Journal of the University of Chemical Technology and Metallurgy, 44, 4, 2009, 395-402

PERFECTION OF MIXING BETWEEN GASEOUS FUEL AND AIR IN INDUSTRIAL BURNERS – TECHNICAL AND TERMINOLOGICAL PROBLEMS

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Received 15 May 2009
Accepted 30 October 2009

ABSTRACT

In this paper the attention is drawn to some peculiarities and differences in the choice of a main criterion for the classification of the different gas burners, which is used in their designation. An analysis for the possibilities of the particular types of such devices to ensure high technical-economical and ecological indicators is made. The trends in the change of the most important regime parameters depending on the place and the mode for implementation of mixing are retraced. Different constructions are presented and the chance for arising of a misunderstanding by unconditional acceptance of only some of their characteristics is discussed. An approach for avoidance of such situations is recommended.

Results from ecological analysis of the advantages, to which the perfection of mixing in burners, operating in a given furnace leads, are presented. On the basis of a typical for the metallurgy example the influence of the improvement of mixing on the environment in the region of the enterprise is estimated.

Keywords: gas burners, classification, improvement of mixing, technical-economical and ecological effectiveness's.

INTRODUCTION

The intensive development of the combustion engineering in the last decades, oriented towards creating of more and more economical and sparing the environment constructions, leads to the necessity of a periodical comparison and actualization of some basic concepts, which in chronological aspect have served for building up the burners' theory and classification. Specially, a huge number of different technical solutions exists for the gas burners preferred by the specialists in design and exploitation of industrial furnaces, because of their numerous advantages over the burners, working with liquid or solid fuels [1].

When developing a new construction normally the leading motive is the achievement of maximal technical-economical and ecological effects, and not the fitting of the new concept into certain obsolete frames, fixed for decades past.

Moreover, since the burners are partially relieved from the imposed on many other products restrictions like the necessity of a type approval etc., the constructors intentionally combine elements from different groups of burners, aiming in this way to get constructions with best indicators. Quite naturally the names and the symbols, with which each new product is identified, are determined much more from marketing and within the firm reasons, that leads to the appearance of a variety of new concepts, referring to one or other feature of the considered object. For example, in some cases the accent is on the place of formation of the fuel-air mixture, in other – on the mechanism for heat transfer from a given burner, and in yet other cases – on the zone of its assembling in the furnace or on the shape of the flame from it.

In the present review article the existence of different classification indications, according to which a particular device may fit into different groups, but it is pointed out the rashly attaching of easy for commercial use "labels", giving an advantage only of one of its marks is unacceptable, because a given object might be called with several different names, which might lead to misperception even persons with technical training. The above mentioned processes are intensified also from the fact that lately most firms do not publish details of constructive character in their materials, until the particular model is on the market, restricting their information only to presentations of basic exploitation indicators, which have a rather demonstrative character, and in this manner transform the selection of a suitable article into a designing process. It can be summarized, that the finding of the exact place of a contemporary device in the already built schemes is a serious task, which can grow up into a debatable problem in the specialized literature.

The purpose of the present work is on the basis of the possible approaches and accents in the choice of a decisive criterion for classification of gas burners to outline the development of their constructions towards higher complex technical-economical and ecological indicators of the furnaces, in which they are assembled.

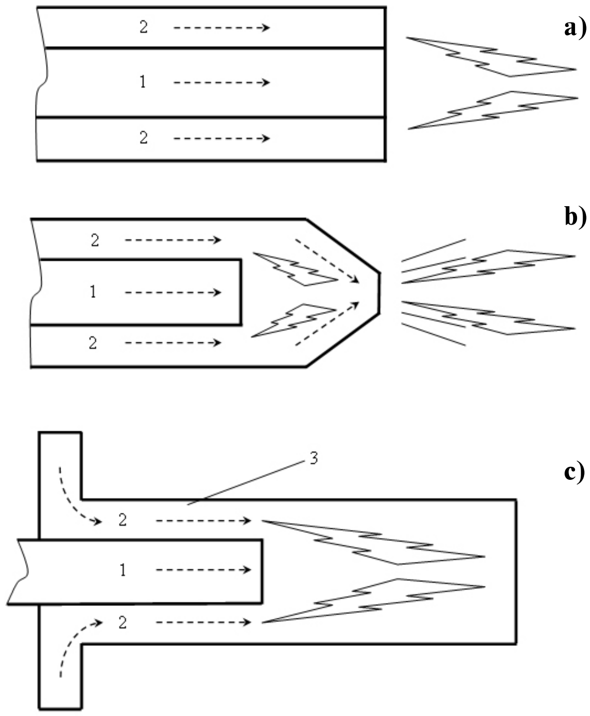

Fig. 1. Scheme of a burner: a) without preliminary mixing of gas and air; b) with partial preliminary mixing of gas and air; c) with preliminary mixing of gas and air (1 – gas; 2 – air; 3 – mixing tube).

