



Krieg & Fischer Ingenieure GmbH

Plant Safety

沼气厂安全

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DQY Biogas plant, Beijing, May 12, 2011



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K&F工程有限公司

Engineering Office, specialized in Design and Engineering of Biogas Plants 专业沼气工程的设计和施工

Foundation 成立于: 1999

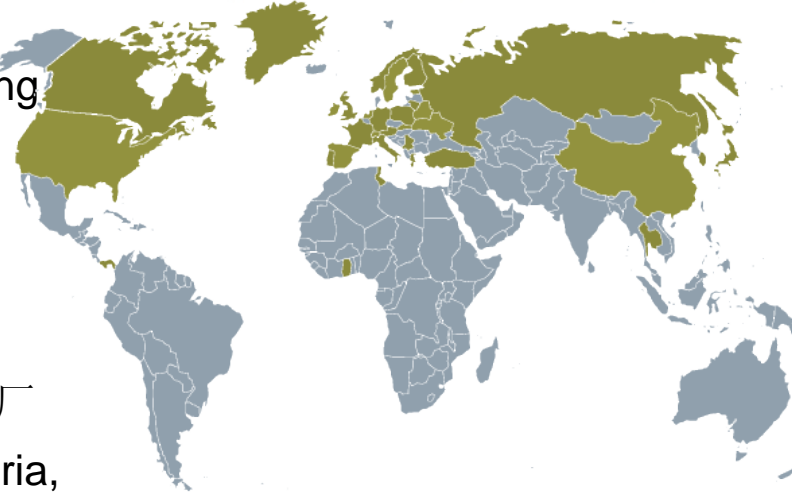
Team 共有员工: 30

Experience 经验: > 25 Years

References 曾设计: ca. 150 Biogas Plants 150多个沼气厂

In 主要在: Germany, Japan, Netherlands, Austria, Switzerland, Lithuania, Italy, Slovakia, Canada, USA, Spain, France, Ireland and Russia

德国, 日本, 荷兰, 澳大利亚, 瑞士, 立陶宛, 意大利, 斯洛伐克, 加拿大, 美国, 西班牙, 法国和爱尔兰



Service offerings of Krieg & Fischer in the field of Biogas

沼气领域内K&F提供的服务

- Studies 调研
- Concept Development 创新发展
- Calculations 核算
- Permits & Approvals 许可和审批
- Engineering 工程
- Tendering and Commissioning 投标和试运行
- Supervision of Construction 建设施工
- Start-up 启动
- Optimization/Retrofits 优化设计
- Supervision and Consulting 监理和咨询
- **Risk assessment**
- **Explosion protection documents**

Plant safety

- It must be possible to operate the BGP under safe conditions for humans and environment
- There will be always a remaining risk, laws are different all over the world. But:
 - task of the **designer** is to reduce the risk to a minimum
 - task of the **operator** is to operate the plant according the manuals and instructions, maintenance, regular tests (leakage test, etc.)
 - task of the plant **owner and/or designer should be**: risk assessment, ex-protection document, manuals, teaching of operators

Determination of possible danger

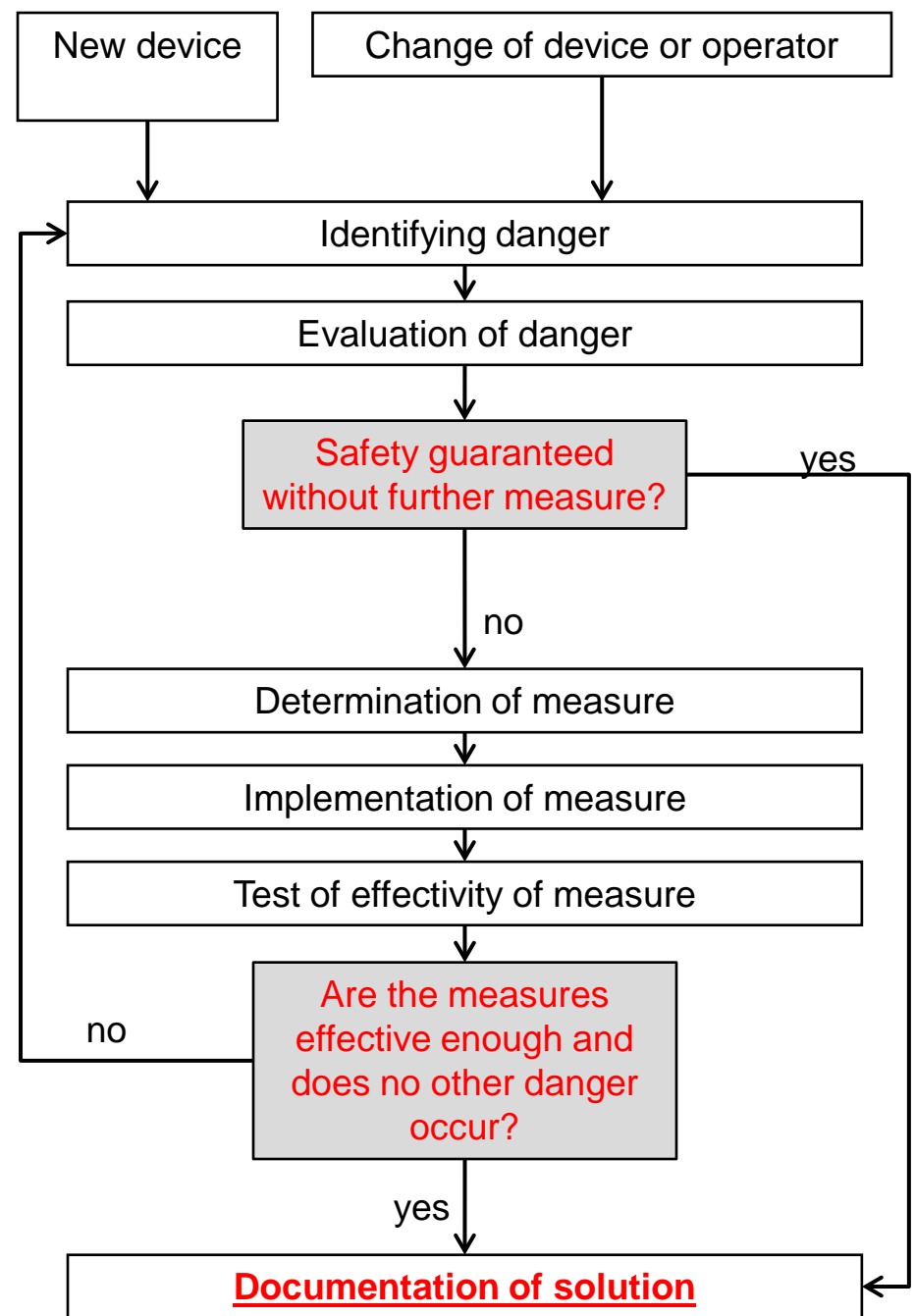
Possible danger/risk:

