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.

Preface from Germany

The safety rules for biogas systems explain and substantiate the requirements for the construction and operation of biogas systems in terms of the operating instructions of § 1 of the accident prevention regulations “Arbeits-stätten, bauliche Anlagen und Einrichtungen” [“Workplaces, Buildings, and Facilities”] (VSG 2.1) [(Regulations for Safety and Health 2.1)]. (German regulation)

These rules intend to provide information to the planning office, the specialty company contracted for the construction, the operator and the employer regarding the construction and operation of agricultural biogas systems that are operated with operating pressures of less than 0.1 bar.

The safety rules are the summary of the most important German regulations; they also provide information about rules to be followed. In addition, generally recognized engineering rules apply. For examples, see Appendix 11. Deviations are possible, if safety is guaranteed in the deviation.

The German safety rules for biogas systems were recommended for implementation on September 30, 2008, by the Advisory Board for Health and Safety.

Table of Contents

Appendices

1. General Information

1.1 Terminology

Biogas system:
System for generating, storing, and utilizing biogas, including all equipment and buildings serving the operation. The generation results from the digestion of organic substances.

Substrate:
Organic substances to be digested.

Digester (reactor, fermenter, digester):
Container in which the microbial breakdown of the substrate occurs.

Gas storage:
Gas tight container or membrane bag in which the biogas is temporarily stored.

Liquid manure storage:
Containers and pits in the ground in which liquid manure, slurry, and the fermented substrate is stored.

Machine room:
Room containing the gas cleaning, gas conveying, or gas utilization equipment including the process control equipment.

CHP unit:
Combined heat and power plant that serves for generating power and heat.

Potentially explosive areas, hazardous EX areas:
Areas in which a dangerous, potentially explosive, atmosphere can occur due to local and operating circumstances.

Zones:
Potentially explosive areas are classified into zones according to the probability of the occurrence of a potentially explosive atmosphere.

Safety distances:
Areas around gas storage that protect the gas storage and its equipment.

Gas processing:
Equipment for cleaning and moisture removal of biogas.

1. General Information

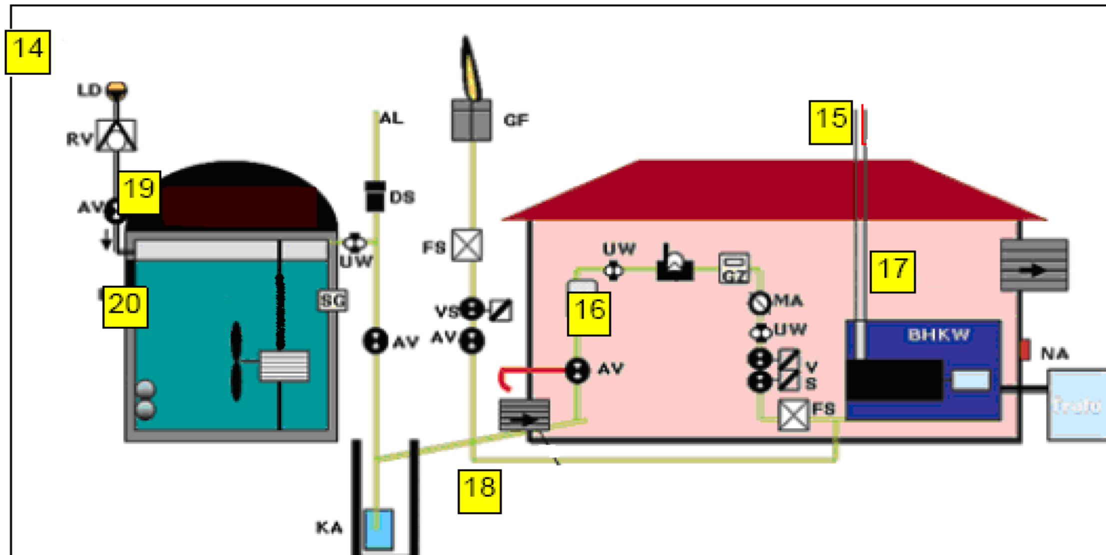
Gas dome:
Top of the digester container in which the biogas is collected and removed.

Gas storage:
Room or area in which the gas storage is housed.

Explosive limits:
If the concentration of biogas in the air exceeds a minimum value (lower explosive limit LEL), an explosion is possible. An explosion is no longer possible when the concentration has exceeded a maximum value (upper explosion limit UEL).

Explosion range:
Concentration in which combustible gases, mists, or vapours when mixed with air or another gas (supporting the combustion), can ignite. This range lies between the explosion limits.

1.2 Gas diagram of a Biogas



14. Air injection (Desulphurization using a pump)
15. Exhaust gas
16. Compressor
17. Air discharge opening
18. Air supply opening
19. Gas storage
20. Digester (fermenter)

Necessary Components

AV	Shutoff valve
AL	Exhaust line
CHP	Combined heating and power unit
DS	Over/under-pressure protection
EÖ	Manhole
FS	Flashback arrester
KA	Condensate separator
NA	Emergency off switch
VS	Closing valve, self-actuated
UW	Low-pressure monitor

Optional Components

FF	Gas micro-filter
GF	Gas flare
GZ	Gas meter
LD	Air dosing pump
MA	Manometer
RV	Non-return valve
SG	Sight glass

1. General Information

1.3 Properties of Biogas

Biogas consists essentially of methane (50 to 80% vol.), carbon dioxide (20 to 50% vol.), hydrogen sulphide (0.01 to 0.4% vol.), and traces of ammonia, hydrogen, nitrogen, and carbon monoxide. The occurrence of particulate matter has to be factored in.

Example: Methane 60% vol., carbon dioxide 38% vol., residual gas 2% vol.

	Biogas	**Natural Gas**	**Propane**	**Methane**	**Hydrogen**
Heating value (kWh/m³)	6	10	26	10	3
Density (kg/m³)	1.2	0.7	2.01	0.72	0.09
Density ratio to air	0.9	0.54	1.51	0.55	0.07
Ignition temperature (°C)	700	650	470	595	585
Maximum flame propagation speed in air (m/s)	0.25	0.39	0.42	0.47	0.43
Explosion range (% vol.)	6-12	4.4 – 15	1.7 – 10.9	4.4 – 16.5	4 – 77
Theoretical air requirement (m³/m³)	5.7	9.5	23.9	9.5	2.4

1.4 Hazard Assessment

The basis for the development of a hazard assessment is to protect and to reduce the exposure to risk and hazards of employees. The employer must determine, evaluate, and minimize the hazards and must consider the acquired knowledge during design and selection of work tools, as well as the design of workplaces, work and production processes, work procedures, and interactions of all of the above . The hazard assessment must be continuously updated according to the current state of knowledge and new operating conditions.

1. General Information

The Labour Protection Law (ArbSchG of Germany) is the legal foundation for performing a hazard assessment.

Supplementary requirements are found in the corresponding ordinances, such as the Ordinance on Industrial Safety, Ordinance on Bio-substances, or the Ordinance on Hazardous Substances.

An obligation to document exists if there are more than ten employees. For activities with hazardous materials and bio-substances and in potentially explosive areas, the obligation to document applies regardless of the number of employees (Register of Hazardous Substances, Explosion Protection Document, etc.).

As a matter of principle, in determining protective measures, technical protective measures are to be preferred, for example, the filling of closed systems compared to organizational protective measures, such as, the time separation between human presence and filling procedures. Personal safety measures, such as wearing respiratory equipment, come into use only when other protective measures have been exhausted.

A hazard assessment must also be performed for maintenance and repair work, as well as when malfunctions are fixed.

The following information must be considered within the scope of the hazards assessment:

The Ordinance on Industrial Health and Safety (BetrSichV, Germany) regulates the provision and terms of work, equipment by the employer, the use of work equipment by the employees during work, and the operation of the systems requiring monitoring.

Work equipment here includes all equipment that is used and serviced by employees, e.g., agitators, pumps, emergency flares, solids feeding equipment, gas condenser, combined heat and power units, etc.

1.4.1 Hazards Due to Work Equipment and Systems Requiring Monitoring in Potentially Explosive Areas

The Ordinance on Industrial Health and Safety regarding systems requiring monitoring applies also to operations without employees, if there is a need for monitoring. This rule applies to biogas systems, due to the danger of biogas explosion. Systems in potentially explosive areas require monitoring, if they are, or contain, equipment, protection systems, or safety or control equipment according to Article 1 of the EU Directive 94/9/EU (ATEX).

Examples

Equipment: machines, resources with potential ignition sources (e.g., agitator), that can cause an explosion

Protection systems: flashback arresters, pressure release valves

Components: triggering devices for protection systems, for example, gas detectors

Section 3 of the BetrSichV (Ordinance on Industrial Health and Safety) applies to all biogas systems, independent of the occupation or employment activity of the workers. Consequently, all biogas systems are subject to inspection obligations according to §§ 14 and 15 of the BetrSichV, regardless of the employment activity or occupation of the workers.

§ 12, Section 1, of the BetrSichV states that systems that require monitoring must be assembled, installed, and operated according to current state of the art technology. The current state of the art technology also includes the requirements of Section 2 of the BetrSichV for the operation.

This implies, in principle, that an Explosion Protection Document is required according to § 6 BetrSichV.

The operator bears the responsibility to ensure that changes to the system are also updated in the documentation, such as, the circuit diagrams, the operating instructions, the Explosion Protection Document, etc.

The requirements of Appendix 4, Section A, in particular, No. 3.8, also apply to all biogas systems. Appendix 4, Section B, applies only to biogas systems that became operational after the BetrSichV came into effect. Here, the adjustments after a change/essential modification of a biogas system must be followed.

Hazardous substances according to the Ordinance on Hazardous Substances are substances that have hazardous properties. Hazardous properties are, for example, "harmful to health," "poisonous," "highly poisonous," or "caustic." Hazardous substances can be solid, in dust form, liquid, or can occur as an aerosol or as a gas.

Examples

1. Hydrogen sulphide (H_2S)
2. Carbon dioxide (CO_2)

Typical hazards

- Danger of asphyxiation and/or poisoning due to fermentation in gas/ biogas intake areas. Release of highly poisonous gases such as hydrogen sulphide.
- Hazards that occur particularly in systems that use additional substrates (waste, animal byproducts) along with renewable raw materials, liquid and solid manure:
  - increased release of hazardous gases such as hydrogen sulphide, especially during mixing due to the reaction of the substances being used.
- Hazards during exchange of the activated carbon filter for gas cleaning.

1.4.2 Hazardous Substances

Assessment and protective measures:
In principle, the development of hazardous gases must be prevented or minimized, to the greatest degree possible, or their release must be prevented or reduced.

When using a chemical substance distributed by a supplier, the operator can use the material data safety sheet (MSDS) to assist the development of a hazard assessment. The MSDS is generally provided by the supplier of the chemical products.

Before accepting delivered substances to be used, rapid tests should be performed, which can check important chemical properties – see information sheets for safety with biogas systems (List of Literature – Appendix 11).

If mixing of different materials is required for operational reasons, no materials should be combined from which the generation of hazardous gas concentrations due to reactions (e.g., acid-base reactions, large differences in temperature) could result. In particular, hydrogen sulphide can be released due to the addition of acidic components; ammonia can be released due to the addition of alkaline components.

In order to be able to assess such reactions, operators of biogas systems must request the following information from the producers of the additional substrates and document in the daily operations log:

Information About Substances Being Used

- Waste code number, essential ingredients or substances, chemical structure, pH value and additives, e.g., stabilizers, preservative agents, etc.,
- Origin information (e.g., from slaughterhouse, from the pharmaceutical production of Heparin ….),
- Transport and delivery conditions (e.g., duration of transport, temperature …), and
- Possible hazards (e.g., "can release hydrogen sulphide with the addition of acidic substances").

If the generation of hazardous gases, especially H_2S, cannot be excluded, their release must be prevented or reduced, e.g., by closed filling, spatial separation or their forced discharge.

Specific requirements for avoiding gas hazards can be found, for example, in Section 2.2.6 of the safety rules.

Notes

Hydrogen sulphide is a highly poisonous, colorless gas that smells like rotten eggs. It can be life threatening even at low concentrations. From a certain concentration, the sense of smell is disabled and the gas is not perceived. Substances with high sulphur content are, for example:

- slaughterhouse waste
- biomass waste (mycelia) from biotechnical processes
- rape-seed cake
- feedstuff residuals (e.g., soy protein)
- food leftovers
- methionine from the animal feed (feedstuff additive)
- residue from the generation of yeast
- preservative agent sodium bisulfite
- additives, e.g., iron sulphate

1.4.3 Biological Agents

In the Ordinance on Bio-substances, “biological agents” are defined as microorganisms that can cause infections or have sensitizing or toxic effects in humans. These are primarily molds, viruses, and bacteria.

