Air/gas ratio control in industrial heating equipment

Air/gas ratio control in industrial heating equipment is of great importance for cost-efficient and safe operation. If the excess air is too high, gas consumption increases while an air deficiency represents a source of danger. There are different methods of controlling and monitoring the air/gas ratio. This article describes and evaluates various system solutions by including the boundary conditions imposed by the processes. The wide spectrum of industrial applications may also require other solutions. In general, it is necessary to consider each individual case, depending on the system and the processes.

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Introduction

In industry, gas burners for heating are used in a variety of processes, for example in thermoprocessing systems (industrial furnaces, drying systems, afterburning installations etc.) or in boiler systems for process steam or hot water generation.

The broad range of applications varies considerably with regard to process specifications and installation:

- Process temperature: from approx. 100°C to over 1,300°C
- Combustion chamber pressure: constant or fluctuating, positive or negative
- Number of burners: single burners and multiple burner systems with up to more than 100 burners
- Type of capacity control: modulating control (infinitely adjustable air and gas flow rates) or impulse control (staged burner operation with defined gas and air flow rates)
- Combustion gas: gases of the public gas supply with virtually constant composition or process gases with varying composition
- Oxidant: cold air, hot air, oxygen and oxygen-enriched air.

Common requirement of all industrial firing systems is to achieve the highest efficiency possible and low flue gas emissions.

Ratio control is an essential point when planning an industrial firing system. The air/gas ratio influences the efficiency and flue gas emissions, in many cases the production quality and often even availability and lifetime of the system. Air deficiency or unstable combustion due to high excess air cause incomplete combustion and therefore the risk of deflagration, explosion or fire.

The latter is of great importance to systems manufacturers as well as for operators on legal grounds. The systems manufacturer must ensure that a new system is safe when placed on the market and must confirm that he has supplied a "safe" system with a declaration of conformity or manufacturer's declaration. The operator is responsible for ensuring that staff is not exposed to any risks that could be avoided.

Directives and standards

Essential requirements relating to the safety of systems are regulated by EU Directives within the European Economic Area. In this context, it is necessary to differentiate between Directives in accordance with Article 95 of the EC Treaty and Directives in accordance with Article 137 of the EC Treaty:

Directives in accordance with Article 95 govern the obligations of a manufacturer when placing products on the market and must be uniformly transposed into national law in all Member States. They aim to reduce the number of handicaps to trade by unifying the laws. Harmonised Standards lay down how the essential requirements of the EU Directives can be fulfilled in accordance with the state of the art.

Directives in accordance with Article 137 outline the employer's obligations relating to the protection of persons who operate equipment or who are exposed to the effects of equipment. However, they only define minimum requirements and the individual Member States can establish more stringent requirements in national regulations. For example, in the Federal Republic of Germany, the Operational Safety Ordinance (Betriebssicherheitsverordnung BetrSichV) is applicable, which is to be implemented by the Technical Regulations (TRBS) that are currently being drafted. Until they come into force, the regulations which have been valid until now are applicable.

The essential Directives and Standards for the installation (placing on the market) of gas-fired installations are listed in **Table 1**. All relevant Directives are to be used in parallel (horizontal application). In this way, thermoprocessing systems are machinery in the sense of the Machinery Directive and boiler systems are subject to the Pressure Equipment Directive. Many devices and components for heating equipment come under the Gas Appliances Directive. For the electrical equipment of heating systems the Low Voltage Directive and the EMC

Table 1: Directives and standards for the installation of industrial heating equipment

Machinery Directive 98/37/EC	Low Voltage Directive 73/23/EEC	EMC Directive 89/336/EEC is to be replaced by 2004/108/EC	Gas Appliances Directive 90/396/EEC	Pressure Equipment Directive 97/23/EC
Essential requirements Health and safety requirements relating to the design and construction of machinery	Essential requirements Safety objectives for electrical operating equipment	Essential requirements with regard to the undisturbed functioning of electrical/electronic equipment relating to electromagnetic fields	Essential requirements for equipment, safety, controlling and regulating devices and assemblies	Essential requirements for vessels, pipes and accessories
Transposition into German Law Equipment and Product Safety Act, 9th Ordinance	Transposition into German Law Equipment and Product Safety Act, 1st Ordinance	Transposition into German Law Electromagnetic Compatibility Act	Transposition into German Law Equipment and Product Safety Act, 7th Ordinance	Transposition into German Law Equipment and Product Safety Act, 14th Ordinance
Harmonised standards: EN 746-1 EN 746-2 EN 954-1 EN 1050 EN ISO 13849-2 EN 60204-1	Harmonised standards: EN 60204-1 EN 60439-1 EN 50156-1 EN 60730	Harmonised standards: EN 50065 EN 60730	Harmonised standards: EN 88, EN 126 EN 161, EN 298 EN 676, EN 1643 EN 12067-1 EN 12067-2	Harmonised standards: EN 12952-8 EN 12953-7

Directive are also always relevant. Further applicable specifications must be applied as well.

