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An expanded range of all-MDI flexible foam slabstock

for HR and CMHR applications

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SUMMARY

The combination of carbon dioxide technology with MDI flexible slabstock foam has expanded the range of High Resilience (HR) foams that can be made with MDI. Traditionally established in the 30kg/m3 and above segments, 'All-MDI' HR foams have been produced at densities down to 20kg/m3 and having excellent comfort and durability properties. The use of solid fire retardant in combination with CO2 also allows MDI to meet UK Fire Requirements at low densities.

This paper describes the properties of foams based on novel MDI formulations that have been developed to provide the slabstock industry with a full range of HR foams based on a single low viscosity MDI grade and HR polyol. The processing characteristics of MDI flexible foams are such that they can be produced on a very compact Maxfoam line fitted with a Cardio* system.

Now a complete range of HR slabstock foams can be made using MDI and benefit from a narrow density and hardness distribution, fast cure and low volatility characteristic of MDI. The use of carbon dioxide ensures that the comfort and durability of MDI foams at low density is excellent.

INTRODUCTION

High Resilience flexible slabstock foam based on MDI was introduced in 1992 and has grown quickly on the basis of its technical advantages, especially

- Good durability under humid conditions,
- Narrow density and hardness distributions through the block,
- Robust processing allowing high, square blocks,
- Fast cure allowing, short production conveyors, quick cutting and transport and, therefore, less storage,
- Simple formulations which do not use polymer polyol to obtain the normal hardness.

It was originally launched under a proprietary, 2-stream isocyanate system composed of a low NCO prepolymer and a second isocyanate stream. This maximized the process benefits of 'All-MDI' flexible slabstock listed above and has been successfully commercialized across Europe during the last 5 years.

To increase the scope of application of MDI slabstock to cover the entire range of Combustion Modified and High Resilience slabstock foam, a high NCO, low viscosity isocyanate has been developed. This retains the process robustness and property benefits of full prepolymer foams but allows

- Less significant modifications to an existing slabstock line
- The freedom to adapt the polyol formulation including the use of high levels of solid fire retardants

This approach can be applied to existing slabstock production lines – conventional, Maxfoam, Maxfoam with traversing head etc. Discontinuous 'All-MDI' slabstock is also made using similar MDI systems.

Another, particularly exciting development, is the use of a purpose built Maxfoam with Carbon Dioxide system which maximizes the production benefits of MDI. The processing of 'All-MDI' slabstock needs a shorter fall plate and conveyor arrangement than is used on existing equipment and therefore requires less factory space.

The saving in factory space resulting in these benefits is an extremely interesting feature of 'All-MDI' slabstock for existing foamers making large volumes of HR foam. In addition, MDI is not subject to the requirement of the revised Major Accident Prevention Directive [1].

A novel isocyanate for All-MDI slabstock foams

Unlike 80/20 TDI, isocyanates from 'All-MDI' slabstock are specifically blended mixtures of the isomers and homologues of MDI and, optionally, prepolymerised with polyols. Some of the features that can be improved through the choice of MDI for flexible foam are the

- density and hardness range that can be made from the isocyanate,
- final mechanical and durability properties of the foam
- initial viscosity of the foaming chemicals
- isocyanate storage stability

There is, therefore, greater freedom to use the isocyanate side of the foam formulation to simplify the foamers' task. For example, by improving the robustness of the foam during processing, and obtaining hardness via the isocyanate rather than a polymer polyol.

To demonstrate this approach, Suprasec 2720* has been introduced as a general isocyanate for continuous HR slabstock production.

Table 1 : Characteristics of Suprasec 2720 for HR slabstock

Property	Units	Typical Value
Specific Gravity		1.20
Isocyanate (NCO) value (by % wt NCO groups)	%	29.8
Typical processing temperature	°C	20-25
Appearance		Clear brown liquid
Flash point (ASTM D92)	°C	192
Fire Point (ASTM D92)	°C	206

In our work, this isocyanate gave the best performance when making a range of HR and CMHR foams from 20 to 55 kg/m^3.

General Characteristics of MDI foam based on Suprasec 2720

In designing an MDI prepolymer for HR flexible foam, slightly different compositions would normally be specified for the 3 ranges of foam which are normally made

- High density (40kg/m3 and above) comfort foams principally for high quality bedding
- Medium density (30-40kg/m3) foams for mattresses and furniture cushions
- Low density foams (20-30kg/m3) for furniture applications

With Suprasec 2720, we have developed a composition that adequately covers the entire range of HR foams requiring only one HR polyol and a limited range of additives. This isocyanate is also compatible with liquid carbon dioxide systems.

