

# Foam Additives and Release Agents for the Production of Low VOC Molded Foams Fulfilling VDA 278 Requirements and Reducing Stack Emissions

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Low VOC requirements for PUR foams established by Global Automotive OEMs have become more and more stringent over the past years. As silicone surfactants are one of the contributing additives to foam emanations, Evonik's Comfort & Insulation Business Line has constantly been decreasing silicone emanations in order to follow this trend and provide products with better overall VOC properties. The first part of this paper will provide an overview about low VOC silicone surfactants which are suitable for producing flexible molded foams across several automotive applications specifically fulfilling VDA 278 requirements.

Reducing the stack emissions during the production process and reducing the emanations released by the final foam product are both important targets for the foam manufacturer. The global emphases to improve both industrial hygiene and protect the environment are key forces setting these targets. In order to fulfill these important targets, new types of release agents are required which allow for significant reduction in stack emissions. The second part of this paper will present an overview on how to reduce stack emissions during the foaming process by changing the type of release agent and discuss new options for applying these products in an environmentally sustainable way.

## INTRODUCTION

Polyurethane foams in the automotive industry already have a long history and have experienced many changes over the years<sup>[1]</sup>: beginning in the 1950s with the first slabstock foams to be used in cars seating, followed by the development of the 'hot cure molded foams process' in the early 1960s, up to the present where seat pads are produced using the "cold cure" process. These changes are both revolutionary and evolutionary.

Revolutionary steps include the development of cold cure foams and the change-over from Freon-blown foams to purely water-blown foams. A significant 'evolutionary' process which is being addressed in this paper is the reduction of the emanations in foams.

Some of these emanations are easily recognized as "window fogging" or the "new car smell". Early on, multiple automakers developed their own test methods to analyze emanations but it was not until the fogging test DIN 75201 method A/B was established that a coordinated and standardized effort was used in a broad range of applications<sup>[2]</sup> among multiple OEMs. Further, it was also understood by the early 1980s, that emanations were not only released by surface materials but also from subordinate materials, like seat pads and therefore raw material suppliers including additive suppliers were asked to help find the sources of these emanations.

It was quickly recognized that limiting the use of BHT until it was completely replaced by other antioxidants made a major impact on the reduction of emanations. However, it was further understood that amines and surfactants contributed to the VOC emanations and therefore also needed to be addressed.

Since the early 1990s, Evonik's Comfort & Insulation Business Line (formerly known as Goldschmidt Polyurethane Additives) introduced the first generation of 'so-called' low fogging products, mostly in MDI foams (TEGOSTAB® B 8715 LF). These were followed by a second generation of the LF-series released four years later offering a significant drop in emitting species of over 50%, like TEGOSTAB® B 8734 LF. Continued optimization of the whole production process led to "eco-friendly" products being phthalate-free that were brought to the market in 2008 as a third product generation (e.g. TEGOSTAB® B 8734 LF2).

As a tribute to the myriad of applications such as weight reduction, noise reduction, comfort, and style, the use of polyurethane foam by the OEMs continues to expand. Very often these applications require different process parameters and their supporting raw materials to fulfill their targets – such as mechanical properties – while still reaching for lower emanation levels. Evonik recognizes that these demands put additional stress on the optimization of our surfactants' profile by further lowering the siloxane emanation level accompanied by fine tuning the carrier so that it still functions as a good compatibilizer between the various siloxane species and fully reacts with the PU matrix. It was therefore necessary to develop ultra-low VOC products meeting these latest expectations.

In addition to optimizing foam formulations to minimize foam emanations, reducing the stack emissions which are produced during the production process is becoming an important topic for foam manufacturers as well. The global emphases to improve both industrial hygiene and protect the environment are key forces setting these new targets. Stack emissions of a foaming plant are mainly caused by the application of release agents which have to be applied to the mold surface to ensure an easy release of the final product without surface defects. Besides providing an ideal release of the finished parts, release agents significantly influence the cell structure of the final foam surface including the tightness and haptic of the skin. State of the art release agents that are widely used in the industry are in principle blends of different waxes dispersed in a carrier combined with special additives that optimize the surface finish. The type and ratio of the carrier, as well as the application method, can significantly impact the stack emissions during the foaming process. The second part of this paper will provide a comparison between different release agent types and their overall contribution to emissions.

## EXPERIMENTAL

### Raw Materials and Formulations

The resulting data in this paper have been established by using a low VOC formulation for MDI and a standard TDI formulation in hand mix foams.