Hazard analysis and risk assessment

Both the Machinery Directive and the Pressure Equipment Directive require the manufacturer to carry out a hazard analysis (as stipulated in Annex 1 to each Directive). The procedure for the risk analysis, risk assessment and, if required, the reduction of risk is described in EN ISO 12100 Part 1–2 (Safety of machinery – Basic concepts, general principles for design) as well as EN 1050 (Safety of machinery – Principles for risk assessment) (**Fig. 1**).

The risk reduction process is completed when all significant hazards relating to the heating equipment have been eliminated through design measures or technical protective measures or the risk has been sufficiently reduced. The application of "Harmonised Standards" is very helpful in this process since the fact that products comply with harmonised standards means that they also comply with the essential requirements of EU Directives.

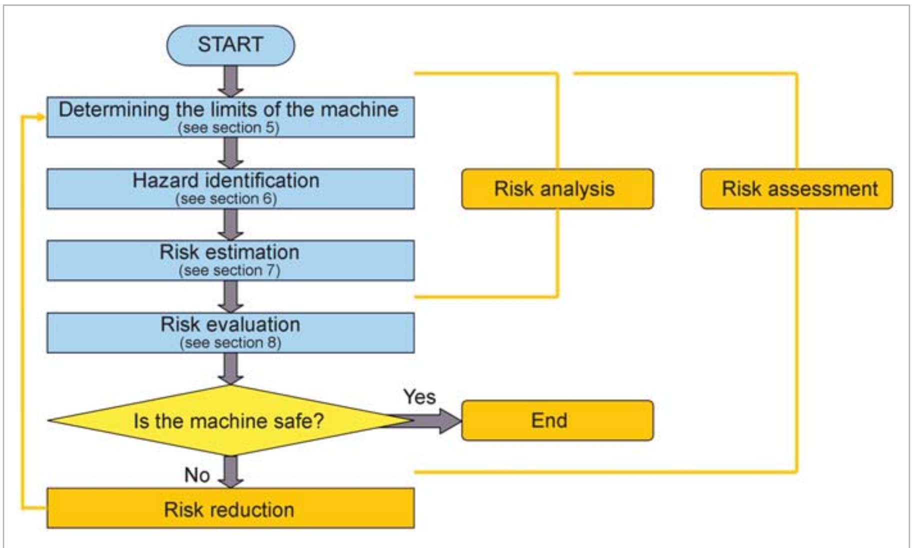

Fig. 1: Risk assessment in accordance with EN 1050, iterative process

Requirements of the standards

In respect of the air/gas ratio control, the different standards set varying requirements:

- For **thermoprocessing equipment**, EN 746-2 (1997) requires in section 5.2.3.3 that the air and gas mass flow to each burner be in ratio that allows stable and safe burner operation.
- The air/fuel ratio on **water-tube boilers** must be controlled within permissible tolerances which are specified in the operating instructions, according to EN 12952-8 (2002), section 5.2. The air/fuel ratio is to be monitored so that the fuel supply will be shut down in the event of an inadmissible ratio. Monitoring must be independent of the control function.
- EN 12953-7 (2002) for **shell boilers** does not contain any special requirements in respect of the air/gas ratio, only a reference to the relevant standards for forced draught burners which are usually used in this system type (EN 676 for gas burners) in section 6.1 – "Burners".
- For automatic forced **draught burners** which are used in many boilers or drying systems, section 4.3.4.12 of EN 676 contains the requirement that the flow rate of combustion air and gas must be controlled in tandem or monitored by a sequential switching system. "The air and gas adjustment devices shall be interconnected (e.g.

