Mixing of biogas from MBT plants with landfill gas, including technical and safety aspects, taking as examples Pohlsche Heide (Heisterholz), Luebeck (Niemark) and Goettingen (South Lower Saxony)

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Mixing of Biogas: Landfill Gas (LFG) and Gas from MB Treatment (MBT) – Technical and Safety Aspects

Keywords
Biogas, LFG, landfill gas, safety features and equipment, ex-zones, BetrSichV (Ordinance on Industrial Safety and Health), explosion protection document, calorific value, risk assessment document, normal operation, zoning, Directive 1999/92 EC

Abstract

When mixing biogas and landfill gas (LFG), problems always arise as regards the technical design and "tuning" of the plants ,as different calorific values (methane contents) exist in these plants. Some of these problems and solutions of the latter are presented in the following.

In addition, the safety-related design does not take into account the new possibilities of the 99/92 EU directive including a "new" definition of "normal operation" regarding zoning of the plants. There are different definitions as far as operation of the plant plant is concerned: e.g. normal operation, O&M work, failures / malfunction, start and stop, etc. This enables varying safety standards in the different fields.

1 General remarks

Landfill sites usually are perfectly suitable for the construction of fermentation-, biogas- or mechanical-biological residual waste treatment plants (MBT plants). Besides the fact that landfills are often located outside of urban areas, this site boasts the advantage that certain technologies are already available and may be used by both the landfill- and the MBT plant operator (such as electricity generation modules (often found in CHP units) or so-called „flares" (usually found in HTF plants). By admixing biogas to landfill gas, disposal of the latter can also be effected below its actual economic and technical utilisation (key word: calorific value). The combination of the utilisation of landfill gas with biogas naturally requires higher technical expenditure and the respective safety aspects need to be taken into account. Table 1 gives a short description of 3 MBT plants which have been installed at a landfill site.

Table 1: Short portrait of the Niemark, Pohlsche Heide, South Lower Saxony MBTs

Name of the MBT	MBT landfill Luebeck – Niemark	MBT Pohlsche Heide	MBT Goettingen – South Lower Saxony
Operator	EBL	GVoA	as-nds
Main company	HAASE Anlagenbau AG	ARGE Horstmann, Fechtelkord & Eggers-mann, Temme, Bad Oeynhausen	Amongst others: AMB für Verfahrenstechnik; different other main companies
Plant size / Throughput	146000 t/a	80000 Mg/a input	133000 t/a
Method (dry / wet fermentation)	Wet	Dry	Wet
Start of construction work / start-up	2004/2005	2004/2005	1.09.2005
Reactor volume	13600 m³	2400 m³	3x4500 m³
Gas yield	Approx. 9000000 m³/a	840000 m³/a	n.s.
Particularity	Aerobic after-treatment, wet	n.s.	n.s.

n.s. – not stated

2 „Problems“ and safety aspects

2.1 „Problem“ fault outage HTF at the Pohlsche Heide MBT

The Pohlsche Heide MBT covers the plant-internal supply at the Pohlsche Heide landfill to gas users such as a CHP, an RTO and a steam boiler. The temporarily occurring excess gas is thermally incinerated via an existing landfill gas HTF which also disposes of excess- or „poor“ landfill gas. In the case that the gas consumers of the MBT are unable to „utilise“ the accumulated biogas and the filling level in the gas container exceeds „MAX“, the excess biogas will be supplied to the landfill gas HTF via a gas transmission pipeline of a length of approx. 200 m.

Therefore, the HTF serves as a „control element“ as far as biogas operation is concerned, and is selected via the filling level in the gas reservoir (ON or OFF). As the HTF is constructed for continuous operation, it must be ensured that the flare is not used for periods which are so short, that extremely strong interval operation prevails. This would result in damage at the mechanical construction (e.g. burner system), the ignition system and at the combustion chamber insulation of the HTF (caused by repeated large temperature variations) (see Illustrations 1 and 2).

