USE IN COMBUSTION PROCESSES FOR A NEW TYPE OF GASEOUS FUEL BASED ON HYDROGEN

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Abstract: - The paper approaches a very actual problem worldwide, concerning the replacing, in combustion processes, of classical fossil fuels by clean energy sources, in order to reduce the greenhouse effect gases, as well as for fossil fuels' saving.
The experiments aimed to obtain an oxy-hydric gaseous fuel, known as HRG gas, resulted by a new procedure of water electrolysis, in a generator conceived and realized in USA and improved in Romania by the company Rokura Industrial Applications, which is, in the present, the owner of licence to apply this fuel in Europe and Israel. The HRG gas contains hydrogen and oxygen in approximately equable proportions and its structure is different of that molecular conventional, conferring its particular properties.
The tests effectuated until now have bringed the HRG gas combustion in association with natural gas and air, the mixture being realized in the combustion area, by injection of HRG gas directly into the flame.
In accordance to the experimental results obtaining, the intensification of combustion process allows the reduction of natural gas consumption by 14.7 %, in the conditions of obtaining the same thermal effect that in case of combustion only of the natural gas.
Also, the partial substitution of natural gas with HRG gas conducts to important decrease of CO proportion in waste gaseous. When the substitution increase more than 20 %, the emissions of CO are reduced almost close to zero.

Key-Words: Hydrogen, clean energy, greenhouse effect gases, burner, flame, energy saving.

1. Introduction

During the last years became evident the worldwide trend to use non-pollutant energy sources, aiming to reduce or to eliminate the combustion products CO_2, CO, NO_x, type that have deleterious effects on the environment quality.
In the framework of priority scientific and technological fields for the technological platforms developed at European level they are inscribed high technology fields, considered as being strategic, where it can be found the alternative energy sources, including those based on hydrogen, and, as a consequence, the HRG gas.
By a new procedure of water electrolysis, a team of American researchers obtained, at the end of past millennium, a new gaseous mixture of hydrogen and oxygen, known as HRG gas. This gaseous mixture, with combustible properties, is very different from previously known gases, being characterized by the absence of a molecular conventional structure.

In its paper [1] Santilli from Institute for Basic Research of Palm Harbor (USA) explains the abnormal characteristics of HRG gas by a magnecular structure of it. So, in accordance to this theory, H_2 contained in HHO gas is composed partly from conventional H-H molecules and partly from the magnecular type HxH, and H_3 is composed partly from the magnecular type (HxH)xH and partly from bonds HxHxH type. As well, the author considers that they are also possible magnecular bonds HxHxO, HxOxO, (H-H)xO, OxOxH and (O-O)xO types.
From an energetic point of view, the HRG gas has a behavior extremely different depending on the conditions where ignition and combustion took place, the temperature developed inside the flame varying from about 130°C, during free combustion in normal conditions of temperature and pressure, up to the melting temperatures of some metals or refractory materials very

difficult to be melted. If the ignited HRG gas is in contact with the surfaces of such a materials it will be possible to be used in the fields of cutting, brazing or welding.

Completely different problems are faced when the HRG gas is used in combustion installations, and it is not in a direct contact with the material subject to the heating.

In order to use the HRG gas in combustion installations from industrial heating furnaces in iron and steel industry, machine building industry, ceramic and refractory industry, glass industry it is forecast the use of it next to other gaseous fuels, by injection in the flame already formed of additional gaseous fuel.

In the following material we will present the experimental results obtained by the Romanian team of researchers as concerns the use of HRG gas in combustion installations next to the natural gas, in three constructive variants of HRG gas distribution in the combustion area of the burner.

2. Testing of HRG gas combustion by injection in the flame

2.1. Adoption of technical solution

Having in mind the above mentioned, the technical problem that have to be solved by the research team is the identification of optimal solution, from a constructive and technological point of view for the distribution of HRG gas in burner's body, so that the energetic and ecologic effect be a maximum one.

