Gas and coal dust combustion with staged air and pulsation effect

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Introduction

Combustion plays a dominant role in energy production, and at the same time it is a main source of the air pollution. With the exception for steam, none of combustion products is absolutely neutral for the environment. However there are methods for limiting the negative influence of combustion process on the environment through modification of the combustion processes. The advantage of implementing primary methods of lowering the emissions is a relatively low level of both: investment and exploitation costs connected with them.

Modifications of combustion process in order to lower the emission of NO_x were started with introducing staged air of combustion. Before that it had been noticed that radicals comprising nitrogen and mixing with reacting substances might as a result of reactions become either NO_x or N_2. Nitrogen oxides are produced with excess oxygen, whereas with oxygen depletion radicals comprising nitrogen react into molecular oxygen. That important chemical observation is the basis for the method of NO_x reduction by air division. The air for combustion is divided in such way so that the first zone of the mixture is short of oxidizing agents (λ<1), and that is followed by the zone which is rich in such agents (λ>1). Sample results of introducing primary methods of emission lowering have been shown in Fig. 1.

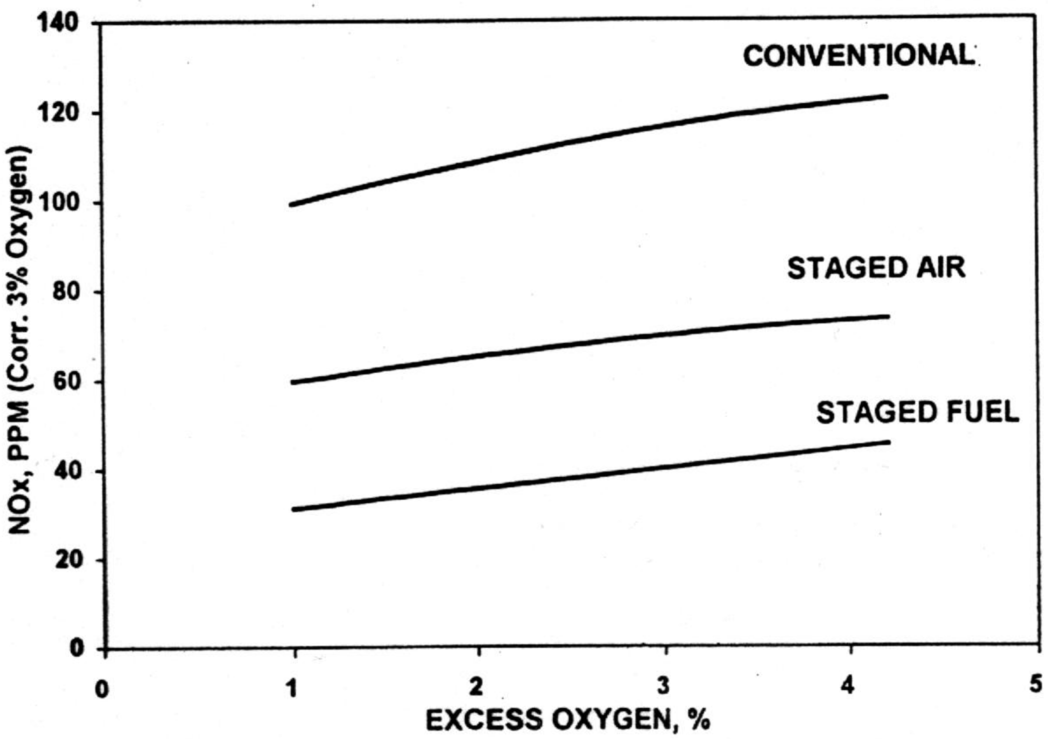

Fig. 1 Comparison of NO_x emissions for conventional and low-emission burners

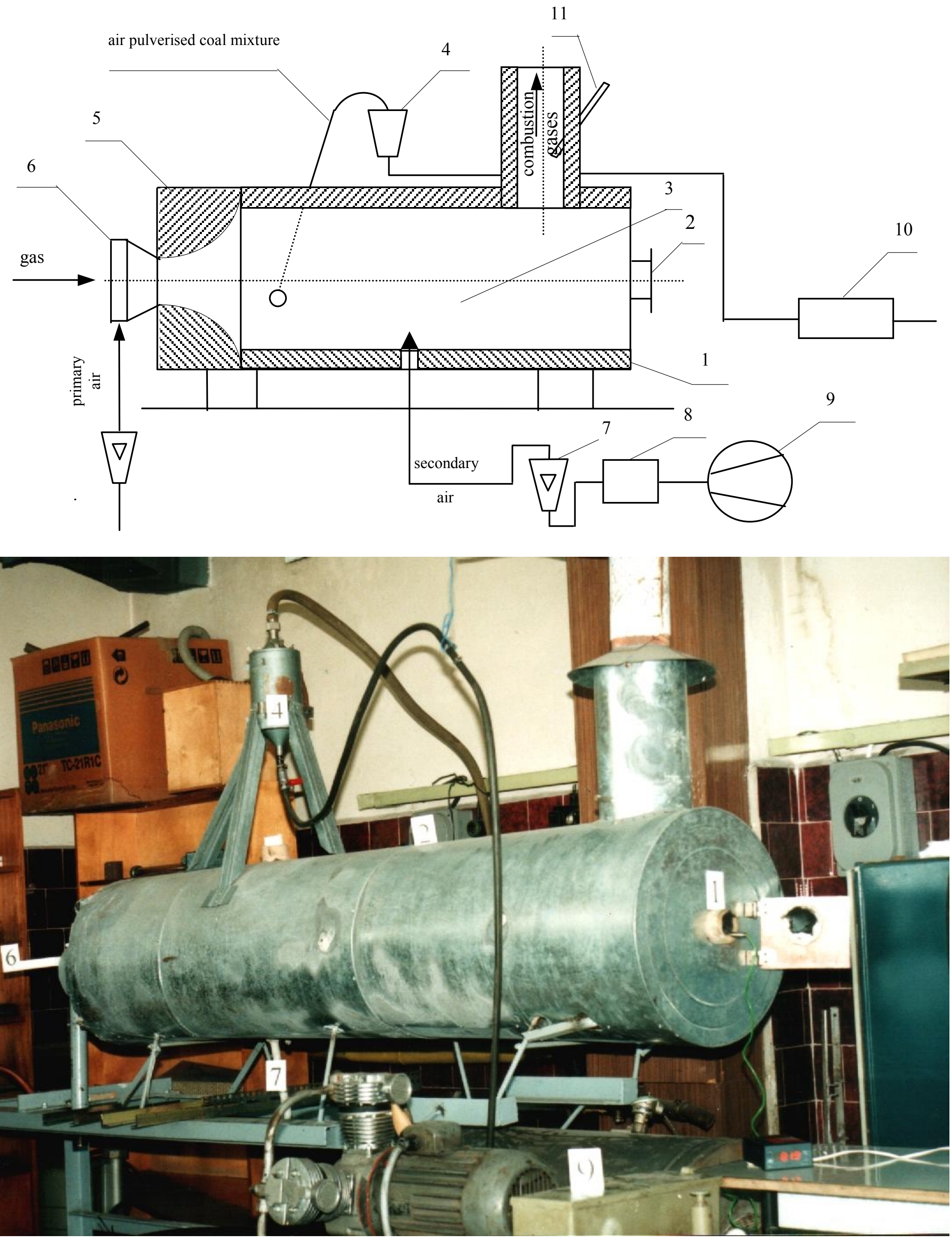

Fig. 1. Testing laboratory for determination of pressure pulsation effect on CO and NO_x emission reduction in combustion gasses of natural gas and pulverised coal.
1 – refractory bricks, 2 – eyehole, 3 – combustion chamber, 4 - pneumatic feeder of fuel, 5 – nozzle of burner, 6 – swirl burner, 7 – rotameter, 8 – generator of pulsation, 9 – air fan, 10 – compressor, 11 – sampling probe.

Description of the carried out tests

