Formation of Air Pollutants at Bio Gas Firing

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HU ISSN 1418-7108: HEJ Manuscript no.: ENV-000624-A

Abstract

The most important process in energy utilization is the combustion of fossil fuels. In the course of high temperature combustion processes air polluting gas components are emitted (SO_2, NO_x, CO, CO_2, C_nH_m). Staged combustion is one of the well-known and more and more extensively applied combustion technology methods to reduce the amount of NO_x air pollutants. At the Department of Combustion Technology of the University of Miskolc research has been carried out for several years now to clarify the theoretical basis of staged combustion. In this work multistage gas combustion has proved to be most useful in NO_x reduction, the practical implementation of which involves the combustion of gas or gas mixture in two stages in one equipment with one stage air inlet. As a fuel we have used a mixture of natural gas and waste gases (eg. bio gas).

1 Introduction

One of the traditional activities in the field of energetics is the utilization of the energy content of waste fuels. The recovery of the energy content of converter and coke gases of steel works and *bio gases of communal waste*, which can be used as fuels, should be examined from both a heat technology and an environment protectional point of view, also taking the local utilization possibilities into account.

Besides the utilization of the physical heat of waste gases, their chemical heat needs to be utilized, too. They are used with different types of boilers to generate steam and at the same time there is the possibility of technological heat utilization when it is mixed with gases of high thermal value.

Its utilization as combination gas also makes it necessary to examine how the waste gases change the combustion parameters and polluting effects of natural gas, especially the NO_x formation.

The most important element of combustion methods applied in order to reduce the amount of NO_x is to change combustion temperature, maximum temperatures in the flame, the duration of stay of combustion products in the high temperature zone and the partial pressure of oxygen in the combustion zones. One of the practical measures to achieve these aims is the staged combustion.

2 The combustion parameters of gas mixtures

Although there are examples of the direct utilization of pure waste gases in the industry it is better justified to use it as combination gas on account of the fluctuation in its heating value and its availability.

A bio gas collector can be seen in Fig. 1. and the change of CH_4 is shown in Fig. 2 [1]. E.g. the fluctuation of heating value of coke gas and bio gas is shown in Fig. 3 and 4 [1] [2].

It is most suitable to mix it with natural gas because this increases and stabilises thermal value and equalizes fluctuation of bio gas quality (Fig. 5).

For our research project the basic calculations are done with a mixture of natural and waste gases.

For the calculations natural and waste gases having the main composition indicated in Fig. 6 were used. The Fig. 7 gives the values of the main combustion parameters which are most important from

