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ScienceDirect

Energy Procedia 128 (2017) 240–247

Energy Procedia

www.elsevier.com/locate/procedia

International Scientific Conference "Environmental and Climate Technologies", CONECT 2017, 10–12 May 2017, Riga, Latvia

Extraction of carbon dioxide from gas mixtures with amines absorbing process

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Abstract

Currently one of the most efficient technologically and economically to extract CO_2 from gas mixtures is the process of chemical absorption using amine absorbents. Choosing an effective absorbent that can be applied to all CO_2 concentration range in gas mixtures can greatly improve the technical and economic indicators of CO_2 absorption extraction systems from gases in general. The calculations were performed using the HYSYS software system. An efficient absorber based on methyldiethanolamine (MDEA) was proposed that can be used to extract CO_2 from the various process gases in a broad range of CO_2 concentration: from 9.3 % to 45.0 %. Application of the absorbent reduces the energy consumption for regeneration of the saturated sorbent solution up to 2.5 times in comparison with traditional monoethanolamine reduces for 30 % the sorbent consumption.

The results of these researches are used to optimize the extraction processes of ozone-depleting carbon dioxide from the process gases and its realization as a commercial product. One of such gases is landfill gas that contains up to 40 % of CO_2. Gas Institute of National Academy of Sciences of Ukraine is the leading Ukrainian technology developer of landfill gas processing. In Ukraine 5 projects for the processing of landfill gas into electricity were implemented with a total power of 6 MW.

Peer review statement - Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".

Keywords: technological gas; biogas; flue gas; synthesis gas; generator gas; carbon dioxide; amines; absorption; desorption; thermal load

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1876-6102
Peer review statement - Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".
10.1016/j.egypro.2017.09.062

1. Introduction

The main sources of air pollution are enterprises of the fuel and energy complex, manufacturing industry and transport. Among gaseous pollutants, the most global atmospheric pollution forms CO_2. A significant increase of CO_2 concentration over the past decades is cause by emissions into the atmosphere from the combustion of fossil fuels.

The contribution of carbon dioxide, as the most potent greenhouse gas, to global atmospheric processes affecting the Earth's climate change is, according to the Lawerence Livermore National Laboratory, USA, 55 % [1].

Operating in Ukraine, thermal power plants (TPP) in the production of electricity and heat consume about 72 % of coal, 4 % of fuel oil and 24 % of natural gas, which is 46 million tons of equivalent fuel [2, 3]. At the same time, the emission of CO_2 into the Earth's atmosphere is about 100 million tons of CO_2 per year

The task is to reduce emissions of harmful substances, including CO_2, from heat generating plants and to reach European levels of maximum permissible emissions, requires their modernization facilities using highly efficient flue gas cleaning systems. The cost of such systems is very significant and amounts is about 25 % of the main heat power equipment cost.

One of the energy-intensive processes is the technology of carbon dioxide emission from process gases. Moreover, CO_2 can be an object of both a target separation, for example, in the production of urea, and ballast or a "polluting" additive in process gases and is a poison in subsequent stages, for example, in the production of certain types of mineral fertilizers. The main raw material for the nitrogen fertilizers production is ammonia, the production of which includes a stage of absorption purification synthesis of gas from carbon dioxide, which costs up to 30 % of the cost of ammonia.

Nowadays, in the world 700−800 billion cubic meters of synthesis gas annually are produced. Thus, for example, the gas obtained by gasification of coal with oxygen and water vapor should first be freed from the main part of CO_2 and only then the gas consisting mainly of CO and H_2 should be methanized.

In addition, over the past decades, there has been a significant depletion of traditional fossil fuels, and therefore it is important to look for alternative sources of energy. These include, in particular, biogas, which, like fuel, is derived from biological raw materials − biomass.

In developed countries, there is a tendency to increase the part of energy produced from renewable sources, in particular, the use of biomass potential in power and heat production as well as in the transport sector [4−8].

The study [9], with the example of Latvia, provides an assessment of the level of support needed to produce biomethane from biogas to put its price in accordance with the cost of natural gas. The average level of support required for biomethane as a feed-in-premium payment on top of the unit production costs is circa 68 EUR/MWh, the support period is estimated at 10 to 15 years.

The methodology of the techno-economical evaluation of the urban energy system, in particular, the production and consumption of biogas (biomethane) from the waste in the transport sector, is described in [10, 11]. The example of Valmiera City in Latvia shows that the application of the waste-to-biomethane strategy can contribute to the complete replacement of diesel fuel in urban buses and and gives savings of around 1,000 t CO_2/year.

In paper [12] authors investigate the CO_2 cost pass-through to electricity prices of the Baltic market. 1 EUR change in the price of CO_2 emissions would increase the price of the Nordic power market by 0.55 EUR and in the Baltic countries by 0.67 EUR.

In Ukraine, the potential of biogas production and use as a renewable energy source from wastes of the agro-industrial complex, domestic waste, waste water is estimated at 3.2 billion cubic meters of methane per year. In addition, it is possible to obtain about 3 billion m^3 / year of CH_4 from energy crops and their processing into biomethane [13]. Solid household wastes (SHW) are much broader class, and only in Ukraine they are generated about 13 million tons annually. Solid wastes are buried in special landfills. Landfills are sources of biogas, consisting mainly of biomethane (methane) and carbon dioxide. As a result of natural processes of anaerobic fermentation, each ton of domestic waste releases up to 200 ÷ 250 m^3 of biogas [14−17]. In Ukraine, there are more than 4.5 thousand solid waste landfills with a total area of more than 7.5 thousand hectares [14], which are, on the one hand, a significant resource for biomethane extraction, on the other, the landfills are the real environmental problem. The above mentioned amount of solid wastes, in the process of anaerobic processing provides about 700 thousand tons of CH_4 and 1800 thousand tons of CO_2 per year. Since methane has 21 times more greenhouse effect than carbon dioxide, this is equivalent to 15 million tons of carbon dioxide. The collection of at least part of the generated biogas will make