- Mechanical danger (moving parts of machines...)
- Danger of fall from height: Persons, loads or material
- Electrical danger
- Danger caused by steam and pressure
- Danger of fire or explosion
- Danger of poisoning
- Thermal danger
- Danger caused by physical impact (noise, vibration shock)

The feasibility of safety measures have to be checked in following sequence:

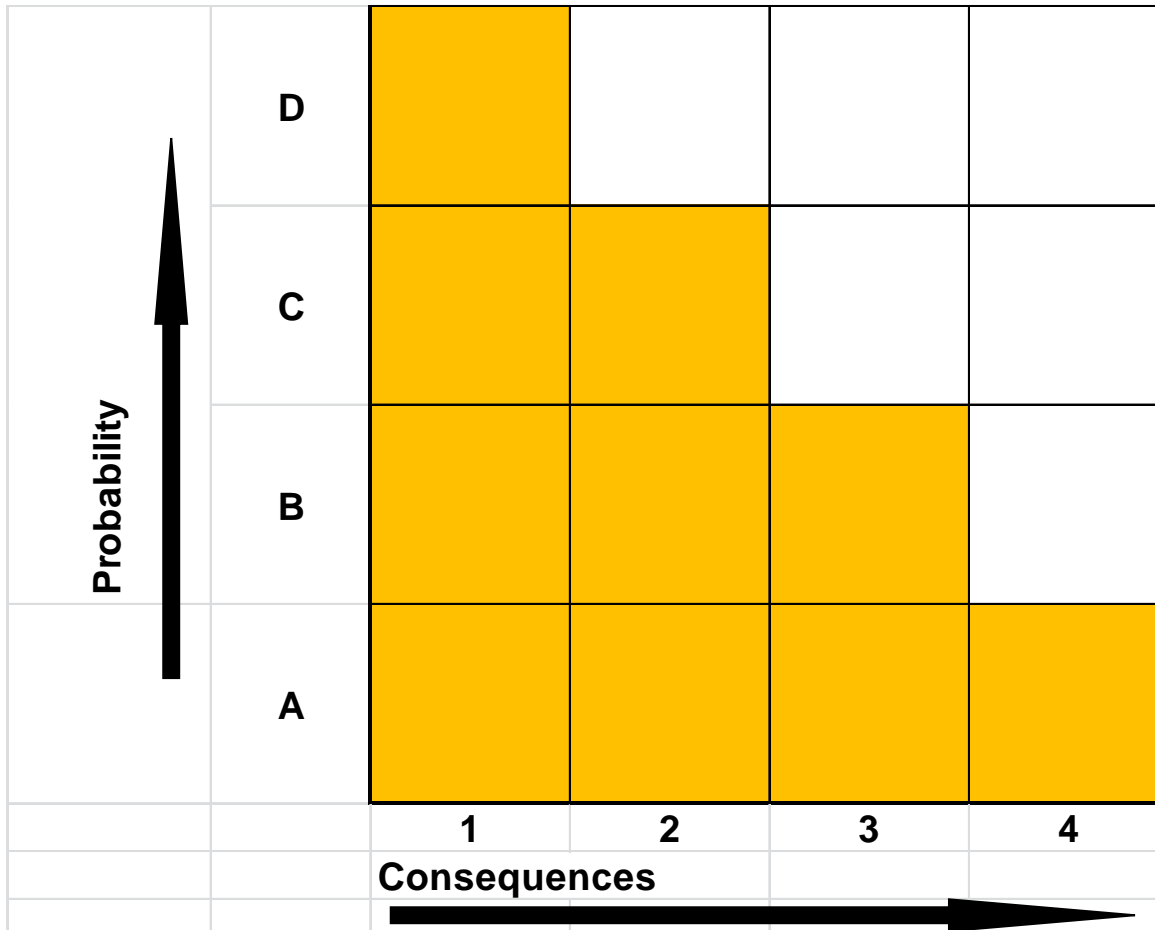
1. Avoidance of danger
2. Residual dangers have to be reduced
3. Protection against danger by technical measures
4. Persons have to be kept away from danger areas
5. Instruction and briefing
6. Protection against danger by personal protective equipment

Evaluation of determined danger



= risk assessment document →

Risk assessment



| | |
|---|----------|
| A | unlikely |
| B | seldom |
| C | casual |
| D | often |

| | |
|--------------------|--------------|
| 1 | marginal |
| 2 | low |
| 3 | critical |
| 4 | catastrophic |
| tolerable risk | |
| not tolerable risk | |

Danger (1) Biogas leakage

- Danger: Biogas leakage
- Probability: seldom - unlikely
- Consequence: low till catastrophic (toxication, explosion)
- Location: gaspipes, gasholder roof, CHP building,....
- Technique: high quality materials,, measurements (CH_4 , H_2S), ventilation
- Organization: regular leakage tests, education and training

Characteristics of biogas

- Methane CH₄ 甲烷: 45-70 %
- Carbondioxide CO₂: 25-55 %
- Hydrosulphide H₂S: 10-30,000 ppmv
- Water vapour 水蒸气: 100 %
- Heating value 4.5-7 kWh/m³