The starting point was the solution adopted in case of using in the combustion installations some gaseous fuels with a high risk in contact with the oxygen necessary for combustion, that consists in injection of this type of fuel into the already formed flame by burning of another gaseous fuel (natural gas, propane, butane etc.) with the combustion air [2]. Besides, this solution is based on a characteristic of combustion reactions, that consists in the capacity to regenerate the so-called "active agent", strongly intensifying the process. One of the active agents is the temperature released by the flame generated by combustion, in a first step of ignition for one of the gaseous fuels with oxygen from combustion air. The radial distribution of the second gaseous fuel, either from the interior to the exterior, or on the other direction (depending on the way to bring inside the burner the two fuels), in already formed flame, contributes to the intensifying of combustion process in a much more strong than in case when it will be used a gaseous fuel obtained by mixing the two fuels before entering into burner's body [3].

Having in mind all these, it was determined as technical solution for oxy-hydric HRG gas combustion, the solution of injection this gas, by a central nozzle with radial or/and axial holes, into the already formed flame by the combustion of main fuel (natural gas) with combustion air necessary to its combustion.

For the design of experimental pilot burner it was observed the fact that the HRG gas has in its composition, an almost stoichiometric proportion, hydrogen and oxygen, so that to realize the combustion conditions it is necessary only a small supplementary addition of combustion air.

The operating principle is based on two mixture steps between the main fuel (natural gas) and air:

- in the first step, the natural gas is distributed by many radial holes in the ring-like section by which enters the primary air, realizing in this way the ignition;
- in the second step, it is radial or/and axial distributed, from exterior to the interior, the secondary combustion air into the fuel-air mixture ignited in first step.

This solution, previously tested, allow to realize an intimate mixture between the natural gas and air, leading to a good combustion yield and a low level of noxious agents emissions.

The HRG gas is brought into the burner's body by a central pipe and it is distributed into the formed flame, intensifying the combustion process, by:

- radial holes at an angle of 70^o versus the longitudinal ax of burner (variant I);
- radial holes at an angle of 70^o and an axial central hole (variant II);
- only an axial hole (variant III).

In Fig.1 is presented the principle diagram of experimental pilot burner.

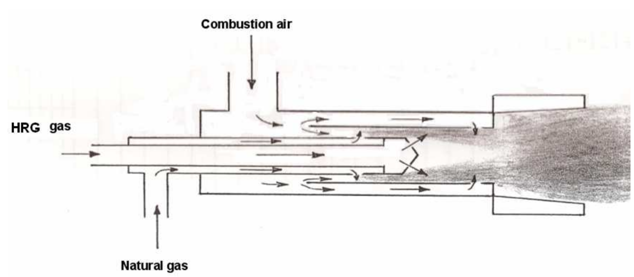

Fig. 1

2.2. Description of operating methodology

The experimental pilot burner, designed and realized for a nominal natural gas flow of 2.25 Nm^3/h and a maximal HRG gas flow of 0.8 Nm^3/h, was tested on a testing stand built in accordance to the European standards [4].

Fig. 2 presents a general image of the testing stand.

Fig. 2

For the measurement of natural gas and air flows it was used two flow meter with directly indication and unified signal. For measure the HRG gas inlet flow supplied by the generator (Fig. 3) it was used a standardized rotameter. The HRG gas line was completed with a Bourdon manometer for pressure control and a safety electro-valve.

Fig. 3

The measurement of cooling water flow, which supplies the heat recuperator and cools the combustion chamber is realized with an ultrasonic flow meter type PORTAFLOW 300.

The pressures of natural gas and combustion air were measured with the digital manometer AFRISO FZM 15.

Also, its were used a mercury thermometer for the measure of cooling water temperatures and a gaseous analyzer AFRISO MAXILYSER for CO, NO, NO_x, SO_2, CO_2 and O_2.

The experimental works aimed two aspects:

- energetic influence of HRG gas addition over the nominal natural gas flow, in different proportion, between 0 - 25%,;
- degree of availability for natural gas (natural gas saving) resulted following the addition of HRG gas, so that to be obtained the same thermal effect, as well as the ecological impact of using HRG gas.

