# RESEARCH OF HOMOGENEITY OF FUEL MIXTURE IN BURNERS WITH DIFFERENT TYPES OF STABILIZERS

***V. Tonu, PhD, assoc. prof., C. Ţuleanu, PhD, assoc. prof., V. Daud***
*Technical University of Moldova*

## INTRODUCTION

Combustion is based on two main processes:

- physical process, within which the direct contact between fuel and oxidant takes place, which essentially determines the homogeneity of mixture subjected to combustion;

- chemical process that determines the speed of development of oxidation reactions of fuel elements from mixture subjected to combustions.

Since the temperature in the locations of combustion exceeds 900°C, the chemical process is performed very rapidly and qualitatively, and in such circumstances the combustion processes obviously remain to be determined by the way of development of physical process, over which the field specialists focus more their attention.

Despite of performances achieved at organizing the physical process by swirling flows, many effects still remain unused, both in terms of mechanism of turbulent interactions, and in terms of concept of performance of devices for organizing these turbulences.

Broad knowledge of turbulent structure of currents and concentration field of natural fuel gases will allow highlighting the possibility of intensifying the combustion process and rational construction of burners and focal points. The homogeneity of mixture is influenced by more factors: degree of turbulence, speed of mixture, and distance from mouth of burner and radius from flame axis. Another important aspect is the influence of type of stabilizer upon the homogeneity of mixture.

There is a need to study the influence of parameters mentioned in different constructions of burners and the relations between the speed $w_{min}$ – minimum power and speed $w_{max}$ – maximum power stabilizer of type A, Fig. 2.

