The simulation of the fields of flow and temperature into a furnace of a burning installation with methane as consequence the variation of heat density of burners using the Finite Element Method

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Abstract: In this paper is presented the analysis of the dynamics flow gas and the temperature distribution into a burning chamber with two identical burners on methan as result of heat density variation of one of them.

Key-Words: methan combustion, burner, Finite Element Method, FLUENT.

1 Introduction

In practice are frequent metting the burning installation on gase with two or more burners.

In this paper is presented the results of changings of the dynamic flow gas and the temperature field distribution into a burning chamber with two identical methan burner, fig.3, as result of the heat density variation of one of them. This it's made through variation of feeding with metane of one burner in limits $Q_{CH4} =(0\div1,5)\cdot Q_{N\ CH4}$. The $Q_{N\ CH4}$, is the nominal flow volume of work.

The burners scheme and their assembling on installation are presented in Fig.1 and Fig.2. The constructive sizes is given in Table 1, [11].

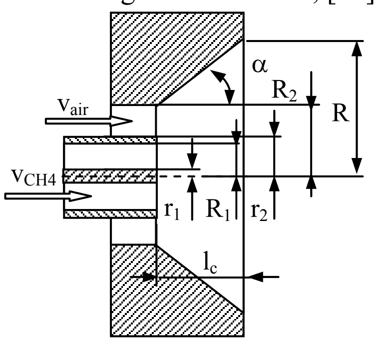

Fig.1

The length l_2 between the axes of two burner and the length l_1 between axes of burner and the wall are both equal with $l_1 = l_2 = 2{,}2\cdot(2R_2)$.

Table 1

r_1	R_1	r_2	R_2	l_c	L	α
[mm]						[°]
3	10	12	30	18	4500	7,5

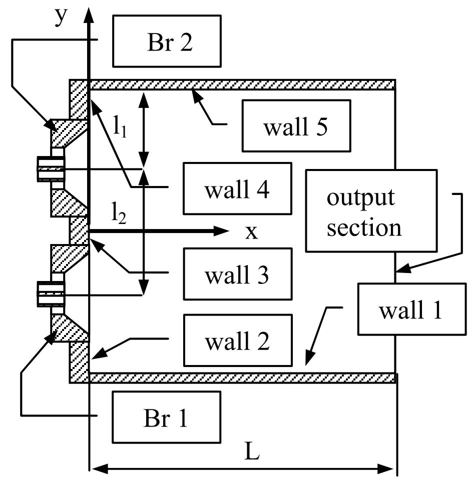

Fig.2

The flow volumes of feeding the burners in simulation are given in Table 2.

Table 2

V_{CH4}	Case	Q_{CH4}	Q_{air}
[m/s]		[m^3/h]	
Burner2	C6	8,23	95,10
Burner1	C1	0	0
4	C2	4,11	47,55
5	C3	5,14	59,43
6	C4	6,17	71,32
7	C5	7,20	83,21
8	C6	8,23	95,10
9	C7	9,26	103,98
10	C8	10,29	118,87
11	C9	11,32	130,75
12	C10	12,35	142,65

The methane burning is made in air excess. The coefficient of air excess is equal with $\lambda = 1{,}1$.

The output of burning chamber is in connection with atmosphere.

The themperature of air and the methan gas introduced into furnace are $T_{CH4} = T_{air} = 300$ K.

2 The analysis using F.E.M.

The analysis with the finite element metod is made with Fluent 6.2.16 programme [16]. The mathematical models used by this programme are: Energy, Solver (Segregaded), Viscous(“k-ε“) and Species Transports & Reactions (Species transport).

In paper are presented the results of analysis concerning the temperature field and the dynamics of gas flow in the plane with maximum heat density. This section plane of study passing through the burners axes, Fig.3.

The model of burning chamber is made with aid of Gambit 2.2.30 programme, [17].

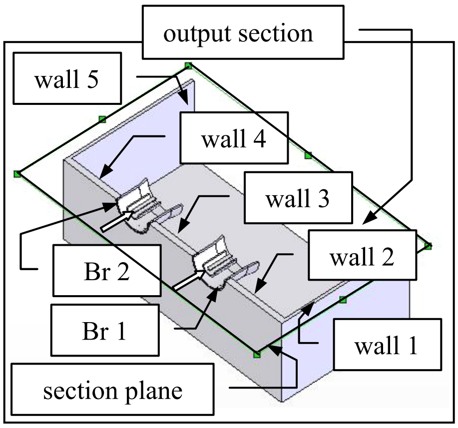

Fig.3

The changing of heat density of burner Br1 impose a separately study of flow and temperature fields on the walls of burning chamber and on the output section of this, Fig.3.