In order to reach the first experimental purpose, they were made the necessary regulations for burning in optimal conditions of the natural gas with combustion air, at a gas maximum flow of 3.49 Nm^3/h and at a gas nominal flow of 2.25 Nm^3/h and it was determined the heat taken over by the cooling water. Then it was added HRG gas, in different proportions, up to 25%, surveying the effect on the heat quantity from cooling water. So it was possible to identify the optimal proportion of HRG gas for that the energetic effect is maximum.

For the second purpose, they were introduced into the flame higher and higher proportions of HRG gas, in parallel to the reduction of natural gas flow, surveying to keep constant the heat taken over by the cooling water at the value corresponding to the combustion without HRG gas addition. For every stabilized thermal regime they were measured the per hour flows for natural gas, combustion air and HRG gas, the chemical composition of exhausted gases, the cooling water flow and temperature and the length of the flame.

2.3. Experimental results

In table 1 are presented the results of tests carried out to determine the influence of HRG gas addition on the heat taken over by the cooling water, using the three constructive variants.

In Fig. 4 is graphically presented the influence of volumetric proportion of HRG gas on the heat taken over by the cooling water. They are presented those influences in the three constructive variants (only radial holes-variant I, radial holes and an axial central hole-variant II and only an axial hole-variant III) for the nominal gas flow.

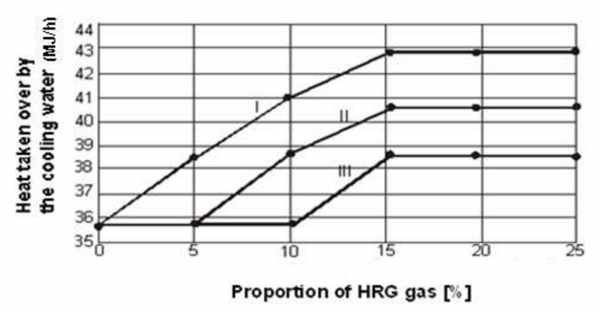

Fig. 4

Analyzing the dates from table 1 and the diagrams from Fig. 4, it is evidently that the constructive variant I offers the great energetical increase by the HRG gas addition. It can be observed that the heat taken over by the cooling water increase with the increase of added volumes of HRG gas, reaching the maximum value of 42.9 MJ/h, in the conditions of a volumetric proportion of HRG gas of 15.1%. Over this proportion of HRG gas, the heat value remains constant, having even tendency to decrease.

This phenomenon was not yet explained, but we suppose that the increased pressure of HRG gas (corresponding to higher flows of HRG gas) influence on its non-conventional structure, worsening the conditions for the development of reaction between hydrogen and oxygen.

In table 2 are presented the experimental results of tests carried out for determination of possibilities to reduce the natural gas consumptions by addition of HRG gas, as well as for measurement of noxious agents emissions. The tests were effectuated only for the constructive variant I.

In accordance to data from above presented table, the addition of 19.9 % HRG gas allows reduction of natural gas flow from 2.25 up to 1.92 Nm^3/h, that means by 14.66 %, in conditions where the heat taken over by the cooling water is kept constant. The volumetric concentrations of CO_2 and O_2 (in dry gases) remain practically unchanged, which is explained by the fact that practically, the hydrogen from HRG gas does not needs oxygen for combustion. But, in the same time with the increase of HRG gas proportion, CO decreases sensible from 58 up to 3 ppm (3,4 mg/Nm^3), and NO and NO_x increases from 56 and 58 ppm up to 83 ppm (153.7 mg/Nm^3) and 88 ppm (162.9 mg/ Nm^3). .