- Ignition temperature: 537° C (methane 595° - 650° C)
- Explosion range: ca. (4.4) 5 – 15 (16.5) Vol%
- Density 0.96 – 1.46 kg/m³
- Ignition energy (methane) 0.28 mJ

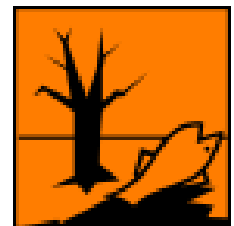
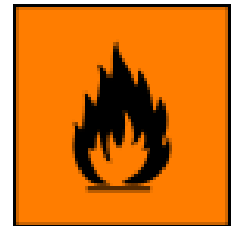
Health risk of H₂S

H₂S 的危险性



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- **10–20 ppm** is the borderline concentration for eye irritation.
10–20 ppm 是刺激眼睛的界限浓度
- At **100–150 ppm** the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger.
100–150 ppm 条件下吸入一些后嗅觉神经受阻，并且味觉消失，同时存在意识丧失的危险
- **320–530 ppm** leads to pulmonary edema with the possibility of death.
320–530 ppm 导致肺部浮肿，并可能致死
- **800 ppm** is the lethal concentration for 50% of humans for 5 minutes exposure (LC50). **800 ppm**条件下暴露5分钟，50%的人有生命危险
- Concentrations over **1000 ppm** cause immediate collapse with loss of breathing, even after inhalation of a single breath.
1000 ppm以上会导致马上昏厥，停止呼吸，即便是只吸入一口



Mixing tank: Severe Accident



Mixing tank

Mixing tank was filled with a rest of dairy products and slaughterhouse waste
→ low pH



Mixing tank

Delivery of gut content (60° C), high content of sulfides
→ high pH (pH 8.5)



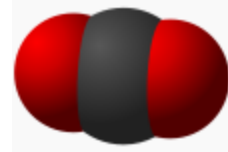
Mixing tank



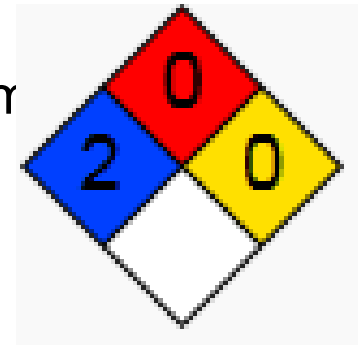
Toxic gas (H_2S) in toxic concentration developed immediately

Health risk of CO₂

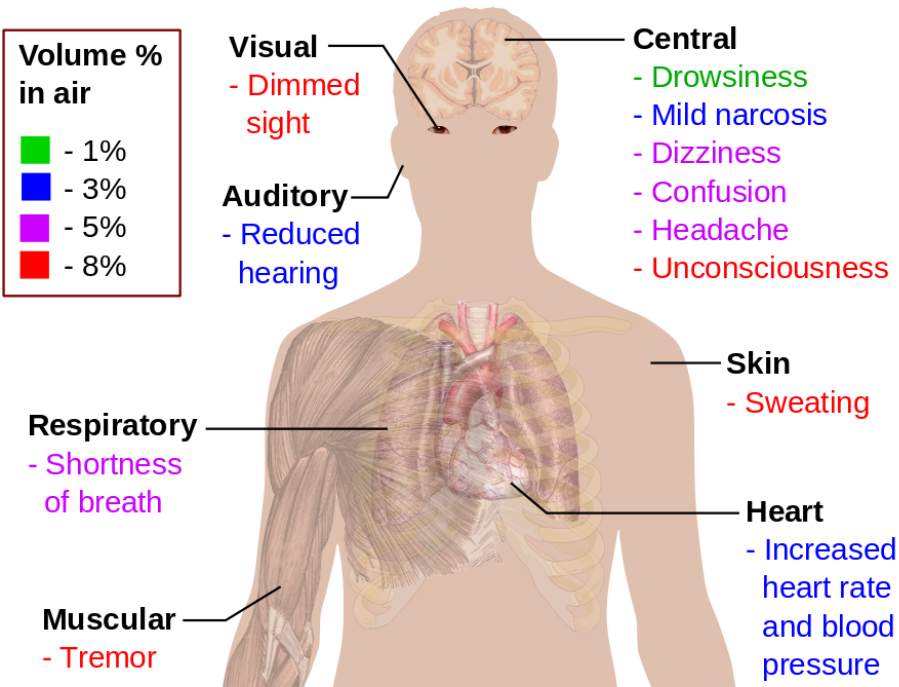
CO₂ 的危險性



- Carbon dioxide extinguishes flames
- Danger of suffocation: displacement of air in cellar room inspection pits

