

# REMOVAL OF METHANE FROM VENTILATION AIR STREAMS

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Several possibilities of removing methane from ventilation streams are presented, depending on its concentration in the stream. In the case of small concentrations of methane and the presence of other contaminants, e.g. hydrogen sulphide or ammonia in the ventilation air from the pig house, a sufficiently effective method of their removal is adsorption on carbon sorbents. The simulation of the methane absorption process in paraffinic solvents in the ChemCad program has shown that at such low concentrations, around 100 ppm or even less, this process occurs with little efficiency. Ventilation air can also be used to burn solid fuels or, for example, biogas produced in the neighbourhood of a pig house. In the case of ventilation air from hard coal mines, if the methane content reaches 1%, catalytic combustion can be successfully applied and at least partially recover combustion energy.

Keywords: absorption, adsorption, combustion, methane, odours

## 1. INTRODUCTION

The methane content in the ventilation air from pig farms from pig farms is usually less than 100 ppm, in the ventilation air the mine reaches 1%. In the air removed from the pig house, its content depends to a large extent on the type of farm, cattle, swine, ventilation efficiency and its control, etc. The ventilation air usually contains small amounts of methane (50 ppm) and hydrogen sulphide (up to 5 ppm). In both cases, methane and other associated pollutants are directed to the atmosphere contributing to the greenhouse effect. Potentially, methane can be removed from the ventilation air using several methods:

1. by adsorption on sorbents, the best sorbent for this task is activated carbon,
2. by absorption in organic solvents of a paraffinic nature, good methane solvents,
3. by burning fuels and gaseous streams in the ventilation air, e.g. biogas combustion,
4. by biological conversion of farmland contaminants including methane on appropriate biological beds,
5. by oxidation of methane and other pollutants by photocatalytic methods.

The object of interest in this presentation are only the first three methods, although the two remaining ones, especially the biological conversion of pollutants in the ventilation gases and methane removal, are gaining more and more application.

## 2. EXPERIMENTAL

In the presented research studies typical apparatus for sorption and desorption of methane and hydrogen sulphide in laboratory conditions were applied. In the case of absorption and combustion of methane studies, chemical process simulation software called ChemCad was used.

## 3. RESULTS AND DISCUSSION

### A. Adsorption of methane on sorbents

Active carbons adsorb both methane and hydrogen sulphide (Table 1). As can be seen from the above data, 1 kg of sorbent can adsorb over 20 g of methane and up to 30 g of CH<sub>4</sub> + H<sub>2</sub>S. The greater part of the methane is adsorbed irreversibly and only about 5 g of methane with 1 kg of carbon are desorbed in a vacuum. In the case of sorbent regeneration by thermal methods, almost the entire amount of methane can be desorbed, i.e. over 20 g / kg. Assuming a volume of filtered exhausted air 1000 m<sup>3</sup>/h, methane content in the air of 50 ppm, mass of sorbent in the

adsorber 500 kg and total sorption of methane on the sorbent, the sorption capacity of methane will be exhausted after about 2 months. Methane can be desorbed in regeneration cycle by heating the adsorption bed. Spent active carbons can be sent to regeneration or simply to utilization by combustion.

Table 1

Comparison of sorption and desorption of methane on two selected activated carbons.

Sorbent	CH <sub>4</sub> [g/kg]			CH <sub>4</sub> +H <sub>2</sub> S [g/kg]		
	ad.	des.	ad./des.	ad.	des.	ad./des.
	$a_{ad,760}$	$a_{des,0}$	$a_{ad,760}-a_{des,0}$	$a_{ad,700}$	$a_{des,0}$	$a_{ad,700}-a_{des,0}$
	1	2	3	4	5	6
OK900-1	22,4	4,32	18,08	30,64	10,08	20,56
OK900-2	26	7,07	18,93	36,64	13,06	23,56

The sorption capacity of carbon sorbents is slightly higher when, in addition to methane, a small amount of hydrogen sulphide in the ventilation air is sorbed (about 5 ppm). The advantage of this solution is the removal from the ventilation air not only of methane but also of hydrogen sulphide and odours.

### B. Methane absorption in paraffin organic solvents, petroleum oil fractions

A simulation diagram of methane absorption in paraffinic oil stream is given in Fig. 1. The aim of the process is the absorption of methane from the ventilation air and desorption it into a stream of e.g. biogas.