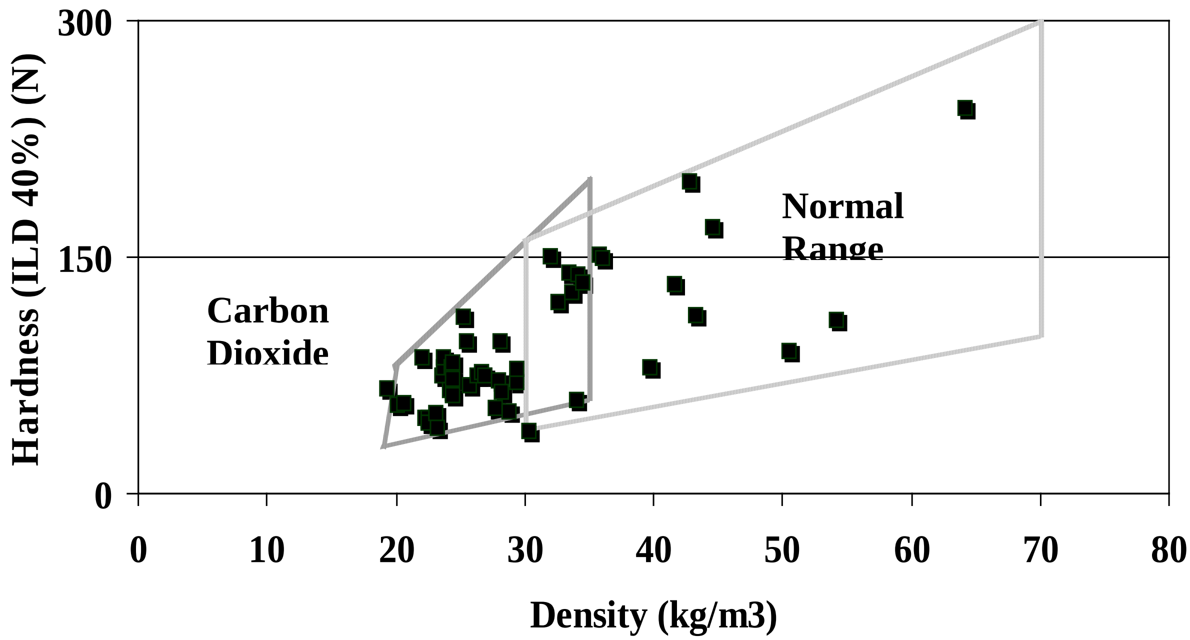
In order to show the range of HR foams that can be made with Suprasec 2720, formulations were based on one standard HR polyol (tri-functional, 6000 Molecular weight, OH_v 28 mgKOH/g). Standard additives used were as shown in the typical formulations in Table 2.

Table 2 : *Typical formulations for HR foams based on Suprasec 2720.*
Foams produced using Cardio contained up to an additional 3% w/w carbon dioxide on the total formulation.
CMHR foams contained additional melamine and TCPP.

Component	Range (parts by weight)
Suprasec 2720	40 - 80
HR polyol (6000 MW)	100
Cell-opener	1.0 – 4.0
Amine Catalyst	0.4 – 0.8
Cross-linker	0 – 1.0
Surfactant	0-0.4
Water	2.0 – 4.0

The resulting density – hardness map for Suprasec 2720 and a 6000MW triol is shown in Figure 1:

Figure 1: *Density – Hardness Map for foams made using Suprasec 2720 based on one HR polyol (OH_v 28mgKOH/g).*



For the foams passing The UK Fire Regulations, discussed below, melamine and TCPP were added as additional fire retardants.

Properties of MDI slabstock produced without assisted blowing

Foams based on Suprasec 2720 show a good match to competitive HR foams. As expected the slightly lower tensile and tear properties are compensated by improved humid compression set and feel.

Table 3 : Properties of selected foams based on Suprasec 2720

Property	Method	Units	Foam 1	Foam 2	Foam 3	Foam 4	Foam 5	Foam 6	Foam 7	Foam 8	Foam 9	Foam 10
Density	ISO 845	Kg/m3	30.4	35.3	35.5	33.7	34.8	39.1	41.4	48.8	45.7	49.4
ILD 40%	ISO 2439	N	156	83	106	127	146	51	106	97	162	222
ILD SAG	"		3.0	2.9	2.9	3.1	2.8	2.9	2.8	2.8	3.1	3.1
CLD 40%	ISO 3386-1	Kpa	3.4	2.1	2.8	2.9	3.6	1.2	2.8	2.3	4.0	6.2
Hysteresis	"	%	31.8	22.7	24.7	26.6	29.6	16.7	21.5	17.5	22.6	24.1
Tear Max	ISO 8067	N/m	202	172	228	116	112	145	198	145	245	265
Mean	"	N/m	174	144	186	93	94	130	166	125	210	225
Tensile	ISO 1798	Kpa	134	67	80	91	76	53	64	62	105	124
Elongation	"	%	130	128	132	89	83	113	133	110	145	100
Rebound	ISO 8307	%	57	62	61	61	59	59	63	63	64	61
C.S. Dry 75%	ISO 1856A	%	7.3	3.2	3.8	3.2	2.7	2.3	2.2	1.8	4.0	5.2
C.S. Dry 90%		%	10.7	2.9	3.9	5.9	5.0		2.6			
C.S. Hum. 70%		%	24.8	4.0	5.4	8.8	3.2	2.6	2.2	2.0	4.9	5.8
HACS 120`C 75%		%	35.8	8.8	10.7	14.6	16.1		6.0			
Fatigue												
ILD Loss	ISO 3385											
T/ness loss : 10`		%	3.0	0.8	1.6	2.1	2.4	0.6	0.7	0.2	1.7	1.6
H/ness loss : 10`		%	33.7	22.3	23.6	23.1	17.4	14.3	21.6	15.0	20.4	16.3