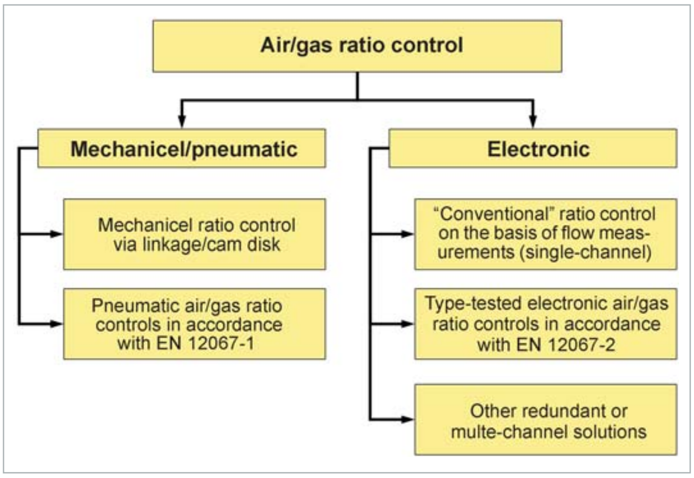

Fig. 2: Methods of ratio control

by mechanical, pneumatic, electric or electronic means) such that the relationship between combustion air and gas is fixed in a repeatable way at any operating point of the burner. [...] The combined control or the sequential switching shall be effected in such a manner that, even in the case of fault, the system will tend towards higher excess air or proceed to safety shutdown."

All standards therefore require that the air/gas ratio be controlled and/or monitored – however, with no detailed specifications for the implementation of this. When planning an industrial firing system, it is the manufacturer's responsibility to determine the appropriate method of air/gas ratio control for the specific application to meet the protection objectives and essential requirements of the European Directives. For this, there are various options (**Fig. 2**), whereby the designs may differ in details.

Mechanical ratio control

In a mechanical ratio control system, only one of the two control elements (gas or air) is equipped with an actuator. The other control element is simultaneously adjusted via a linkage or a cam disk and corresponding mechanical connections.

Mechanical ratio control can be used for both modulating and staged capacity control. It must be set to the relevant pressure ratios when commissioning the system. Experience has shown that this adjustment can be difficult, especially when the adjustment devices for air and gas have a different opening characteristic. The advantage of mechanical ratio control is that a control range of clearly more than 1:10 can be achieved with appropriately dimensioned control elements.

For systems with air preheating, mechanical ratio control is only suitable with restrictions since every change in the combustion air temperature implies a density change and therefore a change in the air mass flow, i.e. the air/gas ratio on the burner varies. Similarly, every change in gas or air supply pressure causes a change in the air/gas ratio, which cannot be detected unless additional monitoring measures are implemented. For this reason, the supply pressure should be monitored when using mechanical ratio control. The scope of the monitoring is to be defined individually for each specific system and should include MIN and MAX pressure switches for both gas and air (**Fig. 3**). Provided that the combustion chamber backpressure is not negligible compared to the air and gas supply pressures, the pressure switches must monitor the pressure differential to the combustion chamber.

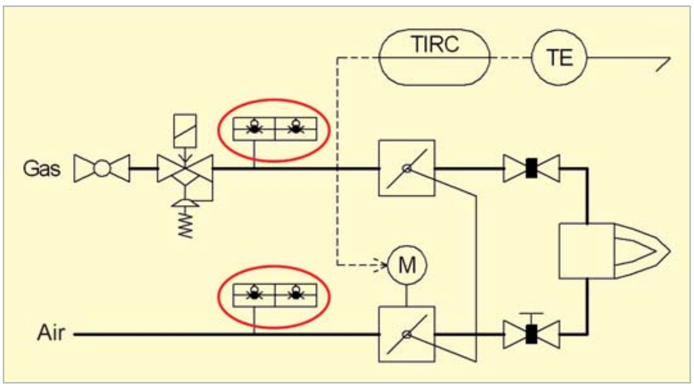

Fig. 3: Schematic diagram of mechanical ratio control with pressure monitoring

Fig. 4: Pneumatic air/gas ratio controls in accordance with EN 12067-1
a) Air/gas ratio control GIK
b) Air/gas ratio control with solenoid valve VAG
c) Variable air/gas ratio control with solenoid valve GVRH