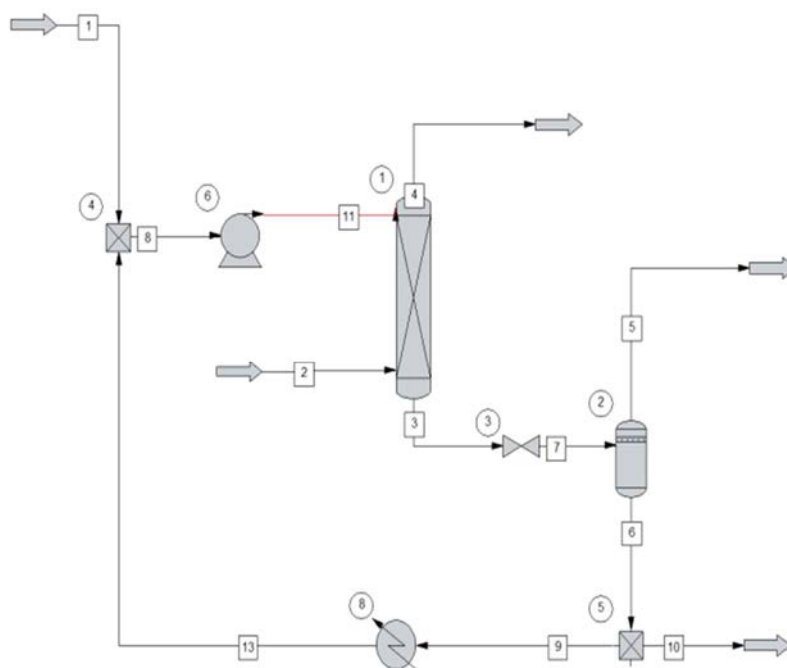


Fig. 1. Simulation scheme of methane absorption in the absorbing paraffin oil in the ChemCad program.

In the methane absorption system, sorption and desorption column 1 and 2, the absorption oil is circulated to absorb methane from the air stream 2 (1000 m<sup>3</sup>/h) flowing from the bottom of the column 1 in counter current to the oil flowing down from the top of the column (fresh oil stream 1 and recirculation stream 13, 100-200 kg in circulation). The methane-free air stream 4 is directed

to the atmosphere. The methane containing oil stream 3 is directed to the desorption column 2 in which, after heating to 70 ° C, the methane is desorbed (5) and the oil is recycled as stream 9 and after cooling in cooler 8 as stream 13 to the sorption column 1 by a mixer 4. These are the assumptions. The simulation however shows that the content of methane in the ventilation air (50 ppm) is too small for its effective absorption in oil. As a result, the methane content in the methane-treated stream is much higher than that of oil.

C. The use of ventilation air for fuel combustion

The simulation diagram of biogas combustion with ventilation air is shown in Fig. 2.

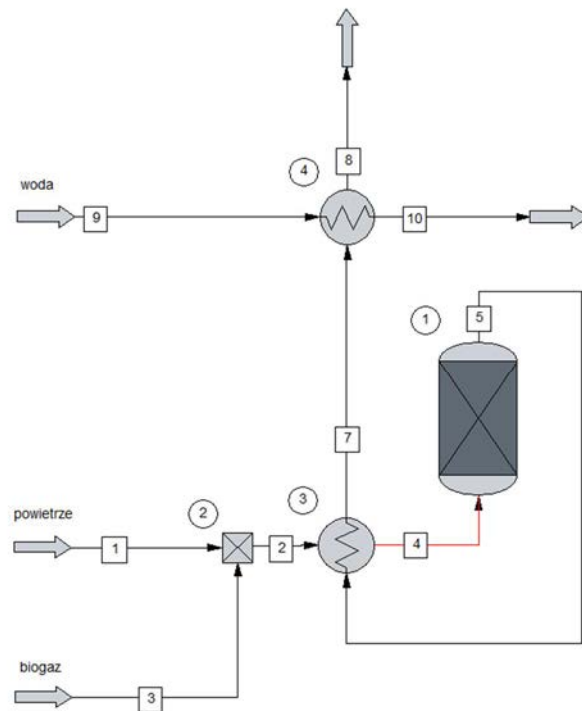


Fig. 2. Simulation diagram of biogas combustion in the ventilation air from the pig house

The ventilation air (1) containing methane is mixed with the biogas (3) in the mixer 2 and heated in the exchanger 3 to 350°C and then flows into the reactor 1 where catalytic burning of methane takes place. It was assumed that combustion of methane is complete and the heat losses to the environment are insignificant (adiabatic system). The flue gases from reactor 1 as (5) at 481°C first heat the stream 2 in the heat exchanger 3 entering the combustion reactor to 350° C and then heat the water in the heat exchanger 4. The mass balance of gas and water streams is shown in Table 2.