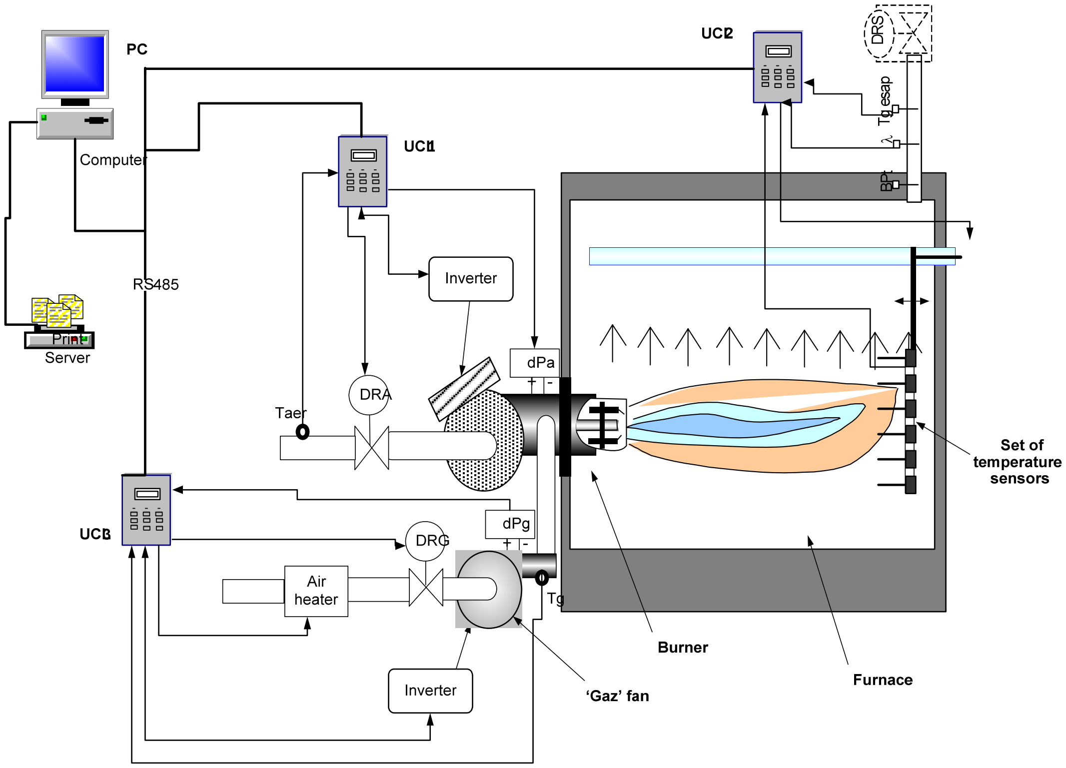

**Figure 1.** General structure of research installation of processes without gases combustion.

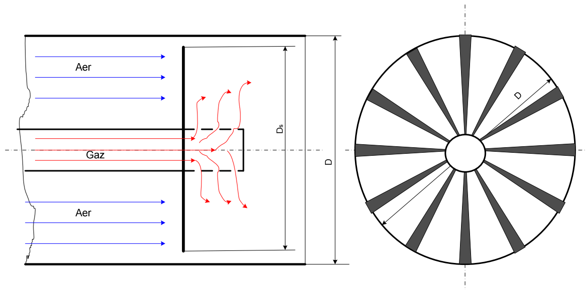

**Figure 2.** Combustion head with type A stabilizer.

## 1. PILOT PLANT

The study of field of concentration of natural gases participating in the process of combustion, formed by using different types of stabilizers, designed on different principles, was conducted on an experimental stand by improvisation of combustion processes of gases that simulate the combustion process through introducing two currents of warm air and cold air, strictly volume controlled in relation $Ca{:}C_g$ = 9,52:1 by help of shutters of DRA, DRG types and frequency convertors, because the performance of such experiments during combustion process by using natural gases is practically impossible. The frequency convertors control the fan speed of both currents. The cold-air flow represents the oxidant at temperature $T_a$= 10÷25ºC, and heated air flow – the “gas” at temperature $T_g$=60-:-120ºC. Therefore, the experiments have been performed at automatic stand, shown in picture 1, replacing the gas with another product – heated air [4, 5]. The stand includes the automatization of performance of experiments in order to enable to multiply the necessary conditions and to observe the effects as significant as possible [3].

The proposed stand includes the following main parts:

- a heating boiler of typical design, equipped with a set of sensors for measuring the temperature of gases, concentration of flue gases, temperature and pressure of coolant;
- a gas burner with independent control mechanisms of gas (heated air) and air flow;
- a set of microcontrollers for controlling and monitoring the experiments

As object of experimentation there were used one piece burners of “DAVA-250” type [2] with three types of stabilizers, hereinafter referred to as A, B, and C [1]:

a. Stabilizer constituted of a disk with sector blades, twisted under an angle *a* towards the air flow and with axial distribution of gas, called.

b. Stabilizer constituted of a number of blades in “V” shape with axial distribution of gas, called stabilizer of type B, Fig. 3;

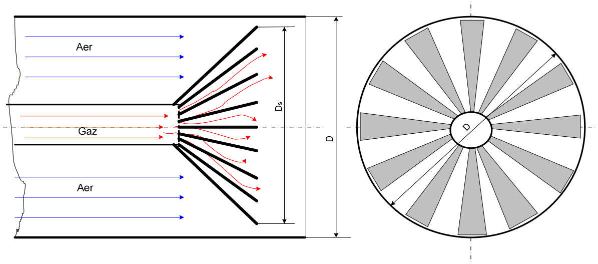

**Figure 3.** Combustion head with type B stabilizer.

c. conical stabilizer with the gas distribution on the peripheral part of cone, called stabilizer of type C, pic.4.

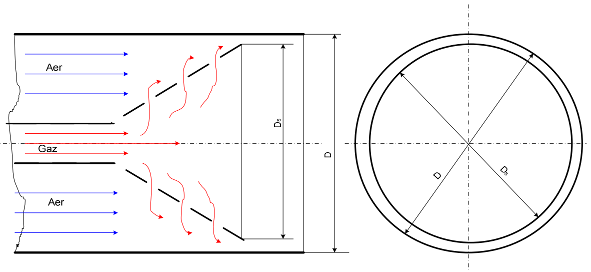

**Figure 4.** Combustion head with type C stabilizer.

## 2. RESEARCH OF FUEL MIXTURE HOMOGENEITY

Based on the analogy between the mass transfer processes and heat, the concentration of gas in mixture air-gas may be determined by changing the temperature of air-gas mixture at various points of the “flame” at the mouth of burner (Fig. 5).