Energetic influence of HRG gas addition — Table 1

No.	Natural gas		Combustion air		HRG gas flow		Composition of exhausted gases					Length of the flame mm	Heat taken over by the cooling water MJ/h
	Flow Nm^3/h	Pressure mbar	Flow Nm^3/h	Pressure mbar	Nm^3/h	%	CO_2 %	O_2 %	CO ppm	NO ppm	NO_x ppm		
Variant I													
1	3,49	18,40	35,88	1,54	-	-	10,9	1,7	65	69	72	400	56,5
2	3,49	18,40	35,88	1,54	0,20	5,4	11,0	1,5	42	79	82	375	61,0
3	3,49	18,40	35,88	1,54	0,65	15,7	10,8	1,9	7	80	84	315	63,3
4	3,49	18,40	35,88	1,54	0,80	19,6	10,7	2,0	5	82	87	300	65,5
5	2,25	10,00	23,13	1,20	-	-	10,9	1,6	58	56	58	300	35,8
6	2,25	10,00	23,13	1,20	0,12	5,1	10,7	1,8	31	58	62	295	38,4
7	2,25	10,00	23,13	1,20	0,25	10,0	10,5	1,9	26	63	67	280	40,7
8	2,25	10,00	23,13	1,20	0,40	15,1	10,4	1,9	10	65	70	260	42,9
9	2,25	10,00	23,13	1,20	0,56	19,9	10,3	1,9	8	69	71	240	42,9
10	2,25	10,00	23,13	1,20	0,75	25,0	10,1	2,0	6	69	72	220	42,9
Variant II													
1	3,49	18,55	35,88	1,59	-	-	11,0	1,6	63	70	74	400	56,5
2	3,49	18,55	35,88	1,59	0,20	5,4	10,9	1,7	45	77	80	390	58,8
3	3,49	18,55	35,88	1,59	0,65	15,7	10,7	2,0	15	79	83	355	61,0
4	3,49	18,55	35,88	1,59	0,80	19,6	10,6	2,0	10	80	84	330	63,3
5	2,25	10,12	23,13	1,21	-	-	10,9	1,6	61	56	59	300	35,8
6	2,25	10,12	23,13	1,21	0,12	5,1	10,9	1,7	38	56	60	300	35,8
7	2,25	10,12	23,13	1,21	0,25	10,0	10,5	1,9	35	60	65	290	38,4
8	2,25	10,12	23,13	1,21	0,40	15,1	10,3	2,0	21	62	66	280	40,7
9	2,25	10,12	23,13	1,21	0,56	19,9	10,1	2,0	16	61	65	270	40,7
10	2,25	10,12	23,13	1,21	0,75	25,0	10,0	2,1	13	62	67	260	40,7
Variant III													
1	3,49	18,43	35,88	1,56	-	-	10,9	1,7	65	67	70	400	56,5
2	3,49	18,43	35,88	1,56	0,20	5,4	10,9	1,7	64	69	72	400	56,5
3	3,49	18,43	35,88	1,56	0,65	15,7	10,8	1,8	63	68	72	390	58,8
4	3,49	18,43	35,88	1,56	0,80	19,6	10,9	1,7	64	69	74	390	58,8
5	2,25	10,05	23,13	1,20	-	-	10,9	1,7	59	56	60	300	35,8
6	2,25	10,05	23,13	1,20	0,12	5,1	10,9	1,7	60	58	63	300	35,8
7	2,25	10,05	23,13	1,20	0,25	10,0	10,9	1,7	61	57	61	300	35,8
8	2,25	10,05	23,13	1,20	0,40	15,1	10,8	1,8	59	59	64	290	38,4
9	2,25	10,05	23,13	1,20	0,56	19,9	10,7	1,9	60	59	63	290	38,4
10	2,25	10,05	23,13	1,20	0,75	25,0	10,8	1,9	59	60	63	290	38,4

Gas saving and ecological impact — Table 2

No.	Natural gas		Combustion air		HRG gas flow		Composition of exhausted gases					Length of the flame mm	Heat taken over by the cooling water MJ/h
	Flow Nm^3/h	Pressure mbar	Flow Nm^3/h	Pressure mbar	Nm^3/h	%	CO_2 %	O_2 %	CO ppm	NO ppm	NO_x ppm		
1	2,25	10,00	23,13	1,20	-	-	10,9	1,7	58	56	58	300	35,8
2	2,14	9,63	20,87	1,11	0,25	10,0	10,8	1,8	20	65	68	280	35,8
3	2,03	9,11	19,64	1,05	0,40	15,1	10,9	1,6	11	70	74	270	35,8
4	1,92	8,59	18,61	0,95	0,56	19,9	10,8	1,8	3	83	88	250	35,8