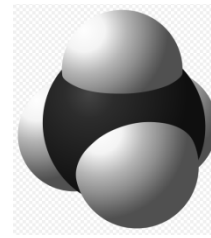


Main symptoms of Carbon dioxide toxicity

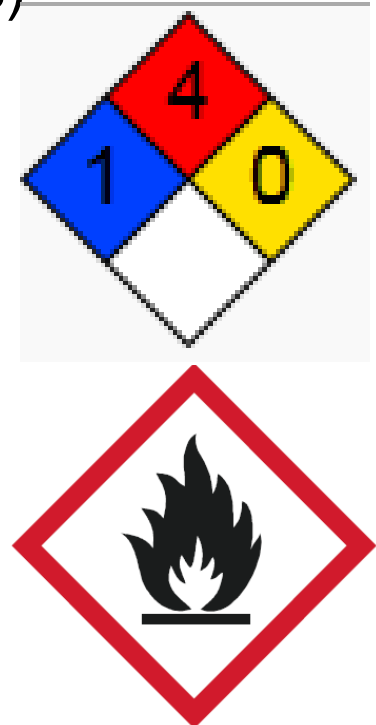


Source: Freiwillige Feuerwehr Hatzendorf

Health risk of methane CH₄

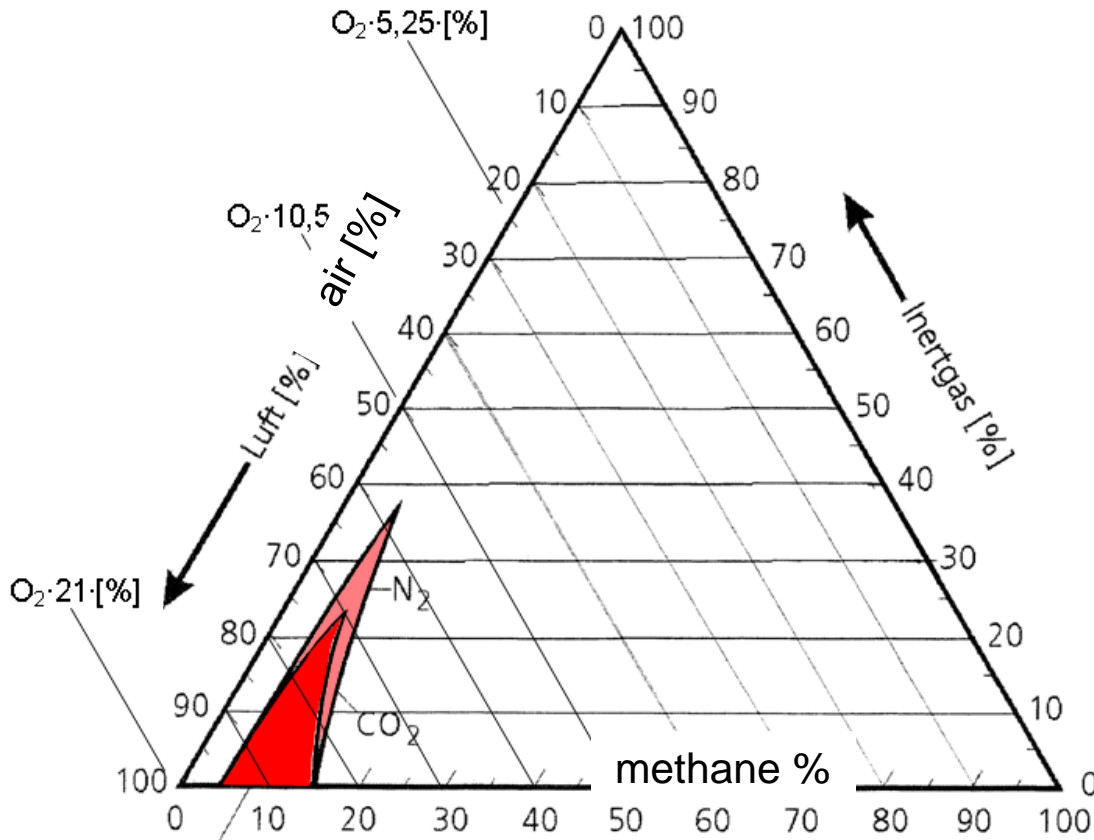


- Not toxic
- Extremely flammable
- Danger of ignition and fire or explosion (explosive mixtures with air between 5–15%)
- Greenhouse gas



Safety

Lower and Upper Explosive Limit



Explosion area:

Exceeding of 11,6 Vol% oxygen
and

between 4.4 Vol% methane (100% LEL) and
16.5 Vol% methane (100% UEL)

source: after Tabarasan /
Rettenberger – UBA
Forschungsbericht 12/1982, Nr.
1030227 Teil 1

Safety 安全

Lower and Upper Explosive Limit

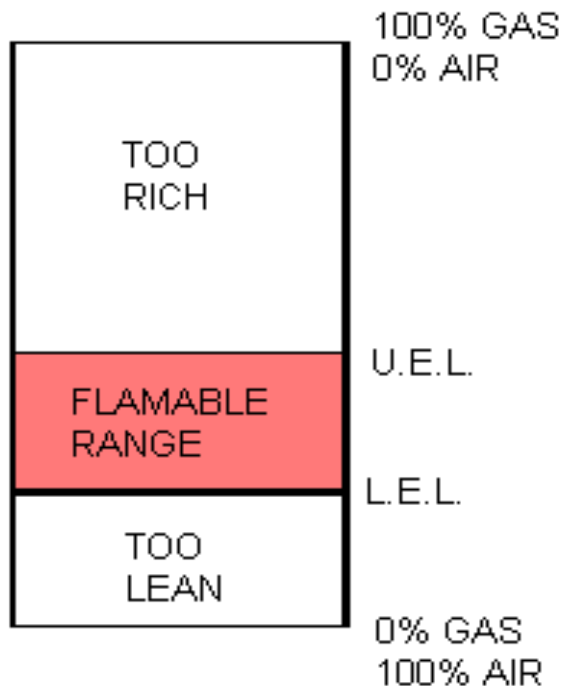
最低和最高爆炸极限



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Explosive limits give the proportion of combustible gases in a mixture, between which limits this mixture is flammable.

爆炸极限指明了可燃混合气体中可爆炸气体的浓度范围



UEL - Upper explosive limit 最高爆炸极限
15 -17 Vol% CH₄

LEL - Lower explosive limit 最低爆炸极限
4,4 – 5 Vol% CH₄

Biogas – dangerous contents

Primary explosion protection:

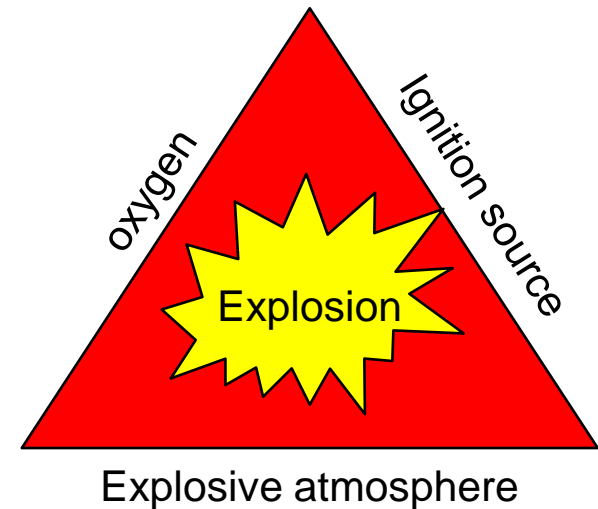
Avoidance of development of explosive atmospheres