<u>Typical Hazards</u>

- inhaling dusts or aerosols containing molds, bacteria, or endotoxins, e.g., from moist silage or dry chicken manure.
- additional hazards in systems using additional substrates (waste, animal byproducts) along with renewable raw materials, liquid and solid manure: biological agents in co-substrate (e.g., pathogens), hand contact during sorting.

Assessment and protective measures

The minimum necessary hygienic measures are described in TRBA 500 [Technical Rules for Biological Agents (Germany)].

Information for the assessment and protective measures can be found, for example, in the TRBA 230 (Agricultural Livestock Husbandry).

Information for assessing hazards and concerning the use of technical and organizational protective measures for systems in which, along with, or instead of, renewable raw materials, substrates such as waste are used, can be found, for example, in the TRBA 214 (Biological Waste Treatment Systems: Protective Measures).

The delivery area for liquid waste for digestion must be constructed in a way that an aerosol buildup is avoided.

In certain concentrations, biogas can be explosive. Potentially explosive atmospheres must be effectively prevented.

If the formation of a potentially explosive atmosphere cannot be prevented, effective ignition sources must be eliminated. This is achieved by eliminating the ignition of the potentially explosive atmosphere.

1. General Information

During the hazard assessment, for example, the following ignition sources must be considered:

1.4.4 Explosion Hazards

Ignition Sources

- Hot surfaces (Example: > 500°C (turbocharger))
- Open flames (Example: Fire, flames, embers)
- Mechanically generated sparks (Example: Rubbing, beating, grinding)
- Electrically generated sparks (Example: Switching operations, loose contacts, equalizing currents)
- Exothermic reactions (Example: Spontaneous ignition of dusts)
- Lightning
- Electrostatic discharges

Explosion hazards must be determined and assessed. In particular, it must be determined where potentially explosive atmospheres can occur. Potentially explosive areas are to be classified into zones according to Appendix 3 BetrSichV.

Potentially explosive areas must be identified at their entrances by appropriate signage with black lettering on a yellow background. For example:

1.4.4.2 Classification of the Zones

Potentially explosive areas are spaces in which a dangerous, potentially explosive atmosphere can occur due to the local situation and the operating conditions.

Potentially explosive areas are classified into zones according to the frequency.

and duration of the occurrence of hazardous, potentially explosive atmospheres (for example, see Appendix 9).

For areas that are subject to explosion hazards due to gases, the following applies:

Zone 0 is an area in which hazardous, potentially explosive atmospheres are present constantly, over long periods, or frequently, as a mixture of air and combustible gases, vapours, or mist.

Note

The term "frequently" is used in the context of "predominant over time". Zone 0 is practically never present with biogas systems during normal operation.

Zone 1 is an area in which during normal operation a hazardous, potentially explosive atmosphere can occasionally form as a mixture of air and combustible gases, vapors, or mists.

Zone 2 is an area in which during normal operation a hazardous, potentially explosive atmosphere as a mixture of air and combustible gases, vapours, or mists does not normally occur, or occurs only briefly.

Explanation

Normal operation according to Appendix 3 of the BetrSichV is defined in TRBS 2152, Section 2, paragraph 2, as a state during which the system is used or operated within its design parameters. It is not considered meaningful to view startup and shutdown of a continuously operating biogas system as normal operation. The startup and shutdown phase of a biogas system is a special operating state that requires separate preventative measures. These operating states should be given special consideration with corresponding operating instructions.

1.4.4.3 Requirements for Equipment in Potentially Explosive Areas

Requirements in Zone 0
In Zone 0, only resources must be used that are approved for Zone 0 and that are appropriately labelled. Basically, only devices and protection systems of the Equipment Group II, Category 1 G, according to Appendix 1 of the Directive 94/9/EU, can be used.

1. General Information

Requirements in Zone 1
In Zone 1, only resources must be used that are approved for Zone 0 or 1 and that are appropriately labeled. Basically, only devices and protection systems of the Equipment Group II, Category 1 G or 2 G, according to Appendix 1 of the Directive 94/9/EU, can be used.

Requirements in Zone 2
In Zone 2, only resources must be used that are approved for Zone 0, 1, or 2 and that are appropriately labelled. Basically, only devices and protection systems of the Equipment Group II, Category 1 G, 2 G, or 3 G, according to Appendix 1 of the Directive 94/9/EU, can be used.

1.5 Operating Instructions, Instruction Manuals, and Training

The manufacturers introduce products into the market with operating instructions. The operating instructions from the component manufacturers must be collected and safely stored. During the transfer of manufacturer documentation for individual components, devices, and machines, ensure that the required operating instructions, including each of the required manufacturer's declarations and, if applicable, the certificates of conformity, are present.

Individual components or devices are, for example:

- CHP components
- complete CHP unit
- Agitators
- Pumps
- ventilating system
- switching systems
- gas control path, or gas train
- flashback arrester
- condenser
- flame detector
- gas sensors
- level monitors
- pressure monitors
- gas condensate system
- under and over-pressure protection, etc.

For the operation of different resources, equipment, etc., the operator has to create an instruction manual which includes content such as the operating instructions, as well as information about hazards that result from the installation conditions.

1. General Information

In addition, special operating states such as startup and shutdown of the system can be addressed using the instruction manual (see Appendix 1 and 6). The employees must be instructed regularly about safe operation, e.g., using the instruction manual. Additionally, with the use of external companies, for example, during corrective maintenance, servicing, and modifications, the instruction manual can be the basis to give the external company or employee what needs to be done (basis for a work order) and how.

Tip

The presence of visitors to a biogas system must be considered separately. Visitors must be instructed regarding the hazards in addition to what is permissible and prohibited.

2. Parts of the System

2.1 General information

Parts of the biogas system are equipment, constructions, buildings, and rooms that are necessary for the operation and safety of the biogas system.

2.1.1 Stability

Parts that are placed out in the open, above ground must be securely built and protected against damage. They must be installed so that they are easily accessible. Sufficient stability must be guaranteed.

2.1.2 Potential equalization

In order to eliminate the occurrence of potential differences, all electrically conductive system parts must be connected together, as well as to the protective conductor and the ground wire, corresponding to the VDE [German Electrical Engineering Assoc.] specification (Potential Equalization).

2.1.3 Gas conveying parts of the biogas system

Gas conveying parts of the biogas system must be protected against impact and damage caused by chemicals and weather and, in hazardous areas, against mechanical influences and damage (e.g., areas where vehicles are operated, protected from collisions).

2.1.4 Maintenance and work platforms and operating parts

In principle, maintenance and work platforms, as well as operating parts of agitators, pumps, and purging devices, must be placed above ground. If this is not possible, fixed, installed forced ventilation must be available. Sufficient air exchange must be guaranteed before entering (follow the instruction manual and warning signage).

Note

For additional information, see BGR 121 and BGR 126 [BGR – Occupational and Health Safety Rules].

2.1.5 Connection points in gas lines

Connection points in gas lines for non-stationary equipment, such as, mobile gas flares, must be equipped with shutoff valves. The shutoff valve must be built in before the connection of the non-stationary equipment, as viewed in the gas flow diagram. Operation must occur without hazard.

2.1.6 Fire Protection

For information regarding equipping with fire extinguishers, refer to BGR 133 “Equipping Workplaces with Fire Extinguishers.” More extensive fire prevention measures must be coordinated with the responsible regional and specialist fire department offices.

2.2 Digester/Fermenter/Reactor

2.2.1 Thermal insulation

The thermal insulation of the digester container must be at least normal combustibility, e.g., B2 DIN 4102. In the area of 1 m around openings, at which gas escapes during normal operation, the thermal insulation must be made from hard material that is difficult to ignite, e.g., B1 DIN 4102.

Tip: See also, DIN EN 13501.

2.2.2 Manhole openings

Manhole openings must have a clearance width of at least DN 800, or at least the dimensions 600 x 800 mm. If entry into a container is necessary for maintenance and repair work, sufficient ventilation must be possible; the same safety measures are necessary also with entry into inspection chambers.

2.2.3 Agitators

Submersible motor agitators or submersible motor pumps must correspond to the protection type IP 68, and they must be operated only in the submersed condition. This should be specified in the operating instructions.

2.2.4 Safety installations

Digester containers must be provided at all times with effective safety installations that prevent an inadmissible change of the internal pressure. The liquid seals must be designed and installed as safety seals, so that the sealing liquid does not spill out during overpressure or under- pressure and flows back again on its own during the alleviation of the overpressure or under- pressure.

In the digester and post digester containers, it must be guaranteed that the fill levels are not exceeded, e.g., in that the fermented substrate is fed via a frost-free riser pipe (spillover) into the liquid manure storage.

2.2.5 Fill openings/plug screw feeder

Fill openings, e.g., solids dosing feeders, should be secured so other objects do not fall. Measures to prevent other objects from falling in are, e.g.:

- covered fill hoppers with a height > 1.30 m combined with a covering
- fill funnels without a covering with a height of ≥ 1.80 m
- fixed installation of grids with a bar grid of ≤ 20 cm
- self-closing flaps with perpendicular openings
- flushing gutters with which perpendicular openings are covered

If the digester is filled by means of a plug screw feeder, a sufficient submersion must be present considering all operating states in order to prevent a possible gas escape. The submersion must correspond at least five-fold of the triggering pressure of the overpressure protection.

2.2.6 Protection equipment against gas hazards at fill openings

In principle, the formation of hazardous gases must be prevented or minimized to the greatest extent possible, for example, through the preclusion of corresponding chemical reactions, temporally spaced fillings, or similar measures.

If the formation of hazardous gases cannot be excluded, their release must be prevented or reduced, e.g., by appropriate filling technology in closed systems or by a spatial separation from other areas of the system.

Fill openings should be arranged regarding the prevailing wind direction so that gases are led away from the operating area.

In the case of arrangement in a building, it is compulsory to lead fermentation gases away. The equipment for leading fermentation gases away must definitely be turned on during filling.

The satisfactory function of the suctioning equipment must be checked and documented before taking the system into operation for the first time.

With fill funnels, if required, an operating platform must be provided for the safe operation of flushing hoses.

The gas hazard must be indicated in the immediate surroundings of the filling device.

If the occurrence of gases in hazardous concentrations in the fill areas is not excluded, warning of the gas hazard, in particular, due to hydrogen sulphide, must be guaranteed through the use of appropriate gas-warning devices.

2.2.7 Discontinuous digestion (e.g., batch)

No gas hazards must arise during feeding and removal.

2.2.8 Containers with fluctuating fill levels

The operation of containers with strongly fluctuating fill levels, such as post digesters or gas tight final storage, must be considered separately, e.g., with regard to explosion protection, due to the changing fill levels.

2.3 Liquid manure storage

The accident prevention regulations of the Agricultural Occupational Health and Safety Agency apply to the construction, equipment, and operation.

2.4 Gas storage

Gas storage must be constructed, maintained, and operated such that the safety of the system operators, service personnel, and others is guaranteed.

2.4.1 Gas storage (pressure < 0.1 bar)

Gas storage must meet the requirements for being gas tight and resistant to pressure, media, UV, temperature, and weather.

For the selection of materials, especially for plastic membranes, the following requirements must be met:

- tensile strength minimum 500 N/5 cm or
- tensile strength 250 N/5 cm
- gas permeability with respect to methane < 1000 cm^3/m^2 x d x bar
- temperature resistance for the use case (mesophilic, thermophilic digestion process)
- gas storage must be checked for tightness before being in operation (Appendix 13)

2.4.2 Safety installations

An inadmissible change of the interior pressure must be prevented by continuously effective safety installations.

2.4.3 Ventilation and exhausting of gas storage rooms

Installation rooms for the gas storage must have effective ventilation (cross ventilation). Diagonal ventilation should be attempted. The supply air opening should be placed in the area of the floor, and the exhaust air opening should be placed below the ceiling.

The supply air and exhaust air opening must each have the following minimum cross sections:

Gas Storage Volume	Cross Section
up to 100 m^3	700 cm^2
up to 200 m^3	1,000 cm^2
above 200 m^3	2,000 cm^2

2.4.4 Doors

Doors must open outwards and must be lockable.

