Operator responsibilities and safety obligation of the project owner

Prof. Dr.-Ing. Gerhard Rettenberger
FH Trier, University of Applied Science, Germany

presented at the
Training for Biogas Design Institutes on „International best practice Middle-Large Scale Biogas-Plant-technology planning, II“
14. – 17.5.2010 Beijing

1.Introduction

Every operator of a biogas plant has the responsibility that his plant does not

- affect the environment in a harmful way

or

- cause accidents which may injure people

Obviously there are various reasons at biogas plants which may cause accidents or dangers to human beings. In general these are:

- The danger to life and health through suffocate or poisoning, for example, through breathing of air which contains higher concentrations of carbon dioxide or hydrogen sulphide for examples in shafts and reservoirs. These two gases are heavier than air.
- Distribution of biogas which can generate explosive atmosphere. Biogas can be classified into a light, heavy or neutral gas comparing with air, according to its composition.
- Explosion of the explosive atmosphere (biogas and air mixture).

The following presentation gives information about duties plant operators has to fulfil due to German right and explains the technical details operators has to follow to meet all the requirements.

2. Duties out of the ordinance for worker protection (ordinance for safe operation of plants ("Betriebssicherheitsverordnung")

The operator has to make sure that the following topics have been worked out:

- Study to assess possible dangers to human beings
- Designation of the requirements for the equipment
- Designation of the requirements for the use of the equipment
- Designation of areas where explosive gas mixtures may occur
- Documentation about the explosion protection measures
- Study for necessary additional protection measures
- Teaching and instructions
- necessary inspections ot the plant and the equipment
- documentation

The ordinance makes a difference between normal equipment and those equipments which needs special control
Equipment means: the plant or the elements of a plant and the various tools
what equipment needs special control:

- All equipment and systems in areas where explosive gas mixtures may occur (explosion endangered areas)
- Systems and equipment which should guarantee secure functions
- Installations between different plant elements

The ordinance asks for a minimum standard the so called "minimum requirements" from the ordinance. This are divided into two parts:

- Organizational measures:
  - Providing sufficient instructions to the employees
  - Written instructions, permission for working, supervision especially when working in explosion endangered areas
  - Explosion endangered areas has to be marked with a warning sign at the access
  - No smoking and no open fire, no access for unauthorized persons in explosion endangered areas
- Measures to prevent explosions:
  - All possible gases or dusts has to be taken into account
  - All systems and equipments in explosion endangered areas are only allowed when they has been proofed in the document for protection against explosion

- All measures for protection against explosion has to be taken into account
- Employees has to be warned optically and acoustically before reaching explosive conditions
- Electrostatic electricity has to be taken into account when d Explosion endangered areas must have sufficient ways for escaping and rescue
- Employees should be equipped with rescue devices
- Before starting of the operation the plant and the total equipment in explosive endangered areas has to be controlled by special authorized persons. This persons must have special knowledge in the field of safety measures
- When the electricity is broken down the plant has to change into a secure condition
- Automatically working systems should be influenced manually if necessary by responsible persons

Especially for the organisation of the work in the explosion endangered areas the following points are important:

- Rules for responsibility, this means that the management of a plant organization should show clear structures
- Written instructions, this means that every work which has to be carried out should be described in detail
- Teaching and instruction even for visitors, this should be documented and signed by the instructed people
- Written permission for starting of work to make sure that only well equipped and competed workers are sent for the work
- Marking of the ways for escaping and rescue

The ordinance demands to mark dangerous areas. This means that all areas which are graded as a zone, has to be equipped with the following security signs:

P02

W21

P06

PO2 means: no open fire, this is strictly forbidden, for example no smoking
W21 means: this is an area where explosion atmosphere can occur
PO6 means: do not enter this area; stay outside, because this is a dangerous area

- Criteria for the selection of equipment and protection systems:

  - In areas where explosive gas/air mixtures can occur and which are classified as zone only special and official accepted devices can be used. They have to fulfil the following requirements.

  - In explosion endangered areas only the following devices can be used:
    - In zone 0: devices of category 1
    - In zone 1: devices of category 1 or 2
    - In zone 2: devices of category 1, 2 or 3

3. Control

Very important for all of the selection of safety measures is the question of how to control it. It can be said that if there is no control there is no devices or measure. Therefore the operator has to select the following points:

- Selection of what has to be controlled (devices, construction, machine), because this part plays a role in the safety measurement concept?
- How has the control to be carried out and is there a special procedure necessary?
- How often has the control to be done?

