Latest development for recycling of PU foam out of end-of-life mattresses into polyol for rigid PU foam application
Since 1987 H&S is one of the leading suppliers of equipment and technologies for polyurethane processing industry.

- equipment and technologies for efficient, safe and environmentally secure storing, dosing, mixing, formulating and processing of polyurethane;

- compliance with European standards;

- compliance with ISOPA standards.

**H&S sales partners**

**Location** : Sulingen, Germany

**Sales partners** : in 18 countries

**Realised projects** : > 300 in around 35 countries

**Export rate** : ca. 80% from total turnover
H&S Portfolio

Tank storage systems for polyol, isocyanate, pentane

Prepolymer reactors

Blending stations for mixing polyols with liquid additives

Reactors and know-how for generating polyester polyol based on PET, phthalic anhydride and natural oils

Blending stations for mixing polyols with solid fillers

Reactors and know-how for chemical recycling of rigid and flexible PU foam residues
H&S service and support in the field of chemical developments includes:

• testing of the customers PU foam residues

• producing of the polyol samples from flask up to industrial scale in the pilot reactors: 90L, 380L, 700L

• foaming tests and analysis of the physical and mechanical properties of the PU foam

• adjusting the parameters of the polyol according to customers’ requirements and specifications

• developing and adjusting of the formulations for PU foam based on polyester polyols and recovered polyols

• comprehensive consultations in all PU issues

• training of the customers personnel by H&S chemists within the framework of common projects

• long-term customer support during presale, start-up and production period
EoL mattresses market overview

Annual amount of EoL mattresses in EU: ≈ 30 Mio. pieces*

Composition of EoL mattresses

- Fibers: 27%
- PU foam: 36%
- Steel: 20%
- Latex: 13%
- Non-woven: 2%
- Other: 2%

= 160 ktons !

Average mattress lifecycle: ≈ 10 years

PU waste are not biodegradable!

* European Bedding Industries' Association
Recycling of post-consumer mattresses

- Chemical Recycling
  - Recovered Polyol for rigid PU foam
- Mechanical recycling
  - Carpet underlay, sport mats etc.

Raw materials recovery

Landfills (60% of mattresses and upholstered furniture)

Energy recovery and thermochemical recycling
H&S has put into operation the world's first recycling installation for converting of PU flexible foam residues into recovered polyol on an industrial scale.

The annual capacity of the installation is 2,400 t/a.

The plant is working successfully since 2013.
H&S recycling technology for post-consumer PU mattresses

H&S has developed a technology of generating stable recovered polyols based on an optimized **acidolysis method**.

The final product is a **recovered polyol**, which can substitute a part of the conventional polyol for **rigid PU foam** production without quality loss.

**Advantages of H&S technology:**

- polyols with stable OH number and molecular weight
- polyols suitable for the PU foam with closed cell structure (e.g. insulation foam)
- high percentage of replacing original polyol by means of recovered polyol (over 40%)
- good reactivity of the resulted polyols
- no primary aromatic amines
Raw materials

1) **Flexible PU foam residues out of post-consumer mattresses**
   Mixed shredded PU residues free from latex, textile, metal, wood etc.

2) **Basic polyether polyol for rigid PU foam**

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU foam out of post-consumer mattresses</td>
<td>40</td>
</tr>
<tr>
<td>Basic Polyol</td>
<td>37</td>
</tr>
<tr>
<td>Acids</td>
<td>13</td>
</tr>
<tr>
<td>Additive</td>
<td>6</td>
</tr>
<tr>
<td>Catalyst</td>
<td>4</td>
</tr>
</tbody>
</table>

3) **Carboxylic acids**
   2 dicarboxylic acids

4) **Additive**

4) **Catalyst**

Manufacturing cost of recovered polyol is 35% lower than the market price of virgin polyols!