Tests were carried out in an experimental ceramic chamber (Fig. 2). The experimental chamber was of the following dimensions: the length: 2.12m and the inside diameter: 0.36m. There is a rotational burner located on one side of the chamber (6). Natural gas and air are delivered to the burner. Next to the chamber there is a nozzle through which the mixture of dust and air is delivered. The mixture is produced in a fluidized feeder. On the other side of the chamber there is an eye-hole window (2) that enables observation and registration of processes taking places inside. In the lower part of the chamber there is another nozzle through which secondary air is delivered – not disturbed or being subject to pulsations of changeable pressure. The pressure pulsations are produced by a mechanical generator.

To the warmed in advance chamber, with the inside temperature of 1000°C, the dust and air mixture was delivered. A stream of burnt dust with 40μm and 71μm graining was between 1 and 2kg/h, respectively. The following measurement tests were carried out:

- emission measurements of waste gas contents during natural gas combustion (V_g = $2m^3/h$),
- emission measurements of waste gas contents during simultaneous combustion of natural gas and coal dust,
- emission measurements of waste gas contents during gas and coal dust combustion, with staged air combustion,
- emission measurements of waste gas contents during gas and coal dust combustion, with staged air combustion and additional pulsation disturbance of the secondary air.

The combustion process was conducted with the total coefficient of excess air λ = 1,0 – 1,9. The waste gas content was assessed by means of TESTO 350 and 360 analysers, with the help of TESTO 335 samples preparations system. Sample results of the analysis of the waste gas escaping from the chamber have been presented in Table 1. Whereas changes in CO and NO_x concentrations, for measurements taking place in different experimental conditions, have been shown in Fig. 3 and 4.

Summary

Coal dust combustion in laboratory environment is a difficult and complicated undertaking. Measurement tests being carrying out during the research activities led to a conclusion that after inserting the dust into the chamber levels of NO_x, CO and SO_2 emissions increase.

In order to limit the emission of those components as much as possible, the air stream was divided in two parts:

- the primary one (80% of the whole volumetric content),
- the secondary one (20% of the whole volumetric content) for a certain excess ratio λ.