Due to the German ordinance the operator has to develop his own concept keeping in mind the official requirements, the general technical standard and the requirements of the manufacturer o the technical equipment. This gives the following systematic concept:

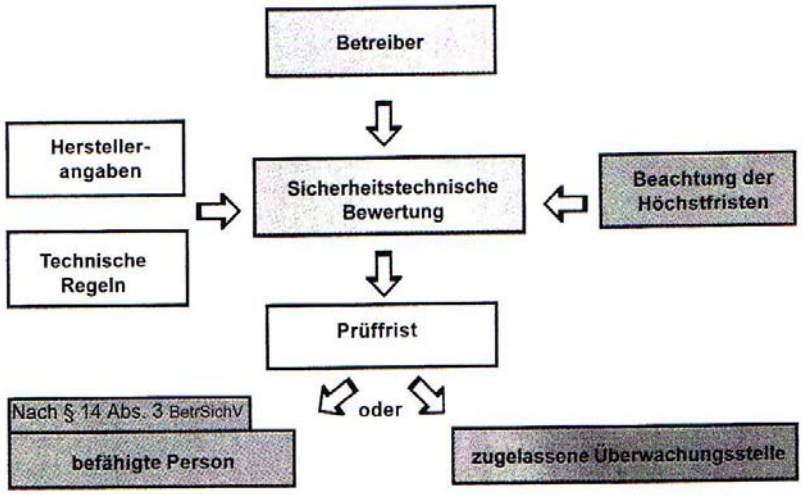

Figure 1: System for the controlling program

- Betreiber: operator
- Herstellerangaben: requirements of the manufacturer
- Technische Regeln: technical rules, technical standard
- Befähigte Person: Person who is doing the control with special qualification due to the ordinance §14, 3 rd. paragraph
- Sicherheitstechnische Bewertung: assessment due to safety standards carried out in the general safety assessment study
- Prüffrist: time period until the control has to be carried out again
- Beachtung der Höchstfristen: Consideration of the maximum time period until the control has to be carried out again
- Zugelassene Überwachungsstelle: official authorized controlling company

As a result of this conception the operator should have a detailed program for every parts and devices of the plant which gives him information of:

- at what time he has to make the controlling
- who has to do the controlling
- with what standards the controlling has to be carried out

When should control be done in general:

- Before starting of the plant
- after essential changes
- After maintenance of those parts which have an essential role in safety measures
- Regular after a certain period dependant from the safety assessment. Maximum period is three years.

4. Primary safety measures and remaining zones

One of the most important points due to the German regulation is the development of the conception to find out the possibly dangerous parts o the plant (assessment of risks and dangers). For this the operator has to investigate his plant if there is any possibility for the production of explosive gas/air mixtures and the presence of ignition sources. If there is any risk the operator has to select the necessary measures (safety measures) to avoid dangers to human beings and the environment. To select the measures the following hierarchy should be taken into consideration:

- Hierarchy of the explosion protection measures:
    - Primary explosion protection measures
      (Avoidance of explosive gas mixtures)
    - Secondary explosion protection measures
      (Avoidance of ignition sources)
    - Tertiary explosion protection measures
      (Measures to avoid that the affect of an explosion may cause any damages)

This means that primary measures should have priority against the other measures if possible. For reaching this aim various options are possible. Therefore in biogas plants the following technical points should be taken into consideration for primary explosion measures:

- Selection of a certain technical process, for example a process which is under overpressure is better than a process which has a vacuum pressure because there is no ability that air can be sucked inside of the plant
- Gastight pipes and fittings, no air can come inside the plant our outside
- Controlling of the gas concentration to prevent explosive mixtures
- Intertization to prevent explosive mixtures
- Possibility to shut down the plant before reaching explosive mixtures
- Natural and technical ventilation
- Gas tightness of connections between two parts of the plant
- Controlling of the level of the water in the condensate tank
- Mechanical protection against damage, damage can cause the possibility that air comes inside of the plant
- Materials less burnable around openings to keep them gastight
- Controlling of the water level in the reactor to avoid damages which my cause air intrusion or emissions
- Water closure valve should not lose the water to keep them gas tight
- Controlling of the gas tightness of the plant, only control makes it sure that the gas tightness is existing

- Only use of special materials f.e. the membranes in gas storages, controlling of the materials, to keep them gas tight
- Openings in rooms with gas storages for venting in between 700 cm² and 2000 cm² , this is a measure of ventilation to dilute gas/air mixtures to avoid explosive atmosphere
- Protection distances between gas storages and other buildings which are not part of the plant should be at least 6 m or the gas engines, when the buildings are higher than 7,5 m then the distance should be calculated after the following equation: 0,4 . H1 + 3 m (H1 height of the building). Inside of this area no flare, no open fire, no smoking, the plant should be surrounded by a fence, the zones should be marked. Venting of gas into the open atmosphere should be done at least one meter above the roof and 5 m away from buildings and roads.
- Gastight pipes for pressure up to 1 bar, if the gas pipe does not suit for this pressure the gas pipe is considered as not gas tight. This means that inside of the pipe in the case of vacuum pressure an explosive gas mixture has to be expected.
- Gastight pipes in the analyzer system
- Special standards for those equipments which have essential functions in the safety measurement system
- Process controlling system of a certain standard

Special primary measures are necessary in a room with gas control and ventilation

- When exceed 20 % of the lower explosion limit an alarm has to be given. Then a mechanical ventilation should start with an air changing value of 5
- When exceeding the lower explosion limit of 40 % the gas flow has to be stopped automatically from an outside valve
- The gas analyzer need a special acceptance by an officially authorized institution
- The system should work even when there is no outside energy supply
- The analyzer should be installed not in the venting air stream
- The alternative solution is a constant venting with permanent control

The following figure 2 shows in the drawing above an example of a primary explosion conception for a gas pumping system with controlling of the gas composition by use of two analyzers.

