Modern heating installations with wide control range

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Depending on the individual process, heating installations impose a wide variety of requirements on the corresponding systems. With systems for thermal flue air purification, such as regenerative or thermal incineration installations, flue gases are frequently so contaminated that the system can run as an autothermal operation. Heating installations with a low-fire rate of approximately 10 percent are then switched off. This means that when the burner is restarted, the entire system of safety interlocks must be run through again. With the help of cascade control, it is possible to extend control ranges to > 1:45. As systems run in continuous operation, care is also taken to ensure that it is possible to control the flame directly with the reliable and low-cost ionisation flame control system.

With regenerative and thermal incineration installations, a large amount of energy is required for initial heating, with this being crucial for the selection of burner size. During operation, as a result of heavily contaminated flue gases it may be the case that the system goes into autothermal operating mode. This means that only a very small supply of energy is required. This results in the following requirements being defined:

- Control range > 1:45
- High degree of efficiency over a wide control range
- Fail-safe system
- Direct ionisation flame control
- Direct electrical ignition
- System protected against thermal destruction
- Use of standard components
- The required burner air pressure is kept as low as possible
- Fully automatic system operation

Apart from the wide control range, the stipulated requirements can be fulfilled using standard burner and control systems. Why standard control systems are subject to limits and how these limits can be exceeded with the application of cascade control are set out below.

Control

For all firing processes, the energy supplied by the combustion system must match the system's requirements at any given moment. In most cases, control ranges of 1:10 are quite adequate for modulating control. In order to show why control ranges cannot be extended without limit, let us first consider a few details of a standard control system with a pneumatically operated air/gas ratio controller (**Fig. 1**).

The air/gas ratio control (3) installed in the gas line (here a VAG combination control) consisting of a pressure regulator and a solenoid valve is connected by an impulse line (4) to the air side of the burner. The signal from the temperature controller acts on the actuator for the air control valve (5 and 6). Depending on the demand for capacity, the control valve opens or closes. The changing air pressure is converted over the impulse line (4) and the combined air/gas ratio control (3) into an equal gas pressure, with the gas pressure and therefore the quantity of gas following the air pressure and the quantity of air. Fluctuations in the gas supply pressure are offset by the air/gas ratio control (3), and on fluctuations in the air pressure, the gas pressure likewise follows the air pressure (**Fig. 2**).

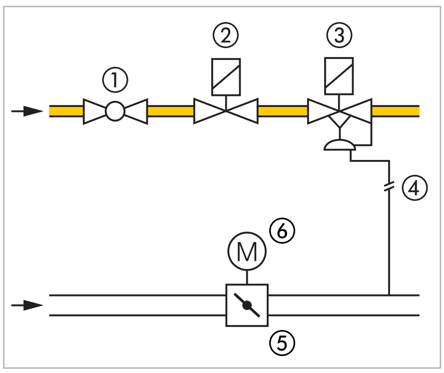

Fig. 1: Modulating air/gas ratio control – standard version

Limitations of conventional air/gas ratio control systems

With pneumatically operated air/gas ratio controllers as are normally used for such systems, for reasons of stability the minimum control pressure in the low-fire setting of the air control valve should not be less than 0.5 mbar. With

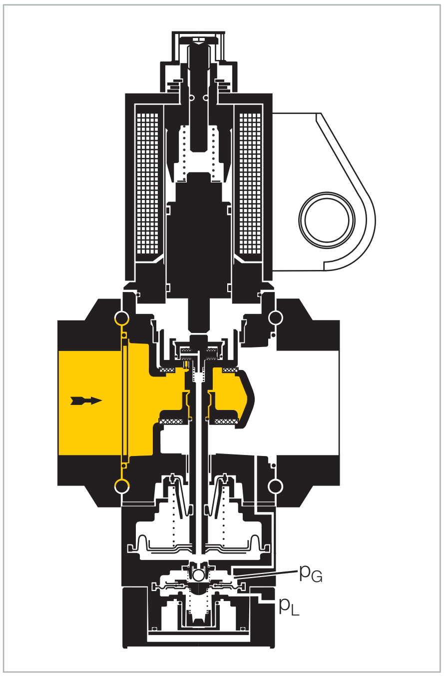

Fig. 2: Section of Type VAG air/gas ratio control with solenoid valve

the air control valve opened fully, a control pressure of 50 mbar can be assumed, producing a control pressure ratio of 1:100. In accordance with the quadratic interrelationship between pressure and flow rate, this produces a control range of 1:10. If, for a maximum available control pressure of 50 mbar, the control range should be increased to 1:45, the minimum control pressure should be only 0.02 mbar. Conversely, for a specified minimum control pressure of 0.5 mbar, the maximum air control pressure should be increased to 1012,5 mbar in order to achieve a control range of 1:45. However, neither of these measures is realistic: either the controller must be operating clearly outside its stipulated capacity and stability range, or the air pressure to be generated no longer allows for commercially viable operation.