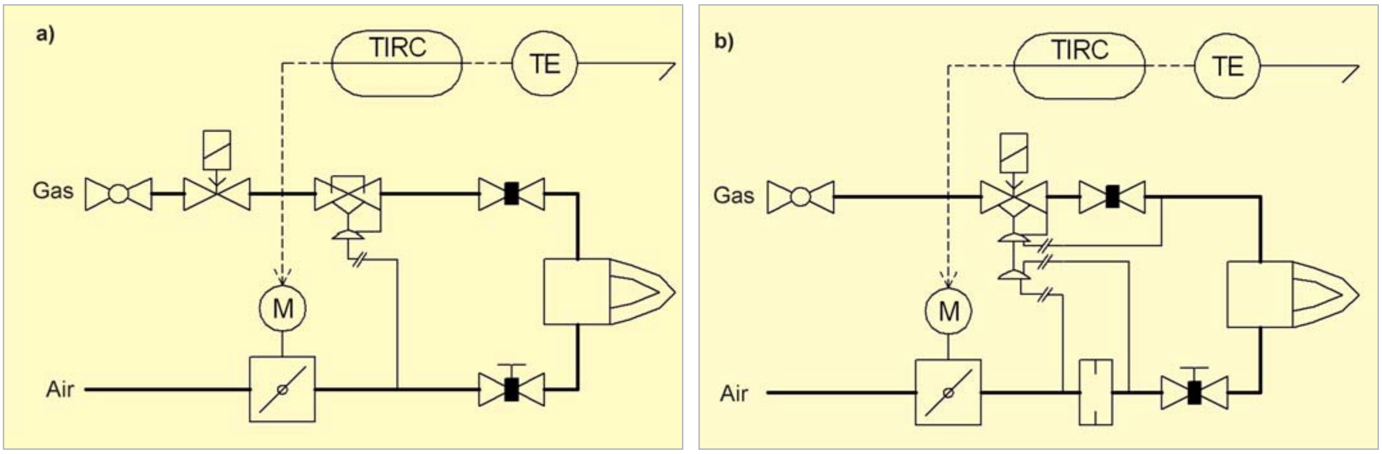

Fig. 5: Schematic diagram of pneumatic ratio control a) Air/gas ratio control, b) Variable air/gas ratio control

Pneumatic ratio control

Pneumatic ratio control is implemented with air/gas ratio controls in accordance with EN 12067-1, whereby combination controls, which also act as shut-off valves, are used frequently (**Fig. 4**). Depending on the design of the control, one can distinguish between air/gas ratio controls and variable air/gas ratio controls.

Air/gas ratio controls record the static air pressure as a reference variable and regulate the static gas pressure to the same value (**Fig. 5a**). Flow adjustment is carried out via manual adjustment elements so that the air/gas ratio on the burner corresponds to the desired value at the same gas and air supply pressure. Fluctuations in the air or gas supply pressure as well as in the backpressure in the combustion chamber do not have an effect on the air/gas ratio since the change in the air and gas flow rates is of the same ratio (same change in the pressure gradient for air and gas).

Variable air/gas ratio controls work with differential pressure measurements instead of static pressure measurements (**Fig. 5b**). The advantage of these controls is that the signals are always proportional to a flow rate and the static pressure must not be considered. The control process is therefore not influenced by the combustion chamber pressure or by damage to/dirt on the burner. Moreover, the variable air/gas ratio control can be used for hot air if the differential air pressure is measured on the "cold side".

The pneumatic air/gas ratio controls present a flexible solution which can be used for modulating and impulse control. Commissioning of burner systems with pneumatic air/gas ratio controls is simple and is confined to adjusting the air and gas flow rates at low-fire rate on the controller and at maximum capacity using manual adjustment elements on the burner. The opening characteristic of the control elements has no influence on ratio control.

In order to guarantee the intended functions of the devices in practice, they must, however, be selected by a competent person for the relevant burner capacities and may only be used under the specified conditions. If the technical data for the devices and the manufacturer's specifications as regards installation and ambient conditions are observed, pneumatic air/gas ratio controls are the most simple and most cost-efficient method of air/gas ratio control. Hundreds of thousands of devices which are being used in industrial applications worldwide demonstrate their operational safety and reliability.