The real benefits however can be seen during production. Table 4 shows the density and hardness distribution of a 30 kg/m3 foam made on a Cannon Viking Maxfoam line. The foam was 2m wide and 1m high. The block was trimmed by 5cm at the top, bottom and sides before samples were taken. The statistical distributions are calculated from 60 samples taken from within the block. The standard deviation on density is less than 3% of the average and the standard deviation on hardness is around 4% of the average.

Table 4 : Density and hardness distributions in foam produced using Suprasec 2720.

Property	Units	Average	Max	Min	Standard Deviation
Density	Kg/m3	32.1	34.7	30.9	0.8
ILD 25%	N	102	110	94	4.3
ILD 40%	N	142	155	130	5.8
ILD 65%	N	315	340	300	10.5

Properties of MDI slabstock produced with liquid carbon dioxide (Cardio)

To make foams below 30kg/m3 a high water and isocyanate content in the formulation is required. This degrades the polymer structure and deleteriously effects the foam durability and mechanical strength.

The use of liquid carbon dioxide as a blowing agent reduces the need for high water levels to make low-density foams and leads to greatly improved foam properties through an improvement in the polymer structure. Properties which, therefore, depend significantly on the polymer structure are almost unaffected by a density reduction from additional liquid carbon dioxide. Foam durability, measured as dry or wet compression set, and energy absorption measured as hysteresis or ball rebound are, therefore, excellent in such CO2-blown foams. The foam ‘feel’ is also preserved and is immediately appreciated by customers.

Mechanical properties of the foam such as hardness, tensile strength and tear strength follow the normal relationships with density. The starting formulation (without liquid CO2) must be appropriately designed to give the desired values after addition of liquid CO2.

Table 5 shows the properties of foams made using the Cardio system.

Table 5 : Properties of selected foams based on Suprasec 2720 and Cardio

Property	Method	Units	Foam 1	Foam 2	Foam 3	Foam 4	Foam 5	Foam 6
Density	ISO 845	Kg/m3	19.4	22.2	24.4	25.4	26.7	28.2
ILD 40%	ISO 2439	N	53	81	62	105	77	118
ILD SAG	"		2.6	2.5	3.0	2.6	2.8	2.6
CLD 40%	ISO 3386-1	kPa	1.3	1.8	1.3	2.6	2.0	3.2
Hysteresis	"	%	30	31	27.5	31	29.3	30.3
Tear Max	ISO 8067	N/m	143	134	142	166	154	151
Tear Mean	"	N/m	121	110	112	147	123	129
Tensile	ISO 1798	kPa	40	46	53	66	66	75
Elongation	"	%	128	110	108	116	96	85
Ball Rebound	ISO 8307	%	55	54	59	55	59	56
C.S. Dry 75%	ISO 1856A	%	7.6	7	9.0	6.4	8.2	4.7
C.S. Dry 90%		%	8	7.8	5.7	7.6	4.1	6.1
C.S. Hum. 70%		%	18.1	14.5	7.1	12.3	6.6	9.3
HACS 120`C 75%		%	15.5	15.7	12.4	22.8	16.9	19.2
Fatigue								
ILD Loss	ISO 3385							
T/ness loss : 10`		%	1.0	2.6	2.5	3.1	2.3	4.6
H/ness loss : 10`		%	28.5	25.7	24.3	29.7	26.5	30.3
CLD loss	NF T 56-114							
T/ness loss : 30`		%	3.1	1.2	1.1	3.9	1.0	3.1
40% loss : 30`		%	28.2	18.9	19.5	31.5	19.5	28.2

Market feedback obtained on liquid carbon dioxide blown foams indicates that Suprasec 2720 produces foams which, compared to currently available HR foams,

- are sufficiently hard, even without the use of polymer polyol,
- have better elasticity,
- have good dry compression set and excellent wet compression set,
- have an excellent feel

without any penalty on density.

Foams made with Cardio also show an excellent density and hardness distribution resulting from the fast cure of MDI and the froth viscosity. In a similar test to the one performed to obtain the results in Table 4, but using a 20.4 kg/m3 65N foam, the standard deviation on density was 0.5 kg/m3 (2.5%) and on hardness was 2N (3.1%).

