Reduction of nitrogen oxides in thermal recycling plants through modern measurement technology

by Albert Book

Within the scope of legal provisions and licensing requirements, the requirements for NOx separation in the exhaust gas of combustion plants with a NOx value in the clean gas of <100 mg/Nm³ at an NH_3 slip of <10 mg/ Nm³ are high. To meet these requirements, the predefined limit temperature inside the boiler must observed strictly as controlled parameter for primary and secondary measures to reduce pollutants. The report explains the methods to measure the temperature in combustion plants.

The nitrogen content of the waste and the high incineration temperatures required to destroy the organic pollutants contribute significantly to the generation of nitrogen oxides in thermal recycling plants. The aim of combustion engineering measures is to avoid largely the development of NOx already during the combustion process. In order to achieve with it low NOx emissions associated with the entire combustion, the particles must remain as long as possible in the primary reducing zone and be well mixed with the combustion air in the secondary zone. Furthermore, pressure is increasing on the operators of coal-fired power stations and thermal incineration plants for waste, substitutes or biomass to reduce their operating costs. At the same time efforts are made to increase the efficiency of the furnace and to minimize the wear and tear of the furnace wall and heat exchangers, in order to increase their lifetime.

In order to meet these requirements and optimize the combustion process, the correct recording and homogeneous distribution of the temperature in the combustion chamber plays a decisive role. According to the German Federal Immission Control Ordinance (BImSchV) and the German Technical Instructions on Air Quality Control (TA Luft), waste incineration plants are to be set up and operated in such a way that a minimum temperature of 850 °C is to be observed for the combustion gases produced during the incineration of waste or substances after the last supply of combustion air. This should keep the pollutant emissions below the permissible limit values. When incinerating hazardous waste with a halogen content of >1 %, the operator must ensure that a minimum temperature of 1100 °C is observed. The optimum temperature range in which a noticeable NOx reduction is achieved is between 850 and 1100 °C, depending on the exhaust gas composition.

The objectives in the operation of combustion plants are to burn the fuel more completely through a temperature-controlled control process, to produce less ash, to meet the requirement of pollutant emission and to use as few reducing agents as possible. In addition, the temperature distribution within the furnace has a considerable influence on wear and lifetime. If the temperature is too high, there is a high risk of slagging on the walls and heat exchangers within a very short time. In addition to the loss of efficiency due to the insulating effect, the lumps of slag can become detached and cause considerable mechanical damage if they fall down. If the temperature is too low, the process time for reducing the nitrogen oxides is reduced, so that the ammonia is not completely dissolved. An ammonia slip is formed, which leads to the formation of ammonia salts. This increases the wear of the plant due to corrosion.

Temperature measurement in combustion plants

Temperature measurement in thermal recycling processes is quite complex. The selection of suitable measuring equipment, the positioning of the measuring points and the interpretation of the measurement results depending on the operating conditions, the fuel as well as the supply of combustion air and reducing agent is a great challenge for the experts to optimize the combustion process.

Much of this is based on empirical knowledge and less on physically deducible evidence. The origin of the fuel and thus the type and composition has a considerable influence on combustion.

If, in addition, an inadequate and unreliable measurement technology is used to record the temperature at the relevant measuring points, mathematical models and adaptive control systems cannot really function either.

A stable and meaningful temperature measurement is the prerequisite for a solid control engineering basis.

Measurement with thermocouples

In many cases, thermocouples are used for temperature measurement, which measure the temperature in the area of a few centimetres close to the wall. However, this does not necessarily correspond to the temperature in the centre of large furnaces with dimensions of up to 20 x 20 m and in particular when the walls are fitted with heat exchangers. Thus a statement about the temperature distribution within the furnace is impossible.

Another problem of thermocouples is a physically caused aging and thus drifting of the measured value. Depending on the gas temperature and pollutant content, the displayed measured value can change slowly within weeks. This problem is minimized by equipping redundant measuring points and regularly exchanging the sensors, which results in permanent consumption costs.

In addition, the inertia of the thermocouples with a reaction time of several minutes prevents a rapid reaction to temporary temperature changes. Accordingly, the variation of the process control is high.

Optical temperature measurement

A modern possibility for temperature measurement is the use of pyrometers. These determine the temperature from the infrared radiation emitted by a measuring object. Since the response time of pyrometers is only a few milliseconds, it can also be used to react to rapid temperature changes. Modern devices based on continuous-wave light technology work without moving parts. They are therefore wear-free and have no time limit on their use.