The velocity field in section plane for cases: C1, C2, C4, C8 and C10 are presented in Fig.4 to Fig.8.

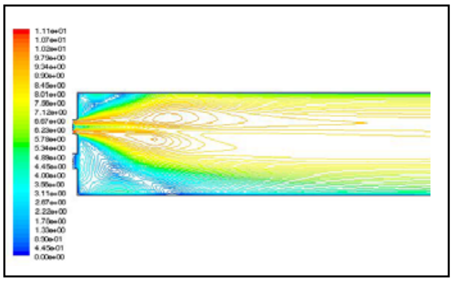

Fig. 4

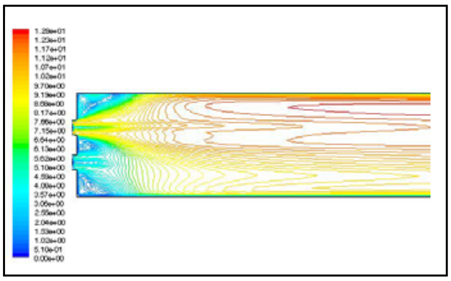

Fig. 5

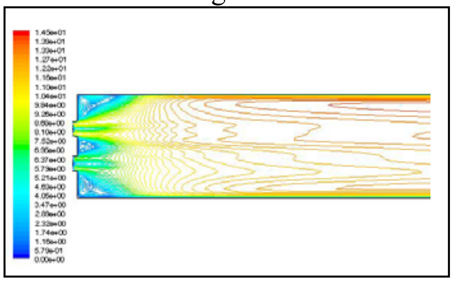

Fig. 6

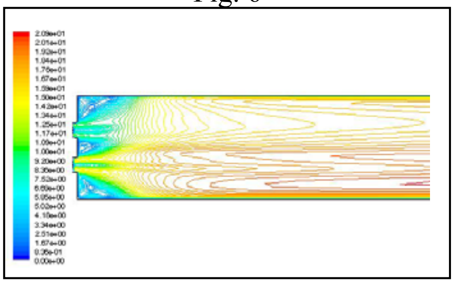

Fig. 7

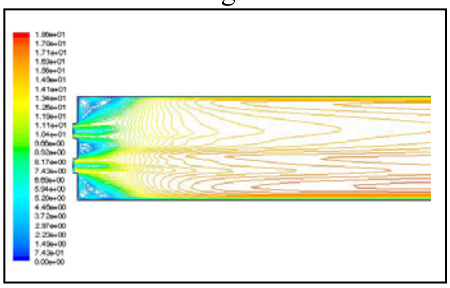

Fig. 8

The medium value and the maximum value of velocity on output section are given in Table 3.

The velocity plots for cases C1 to C10 are presented in Fig.9.

Table 3

case	v[m/s]	
output section	medium value	maximum value
C1	7,36	8,49
C2	11,04	12,43
C3	11,96	13,39
C4	12,88	14,47
C5	13,79	15,05
C6	14,72	16,03
C7	15,64	16,96
C8	16,57	18,57
C9	17,49	19,78
C10	18,42	20,61

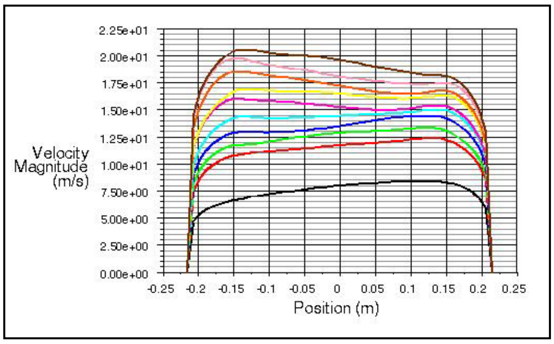

Fig. 9

The temperature field in section plane for cases C1, C2, C4, C8 and C10 are presented in Fig.10 to Fig.14. The medium value and maximum value of the temperature on lateral walls are given in Table 4. The plots of temperature for cases C1 to C10 are presented in Fig.15 to wall 1 and Fig.16 to wall 5.