The use of liquid CO2 is not a barrier to investigating the range of foams that can be produced. The effect of the addition of liquid carbon dioxide is readily characterized. It is straightforward to develop a formulation at high density and to predict its properties and processability at low density after the addition of liquid carbon dioxide.

The ability to make a foam, reduce its density by 30% and still obtain similar foam stability is a measure of the robustness of Suprasec 2720 in flexible foams.

On the production machine it is also straightforward to set up the Cardio gatebar to obtain the correct pressure profile in the gatebar for the laydown onto the conveyor once the viscosity of the chemicals in the mixhead is known.

Fire Performance of MDI slabstock for furniture and bedding applications

All-MDI foams not containing fire retardants

One of the benefits of 'All-MDI' slabstock foams made with Suprasec 2720 is the ability to pass standard fire performance tests without the need for any fire retardants. Table 6 shows foam performance in a variety of commonly used tests for furniture applications.

Table 6: Fire performance of flexible foams made without additional fire retardants using Suprasec 2720.

Foam density (kg/m3)	Foam Hardness ILD 40% (N)	EN 1021-1 Smoldering cigarette Class I textile Cover : 1	EN 1021-1 Smoldering cigarette Class II textile Cover : 2	EN 1021-2 Match flame equivalent Class I textile Cover : 1	Oxygen Index ASTM 2863	Cal 117A Vertical burn Non-aged	Cal 117D part II Smoldering cigarette Cover : 3 and 4	MVSS 302 Horizontal burning	UL94 Horizontal burning 94HBF
24*	**62**	NI	NI	NI	21.0	Pass	Pass	Pass	-
27*	**77**	NI	NI	NI	20.8	Pass	Pass	Pass	Fail
30	**94**	NI	NI	NI	21.0	Pass	Pass	Pass	Fail
36	**150**	NI	NI	NI	21.2	Pass	Pass	Pass	Fail
35	**105**	NI	NI	NI	20.3	Pass	Pass	Pass	Pass
36	**72**	NI	NI	NI	23.2	Pass	Pass	Pass	Pass
42	**125**	NI	NI	NI	23.9	Pass	Pass	Pass	Pass

Notes :

*Made using Cardio

NI = non ignition**,** I = ignition and the following covers were used:
Cover 1 = 100% FR polyester fabric ; 220 g/m2 ; Water soaked, Annex D of EN 1021-1.
Cover 2 = 100 % Cotton velvet ; Class II textile (Eufac) ; ~430 g/m2 ; Water soaked, Annex D of EN 1021-1.
Cover 3 = 100 % Cotton velvet (Momentum Textiles); Pattern 8500; Beige ; 14.9 oz/lin.yd (330 g/m2)
Cover 4 = 100 % Cotton (laundered and dried); 4.2 oz/yd2 (144 g/m2)

Eliminating the need for fire retardants, low additive levels and no requirement for polymer polyols in the formulation has benefits in reducing potential emanations from the foam. Two methods were used to qualitatively detect potential emanations from foam:

- Attenuated Total Desorption followed by GC-MS in which a small sample of foam is placed in a closed vessel and heated from 50˚C to 150˚C at 10˚C/min. The vapors that evolve are collected in a cold trap at -70˚C and identified by flash heating and GC-MS. This method highlights volatiles that may be evolved from the foam during use.
- Solvent extraction followed by GC-MS in which the foam is extracted in boiling methanol at 64˚C for 4 hours and the species in the extract are identified by GC-MS. This indicates which substances may be washed out of the foam in use.

Figures 2 and 3 give typical results from MDI flexible foam with the resulting identification of the peaks found. Only the amine catalyst and anti-oxidant were identified as potential emanations.

Figure 2: Emanations from All-MDI flexible foam. Attenuated Total Desorption GC-MS Spectra.