The following raw materials have been used:

Raw Materials	Description
Base Polyol A	6000 MW base polyol, OH=28mgKOH/g, f~2.2
Base Polyol B	Standard MW 5500 polyether polyol, OH=32mg KOH/g, f~3
Base Polyol C	43% SAN polymer polyol, OH=28mg KOH/g
Isocyanate A	High monomeric polymeric MDI, NCO=32.7
Isocyanate B	Toluene diisocyanate, TDI 80, (80% 2.4-Isomer, 20% 2.6-Isomer)
TEGOAMIN <sup>®</sup> DEOA85	Diethanolamine 85% in water, Evonik Industries AG
TEGOAMIN <sup>®</sup> DMEA	Dimethylethanolamine, Evonik Industries AG
TEGOAMIN <sup>®</sup> 33	33% Triethylenediamine in dipropylene glycol, Evonik Industries AG
TEGOAMIN <sup>®</sup> ZE1	Formulated alkanolamine, Evonik Industries AG
Crosslinker	Glycerine, technical quality
Cell opener	High EO-containing polyether polyol, OH=33mg KOH/g

MDI Surfactants
TEGOSTAB <sup>®</sup> B 8715 LF2, standard MDI surfactant
TEGOSTAB <sup>®</sup> B 8734 LF2, medium potency, low VOC MDI surfactant
TEGOSTAB <sup>®</sup> B 8747 LF2, medium potency, ultra-low VOC MDI surfactant
Competition M1, medium potency, ultra-low VOC MDI surfactant
Competition A1, medium potency, low VOC MDI surfactant
TDI Surfactants
TEGOSTAB <sup>®</sup> B 8738 LF2, low-med. potency TDI or TM20 surfactant (single surfactant)
EP-K-116, low-med. potency, low VOC TDI or TM20 surfactant (single surfactant)
Competition M2, low-med. potency, low VOC TDI or TM20 surfactant (single surfactant)
TEGOSTAB <sup>®</sup> B 8736 LF2, med-high potency, low VOC TDI surfactant (single surfactant)
TEGOSTAB <sup>®</sup> B 8737 LF2, high potency, TDI bulk stabilizer / TEGOSTAB <sup>®</sup> B 8724 LF2, co-surfactant for TDI (combination)
Competition A2, TDI bulk stabilizer & co-surfactant for TDI (combination)

Formulations	MDI	TDI
Base polyol A	100	-
Base polyol B	-	73.00
Polymer polyol C	-	27.00
Water	3.60	4.00
TEGOAMIN <sup>®</sup> DEOA 85	0.70	0.85
Glycerine	-	0.60
Cell Opener	1.0	-
TEGOAMIN <sup>®</sup> DMEA	0.30	-
TEGOAMIN <sup>®</sup> ZE1	0.60	-
TEGOAMIN <sup>®</sup> 33	-	0.41
TEGOAMIN <sup>®</sup> BDE	-	0.06
Surfactant, varied (see below)	1.0	0.20-1.0
Isocyanate A, Index 95 & 75	58.00/46.00	-
Isocyanate B, Index 98	-	46.20
Mold temperature [°C]	55	70
De-mold time [min]	4	5

## Experimental Procedures and Test Methods

### FOAMING PROCEDURE

All foams for evaluation of VOC as well as for assessing processing and testing physical properties were produced by hand mix using the above mentioned MDI or TDI formulations. Foams were molded in a standard rectangular test block aluminum mold (400 x 400 x 100 mm) and for TDI foams, additional front seat cushion (FSC) was used to assess foam flowability. From the test block mold, all necessary foam specimens were obtained for emanation evaluations and mechanical properties tests. Before every pouring of the liquid reaction mixture into the mold, it was prepared with GORAPUR<sup>®</sup> TB 8067E, a solvent-based release agent. Also, the release agent was allowed to dry for at least one minute prior to pouring the foam mixture. Immediately after de-molding the foams were subjected to the standard Force-To-Crush (FTC) test.

### FORCE-TO-CRUSH-MEASUREMENTS

Force-to-crush measurements are used to investigate the effect of how different surfactants influence the openness of the foam. In terms of processing seat pads, openness is an important parameter to ensure the dimensional stability of a molded part so as to not allow the part to shrink once manufactured.