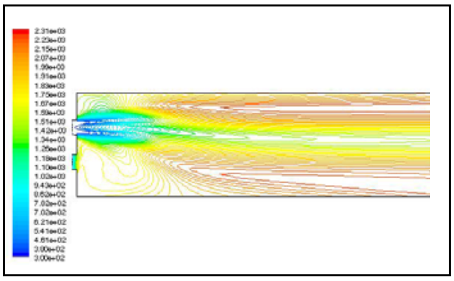

Fig. 10

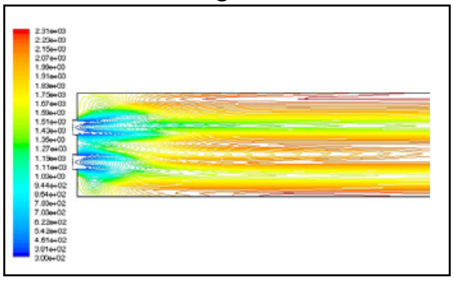

Fig. 11

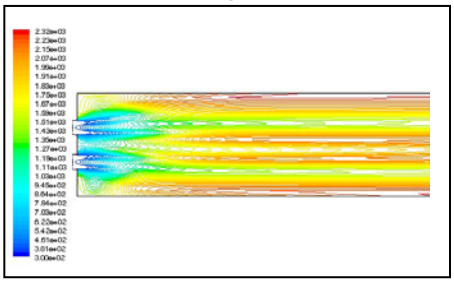

Fig. 12

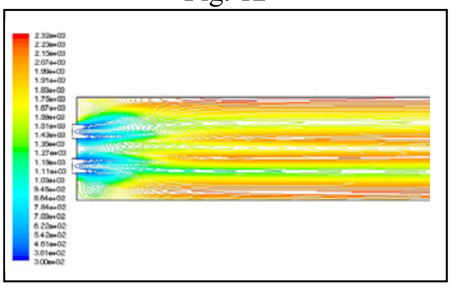

Fig. 13

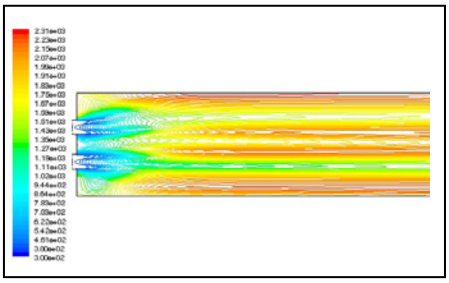

Fig. 14

Table 4

case		T[K]	
		medium	maximum
C1	wall 1	2150,50	2292,57
	wall 5	2093,84	2308,58
C2	wall 1	2151,14	2303,88
	wall 5	2198,74	2313,95
C3	wall 1	2166,06	2305,29
	wall 5	2204,36	2314,74
C4	wall 1	2168,31	2305,49
	wall 5	2205,52	2315,32
C5	wall 1	2162,02	2305,73
	wall 5	2204,01	2315,72
C6	wall 1	2150,90	2305,62
	wall 5	2150,90	2305,62
C7	wall 1	2136,46	2305,36
	wall 5	2196,36	2315,81
C8	wall 1	2120,97	2304,98
	wall 5	2191,04	2315,35
C9	wall 1	2105,56	2304,57
	wall 5	2185,33	2314,47
C10	wall 1	2090,40	2304,15
	wall 5	2179,65	2312,91

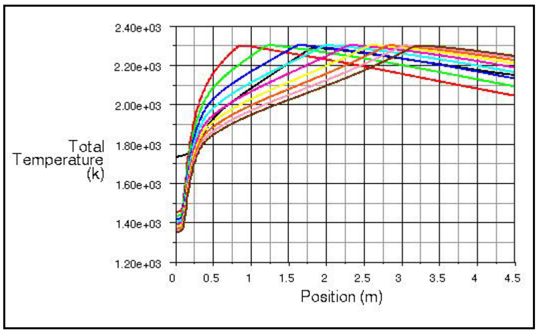

Fig. 15

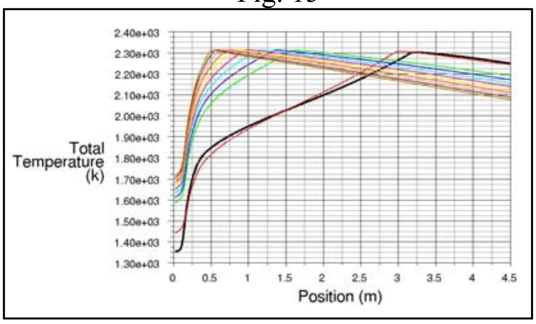

Fig. 16

The medium value and the maximum value of temperature for the frontal walls are given in

Table 5. The plots of temperatures in cases C1 to C10, are presented in Fig.17 to wall 2, in Fig.18 to wall 3 and in Fig.19 to wall 4.