Illustration 1: Example of a burner with damaged burner nozzles (1)

Illustration 2: Example of a burner with damaged burner nozzles (2)

In the past, irregular faults occurred during the shared utilisation of the HTF which were not caused by the aforementioned problems. These problems could be attributed to the operation and control of the HTF. The flare was not directly deactivated via a signal but indirectly via a relay closing a gate in the gas line towards the HTF. Therefore, and as a result of the minimum gas pressure monitoring (monitoring: gas efflux rate >> than the flame backfire velocity), the gas supply to the gas line of the HTF was slowly interrupted. The HTF self-monitoring function thus registered a gas deficiency which led to safety-relevant deactivation of the HTF. The latter switched over to „malfunction“ which could only be acknowledged via the switching station at the equipment cabinet of the gas booster station / HTF unit (at a distance of approx. 600 m from the MBT plant control room). A second problem occurred with regard to the after-run time (purging of the combustion chamber), as the HTF does not switch off immediately. This after-run is adjusted directly at the HTF via an internal PLC. This was not taken into account on the part of the MBT as far as „deselection / OFF“ is concerned. Overlapping of both actions occasionally led to a fault outage of the HTF. Visualisation of the HTF operation at the MBT plant was found to represent another reason for irregular malfunction, as its own signal („selection“) was chosen instead of the actual signal belonging to the HTF („operation“), resulting in the aforementioned fault outage. In summary it may be said that all participating companies need to „attend“ to the necessary planning for the operation of an existing landfill gas - HTF with regard to preliminary arrangements and start-up.

2.2 Solutions with the technical „heat input“ design of the HTF on the South Lower Saxony MBT plant

Since September 1st 2005, 133000 t/a of residual waste have been treated biomechanically in the South Lower Saxony MBT plant. Amongst others, the accumulated biogas is used in two CHP units, an RTO, a dryer and a heating boiler. In the case of maintenance works or malfunction during the aforementioned utilisation possibilities, the accumulated biogas needs to be continuously disposed without harming the environment. For this purpose, the HTF of the Waldshut-Tiengen landfill which had ceased to be used was dismantled and re-installed on the site of the MBT plant.

Here, the HTF needed to be designed for operation with MBT gas, and not with landfill gas. Amongst other things, this measure aimed to thermally dispose of, or incinerate, the excess gas as fast as possible via HTF at a specific filling level in the gas reservoir until the latter showed a minimum filling level.

In this respect, the incineration of biogas in the HTF without harming the environment depends mainly on firing capacity and thus on the methane content and volume flow of the biogas. The primary gas pressure is also decisive for the volume flow in the HTF. The usual operating ranges of landfill gas HTF lie between 4 mbar$_{ü}$ and 99 mbar$_{ü}$. In this case, this corresponds to an adjustment range of 200 to up to 1000 m³/h or of approx. 1000 to up to 5000 kW at 50 vol.- % CH_4 (see equations).

$$H_u = E_{CH4} * k_{CH4} \quad \text{(Equation 1)}$$

$$H_u = 35.9 \text{ MJ/m}^3 / \ 3.6 \text{ kWh} * k_{CH4} \quad \text{(Equation 2)}$$

$$P_f = H_u * Q \quad \text{(Equation 3)}$$

E_{CH4} – Energy content methane

H_u – Lower calorific value [kW/Nm³]

k_{CH4} – Volume percentage methane

P_f – Heat input [kW/h]

Q – Biogas flow [m³/h]

Thus, the first „problem“ to be solved was the determination of the maximum flow towards the HTF, taking into account a biogas-methane content of approx. 60 to 65 vol.-% of CH_4 instead of the landfill gas – which has a methane content of 50 vol.-% of CH_4. According to the simplified formula given in Illustration 3, this results in a maximum of approx. 770 – 833 m³/h of biogas instead of approx. 1000 m³/h required for landfill gas operation.