The measurement was performed in the following manner:

Immediately after de-molding a foam pad (<15 seconds after de-mold), the pad is placed in the FTC machine at the start position with the indenter foot at 115 mm from the bottom plate and in contact with the foam moving at 500 mm/min. Initial foam thickness is measured when the force reaches 5 N. Without stopping at the 5 N point the foot continues to penetrate into the foam at 500 mm/min until it reaches 50 mm distance from the bottom plate and at this point FTC1 is taken. There is no dwell time. The foot comes back to the start position (115 mm from the bottom plate) at 500 mm/min and thus the first cycle finished. Without delay another 9 cycles are completed mimicking the first cycle. After the 10th cycle, the foot stops in the start position. The foam pad is then fully crushed by hand and placed again in the machine and one more cycle (the 11th) is performed under the same conditions as the first 10. The final foam thickness is then measured in the same manner as the initial thickness was measured in the first cycle. Initial foam tightness is judged by FTC1, residual tightness by the difference FTC10-FTC11, and crushability by the shape of the curve (how quickly FTC drops). FTC11 (hardness of fresh foam) can be used as an indication of foam cure.

### FOAM PHYSICAL PROPERTIES TEST METHODS

Another series of foam pads were produced in the method described above and, directly after de-molding, the foam pads were manually crushed opened. During the next seven days, the foam pads were allowed to recover and were stored at constant temperature and humidity conditions (23±2°C, 50±2% relative humidity). After this time, foam specimens were cut according to the requirements of the test mentioned in table 4.

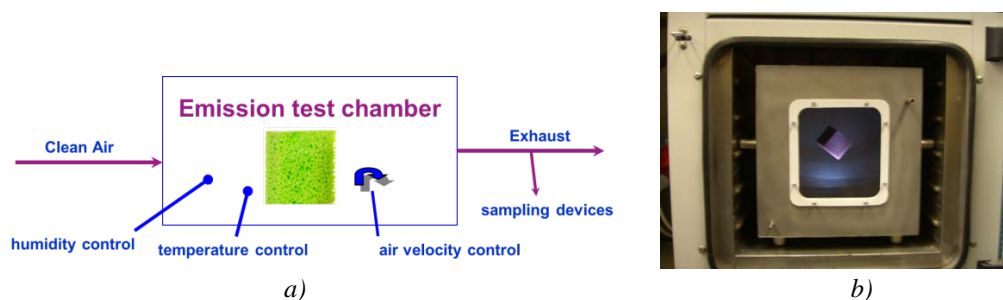
Physical Property	Unit	Test Method
Core Density	kg/m <sup>3</sup>	ASTM 3574-11, Test A (=ISO 845)
70% Compression Set	% (c <sub>i</sub> )	ASTM 3574-11, Test D
50% Wet Set	% (c <sub>i</sub> )	ASTM 3574-11, Test D,L
Tear Strength	N/m	ASTM 3574-11, Test F
Tensile Strength/Elongation	kPa/%	ASTM 3574-11, Test E
Ball Rebound	%	ASTM 3574-11, Test H (=ISO 8307)
IFD	N	DIN EN ISO 2439-09 - Version B
CFD	kPa	DIN EN ISO 3386-1-10
Hysteresis Loss	%	DIN 53577-88

## THERMAL DESORPTION METHOD

The VOC emanation was determined according to the Daimler-Chrysler test method PB VWT 709/ VDA 278<sup>[4]</sup>. The results were reported as toluene equivalent. The thermal desorption was carried out at 90°C for 30 minutes using a thermal desorber “TDS2” with sample changer from Gerstel, Mülheim, Germany, in combination with a Hewlett Packard HP6890/HP5973 GC/MSD system.

## CHAMBER TEST METHOD

Foam emanation was determined by the size-adapted chamber (‘Mini chamber’) test method based on the VDA 276<sup>[5]</sup>. The foam sample (30 g) was placed inside of a 30 litre test chamber at 65 °C with 50 % relative humidity and the air inside the chamber was exchanged at a rate of 0.4 h<sup>-1</sup>. After 2 hours, a sample from the air stream was collected by passing 2 litres of the test chamber atmosphere at a flow rate of 100 ml/min through an adsorption tube filled with Tenax<sup>®</sup>TA (mesh35/60). Thermal desorption was carried out using a thermal desorber “TDS2” with sample changer from Gerstel, Mülheim, Germany, in combination with a Hewlett Packard HP6890/HP5973 GC/MSD system. The results were reported as toluene equivalent.