Table 5

case		T[K]	
		medium	maximum
C1	wall 2	1713,20	1738,80
	wall 3	1414,79	1535,03
	wall 4	1367,63	1444,99
C2	wall 2	1340,81	1457,04
	wall 3	878,53	1010,88
	wall 4	1498,29	1589,42
C3	wall 2	1324,69	1437,22
	wall 3	816,44	929,70
	wall 4	1521,16	1614,85
C4	wall 2	1311,60	1421,32
	wall 3	780,76	882,86
	wall 4	1540,16	1636,16
C5	wall 2	1300,47	1407,86
	wall 3	761,42	857,68
	wall 4	1557,00	1654,99
C6	wall 2	1289,52	1394,70
	wall 3	755,84	850,02
	wall 4	1571,11	1671,44
C7	wall 2	1279,59	1382,96
	wall 3	759,16	853,98
	wall 4	1584,01	1685,88
C8	wall 2	1270,75	1372,62
	wall 3	768,70	865,99
	wall 4	1596,10	1698,89
C9	wall 2	1262,84	1363,39
	wall 3	784,18	885,68
	wall 4	1606,33	1710,51
C10	wall 2	1255,65	1355,05
	wall 3	802,84	909,71
	wall 4	1615,76	1721,24

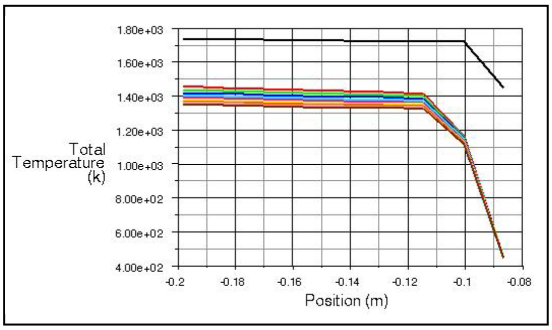

Fig. 17

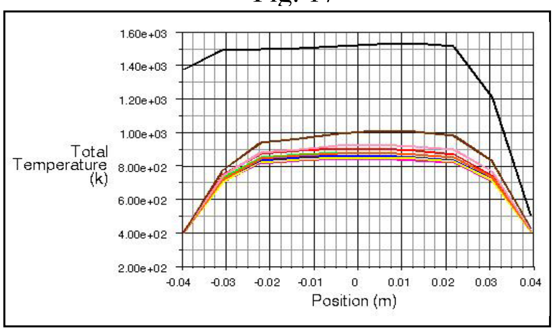

Fig. 18

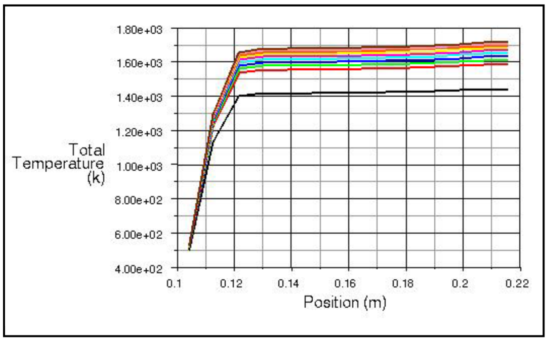

Fig. 19

The medium and the maximum values of temperature on output section of burning chamber are given in Table 4 and the plots of temperature for cases C1 to C10, are presented in Fig.20.