CLASSIFICATION OF THE GAS BURNERS FROM A POINT OF VIEW OF THE PLACE FOR MIXING OF THE TWO MEDIA

Some authors assume, that according to the zone of the device and the mode for implementation of mixing between the fuel and the air, three kinds of constructions can be identified [2, 3].

A. Burners without preliminary mixing of gas and air

In them the two media run out as separate flows in the working space of the furnace, i. e. mixing and combustion run simultaneously.

A scheme of such a device is shown in Fig. 1a [1]. It works on the principle of the interaction of two restricted jets and provides the longest flame in comparison with the other types of gas burners, which will be considered. Since diffusion between the two media is used, the process is called "diffusion combustion".

The burners without preliminary mixing are used, when a concentrated input of heat with few in number powerful devices has to be realized. They are appropriate for high-calorific gases. These burners have a wide range for regulation of their power. Furthermore, they provide an opportunity for working with different gases or with a gaseous fuel and with black oil. They are preferred for directly pointed radiation heat exchange, with a concentrated input of heat to the processed in the furnace material. Also they allow high temperature of preheating of the media, which gives a possibility for considerable economy of fuel.

The most serious disadvantage of the burners without preliminary mixing of the two media is the comparatively high air ratio (α), the values of which often exceed 1.10 [1] and lead to a variety of negative consequences. That is why, without neglecting their place in the contemporary combustion technique as undemanding, flexible and very steady devices, when those are ambitions for implementation of an optimal, from a technical-economical and ecological point of view, combustion process, it is necessary to find more sophisticated constructive solutions such as the ones discussed below.

B. Burners with partial preliminary mixing of gas and air

In this type of devices, called also burners with an improved mixing [3, 4], for some of the media, the mixing takes place in the zone in front of the outlet of the tube for feeding of the gaseous fuel, where eddies are formed, as shown in Fig. 1b [1].

Another part of the two fluxes runs out independently in the working space of the furnace and there the mixing between the gas and air is accomplished.

In comparison with the previously considered case, in the burners of this type a shorter flame is obtained, due to the partial declining of its functions as a medium for implementation of the mixing. They are also used in furnaces, where a concentrated input of heat is necessary, i. e. at direct radiation heat exchange, and they are appropriate for work with highly-caloritic fuels.

The improved mixing allows exploitation with a comparatively low air ratio, the recommendatory boundaries for which are 1.05 – 1.08. This is a considerable advantage of these devices in comparison with the representatives of the former group, since at high temperature of the flame, for the reducing of the heat losses with the outgoing flue gas the decreasing of their quantity is of particular importance [1].

The treated burners have one more important positive property, namely the diminished generation of the dangerous for the human health nitric oxides. Their formation is intensified at continued contact between the fuel and air. That is why, because of the high outflowing velocities of the two ingredients, the residence time in the combustion zone decreases considerably and the generation of these compounds in the flue gas is brought to the possible minimum.

C. Burners with preliminary mixing of the gas and the air

It is often pointed in the literature, that these fuel burning devices work on the principle of the injector. The mixing is carried out in their element, located in front of the outlet for supplying gaseous fuel, called “mixing tube”.

In Fig. 1c the work of such a device is illustrated. The burners of this type have the shortest flame, since its task is only to feeding hot flue gas in the unit. Practically, its whole working space is filled with intensively circulating products of burning, which quickly lose their individuality in the furnace atmosphere, realizing most frequently uniformly distributed radiation heat exchange, which is achieved by combustion of low-calorific gases in a huge number devices with low power. Moreover, they provide a homogeneous temperature field, allowing improving the quality of the processed product and minimizing of the expense for that.

The complete preliminary mixing of the media gives the opportunity to work with the lowest air ratio among all met in practical constructions, the recommendatory boundaries for which are 1.03 – 1.05. The advantages, to which this leads, and also the mentioned practically isothermal medium in the furnace, make the considered devices the most perfect from a technical-economical and ecological point of view, which, however, is accompanied with complicated construction and with an enhanced sensitivity towards changes in their exploitation regime.