2.4.5 Safety distances

To avoid mutual impact in the case of damage, preventing flashover to adjacent systems in the case of fire, and for the protection of the gas storage from damage, such as heating as a consequence of fire, safety distances of at least 6 m must be provided in the horizontal direction between the gas storage and adjacent systems, equipment, or buildings (with a height lower than 7.5 m) not belonging to the biogas system, or to pathways or transport paths. For a building height > 7.5 m (gas storage or building not belonging to the system), the following applies:

0.4 x H1 + 3m

For two building heights (gas storage or building not belonging to the system) greater than 7.5 m, the following applies:

0.4 x H1 + 0.4 x H2

Within the biogas system, a safety distance of at least 6 m must be provided between the gas storage and the installation room for the combustion motors (see Section 2.4.5.2).

2.4.5.1 Dimensioning of the safety distances

For above ground installations, the safety distance is measured from the upright projection of the edge of the storage container.

2.4.5.2 Protective wall

The safety distance can be reduced through sufficient earth covering or sufficiently dimensioned safety wall or fire protection insulation (e.g., firewall). Doors in the protective walls must be fire resistant and self-locking (T 90 according to DIN 4102).

A protective wall can also be an appropriately designed building wall without openings.

The height and width of the protective wall must comply with the guidelines of the respective regional building code.

2.4.5.3 Requirements within the safety distance

Within the safety distances:

- Without advanced protective measures, there must be no storage of combustible substances in quantities over 200 kg; no other buildings and no public streets or paths can be located there. Advanced protective measures can be, for example, fire prevention measures, fire protection measures; fire-fighting measures (for example, see the section on protective walls).
- Transport paths, necessary for the system, are permissible.
- Without advanced protective measures, machines and activities, which can lead to an endangerment of the gas storage, are prohibited (e.g., welding, thermal cutting).
- Gas flares must not be operated.
- Fire, open flames, and smoking are prohibited.

2.4.5.4 Labelling

Areas in which safety distances are to be observed are, if applicable, also the entrances to the gas storages, to be labelled according to VSG 1.5.

Fire, Open Flames, and Smoking are Prohibited

Access by Unauthorized People is Prohibited

2.4.6 Mechanical hazards

Gas storage and its equipment parts must be protected from mechanical damage. For protecting the gas storage and its equipment parts from impact from vehicles in hazardous areas, the gas storage and its equipment parts must be protected, e.g., by bumpers, by areas not accessible to vehicles, by enclosing or complying with the safety distance.

Freestanding gas storage, for example, pillow type storage containers and membrane domes from flexible material, must be protected against mechanical damage. This requirement is to be met using a protective fence that is to be erected around the gas storage. For a protective fence distance of less than 850 mm, the fence must be secure against penetration. The protective fence must be designed as a fence that permits no access, e.g., from wire netting with a height of at least 1.5 m.

2.5 System control and process control engineering

In principle, the safe operation of a system must be guaranteed. In particular, an overfilling of the digester, an unintended flow of substrate into the pipe and container lines of the system, an impermissible pressure increase in the digester, as well as an uncontrolled escape of gas, must be prevented.

Control systems with safety functions must be fail-safe if they are not secured by a redundant system, e.g., a mechanical overpressure protection against overpressure, or e.g., an overflow spillway.

In the case of a failure of the auxiliary energy source (power, hydraulic or pneumatic supply of the biogas system), the safety shutdown, the activation of the emergency shut-off switch, the system, or the relevant system parts must enter into a safe state. The safe state can be reached using control technology, hydraulic, or mechanical measures.

Examples

- Closing the automatic gas rapid shutoff device at the CHP unit.
- Switching off the corresponding gas compressor.
- Switching off all parts that are not EX-protected in gas-pressurized machine rooms (CHP unit, gas cleaning, etc.).
- Enough clearance space so that, in the case of a failure of the agitator, no impermissible build-up of substrate occurs in the digester, and as a result, the cover is lifted off.
- Closing the feeder so that no backflow of the substrate occurs into the feed system (e.g., mixing tank, stall).
- External possibilities for supplying feed must be able to be blocked in the case of a system failure so that the possibility of overfilling is excluded.
- The lowering of the fill level must not lead to an uncontrolled release of gas, e.g., from the feed technology.

In the design of the safety-related control parts, the currently effective standards for electrical equipment of machines and safety-related parts of controls must be consulted. A hazard and risk analysis must occur according to the standards.

2.6 Gas processing

2.6.1 Desulphurization with iron-containing compounds or activated carbon

If biogas is desulphurized by means of iron-containing compounds, or by activated carbon, there exists a danger of self-heating during the regeneration. The safety information from the manufacturer, in particular, information about the exchange of biogas treatment media, must be followed.

2.6.2 Desulphufirzation by air injection in the gas room over the digester

The air-dosing pump must be adjusted so that it delivers at most a volume flow of 6 per cent of the biogas generated in the same time period. The air dosing must be dimensioned so that so that even in the case of a failure of the air flow, no significantly higher quantity of air can be supplied. In the supply to the gas room, a non-return protection (non-return valve) is required, as close to the gas room as possible. Between the non-return protection and the gas room, no additional devices can be inserted except for a blocking device.

2.7 Gas Lines

2.7.1 Design and material

Gas-carrying lines must be designed according to the generally recognized rules of the technology. The correct production and impermeability must be proven, e.g., by manufacturer’s certification (see sample, Appendix 2).

Pipelines must be resistant to its contents and to corrosion. Pipes that are resistant to biogas are composed of, for example, steel, stainless steel, polyethylene (PE-HD) and PVC-U.

Tip – PVC-U pipes: PVC is not UV-resistant and has a low resistance to impact. For PVC use, correct storage and processing must be observed. For this, particular attention must be paid to the information regarding installation and usage, e.g., the manufacturer’s information, as well as the bonding information and the installation information from the Plastic Pipe Association. The expertise of the pipe installer must be verified.

Copper is not resistant to biogas; brass and red brass have proven to be suitable (customary PVC-KG-pipes are not permissible, because they correspond only to a structural stability of maximum 0.5 bar).

Pipelines including all equipment parts and flexible connectors must have the structural stability of at least 1 bar.

2.7.2 General Information

In general, steel pipes should be used for the pipelines. Plastic pipelines can be used, in general, outside of closed rooms with installation under the ground and above ground as a connection line of the membrane storage and as a connection line of the digester. Plastic pipelines must be protected from mechanical and thermal damage.

Spigot and socket joint connections that are not longitudinally force-locked must be secured according to the typical pressures so they cannot be pushed. The pipeline connections must be longitudinally force-locked.

Tip

If gas lines are installed outside of the biogas system or on surfaces that are not in spatial functional connection to the biogas system, plastic gas lines must be laid according to the technical specifications of DVGW [German Technical and Scientific Association for Gas and Water] G 472 Rules.

2.7.3 Protection against mechanical damage

Mechanical damage due to settling (e.g., at passages through walls) must be avoided by appropriate passages and corresponding connections.

2.7.4 Frost safety

In the case of moist gas, the pipelines must be laid so that they are frost-proof. Condensate collectors must be constructed frost-proof and continuously capable of function.

2.7.5 Connection lines

Connection lines to the gas storage within the installation room of the gas store are components of the gas storage.

2.7.6 Labelling

Pipelines must be labelled according to DIN 2403 according to the flow substance and the direction of flow. Color for the labelling: yellow.

The location of underground gas pipelines must be marked with gas pipeline warning tape.

2.7.7 Gas-carrying connection parts belonging to the CHP unit

The suitability of the gas-carrying, flexible connection pieces belonging to the CHP unit and the equipment components of the charge-air cooling must be certified by the manufacturer of the CHP unit.

2.8 Instruments, Safety Equipment, and Gas-carrying System Parts

2.8.1 General information

Instruments, safety equipment, and gas-carrying system parts must be installed so that they are frost-free, according to the generally recognized rules of the technology, and checked for tightness. For the tightness check, the instruments, safety equipment, and gas-carrying system parts must correspond to the requirements of TRBS 2152, Part 2, Section 2.4.3.

In addition, they must be sufficiently resistant to its contents, corrosion, and pressure. With respect to suitable materials, Section 2.7 applies.

2.8.2 Approval

Instruments and gas-carrying system parts for which there is no DVGW approval must be designed to a pressure resistance that corresponds to the ten-fold positive operating pressure and must be resistant to biogas, e.g., sight glass, cover for access opening.

2.8.3 Operation

It must be possible to operate instruments from a secure platform. Fixtures for gas removal must be secured against unauthorized and unintentional opening, e.g., by securing the handles.

2.8.4 Accessibility and sealing liquid

Condensate separator and safety equipment must be accessible at all times. Permanently attached steps are not permissible unless the condensate separator has forced ventilation (see also, BGR 117, GUV R 126).

Pressurization facilities with sealing liquid in overpressure and under-pressure protectors, as well as condensate and dirt separators, must be easy to monitor and maintain without hazard, and should be accessible without having to enter into the shafts or pits.

Pressurization facilities with sealing liquid must be designed so that, during the triggering, the sealing liquid cannot escape but flows back again on its own.

In order to prevent gas from escaping, with sealing liquid facilities that serve as condensate separators and not as overpressure/under-pressure protectors, the fluid facilities must correspond to at least five-fold of the triggering pressure of the overpressure protection.

2.8.5 Flashback safe equipment

Flashback arrestors must be installed in front of gas-consuming equipment, such as boilers and CHP units, as close to the equipment as possible, corresponding to the instructions of the manufacturer.

2.8.6 Arrangement and implementation

Take note of the example for the gas diagram (1.2). Note the arrangement of the overpressure and under-pressure protectors.

2.8.6.1 Safety equipment, overpressure/under-pressure protection

Every gas tight container must be equipped with at least one safety device against exceeding or falling below acceptable pressure. This does not apply to containers that serve only for the storage of gas. If required, the gas that is discharged must be led off without hazard. Through a separate under-pressure monitor in the gas system or an equivalent protective measure, the under-pressure protector must activate a forced shutdown of the gas-consuming equipment and an error message must occur. It must be possible to shut off the gas containers individually and to shut them off from each other.

The overpressure and under-pressure protectors within the system must be designed, arranged, and monitored, and the overall biogas system must be operated so that all operating states in the digester are controlled. Foam formation represents a disruption of the operation, and it must be prevented by operational measures. Destruction due to the formation of foam must be prevented, e.g., by burst protection, pressure release protection, or sufficient storage space. The suitability of the overpressure/under-pressure protector must be proven by a documented evaluation and functional description. If they are implemented in a submerged state, they must not run empty, dry, or freeze.

It must be pointed out in the operating instructions that the safety equipment must always be checked after an operational malfunction and, during normal operation, at least once a week. For this, the specifications of the manufacturer must be observed.

Tip

Safety equipment can become ineffective due to stiffness as a result of contamination, corrosion, stoppages, or freezing. A modification of the interior pressure can be caused by:

- gas production without discharging gas,
- in the case of supplying or removing gas or substrate by pumping.

Liquid seals as safety equipment must be designed so that the sealing liquid can flow back again on its own in the case of an overpressure or under-pressure situation. There must be no means for blocking or shutting off the supply lines to the overpressure and under-pressure protection. Overpressure and under-pressure protection must be designed to be frost-safe. Usually, access to over-pressure and under-pressure protection must be designed and accessible with stairs , because due to the frequent use, there is an increased risk of accidents.

2.8.6.2 Discharge lines of the overpressure/under-pressure protection

The exhaust lines of the overpressure and under-pressure protection must discharge at least 3 m above the ground, and

- discharge 1 m above the roof or the upper edge of the container, or
- must be displaced at least 5 m away from buildings and passageways.

The 1-meter area around the discharge opening of the exhaust lines is a Zone 1 area. Refer to the pollution control regulations. The exhaust gas of the gas flame must be discharged above the roof, or via the exhaust line, which must be at least 5 m from buildings and passageways, and whose discharge must be at least 3 m above the ground (see also, Section 2.4.5.3).

3. Installation Rooms

3.1 Gas firing systems

The technical regulation for gas installations apply to the installation rooms for boilers (see Appendix 11). Refer to the regional ordinances for combustion equipment units.

3.2 Combined heating and power unit (CHP)

3.2.1 Installation in neighbouring buildings without common break rooms

3.2.1.1 Accessibility

Installation rooms must be designed and dimensioned so that the combined heat and power units can be properly installed, operated, and maintained. This is generally achieved if the combined heat and power unit is accessible from three sides. Doors must open in the escape direction.

3.2.1.2 Floor drains

Floor drains must have oil separators. Alternatively, a catch basin, which can hold the entire quantity of motor oil, must be provided underneath the motor.

3.2.1.3 Ventilation

Installation rooms must have supply air and exhaust air openings that cannot be closed. These allow a cross ventilation of the installation room. With technical ventilation, it must be guaranteed that the exhaust is led away from the ceiling area. In the case of natural ventilation, the supply air opening must be located in the area of the floor, and the exhaust air opening must be located on the opposite wall in the area of the ceiling. The exhaust of the CHP installation room must be discharged directly into the open air.