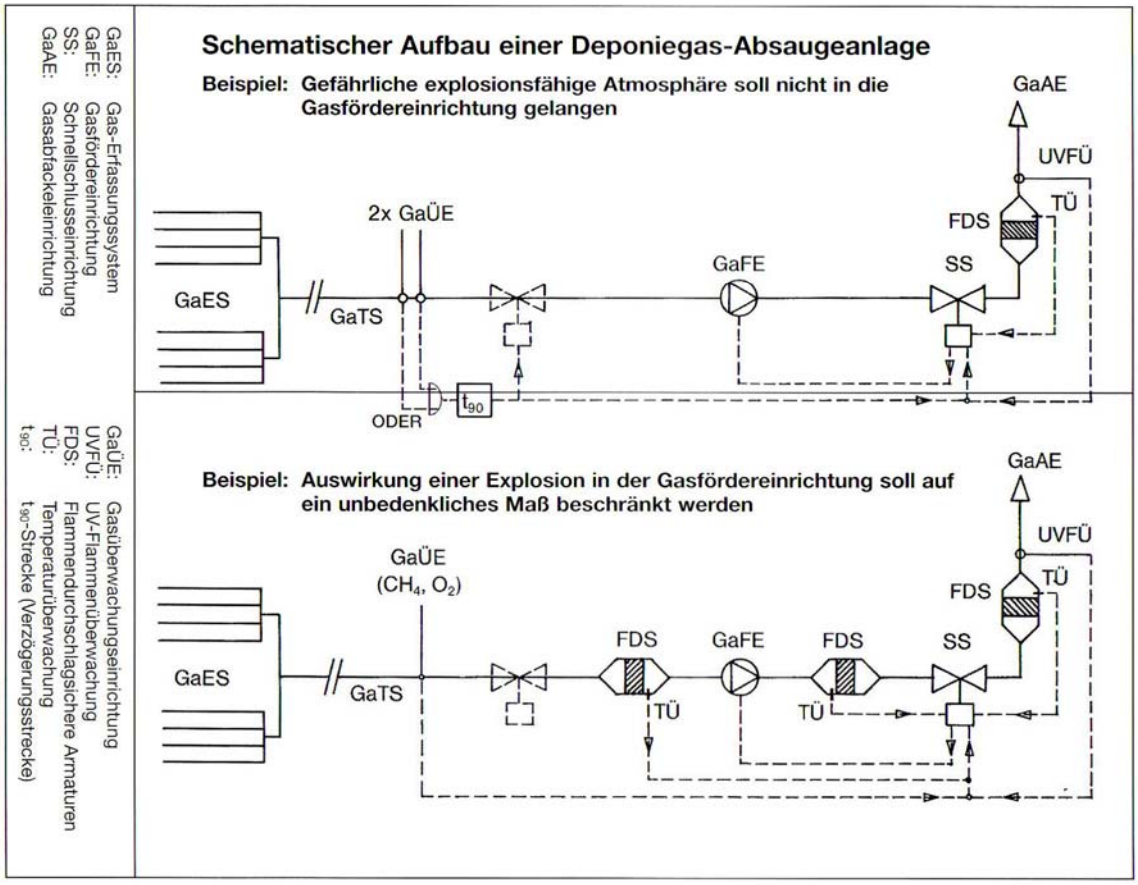

Figure 2: Primary explosion conception and measures for a gas pumping station in a biogas plant (above). Below is the same unit but with tertiary measures (see below).

GaES: Gas collection system
GaTS: Gas pipe
GaFE: Gas pumping unit
SS: Rapid working valve
GaAE: Gas flare
GaÜE: Gas controlling unit (analyzer)
UVFÜ: flame controlling device with UV light
FDS: Flame arrestor
TÜ: Temperature control unit
t_{90}: t_{90} distance (delaying distance (pipe))

In this example the inner area in the pipe is classified as zone 1 (see below). This means that explosive mixtures can occur. The blower is classified in most cases as a ignition source. Therefore safety measures are necessary. The second ignition source in that example is the flare. To prevent that the pump can ignite the gas/air mixture the composition of the gas inside the pipe is controlled. But as it shown in the figure 2 this hat to be done with two fully independent analyzers which are public licensed by an official institution for this kind of measurements.

As the analyzer needs some seconds to indicate the exact value there is a certain possibility that the gas mixture can reach meanwhile the pump. To avoid this the distance between the point where the gas is taken out of the pipe for to be analyzed and the pump should be enough. The distance is calculated in dependence from the speed in the pipe in that way that the gas could not reach the pump until the analyzer has indicated 90 % of the final value. Therefore this distance is called t_{90} distance.

The flare can only be protected with tertiary measures. This will be describes below.

5. Remaining areas with explosive gas mixtures

After primary measures in a safety conception it has to be proven if all risks are eliminated. If this has worked the conception is finished. In most cases this can not be achieved. Therefore the following additional steps are necessary:

Consideration if there are still areas where possibly explosive gas mixtures may occur?