Secondary explosion protection:

Avoidance of ignition sources

Tertiary explosion protection:

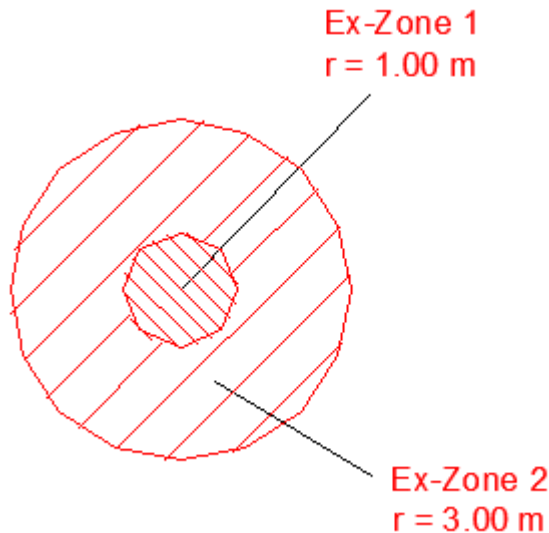
Reduction of consequences of an explosion



Definition Ex-zones

确定防爆区

A place in which an explosive atmosphere
某位置其中爆炸性混合气体



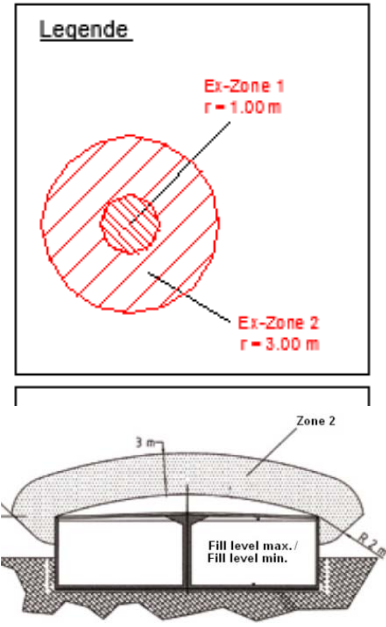
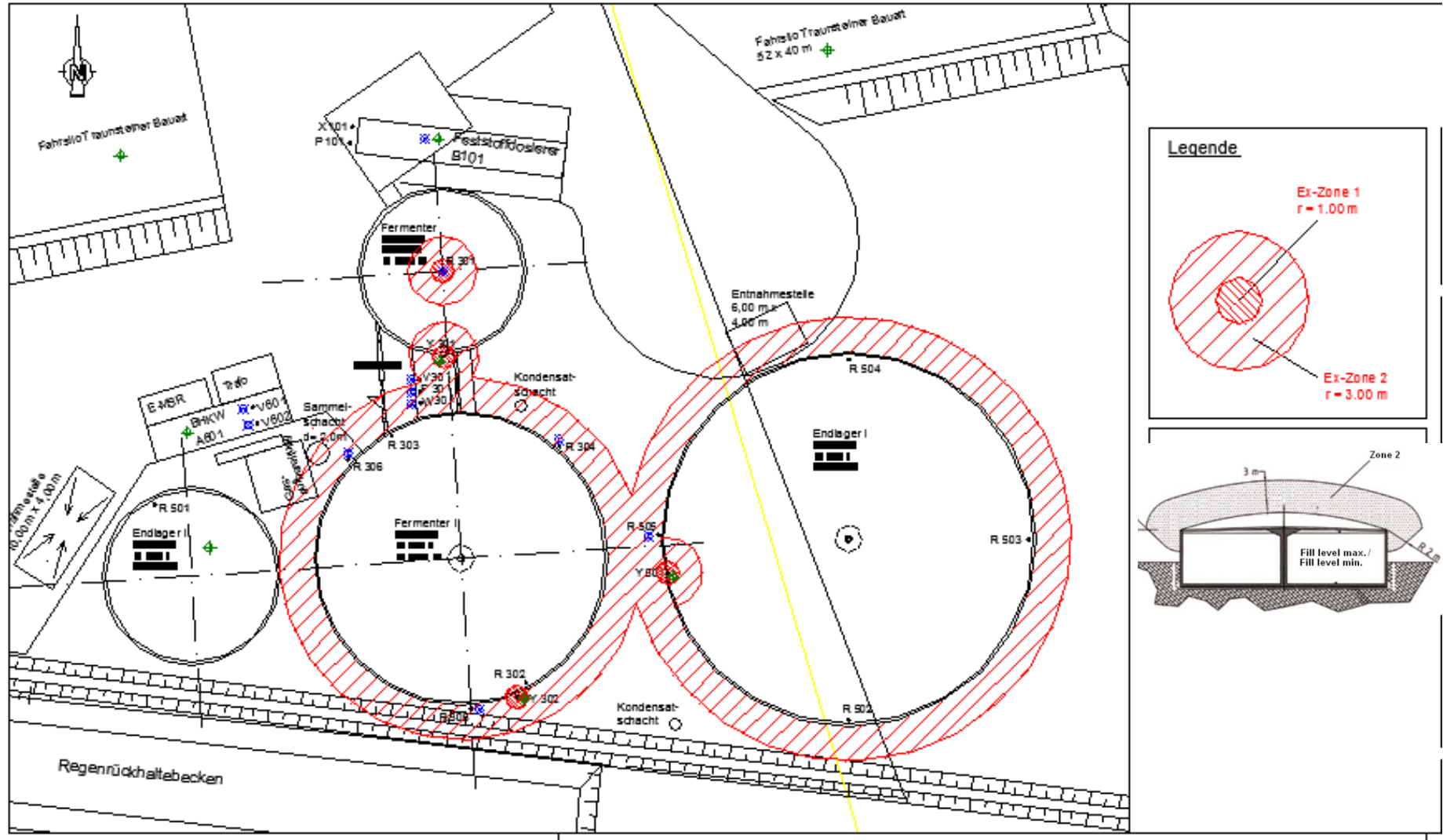
- is present continuously or for long periods or frequently (Zone 0)
长期或者频繁连续存在 (0区)
- likely to occur in normal operation occasionally (Zone 1)
在正常运行时有时可能出现 (1区)
- is not likely to occur in normal operation, but if it does occur, will persist for a short period only (Zone 2)
正常运行是不太可能出现，但一旦出现，会持续较短的一段时间 (2区)

