LOW PRESSURE SEPARATION MEMBRANE: PURIFICATION OF LANDFILL GAS

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SUMMARY: The paper is presenting preliminary results of the on-site trial of the gas purification pilot plant, based on membrane separation technology, operating at relatively low pressure. This trial is an initial phase of a bigger project aiming at production of clean and high calorific value gas that could be used as a substitute of fossil fuel, e.g. for powering vehicles. The objectives of the tests are to find the optimum operating parameters and to prove the environmental impact and economic viability of this technology in comparison with other biogas utilisation options. Results of this project will determine the decision about further developments. The gas pre-treatment train has been extensively tested and proved adequate design. The membrane efficiency results and the economic model will be presented at the conference and will be available on request.

1. INTRODUCTION

Membrane separation technology for landfill gas upgrade has been employed on various sites across the world with considerable success. Separated methane at concentration 90% by volume with a methane recovery of 80% gives renewable replacement for diesel or petrol fuel for road vehicle or landfill site equipment use. Carbon dioxide, if compliant with relevant standards, can be also used for commercial purposes. The advantage of the process being developed by Biogas Technology is that the membranes work under relatively lower pressures than in other installations.

The research undertaken by Biogas Technology is divided by several stages:

- Gas pre-treatment
- Efficient utilisation of the Membrane Technology, linked later to storage and dispensing treated landfill gas
- Refinement requirements and use of by-product of the membrane process (carbon dioxide)
- Outset for manufacturing facility to mass produce the membrane modules in the U.K. for world export of the finished product.

A pilot plant was built specifically for the purpose of this research. The plant should achieve by design 90% concentration of methane on the product outlet and 80% methane recovery.

This project is included in the framework of the U.K. renewable obligation that planned 10.4% of electricity total sales from renewable sources in 2010.

The paper is presenting preliminary results of the on-site trial of the gas purification pilot plant, based on membrane separation technology. This is the first and second stage of the research and the follow up of the project will be based on its results.

2. MEMBRANE TECHNOLOGY AND OTHER GAS SEPARATION PROCESSES

2.1 Membrane Technology

The basis of the process is the differential permeability of gases through polymeric membranes. The permeation of gases involves three steps:

- adsorption of gas at the upstream side of the membrane
- diffusion through the membrane
- desorption at the downstream side of the membrane

Commonly, when landfill gas is introduced into the vessel, the carbon dioxide is permeating through the fibres while the methane is held back.

Operating parameters are set at this stage at 9 bar (g) pressure and a temperature of 10°C above the ambient temperature, which gives a range between 10°C and 30°C. These parameters can be adjusted following observation of the membranes' behaviour and selectivity.

Membrane modules require a pre-treatment to avoid contamination of permeation site. Main contaminants that could affect the performance and finite life of the membranes are water, particles, and trace constituents like halogenated hydrocarbons and hydrogen sulphide.

2.2 Comparison of alternative processes

Two other major processes are used to upgrade the landfill gas: chemical adsorption and pressure swing adsorption.

2.2.1 Chemical absorption

This process is based on physical or chemical absorption of a component in a washing liquid (often water). Carbon dioxide as well as hydrogen sulphide and CFC are removed. The washing liquid is regenerated in several steps of desorption. The methane recovery is approximately 95%.

2.2.2 Pressure Swing Absorption

Pressure swing processes rely on the different adsorption velocities of components to the activated carbon or molecular sieve. The pressure swing process operates in four steps:

- High pressure adsorption (from 25 to 40 bar)
- Depressurisation at ambient pressure
- Vacuum stripping of carbon dioxide
- Repressurisation of the product

The methane recovery is very high for this process (around 98%).

