EXPLOSION PROTECTION –

USING THE DATABASE

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[Images of various equipment and scenes related to chemical safety and engineering.]
Outline

- Database CHEMSAFE
- Safety characteristics
- Explosion protection
  - primary, secondary, tertiary (constructive) explosion protection
- Examples
- Summary
CHEMSAFE

- database for evaluated safety characteristics of app. 3000 flammable substances: liquids, gases, dusts and their mixtures
- project partners: BAM, DECHEMA, PTB
- updated yearly
- languages: German / English
CHEMSAFE contains

1. Safety characteristics for fire & explosion protection, its definitions and information about test methods

2. Occupation safety data

3. Classification and labelling

4. Substance identification and specifications: Synonyms, CAS-, EC-, Index- and UN-No., particle size distributions

5. References, Recommendation of experts

6. Estimation methods (e.g. ISO 10156 flammability and oxidizing potential), graphical tools, data exchange
Example - Benzene

<table>
<thead>
<tr>
<th>mixture name</th>
<th>Benzene</th>
</tr>
</thead>
<tbody>
<tr>
<td>system name</td>
<td>Benzene</td>
</tr>
<tr>
<td>sum formula</td>
<td>C6H6</td>
</tr>
<tr>
<td>CAS-no</td>
<td>71-43-2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UN-recomm.</th>
<th>class</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN-recomm.</td>
<td>packing gr.</td>
<td>II</td>
</tr>
<tr>
<td>IMDG-Co./GGVSee</td>
<td>class</td>
<td>3</td>
</tr>
<tr>
<td>IMDG-Co./GGVSee</td>
<td>packing gr.</td>
<td>II</td>
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<td>ADR/GGUSE</td>
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<td>ADR/GGUSE</td>
<td>packing group</td>
<td>II</td>
</tr>
<tr>
<td>ADR/GGUSE</td>
<td>classification</td>
<td>F1</td>
</tr>
<tr>
<td>RID/GGUSE</td>
<td>class</td>
<td>3</td>
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<tr>
<td>RID/GGUSE</td>
<td>packing group</td>
<td>II</td>
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<tr>
<td>RID/GGUSE</td>
<td>classification</td>
<td>F1</td>
</tr>
<tr>
<td>UN/GGVSeeSch</td>
<td>class</td>
<td>3</td>
</tr>
</tbody>
</table>

T | F

33
1114

description
Explosion region of a ternary system

chamsafe
Primary explosion protection

Safety characteristics for assessing
the explosiveness (flammability) of gases &
liquids:

- Explosion limits
- Limiting values of explosion region
  (MOC, LOC, MXC, Tci), inerting
- Limiting values for chemically unstable
  substances (maximum stability ratio)
- Explosion point, Flash point
Test apparatus for determination of explosion limits of gases

EN 1839-T (tube) min. 100 mm
Apparatus in EN 1839

**EN 1839 -B  Bomb method**
- closed vessel
- spherical or cylindrical
- internal volume of at least 5 Liters
- spark or fusing wire igniter

**EN 1839 -T  Tube method**
- open vessel
- tube (Ø 80 mm, minimum length 300 mm)
- spark igniter
Temperature influence on explosion limits

Source: BAM, CHEMSAFE
Pressure influence on explosion limits

Source: PTB, CHEMSAFE
Explosion diagram

with limiting values

measured data + expl. curve
MOC-line
ICR-line
IAR-line
SCO-line

Explosion range
with limiting values

MOC
(LOC)

MXC
(Tc_i)

UEL
MOC
(MLOC)

SCOs

LEL

inert gas
[concentration %]

flammable gas
[concentration %]

Explosion

oxygen
[concentration %]
Inerting

- Total inverting area (area under LEL and ICR-line)
- Other areas outside explosion region are partially inerted.
Explosion region: Ethylene oxide/N\textsubscript{2}/air

Decomposition

\[ C_2H_4O \rightarrow CO + CH_4 \]