The concentration of “gas” is calculated by formula:

$$C_g^{\,m} = \sum_{j=1}^{n}\left(\sum_{i=1}^{k} C_g^{\,i} \Big/ k\right) / \, n, \qquad (1)$$

where: $C_g^i$ - gas concentration in point *“i”;*

$n$ - number of points;

$k$ - number of repetition of measuring at each point.

The temperature of mixture in focal point has been measured throughout the volume of “flame” on rings with different radii from the burner axis, in four sections of location of sensors and at different distances from burner mouth.

It is determined in all points of a section of “flame” and, respectively, in all its sections. By using the obtained values the field of concentration shall be created on the space of concentration:

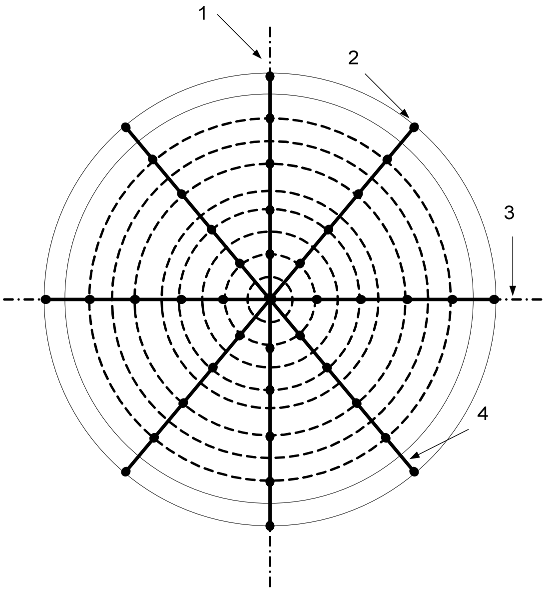

**Figure 5.** Schema of location of temperature sensors for determining the field of gas concentration.

flame. It is to be mentioned that in event the gas concentration reached the lower limit of 10%, it is shall be considered that the mixture is completely formed, otherwise – the mixture is under formation condition. The field of gas concentration has been investigated within the jets obtained by using these three types of stabilizers of different equal dimensions (diameter $D_s$, care forms equal surfaces of obstructing of stabilizers).

Another important factor influencing the field of gas concentration is the velocity of mixture, which correlates with the current power of burner. For this reason three levels of power for experimentation have been established: $P_{min}$, $P_{med}$ and $P_{max}$. It is noted that the volume ratio of cold air and heated air ("gas") was maintained at entrance in burner, corresponding to the quality of mixture $a$ = 1,0.

For each point of experimental plan a cycle of operations was performed by data collection for each section perpendicular on flame axis by step $\Delta(x/D)=0{,}5$. By statistic processing of collected data, then calculating the gas concentration in all points, the field of gas concentration shall be obtained throughout the space of "flame".

Based on the obtained results there have been designed two types of diagrams of the field of gas tridimensional and circular, that allow to observe the dynamics of formation of mixture on the space of "flame" and to make a comparative analysis, to interpret them for each type of stabilizer. The obtained results shall be presented as diagrams in figures 6-:-11.

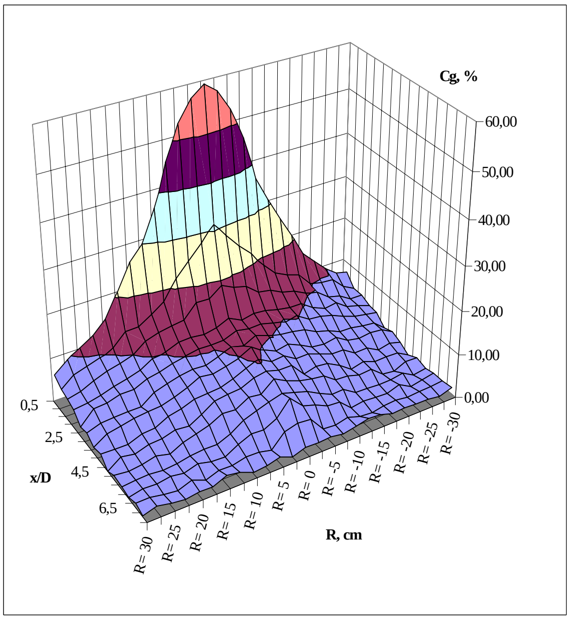

**Figure 6.** Tridimensional diagram of field of gas concentration for burner with a stabilizer of type A at $P_{min}$, $D_s$=124mm.