Tip

The open minimum cross section “A” for the supply air opening/exhaust air opening is given by the following formula, where

A = 10 P + 175
A = free cross section, cm²
P = maximum specified electrical power from the generator, kW
Example: 22 kW el = 395 cm² 30 kW el = 475 cm²

3.2.1.4 Cutoff

It must be possible to shut off the combined heat and power unit at any time by using an illuminated switch located outside of the installation room. The switch must be labeled permanently and be easily visible with "Emergency Shut-off Switch for Combined Heat and Power Unit " and must be accessible.

3.2.1.5 Cutoff for the gas supply

It must be possible to shut off the gas supply to the combined heating and power unit, in the open, outside of the installation room, as close to the CHP unit room as possible. The on and off position must be labeled. The same requirements apply also to electrically-operated shutoff valves.

3.2.1.6 Use of turbo chargers

With the use of motors, in which the gas-air mixture is compressed by the turbo charger, the following precautions are necessary for preventing or limiting potentially explosive atmosphere in the event of damage:

a. room air monitoring of the installation room with gas-warning device (GWE) that, according to RL 9L 95/9/EU, corresponds to at least Category 3 in its ignition protection and its measurement technology function, and an automatic switch-off of the aggregate and the electrical system, or

b. room air monitoring of the installation room with a gas-warning device (in the case of an installation in the EX area complying with RL 94/9/EU with respect to ignition protection of the necessary category), which, if necessary, was also checked for functionability according to RL 94/9/EU, however, at least with a gas-warning device checked for functionability by a national test center, and automatic switch-off of the aggregate and simultaneous switching on of a forced ventilation system that is dimensioned analogously to point c), so that no potentially explosive mixture can form, or

c. forced air ventilation of the aggregate room with a minimum air exchange, which effects a sufficient dilution of the maximum possible gas quantity. The required minimum air exchange amounts to 35 m^3/h of air per 1 kW of installed electrical power. Then, the maximum gas concentration amounts to a maximum of approximately 1.5% vol., and therefore corresponds to approximately 25 per cent of the lower gas explosion limit (methane 4.4–16.5% vol.).

In the case of opened shutoff valves, the fans must run, and their function must be monitored by a flow monitor.

3.2.1.7 Compressors in the installation rooms

The installation room is not a potentially explosive area if the gas-carrying system parts, e.g., gas supplying equipment and CHP unit within the installation room, are constructed to be continuously gas tight during operation.

In addition, the use of gas-warning devices (GWE) can be helpful.

If the tightness of the gas-carrying system parts, e.g., gas supplying devices and CHP unit within the installation room, in ongoing operation is not continuously guaranteed, protective measures must be implemented.

If the following protective measures are deployed, no potentially hazardous zone exists in the installation room:

1. A minimum air exchange is continuously guaranteed by means of a ventilator and an airflow monitor. The air exchange dilutes the maximum possible air quantity to a maximum gas concentration of 20 per cent LEL (lower explosion limit) in the installation room.

Example Ventilation:

$$\frac{V_{max}\ CH_4\ \text{leakage rate}}{V_{biogas} + V_{\text{air of ventilation}}} < 20\%\ \text{of the LEL}\ CH_4\ \text{in air}$$

Note

The leakage rate in this formula is the leakage rate of the compressor.

Depending on the operating pressure and the specified leakage rate, if applicable, a zone must be indicated in proximity to the gas escape site if a potentially hazardous quantity can escape.

The secure discharge of the air from the installation room must be guaranteed.

or

2. The installation room must be provided with a gas-warning device (GWE).

The possible gas escape of a CH_4/CO_2 mixtures into the machine room is monitored and locked by a safety room air monitor with the following safety oriented functions,

e.g., 20% of the LEL (0.9% vol. CH_4) in the room air with the following actions:

- visible and audible warning and
- supply air or exhaust air to 100% performance

e.g., 40% of the LEL (1.8% vol. CH_4) in the room air with the following actions:

- visible and audible warning
- supply air or exhaust air to 100% performance
- automatic switch-off of the gas utilization and closing of the gas supply outside of the installation room or shut down (e.g., energy supply) of all resources in the machine room that are not EX-protected

Information for sufficient dimensioning of the ventilation or exhaust:

$$\frac{V_{max\ CH_4} \text{ with maximum gas supply of the gas compressor the BGA [German Health Authority] (2-F-Case)}}{V_{Biogas} + V_{air\ of\ ventilation\ and\ exhaust}} < 50\% \text{ of the LEL } CH_4 \text{ in air}$$

The gas-warning device must conform at least to the Directive 94/9/EU according to Category 3G. This applies also for the ignition protection of the sensing devices installed in the installation room, as well as for the measurement technology function. The gas-warning device continues to be operated in the case of exceeding the second alarm threshold, i.e., it is not switched off. The maintenance of the gas-warning device must occur according to the manufacturer's instructions.

For ventilation, the secure discharge of the air from the installation room must be guaranteed.

The air must be discharged from the installation room into the open air. Try to achieve cross ventilation. Sometimes, forced ventilation is also necessary (see the manufacturer's instructions).

Along with the gas-warning device, the suction-operating fans of the ventilator must correspond to the device category 3G.

If a CHP unit (or several) and the emergency flare are operated via a compressor, the ventilation in the installation room of the compressor must continue to be operated for as long as the compressor functions.

3.2.1.8 Shutoff valves

Two shutoff valves must be installed in the gas line in front of each motor aggregate. The valves must automatically close when the motor stops. The gas tightness of the intermediate space must be checked regularly. If the supply line to the motor is operated constantly with a primary pressure > 5 mbar, even when the motor is stopped, an automatic monitoring of the intermediate space is required.

3.2.1.9 Rooms into which gas can penetrate

Rooms into which the gas can penetrate and rooms that must be regularly accessible for the operation of the system must be ventilated so that no hazardous gas mixture can form. It should be possible to leave these rooms without entering the CHP unit room. If the rooms cannot be appropriately ventilated, EX-protective measures must be implemented corresponding at least to the requirements of Zone 2. In addition, the occupational exposure limits (OELs) must be maintained continuously and safely.

3.2.2 Installation in building not belonging to the system

3.2.2.1 General information

The specifications of Section 3.2.1.1 to 3.2.1.9 apply accordingly.

3.2.2.2 Implementation

Walls and supports, as well as ceilings above and below the installation room, must be fire resistant F90A DIN 4102, or correspond to the appropriate requirements of DIN EN 13501, and must be composed of noncombustible construction materials. Coverings and insulating layers composed of combustible construction materials must not be used for walls, covers, and supports.

3.2.2.3 Doors

Doors in the fire resistant walls must be at least fire retardant, T 30 DIN 4102, and must be self-locking; this does not apply to doors that lead to the outdoors.

3.2.2.4 Openings

Ventilation lines and other lines can be led through walls and ceilings only if the lines themselves cannot spread fire or if measures have been taken against the spread of fire (e.g., cable shielding with general construction supervision approval, fire prevention dampers).

Intermediate spaces in the openings must be filled with noncombustible and stable material.

3.3 Installation of gas-warning devices

Sensing devices should be placed above, depending on the gas properties, in the proximity of possible release sources. The influences of the ventilation and its possibly different operating states must be considered in the placement.

Evaluation units should be installed outside of the room to be monitored. The installation should be in an adjacent room into which the gas mixture cannot penetrate from the area being monitored and into which also no hazardous gases can be released. It must be verifiably guaranteed that no hazardous gas concentrations can occur due to the gas analysis. Otherwise, a forced ventilation with a minimum air exchange must be installed, which effects a sufficient dilution of the maximum possible gas quantities, or the gas analysis must be implemented in the CHP unit.

Operating instructions must be written for the case of the alarm being triggered by the gas-warning device or interruptions of the gas-warning device.

4. Operation

Operating instructions must be available for taking the system into service (see sample in Appendix 1). The system is taken into service by the respective technical specialist (see Acceptance Log Appendix 2).

The operation and maintenance of the biogas system must be performed only by reliable persons familiar with the work.

At least two persons at the biogas system must have received certified operator training.

The operating instructions with safety information must be observed (see Appendix 3).

Operating instructions must always be placed permanently in the operating room.

An operational log (see Appendix 4) must be kept in which all daily measurements, control, and maintenance work, as well as malfunctions, is recorded.

In the case of malfunctions at the gas-consuming devices, the gas production of the system must be reduced through suitable measures in order to keep the exhaust quantity as low a possible.

Suitable measures for reducing the gas production are, e.g.:

- stop the supply of substrate
- stop the supply of heat to the digester

In the case of malfunctions and for taking the biogas system out of operation, perform the measures listed in Appendix 5 and 6.

Appendix 1

Operating Instructions for Initial Startup/Restart of a Biogas System

Sample

The initial startup of a biogas system is a special operating state, which requires special actions. The EX-zones, specified in the Explosion Protection Document, consider the operating state based on various conditions. Therefore, these particular hazards are considered separately in the operating instructions.

1. During the initial startup, a hazardous, potentially explosive atmosphere can occur in the gas space of the digester container. Ignition sources (see, for example, Section 1.4.4) must be avoided (e.g., operate the agitator submerged).

2. The empty digesters are initially blocked from the gas collection system.

3. The digesters are connected to the atmosphere via the operationally ready overpressure protector and the exhaust lines.

4. The digesters are filled within a short time period with substrate that is as active as possible, until all inlets and outlets (liquid valve closure disks) are sealed with substrate.

5. The fermentation substrate is heated.

6. During the startup/heating of the system, the system must not be fed further.
7. The gas generated during the starting of the digestion process discharges via the exhaust line (gas overpressure protection) into the open air, and displaces the air that is present in the digester.

8. After testing the gas quality, biogas fills into the gas system and the gas storage. The gas quality is sufficient and there is not explosion hazard if the methane content of the gas is greater than 30% and the oxygen content is < 3%.

9. The CHP units are turned on. They automatically suction the gas from the gas storage. Sufficient biogas quality can be determined by gas measurement.

10. All safety equipment must be checked for the proper function.

Appendix 2

Inspection Document for Biogas Membrane Storage, see also Appendix 13

Sample

Address of the site:	Biogas system:
Operator of the system:	
System installer:	
Inspector of the membrane storage:	

Membrane Storage

Manufacturer:	Company:
Material:	
Dimensions:	
Gas impermeability:	For methane: cm^3/m^2, d, bar
Strength:	Tear strength: N/5 cm Tensile strength: N/5 cm
Temperature Resistance	
Seals:	
Installation procedure:	

Leak Test

Test area:	
Test method:	
Test medium:	
Test result:	

Sample

Inspection Document for Gas-Carrying Pipes

Address of the site:	Biogas system:
Operator of the system:	
System installer:	
Inspector of the piping:	

Appendix 2

Piping	in the CHP unit room	in the ground
Manufacturer:		
Material:		
Dimensions:		
Strength:		
Pipe connections:		
Seals:		

Leak Test	Test section from – to
Test method:	According to the technical rules for gas installation DVGW-TRGI 2008 G469 and G600
Test pressure	Initial test with 1 bar, main test with 110 mbar
Test duration	Initial test 10 min, main test 10 min.
Test medium:	Air
Test result:	

Note:

Location/Date:

Stamp/Signature:

Appendix 3

Operating Instruction for a Biogas System in Normal Operation (see Section 1.5)

Sample

Independent of this sample operating instruction, the operating instructions of the manufacturer of all individual components must be observed, such as the CHP unit, pumps, mixer, membrane storage, under-pressure monitor, room air monitor, etc..

In general:

- During filling and emptying, pay attention to pressure fluctuations and ensure good accessibility to the operating equipment.
- Avoid ignition sources, according to 1.4.4, in the zones according to the Explosion Protection Document (see also, Appendix 9).

Daily:

- Record the gas meter reading and operating hours of the motor.
- Check the motor oil level.
- In the control room, at the control box, check whether the malfunction lights are illuminated.
- Check the water pressure in the heating system.
- Check the air-dosing pump of the desulphurization system for operability.
- Monitor the digester temperature.
- Select the agitation intervals so that no layer of scum/sediment layer develops.
- For all inlets and outlets, assure that the liquid manure/substrate flow is maintained according to the process regulations.
- The airflow injected for desulphurization must be matched to the current gas production rate (max. 6% vol.).
- Check the fill levels in the digester and end storage.
- Check the membrane connectors (e.g., attachment hose at the membrane gas storage).