Table 6

Case	T[K]	
output section	medium value	maximum value
C1	1921,26	2245,78
C2	1911,98	2191,56
C3	1913,67	2173,87
C4	1916,54	2186,13
C5	1916,85	2201,27
C6	1918,73	2209,07
C7	1919,03	2213,74
C8	1920,81	2230,08
C9	1920,93	2242,75
C10	1921,27	2251,58

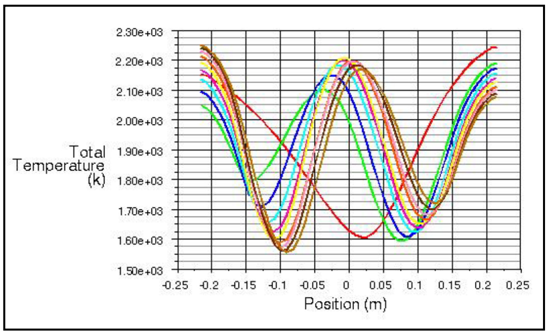

Fig. 20

To estimate the variation of velocity and temperature as consequence of the modification of flow methan volume (burner Br1), on the lateral walls and on the output section of furnace is take as referinces the temperature and the velocity of the nominal regime of work for case C6, see Table 2.

In plots Fig.21 to Fig.27 the abscise represented the percentage of the efective methane flow volume of burner Br1 in report with the nominal volume flow.

The ordonate represented the percentage of the effective value of physical sizes in report with the value of the nominal regime of work.

Considering the values from Table 3 to Table 6, were traced the plots from Fig.21 to Fig.27, which represents :

- $T_{1\,m}(Q_{1ef})$ and $T_{1\,max}(Q_{1ef})$, Fig.21;
- $T_{2\,m}(Q_{1ef})$ and $T_{2\,max}(Q_{1ef})$, Fig.22;
- $T_{3\,m}(Q_{1ef})$ and $T_{3\,max}(Q_{1ef})$, Fig.23;
- $T_{4\,m}(Q_{1ef})$ and $T_{4\,max}(Q_{1ef})$, Fig.24;
- $T_{5\,m}(Q_{1ef})$ and $T_{5\,max}(Q_{1ef})$, Fig.25;
- $T_{e\,m}(Q_{1ef})$ and $T_{e\,max}(Q_{1ef})$, Fig.26;
- $v_{e\,m}(Q_{1ef})$ and $v_{e\,max}(Q_{1ef})$, Fig.27.

In these plots, the medium value is drawing with thin line and the maximum value with thick line.