Combustion

\[ C_2H_4O + \frac{5}{2}O_2 \rightarrow 2CO_2 + 2H_2O \]

Initial conditions: 100 °C, 40 kPa
Test method: EN 1839-B
Explosion region of the system Ethene/H$_2$O/air at different temperatures
Explosion region of the ternary system $\text{CH}_4/\text{N}_2/\text{air}$ at 10 bar and 100 bar
Explosion region of ethane/N₂ with different oxidizing gases

![Graph showing the explosion region of ethane/N₂ with different oxidizing gases. The graph includes lines for chlorine, nitrous oxide, nitric oxide, air, and nitrogen trifluoride.]
Calculation method for flammability (ISO 10156)

If this condition fulfilled – the mixture is classified as **non-flammable**
Determination of $T_{ci}$ from x-y diagram

- **Explosion range methane/nitrogen/air**
  - measurement by Schulz BAM Lab. II.22 (1996)
  - **LEL**: 4.2 mol %
  - **UEL**: 16.3 mol %
  - **$T_{ci}$**: 8.49 mol %

- **Tci (ISO) = 8.4 mol %**

- **ISO 10156 (1996) Tci value for methane was 14.3 mol in %**
Acetylene – Chemically unstable gas

<table>
<thead>
<tr>
<th>C gas comp.1 volume%</th>
<th>C gas comp.2 volume%</th>
<th>stab.r.max</th>
<th>st.pr.lim. bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>10</td>
<td>9.0</td>
<td>1.0 (1)</td>
</tr>
<tr>
<td>80</td>
<td>20</td>
<td>4.0</td>
<td>1.5 (1)</td>
</tr>
<tr>
<td>70</td>
<td>30</td>
<td>2.33</td>
<td>2.2 (1)</td>
</tr>
<tr>
<td>65</td>
<td>35</td>
<td>1.86</td>
<td>3.7 (1)</td>
</tr>
<tr>
<td>60</td>
<td>40</td>
<td>1.5</td>
<td>4.6 (1)</td>
</tr>
<tr>
<td>55</td>
<td>45</td>
<td>1.22</td>
<td>5.1 (1)</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
<td>1.0</td>
<td>12.9 (1)</td>
</tr>
<tr>
<td>47</td>
<td>53</td>
<td>0.89</td>
<td>18.0 (1)</td>
</tr>
</tbody>
</table>

You can get the definition of a characteristic by highlighting it with the mouse and pressing the F1-key.
Stability pressure limits for acetylene with other gases

Ignition energy: 70 Ws

Acetylene in mol%
Dust explosion accident

February 8, 2008
Sugar factory
Savannah, Georgia, USA
Dust explosion test in BAM

1- cubic meter vessel

20-liter sphere
Search for sugar in CHEMSAFE

<table>
<thead>
<tr>
<th>Side condition</th>
<th>1 part size μm</th>
<th>mass frac. weight%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0</td>
<td>&lt;20</td>
<td>20</td>
</tr>
<tr>
<td>&gt;20</td>
<td>&lt;32</td>
<td>30</td>
</tr>
<tr>
<td>&gt;32</td>
<td>&lt;71</td>
<td>34</td>
</tr>
<tr>
<td>&gt;71</td>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

Side condition no. 2

median value, as received, solid, recommended value 32 μm

lower explosion limit, solid, German standard, recommended value 30 g/m³ (1)

(1) Test method: VDI 2263; 1-m³-vessel

You can get the definition of a characteristic by highlighting it with the mouse and pressing the F1-key.
Secondary explosion protection

**Safety characteristics to assess the ignitability of substances**

- Autoignition temperature of gases & vapors
- Minimum ignition temperatures of dusts (clouds, layer, heaps)
- Minimum ignition energy
Autoignition temperature of flammable liquids in function of pressure (autoclave)