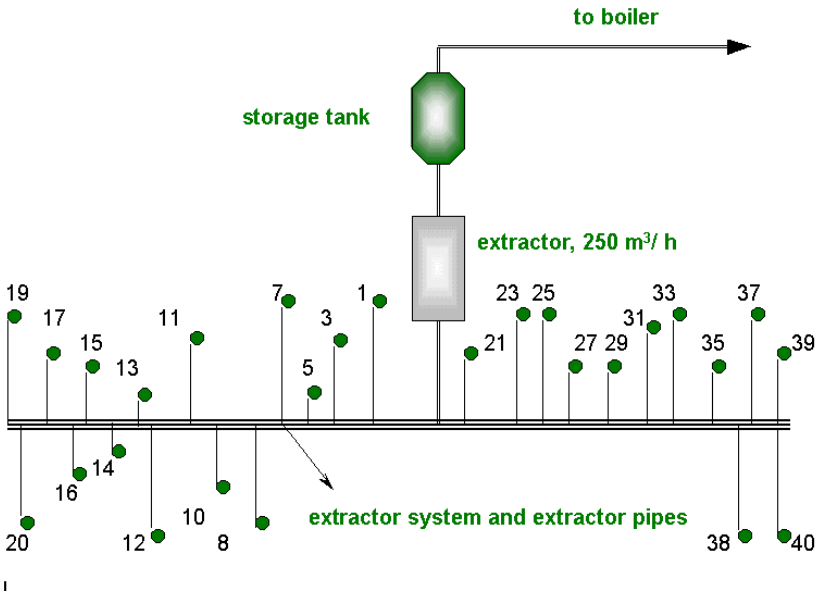

Figure 1: Bio gas collector

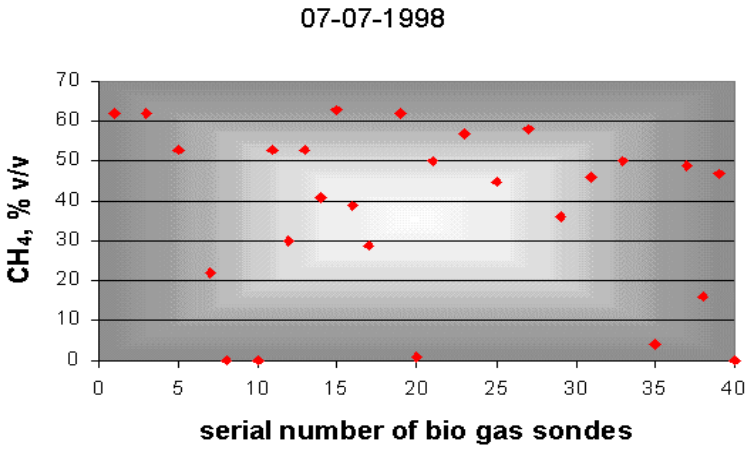

Figure 2: The fluctuation of CH_4 content of bio gas (Slovakia)

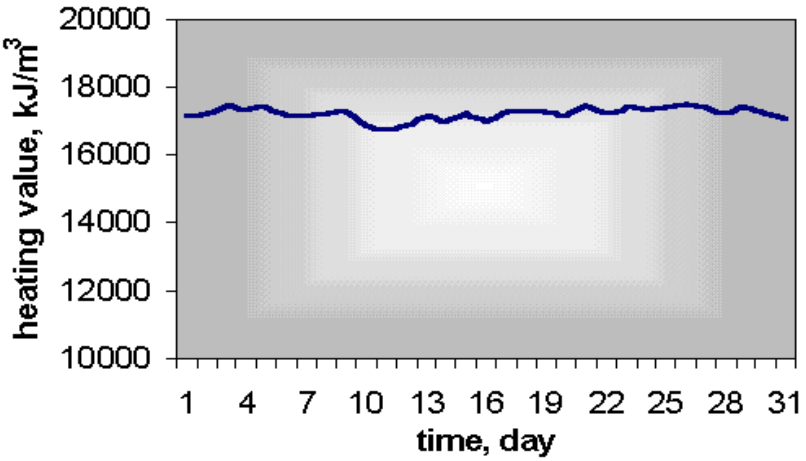

Figure 3: The fluctuation of heating value of coke gas (1999, DUNAFERR Co., Dunaújváros)

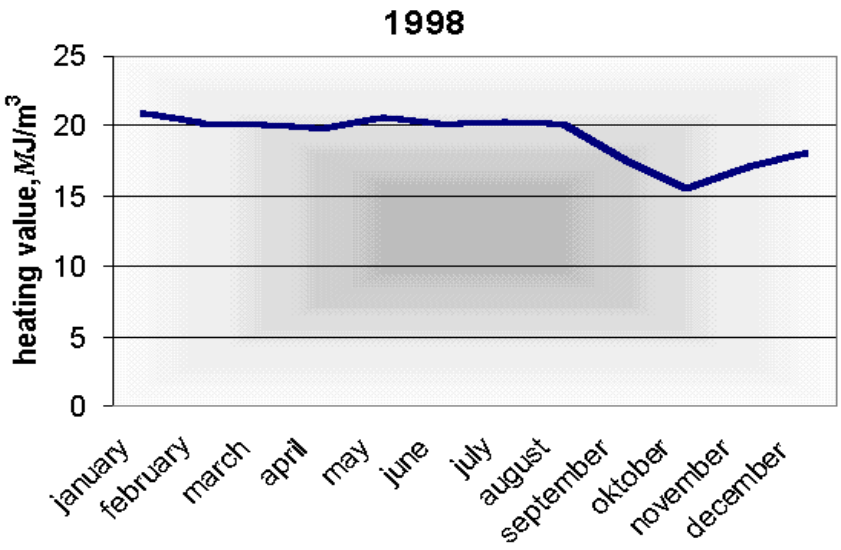

Figure 4: The fluctuation of heating value of bio gas (Bio gas plant, Slovakia)