Process waste:
- water distillate - approx. 2%
- evaporation - approx. 2%
- filtrate – approx. 0.2%
- In total - approx. 4%
Chemical process

Process time
12 hours

- Cooling for polyol
- Reaction phase
- Heating
- Filling of polyol and catalysts
- Filling of PV residues
- Discharge of polyol

H&S Recycling of EoL mattresses_PSE_29.06.17.
### Quality specification of the recovered polyol generated out of post-consumer PU mattresses

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity</td>
<td>4.500 - 7.500 mPas and higher depending on the PU foam</td>
</tr>
<tr>
<td>Hydroxyl number</td>
<td>240 - 310 mg KOH/g</td>
</tr>
<tr>
<td>Acid number</td>
<td>&lt; 1.1 mg KOH/g</td>
</tr>
<tr>
<td>Appearance</td>
<td>Viscous liquid of light brown to dark brown color - depending on the color of the foam residues</td>
</tr>
</tbody>
</table>

**No primary aromatic amines!**

There were generated more than 100 research lab tests as well as 25 batches in lab scale and 10 batches in pilot reactor with repeatable results.
Applications of the polyols out of post-consumer mattresses

- Rigid PUR/PIR insulating foams – proven results of usage up to 50% by weight of recycled polyol in the formulation;
- Pre-polymers for compound materials (rubber mats, covering materials);
- Glues and/or pre-polymers for wood industry;
- Rigid PU block foam;
- Spray foam;
- Can foam (construction foam);
- Compound materials for automotive industry.
Properties of the rigid PIR foam produced with 20% and 50% of recovered polyol produced on a continuous line (example)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Master sample (foam without recovered polyol)</th>
<th>PIR Foam with 20% recovered polyol</th>
<th>PIR Foam with 50% recovered polyol</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of recycled polyol</td>
<td>0</td>
<td>20</td>
<td>50</td>
<td>Perfectly comparable</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>30</td>
<td>30,2</td>
<td>30,9</td>
<td>Perfectly comparable</td>
</tr>
<tr>
<td>Parallel compression resistance</td>
<td>2,45</td>
<td>2,58</td>
<td>2,55</td>
<td>Perfectly comparable</td>
</tr>
<tr>
<td>Dimensional stability at -20 °C (%)</td>
<td>0,5</td>
<td>0,2</td>
<td>0,21</td>
<td>Perfectly comparable</td>
</tr>
<tr>
<td>Dimensional stability at 80 °C (%)</td>
<td>1,25</td>
<td>0,8</td>
<td>1,16</td>
<td>Slightly better</td>
</tr>
<tr>
<td>Thermal conductivity λ (W / m.k)</td>
<td>22,22</td>
<td>21,6</td>
<td>22,06</td>
<td>Slightly better</td>
</tr>
<tr>
<td>Closed cells (%)</td>
<td>89</td>
<td>89,5</td>
<td>88</td>
<td>Perfectly comparable</td>
</tr>
<tr>
<td>Fire resistance (cm), B2 Test UNE-ISO 11925-2</td>
<td>12,5</td>
<td>11,5</td>
<td>12,0</td>
<td>Perfectly comparable</td>
</tr>
</tbody>
</table>
Technology in industrial scale

Annual production capacity (example):

5t Reactor – 2,400 t/a → 1,000 t/a of residues can be converted
(5 t/batch x 2 shifts = 10 t/day x 250 days/a = 2,500 t/a - 4,0% (waste and evaporation) = 2,400 t/a of recovered polyol)
Flexible PU foam recycling plant: 3D model
Conclusions

**Advantages offered by H&S Anlagentechnik post-consumer recycling technology:**

1. One of the most sustainable solutions for EoL mattresses recycling: decrease of landfill and incineration streams.
2. Winning back valuable raw materials from EoL mattresses.
3. Decrease of the manufacturing costs of PUR/PIR foams.
H&S Flexible PU foam recycling plant: Dendro, Poland
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Thank you for your attention!
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