Table 2

**Composition and properties of the most important streams combustion system**

Properties	Stream, composition [kmols]							
	1	3	4	5	7	8	9	10
Temperature, °C	20	20	350	481.7	160.3	90	20	42.37
CO <sub>2</sub>	0	0.1517	0.1517	0.384	0.384	0.384	0	0
CH <sub>4</sub>	0.0045	0.2275	0.232	0	0	0	0	0
N <sub>2</sub>	35.242	0	35.242	35.242	35.242	35.242	0	0
O <sub>2</sub>	9.369	0	9.369	8.905	8.905	8.905	0	0
H <sub>2</sub> O	0	0	0	0.464	0.464	0.464	55.51	55.51

The temperature of preheated water depends on its mass directed to the exchanger. With a water flow of 1 m<sup>3</sup>/h, it can only be heated to a temperature of more than 42 °C. This indicates that only small amount of heat to be used due to the relatively large mass of exhaust gas emitted from the reactor's boiler (a large excess of air). The disadvantage of the solution is that the ventilation air from the pig house next to methane contains small amounts of impurities such as H<sub>2</sub>S and NH<sub>3</sub> which are burned in the reactor in to sulphur and nitrogen oxides. The large excess of air in relation to the stoichiometry of methane combustion causes a large volume of exhaust gases with quite high temperature (90 °C or even higher) which causes considerable losses energy. The advantage of this solution is that at the same time there are incinerated traces of chemical compounds in the ventilation air called odours.

#### D. Combustion of methane in the ventilation air from the mine

Methane in the ventilation air from mines can be burned catalytically provided that its content is higher than 0.5 mole%, and the amount of energy obtained during combustion is sufficient to warm up the ventilation air entering the reactor to the temperature at which combustion can take place. Table 3 summarizes the simulation results for methane combustion in ventilation air at a concentration of 1% mol., flow rate 1000 m<sup>3</sup>/h. The technological scheme of this process is similar to that shown in Fig. 2, except that it does not include a stream of biogas 3 and a mixer 2. These elements do not appear in the scheme of methane combustion in the mine ventilation air. The table below shows the mass balance of the process in which the stream numbers correspond to the number of streams in Fig. 2 Similarly as before, it was assumed that the combustion of methane is total, the ventilation air entering the reactor heated with flue gases up to the temperature of 350 °C and that the heat of exhaust gases flowing to the exchanger 4 to heat the water stream with a flow rate of 1 m<sup>3</sup>/h. The exhaust temperature at the outlet of the final exchanger 4 is only 90 °C and the water can be heated to 82.5 °C.

Table 3

Balance sheet of the methane combustion process, 1 mole % in 1000 m<sup>3</sup>/h

Properties	Streams, composition [kmols]						
	1 and 2	4	5	7	8	9	10
Temperature. °C	20	350	601.37	289.10	90	20	82.5
CH <sub>4</sub>	0.446	0.446	0	0	0	0	0
N <sub>2</sub>	34.800	34.800	34.800	34,80	34.800	0	0
O <sub>2</sub>	9.369	9.369	8.477	8.477	8.477	0	0
H <sub>2</sub> O	0	0	0.892	0.892	0.892	55.51	55.51
CO <sub>2</sub>	0	0	0.446	0.446	0.446	0	0

#### 5. Conclusions

1. Adsorption of methane from ventilation air on activated carbons can be an effective method of purifying it also from hydrogen sulphide and odours.
2. Methane absorption in oil fractions occurs with low efficiency.
3. The use of ventilation air for combustion of, for example, biogas allows effective removal of methane and odours of ventilation air.
4. Combustion of methane in the ventilation air with the assumption of 1% of the content allows for heat recovery for heating purposes or heating of water about 1 m<sup>3</sup>/h / to a temperature of over 80° C, assuming utilization of 1000 m<sup>3</sup> of air per hour.

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