The diagrams from pictures 6 and 7 reflect that the maximum concentration of gas is directly situated at the exit from burner.

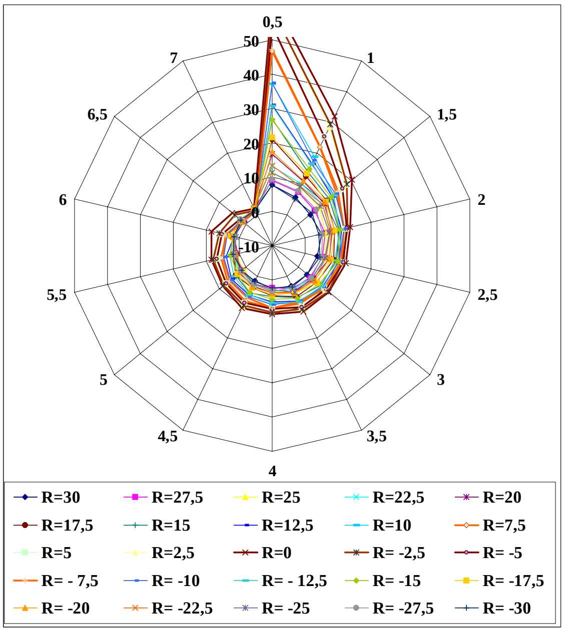

**Figure 7.** Circular diagram of field of gas concentration for burner with stabilizer of type A at $P_{min}$, $D_s$=124

Mixing with air, the concentration of gases suddenly drops down, the mixture becomes homogeneous and stoichiometric on all radial sections of the flame, starting with distance of x/D = 2 -:-2,5, and as consequence the length of flame is extended.

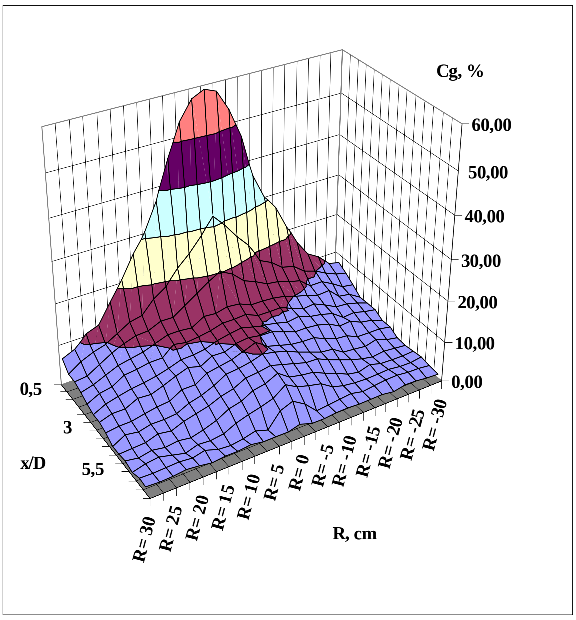

**Figure 8.** Tridimensional diagram of field of gas concentration for burner with stabilizer of type B at $P_{min}$, $D_s$=124mm.

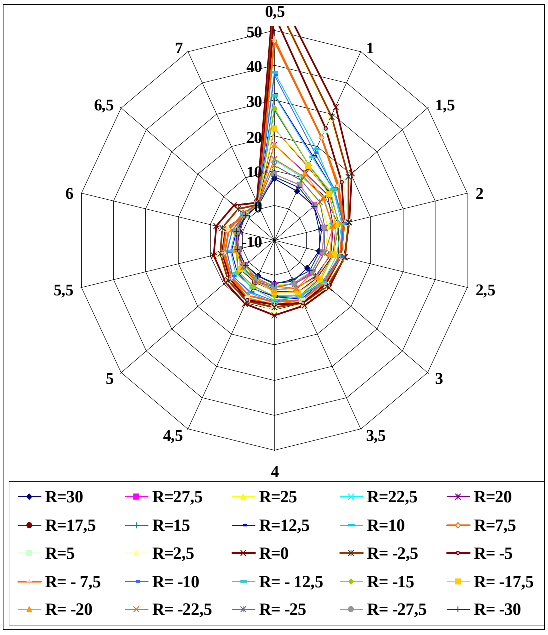

**Figure 9.** Circular diagram of field of gas concentration for burner with stabilizer of type B at $P_{min}$, $D_s$=124mm.