Assessment of the remaining risks which can be done by use of general examples

If there are still explosion risks remain, they will divided into three classes, the so called zones characterized with their spatial extension: This zones are described as follows:

- **Zone 0:** contains areas, where explosive mixtures may occur **constantly**, over a **long period** or **often**
- **Zone 1:** contains areas, where explosive mixtures can occur **occasionally**
- **Zone 2:** contains areas, where normally **no** explosive mixtures may occur and if still this can not be excluded then only **very seldom** and in a **short time period**

Important is that this zones are only taken into consideration for the regular operation. For special operational states like start of the plant or shutting down of the plant no zones has to be defined.

To define the zones it is usual to compare with examples which are given in various handbooks. They contain a list of numerous cases which may be typical for biogas plants. Some examples are listed below:

Designation of zones:

- The gas space in a biogas reactor is zone 1
- If for desulphurisation air is blown into the reactor up to an oxygen concentration of 12 % the gas space is designated into zone 0.
- areas, where there is substrate have a zone
- Around openings into the surrounding space is a zone, zone 1 until 1 m and additional zone 2 until 3 m
- The inner space of a condensate tank with natural venting is zone 1

The following drawings show typical designations for zones at digesters:

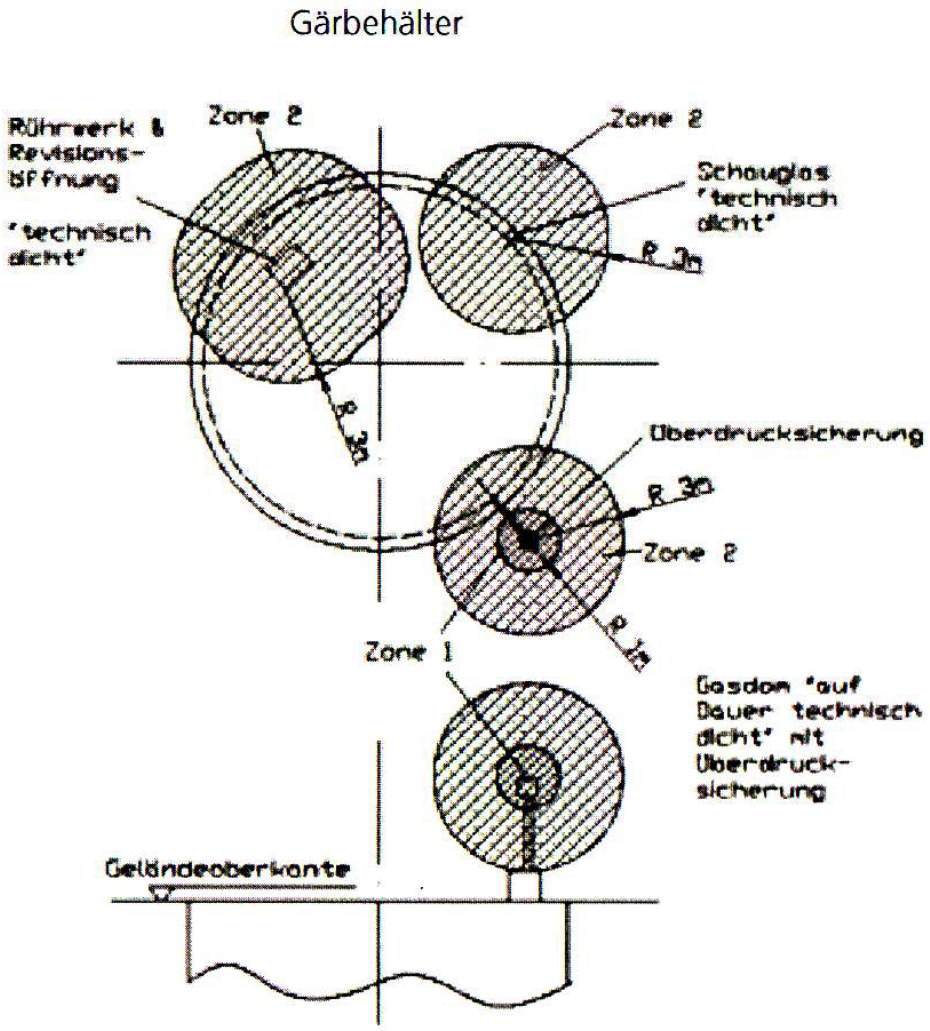

Figure 3: Zones at digestors (from German regulations “Safety rules for Biogas Plants”, published by the “Agricultural Society for Worker Protection; “Sicherheitsregeln für Biogasanlagen”, published by “Landwirtschaftliche Berufsgenossenschaft”)

Gärbehälter: digester
Rührwerk: stirrer
Revisionsöffnung: opening for control and maintenance
Technisch dicht: gas tight due to technical standards
Schauglas: window for optical control
Überdrucksicherung: device for over pressure control
Gasdom: unit on digester where the biogas is collected and leads away
Geländeoberkante: level of the area