Discussion on the classification of the gas burners from the point of view of the place for mixing of the two media

There are certain peculiarities in the presented above classification. Thus for example, in [5] are mentioned only the first and the third group, without considering independently the burners with partial preliminary mixing of the two media. That most probably is due to the fact, that they are an intermediate link in the perfection of the constructions from such without preliminary mixing of the fuel mixture to devices with complete use of this process.

According to [6], the most widely used burners with preliminary mixing are the injection burners, but except them, as pointed out in the cited literary source,

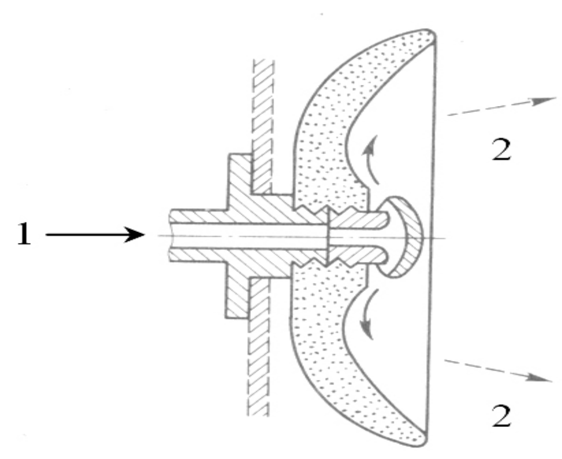

Fig. 2. Ceramic burner [6] (1– fuel-air mixture; 2 – flue gas).

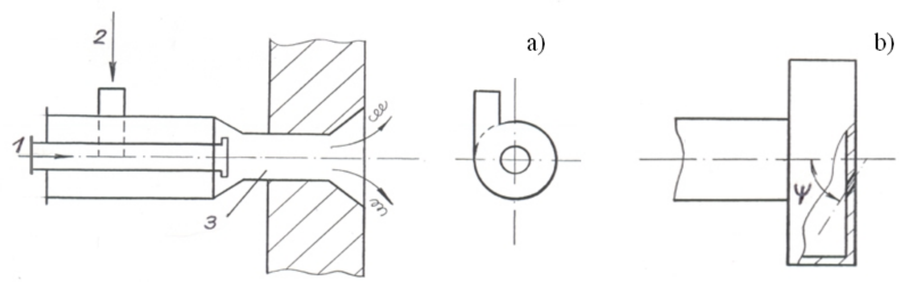

Fig. 3. Schematic presentation [1] of: a) tunnel burner (1 – gas; 2 – air; 3 – tunnel of the burner); b) constructive arrangement of the head for outflow of the gaseous fuel.

to the same type belong the ceramic (Fig. 2) and tunnel (Fig. 3) burners.

The last device is especially of interest both from theoretical point of view in order to find its correct place in the classification of gas burners, and from practical point of view, since it provides some specific opportunities for the organization of the heat exchange in furnaces.

The tunnel burner is not a real device with complete preliminary mixing of the media, but it represents rather a connecting link between the second and the third group, since it is not clearly fixed where in the presented in Fig. 3a scheme the homogenizing of the fuel mixture ends. The frequent assumption on that the tunnel and injection burners concepts are identical, which is made in the older literary sources [2], generates at least two terminological problems – by referring the discussed devices to these with complete preliminary mixing of the media, already estimated as incorrect, and also - by renouncement of the possibility burners with construction other than injection, to be embedded in a tunnel, which is eliminated by the citied above [6]. That is why these articles can be pointed out as an example for well-grounded use of the mentioned concept of devices with improved mixing, without enforcing the condition for complete mixing.

The construction of tunnel burners is again the often employed “pipe in pipe”, but part of the fluxes are mixed in front of the outlet for feeding of the gas. The mutual penetration of the two media can be improved by separation of the one or both fluxes in several single jets.

In Fig. 3b in more details the head from metal or ceramic material, with which ends the gas tube from the presented in Fig. 3c scheme of a tunnel burner is shown. As it can be seen, the fuel runs out from a few outlets with axes, which intersect at a particular angle Y, which in this case is chosen to be 60^o in respect to the air flux. The smaller is the cross section of the orifices, through which the gas is distributed, the more intensive is the mixing. The feeding of air is done in a similar mode by an outer tube with a bigger diameter.