Safety, Explosion zones

安全, 防爆区



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Ignition sources

- Hot surfaces (for example turbo charger)
- Open fire and hot gas (flame of flare)
- Electrical devices (switching operation, defective contact, stray electric current)
- Stray electric current (potential equalization)
- Electrostatic charging (of cloth or persons)
- Mechanical produced sparks (rubbing, hammering, cutting)
- Ultrasound
- Electromagnetic fields
- Lightning
- Electromagnetic radiation (focusing, strong laser radiation)
- Adiabatic Compression (air compressor)
- Ionizing radiation
- Exothermic reaction, self ignition of dust

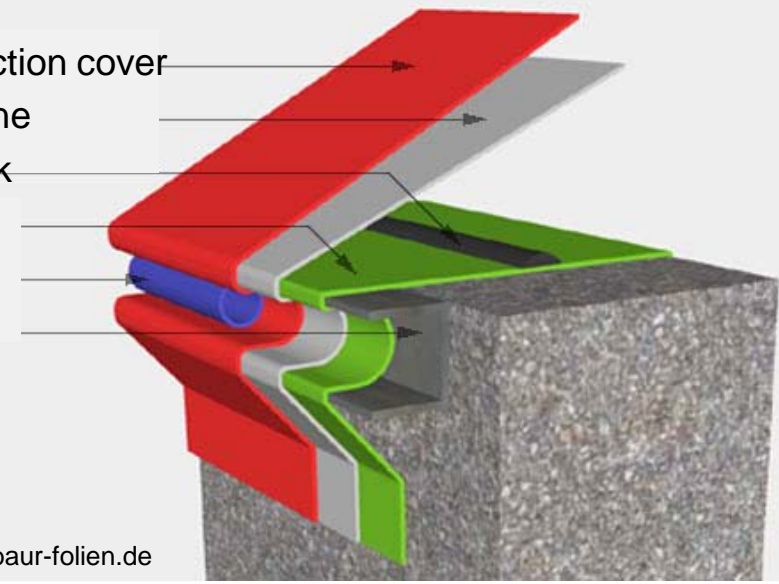
Gas pipes, pressure valves



Gasholder roof



- Water protection cover
- Gas membrane
- Terminal block
- Protection foil
- Jam tube
- U-profile