Quelle: PTB, CHEMSAFE
Constructive explosion protection

Safety characteristics to assess the severity of an explosion

- Maximum explosion pressure
- Maximum rate of pressure rise \((dp/dt)_{\text{max}}\)
- \(K_G\) value for gases and vapors:
  \[K_G\text{-value} = (dp/dt)_{\text{max}} \times V^{1/3}\]  (cubic law)
- \(K_{st}\) value for dust, Dust explosion class
- Maximum experimental safe gap
Constructive explosion protection

50-liter spherical autoclave designed for pressures up to 1.100 bar in BAM

Investigation of detonation phenomena
Explosion pressure in function of concentration of methane in air

Data from SAFEKINEX EU-Project, TU Delft, NL- CHEMSAFE
$K_G$ values in functions of the test vessel and the hydrogen composition in air

Data from SAFEKINEX EU-Project, CHEMSAFE
Experimental setup (IEC 60079-1-1)

- Inner (1) and outer (2) volume is filled with the same flammable mixture.
- Concentration of the flammable mixture is varied.
- Width of the gap (3) is varied by turning the screw (6).
- Ignition occurs in the centre of the inner volume; Power of the ignition source (5) is about 10 J.
- Criterion: flame transmission through the gap observed through window (4).

maximum experimental safe gap (MESG)
Determination and estimation of MESG of mixtures

- Only a few MESG of mixtures are experimentally determined
- MESG determination is time consuming
- Using the lowest MESG of the mixture components rises often technical problems
- Based on some 150 measurements of different mixtures an estimation method was developed
Mixture of methane and dioxane

MESG - measured and estimated

Lines mean linear interpolations at 40 °C and 120 °C

- measured at 120 °C
- estimated
- measured at 40 °C
- estimated

Relative molar amount CH₄

Mixture of methane and dioxane
Minimum ignition energy ⇔ maximum experimental safe gap

<table>
<thead>
<tr>
<th>Substance</th>
<th>MIE in mJ</th>
<th>MESG in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.017</td>
<td>0.29</td>
</tr>
<tr>
<td>Acetylene</td>
<td>0.019</td>
<td>0.37</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>0.19</td>
<td>0.87</td>
</tr>
<tr>
<td>Propane</td>
<td>0.24</td>
<td>0.92</td>
</tr>
<tr>
<td>Methane</td>
<td>0.29</td>
<td>1.14</td>
</tr>
<tr>
<td>Ammonia</td>
<td>14</td>
<td>3.18</td>
</tr>
</tbody>
</table>
Summary

- Safety characteristics of hazardous substances needed under process conditions
- Chemically unstable gases represent further difficulties by explosion protection
- Dust explosion data are needed with particle size distribution
- CHEMSAFE contains this information and data evaluation is given by experts
Acknowledgement

The author would like to thank Dr. M. Sam Mannan, Director of the Mary O’Connor Process Safety Center for the financial support of this presentation and BAM for the presentation materials.
Thank you for attention!
Limiting values of flammable mixture

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>LEL</td>
<td>lower explosion limits (mol%)</td>
</tr>
<tr>
<td>UEL</td>
<td>upper explosion limits (mol%)</td>
</tr>
<tr>
<td>MAI</td>
<td>minimum required amount of inert gas in inert gas-oxidizer mixtures (mol%)</td>
</tr>
<tr>
<td>MXC</td>
<td>maximum permissible amount of flammable gas in inert gas-flammable gas mixture in mol% (if nitrogen then Tci)</td>
</tr>
<tr>
<td>MOC</td>
<td>maximum (permissible) oxidizing gas content in mol% (if air then LOC)</td>
</tr>
<tr>
<td>SCO</td>
<td>stoichiometric concentration for the oxidizing reaction (mol%)</td>
</tr>
<tr>
<td>ICR</td>
<td>minimum inert gas-combustible ratio (-)</td>
</tr>
<tr>
<td>IAR</td>
<td>minimum inert gas/oxidizer (air) ratio (-)</td>
</tr>
</tbody>
</table>