"Conventional" ratio control on the basis of flow measurements (single-channel)

In many industrial applications, electronic air/gas ratio control is implemented by "conventional" means on the basis of flow measurements for gas and air. These measured variables are processed in an industrial controller or a PLC. **Figure 6** shows the schematic diagram of such a system. The temperature setpoint set on the temperature controller TIRC is compared with the actual value measured at the thermocouple TE. The resultant demand for capacity (manipulated variable) is switched to the subordinate ratio controller FFC. This controls the air/gas ratio by applying an adjustment request corresponding to the setpoint to the adjustment devices for air and gas. Feedback and, consequently, a closed ratio control loop is implemented on the basis of flow measurements (actual flow values) on the air and the gas measuring orifices.

The "conventional" electronic ratio control system affords the advantage that flow measurements ensure feedback in relation to the air/gas ratio from the process, whereas all other options for ratio control do not. In the case of hot air, the volumetric flow rate is converted to a mass flow rate on the basis of tempera-

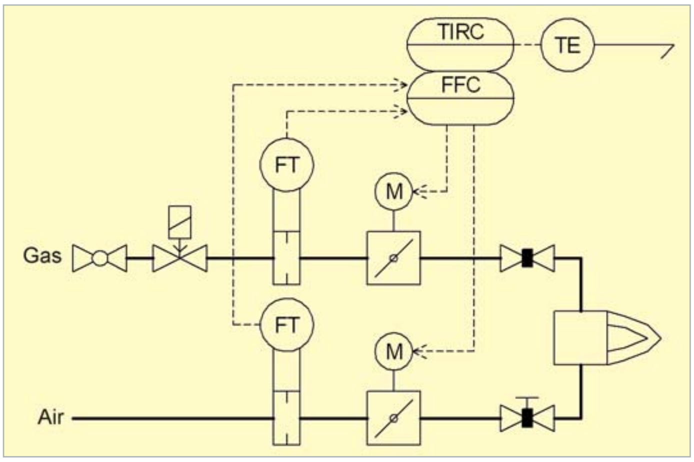

Fig. 6: Schematic diagram of "conventional" electrical ratio control with flow measurements

ture measurement on the air orifice so that this system is suitable for modulating control even in the case of hot air operation. This is witnessed by numerous examples from practical applications. However, the safety of such systems must be rated as questionable.

Type-tested electronic air/gas ratio controls in accordance with EN 12067-2

One other option of electronic air/gas ratio control is to use type-tested air/gas ratio controls in accordance with EN 12067-2. This Standard specifies the electronic air/gas ratio control device as a system, consisting of the electronic controller, the adjustment devices for gas and air and the related feedback signals (**Fig. 7**), operating in a closed control loop. An electronic regulating and control unit processes all essential input and output signals of the connected elements.

In Section 7, Standard EN 12067-2 stipulates stringent functional requirements in respect of the type-tested electronic air/gas ratio control device:

- It must control the air/gas ratio in a manner adequate to prevent the occurrence of dangerous conditions within the combustion process and dangerous conditions in respect of the installation's primary safety.
- The feedback signals must ensure that the preset control values are reached and maintained.
- Under abnormal conditions, the electronic air/gas ratio control device must maintain a defined, safe state.
- The electronic air/gas ratio control device must be linked and permanently connected to the automatic burner control unit in a manner that ensures full compliance with the requirements in respect of automatic burner control units in accordance with EN 298 and the requirements in accordance with EN 12067-2.

The type-tested air/gas ratio control device consequently ensures that the installation is transitioned to a defined, safe state, even in the case of fault.

Type-tested air/gas ratio controls are offered by various manufacturers, and the position of the adjustment devices is normally used as the feedback signal. **Figure 8** shows the schematic diagram of such a system. A comparison with a mechanical ratio control system indicates that both systems are, in principle, the same. They differ only in respect of