**Figure 1:** a) Draft of chamber test method, b) ‘Mini chamber’ according to VDA 276.

## Application of release agents

For the comparison of different release agents regarding their contribution to stack emissions the following release agent types have been used:

- 1) Release agents classified as flammable liquid, flammable material Class 1B, for example GORAPUR<sup>®</sup> LK 8779-20E: Wax dispersions in hydrocarbons with a flash point in the range of 21-55°C (69.8 – 131°F) and a solid content in the range of 1.5-3% (RA1)
- 2) Release agents classified as flammable liquid, combustible material Class 2, for example GORAPUR<sup>®</sup> LK 8901-41B: Wax dispersions in hydrocarbons with a flash point in the range of 56 – 60°C (132.8 – 140 °F) and a solid content in the range of 5-8% (RA2)

The release agents were applied by standard spraying technology using air-assisted spray guns (e.g. W3FZ (nozzle diameter 0.3, 0.5, 0.8 mm; pressure on material approx. 0.4 bar; pressure on air approx. 1.5 bar). In addition release agents of type RA2 were also applied by using electrostatic spraying technology.

## RESULTS AND DISCUSSION

### EMANATION TEST RESULTS – MDI FOAMS

For the evaluation of the thermal desorption according to VDA 278 (10/2011)<sup>[3]</sup> molded foam samples have been produced using the below mentioned MDI surfactants: Industry standard TEGOSTAB® B 8715 LF2, the low VOC surfactant TEGOSTAB® B 8734 LF2 and ultra-low VOC surfactant TEGOSTAB® B 8747 LF2. These Evonik surfactants have been compared with market available competitor products of the same range.

At a foam index of 95, the comparison between our standard TEGOSTAB® B 8715 LF2 vs. our low VOC product TEGOSTAB® B 8734 LF2 shows that siloxane emanation are reduced by over 50%. This finding is in the same range of the competition product named A1. To provide even greater freedom in terms of emanations to formulators our ultra-low VOC product TEGOSTAB® B 8747 LF2 can be applied with a reduction of siloxane emanation of 75% vs. TEGOSTAB® B 8734 LF2. Against competition M1 – that is also stated to be an ultra-low VOC product, we see the similar amount of siloxane emanation contribution; however the FOG profile of the siloxane emanations found in the competitor’s product is much higher.

For NVH applications (Noise Vibration Harshness) where exclusively MDI foams are used, lower indices than 95 are of technical importance to set the right mechanical properties in order to fulfill OEM requirements. In these ‘low index foams’ the general emanation profile is worse and includes other surfactant-related emanations (non-siloxane) which potentially come from their carriers.

Evaluated foams at a relevant index of 75 using the same surfactant selection showed the following results: already the blank foam (foam without surfactant) had a four times higher total VOC than that at an index of 95. TEGOSTAB® B 8747 LF2 showed the lowest siloxane VOC emanation (at least 50% lower in comparison to the competition products), no other surfactant-related emanations, and provided a superior FOG profile compared with all other tested products.

Results of TEGOSTAB® B 8734 LF2 in comparison to TEGOSTAB® B 8747 LF2 in VDA 276 show, in this case, no significant difference. Both surfactants are well suited for this or other chamber tests (e.g. BMW GS 97014-3<sup>[6]</sup>). This case illustrates that relative VOC performance of different surfactants may depend on the test methods used.

Index	95						75					
	No surfactant	-	-	-	-	-	-	-	-	-	-	-
TEGOSTAB® B 8715 LF2 [pphp]	1.0							1.0				
TEGOSTAB® B 8734 LF2 [pphp]		1.0							1.0			
TEGOSTAB® B 8747 LF2 [pphp]			1.0							1.0		
Competition M1 [pphp]				1.0							1.0	
Competition A1 [pphp]					1.0							1.0
Total VOC [ppm]	10	130	70	20	40	50	40	280	150	60	110	100
VOC – Siloxane [ppm]	0	120	52	13	19	45	0	220	78	22	42	61
VOC – other surf.-related emanation [ppm]	0	6	3	0	2	1	0	21	23	0	2	0
VOC Total Surfactant [ppm]	0	126	55	13	22	46	0	221	101	22	44	61
Total FOG [ppm]	90	130	160	90	180	110	160	225	303	200	300	190
FOG – Siloxane [ppm]	0	0	14	2	33	10	0	0	28	12	65	18
FOG - other surf.-related emanation [ppm]	0	19	10	0	1	0	0	49	46	0	30	0
FOG Total Surfactant [ppm]	0	19	24	2	34	10	0	49	74	12	95	18
Total VOC [ $\mu\text{g}/\text{m}^3$ ]	356	-	440	451								
VOC – Siloxane [ $\mu\text{g}/\text{m}^3$ ]	0	-	89	92								
VOC – other surf.-related emanation [ $\mu\text{g}/\text{m}^3$ ]	0	-	0	0								
VOC Total Surfactant [ $\mu\text{g}/\text{m}^3$ ]	0	-	89	92								

## FOAM PROCESSING AND PHYSICAL PROPERTIES – MDI FOAMS

In terms of processing, all surfactants show comparable results except B 8715 LF2, which gives more open foams. Also, in terms of physical properties, no significant differences have been observed.

