ISSN 1611-616X VULKAN-VERLAG · ESSEN 2 2008

HEAT PROCESSING

INTERNATIONAL MAGAZINE FOR INDUSTRIAL FURNACES · HEAT TREATMENT PLANTS · EQUIPMENT

http://www.heatprocessing-online.com

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Published in HEAT PROCESSING 2/2008

Vulkan-Verlag GmbH, Essen (Germany)

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Saving fuel gas in industry by means of optimum burner settings

Christian Schare

The following article highlights the economic advantage of optimum burner settings. It is designed to achieve maximum benefit for industry and the environment at minimum cost. Optimum burner settings and related work guarantee the economy and operational safety and reliability of existing heating equipment with a pneumatic air/gas ratio control system. In addition, energy saving is not only described in theory, but is also shown on the basis of a practical example.

Energy saving will be an important topic in the future – and not just in view of rising prices. There is already a wide range of ideas and possible solutions, ranging from the use waste heat to preheat combustion air and combustion gas to the optimum insulation of the furnace walls. The selection of highly efficient recuperative or regenerative burners or electronically controlled "cam disks" dependent on the oxygen content in the flue duct, for example, will help to save energy.

Figure 1 shows the typical layout of a heating system with a pneumatic air/gas ratio regulator system. In general, the following are connected to the burner: two solenoid valves, one air/gas ratio control and one gas adjuster in the gas circuit. In addition, there is an air control valve and an air adjuster in the air circuit.

Field experience

Burners are often in use despite the fact that they have not been set optimally for years. Extensive burner settings measurement takes time. This is often not scheduled to the extent required during the commissioning phase or during servicing and maintenance work or has to take a back seat behind other work. Often, the service technician can only adjust the burner by sight, which means that the setting will be far from perfect. Some burner suppliers do not provide burner curves, which are important guides for setting the system. A gas meter or rotameter is not fitted, in order to keep costs down, and there is no tapping point to measure the flue gas. Although this results in a functional burner, it does mean, however, that the best possible setting is not achieved. The potential offered by good furnace, burner quarl and burner manufacturers is not utilised by the operator. In fact, it is possible to achieve control ratios of 1:10 and near-stoichiometric combustion by using the correct heating equipment and furnace geometry.

The Technical Service Department at Elster Kromschröder GmbH services around 2000 different thermal combustion systems per year, all with different process requirements in the steel and iron, ceramics, non-ferrous metals, foodstuffs, environment and drying industries. Gas/air ratios of lambda = 1.5 or considerably worse are being identified more and more frequently with excess air levels of 400 to 500 percent being by no means a rarity.

High excess air cools the burner flame. This results in potentially fatal carbon monoxide levels rising in the furnace chamber or the burner operates with an air deficiency. Systems with a CO content of up to 25,000 ppm have been found by technicians in the past. As a result of these incorrect settings, it is possible for dangerous pockets of gas to form in the furnace and, in the worst case scenario, this can cause an explosion. The excess gas very often combusts in the flue gas system because it meets fresh air sources in this system which results in an incineration process which is very similar to deflagration.

The lambda value

The lambda value (λ) used in combustion technology represents the level of excess air relating to complete combustion. If there is an air deficiency, the flue gas will contain carbon monoxide (CO) since there is insufficient oxygen (O_2) for the complete oxidation of carbon monoxide to form carbon dioxide (CO_2). This CO is very dangerous when it exits

Fig. 1: Typical layout of a heating system with pneumatic air/gas ratio control system

the firing system due to its toxicity. CO is slightly lighter than air with a density of 1.250 kg/m³ compared to 1.293 kg/m³. As the air deficiency is reduced, in other words as the O_2 concentration rises, the CO level falls as it is oxidised to produce CO_2. The CO_2 rises correspondingly. This process is completed when $\lambda = 1$. The CO is close to zero and the CO_2 reaches its maximum. There is no more O_2 at this point since the oxygen fed into the system is immediately used to oxidise the CO.