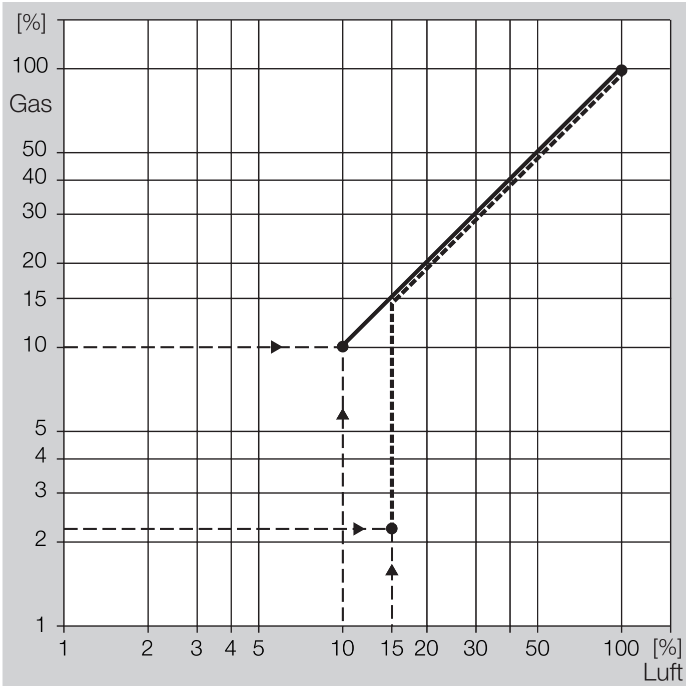

Fig. 4: Gas/air flow rate with standard air/gas ratio control and cascade control

Extended control range

To be able to continue exploiting the great advantages of air/gas ratio control, the control range is subdivided by means of the cascade control system. This means that it is still possible to use standard fans with pressures < 80 mbar.

For a target control range of 1:45, the calculated minimum capacity is 2.2 percent.

Fig. 3 shows the structure of the cascade control system in diagram form, with a linear flow control LFC (8) and a solenoid valve VAS (7) being used in parallel with the combination control VAG (3) as a combination of air/gas ratio control and solenoid valve. In the 100 to 15 percent capacity range, use is made of the time-tested air/gas ratio control system. In the 15 to 2.2 percent capacity range, the system switches over to the bypass. The capacity control function is then switched away from the actuator (6) for the air control valve (5) over to the actuator for the linear flow control (8). During operation in the < 15 percent capacity range, the air control valve remains in its minimum position. In this capacity range, the burner is operated with excess air, so as to ensure that despite the very low gas flow velocities, there is adequate mixing energy available to guarantee reliable and clean combustion.

Fig. 4 shows the difference between the respective gas/air flow rates for standard air/gas ratio control and cascade control systems.

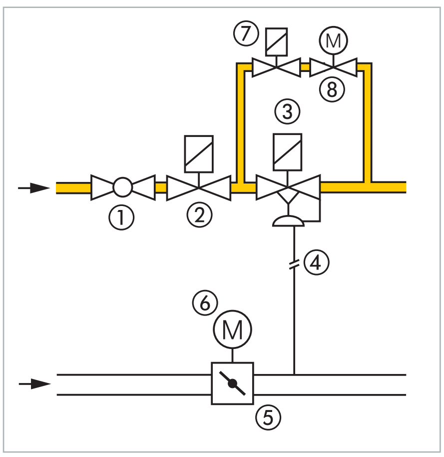

Fig. 3: Modulating air/gas ratio control with bypass line for cascade control

Safety requirements for capacity control

EN 746-2 sets out in detail the safety requirements to be taken into account for heating equipment. An explanation is provided there as to how it can be guaranteed at all times that no uncontrolled gas/air mixtures can occur, giving rise to dangerous situations (**Fig. 5**).