Weekly:

- Check the fill level of the sealing liquids in the overpressure and under-pressure protectors and condensate separator; if necessary, in the case of a danger of frost, check the antifreeze agent (if the weather warrants, daily checks are also required).
- Check the submerged propeller function; observe whether vibrations are present.
- Visually inspect the motor and the lines.

Appendix 3

Weekly:
- Check the gas magnet valve for function and contamination.
- Check the intermediate space of the self-closing gas shutoff valve for tightness.

Monthly:
- Actuate all scrapers a few times so that they are not stuck.
- Possibly remove the oil deposits in the CHP unit and clean the oil catch basin.

Twice a year:
- Check the ventilation and exhaust in the machine room of the CHP unit.
- Inspect the electrical systems for damage.
- Check the under-pressure monitor of the gas system for function.
- Check the function of the gas sensors, fire detector (if present).

Annually:
- Check the gas-carrying system parts for damage, tightness, and corrosion.
- Calibrate the gas sensor with suitable test gas.

Every 2 years:
- Check the fire extinguishers.

In the zones, according to Section 1.4.4.2, ignition sources must be avoided, e.g.:
- smoke, fire
- non EX-protected electrical operating resources

Pits and shafts:
Before entry and during presence in the pits and ducts, it must be guaranteed that there is no hazard of poisoning, as well that there is sufficient breathable air present. Operating equipment must be reliably secured so they don't switch on (lock out procedures). Ensure that there is sufficient ventilation. In the case of insufficient ventilation, there is a danger of asphyxiation, fire, and explosion.

Appendix 4

Operations Log (example)

Sample

Date	Gas Meter Reading [m³]	Gas Con-sumption [m³/day]	Operating Hours [h]	Electricity Meter [kWh]	Digester Temperature [°C]	Substrate Supply [m³]	Maintenance Work	Unusual Incidents

Appendix 5

Operating instructions for a biogas system in the case of malfunction

Sample

Independent of this sample operating instruction, the operating instructions of the manufacturer of all individual components must be observed.

Gas storage room

- shut off gas supply
- empty the gas storage
- avoid ignition sources (see Section 1.4.4)
- entry for authorized personnel only after and with sufficient ventilation, while being accompanied by a second person (who remains in the vicinity of the opening to the storage) and being secured, e.g., with a rescue apparatus and lifebelt (harness)

Heating, hot running machines and parts, substrate or oil becoming hot

- avoid contact with hot surfaces, fluids, gases, ...
- caution with hot water discharge: potential scalding hazard!

Machine room and combined heat and power unit

- shut off gas supply outside of the machine room
- activate the emergency off switch outside of the machine room
- if necessary, force ventilation (e.g., in the case of gas odor)
- if there is a gas odor, avoid ignition sources, e.g., non EX-protected light sources, open flame, or formation of sparks. Danger of explosion!
- if the gas alarm comes from a gas-warning device, separate operating instructions must be created and followed

Electrical system

- work on the electrical systems must be performed only by a skilled electrician

Liquid manure lines and scraper

- Get rid of blockages immediately
- in the case of malfunctions in the pump system: shut off all scrapers after the pumps are stopped

Pumps and mixer

- switch off the electrical supply, and secure the switch against unintentional actuation

Appendix 5

Pits and shafts

- After malfunctions, all safety equipment must be checked for the proper function.

Note

Before entry and while in the pits and ducts, it must be guaranteed that there is no hazard of poisoning, as well as that sufficient breathable air is present. Operating equipment must be reliably secured against switching on. Ensure that there is sufficient ventilation. In the case of insufficient ventilation, there is a danger of asphyxiation, fire, and explosion (see also, Appendix 7).

Appendix 6

Operating Instructions for Shutting Down a Biogas System

Sample

The shutdown of a biogas system is a special operating state that requires special actions. The EX-zones, specified in the Explosion Protection Document, consider the operating state based on various conditions. Therefore, these particular hazards are considered separately in the operating instructions.

1. Stop the substrate supply into the digester container; the substrate removal from the container continues to occur. The quantity of the substrate removed must not be greater than the quantity of generated gas in the digester in order to prevent a potentially hazardous atmosphere.

2. If the quantity of substrate removed can become greater than the quantity of gas generated, the digester container is locked against the gas capturing system, and the connection to the atmosphere is created, e.g., by emptying the sealing liquid supply. By adding air, a potentially explosive atmosphere can develop in the digester. Ignition sources according to 1.4.4 must be avoided.

3. The digester container must be blocked from the gas capturing system in order to avoid a backflow of gas.

4. A potentially explosive atmosphere can form around outlet openings. Ignition sources, e.g., according to 1.4.4, must be avoided.

5. Before entry into and while in the digester container, it must be guaranteed that the danger of asphyxiation, fire, and explosion has been safely prevented by sufficient ventilation and that sufficient breathable air is present. Operating equipment (e.g., pumps and agitators) must be secured against being switched on (lockout procedures).

Appendix 7

Operation Information

Workplace/Work area : Biogas system, liquid manure pits, liquid manure ducts, liquid manure storage facilities, shafts, etc.
Activity: Stirring, flushing, pumping, transferring, removing liquid manure or substrate, repair and maintenance work, and presence in the liquid manure or substrate work areas

Identification of Hazardous Substances

Liquid Manure and Biogases
(Hydrogen sulphide, Methane, Carbon Dioxide, Ammonia)

Hazards for Humans and the Environment

The gases are released especially through the movement of the liquid manure or substrate. In the process, hazardous gas concentrations can develop, which remain over long periods.

- life threatening danger – hydrogen sulphide (H_2S)

Caution: H_2S disables the sense of smell, higher concentrations are no longer noticed

- danger of asphyxiation due to carbon dioxide (CO_2)
- explosion hazard due to methane (CH_4)
- health hazard due to ammonia (NH_3)

Protective Measures and Rules of Conduct

Never enter into the digester, storage facilities, pits, shafts, etc., without protective equipment. Enter only with a breathing apparatus that is not dependent on the surrounding air, e.g., fresh air suction hose device and lifebelt, as well as approved rescue apparatus.

When working with liquid manure or substrate, any kind of ignition source must be avoided:

- switch-off gas jet devices
- smoking is prohibited
- no light test

Appendix 7

- do not perform any welding or thermal cutting – sparks and welding beads can fall also in pits that are far away (If such work is absolutely necessary, ensure good ventilation, e.g., using fans. Pits must be covered.)

Conduct in Dangerous Situations

Enter into pits, etc., for rescuing casualties only with a breathing apparatus that is not dependent on the surrounding air, Lifebelt, and rescue apparatus.

Provide sufficient fresh air.

Contact the fire department!

Conduct in Case of an Accident – First Aid

After breathing liquid manure gas or biogas, provide fresh air.

Unconscious person: Establish breathing and place victim on their side.

Contact the physician immediately! Provide information about poisoning due to hydrogen sulphide.

First Responder:

Physician:

Emergency:

Date:

Employer's signature:

Appendix 8

Proposal for the Contents of an Alarm and Hazard Defence Plan

Sample

A biogas system is a structural system that, for the appropriate assessment of the fire hazard, requires an in-depth examination during the planning and a close coordination of the tactical operational necessities with the leaders of the emergency response forces or the local fire authorities.

As a rule, it is necessary to develop a common plan for the tactical deployment of the fire department in the event of a fire or other technical assistance (fire protection plan).

The fire protection plan is drawn up by the system operator and then must be coordinated with the responsible fire department to their tactical requirements. In its final form, the fire protection plan must be presented to the responsible regulatory agency, at the latest one week before taking the system into operation.

Depending on the circumstances of the individual case, the fire protection plan as a rule must contain information and diagrams for the following points:

1. Access roads and passageways, as well as the deployment areas and movement areas for the fire department.

2. Verification of the necessary water quantity for fire fighting and the verification of the supply of water for fire fighting.

3. Dimensions, position, and arrangement of the reservoir of water for fire fighting.

4. The system of the outer and inner fire retardant locks in the fire compartments or fire fighting sections, as well as the system of smoke compartments with information about the position and arrangement of the components.

5. Position, arrangement, dimensions, and designation of the escape routes on the site and in the buildings with information about emergency lighting.

6. Information about the users of the system.

Appendix 8

7. Position and arrangement of technical systems for the building, especially the cable and duct systems, if necessary, with information concerning fire behaviour in the area of the escape routes.

8. Position and arrangement of possible ventilation systems with information about the fire protection construction.

9. Position, arrangement, and dimension of the smoke and heat exhaust systems.

10. Position, arrangement, and if applicable, dimensions of systems, equipment, and devices for fighting fires (e.g., fire extinguishing devices) with information for protected areas and for the stockpiling of special extinguishing agents.

Appendix 9

Examples Zone Classification

System Part	Type of Impermeability	Zone 1	Zone 2
General			
Around: System parts, equipment parts, connections	Equipment and system parts with operational gas outlet	1 m around the outlet point	2 m around Zone 1
	tight	–	3 m around system part
	permanently tight	–	–
Examples			
Burst safety device that in normal operation seals securely		–	3 m around system part
Outlet opening of exhaust lines		1 m around outlet opening	2 m around Zone 1
Service Opening			
If the service openings are not opened during normal operation	With operational gas outlet	1 m around the outlet point	2 m around Zone 1
	tight	–	3 m around system part
	permanently tight	–	–
Gas Storage			
Around: Simple membrane storage out in the open			3 m from above
Simple membrane domes on digester containers and storage			3 m to the side
Around ventilation and exhaust openings of vapour-sealed gas storage rooms			2 m downward at 45° gradient
Double membrane domes with digester containers and storage, if the through-flow leads the diffusing biogas sufficiently diluted (<< 10% LEL) from the gas storage, and the exiting air is continuously monitored.		–	–

Appendix 9

System Part	Type of Impermeability	Zone 1	Zone 2
Condensate Separator			
Room that contain the condensate collector. With open water locks, formation of a hazardous, possibly explosive atmosphere must be anticipated as a result of puncture or drying out of the water locks, or as a result of faulty operation: a) with the discharge in closed rooms without ventilation – **Zone 0 in the entire room**			
b) with the discharge in closed rooms with natural ventilation		Entire room	1 m around openings of the enclosed room
c) closed drainage system, locks with double locking devices or automatic drainage For the total space, 1 m around openings of the enclosed room.		–	–
Solid Substance Dosing			
If during normal operation, forced submersed supply is guaranteed.		–	–

<u>Dimensioning of the Area of Zone 1</u>

A spherical area with a radius of 1 m around is considered an area of Zone 1 (see also, TRBS 2152) such as system parts, equipment parts, connections, sight glasses, pass-through, service openings at the gas storage and at the gas-carrying part of the digester container and around the outlet openings of exhaust lines, if an operational outlet of biogas must be anticipated.

The radius of 1 m applies in the case of natural ventilation.

Under normal operating conditions, releases into closed rooms must be avoided. If possible, the entire room is Zone 1.

Appendix 9

<u>Dimensioning of the Areas of Zone 2</u>

Gas-Carrying System Parts

A spherical area with a radius of 3 m around system parts classified as impermeable are considered areas of Zone 2 such as equipment parts, connections, pass-through, service openings, as well as burst plates. The radius of 3 m applies in the case of natural ventilation. Closed rooms are entirely areas of Zone 2 (see also, TRBS 2152).

A spherical shell with a radius of 2 m thickness around system parts not classified as impermeable are considered areas of Zone 2, such as equipment parts, connections, sight glasses, pass-through, service openings, and at the gas-carrying part of the digester container, as well as around the outlet openings of exhaust lines, if these have an operational outlet of biogas.

Gas Storage

If the membrane storage is stored out in the open or housed in a room ventilated all around, the area of Zone 2 encompasses the periphery of 3 m upwards and to the side, and 2 m downwards with a 45° gradient. In the case of housing the membrane storage in a vapor-tight and, therefore, extensively gas-tight room, Zone 2 encompasses the interior of the gas storage room and the periphery of 3 m around the ventilation and exhaust opening upwards and to the sides; the extent downwards amounts to 2 m with a 45° gradient.