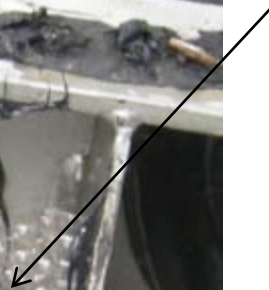


Source: www.baur-folien.de

Leakage test with bubbles



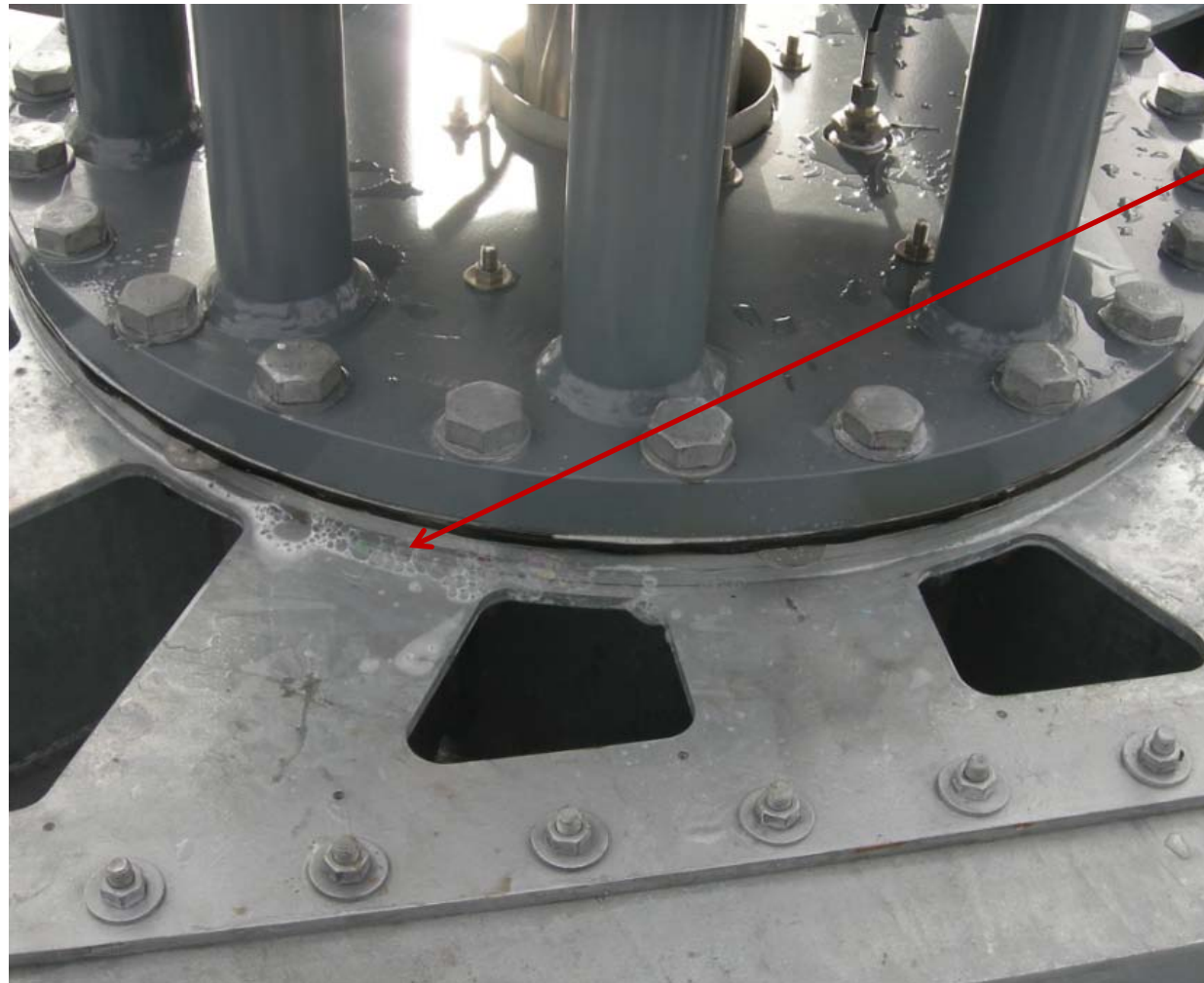
bubbles



sealed



Leakage test with bubbles



Leakage test of a flange with bubbles

Safety in CHP-room

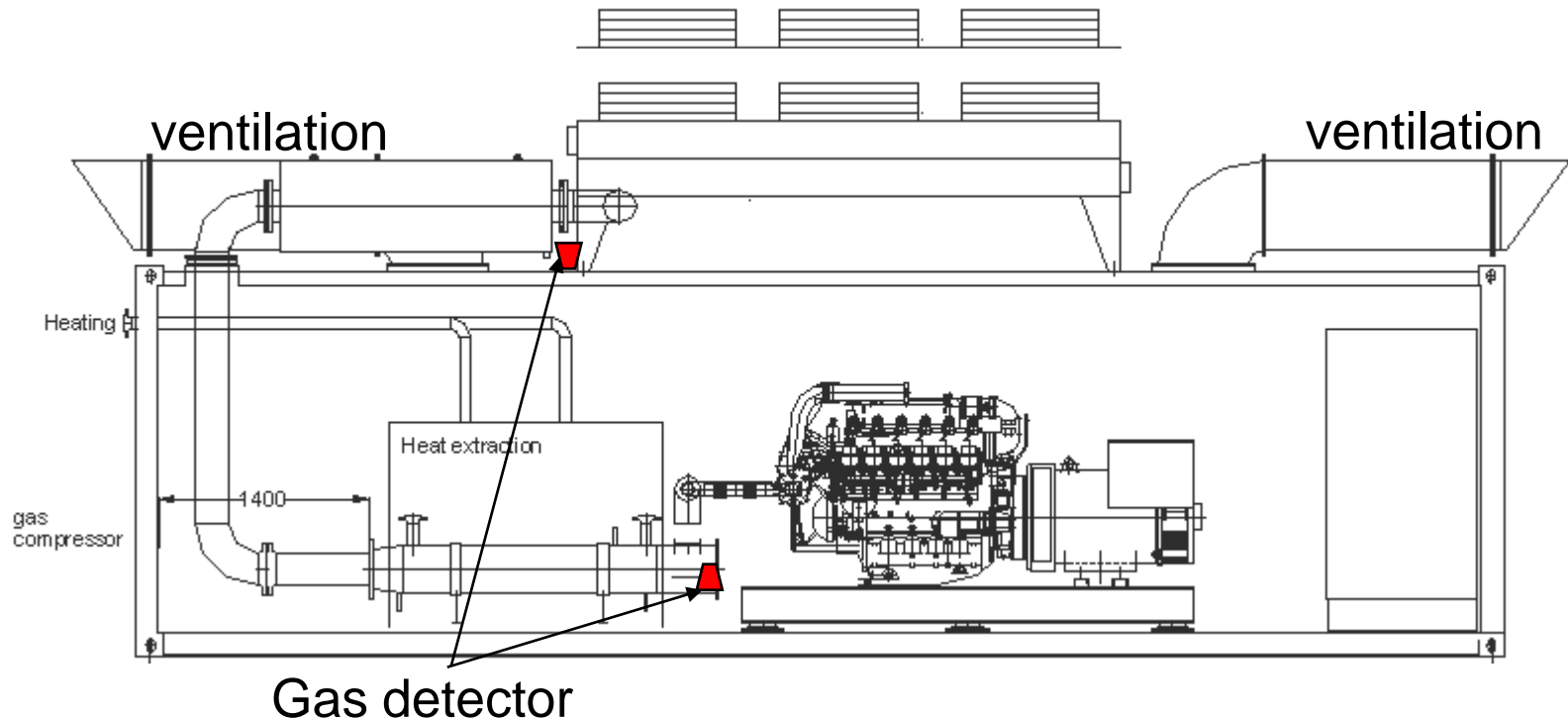
In rooms with gas pipes special safety precautions have to be made:

- 1) avoidance of gas
 - good quality pipes (stainless steel)
 - high frequency of leakage control
- 2) Forced ventilation
- 3) Gas detector: In case of gas leakage automatic ventilation, alarm outside (flash signal, signal horn)

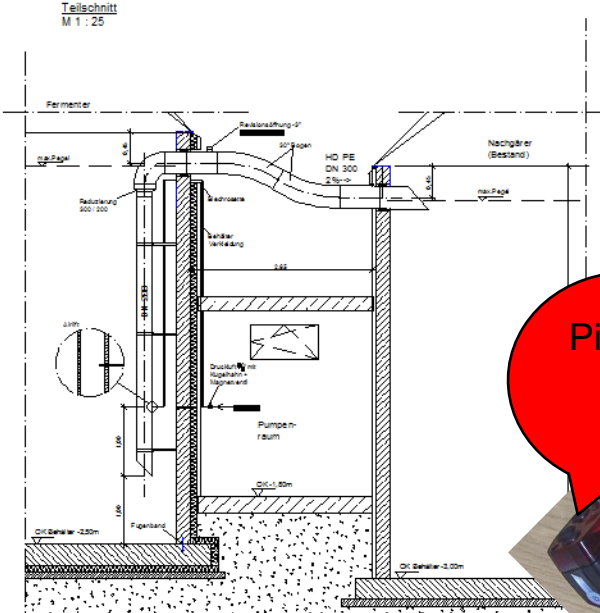
CHP room (or any room with gas connection)

Gas detector

- Full power ventilation at 10% LEL
- switch off gas automatically
- Acoustic and optic alarm



Tank cleaning



Work inside underground tanks



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Source Sewerin

Danger (2) Fall from height

- Danger: Fall from heights
- Probability: often - seldom
- Consequence: low till catastrophic (different impact to the body)
- Location: mixers, CHP container, tanks, ladders, platforms; viewing glasses
- Technique: good equipment (stairs instead of ladders etc.)
- Organization: check points preferably at ground level, training



Fall from height

Ascent high tanks

Are there devices on top of the tank that have to be checked daily?