If the lambda value is greater than one ($\lambda > 1$), the O_2 value increases since the oxygen supplied to the system with increasing excess air is no longer used by the oxidation process as there is not enough CO. However, a certain excess air level is always required to achieve a complete combustion process. On the one hand, the oxygen distribution in the combustion chamber is not uniform, and on the other, the mixing energy (particularly when the burner is set to low-fire and part-fire rate) is not sufficient to mix all the molecules involved in the combustion process perfectly.

Optimum combustion in practice

Optimum combustion is achieved if there is sufficient excess air to achieve a complete combustion (λ = 1.05 to 1.2). At the same time, the excess air must be subject to an upper limit, so that the air is not heated unnecessarily.

These excess air volumes and additional combustion gases, such as nitrogen, are heated without providing any benefit and simply transport the heat through the flue gas system, where it is wasted. The firing efficiency of the furnace system is reduced as a direct result of this.

If the excess oxygen in a firing system is improved by just one percentage point (for example from 5.5 percent to 4.5 percent of O_2), this will generally also increase the efficiency of the system by approximately 1 to 2 percent, dependent on the influence of the heating equipment on the system as a whole (**Fig. 2**).

A lambda value of 1.5 is apparently an acceptable value for many operators. Nevertheless, it is advisable on an aluminium smelting furnace, for example, to adjust the lambda value to around 1.05 if the requirements for this setting have been satisfied (burner, burner quarl, furnace geometry, etc.).

Both the furnace manufacturer and the operator are interested in keeping the oxygen value in the furnace atmosphere as low as possible. On the one hand, corundum formation should be avoided if at all possible since it will result in the furnace "overgrowing" slowly and can only be removed by cost-intensive work when the furnace is cold. On the other hand, oxidation on the surface of the bath causes aluminium to burn off, which results in a loss of product. Finally, once the burner settings have been optimised, the energy balance of the furnace system will increase drastically.

The crucial factor for determining the flue gases is the measuring point. Measurements downstream of a flow interrupter or intake of foreign air into the furnace chamber will inevitably result in false measurement results. If it is not possible to find a suitable measuring point, the furnace manufacturer or service technician (if he is familiar with the system) should be asked. Only a technician who knows the thermal processes that take place in the furnace, and in the material treated therein, can assess at which points an informative analysis must be drawn. Things are made more difficult if it is not possible to take an informative measurement due to the production process. In addition, the gas registration systems (gas meter or rotameter), the burner diagram, the ionisation signal or the assessment of the combustion properties by sight can be used to set the burner.

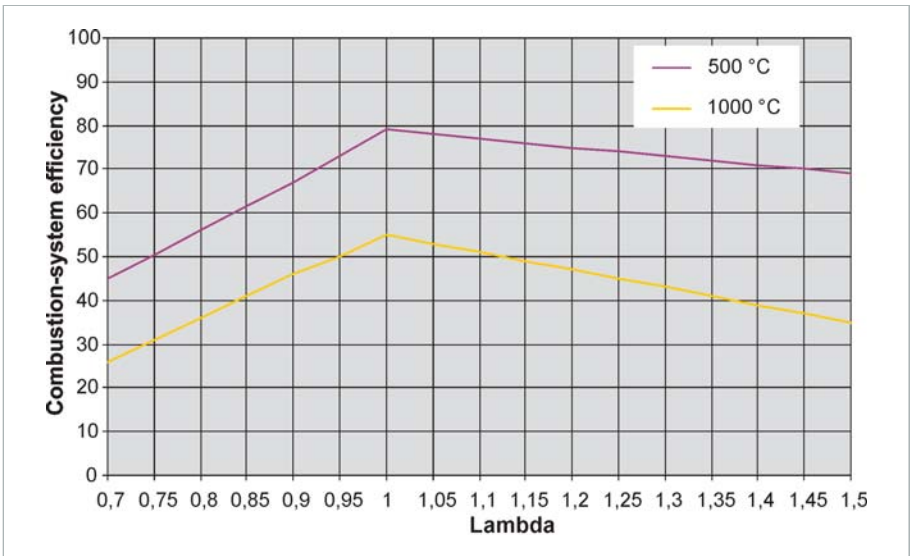

Fig. 2: Firing efficiency as a function of lambda, referred to the flue gas temperature