Beispiel – Einfacher Folienspeicher im Freien

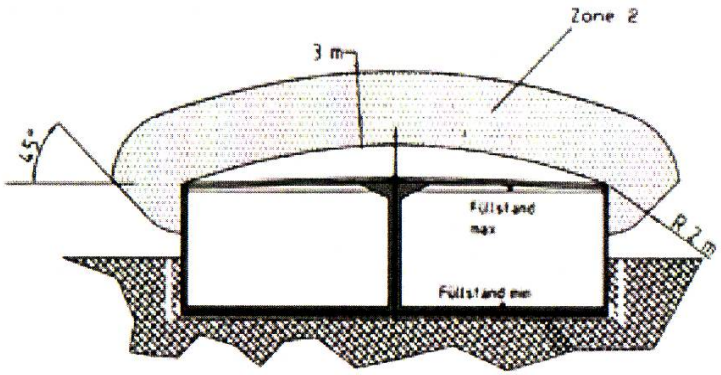

Figure 4: Example – Simple gas storage with membrane in the open atmosphere on top of a digester

Füllstand: water level

If the assessment of the risks shows remaining zones after the primary safety measures additional explosion measures are necessary. In a first step secondary measures has to be taken into account.

6. Secondary explosion measures

Secondary explosion measures means:

- Avoiding of ignition sources

Various measures are necessary to obtain secure conditions. Some of these are the following:

- Utilization of special materials so that no ignition spark can occur with sufficient ignition energy

- Using only of those electrical equipment which are explosion proof
- Earthing with potential equalization , f.e. flanche between PE pipes need earthing and potential equalization, painted fittings need special assessment
- Electrical potential equalization has to be provided (earthing)
- The potential equalization should meet the public regulations

- The selection for the equipment has to be proven for the existing zones
- Electrical equipment has to follow public standards and it has to be make sure that this devices can not be a source for ignition)
- The categories for the used equipment has to be taken into account
- For biogas equipment the explosion group II A for temperature class T1 has to be selected
- Equipment to be used in the various zones has to provide a certification

- The various devices should be suitable for their use

- There should be a minimum distance to hot surfaces
- Turbo turbines should not become a source for ignition
- Sufficient distances f.e. 6 m between gas storage tank and motor container should be meet (for more details see above)

- Gas analyzer should not become a source for ignition f.e. by using a flame arrestor

- Fire alarm units should be suitable for the existing zones

- Electrical equipment in the biogas reactor should be suitable for zone 1 or 0 otherwise they should be free of electrical power when they come out of the water

- Where there are zones only electrostatic conductive pipes or materials can be used, PE-HD-EL or PVC-EL

Due to European laws technical equipment should be characterized with the following description and should meet the technical standard for the use in biogas surroundings. This is shown in the next figure 5.