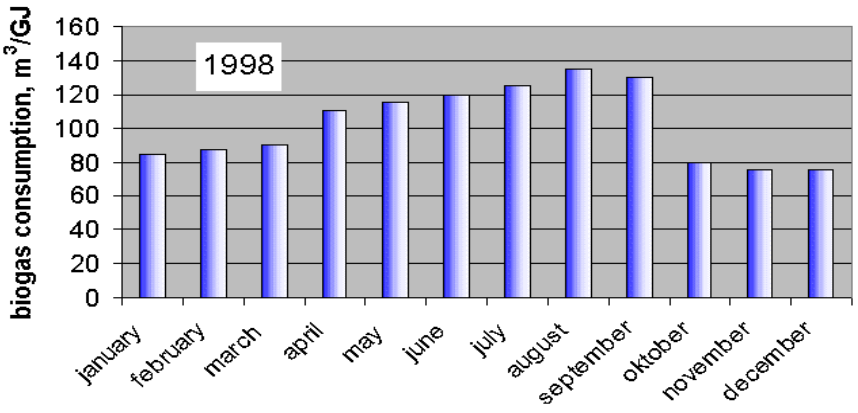

Figure 5: Fluctuation of bio gas quality (Slovakia)

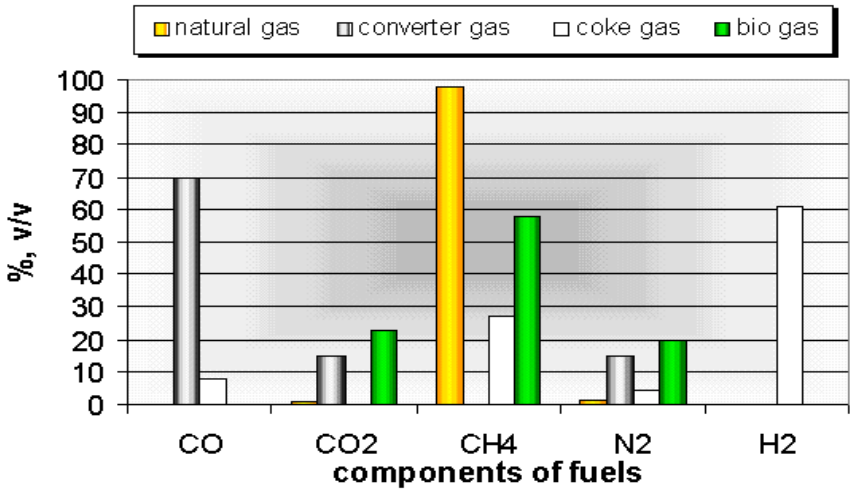

Figure 6: The main components of fuel gases

point of view of burners. In our calculations the ratio of waste gases varied between 0 and 60% in the gas mixture, taking the practice into consideration.

The same heat flow is guaranteed with increment of volume flow of fuel at different heating value of waste gases. For this reason the nozzle of burners applies transformation from time to time. The control of burners is necessary because of different density of waste gases . The theoretical combustion temperature plays a significant role in the heat technology and environmental protection. The bio gas has the minimum combustion temperature among the examined waste gases (Fig. 8) [3].

Mixing with natural gas rich in hydrogen the waste gases is favourable from the point of view of radiational heat transfer which is primarily important for heating furnaces and boilers. Coke gas increases the H_2O content of flue gas, CO_2 content of flue gas will increase at bio gas - natural gas mixing and converter gas firing (Fig. 9).

In the formation of the mixture of waste gas and natural gas it is important to know the rate of flame propagation as well as flammability limits. As it is not an additive parameter, therefore the normal rate of flame propagation of gas mixtures cannot be calculated from the composition with the help of the mixture laws.