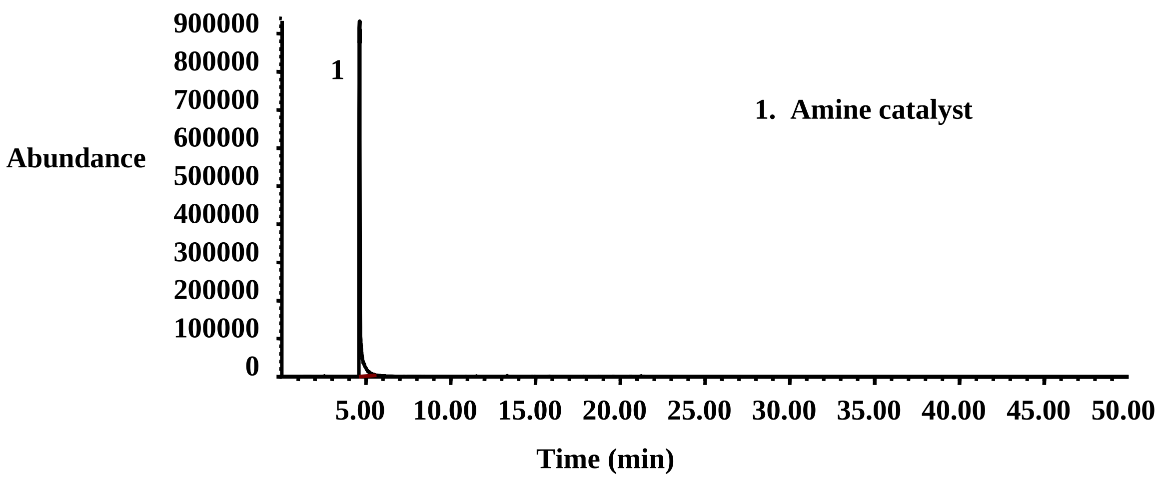
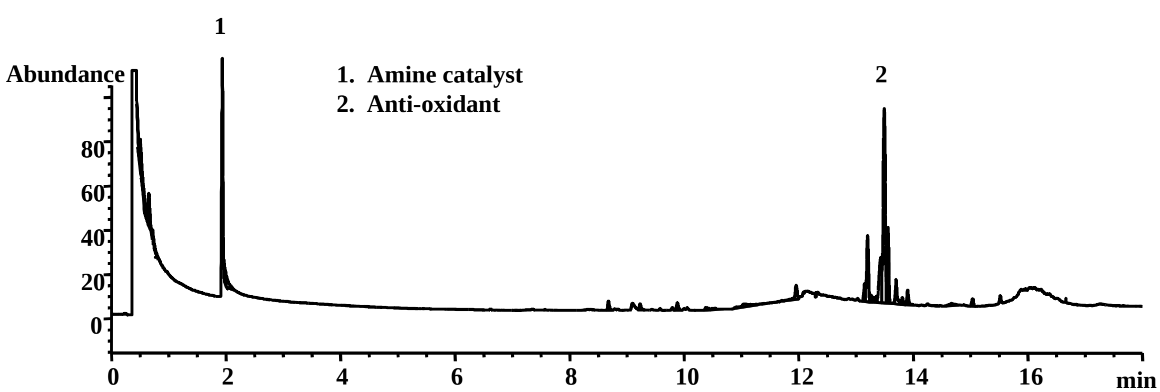


Figure 3: GC-MS spectra following solvent extraction of All-MDI flexible foams



Fire retarded all-MDI foams

However, since a major proportion of CMHR foams consumed in Europe are sold in the UK, formulations were developed which meet The Furniture and Furnishings (Fire) (Safety) Regulations 1988. These require that a maximum of 60g mass is lost during a fire test performed to BS 5852 Part 2 1982 Ignition Source Crib 5.

Such foams were produced using the Cardio system. Melamine and TCPP were used as fire retardants. We found no problem processing levels of melamine up to 18% w/w on total formulation through the Cardio system and performing a normal flush sequence after production. The grade of melamine used had a particle size specification of 99% <300 microns.

The properties of some of the foams produced are shown in Table 7.

Table 7 : Properties of 'All-MDI' Combustion Modified foams made with Suprasec 2720 and Cardio passing the UK Fire Regulations

Property	**Method**	**Units**	**Foam 1**	**Foam 3**	**Foam 4**	**Foam 5**
Density	ISO 845	Kg/m3	28.1	31.4	34.0	41.7
ILD 40%	ISO 2439	N	54	107	139	132
ILD SAG	"		3.6	3.2	3.1	3.6
CLD 40%	ISO 3386-1	kPa	1.5	2.7	3.4	3.1
Hysteresis	"	%	32.8	35.7	37.1	31.5
Tear Max	ISO 8067	N/m	95	134	129	138
Mean	"	N/m	80	114	110	113
Tensile	ISO 1798	kPa	52	56	58	85
Elongation	"	%	70	59	78	93
Rebound	ISO 8307	%	53	55	55	56
C.S. Dry 75%	ISO 1856A	%	13.6	5.1	6.7	4.6
C.S. Dry 90%		%	12.1	6.4	8.9	9.3
C.S. Hum. 70%		%	46.8	21.5	17.7	19.6
Fatigue						
ILD Loss	ISO 3385					
T/ness loss : 10`		%	4.0	3.5	2.9	2.1
H/ness loss : 10`		%	27.8	38.5	30.4	28.6
Crib V ; Wt loss	BS5852	g	26	30	26	23
		Pass/Fail	Pass	Pass	Pass	Pass

The properties of these foams are in line with all foams containing high levels of melamine in particular high sag factors and low tensile properties. However, since the weight loss during the Crib V test shown in Table 7 is quite low, there is scope for property improvement by reformulating the fire retardant package.

These foams were also qualitatively assessed for potential emanations and the results are shown in Figures 4 and 5.