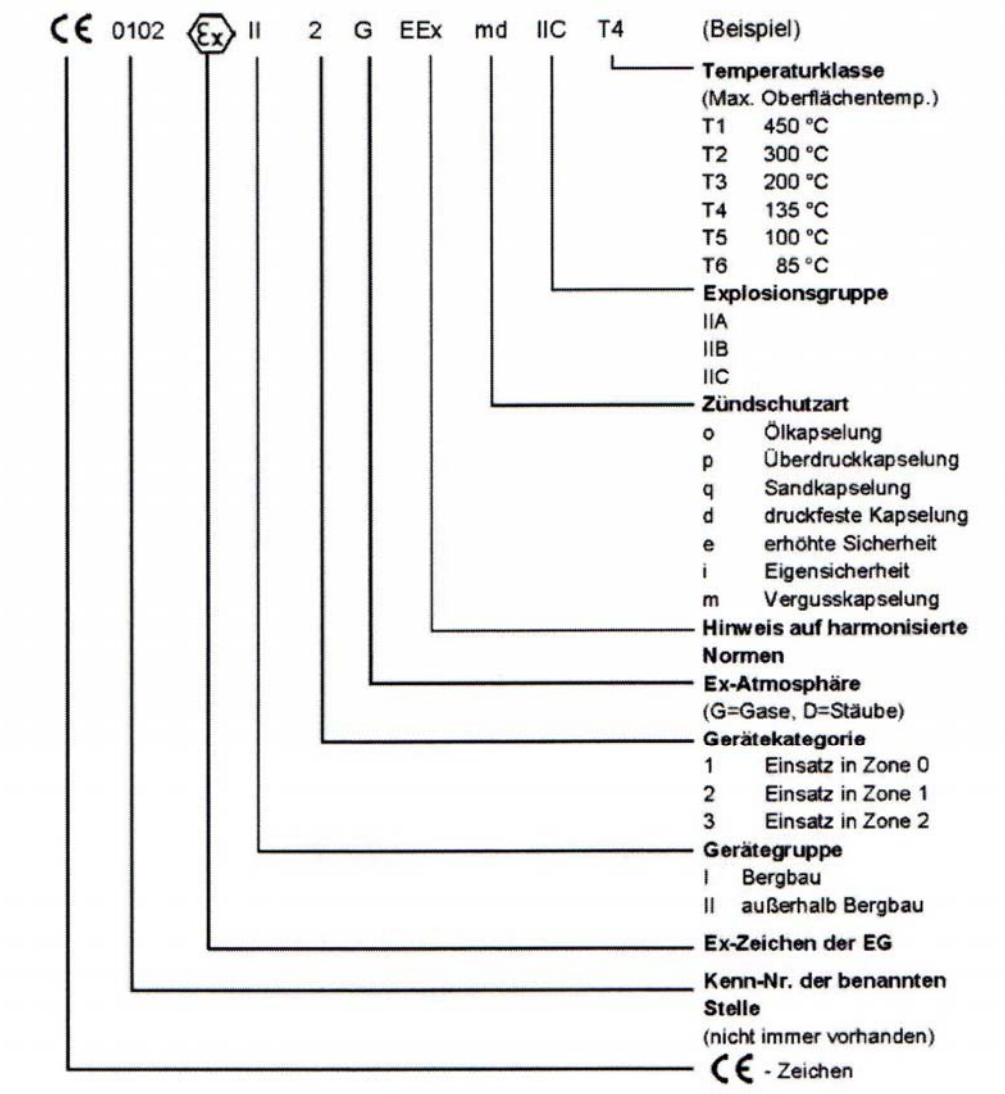

Figure 5: Marking of electrical equipment for zone 1

Temperaturklasse: temperature class
Max. Oberflächentemperatur: Max. surface temperature
Explosionsgruppe: Group of explosion, for biogas IIA is sufficient
Zündschutzart: Technical method of ignition protection
Hinweis auf harmonisierte Normen: Hint for harmonized European norm
Ex-Atmosphäre: Ex-Atmosphere (explosive gas/air mixture)
Gerätekategorie: category of equipment or device for use in zone 1 or zone 2 or zone 3
Gerätegruppe: group of equipment or device ether in mines or not in mines
Ex-Zeichen der EG: Ex mark of the European community
Kenn. Nr. der benannten Stelle: Number of the official institution not always there
CE Zeichen: mark for CE

For biogas use the equipment should have at least the description like in the figure 5. Even the temperature class is sufficient for T1. IIC is necessary for biogas. md is an option for the technical solutions but other options are possible. G stands for gas and is therefore necessary for biogas. Category 1 is necessary for zone 1 and II is enough because the device is used outside mines.

7. Tertiary explosion measures in a gas pumping station

If primary measures and secondary measures are not sufficient tertiary measures are necessary. This means that an explosion has to be accepted. Therefore the plant has to constructed in a way that an explosion does not damage the plant so much that workers will be injured or the environment will be influences negatively.

This makes it necessary that the plant can accept an inside pressure of about 7 bar and that the pressure and heat can not spread in the surrounding piping system and cause explosions there. In that case it has to feared that the explosion becomes a detonation with pressures of much more then 7 bar.

Figure 6 gives an example for a tertiary explosion conception of a gas pumping system.