The diagrams from pictures 8 and 9 prove that the maximum concentration of gas is directly situated at exit from burner, that suddenly and continuously drops down, the mixture becomes homogeneous and stoichiometric on all radial sections of flame, starting with the distance x/D = 2 -:- 2,5.

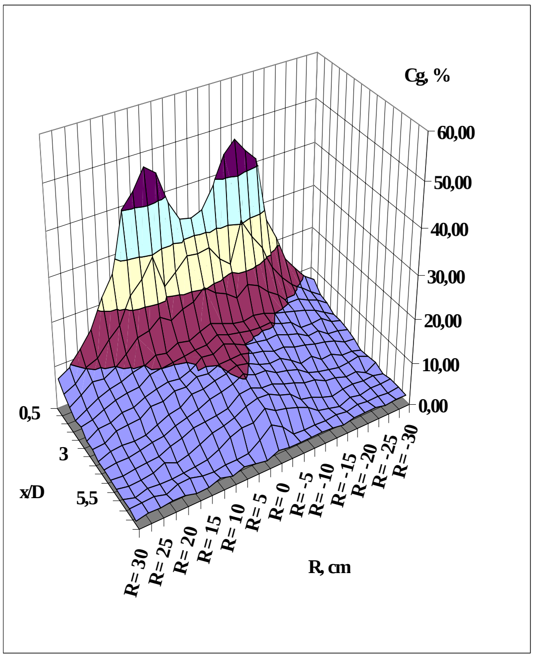

**Figure 10.** Tridimensional diagram of field of gas concentration for burner with stabilizer of type C at $P_{max}$, $D_s$=124mm.

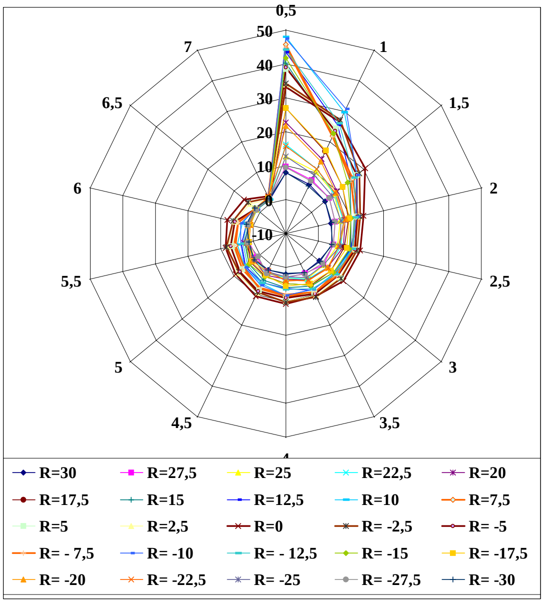

**Figure 11.** Circular diagram of field of gas concentration for burner with stabilizer of type C at $P_{max}$, $D_s$=124mm.

Diagrams from pictures 10 and 11 show that the maximum concentration of gases is found around the diameter of burner exit, that suddenly drops down, the mixture rapidly becomes homogeneous and stoichiometric on all radial sections of flame, starting with distance x/D = 1,5 -:- 2,0.

A generalized characteristic of combustion is represented by equation of distribution of gas concentration depending on the distance from the mouth of burner for each section to the distance *h* from the flame axis. This equation shall be empirically obtained and has the following common form for all types of stabilizers:

$$C_g = k_1 \cdot (x/D)^3 + k_2 \cdot (x/D)^2 + k_3 \cdot (x/D) + C, \quad (2)$$

where: $k_1$, $k_2$, $k_3$ – are proportionality coefficients;

*x/D* – distance from mouth of burner, expressed in proportion to the burner diameter;

*C* – constant.

We present in tabular form the parameters of equation (2) for a set of sections and all types of stabilizers.

