

Primary Methods of Reduction NO_x and CO Concentration in Natural Gas Flame

Stanisław S. Slupek*, Monika K. Poskart **, Lech W. Szczowka **

*AGH University of Science and Technology, Krakow, Poland

** Czestochowa University of Technology, Czestochowa, Poland

Corresponding author, S. S. Slupek: e-mail: slupek@metal.agh.edu.pl

Introduction

The problems of emission reduction gaseous of pollutants, particularly of NO_x and CO are definite necessity because of permanent intensification of combustion process and rigorous environmental protection principles. This force to develop new methods of combustion technology and burners construction in order to reduce the emission of nitrogen and carbon oxides.

High temperature of a flame is a characteristic feature of natural gas combustion in industrial furnaces. It results in intensification NO_x formation. Therefore the basic aim of primary methods of NO_x reduction is decreasing of combustion temperature is [1- 4].

The presented paper describes the influence of combustion gasses recirculation, staged combustion and reburning methods of the reduction of NO_x and CO concentration.

Experiments

The experiments were carried out in isolated cylindrical combustion chamber, 3.8 m in length and 0.12 m in diameter (Fig.1). Laboratory stand was equipped with measurement apparatus to measure all thermal and chemical parameters of combustion process.

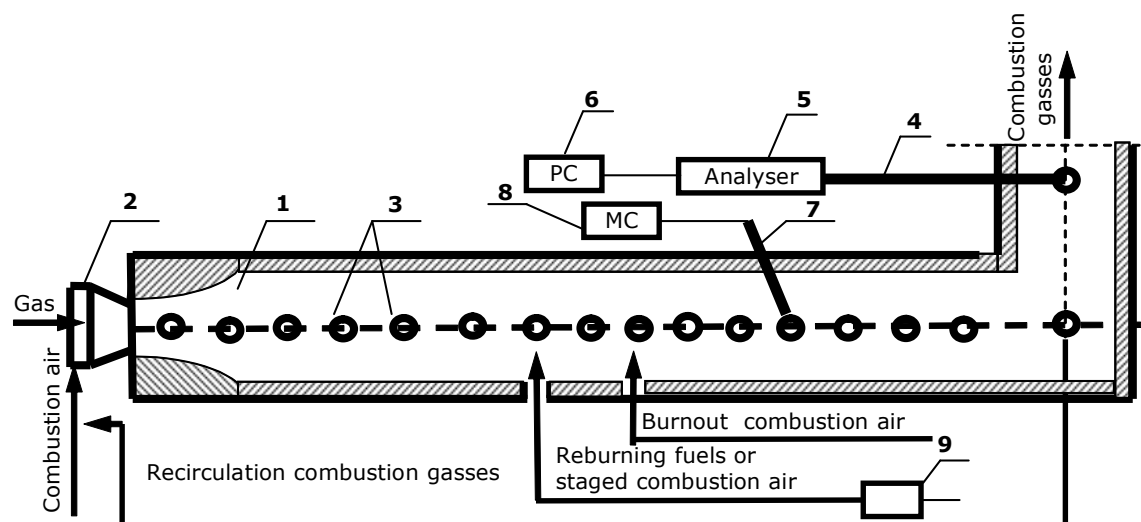


Figure1. Experimental stand: 1- combustion chamber, 2-swirl burner, 3-measurements loop, 4-sampling probe, 5-analyser of combustion gasses, 6- computer, 7-suction pyrometer, 8-measurement card, 9-generator of pressure pulsation.

The natural gas ($\text{CH}_4 = 96.8\%$; $\text{C}_2\text{H}_6 = 0.6\%$; $\text{N}_2 = 2.5\%$; $\text{CO}_2 = 0.1\%$) was used as basic fuel, biogas and natural gas as reburning fuels were injected into the reburning zone of flame.

The conditions of combustion were as follows:

- excess air $\lambda = 1.07$,
- ratio of combustion gasses recirculation $r_c = 0.07 \div 0.15$,
- ratio of secondary combustion air $r_p = 0.11 \div 0.26$ according to total volume of combustion air,
- ratio of reburning fuels $r_b = 0.05 \div 0.17$ according to total volume of natural gas burn in combustion chamber.

Results

The obtained results of the distribution of NOx and CO concentration in the flame of natural gas along the combustion chamber applying of combustion gasses recirculation, combustion air staging and reburning are shown in Figs. 2,3 and 4

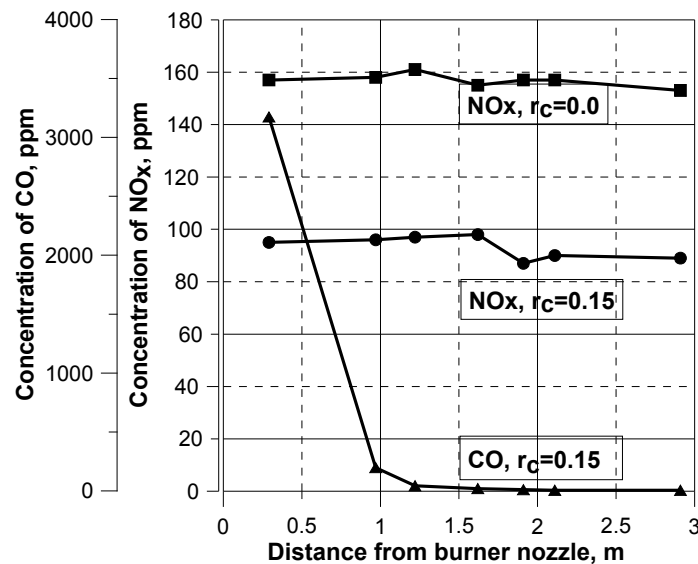


Figure 2. Distribution of NOx and CO concentration in the flame, along combustion chamber for gas combustion recirculation with ratio $r_c=0.15$