Depending on the requirements and needs, pyrometers are used for the different measuring locations of a combustion plant

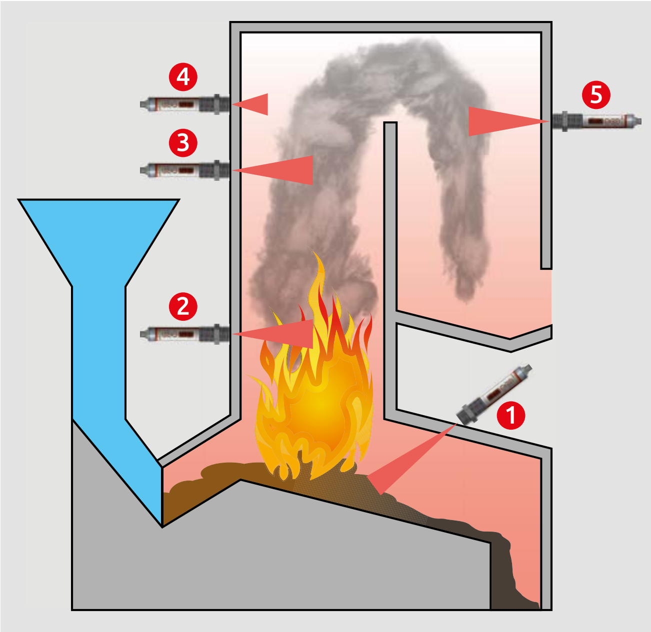

Fig. 1 *Pyrometric measuring locations in an incineration plant*
1: Firebed, 2: Flame, 3: Exhaust gas inside the furnace,
4: Exhaust gas in the area close to the wall,
5: Exhaust gas after the last supply of combustion gas

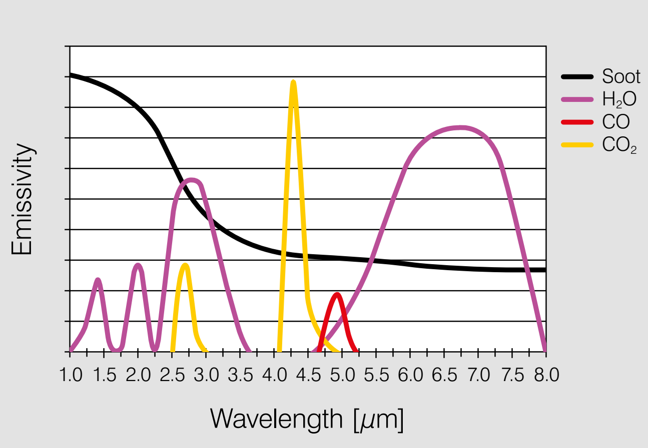

Fig. 2 *Radiation characteristics of combustion gas*

from the measurement of the firebed, the flames, the hot flue gases or the walls (**Fig. 1**). Accordingly, different pyrometer types are required depending on the measuring task.

Measurement of the firebed

When measuring the firebed, pyrometers which cannot be influenced by the hot flue gas in the field of view to the firebed must be used. The devices measure in a very selective wavelength range of 3.9 µm. In this range, water vapour (H_2O) and carbon dioxide (CO_2) are transparent and do not influence the measured value (**Fig. 2**).

Measurement of flame temperatures

So-called flame pyrometers are used for optical temperature measurement of sooty flames. The measurement is based on the two-colour measuring method, i.e. the infrared radiation is detected simultaneously in the near infrared range at two wavelengths and, from this, the temperature is determined. A complex algorithm in the devices ensures that fluctuations in particle density and particle size are compensated for over the length of the measuring distance and do not interfere with the measured value.

Measurement of exhaust gas temperatures

The prerequisite for temperature measurement with pyrometers is an object that emits infrared radiation. Since the particle concentration in the exhaust gas is rather low and not constant, a conventional pyrometer would measure more or less through the gas a mixture of the temperature of the particles and the opposite wall. The measured value would thus depend on the density of the particles under different load conditions.

For the pyrometric temperature measurement, the special radiation characteristic of the exhaust gas is used. In the spectral range of 4.4 - 4.8 µm, hot, carbon-containing gas has a high optical density and thus good radiation properties (**Fig. 2**).

The emission capability of the exhaust gas depends on the wavelength and temperature. As the temperature rises, the absorption band widens towards the longwave range (**Fig. 3**). Accordingly, pyrometers with the appropriate spectral sensitivities should be selected to measure the hot flue gases so that the infrared radiation of the hot CO_2 gas in the furnace room is detected without being disturbed by the cold CO_2 gas near the wall.