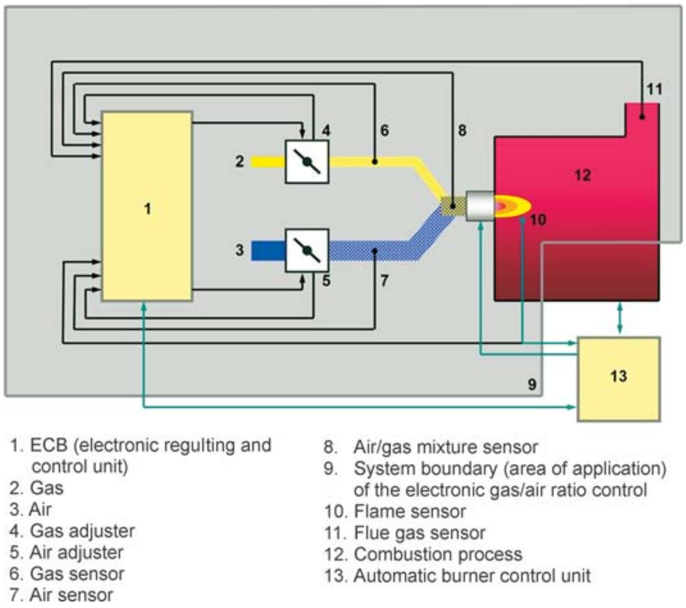

Fig. 7: Schematic diagram of an air/gas ratio control in accordance with EN 12067-2 with pressure monitoring

the link between the control elements that is electrical and not mechanical on the electronic air/gas ratio control. This means that the same restrictions apply to the electronic air/gas ratio control as apply to the mechanical ratio control system.

By comparison with the mechanical ratio control system however, the electronic variant affords the advantage that adjustment is performed on the control unit when commissioning an installation by saving the characteristic curves for the positions of the control elements dependent on the demand for capacity. In order to do this, several points must be approached over the entire capacity range, as is the case with the mechanical ratio control system. The electronic system also offers options for integrating further feedback signals from the process, e.g. an O_2 or λ measurement function [1], which is not possible with the mechanical ratio control system.

Other redundant or multi-channel solutions

The possibility of using various hardware devices, such as PLCs, multi-channel PLCs, fail-safe PLCs or application-specific special electronic circuitry, means that there are a large number of other conceivable implementation options for electronic air/gas ratio control. Besides EN 12067-2, assistance and basic guidelines can be found in document ISO/DIS 23552-1, currently in preparation, and safety assessments in accordance with EN 50156-1, EN 298 and EN ISO 12100-2.

If a programmable electronic control system is used, the interrelationship between demands for capacity and the requirements in respect of the safety functions must be taken into consideration. Consequently, one should consider whether to use a non-fail-safe PLC or a fail-safe PLC. The programmable elec-

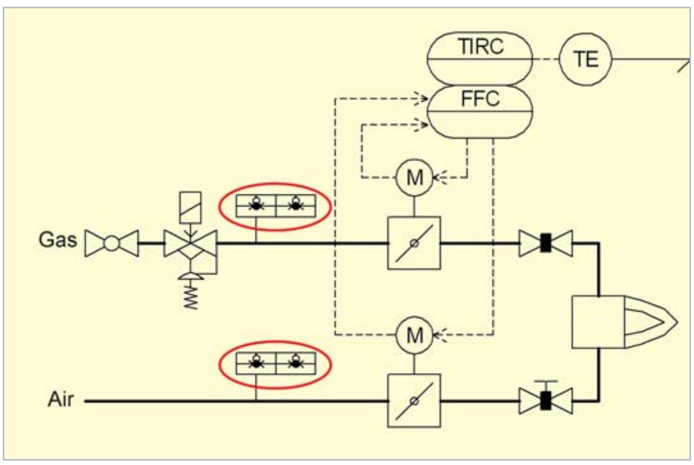

Fig. 8: Schematic diagram of an air/gas ratio control in accordance with EN 12067-2 with pressure monitoring

tronic control system must be designed to adequately minimise the probability of random hardware failures and the systematic failures that could impair the performance of the safety-related control function(s). If a programmable electronic control system performs a monitoring function, the system behaviour if a fault or error is detected must be taken into consideration (see EN ISO 12100-2, 4.11.7 Safety functions implemented by PES).

Using a fail-safe PLC, however, does not guarantee error-free operation. The software as well must be subjected to a safety and error assessment. Many manufacturers offer TÜV-tested function blocks to allow the effort and complexity in particular in the case of error assessment, to be substantially minimised.

Safety considerations

As explained above, the air/gas ratio is relevant to safety. Consequently, it does not suffice to solely consider the functionality. The options described must also be subjected to analysis in respect of their behaviour in the event of fault and, consequently, must be subjected to a risk analysis.