Results plotted in Figure 2 shown that applying of low temperature recirculation of combustion gasses brings about decreasing of NOx concentration and, of course, its emission. At the end of combustion chamber the concentration of NOx with recirculation ($r_c = 0.15$ NOx = 165 ppm) was lower by about 55 % compared to a normal combustion of natural gas ($r_c = 0.0$, NOx = 90 ppm)

The staged combustion experiments were carried out with a ratio of secondary combustion air $r_p = 0.11 \div 0.26$. Results for maximum ratio $r_p = 0.26$ are presented in the Fig. 3.

In the first stage of combustion the concentration of CO reached above 40000 ppm, and NOx about 40 ppm. After secondary air combustion introducing, level of CO concentration dropped to about 5 ppm, level concentration of NOx did not change.

In the practical industrial combustion system with so high secondary level of combustion air $r_p = 26\%$ is very rare. The results of NO_x concentration obtained with $r_p = 0.20$ proved the emission decreasing by about 70 %.

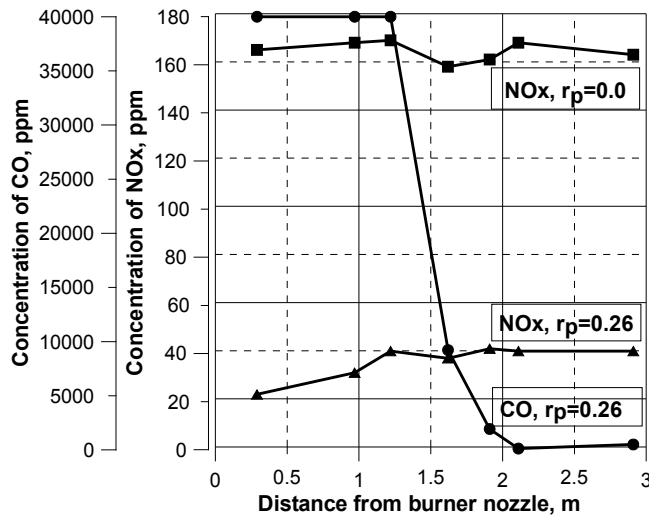


Fig.3. Distribution of NO_x and CO concentration in the flame, along combustion chamber for staged combustion with ratio $r_p = 0.26$

The experiments of combustion with reburning fuels injection (Fig.4) show that highest level of CO concentration was reached just after reburning zone and was equal to about 13500 ppm. The results with biomass and natural gas as reburning fuels were similar. Applying secondary air as burn out air reduced concentration of CO to about 200 ppm. NO_x concentration reduction depended on ratio of reburning fuel. With increasing of reburning ratio, NO_x concentration decreased. For $r_b = 0.17$ concentration level of NO_x reduced from 165 to 90 ppm.

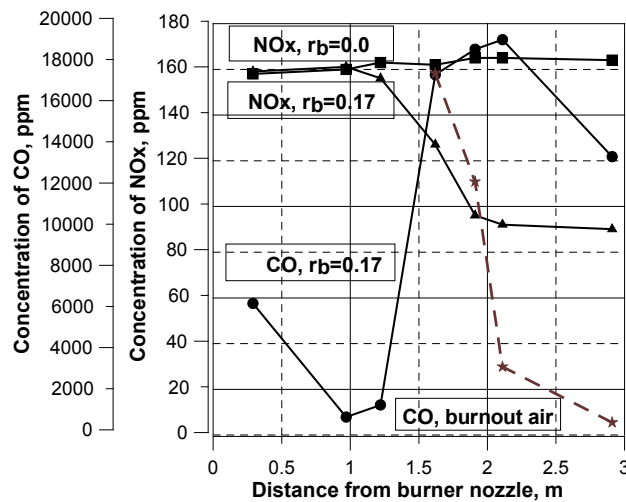


Fig.4. Distribution of NO_x and CO concentration in the flame, along combustion chamber for reburning combustion with ratio $r_b = 0.17$

Summary

Based on obtained results of low emission combustion experiments it was found that applying of primary methods of combustion processes reduces of NO_x and CO emission to the suitable level. The staged combustion method occurred the most effective one. The results of combustion gasses recirculation method and reburning combustion method are comparable.

Acknowledgement

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References

1. Slupek S., Szecowka L., Poskart M.: Nitrogen Oxides Reduction in Flame of Natural Gas. Proceedings of the Second Mediterranean Combustion Symposium, Sharm El-Sheikh, Egypt, 2002, p.756
2. Slupek S., Szecowka L.: Effect of Pulsation Disturbance in Flame Reburning Zone on NO_x Emission Reduction. Proceedings of the 6th Asia-Pacific International Symposium on Combustion and Energy Utilization. Kuala Lumpur, Malaysia, 2002, p.441.
3. Szecowka L., Poskart M., Slupek S.: Numerical Modelling of Nitrogen Oxide Emission and Experimental Verification. Third Mediterranean Combustion Symposium. Marrakech, Maroko, 2003
4. Slupek S., Poskart M., Szecowka L.: Reduction of NO_x in Natural Gas Flame Using Biomass as Reburning Fuel. Proceedings of the 7th Asia-Pacific International Symposium on Combustion and Energy Utilization, Hong Kong, 2004, CD-B5 p. 229