It can only be specified with the help of measurements [4]. Fig. 10 summarises the results of our measurements done to specify the exact values of flame propagation through example of coke gas [5].

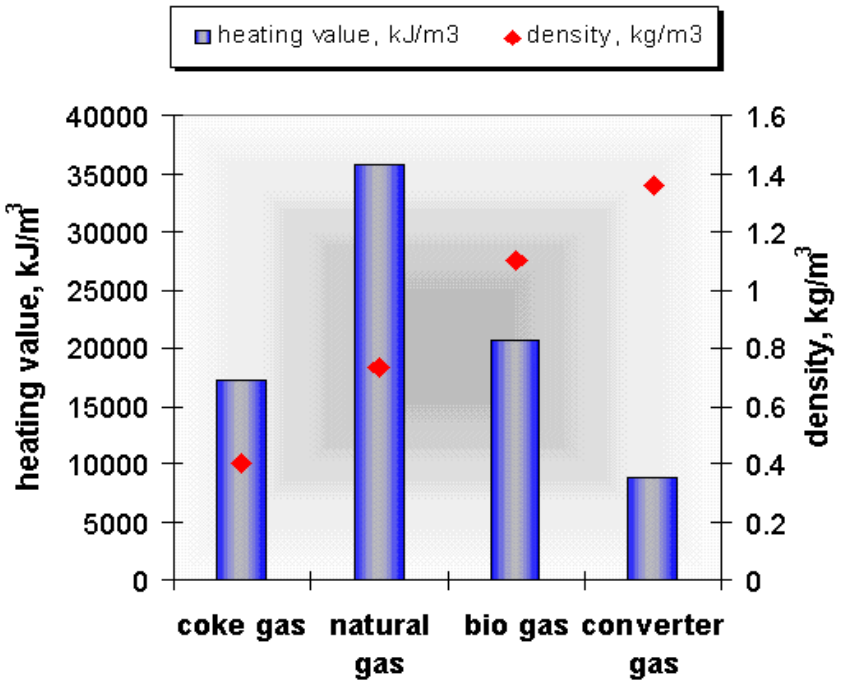

Figure 7: The change of heating value and density at different fuel gases

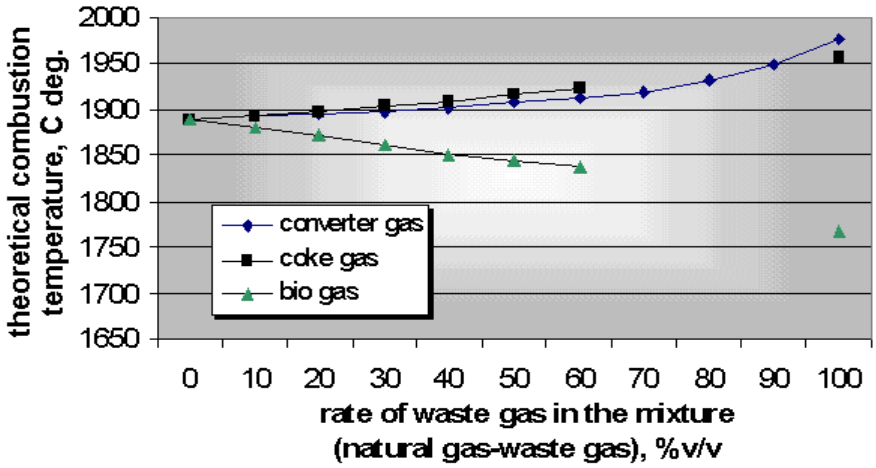

Figure 8: The change of theoretical combustion temperature of gas mixture

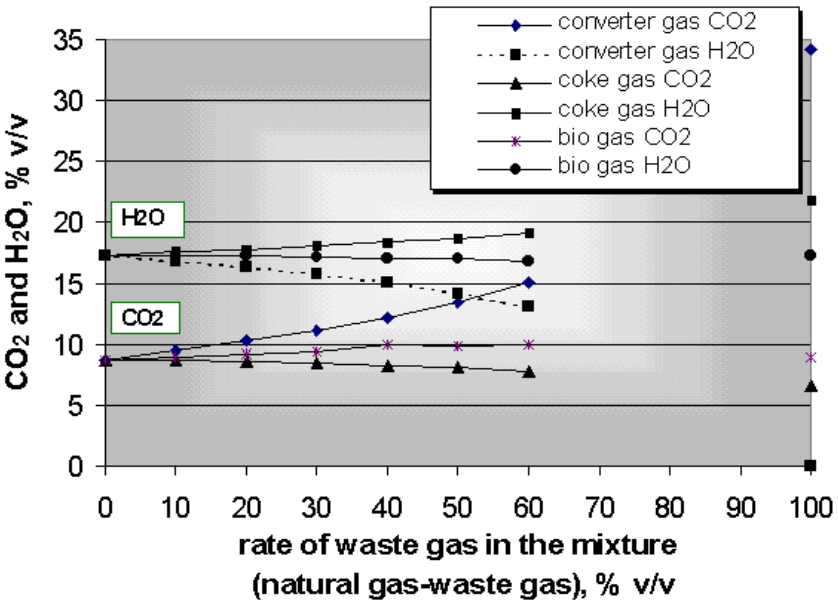

Figure 9: CO_2 and H_2O content in the flue gas

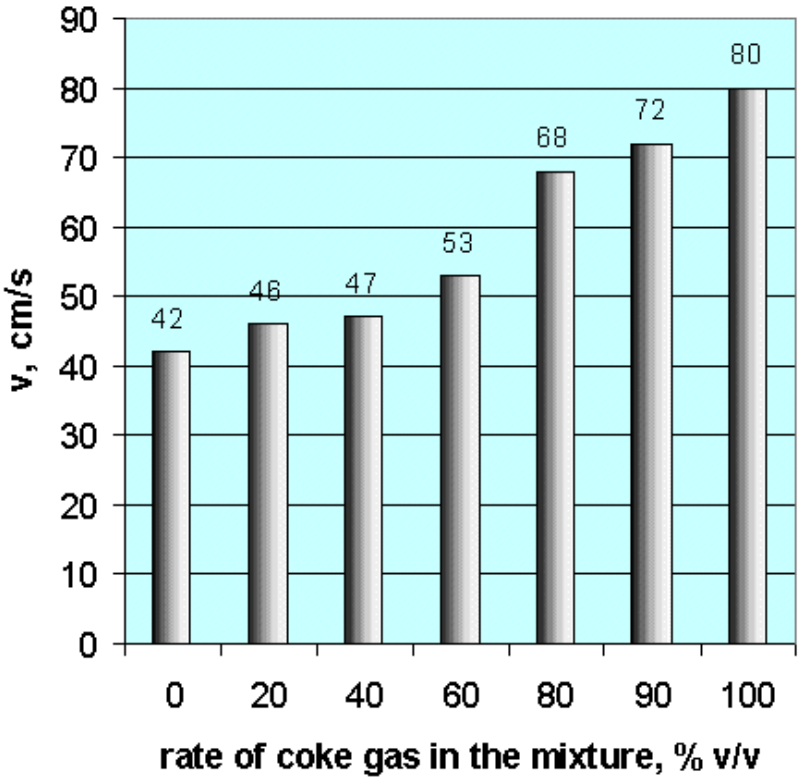

Figure 10: Flame propagation (v) of gas mixtures (natural gas-coke gas)

3 The formation of polluting gas components at staged firing

Environment protectional tests have been done to find out to what extent the amount of gaseous pollutants found in the combustion products of natural gas changes during the energetics utilization of the chemical heat of high CO, CO_2 and high H_2 content waste gases.

At the Department of Combustion Technology of University of Miskolc research has been carried out for several years now to clarify the theoretical basis of staged combustion. In this work two-stage gas combustion has proved to be most useful in NO_x reduction.

Our experiments have been carried out under two-stage combustion. During two-stage combustion all the combustion air was added to natural gas which yielded a primary combustion zone of high air factor and then the waste gas was led into the secondary combustion zone, the combustion with the final air factor came into being.

For our research purposes a test furnace has been designed and built (Fig. 11 and Fig. 12). The test burner designed for our measurements was suitable for both normal and two-stage combustion.