Vapour-tight rooms can be rooms constructed with, e.g.:

- brickwork walls with trim
- concrete walls
- walls whose coating consists of non-combustible and spackled plates
- standardized containers with metal walls

<u>Note</u>

Around system parts that are permanently impermeable, according to TRBS 2151, Section I 1.3.2.2 (see Appendix 10), there is no zone

Appendix 9

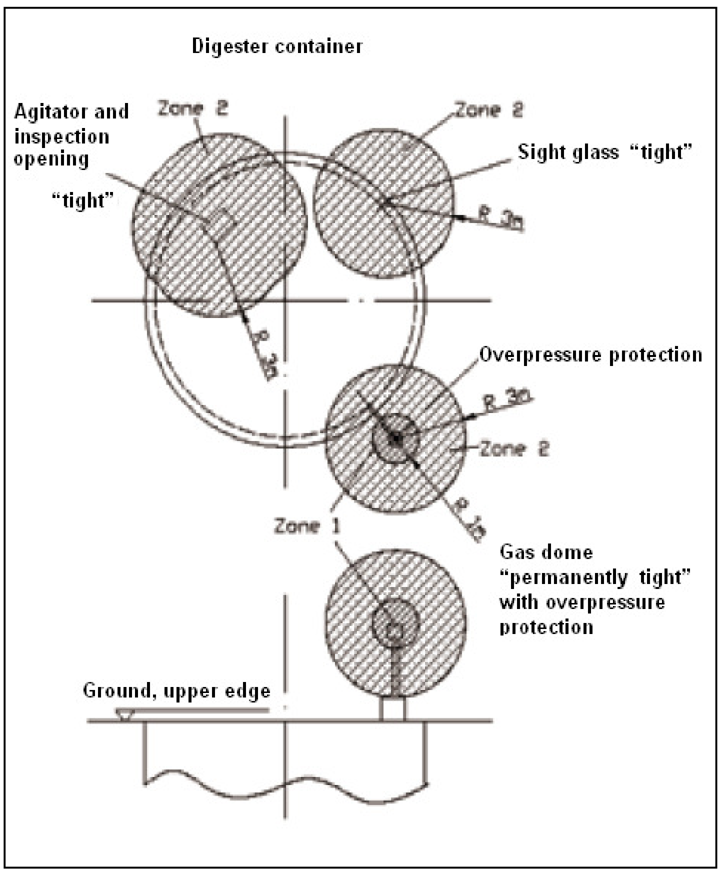
Double Membrane (Support Air)

No zone is present around the outer membrane and in the intermediate space between the two membranes if the through flow sufficiently thins (< 10% LEL) the biogas diffusing from the gas storage and leads it off in a targeted manner, and the air that is being discharged is continuously monitored according to the maintenance plan (manufacturer specification).

A ring-shaped potentially explosive atmosphere can occur around the transition to the digester if the connection is not implemented in a permanently impermeable manner.

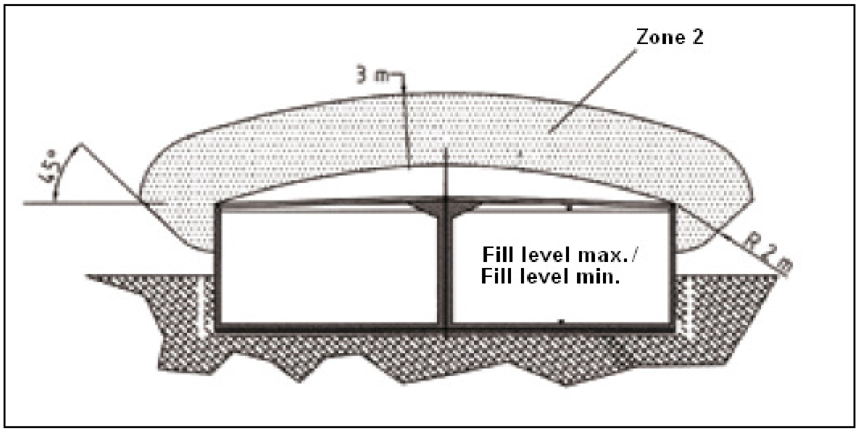
If it is not possible to prevent backflows into the support air blower, these are to be implemented according to 94/9/EU.

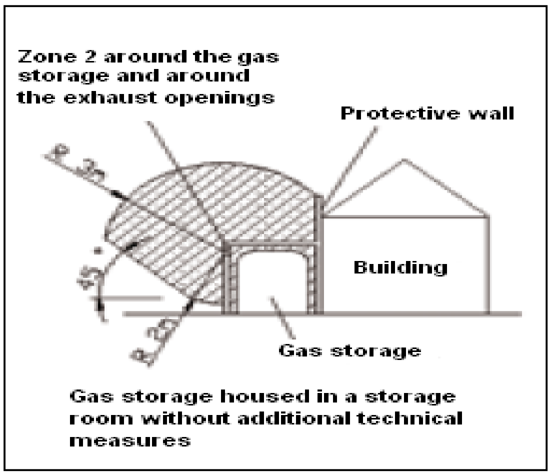
Example – Biogas System, Top View with Permanently Tight System Parts

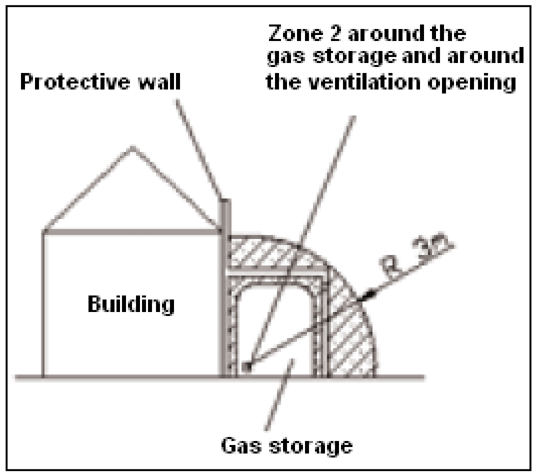


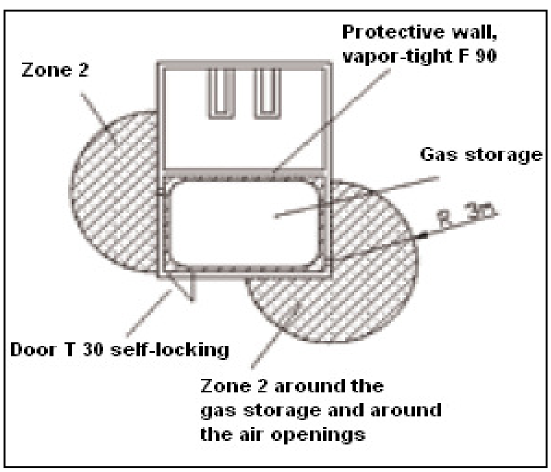
Appendix 9

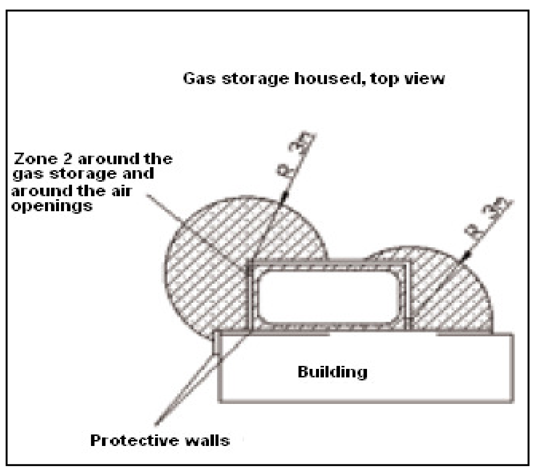
Example – Housed Gas Storage (Storage Room Without Further Technical Measures)











Appendix 10

Tightness of System Parts (see TRBS 2152, Part 2, Section 2.4.3)

1. **General Information**

The formation of a hazardous, potentially explosive atmosphere outside of system parts can be prevented or limited by the impermeability, or tightness, of the system parts. For this, distinction is made between:

- tight system parts,
- permanently tight system parts, and
- system parts with operational outlet of combustible substances.

Tip 1
With the construction of system parts for handling combustible gases, liquids, and dusts, the material should be selected so that it can withstand the anticipated mechanical, thermal, and chemical operational demands. Hazards due to reactions of the wall materials with the combustible mixture must be excluded.

Tip 2
For the material selection, the corrosion behaviour must be considered. With laminar wear, the calculation of the wall thickness must consider extra thickness; against pitting corrosion, suitable materials must be selected as principal protective measures; in addition and in particular, appropriate preservative measures must be performed during the idle state.

1.1 Permanently Tight System Parts

1. With system parts, which are permanently tight, no releases are to be expected.

2. System parts are considered as permanently tight, when:
   a. they are designed so that they remain tight due to their construction, or
   b. their technical impermeability is continuously guaranteed through maintenance and monitoring.

3. System parts, which are permanently tight, due to their construction, do not cause any potentially explosive areas in their surroundings in the unopened state.

Appendix 10

4. Permanently tight system parts and equipment parts according to Section 2 a) are, e.g.:

1. Welded system parts with:
    a. detachable components, where the detachable connections required for this are only rarely detached during operation and are constructively formed like the detachable pipe connections described below (exception: metallic sealing connections),
    b. detachable connections to pipelines, fixtures, or temporary covers, where the detachable connections required for this are only rarely detached during operation and are constructively formed like the detachable pipe connections named below
2. Shaft feed-through with double-acting slide ring seals (e.g., pumps, agitators).
3. Canned motor pumps.
4. Magnetically coupled packing-less pumps.
5. Fixtures with seals of the stem extension by means of bellows and safety joints, stuffing box joint seals with self-adjusting sealing material.
6. Fixtures without packing box with permanent magnetic drive.

5. Permanently tight pipeline connections according to Section 2 a) are, e.g.:

1. Non-detachable connections, e.g., welded.
2. Detachable connections, which are only rarely detached during operation, e.g.:
    - flanges with welded lip seals
    - flanges with groove and tongue
    - flanges with projections and recesses
    - flanges with V-grooves and V groove seals
    - flanges with smooth raised sealing face and special seals, soft materials seal up to PN 25 bar, metal interior edge contained seals or metal clad seals, if with use of DIN flanges a rated verification has sufficient reliability against the yield strength.

6. Permanently tight connections according to Section 2 a) for connecting fixtures are, as long as they are only rarely detached, e.g.:

1. the pipeline connections named above, and
2. NPT-threads (National Pipe Taper Thread, tapered pipe thread) or other conical pipe thread with seals in the threads up to DN 50, as long as they are not used with alternating thermal loading (Δt > 100° C).

7. Along with the purely constructive measures, according to Section 2 b), technical measures can also be combined with organizational measures to achieve a permanently technical tight system part. Among these are, with monitoring and maintenance, e.g.:

1. dynamically stressed seals, e.g., with shaft feed-through at pumps,
2. thermally stressed seals at system parts.

8. The extent and frequency of the monitoring and maintenance conform in detail to the type of the connection and construction, mode of operation, stress, as well as the state and properties of the materials. It should guarantee the permanent technical tightness. It should be noted that the extent and frequency for the monitoring and maintenance for maintaining the permanent technical tightness are specified in the Explosion Protection Document or the documents referred to there, e.g., in the associated operating instructions or in the maintenance plan.

9. For monitoring, one of the following measures can be sufficient:

1. Inspecting the system and checking, e.g., for flow marks, ice formation, odour, and noise as a consequence of leaks.
2. Inspecting the system with mobile leak detecting devices or portable gas detecting devices.
3. Continuous or periodic monitoring of the atmosphere by automatic, permanently installed measurement devices with alarm function.

Tip
System parts with the classification of 0.5 or 1 according to TRGS 420-Appendix 1 are considered permanently tight.

Note
Suitable preventive maintenance can reduce the extent and frequency of monitoring for tightness.

1.2 Tight System Parts

1. With system parts that are tight, infrequent releases are to be expected.

2. System parts are considered tight when no leaks can be detected with a tightness test suitable for the application, or tightness monitoring or tightness inspection, e.g., with foam forming agents or with leak detection devices or leak indicator devices.

3. Examples of tight system parts are:
    1. Flange with smooth raised face and no special constructive requirements of the seal.
    2. Cut and clamp connections in cables larger than DN 32.
    3. Pumps whose tightness depends only on a simply acting slide ring seal.
    4. Detachable connections according to No. 1.1, which are only rarely disconnected.

1.3 Minimizing Operational Discharge of Combustible Substances

1. Outside of system parts, which are neither permanently tight nor tight, the formation of a hazardous, potentially explosive atmosphere through operational discharges of combustible liquids, gases, steam, or dust must be expected.

Note 1
Operational discharge locations are, e.g., ventilation and relief lines, fluid transfer connection points, manual outlet valves, sampling points, drainage installations, and with dust, e.g., transfer points.

Note 2
Other possible discharge points are flange or gas dome connections that are not controlled (e.g., pump housings).