**Table 1.** Parameters of distribution equation of gas concentration.

| Type of stabilizer | Diameter, $D_s$, mm | Power developpped | Section radius, cm | Parameters | | | |
|---|---|---|---|---|---|---|---|
| | | | | $k_1$ | $k_2$ | $k_3$ | C |
| A | 124 | *Pmin* | 0/2,5 | -0,116 | 3,028 | -25,078 | 73,93 |
| | | *Pmed* | 0/2,5 | -0,0864 | 2,2934 | -19,977 | 66,873 |
| | | *Pmax* | 0/2,5 | -0,077 | 2,09 | -19,042 | 70,94 |
| B | 124 | *Pmin* | 0/2,5 | -0,1217 | 3,153 | -25,815 | 75,027 |
| | | *Pmed* | 0/2,5 | -0,085 | 2,289 | -20,18 | 67,673 |
| | | *Pmax* | 0/2,5 | -0,0814 | 2,17 | -19,47 | 70,97 |
| C | 124 | *Pmin* | 0/2,5 | -0,0511 | 1,49 | -12,098 | 44,605 |
| | | *Pmed* | 0/2,5 | -0,0557 | 1,4466 | -12,119 | 45,33 |
| | | *Pmax* | 0/2,5 | -0,0546 | 1,395 | -11,52 | 44,83 |

## 3. CONCLUSIONS

The comparative analysis of experimental results processed by means of formula (1) shows that the field of gas concentration is approximately the similar for all types of stabilizers, with some exceptions near the mouth of exit mouth of burner. Such exception is explained not so much by the dependence of stabilizer's shape, as by the gas inlet mode: axial or peripheral.

The other areas of field of gas concentration are quite similar and are based on two factors: the degree of turbulence and velocity of air-gas mixture.

When using the stabilizer of type C it may be noticed that the mixture becomes homogeneous more rapidly and, therefore, the combustion will occur in a flame of a length shorter in relation to the cases of using the stabilizers of type A and B.

The distribution of gas concentration depending on the distance from the exit mouth of burner, calculated by formula (2) for each section at the distance *h* from the flame axis shows that the factors that significantly influence the homogeneity of mixture quality are the degree of turbulence of mixture and its velocity. The reduction speed of field of gas concentration characterizes the quality of mixture formation and, consequently, determines the outlet angle and flame length. The quality of homogeneity of mixture significantly depends on dimensions of stabilizers that contribute to formation of turbulence.

## *Bibliography*

1. **Daud V., Tonu V.** *Research of stabilizing techniques of combustion processes within combustion plants with variable power. Conference with international participation "Installations for constructions and ambiance comfort", Timişoara, 2011.*
2. **Daud V.** *Automatic one piece gas burner of "Dava" type. In: National Conference Abstracts "Installations for constructions and ambiance comfort", Timişoara, 2002. p. 125-128.*
3. **Daud V.** *Calculation program of temperature of boilers for optimization of technological processes in thermal power systems. In: State Register of works protected by copyright and related rights. Series PC, no. 358/1411, AGEPI, 2007.*
4. *Daud V. Stand of technical tests of burner "Dava". – In: Abstracts of scientific-technical Conference "Actual issues of urbanism and land use planning", Vol. II, Chisinau, 2002, p.328-332.*
5. *Nicu R., Daud V. Means and procedures of automated experimentation and simulation of combustion processes of gases. – In: Proceeding of the 2nd International Conference "Telecomunications, Electronics, Informatics". Vol. I. Chisinau, 2008, p. 193-198.*
6. *Roper, F. G. Prediction of Laminar Jet Diffusion flamc Sizers. I, Theorctical-Moddel." Combustion and Flame, 1977, Vol. 29, pp. 219-226.*
7. *Spiegler E., Wolfsntein M., Manheimer-Timnat Y. A model of unmixedness for turbulent reacting flows//Acta Astronautica. 1976. V.3. №3-4. P. 265-280.*
8. *Socolic A.S. Karpov V.P.,Semeonov E.S. Turbulentnoe gorenie gazov. Teoria i praktica szhiganija gaza. L: Nedra, 1964, p. 139 – 156.*

***Recomandat spre publicare: 25.06.2011.***