In addition, the secondary air stream was disturbed by pressure pulsations. The usage of the mentioned actions caused 90% CO emission reduction, and with low levels of excess air ration the NO_x emission was also about 10 – 20% lower. Additionally levelling of temperature inside the combustion chamber was observed.

References

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Tab. 1

Chemical analysis of waste gas effusion from the chamber.

A		b	
$\%CO_2$	10,2	$\%CO_2$	10,1
$\%O_2$	3,1	$\%O_2$	3,2
λ	1,17	λ	1,17
ppm NO	47	ppm NO	212
ppm NO_2	0	ppm NO_2	0
ppm NO_X	47	ppm NO_X	212
ppm SO_2	0	ppm SO_2	348
ppm CO	515	ppm CO	480
°C AT	807	°C AT	837
C		**d**	
$\%CO_2$	10,5	$\%CO_2$	10,5
$\%O_2$	2,54	$\%O_2$	2,5
λ	1,13	λ	1,12
ppm NO	190	ppm NO	175
ppm NO_2	0	ppm NO_2	0
ppm NO_X	190	ppm NO_X	175
ppm SO_2	405	ppm SO_2	303
ppm CO	865	ppm CO	266
°C AT	877	°C AT	871

a – natural gas was burnt,
b – natural gas and coal dust were burnt,
c – natural gas and coal dust were burnt, with combustion air gradation
d – natural gas and coal dust were burnt, with secondary air pulsation disturbances
The burnt amounts were as follows:
gas: 2 m^3/h; dust: 1,5 m^3/h; dust graining: 71 μm.

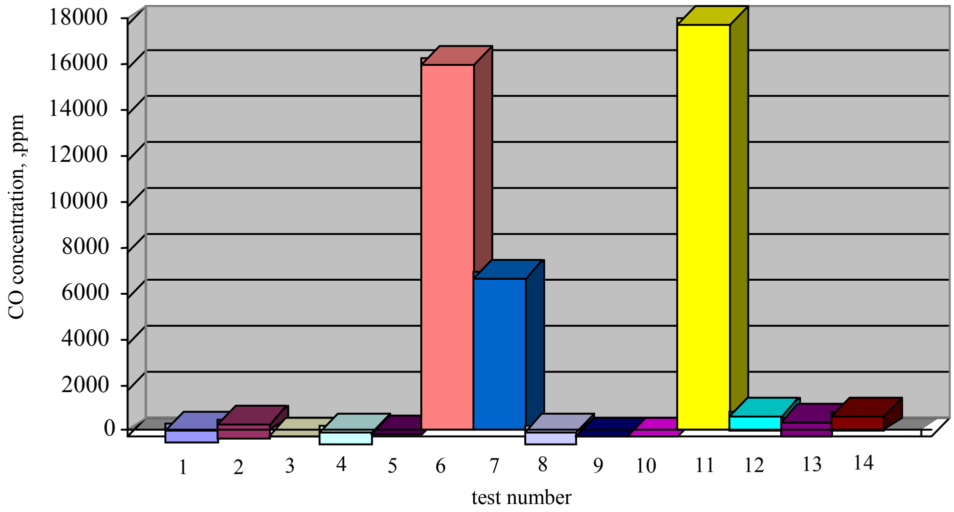

Fig. 3. Distribution of CO concentration at the combustion chamber outlet (3rd series of tests)

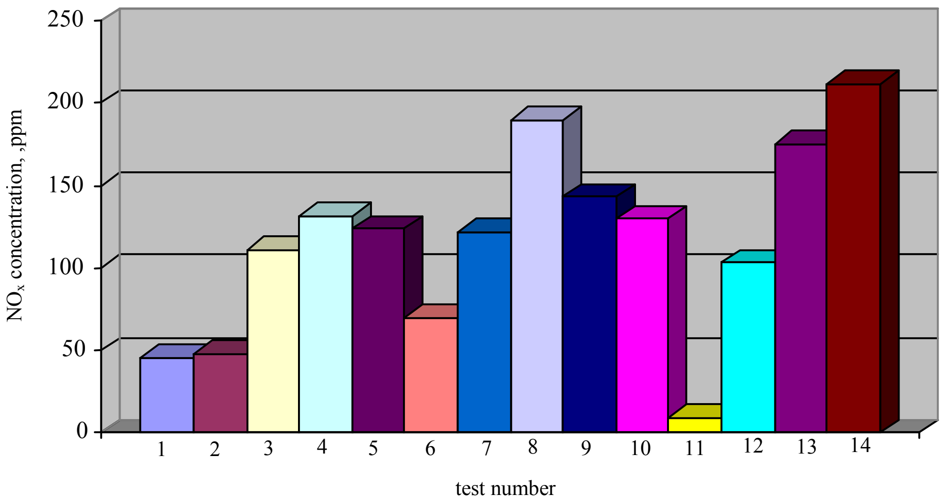

Fig. 4. Distribution of NO_x concentration at the combustion chamber outlet (3rd series of tests)