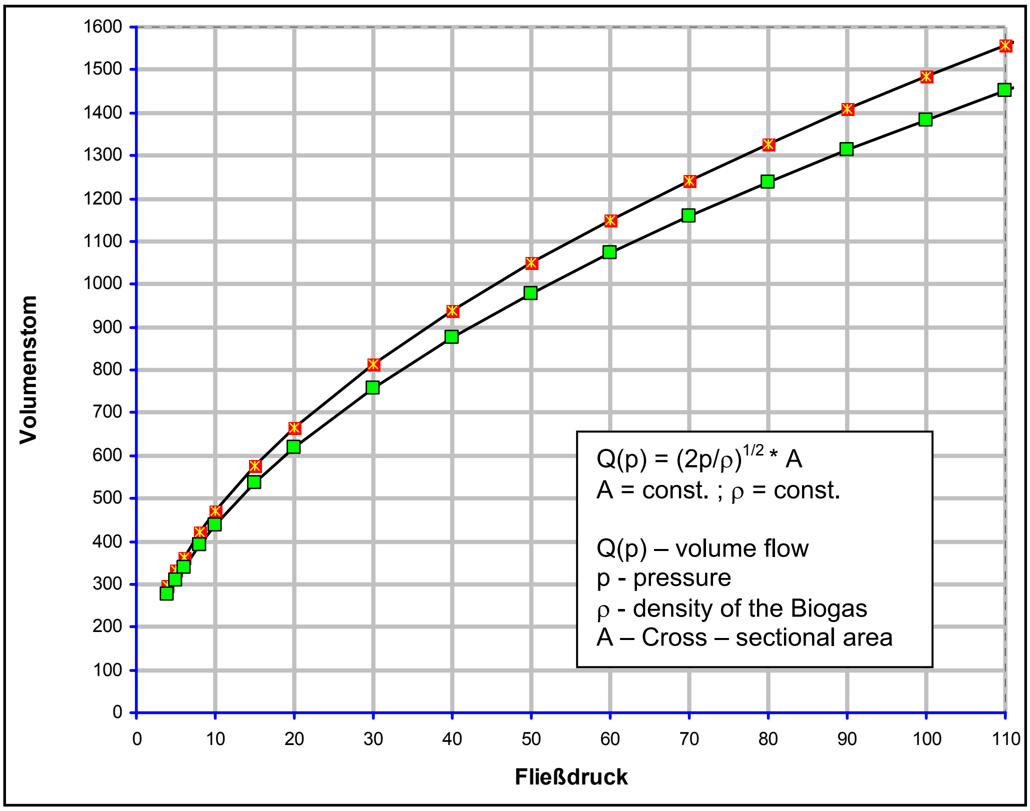

Illustration 3: Schematic representation of the correlation: primary pressure nozzle and flow in a HTF

The second „problem“ to be solved was the constant final pressure of the MBT plant which measured between approx. 85 and 100 $mbar_ü$ (static and „flowing“ pressure), as the gas volume flow towards the HTF increases with an increasing operating pressure (see Illustration 3). However, the higher the flow rate, the higher the heat input (see equation 3). This also applies to the start sequence. This means that a pressure-reducing valve needs to be installed in the gas line leading towards the HTF. Different amounts of gas may thus be oxidised in the HTF during the start-up phase (usually approx. 10 – 60 s) and during the operating phase (in this case: full load, if possible). Methane content and primary pressure are therefore decisive for the design of the HTF.

The third „problem“ to be solved at the South Lower Saxony MBT plant involved the position of the fresh air flare louvers the start-up procedure of the former landfill gas HTF during the start sequence (excess air). In order to reach maximum heat input within the shortest period of time (which in itself represents a problem because of the slow temperature control), the fresh air louvers are set to fully „open“ during the start sequence. Operation is thus leaner than stoichiometric. The temperature control is then released with a delay.

If MIN is triggered (meaning that the gas reservoir has been emptied to a certain degree), the HTF switches off and returns to its starting position. Subsequently, the procedure restarts, possibly with a new max. limit value.

2.3 Safety aspects at the Niemark MBT landfill

Prior to the start-up of any MBT plant, biogas plant etc., a safety-related inspection takes place. The flare needs to be carried out by a „competent person“ in the sense of the 99/92 EU - Directive or, as far as plants with a heat input or furnace thermal capacity of over 1 megawatt (in accordance with the 4th BImSchV) are concerned, by an „expert“ in accordance with § 29a BImSchG (Ordinance for the Implementation of the Federal Immission Control Act). The latter inspection does not need to be carried out by an institution. The experts in accordance with 99/92/EC or § 29a refer to people and each federal state „designates“ experts for different plants which are subject to licensing in accordance with the 4th BImSchV (for example plants in accordance with 1.2, 1.4, 8.1, 8.6 etc.). Furthermore, the „announcement“ includes different special fields as per „Item no. 3.1 c of the „Richtlinie für die Bekanntgabe von Sachverständigen nach § 29a Abs. 1 des BImSchG“ (directive regarding the announcement of experts) of the „Länderausschuß für Immissionsschutz (LAI)““ (committee of the states for the control of immissions), such as: „...2. Construction of plants,..., 3.Process control and design, … , 7./8. Provision with energies and media, 9.Electrical engineering, 11.Risk analysis, 16.Explosion protection, 17.Safety management ...“ etc.

Generally, either the operator or the constructor of the future plant is responsible for the selection of the expert (“competent person”). The person in charge should take into account the necessary qualification of the expert, as „expert“(“competent person”) e.g. in Germany is not a protected expression, with the exception of „public approved and sworn expert witnesses“.