2.2.3 Advantages of the membrane technology

Operating parameters listed below indicate following advantages of landfill gas upgrading process using polymeric membranes technology:

- Low maintenance cost with no effluent or waste treatment
- Low overall running cost due to a low pressure and low temperature
- Long term durability

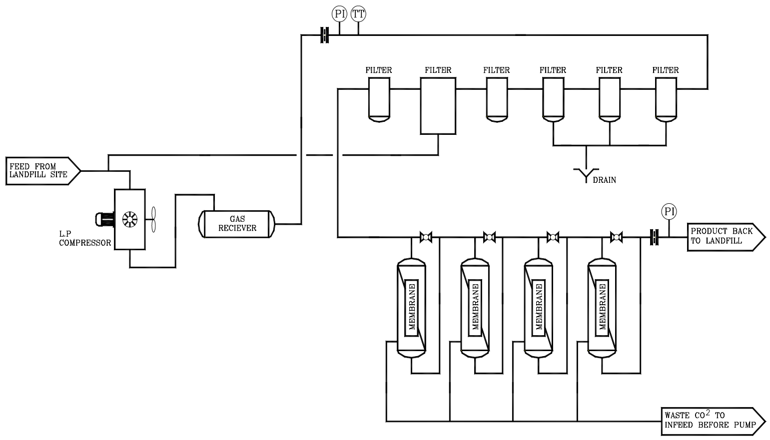

Figure 1. Schematic diagram of the pilot plant

The methane recovery does not exceed 80% with the configuration chosen for the pilot plant but it can be improved with a second stage of membranes in the permeate recycle. The product gas contains 90% methane by volume.

3. MEMBRANE PILOT PLANT

In this process, the landfill gas is fed through non-porous polysulphone membranes.

The pre-treatment unit comprises of a chain of filters including, in order from 1 to 5 (see Figures 1 and 4), water separator, particle filter, coalescing filter, activated carbon, desiccant package (dryer and filter). The regeneration of the desiccant column requires expending 15% of the flow of clean gas. The residues are exhausted by the line connected to the knock out pot located before the compressor. Each filter can be isolated and bypassed if necessary.

Figure 2. Four membrane units of the pilot plant

The pilot plant is composed of four membranes (Figure 2). Each membrane module can be by-passed. As membrane modules are in a serial configuration, each membrane has a different permeability in order to optimise the separation. The process connection with the existing landfill gas installation has been carried out to avoid disturbing the power generation on site. This means that all the gas taken from the system is returned back to pipes, with no interference with existing system. The connection of the permeate gas is located on the suction side of the gas train at -100 mbar (g). Thus, the permeate flux which is function of the differential pressure between permeate and product can benefit of this suction.

Pilot installations have been the most common approach to refine the knowledge about the technology and determine optimum parameters to operate and develop technique and economic model for full scale plant. Temperature, pressure and flow are measured in various points crucial for the process. Gas samples can be taken in ten different points along the process line.

The pilot plant is equipped in supplementary control, sampling and monitoring points enabling extensive monitoring and control of the separation process. Hazard Operability study (HAZOP) carried out before commencing of the trials resulted in implementing over 300 actions giving the operator confidence in safe operation of the plant and associated equipment.

4. TRIALS

4.1 Method

Programme of tests has included analyses of inlet, outlet and residual gases, condensate and filter residues in order to build a mass balance picture. The trial has been divided into short-term (dynamic) and long-term steps. The short-term phase intended to establish efficiency of the gas pre-treatment in its first stage and to find out the correct process parameters. The purpose of the long-term phase is to demonstrate the durability of the membranes and their response to changing gas parameters (pressure and flow). Effect of residual gas contaminants on the long-term performance of the membranes and their fate in the process is considered, too. An environmental impact and economic viability of the process is going to be assessed in comparison with other biogas utilisation technologies.

4.2 Results

4.2.1 Pre-treatment

The finite life of the membrane module depends on primary treatment of the landfill gas. Two main components have been analysed: water and hydrogen sulphide. Water and hydrogen sulphide have been tested with indicating tubes that offered an accuracy of 10 to 15%. The comparison with laboratory results has showed a divergence of 5-8%.

These results show that the efficiency of the filtration chain for water removal is correlated to the operating pressure (Figure 3). An increase of 32% of the water content in the pre-treated gas after the last filter has been observed for a pressure drop of 4 bars. The flow rate did not seem to affect the efficiency of the water removal.

Figure 4 represents the evolution of the water content in the filter chain. The same results have been observed for varying flow at the same pressure range.

The water removal results will be used to predict the finite life of the membrane modules with consideration of other options of filtration chain. In particular this regards, the need for the desiccant package, which reduces the compressor efficiency requiring 15% of the total gas flow for regeneration.