Fig. 13 shows the principle the two-stage test burner designed and produced for experimental purposes. It can be operated both in a traditional operational mode and with two-stage firing. Base of this burner is an high speed impulse burner.

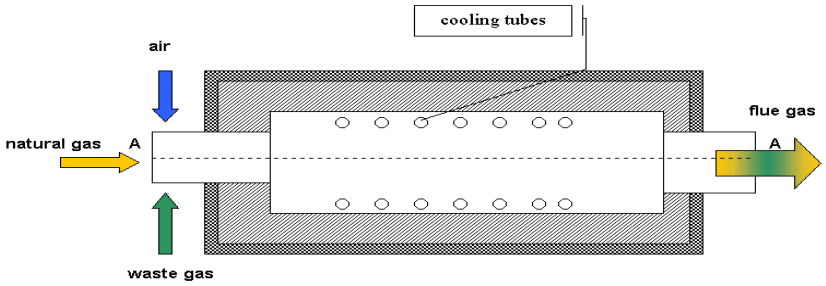

Figure 11: A. Line diagram of test furnace

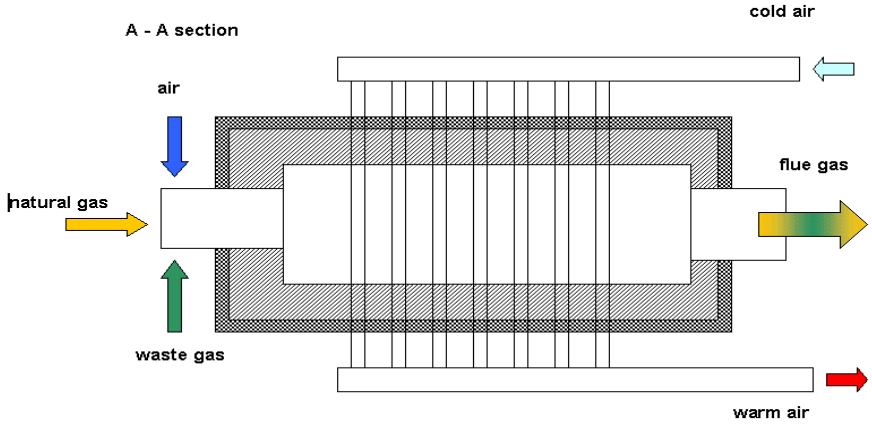

Figure 12: B. Line diagram of test furnace

Fig. 14 and 15 summarises the results of our measurements done to specify the NO_x reduction with *e.g. bio gas mixtures*.

4 Summary

One of the possibilities of the energetics utilization of waste gases (converter gas, coke gas, *bio gas*) is to use them mixed with natural gas. It is necessary to know the change of firing parameters, the air pollution and the optimal mixing rate. On the basis of the staged combustion technological and environment protectional tests of the utilization of waste gases, as mixed gas we can come to the conclusion that a waste gas - natural gas mixture of a max. 20-50% waste gas content (*20% bio gas*) can be recommended (NO_x *reduction:* $\sim$30%) for the purpose of the utilization of the chemical heat of the gas mixture. The air factor of primary combustion chamber plays a significant role in this firing technology. The realization of our research aims has been supported by the National Research Foundation (OTKA T 022019 and 029199) and Environmental Ministry (1/0322/98).

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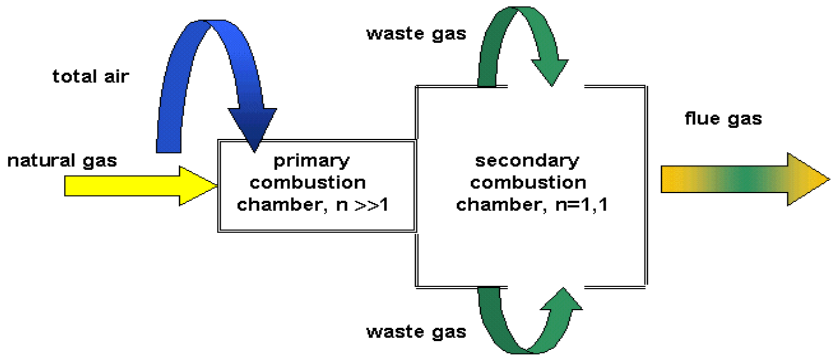