3. Estimated economic efficiency

In accordance to the experimental results obtaining with injection of HRG gas directly into the flame, the intensification of combustion process allows the reduction of natural gas consumption by 14.7%, in the conditions of obtaining the same thermal effect that in case of combustion only of the natural gas. At the actual price of natural gas, of 210 €/1000 Nm^3 it results that the value of fuel saving versus 1 Nm^3 of natural gas is:

$$0.147 \cdot 210 \cdot 10^{-3} = 0.0307 \text{ €}/Nm^3 \text{ natural gas}$$

The HRG gas necessary to replace the effect of natural gas is 0.199 Nm^3 HRG gas/ Nm^3 natural gas (experimental result). For the production of HRG gas in generator it was consumed 4.7 kWh/Nm^3. In present, we are working to realize new generators with HRG gas production of 50 Nm^3/h and power consumption of 3.8 kWh/Nm^3. Therefore, it is necessary a supplementary power consumption of:

3.8 . 0.199=0.76 kWh/Nm^3 natural gas (utilizing new type generator).

For energetical efficiency is necessary that the HRG gas production and storage to be realized at night, when the power price is very small. Estimating this price at 10 €/MWh, result that the power consumption value is:

0.76 . 10 . 10^{-3} = 0.0076 €/Nm^3 natural gas.

So, the net value of natural gas saved is:

0.0307 – 0.0076= 0.0231 €/Nm^3 natural gas.

If we consider that an industrial heating furnace with an average capacity has a per hour consumption of natural gas of 200 Nm^3/h and an operating time per year of 6000 hours, it results that the value of fuel saving can reach: 200 . 6000 . 0.0231 = 27.72.10^3 €/year & furnace.

4. Conclusions

a. The oxy-hydric HRG gas is a gaseous fuel produced by a new water electrolysis procedure. Its structure, totally different from other gases, confers to him some characteristics and properties, that recommend it for operation of cutting, brazing, welding, where the HRG gas is brought in direct contact with materials subjected to local heating and melting.

b. The scientific purpose of researches, that are presented in this paper, is to find out the technical solutions, on the basis of experiments, for the HRG gas combustion in combustion installations for technological processes of heating by convection or radiation.

c. The tests aimed the combustion of HRG gas with the natural gas by injection of HRG gas in already formed flame by burning of natural gas and combustion air, using three constructive variants for distribution of the HRG gas. The experimental tests were showed the replacing of about 14.7% from natural gas flow by HRG gas, in the conditions of keeping the same thermal regime and to reduce the emissions of CO almost close to zero.

d. Having in mind the supplementary consumption of electric power for the production of HRG gas in generator, of 3.8 kWh/Nm^3 HRG gas, the value of net natural gas saving reaches 23.1 €/1000 Nm^3 natural gas.

References

[1]. Santilli R.M, A new Gaseous and Combustible Form of Water, *Technical Report*, Institute for Basic Research, Palm Harbor.2003

[2]. Waibel R.T, Advanced Burner Technology for Stringent NO_x Regulations, *American Petroleum Institute Mydyear Refining Meeting Joint Meeting of the Subcomitte on Heat Transfer Equipment*, Orlando-Florida, 1990.

[3] Gadea Suzana ş.a., *Manualul inginerului metalurg*, Editura Tehnică, Bucureşti, 1978.

[4] Paunescu L., Surugiu Gh., Utilizarea gazului HRG (HHO), obtinut printr-un nou procedeu de electroliză a apei, în procese de combustie in cuptoare industriale de încălzire, pentru reducerea substanţială a emisiilor de CO_2 şi CO din gazele arse, *Raport Tehnic,* Institutul de Cercetări Metalurgice, Bucureşti, 2006