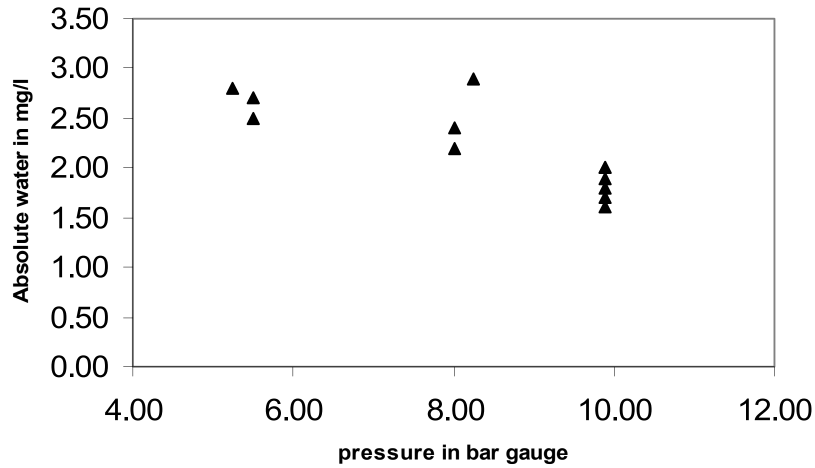

Figure 3. Water content as a function of the operating pressure

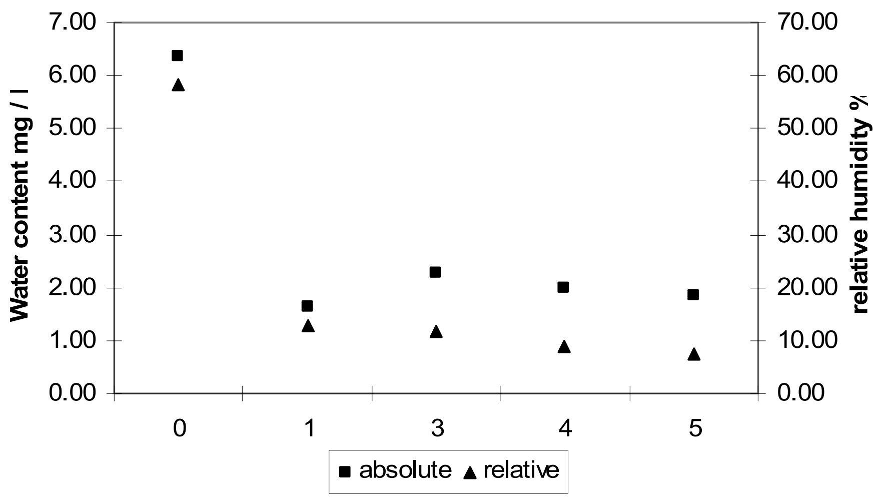

Figure 4. Evolution of the water content in the filter chain

Hydrogen sulphide concentration appears to be quite stable in all the process. A new design for the activated carbon filter has been investigated to prevent suspected negative effects of this pollutant on the membrane selectivity and life span. First indication of the field tests shows that hydrogen sulphide is permeating through the membranes without significant deterioration of the module efficiency.

4.2.2 Membrane modules

Due to delays caused by modifications of the pilot plant following HAZOP study and site implementation issues, this paper does not contain data on membrane efficiency and economics. The tests are continuing and the results will be presented at the symposium in October and will be available on request as a supplement to this paper.

5. CONCLUSIONS

The filtration system, in its actual configuration, removes more than 90% of the water content which is suitable for the membrane unit. However, hydrogen sulphide is not currently removed. The early second stage results have demonstrated permeation of the hydrogen sulphide through the membrane without its apparent degradation. H_2S, although present in relatively low levels in landfill gas used for trials, may have to be removed to protect the membranes and to upgrade the CO_2 for industrial applications.

Results of the second stage of trials will be published at this symposium in October.

It is intended to establish optimal parameters for the process, present the efficiency of the membrane separation, demonstrate viability of the process and collect data for scaling up the pilot plant to the full scale version. A study into the economics of purified landfill gas as an alternative to fossil fuel will also be carried out.

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