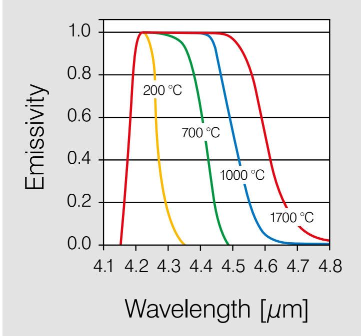

Fig. 3 *Emissivity of CO_2-containing gas as a function of wavelength and temperature*

In the area close to the wall, the temperatures are significantly lower than in the middle of the combustion chamber (**Fig. 4**). Depending on the requirements of the measuring task, either the temperature near the wall is measured as an alternative to the thermocouples, or the temperature inside the combustion chamber, which is decisive for the process. Accordingly, pyrometers with a small or large visibility depth should be used. Since gas is a volume emitter, a pyrometer determines an average value over the visibility depth. The visibility depth depends on the CO_2 concentration of the hot gas.

Mounting and selection of pyrometers

A homogeneous temperature distribution in the combustion chamber is decisive for an optimum combustion with a low NOx content and minimum wear of the furnace. A two-dimension-

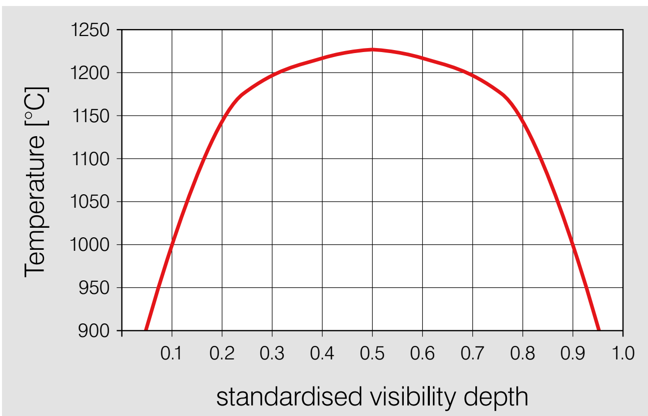

Fig. 4 *Temperature distribution inside the combustion chamber*

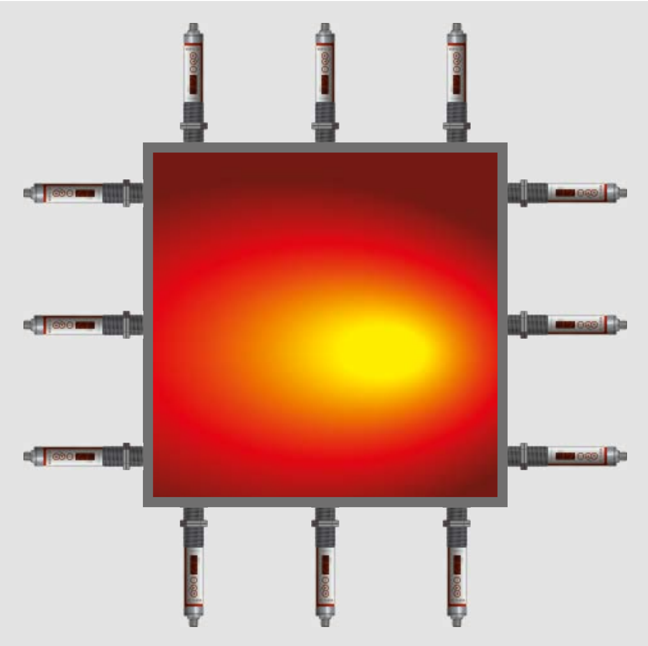

Fig. 5 *Two-dimensional thermal image to display the imbalance of temperature distribution*

al temperature profile is determined from a matrix of devices. In this way, thermal imbalances can be detected and primary combustion engineering measures initiated (**Fig. 5**).

Fig. 1 shows the typical measuring locations depending on the measuring task. When selecting the pyrometers, care must be taken to ensure that the instruments have a sufficiently narrow optical field of view to be able to measure through the combustion furnace openings, some of which are only 1 inch in size. Recently, pyrometers with integrated video cameras have also been used, which, in addition to the measured value, simultaneously transmit the video image for visual control on a monitor in the control room. For fast control measurements, the market now offers portable devices for the respective measuring task and measuring location.

To record a two-dimensional temperature profile, up to three pyrometers are installed on one level per wall. Pyrometers with modern digital interfaces such as IO-Link are ideal for networking and interference-free data transmission (**Fig. 6**).

Fig. 6 *Compact pyrometer with innovative IO-Link interface for networking of devices*

Conclusion

Pyrometers are ideally suited to solve the various measuring tasks for temperature measurement in coal-fired power plants and incinerator plants when correctly selected and installed. As they are not subject to wear or ageing, they work reliably over a long period of time. Even rapid temperature fluctuations can be detected due to the short response time and can be immediately incorporated into the control process.

Due to the complexity of temperature measurement, however, it is advisable to call on the support of experts in the selection of the measurement system, the measurement value analysis and the integration into the control process.

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