What has to be transported? Tools?

How is the physical condition of the operator?





Fall from height

Assembly and maintenance gas holder roof

Above a certain height a solid platform is necessary / advisable

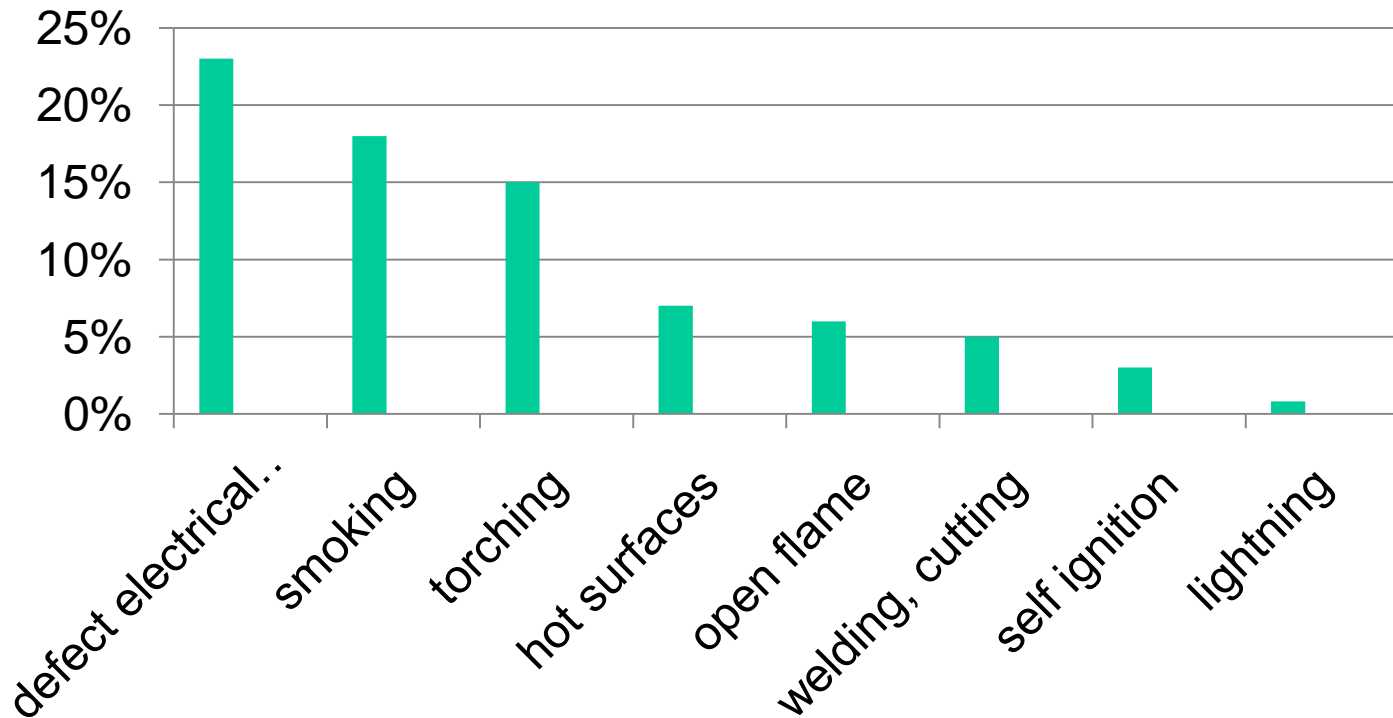


Danger (3) Fire

- Danger: Fire
- Probability: seldom
- Consequence: low till catastrophic
- Location: switchboards, gasholder roof
- Technique: avoidance of ignition sources, priority to not burnable materials
- Organization: control electricity, fire drill, positioning of extinguisher

Danger caused by fire

Reasons of fire



Source: DAS – IB GmbH, Biogas- und Deponiegashandbuch, 2011

Danger caused by fire

Fire test of a single membrane gas holder roof



The membrane is burned through and biogas is set free and is burning.

Source: German Biogas Association,
M001: Brandschutz bei Biogasanlagen,
Aug 2010

Organization, Operator

- Good instruction in the operation of the plant
- Regular education
- Regular training
- Risk assessment, explosion protection document



Hazard symbols



Explosive air

Electrical
danger

Flammable



Falling hazard

Hand pinching

Explosive

Sign giving orders



Use eye protection



Use safety gloves

Use ear protection

Disconnect electrically before starting work

No symbols



No mobile
phone



Keep out



No naked flame,
no naked light,
no smoking



No smoking

Safety rules 安全守则

Safety Rules for Biogas Systems



German Agricultural Occupational Health and Safety Agency

This is a translation from the original German version entitled "Technische Information 4 Sicherheitsregeln für Biogasanlagen". Every effort has been made to make it as accurate as possible, but the original German version should be the authoritative source.

German Agricultural Occupational Health and Safety Agency

- The safety rules for biogas systems explain the requirements for the construction and operation of biogas systems
沼气系统安全守则解释了系统建设和运行的要求
- The safety rules are the summary of the most important German regulations
安全守则总结了最重要的德国相关法规

Conclusions

State of the art technique is necessary!
Operators must be educated!

Local laws are different all over the world.

Safety NOT !



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Plant Safety II (P)

沼气厂安全II

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