Figure 4: *Emanations from All-MDI flexible foam passing UK Fire Regulations. Attenuated Total Desorption GC-MS Spectra.*

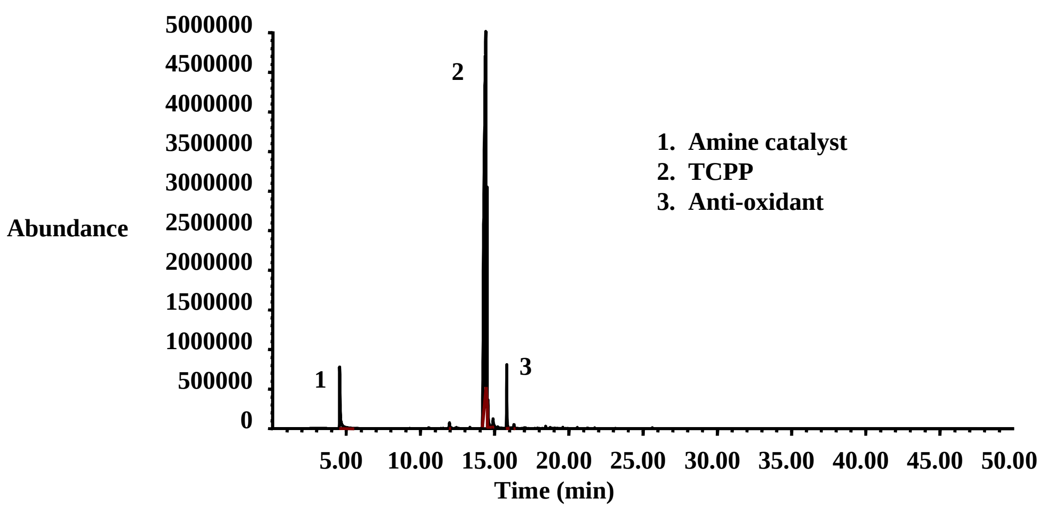
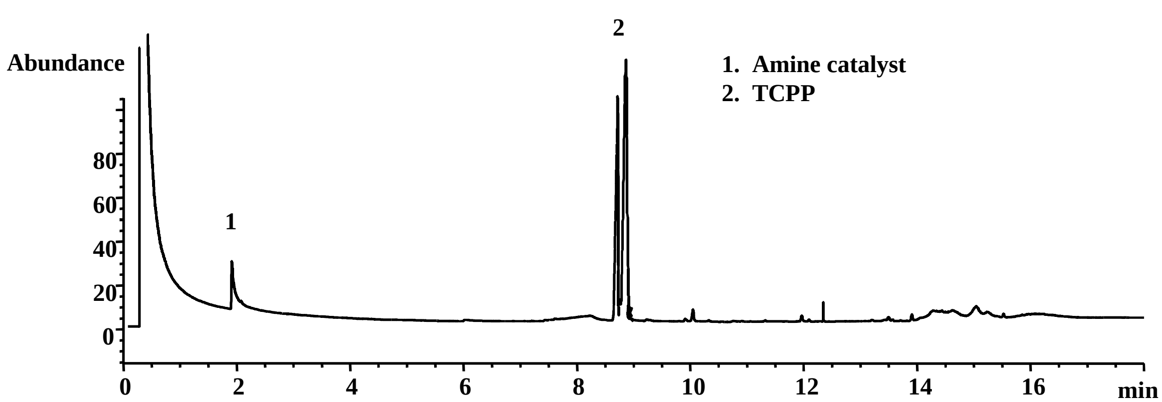


Figure 5: *GC-MS spectra following solvent extraction of All-MDI flexible foams meeting UK Fire Regulations.*



These tests indicated that the only substances that are potentially evolved from these foams based on Suprasec 2720 are the amine catalyst, the antioxidant in the polyol and TCPP.

Factory considerations

The full benefits of 'All-MDI' slabstock, in terms of increased production efficiency, reduced factory space and the ability to produce low-density HR foams, can be obtained using a specially developed Maxfoam slabstock machine equipped for liquid CO2 injection.

Of particular interest is the ability to use the viscosity of 'All-MDI' systems to increase the angle of the fall plates and run the conveyor at a slow speed without problems of under-running. This high viscosity comes from

- the fast reactivity of MDI,
- its initially higher viscosity of the foaming chemicals compared to TDI and,
- in the case of CO_2 blown foams, the high viscosity of the CO_2 froth.. (Using Cardio we have run with the first fall plate at 16°)

In order to match the typical time to end of rise of an MDI system using a slow conveyor, the fall plate must be designed for greater flexibility than on a standard Maxfoam machine. The fall plates should be 4.5m long and have at least 5 plates to obtain the flexibility and steepness required.