The mechanical ratio control system can be rated as fail-safe for cold air applications provided the link is designed as positive or form-fit and provided the supply pressures are monitored as described above. The pressure switches must disconnect the gas supply in the case of inadmissible deviations and must also be integrated in the control unit's safety interlocks. Electronic air/gas ratio controllers in accordance with EN 12067-2 are also fail-safe provided the manufacturer's specifications are complied with and provided the supply pressures are monitored (see "Mechanical ratio control system"). The greatest risk relates, in the case of both systems, to commissioning during which setting and programming are to be performed accurately, allowing for the differing opening characteristics of the air and gas adjustment devices. Settings and parameters must be documented and must be checked regularly when operating the installation.

In accordance with EN 12067-1, pneumatic air/gas ratio controls are type-tested control devices for which the Standard stipulates design and functional requirements and the test procedure. Permitted use is described in the manufacturer's documentation. As previously mentioned, many years of experience and the high number of controls in operation indicate that the devices are safe if used correctly. Nevertheless, a check must be conducted within the installation-specific risk assessment, as to whether and, if applicable, what measures must be taken to monitor the air/gas ratio, in addition to use of the pneumatic air/gas ratio controls. This involves assessing the risk potential installation-specifically (experience with comparable installations, number of burners, combustion chamber and flue gas temperature etc.). On an installation with many burners, a change in mixture on one burner in the event of fault entails a far lower risk than is the case with only a few burners or even a single burner. Installations with low flue gas temperature always involve a higher risk potential than installations with high flue gas temperatures.

Conventional single-channel electronic air/gas ratio control on the basis of flow measurements is not fail-safe. It involves a high risk potential since it is normally an installation-specific, stand-alone solution and includes several potential error sources. Corresponding measures should be taken to reduce risk in order to protect against personal injury and damage to property and in order to protect against production outage. A risk assessment for the entire system frequently indicates a demand for additional monitoring measures. Alternatively, it is possible to configure the system redundantly and achieve a safety level comparable with fail-safe devices using 1-out-of-2 redundancy. However, this option is frequently not used in practice for reasons relating to costs.

All variants of air/gas ratio control basically require regular maintenance and inspection since damage to the devices or to single components may lead to risk resulting from an undefined air/gas ratio.

Options for ratio monitoring

The air/gas ratio must be monitored separately from air/gas ratio control (with no feedback) so as to achieve an increase in the safety level as an additional measure. There are also various options involving various advantages and disadvantages for air/gas ratio monitoring:

- Flue gas measurement (CO, O_2, λ)
- Mass flow or volumetric flow measurements
- Pressure switches

Flue gas analysis and mass flow measurements, each with corresponding evaluation, are equally suitable for hot air applications. However, referred to the relevant application, it will be necessary to observe certain restrictions. A flue gas measurement can be influenced by infiltrated air in the process, e.g. in the case of fluctuating or negative combustion chamber pressure. Mass flow measurements have a restricted control range and, consequently, need to be designed accordingly. Nevertheless, in many cases both systems, as additional, independent monitoring measures, represent a suitable means of detecting errors in air/gas ratio control and initiating shut-down of the burners.

Signals from pressure switches for monitoring in the case of intermittent control and defined operating points of the burner can be processed in fail-safe manner – for example with Kromschröder's burner control unit BCU 465. However, they are suitable only for cold air applications since the pressures required for maintaining a constant air/gas ratio change with the temperature of hot air.

Besides these additional measures, flame control may, in many cases, also be rated as a safety measure if it leads to shut-down of the burner in the case of critical air deficiency or high excess air. However, flame control as the sole monitoring measure is generally inadequate since the burners generate a flame signal even in the case of a critical air/gas ratio.

Conclusion

Owing to the broad range of industrial applications, it is not possible to propose any universal solution for air/gas ratio control. On a general basis, an installation-dependent and process-dependent consideration will be required in each individual case. **Figure 9** shows possible system solutions for single and multiple burner systems – each dependent on the type of control – to assist the reader in this.

The pneumatic ratio control system offers a solution for virtually all applications, and it will be necessary, in each individual case, to decide whether additional monitoring measures are required. In the case of multiple burner systems, this will largely not be necessary since a change in mixture on a single burner will not lead to a hazardous state of the entire system. In the case of flue gas temperatures above ignition temperature of the relevant gas, additional monitoring will not be required since non-combu-