Index	95					75				
TEGOSTAB® B 8715 LF2 [pphp]	1.0					1.0				
TEGOSTAB® B 8734 LF2 [pphp]	1.0					1.0				
TEGOSTAB® B 8747 LF2 [pphp]	1.0					1.0				
Competition M1 [pphp]	1.0					1.0				
Competition A1 [pphp]						1.0				
FTC 1 [N]	612	835	846	834	809	364	856	922	919	829
FTC 2 [N]	261	353	375	353	320	123	337	350	347	323
FTC 10 [N]	210	223	226	223	222	124	140	134	133	134
FTC 11 [N]	163	162	167	159	162	106	109	113	109	107
Surface	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Subsurface Area	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.
Cells [cm]	10.0	10.0	10.0	10.0	10.0	9.5	9.5	9.5	9.5	9.5
Core Density [kg/m³]	41.7	42.1	42.0	41.9	41.7	40.8	41.3	41.9	41.3	41.5
Ball Rebound [%]	65	65	65	65	65	68	68	67	67	68
IFD 25% [N]	140	141	142	143	142	72	75	76	74	73
IFD 40% [N]	223	224	229	226	223	112	114	117	113	112
IFD 65% [N]	515	515	521	522	510	251	258	263	257	254
Support Factor	3.7	3.7	3.7	3.7	3.6	3.5	3.4	3.5	3.5	3.5
CFD 40% [kPa]	4.3	4.5	4.5	4.4	4.4	2.0	2.2	2.2	2.1	2.1
Hysteresis [%]	21.6	22.2	22.5	21.9	21.7	15.9	16.0	16.2	16.4	15.8
Compression Set [%] (70°C/70%)	11	10	11	12	11	8	8	8	9	8
Wet Set [%] (50°C/50%/ 95% RH)	11	11	11	10	11	7	6	6	6	6

## EMANATION TEST RESULTS – TDI FOAMS

For the evaluation of the thermal desorption according to VDA 278 (10/2011) in TDI molded foams, two different groups of surfactants were tested. The first group includes TEGOSTAB® B 8738 LF2 along with our already established low VOC surfactant TEGOSTAB® B 8736 LF2 and the newly developed low VOC surfactant EP-K-116. These were compared against market available competitor products of the similar range. The second group consisted of a bulk stabilizer in combination with a cell regulating co-surfactant suitable for TDI systems namely TEGOSTAB® B 8737 LF2/B 8724 LF2 and our new low VOC combination TEGOSTAB® B 8736 LF2/EP-K-109. Once again, these Evonik surfactant combinations were compared against a market available competitor's product combination of similar potency and processing.

The comparison of a standard product like TEGOSTAB® B 8738 LF2 and a low VOC product like EP-K-116 shows that the siloxane emanation in VOC has been reduced by about 75%. This value is very similar to the competition M2, but the M2 product shows a very significantly higher - other surfactant-related - emanation in VOC. Remarkable is also the high siloxane emanation value of the competition M2 in FOG, whereas TEGOSTAB® B 8738 LF2 as well as EP-K-116 is less than 50 ppm siloxane emanation.

For the evaluation of the surfactant combinations, the comparison shows that the standard TEGOSTAB® B 8737 LF2/B 8724 LF2 gives similar siloxane emanations in VOC to the competition A2. The biggest difference between these two industry standards is the high amount of other surfactant-related emanation in VOC and in FOG observed in the competition A2, whereas TEGOSTAB® B 8737 LF2/B 8724 LF2 show no detectable other surfactant-related emanation. The new low VOC combination TEGOSTAB® B 8736 LF2/EP-K-109 vs. industry standards TEGOSTAB® B 8737 LF2/B 8724 LF2 reflects an improvement in siloxane VOC emanation of about 75%. This general improvement is also visible in siloxane FOG emanations of 25% lower vs. TEGOSTAB® B 8737 LF2/B 8724 LF2.