In addition, an „explosion protection document“ needs to be developed in accordance with 99/92/EC directive prior to starting works. Within the scope of this explosion protection document, the main components, such as a digester / fermenter / reactor and gas utilisation system / gas system, and the essential ancillary systems should be considered and defined in detail including the required safety devices for start-up, shut-down and normal operation, the necessary maintenance and repair works and malfunction scenarios, as this constitutes an integral part of safety-related approval and plant protection. It is not required, as was the case in the past, to install the entire safety equipment for normal operation with regard to a possible breakdown or maintenance works.

For an MBT expert’s report (§ 29a BImSchG – approval certificate), general net costs as indicated on the market range between Euro 6,000 and Euro 40,000, depending on the scope of the tests and on the services rendered. But what do I, in my capacity as operator, need? An X-ray examination of the substrate ducts (Water Resources Act) should be questioned, as such an examination should already be carried out by the manufacturer in accordance with DIN DVGW (The German Technical and Scientific Association for Gas and Water) (welding certificates and manufacturer’s certificates). Do I, as the operator, achieve a higher level of safety when different weld seams are X-rayed by an expert or when I receive the corresponding manufacturer’s certificates? Rather, the question should be: Who is liable for what? And wouldn’t an X-ray examination in accordance with the Water Resources Act also require X-raying of the oil pipes of the CHP? Does this make sense? What does make sense?

This simple example shows that safety is not enhanced by expending costs on experts. Furthermore, one should always bear in mind: „There is safety, when the risk, which is composed of occurrence probability and significance of the event, is acceptable“. There is always a degree of risk that remains. Finally, the operator may decide what kind of security he wants to rely on: Insurance? Sureties? Confidence? Reports?

During numerous presentations and in our biogas and landfill gas specialist book, we inform you about the fundamental developments regarding this matter, according to the mottoes: „Discover the possibilities“ and: „Nothing is impossible“.

However, the following question is of vital importance: Is there really an „explosible atmosphere“ in my plant? The explosible atmosphere is illustrated in the ternary diagram (Illustration 4).

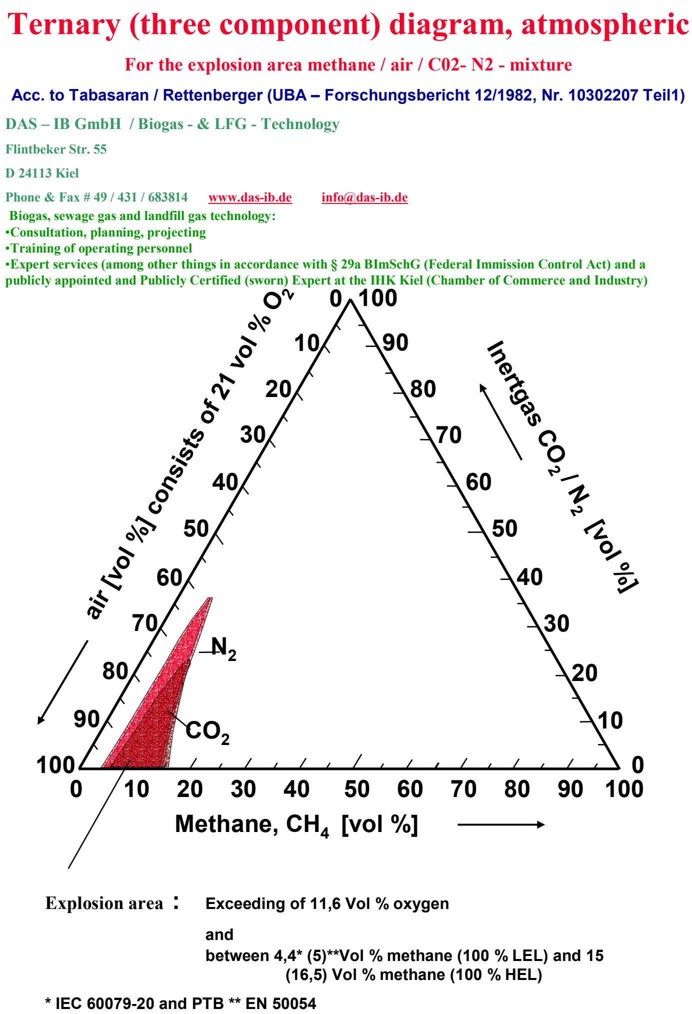

Illustration 1: Ternary (three component) diagram, atmospheric. For the explosion area me-thane / air / CO_2- N_2 – mixture