However, the purpose of this article is to deal solely with the specific aspects of the cascade control system.

At a capacity demand of between 100 and 15 percent, the system operates with a pneumatic air/gas ratio control system. Capacity is adjusted by activation of the actuator (6) for the air control valve (5). The system is adapted to the required gas and air pressures by means of fixed orifices or adjusters (9 and 10) during commissioning. Given proper adjustment and intact devices, any uncontrolled mixture of gas and air is therefore excluded (**Fig. 6**).

Maximum burner capacity is defined with the air control valve (5) fully open, and minimum capacity at the low-fire setting. Both of these positions are set by means of the limit switches on the actuator (6). The capacity range between 15 and 2.2 percent can only start when the air control valve (5) has reached its minimum position. After a time delay, the system switches over to the linear flow control LFC (8). The air

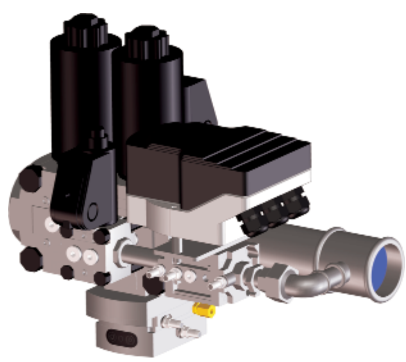

Fig. 5: Gas safety and control system bypass consisting of 2 x VAS, VAG and LFC for cascade control

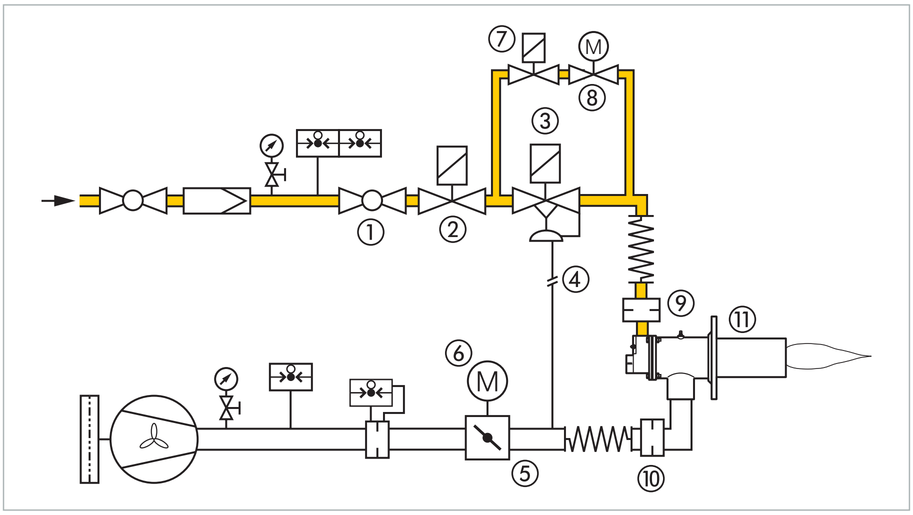

Fig. 6: Heating installation as per EN 746, Part 2

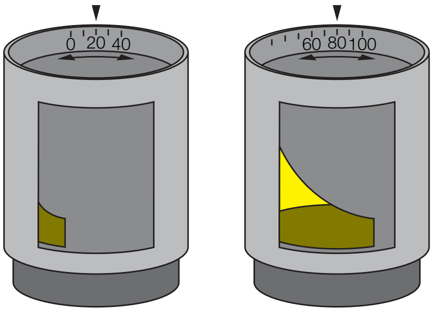

Fig. 7: Flow restricting cylinder and linear slide control valve for linear flow control LFC

control valve remains in this position, with capacity being adjusted on the gas side. The maximum gas volume is set to the required 15 percent during commissioning with the linear flow control (8) fully open, by means of the flow restricting cylinder provided in the device. The minimum position is limited at 2.2 percent by means of a limit switch (**Fig. 7**).

The result of these measures is that at no time is it possible for uncontrolled volumes of gas to flow into the combustion chamber. To ensure that no deposits build up in the controls and pipelines, the air must be clean or conditioned. The air pressure monitoring system must be in operation to guarantee that the necessary air pressure is available.