Possible interference to optimum combustion

Possible interference to a combustion process may include the following:

- Air pressure fluctuations caused by soiled air filters or pipelines
- Fluctuating combustion air temperature or density by drawing in the combustion air outside the building, where temperatures of -20°C to +50°C (winter/summer) may prevail
- Calorific value shifts in the gas, particularly in biogas systems, gases produced by the operator or if combustion additive gases are introduced
- Gas pressure fluctuations if additional consumers in the combustion gas network are activated or deactivated
- Furnace chamber pressure fluctuations by charging the furnace chamber, valve settings in the furnace chamber and fans drawing in or pushing out air
- Dirt or deposits on the burner, in the pipeline, in gas and air valves (particularly bypass orifices), in the combustion chamber or in the flue ducts
- Thermal stress on the burner head or burner nozzle block, burner quarl or other elements directly affected by the flames
- Mechanical wear on the spindle guide of the pressure regulator, if the air/gas ratio control diaphragms become brittle and hard, hysteresis of the valves (particularly with burner capacities of 1:10, pressures of 1:100

Fig. 3: Aluminium smelting furnace at high-fire rate. The furnace is charged with aluminium ingots. It is fired by two Elster Kromschröder burners ZIO 165 with a rated output per burner of 630 kW

Fig. 4: Aluminium smelting furnace at low-fire rate. The furnace is charged with aluminium ingots. It is fired by two Elster Kromschröder burners ZIO 165 with a rated output per burner of 630 kW

are required by the mechanical components, depending on

$$\frac{\dot{V}_1}{\dot{V}_2} = \sqrt{\frac{\Delta P_1}{\Delta P_2}}\ ).$$

Normative background

The heating system should undergo servicing and maintenance work every time the burner is adjusted – a process which is recommended on an annual basis. This should comprise recurring seal and function tests, which enhance the operational safety and reliability of the system.

The requirements on operators are explained to a great extent by the German Ordinance on Industrial Safety and Health and Code of Practice G1010 (Requirements on the qualifications and organisation of operators of natural gas systems on plant sites). Generally the burner settings must be measured after the heating system has undergone maintenance work.

The maintenance interval for thermoprocessing equipment essentially depends on the maintenance instructions provided by the equipment manufacturer and the conditions in which the equipment is used. The normative principles include EN 746 Part 2 (Common safety requirements for industrial thermoprocessing equipment), DVGW Codes of Practice (for example, G 1010) and the German Ordinance on Industrial Safety and Health. Taking into account the standards and the servicing instructions provided by the equipment manufacturer, the operator must conduct a risk assessment of every single piece of equipment (gas pressure control and safety system, heating system or thermoprocessing system) and then produce various documents, including a revision plan and a maintenance plan.

The operator bears general responsibility for the safe operation of the thermoprocessing equipment. This duty can be satisfied by carrying out regular maintenance work.

Practical example

An aluminium smelting furnace (**Fig. 3 and 4**) operated by a wheel rim manufacturer is fitted with two ZIO 165 burners (nominal rating per burner 630 kW) and consumes 1,600 m^3 (66.66 m^3/h) of natural gas over a period of 24 hours. Production runs six days a week. Energy price: 3.9 cents/kWh; combustion air temperature: approx. 20°C, furnace chamber temperature: approx. 800°C.

The system was found to have a lambda value of $\lambda = 1.5$. An oxygen content of around seven percent was measured. As a result of optimising the system, the oxygen value was reduced to approx. 1.5 percent.

The reduction in excess air as an additional combustion gas resulted in savings of around 2000 euros per month (detailed calculations of the molar masses, flow rates, substance equations, etc. are available from c.schare@kromschroeder.com).

Conclusion

Large savings (in the example described above of around 2000 euros per month per furnace) are possible if the parameters such as furnace geometry, burner quarl and burner equipment are coordinated to each other and the service technician can and may carry out the appropriate settings. Simple burner adjustment work on the thermoprocessing equipment results in optimum cost efficiency and also makes an active contribution to minimising CO_2 and relieving the strain on the environment.

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