According to Illustration 4, an explosible area only develops at an oxygen content of > 11.6 vol.- % and above **and** a methane content of between 4.4 vol.- % CH_4[1] (corresponds to 100% LEL) and 16.5 vol.- % CH_4 [1] (corresponds to 100 % UEL) or between 5.0 vol.- % CH_4[2] and 15 vol.- % CH_4[2]. The premise for this is an atmospheric pressure between 0.8 and 1.1 bar_a and a temperature range between - 20 °C and + 60 °C. Beyond these ranges, inert or combustible gas is present instead.

[1] IEC 60079-20

[2] PTB EN 50054

And should an explosible atmosphere develop: Does one of the following ignition sources exist at the same moment in time or am I able to prevent these?

- Hot surfaces (e.g. components), self-ignition of methane from temperatures of > 500 °C onwards
- Flames and hot gases, depending on the shape, structure and retention time
- Mechanically generated sparks through friction, striking or abrasion
- Electrical plants (sparks, e.g. switching processes, loose connections or equalising currents)
- Electrical equalising currents, cathodic corrosion protection such as stray or reverse currents (see welding installations),body contact or ground fault or in the case of magnetic induction (I, HF) and lightning stroke
- Static electricity, e.g. discharge of charged conductive parts (isolated arrangement) or of charged parts made of non-conductive materials (e.g. plastics), bunch discharges or during separating processes
- Lightning discharges, direct or indirect (induction)
- Electromagnetic waves in the range of 10 kHz up to 3 billion kHz (HF), e.g. radio transmitters or welders; in the range of 300 million kHz up to 3 trillion kHz, e.g. focusing or strong laser radiation
- Ionising radiation, e.g. X-rays or radioactive radiation
- Ultrasound / Ultrasonic
- Adiabatic compression and shock waves
- Exothermic reactions including the self-ignition of dusts

With the start-up of the digester / gas reservoir it must be taken into account that, over a short period of time, an explosible mixture develops which needs to be discharged. In the Niemark MBT plant, this mixture emerged via the roof and separated in the ambient atmosphere to values below the lower explosion limit (LEL). From a methane content of > 25 vol.- % onwards (taking into account that, to reach this value, measurements need to be carried out several times a day during the start-up phase), the developing gas is thermally disposed of via the HTF at the beginning and, subsequently, via the CHPs during normal operation.

Due to these facts, the area where the biogas mixture is discharged is subdivided into defined zones (zone 0, zone 1 and zone 2) during the start-up, in accordance with EU Directive 99/92. The definition of such zones is revoked with the change-over of the operating gas >> of the UEL and start of normal operation.

In accordance with EN 60079-10 / VDE 0165 Part 101 and the EU Directive 99/92, endangered areas are subdivided into zones as follows, with regard to the frequency of occurrence and the duration of the existence of an explosible gas atmosphere:

Zone 0: A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is present continuously or long periods or frequently

Zone 1: A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally

Zone 2: A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only

Information for practical information: In contrast with past practice, operation of your plant now determines normal operation, and not an outside institution "competent person". Division into zones is included in the scope of the explosion protection document and should be undertaken in accordance with 99/92/EC Appendix II, Item 2.8 by qualified persons who are aware of the properties of the flammable materials, the process and of the service fluids. Likewise, the document should be developed in cooperation with the operating personnel.

In general, the following fundamental requirements apply to an explosion protection document:

- Identification of hazards
- Determination of ex-hazards and evaluation of an ex-atmosphere
- Determination of areas (zones), in which an explosion hazard may occur
- Identification of possible ignition sources
- Measures in order to prevent a hazard or respond to the latter, estimation of the effects of an explosion, where required („shot glass")
- Risk assessment and risk reduction measures
- Definition of criteria for the tools (ex-areas or zones)
- Separated description of organisational measures: normal operation, maintenance, malfunction etc.

3 Literature

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4.BImSchV	1985	4th Ordinance for the Implementation of the Federal Immission Control Act (Article 1 of the ordinance for the amendment and alteration of ordinances for the implementation of the BImSchG); version dated 20.06.2005
BImSchG	1974	Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena, version dated 25.06.2005
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99/92/EC	1999	Directive 1999/92/EC of the European Parlament and of the council of December 16th 1999 – on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC
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