Burners

The system presented in Fig. 4 – with the example here being a Type ZIC 200 RB 0/ 235 industrial gas burner combined with a Type TSC 200 ceramic tube set – can be used in lightweight construction for high furnace temperatures as well. No additional burner quarl is necessary.

The burner (**Fig. 8**) is designed for near-stoichiometrical operation and a control range of 1:10 with its special burner head construction for low-CO or CO_2-optimised combustion.

As the burner can be directly electrically ignited and subjected to ionisation control, flame control by means of a UV sensor – which is very complicated and expensive for continuous operation – is not necessary. In combination with the cascade control system, the burner is capable of operating even with very low connection ratings. Under laboratory conditions, it has been possible to achieve control ranges of > 1:50, and > 1:45 is achievable in practice (**Table 1**).

Electrical control unit

The requirements of EN 746-2, EN 60204 and EN 50156 must be taken into account in the design of the control unit. These standards describe the functions and requirements to be fulfilled by the control unit in respect of burner monitoring and control (**Fig. 9**).

Examples:

- Min./max. gas pressure
- Min. air pressure
- Pre-purge
- Tightness control
- Burner start (specified start gas rate)
- Flame control
- Control

By way of example, Fig. 7 shows a control cabinet with an automatic burner control unit for single burner applications of Type BCU 370. Apart from automatic burner start and flame control, this unit fulfils some of the functions indicated above as well.

Fig. 9: Control cabinet for a cascade control system for a single burner

Fig. 8: Industrial gas burner ZIC 200 combined with ceramic tube set TSC

Table 1: Various burner sizes, suitable for wide control ranges in conjunction with cascade control system. For natural gas with R- burner head, ionisation flame supervision and cold air opreation

Type of Burner	Capacity [kW]	Switchover [kW]	Min. Capactiy [kW]	Regulating range [1]
BIC 65	50	5	1, 7	1 : 30
BIO 80	150	15	3, 8	1 : 40
BIO 140	450	65	11	1 : 40
ZIO 165	630	63	18	1 : 35
ZIC 200	1000	150	22	1 : 45

Table 2: Electrical activation of control elements and limit switch scanning

	Main Gas		Bypass			Air	
	Pos. 2	**Pos. 3**	**Pos. 7**	**Pos. 8**		**Pos. 5 u. 6**	
Condition	Gas valve	Gas valve/ Regulator	Gas valve	Linear flow control LFC		Motor IC 20 for linear flow control	
	VAS	VAG	VAS	Position	Switch max.	Position	Switch min.
Burner off	Closed	Closed	Closed	-	-	MIN	On
Purging	Closed	Closed	Closed	-	-	100%	Off
Ignition	Open	Open	Open	Open	On	MIN	On
Gas <= 15%	Open	Closed	Open	AKITV	Off	MIN	On
Gas >15%	Open	Open	Open	Open	On	AKTIV	Off

However, for flame control with a cascade control system, any other automatic burner control unit (for continuous operation) can be used. The crucial point for operation is that the control elements switch at a capacity of 15 percent. **Table 2** shows which valve/control element is activated at what point in time, or how it should be positioned.

To achieve this complex activation and control system, a mini PLC is used along with the automatic burner control unit.

The air and gas control valves are normally controlled by means of a three-point step signal. In order to prevent constant switching of capacity ranges in the vicinity of a 15 percent capacity demand, there is a hysteresis integrated within the mini PLC. The parameters for this hysteresis can be adapted in line with the local system conditions.

The two seven-segment displays provided in the control cabinet door provide information on the current position of the actuators (6 and 8) for the air control valve and the linear flow control.

A selector switch in the control cabinet door can be used for manual capacity adjustment between 2.2 percent and 100 percent. Alternatively, a temperature controller can be used (not present in the control cabinet illustrated) (Table 2).

Conclusion

With the aid of the cascade control system, it is possible to extend the control range to > 1:45 with the use of conventional control, safety and burner systems. At the same time, it is also possible to exploit the advantages of air/gas ratio control. The alternative – UV flame control systems for continuous operation – is extremely complicated and expensive and has to be replaced after around 10,000 hours of operation. Another advantage of cascade control is that time-tested air/gas ratio control systems can be used with standard fans (pressure range < 80 mbar). Use can be made of industrial burners for high-temperature applications providing maximised combustion and a high degree of efficiency. The systems operate with the standard supply pressures for gas and air. In continuous operation, flame control is applied safely, simply and inexpensively by means of ionisation control.

Literature

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