Figure 13: Principle of staged gas firing

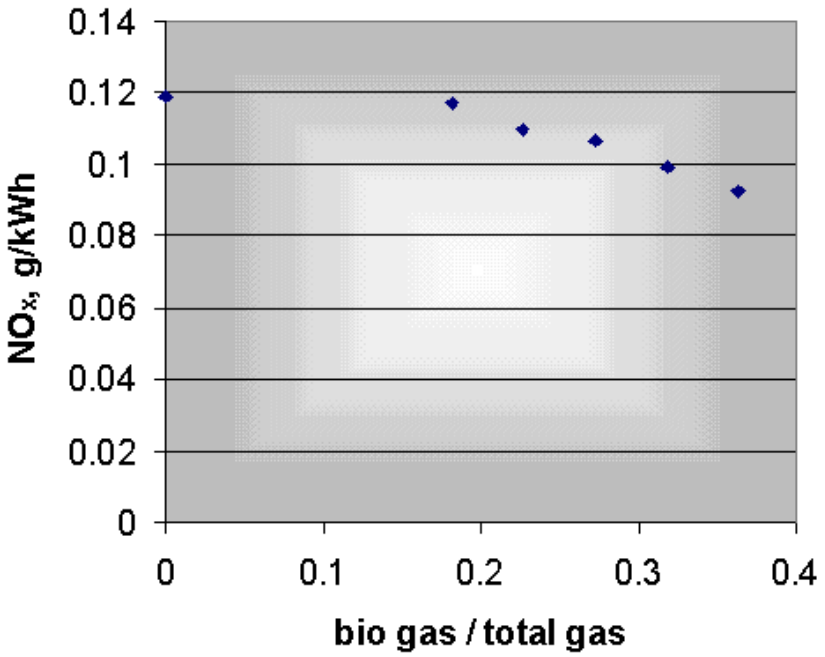

Figure 14: Change of NO_x formation at different rate of primary and secondary gas (natural gas- bio gas) ($q_{vgas} = 2,2m^3/h$; **normal firing**)

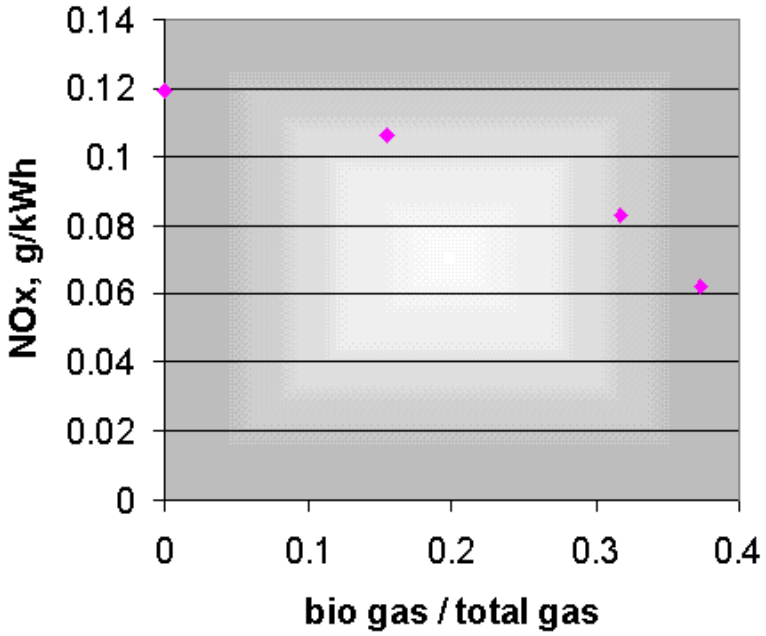

Figure 15: Change of NO_x formation at different rate of primary and secondary gas (natural gas- bio gas) ($q_{vgas} = 2,2 m^3/h$; **staged firing**)

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