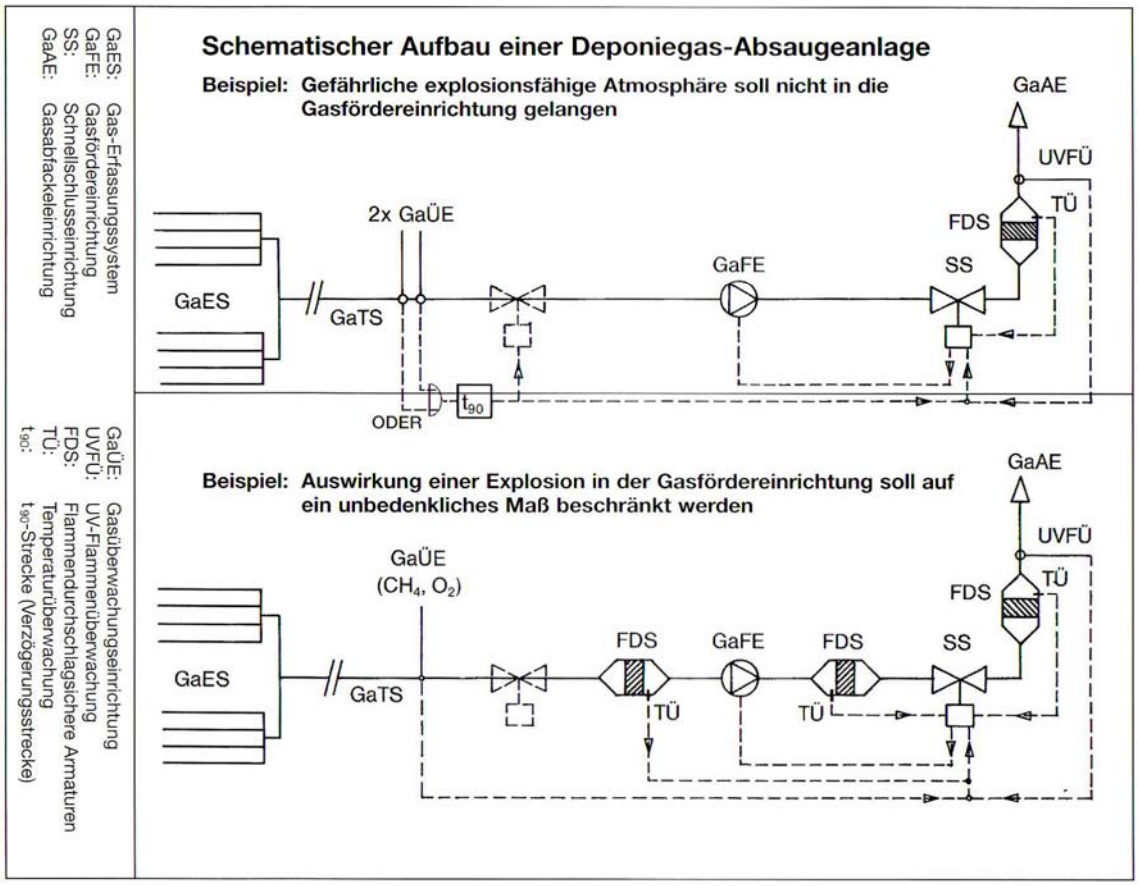

Figure 6: Tertiary explosion conception of a gas pumping system (below) in comparision to a primary conception (above)

GaES: Gas collection system
GaTS: Gas pipe
GaFE: Gas pumping unit
SS: Rapid working valve
GaAE: Gas flare
GaÜE: Gas controlling unit (analyzer)
UVFÜ: flame controlling device with UV light
FDS: Flame arrestor
TÜ: Temperature control unit
t_{90}: t_{90} distance (delaying distance (pipe))

In the case of a tertiary conception the pump has to be surrounded by two flame arrestors to prevent the distribution of the explosion. The total system has to be designed for a pressure of 7 bar. The flame arrestors have to be temperature controlled to prevent that in the case of a fire they will be going out of function. In that case the plant should be shut down through the temperature device. In the case of tertiary conception only one gas sampling point is sufficient. There is no need that they work independent.

The flare is also controlled with a tertiary conception. To prevent that the flame can ignite the gas in the pipe to the flare a flame arrestor is necessary.

8. Study to investigate the necessary measures for explosion protection

All the measures for the explosion protection has to be described and documented in a report. This report has to contain the following chapters:

- Description of the plant
- Responsible persons
- Description of technical details
- Description of the process
- Data of the used chemicals
- Assessment of possible dangers
- Safety conception

In detail the chapters should document the following points:

- **Description of the plant**
  - Description
  - Maps and drawings
  - Design of the plant
  - Escape and rescue paths

- **Descrition of the process**
  - Description
  - Process flow
  - Venting concept

- **Description of the used materials**
  - description
  - Data sheets of the used chemicals
  - Physical and chemical datas

- **Description of the assessment for possible dangers**
  - Description of how to identify the possible dangers
  - Assessment of the endangered explosive areas in the inner part of the plant and the outside parts
  - Possible dangers during normal operation, starting phase and stopping phase, during breaks in operation and cleaning of the plant
  - Map of the zones

- **Description of the measures for explosion protection measures**
  - Primary, secondary and tertiary measures
  - Requirements for the selection of the equipment

- **Organisational measures**
  - Written instructions for the operation
  - Instruction for the use of the equipment
  - Description of the individual equipment for protection
  - Documentation of instructions
  - Documentation of the system for giving permission for work
  - Description about maintenace and controlling periods
  - Documentation of the marking of the areas with explosive dangers

So this explosion protection document describes the total plants and the measures completely together with the necessary organisation and the detailed instructions for the workers.

9. Documentation, alarm plans

Important is that the operator of a biogas plant collects all the data from his plant in a special document. These are nor only the documents about the equipment but also about the controlling actions and the instructions to the workers. Also a conception for the fire brigade should by developed together with these experts and be described in that document. In summary the document should contain the following topics:

- Plan for the fire protection brigade
- Concepts for the alarm plan and how to fight against dangers
- Schematic diagram of the plant
- Plan for maintenance
- Conception for controlling
- Certification of the manufacturers of the equipment
- Certification for the suitability for the existing zones
- Certification for the gas tightness and controlling
- Certificates for the plant elements
- datas of the installed equipment
- Operational instructions for starting of the plant, operation, stopping and breaks

- Documentation of the explosion concept
- Assessment of the possible dangers

- Inventory of teaching and instructions

An example for an operational instruction for the workers which has to be available constantly at the plant and should be seen by everybody who is working there is given in figure 7.