2. Through technical measures, the quantities discharged, the zone extension, or the likelihood of the discharge of potentially explosive atmospheres can be reduced, if, e.g.:
    1. a complete hose system is used during fluid transfer,
    2. fluid transfer is performed in closed systems using the gas return,
    3. ventilation and relief lines are routed into the gas collecting system,
    4. it is guaranteed by using special equipment that only small quantities can escape at sampling points and manual outlet valves,
    5. drains are implemented via sluices of low capacity with mutually locking shutoff valves,
    6. the transfer points of dusty or dust-containing products are provided with a flexible encasement made of largely dust impermeable materials,
    7. at operational discharge locations, a discharge of combustible substances can be avoided through low-pressure operation mode,

8. with the use of the low-pressure operation mode (e.g., 900 mbar abs.) the likelihood of a discharge of a hazardous, potentially explosive atmosphere near the system parts (e.g., openings, shaft feed-through) is very low.

1.4 Testing the System Parts for Tightness

Systems according to 1.1, Section 2 a), must be tested for tightness as a whole or in sections before beginning operation for the first time, as well as after longer interruptions in operation, changes, and repair or large scale retrofitting. Tight systems and systems according to 1.1, Section 2 b), must be tested for tightness additionally on a regular basis according to their test schedule.

Appendix 11

Additional Regulations and Rules

Accident Prevention Regulations (VSGen) of the Agricultural Occupational Health and Safety Agency

VSG 1.1	General Regulations for the Protection of Health and Safety
VSG 1.4	Electrical Systems and Operating Resources
VSG 2.1	Workplaces, Structural Systems, and Equipment
VSG 2.2	Storage Facilities
VSG 2.8	Storage of Liquid Manure, Pits, Canals, and Wells
	Information CD – Prevention at a Glance
Source:	The VSGen can be requested at any of the responsible Agricultural Occupational Health and Safety Agencies (see the list on the last page of this brochure). All information is also available via the Internet at www.lsv.de.

Information from the Agricultural Occupational Health and Safety Agencies:
Handouts for Safety with Biogas Systems

Ordinances:
Ordinances concerning the protection of health and safety with the provision of work materials and their use during work, concerning safety during operation of systems requiring monitoring, and concerning the organization of the operational work safety (Ordinance on Industrial Health and Safety – BetrSichV).

Ordinances of the Ministry for the Environment and Transportation concerning systems for the handling and transporting substances that are harmful to water and concerning specialist operations (System Ordinances for Substances that are Harmful to Water, VAwS), in the version of the respective Federal States in Germany.

Ordinances of the Commercial Employer's Liability Insurance Association

BGR 104	Explosion Protection Rules
BGR 117	Working in Containers, Silos, and Narrow Enclosures
BGR 133	Equipping Workplaces with Fire Extinguishers
Source:	Carl Heymanns Verlag KG, Luxemburger Str. 449, 50939 Köln, Germany, or via the Internet at the website of the German Statutory Accident Insurance www.dguv.de

Appendix 11

Government Rules (Germany)

TRBS 2152	Hazardous, Potentially Explosive Atmospheres – General
TRBS 2152 Part 1	Hazardous, Potentially Explosive Atmospheres – Assessment of the Danger of Explosion
TRBS 2152 Part 2	Avoiding or Limiting Hazardous, Potentially Explosive Atmospheres
TRBA 214	Waste Treatment Plants including Sorting Systems in Waste Management
TRBA 230	Protective Measures during Activities with Biological Work Materials in the Agricultural and Forestry Industries with Comparable Activities
TRBA 500	General Hygiene Measures: Minimum Requirements
Source:	www.baua.de

Standards

DIN 2403	Labelling of pipelines according to the material flowing In them
DIN 2470 – 1	Gas lines of steel pipes with permissible operating pressures up to 16 Bar; requirements on the pipeline parts
DIN 4102	Fire characteristics of construction materials and components
DIN EN 13463	Non-electrical devices for use in potentially explosive areas
DIN EN 13501	Classification of building products and types of buildings based on their fire characteristics
DIN EN ISO 14122	Fixed access to mechanical systems
Source:	Beuth Verlag, Burggrafenstr. 6, 12623 Berlin, Germany

VDE Regulations: [VDE – German Electrical Engineering Association]

DIN 0100 Part 705	Building Low Voltage Systems
VDE 0165 Part 1/ EN 60 079-14	Electrical Equipment for Potentially Explosive Gas Hazard Areas – Part 14: Electrical Systems in Potentially Explosive Areas (except mining operations)
VDE 0170/0171	Electrical Equipment for Potentially Explosive Areas
VDE 0185-305-1	Protection from Lightning
VDI/VDE 2180	Sheet 1–3; Securing Process Engineering Systems with Means of Process Control Engineering (PLT)
Source:	VDE-Verlag GmbH, Bismarckstr. 33, 10625 Berlin, Germany

Appendix 11

DVGW Rules: [DVGW – German Technical and Scientific Association for Gas and Water]

G 600	Technical Rules for Gas Installations DVGW-TRGI 2008
G 262	Use of Gases from Regenerative Sources in the Public Gas Supply
G 472	Gas Lines Up To Operating Pressures of 10 Bar, Composed of Polyethylene (PE 80, PE 100 and PE-Xa); Installation
G 469	Compression Test Methods for Lines and Systems of the Gas Supply
G 462 Part 1	Installation of Gas Lines of Steel Pipes with Operational Pressure of Up To 4 Bar
G 462 Part 2	Gas Lines of Steel Pipes with Operational Pressures of More Than 4 Bar and Up to 16 Bar; Installation
VP 265 ff	Systems for Processing and Supplying Biogas into the Natural Gas Network
Source:	Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Postfach 14 01 51, 53111 Bonn, Germany

Appendix 12

Test Plan for Work Material According to BetrSichV by Qualified Personnel of the Biogas System

<u>Sample</u> (Work material= control methods)

Name of the work material	Last test	Next test	Deficiency detected? Yes	Deficiency detected? No	Deficiency immediately remediated? Yes	Deficiency immediately remediated? No	Test results, notes, comments Possible entry into operating log	Name of test organization qualified person	Notification acknowledged by management
1. CHP unit complete visual inspection/ functional test									
2. Substrate pumps, visual inspection/ functional test									
3. Gas storage Visual in section/ functional test									
4. Gas compressor Substrate pumps, visual inspection/ functional test									
5. Emergency flare, visual inspection/ functional test									
6. Agitators, visual inspection/ functional test									
7. Solids feeder Substrate pumps, visual inspection/ functional test									

Appendix 12

Name of the work material	Last test / Next test	Deficiency detected?		Deficiency immediately remediated?		Test results, notes, comments	Name of the qualified person at the test organization	Notifi-cation ac-knowl edged by man-agem ent
		Yes	No	Yes	No			
1. EX-zone of digester in which devices with their own ignition sources are present								
2. EX-zone of the gas storage in which devices with their own ignition sources are present								
3. EX-zone Condensate separator with submerged pump								
4. Operator's inspection/test log book								
5. Check of the performed electronic test								
6. Check of the protection equipment and PPE								
7. Check of the safety labelling								
8. Check of the escape routes and emergency plans. Additional checks according to need and implementation of the respective biogas system corresponding to the legal requirements and standards								
9. Automation components Visual inspection Electrical inspection by an electrician Functional test of the safety function control technology (emergency off system, fill level monitoring, etc.) Functional test of all sensors, switches, and drives								

Appendix 12

Tightness Test for Gas-Carrying Container Parts and the Gas Storage

1. Tightness Test

In principle, gas-carrying container parts and gas storage can have a low permeability for gaseous substances. Therefore, the test of the technical tightness must be carried out through verification that no significant leak points are present (direct tightness test), or through verification that the leakage rate does not exceed a permissible limit value (indirect tightness test).

The direct tightness test represents a practical, reliable test method, especially for biogas systems operated with the maximum operational pressure of 5 mbar, (membrane domes, and membrane storage bags).

The indirect tightness test yields reliable results with rigid enclosed biogas systems, which are operated at higher operational pressures and have only very low gas temperature fluctuations in the gas room.

1.1 Direct Tightness Test

1.1.1 Test Pressure

For testing the technical tightness, the digester, gas-carrying container, and gas storage must be subjected to a sufficient test pressure so that an escape of gas through a leakage point can be caused. In principle, the test must be performed with 1.5 times the maximum permissible operating pressure. If this is not inherently possible for the system (e.g., with freestanding elastomer single membrane dome gas storage systems) the test must be performed with the maximum permissible operating pressure.

1.1.2 Test Media

Preferably, air is used as a test media for systems that have not yet begun operation. If the tightness test is to be performed in systems that have already begun operation, as a rule, gas detectors must be used, which can safely detect methane, in particular, in the measurement range of 0 to 1% vol. Fog forming agents that are introduced into the gas phase have also proven useful for the detection of leaks.

1.1.3 Tightness Test

The direct tightness test can be performed as a visual inspection with a foam-forming agent, with fog generating agents, or as a test with a gas detector. In particular, the wall connection of container coverings and the connection nozzles, which are located in the gas area of the container, must be tested for tightness.

Appendix 13

1.2 Indirect Tightness Test

1.2.1 Test Pressure

For testing the technical tightness, the digester, gas-carrying container and gas storage must be subjected to a sufficient test pressure so that an escape of gas through a leakage point can be caused. In principle, the test must be performed with 1.5 times the maximum permissible operating pressure. If this is not inherently possible for the system, the test must be performed with the maximum permissible operating pressure.

1.2.2 Permissible Leakage Rate

The permissible leakage rate includes the losses as a result of the permeability, e.g., of membranes and their fastening components, as well as all seals mounted on the biogas container. With respect to the possible measurement accuracy under normal operating conditions with a test pressure of 20 hPa, the permissible leakage rate amounts to:

up to	50 m^3 nominal capacity	0.4 m^3/24h
up to	100 m^3 nominal capacity	0.6 m^3/24h
up to	200 m^3 nominal capacity	0.8 m^3/24h
up to	500 m^3 nominal capacity	1.0 m^3/24h
above 500 m^3 nominal capacity		2% vol. nominal capacity/24h

If the measurement occurs with a test pressure other than 20 hPa, the permissible leakage rate must be multiplied by the factor **X = test pressure/20 hPa**.

1.2.3 Tightness Test

For the indirect tightness test, the gas container is placed under test pressure, and the volume loss over the duration of the test period (creep testing) is determined. Derived from the state equation of gases, the following applies for the volume loss ΔVN:

$$\Delta VN = VA * pA/pN * TN/TA - VE * pE/pN * TN/TE$$

where:

- VA/E = volume of the enclosed gases at start of measurement/end of measurement
- pA/E = atmospheric pressure + test pressure at start of measurement/end of measurement
- pN = standard pressure = 1013.25 hPa
- TA/E = absolute temperature at start of measurement/end of measurement
- TN = standard temperature = 273.15 K

Appendix 13

The leakage rate is obtained by dividing the volume losses ΔVN by the measurement time.

Depending on the possible ways to perform the measurement determined by the construction type of the biogas container, the volume loss can be determined in two different ways:

- Measurement of the change of volume with a constant test pressure
- Measurement of the change of test pressure with a constant volume (VA = VE)

During the test period, the test gas quantity enclosed in the gas container is subjected to the following ambient conditions that cannot be influenced, such as temperature change and change of the atmospheric pressure, which exert the following influence on the test gas quantity:

- at constant test pressure: 3.5% volume change per degree K of temperature change
- at constant test volume: 3.5 hPa test pressure change per degree K temperature change
- at constant test pressure: 1% volume change per degree hPa of atmospheric pressure change
- at constant test volume: 1 hPa test pressure change per hPa atmospheric pressure change

For the measurement verification of the maximum leakage rates, specified in Section 1.2.3, it is recommended to minimize the above-named influences by using the smallest possible quantity of test gas.

If a complete filling of the biogas container is necessary for generating the test pressure, such that a volume dilation of the test gas is not possible, the maximum permissible overpressure of the container must not be exceeded during the test.

The duration of the test period must be defined such that the leakage rate can be determined clearly outside the measurement error limits. For this, the measurement errors for the measurement of volume, test pressure, atmospheric pressure, and temperature must be considered.

It is recommended to measure the temperature at a time when the temperature of the biogas container is not changed by solar radiation. The most favourable time to perform the measurement is in the morning before the start of the solar radiation. A measurement time period of 24 hours is recommended. If the measurement cannot be performed due to the type of construction of the biogas container, the biogas container is considered not tight. Supplementary protective measures must be deployed.

Appendix 14

Information of the Property Insurer

Information on Damage Prevention from the Perspective of Material Asset Protection (Informative)

The following information provides further measures to prevent material damage, supplementing the safety rules for biogas systems that are primarily aimed at personal protection. They have been developed by experts of the German Insurance Association (GDV) based on damage experience. They are intended to prevent or limit material damage.