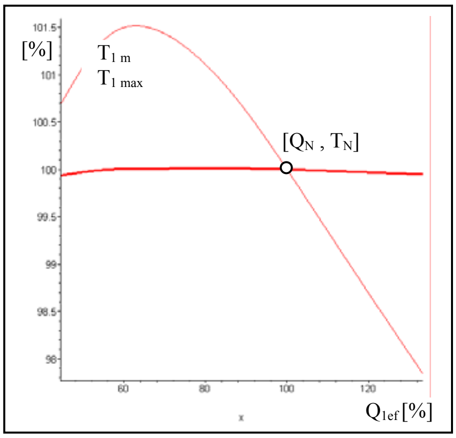

Fig. 21

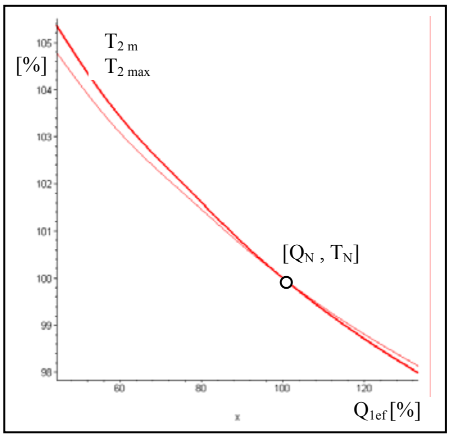

Fig. 22

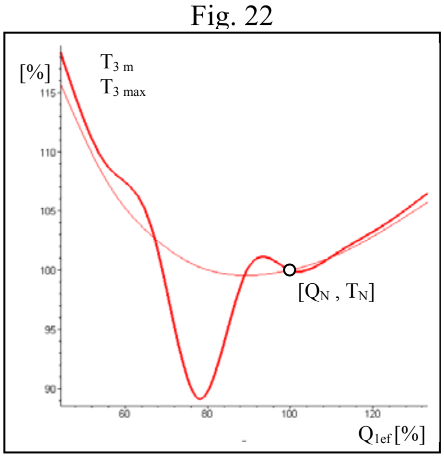

Fig. 23

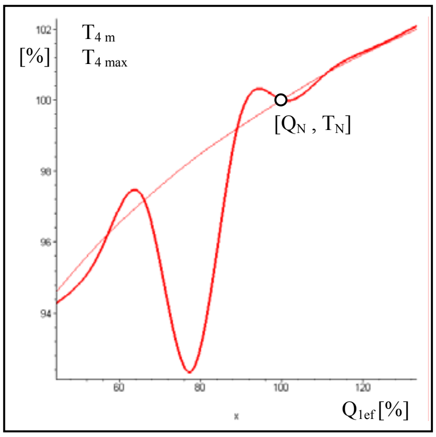

Fig. 24

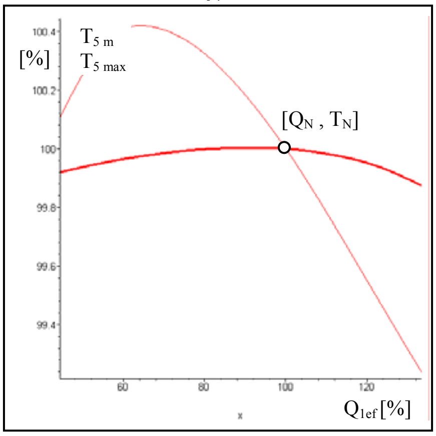

Fig. 25

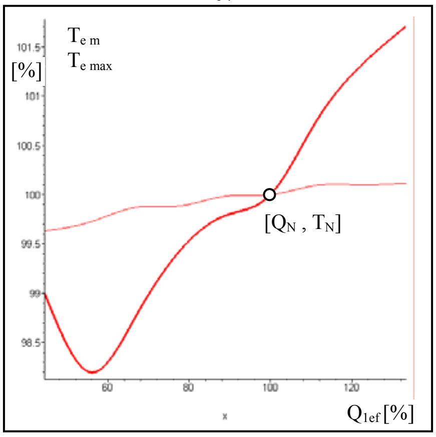

Fig. 26

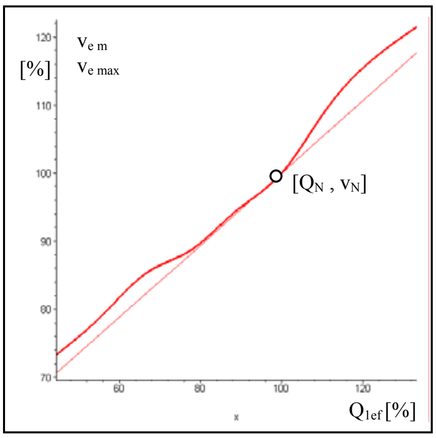

Fig. 27

3 Conclusion

The analysis with the finite element method made evident the turbulent flow character of mixture (air+methane) into furnance together with the recirculation zones of flow (both internal and external) Fig.4 to Fig.8.

With increasing the flow volume of methane, the value of temperature field increases and moving them to output section of burning chamber, Fig.10 to Fig.14. The fields of temperature and of the velocity have axial symmetry shape in relations with the mediane plane of furnace in nominal regime of work.In Table 7 are given the minimum and the maximum values of temperature T_m and T_{max} corresponding to plots from Fig.21 to Fig.26.

Take into consideration the deviation of her in report with the point which correspond to nominal regime of work (the point which is marked with [Q_N , T_N]) in Table 8 are given the absolute values of deviations.

Table 7

	T_m	T_{max}
	[%]	
wall 1	[-3,50;1,50]	[-0,10;0,15]
wall 2	[-1,90;1,50]	[-2,00;5,20]
wall 3	[-1,00;16,0]	[-10,0;18,0]
wall 4	[-5,20;2,00]	[-8,00;2,00]
wall 5	[-0,80;0,40]	[-0,012;-0,004]
output section	[-0,40;0,10]	[-1,80;1,70]

Table 8

	$\lvert \Delta T_m \rvert$	$\lvert \Delta T_m \rvert$
	[%]	
wall 1	5,00	0,25
wall 2	6,80	7,20
wall 3	17,0	28,0
wall 4	7,20	10,0
wall 5	1,20	0,08
output section	0,50	3,50

Considering the values of deviation from Table 8 we can concluded:

- on the lateral walls, for the wall 1 the deviation of temperature is bigger then the deviation of the wall 5, because the wall 5 is in vicinity of the burner Br2 with constant flow volume of methane ;
- on the frontal walls, the wall 3 have the maximum deviation of temperature, in order follow the wall 4 and the wall 2; also in this case is visible the influence of the constant heat density of burner Br2.
- the output sections of burning chamber have the minimum deviation of temperature.

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