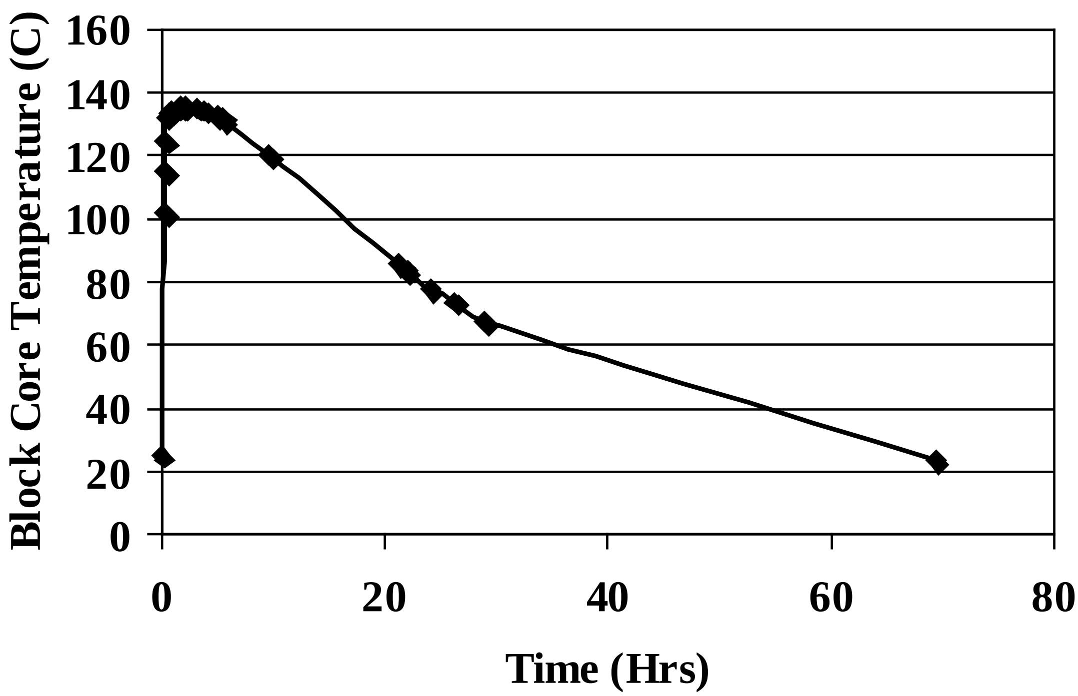
This technique gives sufficient residence time on a short conveyor to ensure that the surface of the foam is fully cured before cutting the block without any compromise on block height. In fact, it is possible to produce nice square blocks of HR foam at densities from 20 to 45kg/m^3 with a block height exceeding 1.1m at outputs from 150 to 300 kg/min on correctly operated lines, Table 8.

Table 8 : Process conditions giving 1m block heights at slow conveyor speeds using Suprasec 2720

	Production of 2.1m wide blocks on a short conveyor			
Foam density (kg/m3)	45	30	25	22
Carbon dioxide added (% on formulation)	-	2	1.9	2.5
Conveyor speed (m/min)	2.8	2.3	2.7	3.0
Laydown device	Trough	Gatebar	Gatebar	Gatebar
Machine output (kg/min)	295	156	154	155
Block height achieved (m)	1.15	1.10	1.10	1.12
Side and bottom paper removal	After 4 min			
Initial block cutting on conveyor	After 5 min			
Block cooling period	Overnight			

Given the lower conveyor speed and steep fall plates, such a slabstock line requires a significantly smaller factory size than a conventional Maxfoam line. It has a footprint which is 30m by 3m wide. In total, about 1400m^2 is required to house the machine, and cool the foam produced in addition to the area for bulk chemicals and carbon dioxide storage.

Figure 6 : *Block cooling profile for a 30 kg/m3 110N foam block 2m wide by 2m long and 1m high stored in an open warehouse.*



The shortness of the line means it can be supplied as a complete metering and fall plate module requiring only the construction of the conveyor and attachment of pipework and power supplies.

Figure 7 : *Slabstock module during dispatch at Cannon Viking, Manchester, UK. This module houses the fall plates and mixhead, control and electrical panels, additive tanks and pipework local to the mixhead. Bottom and side paper handling equipment is included.*

With the cost advantages of occupying such a small factory area and the quality of the foams, especially at low density, it makes sense for a foamer to consider a separate MDI slabstock unit for HR foam production.

A readily noticeable benefit of MDI flexible foams is the low volatility of the isocyanate used combined with its faster cure.

Measurements of personnel exposure to MDI under real production conditions using the established full prepolymer approach give an indication of the potential exposure expected using Suprasec 2720. The results show that the exposure to MDI for the operators of the slabstock line was an order of magnitude below the permitted 8 hr exposure limit to MDI. This is based on measurements made for the operators working at the foam laydown, paper removal station and cut-off saw in this particular test. In the same test, no MDI or VOC's were detected during production at the cut off saw and the foam store [2].
Also in the same test, measurements of the air extracted from the slabstock line showed that 1-2mg/m3 of VOC's were detected in the conveyor area. MDI levels in the extracted air were all less than 0.01mg/m3. It is estimated that about 0.005g MDI is lost to air during the production of 1 te of MDI slabstock foam.