Index	98							
No surfactant	-							
TEGOSTAB® B 8738 LF2 [pphp]	1.0							
EP-K-116 [pphp]		1.0						
Competition M2 [pphp]			1.0					
TEGOSTAB® B 8736 LF2 [pphp]				1.0				
TEGOSTAB® B 8737 LF2/B 8724 LF2 [pphp]					0.25/0.75			
Competition A2 [pphp]						0.25/0.75		
TEGOSTAB® B 8736 LF2/EP-K-109 [pphp]								0.8/0.2
Total VOC [ppm]	210	470	280	380	310	844	1490	410
VOC – Siloxane [ppm]	0	236	59	51	72	601	574	157
VOC - other surf.-related emanation [ppm]	0	0	0	113	1	0	659	1
VOC Total Surfactant [ppm]	0	236	59	164	73	601	1233	158
Total FOG [ppm]	20	50	40	290	40	60	180	60
FOG – Siloxane [ppm]	0	37	24	245	8	40	85	29
FOG - other surf.-related emanation [ppm]	0	0	0	0	0	2	60	0
FOG Total Surfactant [ppm]	0	37	24	245	8	42	145	29

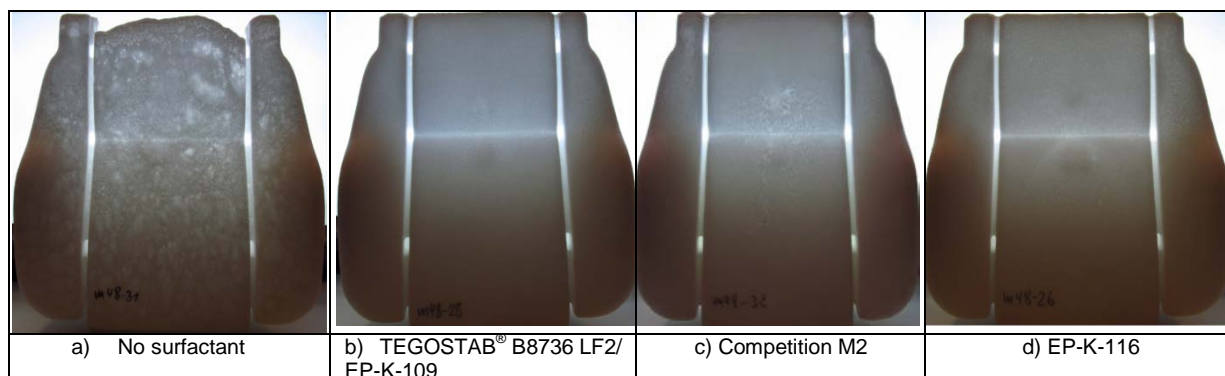
#### FOAM PROCESSING AND PHYSICAL PROPERTIES – TDI FOAMS

In terms of processing, the only observed differences were somewhat lower FTC values for EP-K-116, TEGOSTAB® B 8737 LF2/B 8724 LF2 and the competition M2 and slightly coarser cell structure for TEGOSTAB® B 8738 LF2 and EP-K-116.

Regarding physical properties there were no significant differences except that EP-K-116 gave slightly higher IFD values which may be related to its cell structure.

Index	98							
TEGOSTAB® B 8738 LF2 [pphp]	1.0							
EP-K-116 [pphp]		1.0						
Competition M2 [pphp]			1.0					
TEGOSTAB® B 8736 LF2 [pphp]				1.0				
TEGOSTAB® B 8737 LF2/ B 8724 [pphp]					0.25/0.75			
Competition A2 [pphp]						0.25/0.75		
TEGOSTAB® B 8736LF2/ EP-K109 [pphp]								0.8/0.2
FTC 1 [N]	1872	1656	1691	1895	1723	1889	1876	
FTC 2 [N]	1207	947	995	1293	1082	1299	1270	
FTC 10 [N]	184	212	176	212	173	186	201	
FTC 11 [N]	146	158	140	140	144	146	141	
Surface	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	
Subsurface Area	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	o.k.	
Cells [cm]	10.5	10.0	11.5	11.5	11.0	11-11.5	11.5	
Core Density [kg/m³]	31.1	30.9	32.2	31.6	31.3	30.7	31.6	
Ball Rebound [%]	66	65	68	66	67	67	67	
IFD 25% [N]	95	104	91	89	92	89	88	
IFD 40% [N]	155	168	152	149	152	148	148	
IFD 65% [N]	339	360	343	337	337	334	334	
Support Factor	3.6	3.5	3.8	3.8	3.7	3.8	3.8	
CFD 40% [kPa]	3.0	3.2	3.3	3.1	3.0	2.9	3.0	
Hysteresis [%]	21.9	22.5	21.6	22.4	21.7	21.7	22.0	
Compression Set [%] (70°C/70%)	4	5	5	5	4	6	4	
Wet Set [%] (50°C/50%, 95%RH)	25	24	23	23	22	22	23	