Except for the already specified positive properties, the tunnel burner possesses the following advantages, resulting from the organization of the motion of the two media:

- The mixing is intensified as a result of the tangential feeding of the air and the securing of its further swirling motion.

- After the fusion of the two fluxes, the mixture continues with its movement in a specifically formed tunnel (position 3 in Fig. 3a), which has given the name of the whole device. This provides one very important technical possibility for organization of the heat exchange in contemporary furnaces, namely the using of the burner as an overhead one.

In Fig. 4a–d are offered different modes of constructive design of the tunnel [7], and Fig. 4e displays a multiple tunnel burner [6], which is a version for construction of such an equipment, combining several from the enumerated methods for improvement of mixing.

Another possibility for achievement of a more complete mixing is the evocation of a swirling motion of one of the fluxes or both, which is realized not only by tangential feeding mostly of the air, but also by installing of turbulizing bodies in the way of at least one of the media, as shown in Fig. 7.

By using combinations of the discussed approaches, without sticking to the characteristics of one or another group of burners according to the presented

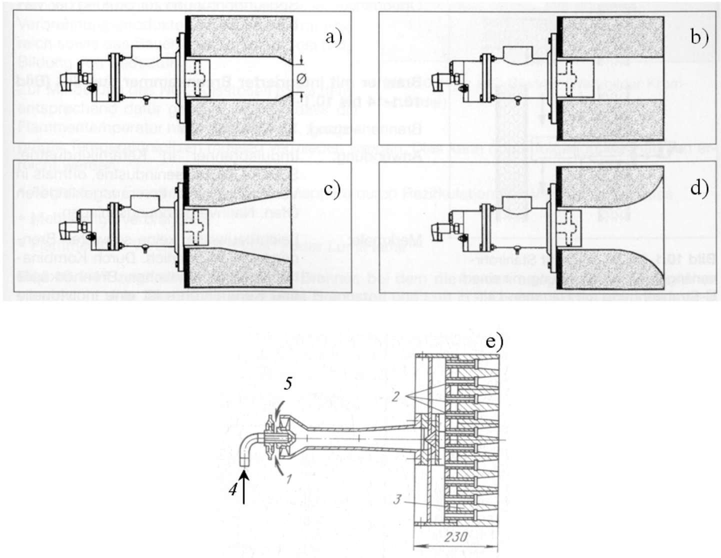

Fig. 4. Modes for constructive arrangement of the tunnel (1 – mixer; 2 – distributing box; 3 – ceramic prisms; 4 – gas; 5 – air).

above classification, are obtained constructions, which formally are attached to the devices with partial preliminary mixing, but according to the degree of combustion, which they can ensure, approach those with preliminary mixing of the gas and air.

Types of gas burners from the point of view of other constructive and technological features

We will briefly discuss the influence of factors like the regime for heat transfer from the burners to the processed material, the place of their mounting in the furnace, and the shape of their flame, on the genesis of the names of these articles.

The tunnel burner is a typical example for a device, allowing for realizing of an indirect pointed radiation heat exchange both when mounted in the wall, or in the arch of the furnace. In the two cases the selective radiation of the flame and the flue gas is replaced by this of the refractory material, forming the tunnel, while the radiation heat flux from it to the product in the furnace is with a continuous spectrum in the whole range of the visible and the infrared rays, characteristic of solid bodies. The same advantages has the displayed in Fig. 2 ceramic burner. Because of these two constructions find a very wide application in contemporary furnaces. Depending on the place of the mounting of each of them, the burner can be called overhead [7] or wall [8] (radiation) burner, examples for whichare given, respectively, in Fig. 5a and 5b.

The shape of the flame introduces another impact on the terminology. With an appropriate arrangement of the outlets for running out of the mixture, it is possible to achieve a flat flame (with the shape of a fan or a plate), and the burner itself is called a flat-flame burner. In Fig. 6ű and 6b are presented examples with