These results indicate that under normal operating conditions and with typical slabstock line ventilation, standard protective equipment is sufficient [3]. In addition, extracted air requires no futher abatement measures before emission under current standards for isocyanate emission.

Also, the low water content of MDI slabstock formulations, especially when using liquid carbon dioxide greatly reduces the risk of scorch or fire. However, the risk of an equipment failure resulting in metering a formulation with an unacceptably high exotherm must still be considered for safety reasons.

Finally, the requirements of the Major Accident Prevention Directive do not apply to MDI.

The economics of 'All-MDI' flexible foams

The market for slabstock foams is becoming more cost conscious and environmentally sensitive. It needs cost effective, innovative technology if it is to compete with other materials. This is a dilemma in a highly competitive and mature industry.

MDI flexible foams contribute to the well-being of the industry. They offer competitive technology and new products that conform to market demands in terms of price, HR performance and enhancing the environmental position of PU materials.

MDI flexible foams have proven to be cost effective. The combination of advanced technology in the form of specialized isocyanates and liquid CO2 equipment offers to extend this into low density foams and increased cost savings in several areas.

- Efficient use of factory space either by expanding production without requiring new blockfoam curing areas
- Production efficiency savings in the manufacture of HR foams through high, square blocks.
- Competitive raw material costs even more so with reduced additive packages and the freedom to formulate around existing polyols with the introduction of Suprasec 2720.

However, in order to realize these savings some of the successful but traditional production and marketing ideas need to be revisited if Foamers are to capitalize on such benefits.

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CONCLUSIONS

MDI flexible slabstock foam, especially in combination with liquid carbon dioxide, based on a single high-NCO prepolymer is capable of covering the entire High Resilience range of foams for furniture and bedding.

Such foams, especially at low density, give the customer benefits in terms of feel, durability and inherent fire resistance.

In addition, formulations are available which meet the UK Fire requirements.

The processing benefits of MDI give a noticeable improvement in the factory environment, a means to further reduce emanations from foams and are consistent with most forms of recycling including Huntsman's own chemical recycling process.

Finally, there are potentially considerable savings in factory and curing space if MDI HR foams are produced. Block yield can be increased because the fast cure and highly stable formulations allow higher and squarer blocks to be produced.

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BIOGRAPHICAL NOTES

Denis Hicks is the Slabstock Technology Manager for the Furniture Business of Huntsman Polyurethanes in Europe. He is a mechanical engineer from Imperial College, London. For three years he was Plant Engineering Manager in ICI's Teeside chemicals complex and became a Chartered Mechanical Engineer and Member of the Institution of Mechanical Engineers in England in 1989. At the same time he moved into ICI's Research and Technology Group becoming Extrusion Technical Service and Process Development Manager for acrylic polymer extrusion. He joined Huntsman Polyurethanes in Belgium in 1992 and was responsible for ICI Polyurethanes' recycling programme and the development of new process technology for using polyurethanes.

Severino Spertini is a Slabstock Applications Specialist for Huntsman Polyurethanes' Furniture Business based in Ternate, Italy. He has a diploma in Chemistry from the Technical Institute of L Cobianchi. His career in polyurethanes started in 1968 with Pirelli in their flexible foam R&D department. In 1971 he moved to Nord Italie Resina. He joined ICI in 1988 providing technical Service in Flexible Foams before moving to the R&D Dept in Everberg, Belgium in 1991. He started in his current position in Ternate in 1995.

Glyn Davies is a Research Scientist in the Slabstock Research and Development, Team of Huntsman Polyurethanes, based in Everberg, Belgium. He graduated from Manchester Polytechnic in 1985 with an honours degree in Polymer Science and Technology and joined ICI Polyurethanes in the UK in 1990 where he spent 5 years in a technical service role with automotive and furniture, flexible moulding customers. In 1995 he moved to the R&D Dept and has since worked on the development and application of MDI flexible foam slabstock technologies. More recently this has involved leading the team developing the use of carbon dioxide with MDI on Huntsman`s large-scale development machine at Rozenburg, Netherlands.

Pierre Chaffanjon is the Slabstock Development Team Leader within the International Product R&D group of Huntsman Polyurethanes at Everberg, Belgium. He joined the Research group of ICI Polyurethanes in 1988 upon completion of his Ph.D. in Polymer Chemistry obtained from the Strasbourg University in France. Over the first 6 years, he has been in charge of various research projects dealing with Flexible Foams, including raw materials developments and understanding of the mechanisms which govern the foam processing and properties for both slabstock and moulding foams. He then moved to the slabstock application 5 years ago and since then, he has led the Application Development Team within the International R&D department.

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