To check flowability, all surfactants were foamed at 1 pphp using a front seat cushion mold. All surfactants resulted in an acceptable foam quality as illustrated by the foam d). Competition M2 did show somewhat worse surface/subsurface regulation at the pour point, whereas the combination of TEGOSTAB® B 8736 LF2/ EP-K-109 was overall slightly better than the others.



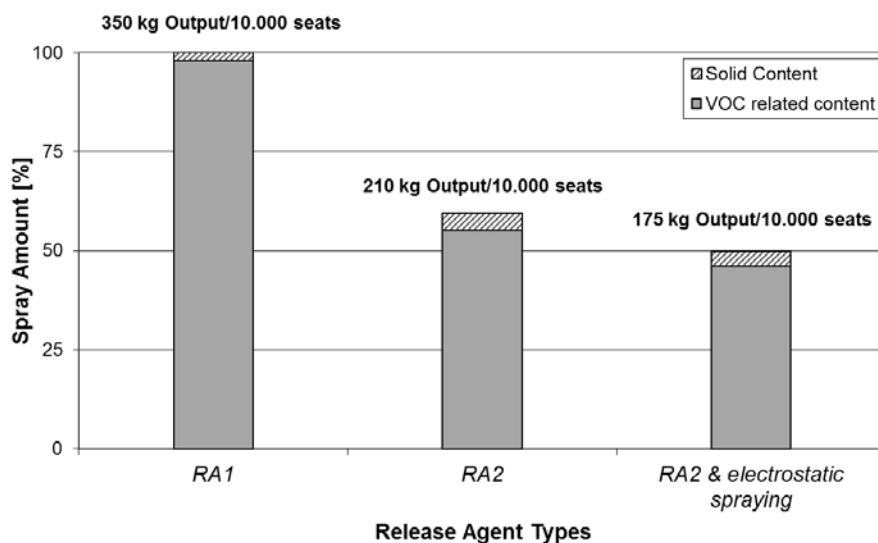
**Figure 2:** Flowability in Rover Front Seat Cushion Mold.

### Contribution to stack emissions of different release agent types

Standard release agents available on the market are generally classified according to their carrier type and overall solid content. Based on their composition, Evonik release agents can be classified into the following categories: a) release agents with flash points in the range of 69.8 to 131°F classified as flammable liquid, flammable material Class 1B (Evonik product series GORAPUR® LK -E); b) release agents with flash points in the range of 132.8 to 140°F classified as flammable liquids, combustible material Class 2 (Evonik product series GORAPUR® LK -B); c) low solid release agents with a solid content less than 3% and d) high solid release agents with a solid content in the range of 5-8%. In addition to solvent based release agents, there are also different types of water based release agents available. The dominant carrier systems in the market continue to be based on organic solvents since they provide some outstanding benefits compared to water-based products. For example, less build up and therefore less cleaning cycles and the release performance of water-based products are often less efficient compared to their solvent analogues.

To achieve an optimum release performance, a minimum thickness of a homogenous, continuous release film is required. The quality of film formation is directly related to the characteristics of the product combined with the efficiency of the spraying process. As shown in Figure 3, low solid products like RA1 require the highest spraying outputs in order to provide the optimum release film which, in turn, results in the highest contribution to the overall emissions. Changing the carrier type from hydrocarbons belonging to flammable Class 1B to hydrocarbons belonging to combustible Class 2 allows for an increase in active release ingredients. Due to the higher solid content in RA2 types, about 40% less product needs to be sprayed which is accompanied with a significant reduction in solvent related emissions. Another advantage of the GORAPUR® LK -B product series (RA2, Fig.4), along with the higher flashpoint of these products, is the possible use of electrostatic spraying devices. In this case, the sprayed material is charged by an electrode at the outlet of the spraying equipment. Due to a strong electrical field between an electrode and the mold which is grounded, the particles are accelerated in the direction of the mold surface and compelled to follow the lines of force. We found that the advantages of this technology are high efficiency and low waste due to minimized overspray along with increased reachability of difficult-to-access mold areas. The lowest output of solvent-based products can be achieved when applying release agents belonging to GORAPUR® LK -B product series in combination with electrostatic spraying technology. An overall reduction in output of 50% is possible while maintaining the same excellent release performance.