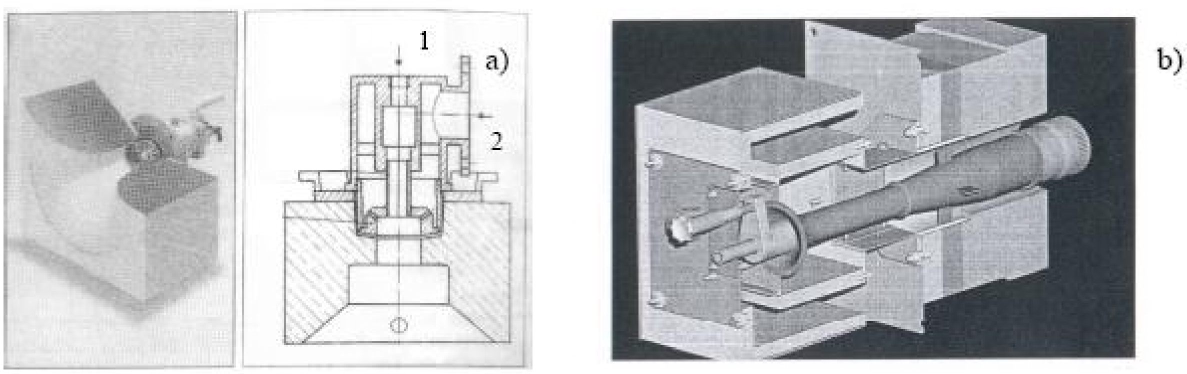

Fig. 5. Radiation burner: a) overhead [7] (1– gas; 2 – air); b) wall [8].

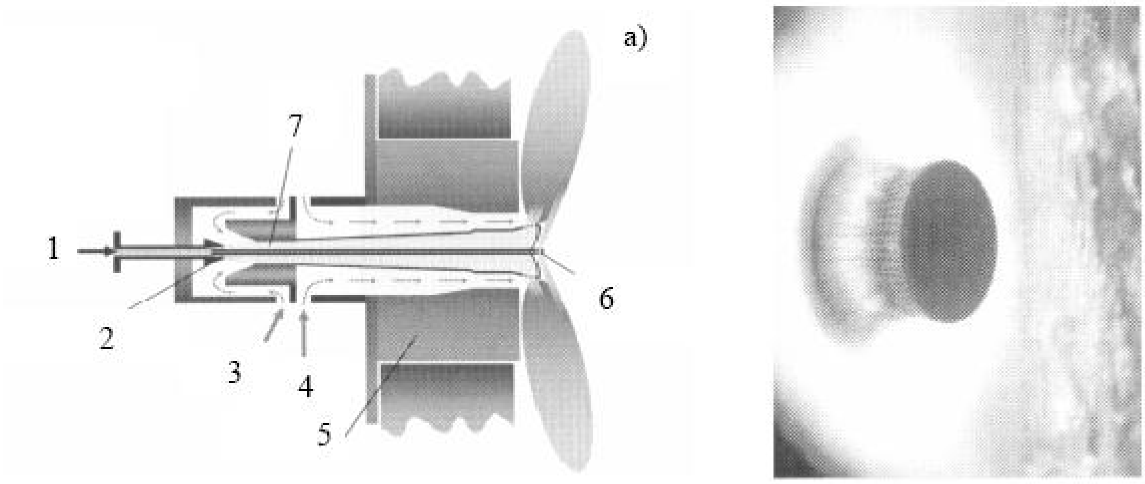

Fig. 6. Flat-flame wall burner (1– gas; 2 – orifices for supplying with primary air; 3 – primary air; 4 – secondary air; 5 – tunnel; 6 – orifices for supplying with secondary air; 7 – Venturi-tube).

such devices, destined for assembly in the walls of the corresponding furnace [9].

In Fig. 7c – 7d are shown several more constructive solutions for manufacturing of flat-flame burners [6].

Flat flame can be achieved also with the already introduced tunnel and ceramic burners.

There are even designs, it which the outflow of the two media or of the mixture is done at an angle in respect to the longitudinal axis of the device, exceeding 90°, i. e. the jets from the outlets form an angle with the wall of the furnace, in which the device is installed. Thus, the wall heating is facilitated, in order to attain an indirect stricken radiation heat exchange from the brickwork to the material processed in the furnace. In this design, however, the serious shape pressure loss, which is obtained by the superposition of the running from a space with a large cross section (the corresponding tube) into such one with limited dimensions the orifice) and the change of the direction of the motion wit more than 90° should be taken into account.

CLASSIFICATION OF THE GAS BURNERS FROM THE POINT OF VIEW OF THE MIXING MECHANISM OF THE TWO MEDIA

A different approach to the classification of devices for burning of gaseous energy carriers is demonstrated in certain more contemporary sources. Their the attention is focussedon the processes, running in the flame [10].

It was already mentioned, that in the burners without preliminary mixing diffusion between the two singly mixed media is realized [11] and therefore the process is named diffusion combustion, and the formed torch – a diffusion flame [12].