Single burner				Multiple burner system				Air/gas ratio control
Modulating control		Impulse control		Modulating control		Impulse control		
cold air	hot air	cold air	hot air	cold air	hot air	cold air	hot air	
✓		✓		(✓)		(✓)		Mechanical ratio control 1)
✓	✓	✓	✓	✓	(✓)	✓	✓ 4)	Pneumatic ratio controls in accordance with EN 12067-1 2)
	✓				✓			„conventional" ratio control via flow measurements (single-channel) 3)
✓		✓		(✓)		(✓)		Type-tested electronic ratio controls in accordance with EN 12067-2 1)
			✓		✓		✓	Other redundant or multi-channel solutions

✓ = suitable (✓) = suitable with restrictions

1) Supply pressure monitoring required

2) Dependent on system-specific risk analysis or, if necessary, monitoring by pressure switches or flue gas/mass flow measurements

3) With monitoring by flue gas measurements or mass flow measurements

4) Variable air/gas ratio control in the case of a separate recuperator for each burner

Fig. 9: System solutions for ratio control

sted components in the flue gas are immediately after-burned on contact with air and there is a low risk of occurrence of a potentially explosive mixture.

A mechanical ratio control system or electronic air/gas ratio controls in accordance with EN 12067-2 may be alternative solutions for installations without air preheating. In the case of multiple burner systems however, they do entail the disadvantage that only the ratio is controlled for all connected burners in total. In this case, pneumatically operated air/gas ratio controllers offer a far cheaper option for ratio control on each individual burner.

For installations using hot air mechanical ratio control and electronic air/gas ratio controls in accordance with EN 12067-2 currently available on the market do not represent a practical solution since they do not allow hot air compensation. In this case, pneumatic ratio control with variable air/gas ratio controls is virtually predestined for single-burner systems. In the case of multiple burner systems with modulating control, conventional electronic air/gas ratio control with flow measurements is still a feasible solution, but additional monitoring measures to ensure the air/gas ratio are recommended. Multiple burner systems with intermittent control necessitate a multi-channel solution so as to maintain the air/gas ratio constant in the case of variable hot air temperature and to monitor the ratio.

In the case of all industrial heating equipment, the air/gas ratio control method used must be selected after considering the aspects of functionality, risk potential and costs, allowing for the installation-specific boundary conditions and requirements, in addition to the risk assessment. In individual cases, solutions other than those shown in Figure 9 may be necessary for process-related or installation-related reasons.

Literatur

[1] Altendorf: Möglichkeiten eines elektronischen Steuerungsgerätes mit Brennstoff/Luft-Verbundregelungen bei Verbrennungsprozessen (Potentials for an electronic control unit with fuel/air compound control in combustion processes), GASWÄRME International (54), No. 4/2005, p. 228 – 232

List of relevant EU Directives and Standards

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Directive of the European Parliament and of the Council on the approximation of the laws of the Member States relating to machinery, 22.06.1998

Pressure Equipment Directive 97/23/EC
Directive of the European Parliament and Council on the approximation of the laws of the Member States concerning pressure equipment, 29.05.1997

Gas Appliances Directive 90/396/EEC
Council Directive on the approximation of the laws of the Member States relating to appliances burning gaseous fuels, 29.06.1990

Low Voltage Directive 73/23/EEC
Council Directive relating to electrical equipment designed for use within certain voltage limits (73/23/EEC), amended by Directive (93/68/EEC) of 30.08.1993

EMC Directive 89/336/EEC
Council Directive on the approximation of the laws of the Member States relating to electromagnetic compatibility, 03.05.89

German Act on Technical Work Equipment and Consumer Products, 09.01.2004, Equipment and Product Safety Act – GPSG

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Part 1: Basic terminology, methodology

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Part 1: Common safety requirements for industrial thermoprocessing equipment

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Part 1: Type-tested and partially type-tested assemblies

EN 60730, January 2005
Automatic electrical controls for household and similar use – Part 1: General requirements

EN 60730, December 2005
Automatic electrical controls for household and similar use – Part 2: Particular requirements for electrical controls for electrical household appliances

EN 50065, February 2002
Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances

EN 50065, February 2002
Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz – Part 2: Procedures for measuring high-frequency emitted interference (radio interference) and immunity

EN 88 + A1, June 1991 + June 1996
Pressure governors for gas appliances for inlet pressures up to 200 mbar (contains Amendment A1: 1996)

EN 126, July 2004
Multifunctional controls for gas burning appliances

EN 161, June 2002
Automatic shut-off valves for gas burners and gas appliances

EN 1643, February 2001
Valve proving systems for automatic shut-off valves for gas burners and gas appliances

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