**Figure 3:** Relative comparison of spraying amount for different release agent types. RA1: Release agents classified as flammable liquid, flammable material Class 1B, for example LK 8779-20E: Wax dispersions in hydrocarbons with a flash point in the range of 21 - 55 °C (69.8 – 131 °F) and a solid content of 1.5 - 3%. RA2: Release agents classified as flammable liquid, combustible material Class 2, for example LK 8901-41B: Wax dispersions in hydrocarbons with a flash point in the range of 56 – 60°C (132.8 – 140 °F) and a solid content of 5 - 8%.

## CONCLUSIONS

The polyurethane industry has dramatically evolved in the past years to focus on low emissions. This accounts also for car interiors and the requirements in this respect of the OEMs towards the manufacturers of polyurethane products. The evolving OEM request is to use low emission products in terms of emitting substances from the raw materials and additives. Evonik Industries AG has followed this evolution very closely for the past 20 years and continues to do so.

As noted, Evonik Industries Comfort & Insulation Business Line already provides products fulfilling the current stringent VOC requirements (e.g. VDA 278) with products like TEGOSTAB® B 8734 LF2 for predominantly MDI-based foams. In order to give more flexibility to our customers in the development of new formulations and in anticipation of even more stringent future VOC requirements, we have pro-actively developed the new ultra-low VOC product TEGOSTAB® B 8747 LF2. This product provides the same excellent foam processing and physical properties at dramatically reduced emanation.

For predominantly TDI-based formulations, we offer TEGOSTAB® B 8736 LF2 which already allows customers to meet today's above mentioned stringent VOC requirements. As some customers prefer lower potency surfactants like TEGOSTAB® B 8738 LF2 which produce a coarser cell structure we have developed EP-K-116, a product with lower VOC performance and dramatically reduced emanation.

Besides 'one-surfactant-approach', there are some customers that prefer 'dual-surfactant-approaches'. For such customers that currently may use our combination of TEGOSTAB® B 8737 LF2/B 8724 LF2, we have presented a new low VOC combination TEGOSTAB® B 8736 LF2/EP-K-109, which improves significantly the overall VOC performance.

Stack emissions can be reduced up to 50% when changing from low solid, low flashpoint release agents to high solid release agents with flash points in the range of 132.8 – 140°F combined with electrostatic spraying equipment. The technology of the Evonik Industries product series GORAPUR® LK-B allows for significantly improved industrial hygiene while maintaining excellent release performance. GORAPUR® LK-B release agents are also available as amine- and tin free versions like LK 8516-20B which is an additional step towards more environmentally friendly and less toxic products.

These innovations show that Evonik Industries AG's Comfort & Insulation Business Line is committed to the polyurethane industry and will continue pro-actively to develop new products in support of foam manufacturers allowing them to meet future challenges.

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## BIOGRAPHIES

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Dr. Eva Emmrich-Smolczyk studied chemistry at the University of Essen and Strasbourg (F), receiving her diploma in 2000 and in 2004 her Ph.D. in cooperation with the University of Toulouse (F). Joining Bayer Material Science AG (Germany) in Leverkusen in 2004, she was responsible for system development for Footwear and semi-rigid foams for automotive applications. Since 2008 she is working at Evonik Industries AG as global technical manager automotive & footwear.

### Annegret Terheiden



Dr. Annegret Terheiden received her Ph.D. in Chemistry with an emphasis on interfacial and physical chemistry at the University of Duisburg-Essen, Germany. In 2006 she joined the former Goldschmidt GmbH as a technical manager for flexible foam where she was responsible for the development of additives for flexible foam applications. Today she is working at Evonik Industries AG as global technical director for molded foam applications.

### Mladen Vidakovic



Mladen Vidakovic obtained his BS degree in chemical engineering and MS degree in polymer chemistry. Since 26 years he has been working in polyurethane industry in different positions. Before joining Evonik Goldschmidt Polyurethane Additives Division in 2003 he spent 8 years in R&D department of Woodbridge Foam Corporation dealing with development of HR-molded foam formulations. At Evonik Industries AG he is working as a manager in technical service responsible for application development and customer service in the area of additives for HR-molded foam.