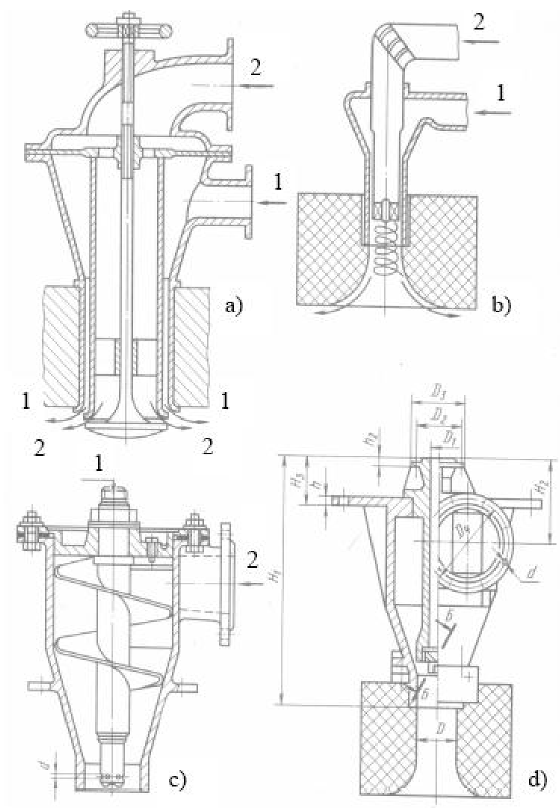

Fig. 7. Different constructions of flat-flame burners (1 - gas; 2 - air).

The other possibility is the realization of kinetic burning, which is available for a preliminary prepared mixture. Often it is called premixed combustion [9]. Its velocity is many times higher and is limited by the kinetics of the chemical reactions carried out in the flame, which is reflected also in the name of the process itself.

Both types of combustion can be laminar or turbulent, the latter being preferred in industrial installations in view of their much higher intensity [11].

This approach avoids the plunge into technical and technological particularities, which simplifies the classification, but also does not provide information about the concrete constructive design of the burner, the mode of input of heat from it to the processed product, the place for its assembly in the furnace, and the shape of the obtained flame.

Other criteria are also possible, according to which the devices for combustion of gaseous energy bearers can be classified. In particular cases it is justifiable to put the accent on the predominating mechanism for heat transfer to the processed in the furnace material, which has been mentioned as a limiting factor in the treatment of the above concrete designs.

From our review of the approaches for classification of the gas burners it becomes clear, that each of them has advantages and weak sides. Because of that, it can be recommended, the name of the device to reflect several different significant characteristics, regardless of the inconveniences from its extension. Thus for example, if in a given publication only once the expanded description “wall flat-flame tunnel radiation gas burner” is used, practically all important marks of this article become clear. After that it can be introduced a shorter and commercially orientated conventional designation.

ECOLOGICAL ANALYSIS OF THE ADVANTAGES FROM THE IMPROVEMENT OF MIXING

The perfection of mixing in a given device leads directly to the possibility for reducing of the air ratio in it. The technical-economical effect of that is described at length in a number of publications, where the computation of the quantities, characterizing the combustion is considered [13], so this does not need additional reasoning.

Here we will focus briefly on the ecological impact of the improvement of mixing. If in one typical for the metallurgy heating furnace with consumption of natural gas of 1 m^3/s, burners without (a = 1.10) are replaced by burners with preliminary mixing of the media (a = 1.04), our own calculations show, that the decreased emission of exhausted gases would have annual influence on the environment, equivalent of the pollution from more than 1300 modern motor cars. By maintenance of all other priorities from technical-economical nature, which affords such a device, this shows the enormous potential of the perfection of mixing of the gaseous fuel and the air in industrial burners.

CONCLUSIONS

The existing of a great and often gratuitouse variety of concepts and names of gas burners has been demonstrated. It can lead to embarrassed orientation or to rising in absolute of only some features and properties of a given device at the expense of other of its characteristics.

For avoidance of the mentioned uncertainty it is recommended that the presentation of a given burner should use two descriptions – an extended one, which should point out its substantial features and a short one (commercially orientated) designation for frequent use with a less informative character.

The statement, that the development of the combustion technique is immediately connected with the perfection of the processes of mixing between the two media is confirmed. Our own calculations for a typical metallurgical unit show that the decreasing of the value of the air ratio from 1.10 to 1.04 would have annual effect on the environment, equivalent to the pollution from more than 1300 modern motor cars.

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