It describes the following:

a)Betriebsanweisung: operational instruction
b)Gefahrstoffbezeichnung: description of the dangerous materials
c)Gefahren für Mensch und Umwelt: dangers to human beings and environment
d)Schutzmaßnahmen und Verhaltensregeln: protection measures and rules for behaviour
e)Verhalten im Gefahrenfall: behaviour in the case of danger
e)Verhalten bei Unfällen –erste Hilfe: behaviour in the cases of accident – first aid

In summary this instruction contains the following:

a) description of the working area (biogas plant, storages, sewers, shafts, storages for manure) and the kind of work which is to do like stirring, flushing, pumping, sampling, maintenance and repairing, stay in manure or substrate storages
b) manure and biogases like hydrogen sulphide, methane, carbon dioxide ammonium
c) gases can be released during stirring and dangerous gas concentrations can occur. Danger to life can occur because of H_2S, be cautious because H_2S paralyze the olfactory nerve and higher concentrations will nor be perceived, suffocation will occur because of CO_2 , explosions will occur because of CH_4, dangers to health will occur because of NH_3
d) never climb into the digester, storages, shafts deep storages without any protection equipment, it is not allowed to go into without breathing protection equipment which is independent from the surrounding air and rescue devices like rescue strap and equipment (crane). When working with manure or other substrates avoid any kinds of ignition sources like gas spraying facilities, no smoking, no tests with light, no welding or cutting sparks and bead of perspiration can be spread in storages or shafts which are far away. If this kind of work has to be done, ventilation has to be installed f.e. by use of a pump. Storages have to be covered.
e) never climb into the digester, storages, shafts deep storages without any protection equipment, it is not allowed to go into without breathing protection equipment which is independent from the surrounding air and rescue devices like rescue strap and equipment (crane). Take care for sufficient fresh air
f) When breathe in gases from manure or biogases breathe fresh air, unconsciousness persons bring in a stable position and look if the are

breathing, At once ask for the doctor and give hints to a possible poisoning because of H_2S, telephone number of first aid, doctor and emergency call

Betriebsanweisung

Arbeitsplatz/-bereich:
Biogasanlage, Güllegruben, Güllekanäle, Güllelagerstätten, Schächte usw.

Tätigkeit:
Aufrühren, Spülen, Pumpen, Umpumpen, Entnehmen von Gülle o. Substrat, Reparatur- und Wartungsarbeiten und Aufenthalt in Gülle- oder Substratarbeitsbereichen

GEFAHRSTOFFBEZEICHNUNG

Gülle- und Biogase
(Schwefelwasserstoff, Methan, Kohlendioxid, Ammoniak)

GEFAHREN FÜR MENSCH UND UMWELT

Die Gase werden insbesondere durch Bewegen von Gülle oder Substrat freigesetzt. Dabei können gefährliche Gaskonzentrationen entstehen, die sich über längere Zeit halten.

- Lebensgefahr durch Schwefelwasserstoff (H_2S)
  Vorsicht: H_2S lähmt den Geruchsnerv, höhere Konzentrationen werden nicht mehr wahrgenommen
- Erstickungsgefahr durch Kohlendioxid (CO_2)
- Explosionsgefahr durch Methan (CH_4)
- Gesundheitsgefahren durch Ammoniak (NH_3)

T
giftig
EX

SCHUTZMASSNAHMEN UND VERHALTENSREGELN

Niemals ohne Schutzausrüstung in den Fermenter, in Lagerstätten, Gruben oder Schächte usw. einsteigen.

Einstieg nur mit umgebungsluftunabhängigem Atemschutzgerät z. B. Frischluftsaug-schlauchgerät und Rettungsgurt sowie Rettungsgerät zulässig.

Bei Arbeiten mit Gülle oder Substrat sind jegliche Zündquellen zu vermeiden:

- Gasstrahlgeräte ausschalten
- Rauchverbot
- keine Lichtprobe
- keine Schweiß- und Schneidarbeiten durchführen, Funken und Schweißperlen können auch in weiter entfernt liegende Gruben fallen
  (Sind solche Arbeiten unbedingt erforderlich, so ist für eine gute Belüftung z. B. durch Gebläse zu sorgen. Gruben sind abzudecken.)

VERHALTEN IM GEFAHRFALL

Einstieg in Gruben usw. zur Bergung Verunglückter nur mit umgebungsluftunab-hängigem Atemschutzgerät, Rettungsgurt sowie Rettungsgerät.

Für ausreichend Frischluft sorgen.

Feuerwehr alarmieren!
☎ 112

VERHALTEN BEI UNFÄLLEN – ERSTE HILFE

Nach Einatmen von Gülle- oder Biogasen Frischluftzufuhr.

Bewusstlose Personen: Feststellen der Atmung und stabile Seitenlage.

Sofort Arzt hinzuziehen. Hinweis auf Vergiftung durch Schwefelwasserstoff geben.

Notruf
☎ 112

Ersthelfer: ☎ Arzt: ☎

Datum Unterschrift des Unternehmers

Figure 7: example for an operational instruction for biogas plants (from German regulations “Safety rules for Biogas Plants”, published by the “Agricultural Society for Worker Protection; “Sicherheitsregeln für Biogasanlagen”, published by “Landwirtschaftliche Berufsgenossenschaft”)

10. Other responsibilities

Besides the measures against explosions and dangers causes by gases it should not be forgotten that at biogas plants there are other duties to operators and that there are a lot of other possible dangers which should be taken into consideration:

- Designate one person who is responsible for the safety affairs at a plant
- Check for possible dangers
- Mechanical, electrical, chemical, biological dangers
- Dangers because of fires
- Thermal and physical dangers
- Other dangers for the employees (working during bad weathers, carrying of heavy loads)