommended to re-test a component part initially rated with 4.0 under controlled conditions.

Table 7: Overview of results from tests of KRAIBURG TPE materials produced in Malaysia, performed at different imat-uve laboratory sites

Test		VDA 278	VDA 278	VDA 270 B-3
		VOC	Fog	Odor
Compound	imat-uve laboratory site	µg/g	µg/g	Grade
TC6MLZ – 60 ShA AD1 series	Germany	26	151	3.5
	China	18	112	2.5
TC6PAZ – 60 ShA AD/PA series	Germany	67	791	4.0
	China	45	512	3.5
TC7MGZ – 70 ShA Custom-engineered	Germany	22	155	3.5
	China	17	117	3.0

6. "ODOR MAP" OF INTERIOR MATERIALS

The interior of a modern car comprises a variety of individual components, which are made of different materials and material combinations. The combination of all odor-emitting components creates the overall odor impression in a passenger compartment.

That is why everyone involved in the value-added chain faces a challenge when assessing the odor of materials and components. Each material used has its specific smell and contributes to the final odor impression of a car's interior. Therefore, it was important for KRAIBURG TPE, along with acquiring knowledge about its own TPS materials, to gain a full overview of the emission and odor behavior shown by competitors' TPEs and other material classes.

Table 8 shows an example of the odor ratings of different materials in accordance with VDA 270. The A, B, and C variants of the test sample were chosen depending on the typical part size, the storage condition was kept constant with variant 3. Most of the materials are at a level between 3.0 and 4.0.

Table 8: Automotive interior odor map

Materials group	**Thermoplastische elastomers (TPE)**		**Thermoplastics**		**Other materials used in a car's interior**	
Odor VDA 270 Variant and evaluation	TPC	**B3 3.0**	PP Standard type	**B3 4.0**	PVC-P	**C3 3.5**
	TPU	**B3 3.0**	PP odor-optimized	**B3 3.0**	EPDM	**A3 3.5**
	TPO	**C3 4.0**	ABS	**B3 3.0**	CR	**A3 4.5**
	TPS (competitor)	**B3 3.5**	PC/ABS	**B3 3.5**	Leather standard type	**C3 4.0**

7. "HIGH PRECISION STANDARD MATERIALS" BY IMAT-UVE

Even trained odor panels face big challenges performing odor tests with a variety of different material types. An effect not mentioned so far is a certain "conditioning" of the nose. It can be observed that test people who often evaluate only a specific class of materials react more sensitively when they evaluate new or rarely tested material classes.

In order to take this issue into account, possible solutions were developed in cooperation with imat-uve. Each material class has a specific odor. If the odor range within a specific material class can be

standardized, odor panels can focus on specific individual materials classes.

The imat-uve „high precision standard material" was developed from this idea. This is also available for TPE materials and contains specially manufactured materials from KRAIBURG TPE in various odor categories. The material package can be obtained from the imat-uve web shop.

There the achieved scores are reported back for validation. The user immediately receives information about the range of his values and can reorder material in case of deviations.

Picture 2: The „high precision standard material" TPE package from imat-uve

8. OUTLOOK: IS A "SUPER LOW EMISSION COMPOUND" POSSIBLE?

The values of emission and odor can be further reduced using precisely adjusted process parameters and optimized raw materials. This way KRAIBURG TPE has developed a material that is practically free of fogging, has very low emission values and an odor behavior that was rated with 2.5. This optimized material is very close to the desired super-low-emission compound.

Table 9: Comparison of a standard TPS type and an optimized TPS type from KRAIBURG TPE

Test	VDA278	VDA278	VDA270	DIN75201-B
	VOC	Fog	B-3	Fogging
Unit	µg/g	µg/g	Grade	mg
Standard TPS	66	793	3.0	0.26
Optimized TPS	63	128	2.5	0.02

9. BENEFIT FOR CUSTOMERS AND OEMS

The acquired knowledge can be used to provide target support and expert advice to customers and automobile manufacturers in projects for automotive interiors – whether it is related to the selection, qualification, and validation of materials or when irregularities occur. The wide range of data gained enables unrealistic test results to be quickly identified or necessary corrective actions to be recommended and taken. The creation of an emission and odor map is also a great help in this context. The expertise we have gained, starting from the selection of raw materials and the compounding process through to the processing at molding companies, enables us not only to offer materials from our portfolio but also to develop custom-engineered solutions for individual customer demands.

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CUSTOM-ENGINEERED **TPE** AND MORE

AUTORS

ANDREAS DÖRNER

Project Manager Advance Development
KRAIBURG TPE GmbH & Co. KG

FLORIAN VETTER

Development Automotive
KRAIBURG TPE GmbH & Co. KG

DR. DARIJO MIJOLOVIĆ

Director of Corporate R&D and QM
KRAIBURG TPE GmbH & Co. KG

PRESS CONTACT

Europe, Middle East, Africa

Simone Hammerl
Communications Manager

Phone: +49 8638 9810-568
simone.hammerl@kraiburg-tpe.com

Asia Pacific

Bridget Ngang
Marketing Manager Asia Pacific

Phone: +603 9545 6301
bridget.ngang@kraiburg-tpe.com

Americas

Gabriela Yohn
Marketing Manager Americas

Phone: +1 678 475 6498
gabriela.yohn@kraiburg-tpe.com

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