This information is nonbinding. The insurance underwriter can also accept different safety provisions and measures in individual cases depending on the risk conditions and the risk assessment.

1. Fire Protection

1.1 Building Fire Protection

Systems and equipment that are important for the operation, e.g., machine room (CHP unit), control room, process control, as well as operating areas with increased risk of fire, e.g., work shop, must be separated in a fire resistant manner from the adjacent building areas, in order to prevent the spread of damage as much as possible. Rooms are considered separated in a fire resistant manner if they are enclosed by fire resistant ceilings and walls with fire resistant partitions of existing openings. Suitable fire alarm devices in the machine room should be able to detect excessive temperatures early. Thus, potential fires can be contained at an early stage.

Tip
VdS 195 "Technical Guidelines for the Fire Insurance and the Insurance of Operating Disruption due to Fire; Risks, Protection Goals, Protection Concepts, And Protection Measures"; VdS 2095 "VdS Guidelines for Automatic Fire Alarms; Planning, and Installation"

1.2 Protection of Electrical Equipment

- The electrical equipment must be constructed according to the accepted rules of electrical engineering (Regulation of the Association of Electrical Engineering, Electronics, and Information Technology, VDE e.V.)

- The electrical equipment must be tested before being taken in operation and must be maintained in good condition according to the legal and regulatory safety ordinances, as well as according to the VDE regulations. If deficiencies occur, they must be remediated immediately by electrical specialists.

Tip
VdS 2046 "Safety Regulations for Systems up to 1000V", BGV A3 "Electrical Systems and Resources", VSG 1.4 ""Electrical Systems and Resources"

- If over voltage protections are missing, over voltage due to lightning strikes or other causes can lead to damage of the system control and to disruptions of the operation. Therefore, over voltage protection (internal lightning arrestor) and consistent potential equalization are required for the electrical equipment and for electronic control, data processing, and telecommunication systems. The network form as a 5-conductor network (TN-S System) in conjunction with the potential equalization serves to avoid equalizing current. For larger systems, measures of the lightning protection Cass III may be required.

Tip
VdS 2017 "Lightning and Over voltage Protection for Agricultural Operations" and VdS 2010 "Risk Oriented Lightning and Over voltage Protection, Guidelines for the Prevention of Material Damage"

1.3 Organizational Fire Protection

- Work representing a potential fire hazard is permitted only with written permission by the management of the organization (permit procedure for work involving fire hazards).

Tip
VdS 2008 "Work with Fire Hazards, Guidelines for Fire Protection"

- Fire extinguishers of the fire classes A, B, and C according to DIN EN 3 must be installed at suitable locations and must be maintained in operational working condition.

Tip
Workplace Guideline "ASR 13/1.2 Fire Extinguishing Equipment"

- Containers with fresh oil and used oil must be stored outside the machine room if they are not procedurally integrated.
- Oil catch basins below the motors must be emptied and cleaned regularly.

Tip
VdS 2000 "Guideline for Fire Protection during Operation"

2. Operation of Machines and Equipment

2.1 CHP unit

- Depending on the contents of hydrogen sulphide and/or silicon compounds, the lubrication properties of the motor oil can be reduced, or deposits at pistons, bushings, and valves can cause abrasive processes (increased wear). Both effects can lead to substantial damage.

- Therefore, the gas quality should be monitored continuously. Through appropriate gas cleaning, the contaminants can be removed in order to prevent damage and premature wear. The manufacturer's specification must be followed.
- With pilot injection engines, too small a quantity of pilot fuel can lead to an insufficient cooling of the injection valves. Therefore, the injection valves must be checked every 1200 to 1500 operating hours and changed if necessary. Dripping injection valves lead to serious damage at the pistons and bushings. This can result in potentially serious engine problems.
- An effective method to monitor the respective combustion chamber temperatures is a measurement with an alarm trigger for each cylinder. This way, damage due to overheating can be prevented through timely shut off.
- Gas motors can be adapted to lower quality gas with lower methane content through changes of the ignition point. Here, a knocking of the engine is generally not expected (biogas has a high knock resistance), unless the system is operated in a bivalent mode with liquid gas.
- Motors suited for biogas also have in individual cases still small amounts of non-ferrous metals (piston rod bearing bushing, oil cooler, camshaft bearing, etc.) and, therefore, are susceptible to acids. If the specified gas and oil qualities are not maintained, the motors can fail due to repairs already long before the scheduled larger service.
- For buffering of acids, for instance, the motor oil volumes can be increased. This way, potential contaminants are thinned. The oil change schedules and the oil qualities specified by the manufacturer must be

maintained. With increasing acid content, the motor oil loses its lubrication properties. Therefore, it is recommended that oil analyses adapted to the operating conditions be performed, with determination of the TAN value (total acid number). The results should be documented, and the intervals should be adapted accordingly.

- The exhaust system should be constructed from welded (not inserted or clamped) stainless steel pipes. Exhaust gas lines must lead the exhaust gases away hazard free. A distance of at least 20 cm to flammable building materials must be maintained.
- Feed and return lines of lubrication oil of the turbo charger should be checked regularly for tightness through visual controls.
- If the manufacturer does not specify service intervals, for gas motors, the following must be performed every
  - 20,000 operating hours – a partial reconditioning (check: cylinder head, turbo air cooler, piston rod bearings, pistons, and running bushings; exchange depending on wear; and every
  - 40,000 operating hours – a fundamental reconditioning, with exchange of all wear parts (generators, agitators, and separators must be included),
- for pilot injection motors, every 15,000 operating hours – a partial reconditioning, and every 30,000 operating hours – a fundamental overhaul.

For the CHP unit, a service schedule must be created in which all checks to be performed and all service intervals are specified.

Tip
Renewable Energy, Complete Overview of the Technical State of the Art and the Potential Danger, Status: March 2008, page 387. Free download at: www.gdv.de/Themen/SchadenundUnfallversicherung AllgemeineHaftpflicht-versicherung/inhaltsseite17075.html

2.2 Digester Container

- Digester containers made of concrete must be built with sulphate resistant cement. The concrete should have the strength class C30/37 (B35) or higher.
- Above the area always covered by the substrate, the container should be protected additionally through a coating or cladding. In this area, sulphur deposits occur that attack the construction substance.
- The motor of the agitator must be protected by a motor protection circuit. In order to avoid cable breaks, the cables should be replaced at regular intervals.

Appendix 14

It is recommended to use only winch capable cables of the V4A quality. Iron II chloride for buffering the acid can to corrode stainless steel if it is not dosed optimally. A failure of the agitator technology (cables, propeller) can result.

2.3 System Control

- If EC (Electro-Chemical) sensors are used for the gas analysis, they must be exchanged regularly due to their increased wear.
- The pH sensor and the temperature sensor should be replaced once a year to increase the reliability of the measurements.
- A maintenance contract for the components of the system control must be negotiated.
- If the system is not constructed by a general contractor, the interfaces between the individual system parts must be defined and documented accordingly.
- It must be guaranteed through appropriate measures (possibly through filters), that only clear air is fed to the machine room/the control room.

3. Environmental Protection, Aspects of Environmental Hazards

The construction and the operation of the biogas system must first occur in such a manner that people and the environment is impacted as little as possible. For this purpose, it is necessary that the relevant laws (e.g., Federal Construction Law [BBauGB], Federal Emission Protection Law [BimSchG] in conjunction with the corresponding regulations, Water Management Law [WHG], Fertilizer Law [DüngeMG], Fertilizer Ordinance [DüngeVO][MinöStG], Hygiene Regulation, (Petroleum Tax Law), as well as possible changes in the law, should always be heeded.

3.1 Water Protection

- According to the water management law [WHG], systems for storing and processing liquid manure and slurry must be constructed such that a contamination and endangerment of water bodies cannot occur. The systems must be constructed and operated according to the acknowledged rules of technology.
- The stability of the containers for fermentation and final storage must be verified through tests.
- In Zones I and II of water protection areas, the construction of systems for storing and processing of liquid manure and slurry is not permitted.

- **Systems for storing and processing of liquid manure and slurry must maintain a distance of at least 20 m from above ground water bodies, as well as runoff ditches, roadside ditches, etc., that do not carry water continuously.**

3.2 Recovery of Recycling Material

- With the recycling of the final substrate, it must be assured that it remains as pollutant-free as possible. It can be problematic to apply it as fertilizer for acreage that is used for agriculture or horticulture if co-ferments are used whose composition and degradation have not been analyzed sufficiently.
- In order to prevent possible damage of the acreage or the crop products with the recycling of the final substrate, a regular analysis according to the fertilizer ordinance/biowaste ordinance should be performed by accredited laboratories (e.g., by laboratories designated by government agencies according to the biowaste ordinance). If liquids are dispersed into open waters, regular assessments should be performed to prevent damage. Appropriate monitoring is extremely helpful to defend against claims that may be registered only later.

4. Insurance

The insurance of biogas systems requires special coverage concepts that go beyond the typical agricultural property and public liability insurance. For instance, the technical operational risk can be secured by a machinery failure insurance and machine service interruption insurance; the environmental risk can be secured by environmental liability insurance and the environmental damage insurance. An inspection of the biogas system by the insurer for the correct determination of the risk and for specifying the required insurance protection should be a normal course of action for the system operator as well as the insurer.

Contact your insurer to resolve questions or to seek clarification.

The technical publications of the insurance industry mentioned in the text can be obtained from:

VdS-Verlag
Amsterdamer Straße 174
50735 Köln
Germany

Contacts

Landwirtschaftliche Berufsgenossenschaft Schleswig-Holstein und Hamburg [Agricultural Occupational Health and Safety Agency Schleswig-Holstein and Hamburg]
Schulstraße 29
24143 Kiel, Germany
Telephone 0431 7024-0
Fax 0431 7024-6120
Email post@kiel.lsv.de

Landwirtschaftliche Berufsgenossenschaft Niedersachsen-Bremen [Agricultural Occupational Health and Safety Agency Lower Saxony-Bremen]
Im Haspelfelde 24
30173 Hannover, Germany
Telephone 0511 8073-0
Fax 0511 8073-498
Email info@nb.lsv.de

Landwirtschaftliche Berufsgenossenschaft Nordrhein-Westfalen [Agricultural Occupational Health and Safety Agency North Rhine-Westfalia]
Hoher Heckenweg 76-80
48147 Münster, Germany
Telephone 0251 2320-0
Fax 0251 2320-554
Email mailbox@nrw.lsv.de

Land- und forstwirtschaftliche Berufsgenossenschaft Hessen, Rheinland-Pfalz und Saarland [Agricultural and Forestry Occupational Health and Safety Agency Hessen, Rhineland Palatinate and Saarland]
Bartningstraße 57
64289 Darmstadt, Germany
Telephone 061 51 702-0
Fax 061 51 702-1260
Email info.da@hrs.lsv.de

Land- und forstwirtschaftliche Berufsgenossenschaft Franken und Oberbayern [Agricultural and Forestry Occupational Health and Safety Agency Franconia and Upper Bavaria]
Dammwäldchen 4
95444 Bayreuth, Germany
Telephone 0921 603-0
Fax 0921 603-386
Email kontakt@fob.lsv.de

Contacts

Land- und forstwirtschaftliche Berufsgenossenschaft Niederbayern/Oberpfalz und Schwaben [Agricultural Occupational Health and Safety Agency Lower Bavaria Upper Palatinate and Schwabia]
Dr.-Georg-Heim-Allee 1
84036 Landshut, Germany
Telephone 0871 696-0
Fax 0871 696-488
Email lsv@landshut.lsv.de

Landwirtschaftliche Berufsgenossenschaft Baden-Württemberg [Agricultural Occupational Health and Safety Agency Baden-Württemberg]
Vogelrainstraße 25
70199 Stuttgart, Germany
Telephone 0711 966-0
Fax 0711 966-2140
Email post@bw.lsv.de

Landwirtschaftliche Berufsgenossenschaft Mittel- und Ostdeutschland [Agricultural Occupational Health and Safety Agency Central and East Germany]
OT Hönow
Hoppegartener Straße 100
15366 Hoppegarten, Germany
Telephone 03342 36-0
Fax 03342 36-1230
Email mail@mod.lsv.de

Gartenbau-Berufsgenossenschaft [Horticultural Occupation Health and Safety Agency]
Frankfurter Straße 126
34121 Kassel, Germany
Telephone 0561 928-0
Fax 0561 928-2486
Email info@gartenbau.lsv.de

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Bundesverband der landwirtschaftlichen Berufsgenossenschaften
Weißensteinstraße 70-72
34131 Kassel, Germany
www.lsv.de

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